RRC Environmental Courses - Sample Material

NEBOSH Environmental Certificate
NEBOSH Environmental Diploma
IEMA Introduction to EMS
IEMA Foundation Certificate in EM
IEMA Associate Certificate in EM

nebosh
Accredited centre
335

RRC TRAINING

RRC Environmental Sample Material

Contents

NEBOSH Certificate Unit NEC1

Element 5: Control of Contamination of Water Sources

RRC TRAINING

Contents

Element 5: Control of Contamination of Water Sources

Learning Outcomes

On completion of this element, you should be able to demonstrate understanding of the content through the application of knowledge to familiar and unfamiliar situations. In particular you should be able to:

- Outline the importance of the quality of water for life.
- Outline the main sources of water pollution.
- Outline the main control measures that are available to reduce contamination of water sources.

Hints and Tips

After reading a section of text try to write out a summary of that section using your own words.

Importance of the Quality of Water for Life

Key Information

- Drinking water is sourced from groundwater, reservoirs and rivers. It is treated to provide an adequate and continuous supply of water free from pathogens and other undesirable characteristics.
- Water is continuously transported around the water cycle, in either liquid, vapour or ice.
- It is important we protect groundwater and rivers as they are an essential resource.
- Water conservation is important as less than 1% of the water on the planet is available for use.
- Pollution of water can affect human health and impact ecosystems.

What is Meant by Safe Drinking Water

Jargon Buster

Pathogens

Disease-causing organisms, such as bacteria and parasites that cause diseases such as cholera, typhoid, dysentery, bilharzias and hookworm.

Water can carry a large number of pathogens. It is not only important to have access to water, but also for that water to be clean and wholesome. Water supply companies have a legal duty to supply water that is fit to drink. It is typically sourced from groundwater (springs, boreholes), reservoirs and rivers and delivered via an often leaky mains pipe network.

Natural waters may have undesirable characteristics:

- Colour, e.g. due to dissolved organic matter.
- Turbidity, e.g. suspended mineral or organic matter.
- Pathogenic bacteria.
- Excessive hardness.
- Taste and smell, e.g. due to sewage contamination.
- Harmful mineral content, e.g. absorbed from soil.

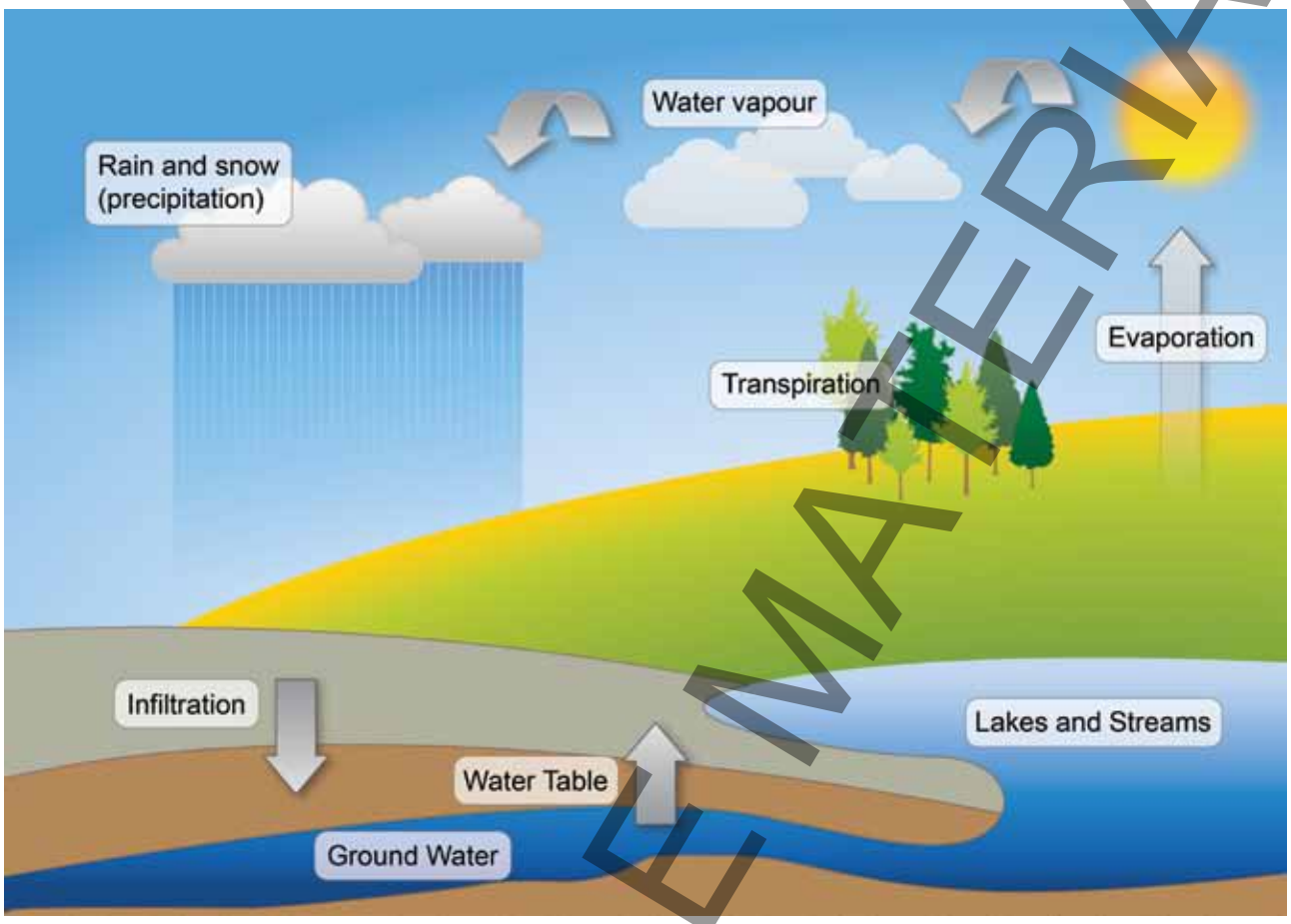
Purification is needed to varying extents (groundwater typically requires relatively little purification). Water treatment is required to produce an adequate and continuous supply of drinking water which is:

- Clear, i.e. no turbidity or suspended matter.
- Palatable, i.e. no unpleasant taste.
- Safe, i.e. no disease, organisms or harmful mineral content.
- Reasonably soft.

The Water Cycle

The water cycle (see diagram on next page) is unique in that water is present throughout only as the molecule H_2O, albeit existing in three physical states - vapour, liquid and ice. It is not chemically transformed.

Liquid water **takes in latent heat energy** to become water vapour; and water vapour condenses to liquid water, **releasing latent heat energy**. The amounts of energy involved are very large and the dynamics of weather are in great measure driven by them.



The Water Cycle

Although there appears to be a vast abundance of water available on the planet, we need to examine how this water is distributed. Only a small fraction of it is actually available to us for drinking, industry, agriculture, etc.

Distribution of Water Across the Planet

Location	% of Total
Oceans	97.24
Glaciers and icecaps	2.14
Groundwater aquifers	0.61
Lakes (freshwater)	0.009
Inland seas	0.008
Moisture held in soil	0.005
Atmospheric moisture	0.001
Rivers	0.001
Total	100%

Drinking water is collected from a variety of sources:

- **Surface Reservoirs**

  Particularly in Scotland, the north of England and Wales (98% of Welsh water is provided from surface reservoirs).

- **Underground**

  Particularly in southern England where:

  – Water is in relatively short supply, compared with demand.

  – Around 80% of the public water supply is from groundwater.

  In England and Wales as a whole, approximately 35% of the potable water supply is pumped from underground strata.

Jargon Buster

Potable

Suitable for drinking.

Being such a valuable and essential resource, water is:

- Continuously reused and recycled and great attention is paid to protecting rivers and groundwater.
- Vigorously protected by criminal law, with significant penalties available to the courts for anyone who pollutes a source of drinking water.

The term "controlled waters" is used in Section 104 of the **Water Resources Act 1991** to define those waters that the Environment Agency is responsible for protecting. Controlled waters are defined as:

- Relevant territorial waters.
- Coastal waters.
- Inland freshwaters.
- Groundwater.

Permits are required under the **Environmental Permitting (England and Wales) Regulations 2010** where anyone wishes to discharge into the above waters.

Water for Agriculture and Industry

The vast majority of our water from rivers and groundwater is used for irrigation of crops (both food and non-food), the actual figures varying between regions/climates. A large quantity is also used in keeping farm animals alive (both directly and indirectly through the food they eat). For example, about 15m^3 of water is required to produce each kg of beef. Industry is also a significant user, with water being used in the product directly (such as food/drink, chemical solutions) but also as process water (cooling, solvent, cleaning).

Impact of Water Pollution on Wildlife

Pollution of water does not only affect humans. Wildlife also relies on water to sustain life and while many species can survive using poor quality water, other species require a high standard of water to survive. Pike can be found in many rivers as they are quite tolerant to many forms of pollution, but trout and salmon are found only in good clean rivers that have high dissolved oxygen levels.

Water Conservation

With less than 1% of the water on the planet actually available for use, water should be treated as a valuable resource. Even in countries such as the UK where it is comparatively readily available, we should make an effort to conserve water where possible. This conservation also has a direct and positive effect on energy savings, as energy is used throughout the process that brings water to our taps.

Some of the ways to conserve water include:

- Toilets – if installing a new toilet, ensure it has a dual flush system which allows less water to be used if a full flush is not required. Indeed, consider not always flushing the toilet; even a short flush system uses several litres of clean water and may not always be necessary. If you have the older, single flush system, then consider a water-saving device, such as a "Hippo" – a plastic container open at the top that retains a portion of the water that would have been used in the flush.
- Fit a water meter – knowing you are being charged for what you use is a great incentive to reduce water consumption. It can also save you money on both your water bill and sewerage bill as this is calculated from the amount of water you use.
- Stop dripping taps – according to Waterwise (a not-for-profit water organisation funded by the water industry), a dripping tap wastes at least 5,500 litres of water a year.
- Water garden plants in the evening – this ensures that more of the water remains available to the plants and so in the long run less has to be used.
- Fit diffusers on taps – they won't make much difference when filling a bowl or basin, but if you wash anything under a running tap they will reduce the amount of water needed.
- Grey water recycling – using bath and washing water to flush the toilet can save large quantities of fresh, clean, drinking water from simply being flushed away.
- Fit low flow showerheads and take more showers than baths.

The Potential Effects of Pollution on Water Quality

Drinking contaminated water may affect human health in a variety of ways, depending on the concentration and nature of the contaminant.

One common method of classifying river quality uses invertebrate species as a basis for measurement. Known as the Biological Monitoring Working Party (BMWP) score, it attaches a score between 1 and 10 to species of aquatic invertebrates depending on their tolerance to pollution (the less tolerant a species is, the higher the score). Sensitive species such as stonefly nymphs attract a score of 10, while more tolerant species such as worms have a much lower score. By using a simple hand net, a sample can be obtained and examined and scores given for the number of species found in the sample. (Note that scores are for number of species, not number of individuals found, so five stonefly nymphs still attract a score of 10, as would one stonefly nymph.)

Jargon Buster

Aquatic Invertebrates

Animals without a backbone living in a water environment.

As we saw in Element 1, excessive levels of nitrates and phosphates in relatively still waters such as lakes can lead to a process of nutrient enrichment known as **eutrophication**.

Topic Focus

Eutrophication

In this process the excess nutrients cause an excessive growth of aquatic plants as well as green and blue-green algae. This eventually reduces the level of oxygen in the water and blocks out sunlight from the lower levels of the lake, causing aquatic animals and other vegetation to die off.

Because the pollution is usually from a diffuse (non-point) source, it is often difficult to control. Two possible methods of reducing the effect are:

- Artificial aeration of the water using pumps.
- The use of barley bales (bales of barley) in the water. It is still not entirely understood how the barley bales work, but they have been found to be effective at reducing the effect of eutrophication, and are thought to encourage bacteria that prevent algae growth.

Revision Question

1. Virtually all water bodies such as rivers, lakes and groundwater are protected by criminal law. Explain why it is important that **all** types of water body are protected.

(Suggested Answer is at the end of Unit NEC1.)

Main Sources of Water Pollution

Key Information

- Water pollution can be caused by 'point sources' or 'diffuse sources'.
- Pollution can be from surface water drainage, spills and leaks, process and cooling water, sewage and solids.

Some pollutants are particularly harmful:

- Just 250 grams of pesticide could be enough to exceed the permitted limits in the whole of London's water supply.
- A gallon of oil can pollute an area of water the size of two football pitches.
- One litre of the common degreasant trichloroethylene (a solvent) could contaminate 100 million litres of drinking water (the equivalent of 50 Olympic-sized swimming pools).

Water Polluted with Oil

In 2008 there were 442 serious pollution incidents affecting water in England and Wales, 74 of them Category 1 (Major) and 368 Category 2 (significant) incidents (source: DEFRA). Many of these were caused by the sewage and water industries, agriculture and industry. Many sources cannot be identified.

There are two main categories of water pollution:

- **Point sources** – distinct sources such as pipelines, ditches, etc. and relatively easy to identify and control.
- **Non-point or diffuse sources** – including run-off from fields of fertilisers and pesticides and acid rain. They are more difficult to identify than point sources and therefore harder to control.

Topic Focus

Some of the **main sources of water pollution** include:

- **Surface water drainage** – collects rainwater falling on a variety of surfaces and will wash into the system any contaminants on the surface where rain has fallen. These will then be washed into the watercourse. This source is a mix of diffuse and point source as the initial pollutant may come from a wide area (leaking oil from cars on roads, build-up of dirt and solids, etc.) but the final source will likely be a point source such as a drainage pipe into a river.
- **Contamination from spills/leaks** – many industrial sites will have a combination of foul water drains and surface water drains. It is essential that these are identified. Spills must be contained and the appropriate regulator informed if there is a risk that the pollution will enter either a controlled water or a sewerage system. Spills and leaks from disused process facilities, tanks, etc. may also go directly onto unmade ground eventually contaminating controlled waters, such as groundwater.

(Continued)

Topic Focus

- **Process and cooling water** – water is often used as a coolant and so will collect heat. Warm water retains much lower levels of oxygen than cold water and so volumes discharged into controlled waters must be managed to reduce any damage to the natural environment. The **Environmental Permitting (England and Wales) Regulations 2010** require an organisation to have a water discharge permit that defines the properties of the discharge that are allowed. Examples of processes using large volumes of water either within the process or as a coolant are cement manufacture, paper manufacture and power generation.
- **Sewage** – should be kept separate from controlled waters. However, many sewage works have storm-water systems that allow the discharge of raw sewage to a river in the event of high rainfall. Other failures in the sewerage system, such as the blocking or breaking of sewer pipes, can lead to contamination.
- **Solids (grit, plastics, etc.)** – large amounts of litter (particularly plastic bottles and wrappers) end up in our rivers, lakes and on beaches. Grits and silts (such as cement) also end up in rivers, washed from building activities.

Grit and silt from construction activities can run off into rivers and lakes

Revision Questions

2. State the two main categories of water pollution sources.
3. List any three of the main sources of water pollution.

(Suggested Answers are at the end of Unit NEC1.)

Main Control Measures Available to Reduce Contamination of Water Sources

Key Information

- Contamination of water can be reduced by considering the control hierarchy.
- Trade discharges into sewers require a consent to discharge under the **Water Industry Act 1991**.
- Polluting discharges into controlled waters require a permit under the **Environmental Permitting (England and Wales) Regulations 2010**.
- Physical measures to prevent or reduce pollution to water include:
  - Bunding of stores.
  - Use of oil interceptors.
  - Spill response procedures.
  - Coagulation to remove solids.
  - Correction of pH and temperature.
  - Screening, sedimentation, filtration and centrifugal separation to remove solids.
- Reactive and active (proactive) methods can be used to monitor contamination of water sources.

Control Hierarchy

The Environment Agency (EA) in England and Wales and Scottish Environment Protection Agency (SEPA) in Scotland are responsible for:

- The protection of water resources.
- Control of abstraction from and discharge to water resources.

We discussed the main legislative controls in Element 1. You should remember the hierarchical duty to "eliminate, minimise and render harmless" emissions to the environment that we discussed in Element 4.

Topic Focus

Control Hierarchy for Water Pollution

- **Eliminate:**
  - Replace chemicals that are harmful to the aquatic environment with non-hazardous alternatives.
  - Change of process to produce a solid rather than a liquid waste.
- **Minimise:**
  - Reduce the amount of water used in a process or activity.
  - Store smaller quantities of hazardous substances at any one time.
  - Reduce the amount of fertilisers used on agricultural land.
- **Render harmless:**
  - The techniques described in the subsection on Control Methods in this element either minimise pollutants or render them harmless before they are discharged to water.

Control Methods

We will now look at some of the legal and physical controls available to reduce pollution of water resources.

Consents/Permits to Discharge

Water Industry Acts 1991 and 1999

The **Water Industry Act 1991** requires water companies and regional water authorities to provide a supply of wholesome drinking water. These organisations are now referred to as water undertakers. The regional water authorities also have a responsibility to provide sewage services (water and sewerage undertakers).

The Act makes it an offence for any trade premises to discharge any trade effluent into a public sewer unless authorised by the sewerage undertaker. Any authorised discharge must then comply with the terms of the discharge consent.

A consent to discharge to the sewer is generally required if more than 5 m^3 per day is produced. Consents to discharge cover conditions relating to:

- Maximum permitted flow rate (daily and hourly).
- Temperature.
- Maximum Chemical Oxygen Demand (COD) or Maximum Biological Oxygen Demand (BOD). These and related terms are described in more detail below.
- pH range (typically 5 – 9).
- Maximum concentration of suspended solids.

Consents to discharge conditions may also cover:

- Limits of amounts of dissolved oil, metals (e.g. copper, zinc), organic chemicals (e.g. phenols). (These can affect operation of sewage treatment works.)
- Limits on prescribed substances (e.g. cadmium, mercury and other so-called Black List and Red List substances (the most serious), and Grey List substances (less harmful)). The **Trade Effluents (Prescribed Processes and Substances) Regulations 1989, as amended**, identify such substances. (This is due to constraints set by the EA/SEPA for final discharge, such applications being referred to the EA/SEPA for approval.)

The actual consent conditions will vary depending on the process that gives rise to the discharge.

The **Water Industry Act 1999** made some amendments to the 1991 Act, mainly in relation to the provision of water meters and the consumer's right to demand to be charged for the volume of water used rather than by the rateable value of their property.

Water Resources Act 1991

The **Water Resources Act 1991** makes it an offence to abstract from controlled waters without authorisation unless the volumes are very small (<5 cubic metres per day needs no agreement; between 5 and 20 cubic metres needs agreement but no formal permit is required).

The **Environmental Permitting (England and Wales) Regulations 2010** make it an offence to:

- discharge poisonous, noxious or polluting matter, waste matter, trade or sewage effluent into freshwaters, coastal waters, estuaries;
- discharge trade effluent or sewage effluent by a pipe from land into the sea;
- remove materials from inland freshwaters that have built up from a dam, weir or sluice, if material is carried away by the water;
- cut or uproot large amounts of vegetation in inland freshwaters without taking reasonable steps to remove it;
- discharge a pollutant directly or indirectly into groundwater;

unless a permit has been granted and the terms of the permit are complied with.

A discharge to coastal waters that would require a permit

The Environment Agency is the regulating body for authorising discharge to and abstraction from controlled waters. As with the discharge consent under the **Water Industry Act** (above), the permit will include:

- volume and rate of discharge;
- temperature of the water to be discharged; and
- the properties and concentrations of any pollutants that may be contained in the water.

The **Water Resources Act** also allows the Secretary of State for the Environment to set Water Quality Objectives for designated areas. Once these are set, it is the responsibility of the Environment Agency to manage discharges so as to ensure the objectives are met.

Monitoring Water Quality

Conditions in consents and permits may include specific monitoring (for water quality) and maintenance requirements. Monitoring should include a mixture of active (proactive) and reactive measures.

Topic Focus

Active and Reactive Monitoring

Active monitoring is undertaken before there has been a failure. Examples would include:

- Sampling the quality, flow rate, pH and other parameters of the water discharge.
- Mass balance calculations for underground storage tanks.
- Site inspections to identify potential risks.
- Calibration of monitoring equipment to ensure accurate results.

Reactive monitoring is undertaken following a failure. Examples would include:

- Collecting data on near-misses.
- Monitoring of complaints from neighbours or workers.
- Information on enforcement action.
- Records of past incidents or spillages.

(**Note**: similar active and reactive monitoring is appropriate for emissions to air.)

Active monitoring of the water quality includes parameters such as temperature, flow rate and chemical constituents, but there are three other measures that are important and may need to be monitored:

- Chemical Oxygen Demand (COD).
- Biological Oxygen Demand (BOD).
- Total Oxygen Demand (TOD).

Topic Focus

COD, BOD and TOD

- **Chemical Oxygen Demand (COD)**
  - A test commonly used in environmental chemistry to indirectly measure the amount of organic compounds in water.
  - Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality.
  - COD is expressed in milligrams per litre (mg/l), which indicates the mass of oxygen consumed per litre of solution. Older references may express the units as parts per million (ppm).
- **Biological Oxygen Demand (BOD)**
  - Also known as Biochemical Oxygen Demand.
  - A chemical procedure for determining how fast biological organisms use up oxygen in a body of water.
  - Used in water quality management and assessment, ecology and environmental science.
  - Not an accurate quantitative test, although it could be considered as an indication of the quality of a water source.
- **Total Oxygen Demand (TOD)**
  - Represents the total amount of oxygen necessary for the complete oxidation of organic and inorganic compounds present in a sample of water.
  - The resulting figures are expressed in milligrams of oxygen per litre and represent an index of the degree of water pollution by oxidisable substances, mainly organics.

COD, BOD and TOD are all measures of the potential oxygen depletion that can be caused following discharge of pollutants into water. This occurs from the breakdown of organic materials by micro-organisms which subsequently take oxygen out of the water as part of the process of decomposition. Such oxygen depletion can severely affect aquatic life, causing fish kills for example (fish do not have enough oxygen to breathe). Substances that cause such pollution include milk, beer, sewage, blood, etc. As such, all have to be discharged

within consent conditions (this is also obviously a legal requirement) and protected from spilling into surface waters and public sewers.

Jargon Buster

Micro-organism

An organism that is microscopic, including bacteria, fungi, microscopic plants and animals such as plankton.

Controls for Storage and Spillage

Preventing Spillages

Since spillages of noxious chemicals are a ready source of pollution, the most effective strategy is to prevent spills in the first place:

- Sloppy chemical transfer practices create an unnecessary risk of spillage, whereas more careful operating procedures prevent or minimise such losses.
- Maintenance and inspection will identify potential or actual spills and leaks early on, preventing them from either developing or getting worse. For example, corrosion, if allowed to develop unchecked, will ultimately cause the container/pipe to fail.
- Proper storage of materials will also help prevent spillage, e.g. siting dangerous chemicals away from internal traffic routes or with barriers to protect from collision.

Corrosion of containers will ultimately cause them to fail

Keeping Systems Separate

Appropriate Storage of Incompatible Materials

When incompatible materials come into contact with each other, e.g. during an accidental spill, the substances may react together to cause a fire or explosion or to form a toxic substance. Careful consideration of storage requirements given in material safety data sheets will assist in determining the appropriate storage arrangements. Consider:

- Are materials likely to result in a violent chemical reaction if they come into contact with one another?
- Should a fire occur involving one material, would fire suppression substances, such as water, cause a problem with other materials?
- Are flammable goods stored away from oxidising agents?
- Would a spillage of one material damage or disintegrate the packaging and containers of other stored materials?

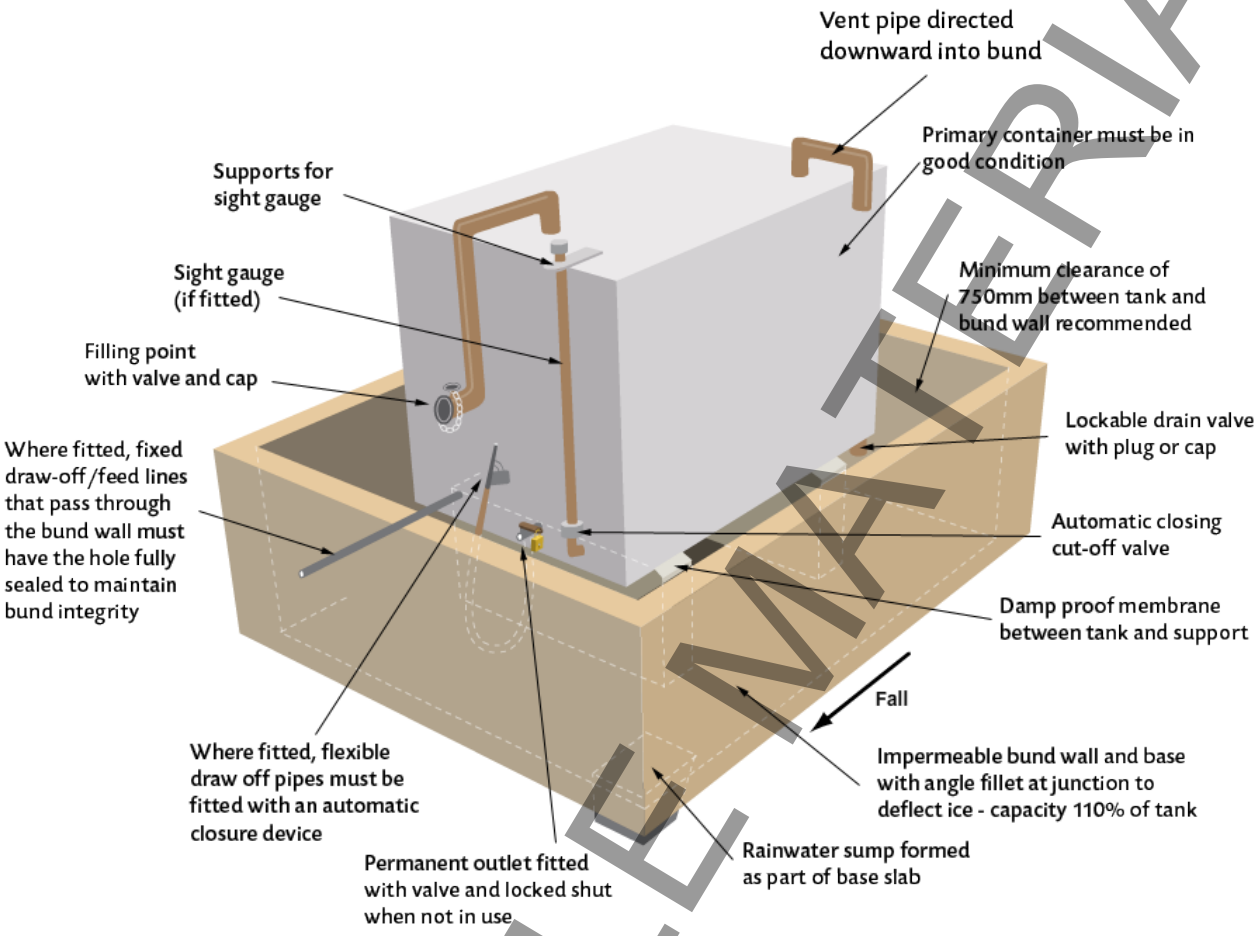
Bunding of Chemical and Oil Stores

Jargon Buster

Bund

A secondary, impermeable container in which the primary container sits. Commonly used for larger storage vessels, bunds typically consist of a wall surrounding the primary container, the inside surfaces (and floor) all being rendered impermeable. The bund is sized to 110% of the volume of the primary container.

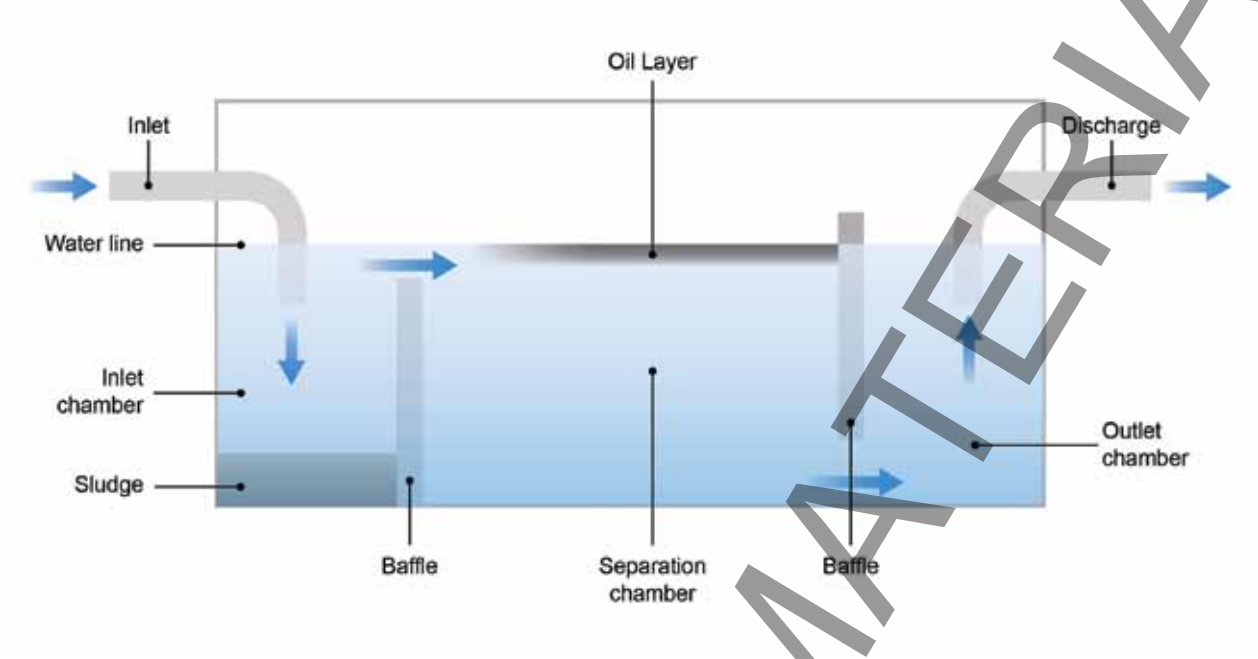
Oil storage is required to meet standards set out in the **Control of Pollution (Oil Storage) Regulations 2001**. While chemicals are not specifically covered by these Regulations, they still provide a good standard to work to and if followed will likely provide a good level of protection. One of the key requirements is to use a suitably designed and constructed bund.



Bunded Oil Tank Showing Arrangements for Fixed and Flexible Draw-Off Points (after Pollution Prevention Guidelines PPG2)

Use of Oil Interceptors

Oil interceptors use the fact that oil (including oil-based fuels) floats to prevent it being discharged. Regular inspection of interceptors is essential to ensure they are not blocked or overloaded with excess volumes of oil. Different types of oil interceptors are available for different uses. For example, oil interceptors are used in surface water drainage systems from hard standings such as car parks (where obviously oil leaks from car engines can build up).



Simple Oil Interceptor

Separation and Marking of Drain Systems

Sewerage and surface water systems should not mix. Process water should also be kept separate, if possible, as this will enable any sources of pollution to be more easily identified. Drain covers should be marked with both the type of drain (surface, sewer, process, etc.) and the direction of flow. A clear colour coding system should be used and the direction of flow should not be marked on the cover itself but on the surround. Usually, blue is used to denote surface water drainage (i.e. for uncontaminated rainwater) and red for foul water drainage (i.e. for sewage and/or trade effluent).

Dealing with Spillages

Provision of spill kits suitable to deal with the type of pollution likely to occur and training in the proper use of the kits is an important control system. The kits must be maintained and available at the locations where spills are likely to occur, as quick action is required if pollutants are to be prevented from entering the water source.

Controls for Waste Water

Screening

This is a simple process which uses a screen (e.g. stainless steel mesh) to filter out large solids and organic matter (such as sticks, weeds) – commonly used in water treatment works.

Solids Separation and Removal of Organic Load (Coagulation)

Fine particles such as clay, metal oxides and some organic substances are difficult to settle out of suspension under natural conditions. Coagulants are used to encourage these particles to come together in what are known as "flocs". Aluminium is a commonly used coagulant. Once the coagulants have been added, the water must be mixed at high speed to ensure effective mixing takes place. Once thoroughly mixed the water is passed to another tank where it is stirred slowly allowing even larger flocs to form. Eventually the water moves to another tank where there is very little movement and the flocs sediment out to the bottom.

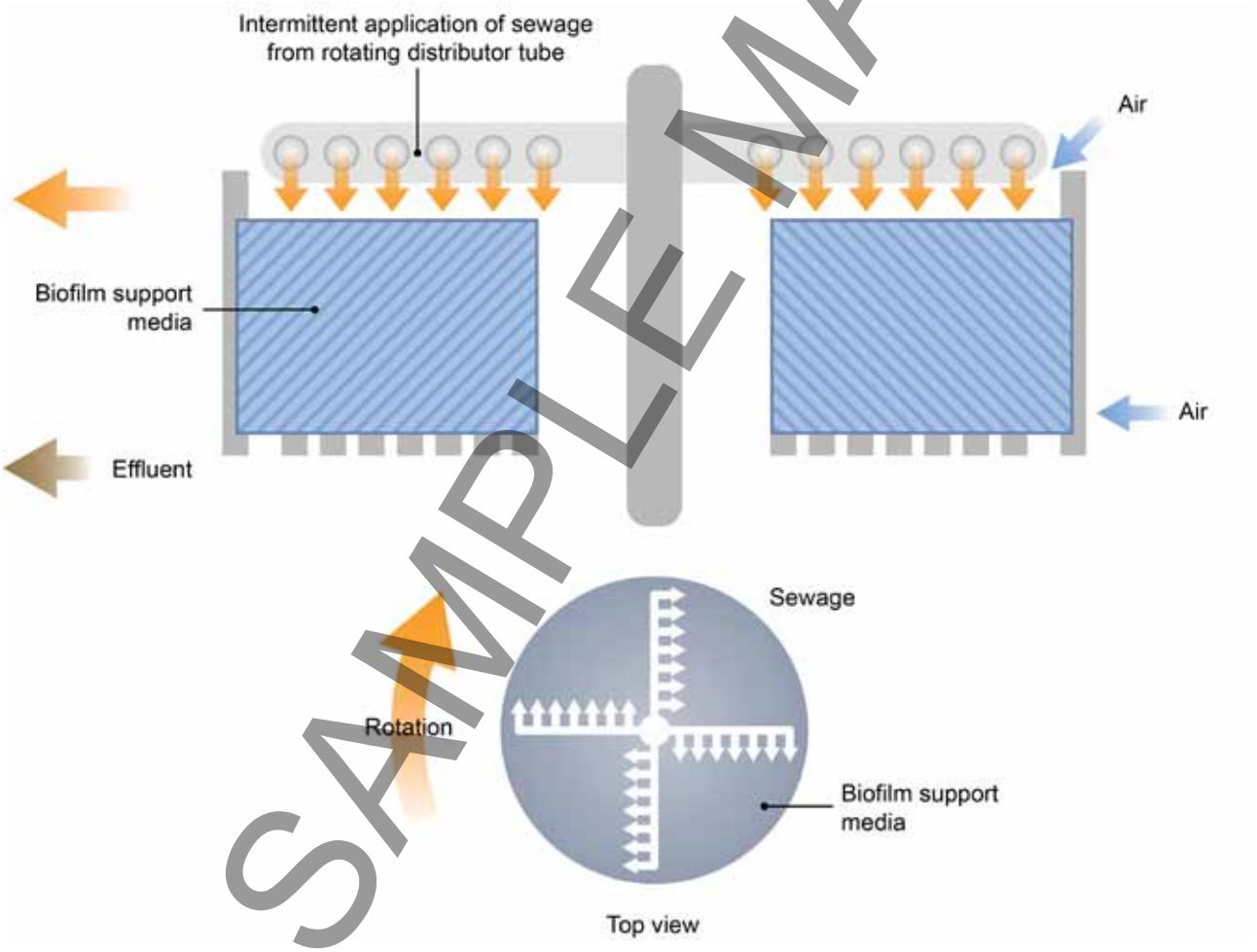
Sedimentation/Flotation

Sedimentation is where the water is stored in a tank and any suspended solids are able to sink to the bottom under gravity. Alternatively flotation can be used, where air is blown into the water increasing the buoyancy of the particles as they absorb air. When they reach the surface they can be skimmed off using rotating blades.

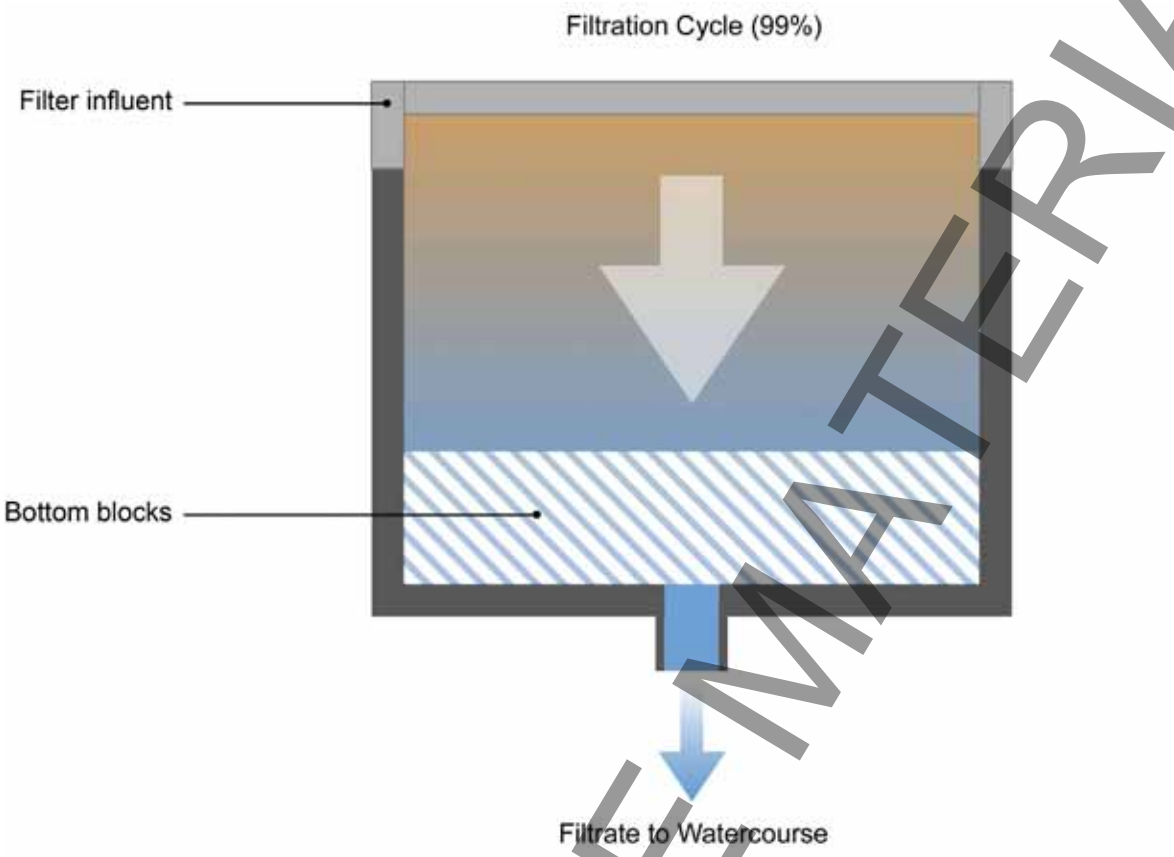
Filtration

Filtration is a separation technique whereby solids are trapped in a filter medium and the liquid is allowed to pass through. Depending on the nature and extent of the solids loading, different media can be used. For example, tertiary treatment of water in a sewage works would typically involve the use of a sand filter (anthracite may also be used).

Primary treatment of sewage commonly uses **biological** or **trickling filters**. This is where primary settled sewage is intermittently spread by a rotating distributor tube over a bed of gravel. Liquor flows over the surface of the gravel, on which a biofilm of micro-organisms develops and grows by digesting the sewage. It seeps down and is collected at the bottom. It is important that the beds do not become waterlogged.



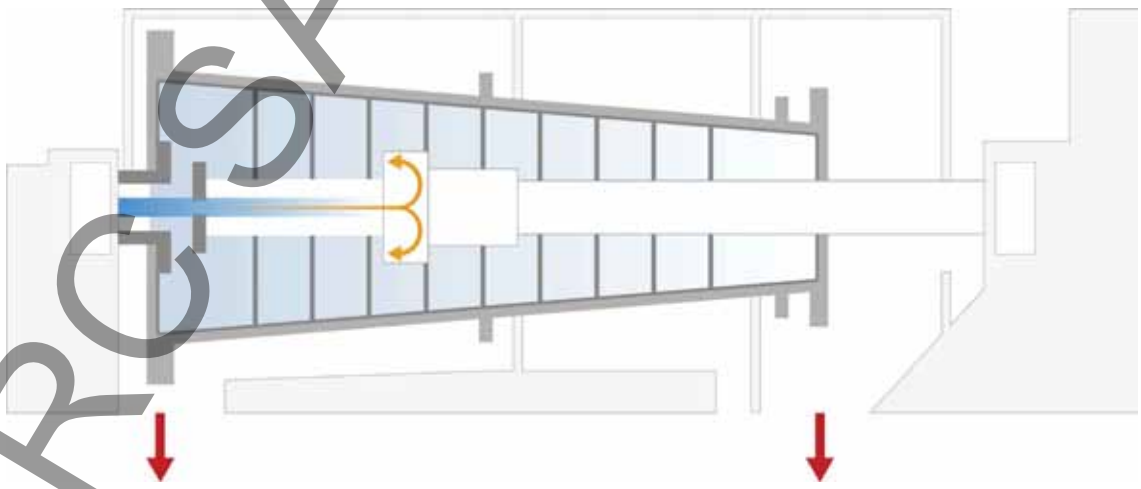
Trickling Filter System - Cross-Section and Top View



Sand Filter Filtration Cycle

Centrifugal Separation

Centrifugal separation is really a form of accelerated settling. Normal settling leads to relatively slow separation of solids from liquids, forming a sediment at the bottom, under the influence of gravity. In centrifugal separation the water is fed into a centrifuge that spins at high speed. The centrifugal forces act on the heavier particles in the water, forcing them to the outside where they are collected and fed away from the water. The clean water passes through the system. The technique is typically used to de-water sludge (from sewage treatment operations).



Simple Decanter Centrifuge

Correction of pH

As mentioned earlier for discharge consents and permits, the pH has to be adjusted to within certain limits. If the waste water is too acidic, it can be adjusted with alkaline materials such as lime (calcium oxide/hydroxide) or sodium carbonate. If it is too alkaline, it can be adjusted with acids such as hydrochloric acid.

Revision Question

4. List five methods used to reduce contamination of water resources.

(Suggested Answer is at the end of Unit NEC1.)

Unit NEC2: Environmental Practical Application

Now that you have studied approximately half of the course, you should be in a position to send your tutor a rough outline of your practical application.

You should have already decided on your chosen area and approached management to ensure that they are happy to co-operate in terms of providing information. You should also have discussed with them any confidentiality issues that may exist. Now you should send your tutor a brief outline of the area you intend to cover and the issues you expect to encounter there.

There are a couple of points to remember before you submit this:

- The area must be sufficiently simple and small to allow you to complete the practical application within three hours (even if this means selecting a small area within the site, such as a warehouse, maintenance depot or single production area, if your site is large).
- The NEBOSH proforma to be used for the practical application (shown in your guidance for Unit NEC2):
  - Is designed to cover the principal topics contained in the syllabus.
  - Will help you to structure your practical application work.
  - Will help you in completing your outline for your tutor.

You can see from it the kind of issues that NEBOSH expect you to cover in your practical application, so don't forget to look at it. Some sections in the proforma may not be relevant to your particular site, but your chosen area does need to cover a sufficiently wide range of topics.

Submit your outline plan for your practical application to your tutor:

- using the e-mail system; or
- by post (using the submission form provided in your NEC2 guidance).

If you have any queries on the proforma before you submit your outline, contact your tutor for help.

Summary

This element has dealt with the control of contamination of water sources.

In particular this element has:

- Explained that water supply companies have a legal duty to supply water that is fit to drink, sourced from groundwater, reservoirs and rivers. Varying levels of purification are required to produce water which is clear, palatable, safe and reasonably soft.
- Emphasised that water should be treated as a valuable resource. Methods of water conservation include: dual flush toilets; installation of a water meter; and grey water recycling.
- Outlined the two main categories of water pollution:
  - Point sources, e.g. pipelines, ditches.
  - Non-point or diffuse sources, e.g. run-off from fields, acid rain.
- Described the main sources of water pollution including:
  - Surface water drainage.
  - Contamination from spills and leaks, sewage, process and cooling water.
  - Solids such as grit, plastics, etc.
- Outlined the main control measures available to reduce contamination of water sources including:
  - Conditional consents to discharge to a sewer (e.g. maximum permitted flow rate, temperature, pH range, etc.) under the **Water Industry Act 1991**.
  - Control of abstraction from controlled waters under the **Water Resources Act 1991**.
  - Conditional permits to discharge to a controlled water under the **Environmental Permitting (England and Wales) Regulations 2010**.
  - Controls for storage and spillage: prevention of spillages in the first place with the use of appropriate procedures and techniques; appropriate storage; separation and marking of drain systems; use of oil interceptors; bunding of chemical and oil stores; and speedy clearing of spillages.
  - Controls for waste water: screening; solids separation and removal of organic load (use of "flocs"); centrifugal separation (accelerated settling); sedimentation/flotation; filtration (solids are trapped in a filter medium and the liquid passes through); and correction of pH.

Exam Skills

ELEMENT 5 CONTROL OF CONTAMINATION OF WATER SOURCES

Question 1

Describe the essential features and mechanisms of "The Water Cycle". (8)

Question 2

(a) Give the meaning of the following terms:

(i) Chemical oxygen demand (COD). (2)

(ii) Biological oxygen demand (BOD). (2)

(b) **Outline TWO** different sources of pollutants that may cause increased biological oxygen demand in surface water. (4)

Approaching Question 1

As before, using good exam technique you must:

- Read the question.
- Consider the marks available. In this case there are eight marks available so you should spend around nine minutes answering the question and provide eight pieces of significantly different information.
- Highlight the key words. In this case they would include Describe, features, mechanisms, Water Cycle.
- Read the question again.
- Jot down an outline plan. This might include:
  - Evaporation, transpiration, respiration, clouds, precipitation, ice/glaciers, groundwater, abstraction, recharge, purifying effect.

Note that this is a 'Describe' question so a fuller answer is required, which is represented by the full eight marks being available with no subdivision of the question.

Now attempt this question by providing an answer as you would in the exam.

Remember you can contact your tutor if you have any queries.

Suggested Answer to Question 1

Now you have finished your answer, read the suggested answer below and compare it to your answer.

The essential features of the water cycle include that water is evaporated by energy from the sun. Such water sources include lakes, rivers and the sea. Plants also emit water vapour to the air through the process of transpiration and animals through respiration. Water vapour forms clouds higher up in the atmosphere. Cooling leads to condensation (vapour to liquid) which forms rain, ice or snow, which will then fall back to the surface of the Earth. It may also fall onto glaciers or in cold regions of the world where it will form ice. The precipitation will also fall directly onto watercourses. The precipitation may also fall onto the ground where it may form groundwater. Humans may abstract water from the ground or from surface water. Groundwater often feeds into watercourses, thus completing the cycle. The water cycle plays an essential role in naturally purifying water of contaminants and pathogens.

Exam Skills

ELEMENT 5 CONTROL OF CONTAMINATION OF WATER SOURCES

Approaching Question 2

- Read the question.
- Consider the marks and time available.
- Highlight the key words. In this case they would include:

  (a) Meaning, terms chemical oxygen demand, biological oxygen demand.

  (b) Outline, TWO sources, pollutants, increased BOD.
- Read the question again.
- Jot down an outline plan. This might include:

  (a) (i) Oxygen consumed, oxidising agent, heated, inorganic/organic matter.

  (ii) Micro-organisms, incubating, five days, organic.

  (b) Food production, sewage treatment, agriculture, brewing (two only).

Now attempt this question by providing an answer as you would in the exam.

Remember you can contact your tutor if you have any queries.

Suggested Answer to Question 2

Now you have finished your answer, read the suggested answer below and compare it to your answer.

(a) (i) COD is the amount of oxygen that is consumed from an oxidising agent (such as potassium/sodium dichromate) when an aqueous sample is heated (usually for four hours under acidic conditions). The oxygen may be consumed by organic and some inorganic matter.

(ii) BOD is determined by incubating an aqueous sample with oxygen and micro-organisms present for five days at a temperature of 20°C. The oxygen is mainly consumed by biodegradable organic matter.

(b) Two of the following:

Waste from food production could be an important source of pollutants with a high BOD. Ingredients such as milk, etc. could cause increased oxygen demand on water should they be spilled or released.

Sewage released from sewage treatment works due to breaches in containment or pipes may cause sewage to spill into a nearby watercourse, causing an increase in oxygen depletion.

Slurry and silage liquor from farms can also cause oxygen depletion. It may be released from a breach of containment or from spreading too much slurry onto the land (particularly when ground is frozen or saturated).

Brewing may also be a source of high BOD materials. A spillage of beer or aqueous by-products of the brewing process can have a high oxygen demand.

NEBOSH National Diploma in Environmental Management Unit ED1

Element 10: Gaseous and Particulate Releases to Atmosphere

RRC TRAINING

Contents

Element 10: Gaseous and Particulate Releases to Atmosphere

Learning Outcomes

On completion of this element, you should be able to:

- Describe the characteristics of emissions to the atmosphere and assess whether emissions are likely to be subject to specific legal requirements.
- Explain the relevant legal requirements for the management of emissions to atmosphere.
- Describe strategies for monitoring atmospheric emissions.
- Describe appropriate control strategies and measures for releases to atmosphere.

Hints and Tips

It is important that you study this element in conjunction with the online *RRC Environmental Health & Safety Law Guide*, where you will find details of cases and Acts and Regulations mentioned in the course material.

Log in to RRC's support website at: http://www.rrc.co.uk to access this important learning resource.

Emissions to The Atmosphere

Key Information

- Solid particles in air may be classified as fumes, smoke, dust or grit, depending on particle size.
- Liquids suspended in air can be classified as vapours, mists and droplets.
- Legal standards for smoke emissions class smoke as dark or black by reference to a shade on the British Standard Ringelmann Chart.
- The **Environment Act 1995, Air Quality Standards Regulations 2007** and EU **Directive 2008/50/EC** on ambient air quality and cleaner air for Europe are the main laws covering air quality.

Types of Emission

Solid particles may be classified as fumes, smoke, dust and grit, depending on particle size. Liquids suspended in air can similarly be classified as vapours, mists and droplets with increasing particle size. Air emissions can also be in the form of gases or fibres.

Jargon Buster

Gaseous

Pure gases are substances which remain in the gaseous phase at the process temperatures and pressures, e.g. carbon dioxide, nitrogen and ozone.

Vapours

Are the gaseous state of materials which are liquid at normal temperature and pressure. Mists are formed when vapours condense and are composed of very fine droplets in the range 0.01 to 10.0 microns. Droplets are normally generated by mechanical action on static or flowing liquids, but may form by the further condensation and coalescence of mist. Droplets normally sediment out of the air stream. However, under certain conditions evaporation from the droplet surface may result in the formation of mists.

Mists

Are fine liquid droplets, usually nucleated by a particle.

Fumes

Are small solid particles produced by condensation of vapours or gaseous combustion products

(Continued)

Jargon Buster

(i.e. cooling of combustion products from hot processes). Particle size is in the range 0.01 to 1 micron.

Smoke

Particles in the range 0.1 microns to 10 microns are seen as smoke. There are no clearly established size definitions for these particulates and different publications suggest other overlapping size bands. In industrial air streams, the very fine particles may increase in size by coagulating into larger particles. Those greater than 20 microns tend to sediment out rapidly. Therefore, most particle sizes encountered are between 0.1 and 20 microns in size.

Dust

May consist of any size or shape of particle, crystalline or amorphous. Particle sizes capable of inhalation are up to 10 microns; particle sizes of less than 7 microns are capable of penetrating lung tissue.

Grit

Is defined as particles exceeding 76 microns in diameter (**Clean Air (Emissions of Grit and Dust from Furnaces) Regulations 1971**).

Fibres

Are solid particles with an increased aspect ratio (the ratio of length to width). Fibres have special properties due to their ability to be suspended in the air just like dusts and other aerosols.

Types of Substances Prescribed for Release to the Atmosphere and Types of Prescribed Processes

Prescribed Activities under the IPPC Directive

The following Annex is taken from the *Official Journal of the European Communities*, L257, Volume 39, 10th October 1996.

Annex 1

Categories of Industrial Activities Referred to in Article 1	
1.	**Energy Industries**
1.1	Combustion installations with a rated thermal input exceeding 50 MW.*
1.2	Mineral oil and gas refineries.
1.3	Coke ovens.
1.4	Coal gasification and liquefaction plants.

*The rate at which fuel can be burned at the maximum continuous rating of the installation multiplied by the net calorific value of the fuel and expressed as megawatts thermal.

2.	**Production and Processing of Metals**
2.1	Metal ore (including sulphide ore) roasting or sintering installations.
2.2	Installations for the production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2.5 tonnes per hour.
2.3	Installations for the processing of ferrous metals: Hot rolling mills with a capacity exceeding 20 tonnes of crude steel per hour. Smitheries with hammers the energy of which exceeds 50 kilojoules per hammer, where the calorific power used exceeds 20MW. Application of protective fused metal coats with an input exceeding 2 tonnes of crude steel per hour.
2.4	Ferrous metal foundries with a production capacity exceeding 20 tonnes per day.
2.5	Installations: (a) For the production of non-ferrous crude metals from ore, concentrates or secondary raw materials by metallurgical, chemical or electrolytic processes. (b) For the smelting, including the alloyage, of non-ferrous metals, including recovered products, (refining, foundry casting, etc.) with a melting capacity exceeding 4 tonnes per day for lead and cadmium or 20 tonnes per day for all other metals.
2.6	Installations for surface treatment of metals and plastic materials using an electrolytic or chemical process where the volume of the treatment vats exceeds $30m^3$.
3.	**Mineral Industry**
3.1	Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day, or lime in rotary kilns with a production capacity exceeding 50 tonnes per day, or in other furnaces with a production capacity exceeding 50 tonnes per day.
3.2	Installations for the production of asbestos and the manufacture of asbestos-based products.
3.3	Installations for the manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day.
3.4	Installations for melting mineral substances including the production of mineral fibre with a melting capacity exceeding 20 tonnes per day.
3.5	Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day, and/or with a kiln capacity exceeding 4m3 and with a setting density per kiln exceeding 300 kg/m^3.

4.	**Chemical Industry**
	Production within the meaning of the categories of activities contained in this section means the production on an industrial scale by chemical processing of substances or groups of substances listed in sections 4.1 to 4.6.
4.1	Chemical installations for the production of basic organic chemicals, such as: (i) Simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic). (ii) Oxygen – containing hydrocarbons such as alcohols, aldehydes, ketones, carboxylic acids, esters, acetates, ethers, peroxides, epoxy resins. (iii) Sulphurous hydrocarbons. (iv) Nitrogenous hydrocarbons such as amines, amides, nitrous compounds, nitro compounds or nitrate compounds, nitriles, cyanates, isocyanates. (v) Phosphorous-containing hydrocarbons. (vi) Halogenic hydrocarbons. (vii) Organometallic compounds. (viii) Basic plastic materials (polymers, synthetic fibres and cellulose-based fibres). (ix) Synthetic rubbers. (x) Dyes and pigments. (xi) Surface-active agents and surfactants.
4.2	Chemical installations for the production of basic inorganic chemicals, such as: (i) Gases, such as ammonia, chlorine or hydrogen chloride, fluorine or hydrogen fluoride, carbon oxides, sulphur compounds, nitrogen oxides, hydrogen, sulphur dioxide, carbonyl chloride. (i) Acids such as chromic acid, hydrofluoric acid, phosphoric acid, nitric acid, hydrochloric acid, sulphuric acid, oleum, sulphurous acids. (i) Bases, such as ammonium hydroxide, potassium hydroxide, sodium hydroxide. (i) Salts, such as ammonium chloride, potassium chlorate, potassium carbonate, sodium carbonate, perborate, silver nitrate. (i) Non-metals, metal oxides or other inorganic compounds such as calcium carbide, silicon, silicon carbide.
4.3	Chemical installations for the production of phosphorous-, nitrogen- or potassium-based fertilisers (simple or compound fertilisers).
4.4	Chemical installations for the production of basic plant health products and of biocides.
4.5	Installations using a chemical or biological process for the production of basic pharmaceutical products.
4.6	Chemical installations for the production of explosives.
5.	**Waste Management**
	Without prejudice of Article 11 of **Directive 75/442/EEC** or Article 3 of Council **Directive 91/689/EEC** of 12th December 1991 on hazardous waste.
5.1	Installations for the disposal or recovery of hazardous waste as defined in the list referred to in Article 1 (4) of **Directive 91/689/EEC**, defined in Annexes IIA and IIB (operations R1, R5, R6, R8 and R9) to **Directive 75/442/EEC** and in Council **Directive 75/439/EEC** of 16th June 1995 on the disposal of waste oils with a capacity exceeding 10 tonnes per day.
5.2	Installations for the incineration of municipal waste as defined in Council **Directive 89/369/EEC** of 8th June 1989 on the prevention of air pollution from new municipal waste incineration plants and Council **Directive 89/429/EEC** of 21st June 1989 on the reduction of air pollution from existing municipal waste-incineration plants with a capacity exceeding 3 tonnes per hour.

5.3	Installations for the disposal of non-hazardous waste as defined in Annex IIA to **Directive 75/442/EEC** under headings D8 and D9, with a capacity exceeding 50 tonnes per day.
5.4	Landfills receiving more than 10 tonnes per day or with a total capacity exceeding 25,000 tonnes, excluding landfills of inert waste.
6.	**Other Activities**
6.1	Industrial plants for the production of: (a) Pulp from timber or other fibrous materials. (b) Paper and board with a production capacity exceeding 20 tonnes per day.
6.2	Plants for the pre-treatment (operations such as washing, bleaching; mercerisation) or dyeing of fibres or textiles where the treatment capacity exceeds 10 tonnes per day.
6.3	Plants for the tanning of hides and skins where the treatment capacity exceeds 12 tonnes of finished products per day.
6.4	(a) Slaughterhouses with a carcass production capacity greater than 50 tonnes per day. (b) Treatment and processing intended for the production of food products from: – Animal raw materials (other than milk) with a finished product production capacity greater than 75 tonnes per day. – Vegetable raw materials with a finished product production capacity greater than 300 tonnes per day (average value on a quarterly basis). (c) Treatment and processing of milk, the quantity of milk received being greater than 200 tonnes per day (average value on an annual basis).
6.5	Installations for the disposal or recycling of animal carcases and animal waste with a treatment capacity exceeding 10 tonnes per day.
6.6	Installations for the intensive rearing of poultry or pigs with more than: (a) 40,000 places for poultry. (b) 2,000 places for production pigs (over 30 kg) or 750 places for sows.
6.7	Installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with a consumption capacity of more than 150 kg per hour or more than 200 tonnes per year.
6.8	Installations for the production of carbon (hard-burnt coal) or electrographite by means of incineration or graphitisation.

Note: the excerpt describes the **IPPC Directive** processes, i.e. the Part A(1)/A(2) processes, Part A in Scotland. The descriptions of Part B processes are to be found in the **Environmental Permitting Regulations 2010**.

More...

Further information on the **IPPC Directive** can be found on the European Commission website:

http://ec.europa.eu/environment/air/pollutants/stationary/ippc/index.htm.

Pollutants

The **Environmental Permitting Regulations 2010** state that the following pollutants, if they are released into the air or there is a likelihood that they may be released into the air, must not be Part B processes:

1. Sulphur dioxide and other sulphur compounds.
2. Oxides of nitrogen and other nitrogen compounds.
3. Oxides of carbon.
4. Organic compounds and partial oxidation products.
5. Metals, metalloids and their compounds.
6. Asbestos (suspended particulate matter and fibres), glass fibres and mineral fibres.
7. Halogens and their compounds.

8. Phosphorus and its compounds.
9. Particulate matter.

Classification of Smoke

Current legislation uses the term "dark smoke", which requires explanation.

Topic Focus

Meaning of "Dark Smoke"

Where legal standards of emission are prescribed for smoke they refer to "dark" and "black" smoke.

Dark smoke is defined by reference to a shade on the British Standard Ringelmann Chart, defined in BS 2742:1969, and means smoke which, if compared with the Ringelmann Chart, would appear to be as dark as or darker than Shade 2 on the chart.

Ringelmann 1 = 20% obscuration.

Ringelmann 2 = 40% obscuration.

Ringelmann 3 = 60% obscuration.

Ringelmann 4 = 89% obscuration.

Use of a Ringelmann Chart measurement is not compulsory for the purposes of securing a prosecution under the **Clean Air Act**.

Meaning of Black Smoke

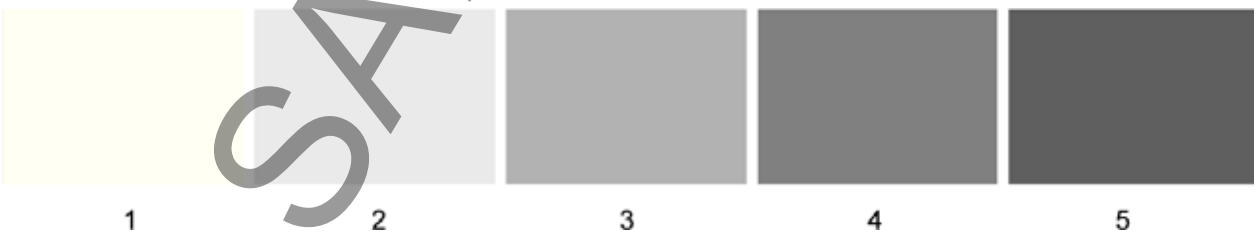
Black smoke, as defined in the **Dark Smoke (Permitted Periods) Regulations 1958**, means smoke which, if compared with the Ringelmann Chart, would appear to be as dark as or darker than Shade 4 on the chart.

Prohibition on Smoke, Grit, Dust and Fumes

Any installation must be capable of operating continuously without emitting smoke.

All furnaces (except domestic appliances) must be equipped with a grit and dust arrestment plant, which must be properly maintained.

Domestic appliances are those rated at less than 16.12 kilowatts. Section 6 of the **Clean Air Act** defines when an arrestment plant is required, and grit and dust are defined in BS 3405.



Approximation of Ringelmann Shades

Jargon Buster

Ringelmann Chart

A chart of various shades of grey (1-5) that is compared to an emission to air to determine compliance with the **Clean Air Act** and associated regulations. The British standard BS 2742:1969 identifies how it should be used.

Air Quality Objectives and Standards

National Air Quality Strategy

The **Environment Act 1995**, Part IV, Section 80, introduced a National Air Quality Strategy which was put into effect in March 1997. Objectives for each pollutant were set and given statutory authority in the **Air Quality Regulations 1997**, later repealed by the **Air Quality (England) Regulations 2000**. A revised strategy was published in January 2000 and an addendum published in 2003.

The latest version of the strategy was published in 2007 and identifies air quality objectives and target values for the protection of human health for the following substances:

- Benzene.
- 1,3 Butadiene.
- Carbon monoxide.
- Lead.
- Nitrogen dioxide.
- Particles (PM10).
- Particles (PM2.5).
- PAH.
- Ozone.
- Sulphur dioxide.

Air quality objectives and targets are also set for the protection of vegetation and ecosystems for nitrogen oxides, sulphur dioxide and ozone.

As well as the identification of air quality objectives, the strategy also includes determination of current air quality, the tasks that the Government are undertaking to achieve the strategy's objectives and contributions from other industry sectors such as local government and transport.

Standards for air pollution are concentrations over a set period of time that are considered to be acceptable in comparison to scientific knowledge regarding the effects of the pollutants on humans and the environment. They also have the ability to operate as a benchmark to determine whether air quality is improving or declining.

An exceedance of a standard is defined as a period of time (which is identified in each standard) that the concentration is greater than that identified by the standard. An objective is the date on which exceedances of a standard must not exceed a specified number.

The Air Quality (England) Regulations 2000 and the Air Quality (England) (Amendment) Regulations 2002 incorporate the objectives of the Air Quality Strategy into law, against which local authorities are required to review and undertake an assessment of air quality.

More...

The Air Quality Strategy can be downloaded from the DEFRA website at:

http://www.defra.gov.uk/environment/quality/air/airquality/strategy/.

Air Quality Standards Regulations 2010

These Regulations replace the **Air Quality Standards Regulations 2007**. They largely implement the EU **Directive 2008/50/EC** on ambient air quality and cleaner air for Europe.

The Regulations cover 13 key air pollutants:

- Sulphur dioxide.
- Nitrogen dioxide.
- Oxides of nitrogen.
- Particulate matter.
- Lead.
- Benzene.
- Carbon monoxide.
- Arsenic.
- Cadmium.
- Mercury.
- Nickel.
- Benzo(a)pyrene or other polycyclic aromatic hydrocarbons.
- Ozone.

They require the Secretary of State to:

- Divide the country up into a number of zones.

- Use a classification system for each zone based on the exceedance of upper and lower assessment thresholds (stated in the Directive) for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide in ambient air in all zones.
- Measure pollutants - this may include estimation or modelling but where standards are breached then fixed measurement must be used.
- Draw up an action plan where levels are being breached to remedy the situation, and consult the public on this.
- Make the public aware of air quality.
- Produce a report on an annual basis for all the pollutants covered by the Regulations.

This is a very similar regime to that described in the **Environment Act 1995**, Part IV above. It is DEFRA's plan to produce one joined up regime in the near future.

The corresponding Regulations in other parts of the UK include:

- The **Air Quality Standards (Scotland) Regulations 2010**.
- The **Air Quality Standards (Wales) Regulations 2010**.
- The **Air Quality Standards (Northern Ireland) Regulations 2010**.

EU Legislation

The EU Framework **Directive on Air Quality Assessment and Management (96/62/EC)** had, as its main objective, the need to protect human health and the environment by avoiding, reducing or preventing harmful concentrations of air pollutants by means of:

- Defining and fixing air quality objectives, setting limit values and/or alert thresholds and/or target values for ozone.
- Assessing air quality in a uniform manner.
- Making information publicly available.
- Maintaining and improving ambient air quality.

The Directive also acquired **daughter** Directives dealing with sulphur dioxide, ozone, benzene, carbon monoxide, PAHs, cadmium, nickel and arsenic compounds, and mercury. In the UK, these were implemented through the **Air Quality Standards Regulations 1989**.

The first of the daughter Directives was **99/30**, the Directive relating to the limit values for sulphur dioxide, oxides of nitrogen, particulate matter and lead, and was implemented in the UK through the **Air Quality Limit Values Regulations 2001.** This Directive sets limit values for certain pollutants and requires that where the limit value is likely to be exceeded on more than a permitted number of days per year, then action programmes must be developed to meet the target. When alert values are reached, information must be given to the public. Information must be updated at specified intervals.

Another daughter Directive was adopted to establish carbon monoxide and benzene levels, and a third daughter Directive concerned ozone in ambient air.

Member states are required to identify zones and agglomerations where the target values or long-term objectives are unlikely to be met within the specified period.

Directive 2008/50/EC on ambient air quality and cleaner air for Europe came into force on 11th June 2008. The Directive combines four existing Directives into a single Directive on air quality. It also identifies new standards and target dates for decreasing concentrations of fine particles (PM2.5). The Directive requires member states to reduce exposure to PM2.5 in urban areas by an average of 20% by 2020, based on 2010 levels. It also requires them to bring exposure levels below 20 micrograms/m^3 by 2015.

More...

The UK Air Information Resource contains various information on local air quality, including air pollution summaries and forecast maps - see http://www.airquality.co.uk/.

Industrial Air Pollution Control

The technology to remove contaminants from the air stream is often referred to as 'end-of- pipe technology' because it is designed to remove contaminants after the waste has been generated by the process and before it enters the atmosphere. Such technology results in two components: treated exhaust air, more or less cleaned, and the waste captured by the air- cleaning device. This waste has still to be dealt with, either by reuse, recycling or disposal. Generally, disposal to landfill is the chosen route. The exception to this rule is **incineration**. When operated efficiently, the waste gases in an exhaust stream are broken down into simple components and dispersed safely into the atmosphere. Since there is no resultant waste collected from an incineration process, this has become an increasingly popular gas cleaning and waste disposal technique.

There is a wide variety of particulate, droplet and gas capture devices available and the choice will depend on the process parameters. There is considerable overlap in the functions and collection efficiencies of the various technologies. By way of example, a device designed to

remove particulates from an air stream by capturing the particles in water droplets from a spray will also remove soluble gases from the air stream.

Each type of device will be described in the Control Strategies and Measures section of this element and the overlaps discussed.

Examples of Processes Giving Rise to Air Pollutants

- **Gases**
  - Combustion of oil, coal, gas, etc.
  - Biodegradation of organic materials.
  - Electrical sparking, e.g. from arc welding, electric motors and laser printers.
  - Fugitive emissions from leaks in pipes, seals, valves, etc.
- **Vapours**

  (Vapours are gases in equilibrium with a liquid.)
  - Cleaning and degreasing by solvents.
  - Paints and surface coatings.
  - Sterilising liquids, e.g. aldehydes.
  - Oven dryers.
  - Incomplete combustion of petroleum fuel.
- **Particulates**
  - Wood sawing.
  - Animal dust and grain dusts.
  - Combustion of solid fuel.
  - Pottery and ceramics manufacture.
  - Construction.

The waste air stream may also exhibit a variety of physical and/or chemical properties, e.g. it may be hot, sticky, acidic or alkaline.

Revision Questions

1. Describe the classification of smoke.
2. Why is it necessary to develop air quality standards? Which UK Regulations are specifically concerned with air quality?

(Suggested Answers are at the end of this book.)

Legal Requirements

Key Information

- As part of installation permit requirements under the **Environmental Permitting Regulations 2010**, installations must use BAT to control air emissions.
- The **Clean Air Act 1993** prohibits emissions of dark smoke from chimneys which serve boiler plants and from other activities producing smoke (other than via a chimney).
- The **Solvent Emissions Directive** has been developed to reduce emissions of VOCs from industrial solvent use.
- **EU Regulation 1005/2009** and the **Environmental Protection (Controls on Ozone-Depleting Substances) Regulations 2002** place controls on production, placing on the market and use of ozone-depleting substances (ODSs).

We will begin with a historical overview of air pollution controls through the framework of legislation, from the birth of the Industrial Revolution.

The UK has the oldest and largest established regulatory regime for air quality control in the world. This is mainly due to its long history of industrial development, dating from the Industrial Revolution in the 1700s. All of the legislation was **reactive**, developed in response to perceived problems. There was no attempt to **foresee** problems, only to react to problems once they had manifested themselves. A proactive approach did not start until the advent of the **Environmental Protection Act** in 1990.

Historical controls include:

- **Alkali, etc. Works Regulations 1863.**
- **Public Health Acts of 1875 and 1936.**
- **Clean Air Acts of 1956 and 1968.**
- **Health and Safety at Work, etc. Act 1974.**
- **Emissions into the Atmosphere Regulations 1983.**
- **Environmental Protection Act 1990.**
- **Clean Air Act 1993.**

Duties of Operators of Prescribed Processes

Integrated Pollution Prevention and Control

The IPPC Directive

The European Council adopted **Directive 96/61** on Integrated Pollution Prevention and Control (the **IPPC Directive**) in September 1996. The Directive is derived in a large measure from Integrated Pollution Control (IPC), although there are some important differences. IPC was the **Environmental Protection Act 1990** system introduced in 1991, under which the Environment Agency (for England and Wales) and the Scottish Environment Protection Agency were given authority to regulate the largest and most polluting industrial processes.

The **IPPC Directive** has since been updated to include previous amendments and to introduce changes and adaptation (e.g. updating the number of legislation that is referred to in the Directive). The Directive in its latest version is now known as **Directive 2008/1/EC** of the European Parliament and of the Council of 15th January 2008 concerning Integrated Pollution Prevention and Control.

The **IPPC Directive** requires member states to prevent or, where that is not possible, to reduce pollution from a range of industrial and other installations. This is by means of an integrated permitting process based on the application of Best Available Techniques (BAT). The integrated permitting process takes a wide range of environmental impacts into account. These include emissions of pollutants to air, water and land; energy efficiency; consumption of raw materials; noise; and site restoration; with the aim of achieving a high level of protection for the environment as a whole.

The application of IPPC to industrial activities and the current threshold limits are listed in Annex 1 of the Directive and, in England and Wales, in the **Environmental Permitting Regulations 2010**.

Categorisation of Installations

Installations are categorised as Part A(1) or (2), Part B and waste operations according to their potential for pollution.

- Part A(1) activities are regulated by the Environment Agencies.
- Part A(2) activities are regulated by local authorities.

- Part B activities are regulated by local authority control.
- Waste operations (England and Wales only) are regulated mainly by the Environment Agency, unless the waste operations are undertaken as part of the Part A(2) or Part B installations or Part A(2) and Part B mobile plant.

It should be noted that in Scotland, the Scottish Environment Protection Agency will be the sole regulator. In Northern Ireland, Part A and B installations are regulated by the NIEA and Part C installations by district councils.

Frequency of Permit Reviews

Permits will be reviewed by the regulators periodically and at any time.

A review will be carried out where:

- The pollution caused by the prescribed installation is of such significance that the existing emission limit values of the permit need to be revised or new emission limit values need to be included in the permit.
- Substantial changes in the Best Available Techniques make it possible to reduce emissions from the prescribed installation significantly without imposing excessive costs.
- The operational safety of the activities carried out in the prescribed installation requires other techniques to be used.

Air Pollution Control

Topic Focus

The Clean Air Act 1993

This Act effectively prohibits emissions of dark smoke (Shade 2 on Ringelmann chart) from chimneys which serve boiler plants and from other activities producing smoke (other than via a chimney).

The Act covers England, Scotland and Wales. It came into force in August 1993 and consolidates the **Clean Air Acts 1956 and 1968** (which are repealed). It also incorporates clean air legislation contained in other Acts, such as the **Control of Pollution Act 1974** and the **Control of Smoke Pollution Act 1989** (which is also repealed).

Similar controls in Northern Ireland are provided in the **Clean Air (Northern Ireland) Order 1981**.

Parts I, II and III of the **Clean Air Act** do not apply to processes prescribed for control under the **Environmental Permitting Regulations 2010**.

Furnaces

The **Clean Air (Emissions of Grit and Dust from Furnaces) Regulations 1971** identify the quantities of grit and dust which may be emitted based on the rating of the boiler or furnace.

The Regulations do not apply to incinerators that burn waste as incinerators regulated under the environmental permitting regime. The Regulations require all furnaces apart from domestic furnaces to be fitted with grit and dust arrestment plant, which must be approved by the local authority. Arrestors must also be properly maintained. The Regulations also provide for the local authority to serve a notice requiring the measurement of grit, dust and fume emissions from time to time.

Processes Authorised under the Radioactive Substances Act 1993

The **Radioactive Substances Act 1993** was partly concerned with obtaining authorisation for the keeping of radioactive materials and the disposal of radioactive waste. These powers have now been replaced by those covering **radioactive substances activities** in the **Environmental Permitting (England and Wales) Regulations 2010** (see later in this element).

The Solvent Emissions Directive

Directive 1999/13/EEC on the limitation of emissions of Volatile Organic Compounds (VOCs) - the **Solvent Emissions Directive** - was issued on 11th March 1999. Its objective is to reduce emissions of VOCs from industrial solvent use by 57% from 1990 levels.

The reason for reducing VOCs is that they assist the production of low-level ozone, which has a detrimental effect on human health and on crops and building materials.

The Directive covers a wide range of industry including surface cleaning, vehicle refinishing, adhesive manufacture, lamination of wood, etc.

In England and Wales, the Directive is implemented under the **Environmental Permitting Regulations 2010** through conditions in environmental permits, and in the rest of the UK through the IPPC regime.

Operators have the following options:

- Emission limit compliance option.
- Substitute materials compliance option.

Operators who emit one tonne or more of chlorinated solvent are required to develop a Solvent Management Plan.

In general, the requirements did not come into force until 31st October 2007, but some conditions were required to be implemented "in the shortest possible time". These were:

- If the VOCs were classified as carcinogens, mutagens or toxic to reproduction, they had to be phased out in the shortest possible time. These are substances with risk phrases R45 (may cause cancer), R46 (heritable genetic damage), R49 (cause cancer by inhalation), R60 (impair fertility) or R61 (harm to the unborn child).

  A plan had to be prepared to phase out such substances and plans should have been given to the EA by 22nd March 2003. "Shortest possible time" was to be discussed with the EA.
- Where the mass flow of the VOC discharge was greater than ten grams per hour, a concentration limit of 2 mg C/Nm3 had to be achieved in the shortest possible time.
- Where halogenated solvents with risk phrase R40 were in use and the mass flow was greater than 100 grams per hour, an emission limit of 20 mg C/Nm3 had to be achieved in the shortest possible time.

Precautions shall also be made to control emissions on start-up and shutdown.

- For installations not using the reduction scheme (see below), any abatement equipment installed after 1st April 2001 must meet the Directive requirements.
- Information shall be supplied to the regulator annually or as required to verify compliance.
- Channels to which abatement equipment is connected and which emit over 10 kg/hour of Total Organic Carbon will be monitored continuously.

Emission Reduction Option

The operator had to forward a reduction plan on the following timescale:

Time period		Maximum allowed total annual emissions
New Installations	Existing Installations	
By 31.10.2001	By 31.10.2005	Target emissions × 1.5
By 31.10.2004	By 31.10.2007	Target emission

The annual **reference** emission is calculated by multiplying the mass (the total solids in the coating or ink, etc.) by a sector factor, e.g. the aerospace coating factor is 2.33.

The **target** emission is the reference emission multiplied by a percentage depending on the sectors in Part III, Schedule 1 of the Directive (varies between +15 and + 5).

Compliance is achieved if the actual emission determined from the solvent management plan is equal to or less than the target emission.

Full details of threshold and emissions controls per industry sector may be found in the Directive.

Ozone-Depleting Substances Regulations

Topic Focus

EU Regulation 1005/2009

This Regulation (which consolidates earlier provisions) places controls on production, placing on the market and use of ozone-depleting substances (ODSs). Amongst other things, it implements European obligations under the Montreal Protocol. In the UK, the national enforcement regime (offences, penalties, powers, etc.) for the EU Regulation is contained within the **Environmental Protection (Controls on Ozone-Depleting Substances) Regulations 2002**.

ODSs have been widely used in refrigeration and air-conditioning equipment. **EU Regulation 1005/2009** requires a range of measures, including ban of use of ODSs (such as CFCs, HCFCs, halons) in new equipment and, for existing equipment containing ODSs: the prevention/minimisation/repair of leaks, annual leak testing, recovery of ODSs (during maintenance, before disposal, etc.), and use of a qualified person for maintenance/decommissioning. **EU Regulation 744/2010** amended **EU Regulation 1005/2009** to continue the use of specific halons (1301, 1211 and 2402) for critical uses (e.g. military, aircraft, nuclear power and Channel Tunnel). Cut-off dates are identified when the halons must no longer be present in new equipment (the latest being 2014) and also for decommissioning of equipment containing the halons (the latest being 2040).

Duties of the Secretary of State and Local Authorities

As well as setting standards and objectives for air quality, the National Air Quality Strategy incorporates a requirement for assessment of air quality, and includes the Government and others in taking action to improve air quality. Local authorities are advised to develop an Air Quality Strategy and to ensure that air quality is included in transport and planning policies.

Duties of the Secretary of State

The Secretary of State's duties with regard to Part IV (Air Quality) of the **Environment Act 1995** include:

- Prepare and publish the strategy containing policies with respect to the assessment or management of the quality of air.
- Keep the strategy under review and modify it from time to time.
- The strategy must contain air quality objectives and standards and measures taken to achieve the objectives.
- In preparing the strategy, the Secretary of State is required to consult the Environment Agencies of the UK, local government, industry and other bodies as appropriate.
- Publish a draft of the strategy or modification and take into account any comments.

Reserve powers of the Secretary of State or SEPA in Scotland include:

- Revisiting air quality from time to time within the area of local authorities.
- Assessing whether standards and objectives are being achieved/likely to be achieved.
- Identifying parts of a local authority area where it appears standards or objectives are not likely to be achieved.
- Giving direction to a local authority requiring it to take steps to achieve air quality objectives and standards when it has failed to undertake duties required in relation to air quality by the Act, when measures to achieve compliance are not appropriate or when they are not in line with scientific developments. The direction must be published in the London and Edinburgh Gazette.
- Requiring a local authority to conduct an air quality review, a new air quality review or designate an air quality management area.

Powers and Duties of Local Authorities

The **Environment Act 1995** placed certain duties on the local authorities. These were:

- To review air quality in their areas, with reviews to be completed by June 2000.
- Air quality management areas to be designated by September 2000.
- A further review to be undertaken by December 2003.

Guidance was given to local authorities on carrying out these tasks. Revised policy guidance has been issued requiring local authorities, having completed the first round of reviews, to carry out updating and screening assessments. Assessments and reports are submitted to DEFRA.

Local authorities are required to make air quality review information available to the public. Many, particularly those in London, hold air quality information on their websites.

The **Air Quality (England) Regulations 2000** (similar regulations exist for Scotland and Wales) revoked the 1997 Regulations and tightened the requirements for some of the pollutants named. The **Air Quality Regulations** incorporate the objectives of the Air Quality Strategy. They give powers to local authorities to:

- Meet air quality standards.
- Prohibit or restrict certain activities, vehicles or mobile equipment access, both in general and in certain circumstances.
- Make air quality information publicly available.

Local authorities are also allowed to designate air quality management areas and action plans, and carry out vehicle emission spot checks.

Offences under the Clean Air Act 1993 and the Environmental Permitting (England and Wales) Regulations 2010

The Clean Air Act 1993

Topic Focus

Offences

Prosecutions for most offences under the **Clean Air Act 1993** are dealt with in the Magistrates' Court (Sheriff Court in Scotland); offences are subject to a fine of up to £20,000, plus a daily fine if the offence continues.

- **Prohibition of Dark Smoke from Chimneys**

  The emission of dark smoke from the chimney of any building is prohibited; the Act also applies to chimneys not attached to a building serving furnaces, fixed boilers or industrial plant.

  There are a number of defences available in any proceedings for dark or black smoke emission. These are that the alleged emission was:

  – Solely due to lighting a furnace from cold and all practicable steps had been taken to minimise emissions.

(Continued)

Topic Focus

  – Solely due to unavoidable mechanical failure of part of the plant, that this could not reasonably have been foreseen, or if foreseen could not reasonably have been provided for and that the emission could not have been prevented after failure occurred.
  – Solely due to unavoidable use of unsuitable fuel, suitable fuel not being available and the best available fuel being used; and all practical steps being taken to minimise the emission; due to any combination of the above.

- **Statutory Defences under the Clean Air Act**

  Although there are statutory defences under the **Clean Air Act**, they are not absolute defences and are available only if every practical effort is made to avoid and/or minimise emissions.

- **Prohibition of Dark Smoke from Industrial or Trade Premises**

  Subject to certain exemptions, it is an offence to cause or permit the emission of dark smoke from industrial or trade premises (as distinct from chimneys). Unless the contrary is proved, an emission of dark smoke is deemed to have taken place if material is burned on those premises in circumstances where the burning would be likely to give rise to the emission of dark smoke. This can include night-time burning and removes the necessity for a local authority to prove by direct observation that dark smoke has been emitted.

  Land being used for agriculture or horticulture is also a "trade premises".

Radioactivity Requirements of the Environmental Permitting (England and Wales) Regulations 2010

Offences

The **Environmental Permitting Regulations** in England and Wales have replaced the requirements for certificate of registration and radioactive waste authorisation under the **Radioactive Substances Act 1993**. Such regulated facilities are now classed as radioactive substance activities.

We have already considered offences under the **Environmental Permitting Regulations** earlier in the course, but below is a summary of their key points.

Penalties

Penalties on summary conviction vary with the offence but may include two to five years' imprisonment.

Enforcement

Under these Regulations, the Environment Agency may issue enforcement, suspension and revocation notices where conditions of the permit are being contravened or where there is the likelihood of environmental harm. The notice may impose conditions and timeframe for action.

There are rights of appeal against conditions or against refusal of a certificate. Appeals are determined by the Secretary of State. Works to make safe or carry out disposal of radioactive waste may be undertaken by the Environment Agency and costs recovered from the owner or occupier of the premises. There is also a requirement to keep documents relating to the permit on a public register.

Revision Questions

3. What are the three categories of control regime, for installations designated under the **Environmental Permitting Regulations**? Which regulatory body is responsible for each?

4. When would a Solvent Management Plan be required to be developed by industrial operators?

(Suggested Answers are at the end of this book.)

Strategies for Monitoring Atmospheric Emission

Key Information

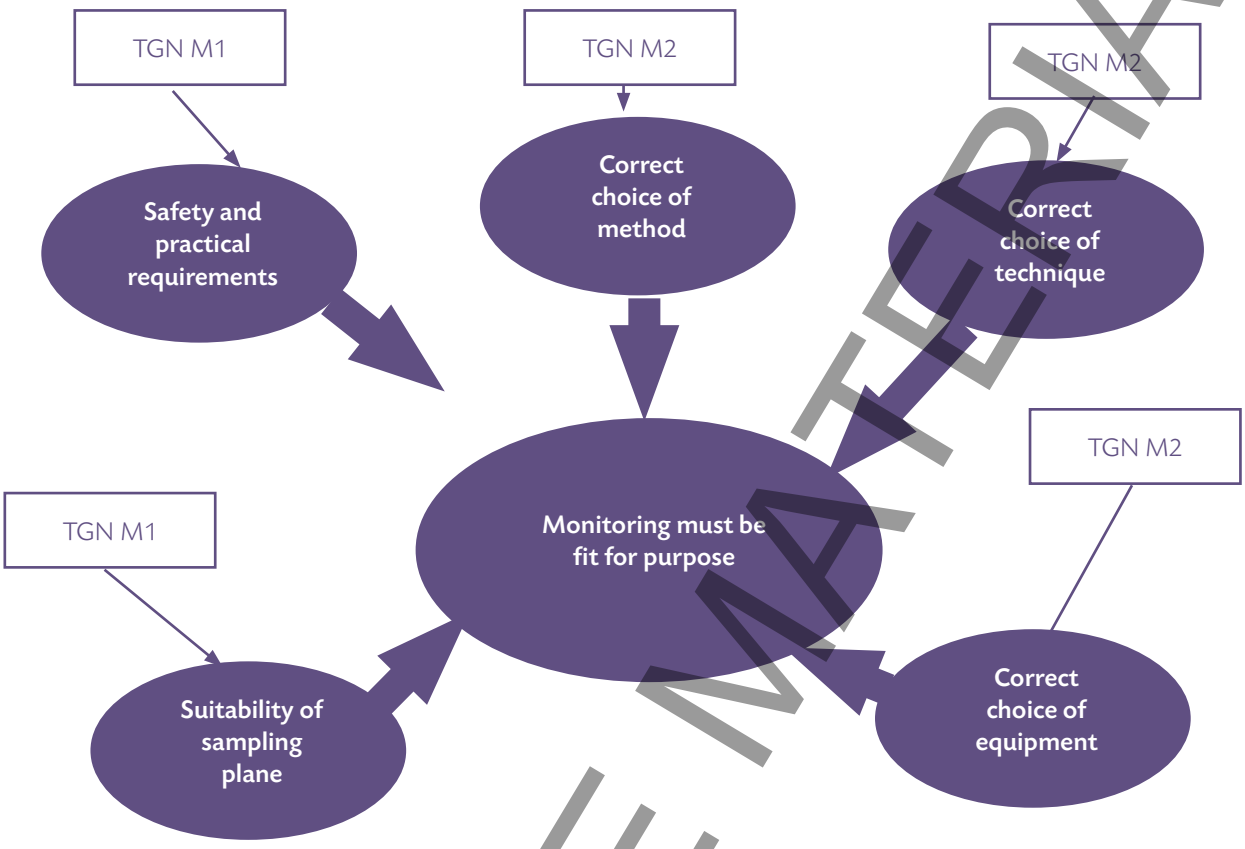
- Current legislation includes several specific requirements to sample, monitor and measure emissions from stacks, chimneys and process vents.
- Periodic measurement is a measurement regime carried out at periodic intervals, e.g. six months.
- Continuous Emissions Monitoring (CEM) measurements are taken automatically, with few if any gaps in the data produced.
- Common measurement techniques for air pollutants include particle charge transfer probe, transmissometers (opacity monitors), beta radiation attenuation, CEGB probe and deposition gauges.
- Common methods of sample analysis include gravimetric analysis, microscopic analysis, gas liquid chromatography, mass spectrometry, atomic absorption spectrophotometry, chemiluminescence, electrochemical cells, atomic emission spectrophotometry, spectrophotometry and ultraviolet/infrared spectrometry.

Current legislation includes several specific requirements to sample, monitor and measure emissions from stacks, chimneys and process vents. In addition, it is necessary to accurately measure process emissions in order to specify arrestment plant to meet statutory requirements. In some cases, it is important to sample and measure stack emissions in order to demonstrate that the emissions are harmless to local communities living around the plant.

Monitoring of the waste gas stream as it leaves the chimney or flue stack may be required in order to demonstrate compliance with the **Environmental Protection Act**, the **PPC Act** or the **Clean Air Act**. The choice and specification of the sampling equipment is outside the requirements of this course, but the following general principles apply.

Principles of a Monitoring Strategy

Refer to the following figure.



Factors Contributing to Fit-for-Purpose Monitoring, after Environment Agency Guidance Note M2

The methods used to assess stack particulates emissions vary depending on the information required and the accuracy of the data needed. In some cases, continuous monitoring of particulate or other emission is required. Particulate measurement can be achieved by installing an **opacity meter**, which simply consists of a light source detector. As particles pass through the light beam, the amount of light reaching the detector is decreased. The signal from the detector can then be calibrated against the dust concentration. More sophisticated devices have a reference beam to exclude fluctuations in other conditions in the stack. Direct reading dust samplers are also available.

Originally published by HMIP in 1993, the current guidance is contained in Technical Guidance Note (Monitoring) M1, *Sampling requirements for stack-emission monitoring*, Environment Agency, July 2006, Version 4.

More...

Both TGN M1 and M2 can be viewed at the Environment Agency website - see:

http://publications.environment-agency.gov.uk/pdf/GEHO0110BRRO-E-E.pdf;

http://publications.environment-agency.gov.uk/pdf/GEHO0710BSXF-E-E.pdf.

Sampling Principles

Key Terms in Stack Emission Monitoring

Jargon Buster

Sampling Point

The specific position on the stack where the sample is extracted.

Sampling or Access Ports

Points on the wall of the stack, duct or flue through which access to the emission can be gained.

Isokinetic Sampling

'Same speed' sampling - a technique of drawing sampling air through a probe containing a collection filter at the same rate as the gas flow in the stack. It is very important for air streams containing particulates where, due to the wide range of particle sizes, it is necessary to sample isokinetically to ensure that a representative gas sample is obtained.

Monitoring Approach

Whether the monitoring is periodic or continuous.

Monitoring Techniques

The analytical principles behind the monitoring, e.g. infrared absorption, chemiluminescence, etc.

Monitoring Method

The published or documented procedure for using the monitoring approach and technique so that comparable results can be obtained when the monitoring is carried out at different times and by different organisations.

Monitoring Equipment

The instruments and apparatus used.

Monitoring Approaches

There are two main approaches to measuring stack emissions - periodic measurement and Continuous Emissions Monitoring (CEM).

Jargon Buster

Periodic Measurement

Is a measurement regime carried out at periodic intervals, e.g. six months. Samples are usually taken from the stack and measured elsewhere (**grab or extractive sampling**). Instrumental or automatic techniques can be used where an online analyser carries out the sampling and analysis; or a manual technique may be used where a sample is extracted on-site and analysed later in a dedicated laboratory.

Samples may be collected over lengthy periods of several hours, or can be **spot** or **grab samples** taken over much shorter periods, from a few seconds to a few minutes.

Continuous Emissions Monitoring (CEM)

Is measurements taken automatically, with few if any gaps in the data produced.

Measurement can be carried out in situ or the sample gas can be extracted and measured remotely on an instrument permanently located elsewhere.

CEM is also referred to as Automatic Monitoring Systems (AMS).

The two types of techniques are compared in the following table, taken from Technical Guidance Note (Monitoring) M2, *Monitoring of stack emissions to air*.

Important Characteristics of CEMs and Periodic Monitoring

Characteristic	CEMs	Periodic Monitoring
Sampling period	Monitoring covers all or most of the period that substances are emitted.	Snapshots of the long-term emissions profile.
Speed of results generation	Almost always real-time output of results.	Real-time results if instrumental analysers used; delayed results if manual method with laboratory end-method used.
Averaging of results	Results continuously averaged, typically over one hour or 24 hours.	Result over period of test, typically 30 minutes to several hours.
Calibration and traceability	CEMs require calibration against a standard reference method (SRM) and with certified reference materials.	Standard reference methods can be used for periodic monitoring; also instruments calibrated with certified reference gases can be used.
Capital cost	Tends to be higher than the cost of periodic monitoring equipment.	Tends to be lower than the cost of CEMs.
Operating cost	Tends to be lower than periodic approach, as not usually labour intensive. Requires routine maintenance and calibration only.	Tends to be higher than CEMs approach because labour intensive. Trained team on site for whole duration of monitoring campaign.
Certification of equipment	MCERTS certification of equipment available.	MCERTS certification of transportable stack-monitoring equipment available.
Accreditation of monitoring	Quality assurance of the calibration and maintenance of CEMs is covered in EN 14181.	UKAS accreditation to ISO 17025 for the MCERTS performance standard for organisations carrying out periodic monitoring. Accreditation to the MCERTS standard includes the requirement for individuals carrying out monitoring to be certified under MCERTS as competent.

Source: Technical Guidance Note (Monitoring) M2, Monitoring of stack emissions to air, Environment Agency, 2010 (http://publications.environment-agency.gov.uk/pdf/GEHO0710BSXF-E-E.pdf)

Jargon Buster

MCERTS (Monitoring Certification Scheme)

Is a certification scheme for pollution monitoring equipment based on internationally-accepted performance standards.

MCERTS focuses initially on Continuous Emission Monitoring Systems (CEMS) and provides regulators and industry with the best basis on which to monitor releases from industrial processes.

MCERTS is based on:

- ISO 17025 for monitoring and equipment testing.
- EN 45004 for inspection.
- EN 45011 for product certification.
- EN 45013 for personnel competency.

Technical Guidance Note (Monitoring) M2 gives detailed comparisons of the sampling methods which may be applied to key pollutants.

Particulate Matter

Type of monitoring	Monitoring technique	Monitoring standard	Further information
Manual	Isokinetic sampling followed by weighing	BS EN 13284-1 and MID	Reference method for concentrations below to 50 mg m^{-3}. However the scope states that it can be used for higher concentrations. Primarily developed for waste incinerators, however the scope also states that it can be applied more widely. Reproducibility (worst quoted) ±5.7 mg m^{-3} at 6.4 mg m^{-3} and 30 min sample. Validated at concentrations around 5 mg m^{-3} and 30-minute sampling duration. The overall uncertainty of the method complies with the uncertainty of ±30% required by WID.
		BS ISO 9096	Suitable for particulate concentrations above 50 mg m^{-3}. Upper limit 1000 mg m^{-3}.

Particulate Matter Size Fractionation[1]

Type of monitoring	Monitoring technique	Monitoring standard	Further information
Manual	Impaction based on a round nozzle two stage impactor	BS EN ISO 23210[2]	Allows simultaneous measurement of <PM10 to > $PM_{2.5}$ concentrations and <$PM_{2.5}$ concentrations using a cascade impactor. The standard does not measure the contribution of stack gas emissions to the formation of secondary particulate matter in ambient air. Developed especially for measurements of mass concentrations below 40 mg/m^3 at STP[3]. It is suitable for combustion sources, cement and steel processes. It cannot be used to measure stack gases that are saturated with water vapour. It cannot be used for the measurement of total mass concentration of particulates.

[1]EA TGN M15 provides guidance on size fractionation measurements. TGN M15 is available from www.mcerts.net.

[2]BS EN ISO 23210 has replaced US EPA M201. MCERTS accreditation will not be available for US EPA M201 from 1 January 2011.

[3]For stack gas emissions with particulate concentrations >40 mg/m^3 a cyclone may be used. Information on cyclones is provided in US EP M01.

Source: Technical Guidance Note (Monitoring) M2, Monitoring of stack emissions to air, Environment Agency, 2010 (http://publications.environment-agency.gov.uk/pdf/GEHO0710BSXF-E-E.pdf)

BS 1747 identifies methods of undertaking the measurement of numerous air pollutants. The parts of the standard for different air pollutants are provided in the table below (note that some parts of the standard not identified have been withdrawn).

BS 1747

Standard	Name
BS 1747-1:1969	*Methods for the measurement of air pollution. Deposit gauges*
BS 1747-2:1969	*Methods for the measurement of air pollution. Determination of concentration of suspended matter*
BS 1747-3:1969	*Methods for measurement of air pollution. Determination of sulphur dioxide*
BS 1747-5:1972	*Methods for the measurement of air pollution. Directional dust gauges*
BS 1747-6:1983	*Methods for measurement of air pollution. Sampling equipment used for the determination of gaseous sulphur compounds in ambient air*
BS 1747-9:1987	*Methods for measurement of air pollution. Determination of the mass concentration of nitrogen oxides in ambient air: chemiluminescence method*
BS 1747-11:1993, ISO 9835:1993	*Methods for measurement of air pollution. Determination of a black smoke index in ambient air*
BS 1747-12:1993, ISO 10313:1993	*Methods for measurement of air pollution. Determination of the mass concentration of ozone in ambient air: chemiluminescence method*
BS 1747-13:1994, ISO 9855:1993	*Methods for measurement of air pollution. Determination of the particulate lead content of aerosols collected on filters: atomic absorption spectrometric method*

Remote Sensing

Jargon Buster

Remote Sensing

Is simply observing or measuring things from a distance. As part of an integrated observing strategy, satellite measurements provide a context for localised observations and help to extend these observations to continental and global scales.

Remote sensing enables the viewing of the Earth across great distances and at wavelengths of light that are invisible to the human eye. Remote sensing is undertaken by using detectors to record light as it is discharged by the element of interest. Remote sensing has many uses including the assessment of air pollution.

A method of remotely sensing air pollution is the **tunable pulse laser system**. This uses laser pulses to transmit and receive electromagnetic radiation. Most pollutants present in air exhibit optical absorption bands in the ultraviolet, visible, or infrared portions of the spectrum. The concentration of gaseous pollutants may be monitored by the application of a pulse LIDAR (light detection and ranging) over great distances, recording the absorption that is attained at one wavelength that corresponds to a strong absorption band in a gas and making comparisons with absorption at an adjacent wavelength where there is no absorption of the gas. This is known as the tunable pulse laser measurement of air pollutants. Differential absorption has been applied to the measurement of many air pollutants including ozone, nitrogen oxides, sulphur oxides and mercury vapours.

Principles of Analysis Techniques

In this subsection we briefly describe common measurement and analysis techniques used to determine the amount of a substance in a sample of contaminated air.

Measurement Devices

Particle Charge Transfer Probe

This measurement device is based on the principle that when two materials that have differing electronic properties contact there is a passage of electrons from one material to the other when they separate. During this process the transfer of charge is dependent on a number of factors including the properties of the substances (particle resistivity), duration and areas of contact and particle deformation. Analysers that use such devices generally consist of a metal probe that is inserted into a stack. When particles hit the probe a very small level of charge is passed to it. This charge is the basis for dust measuring instruments using the triboelectric principle whereby the difference in charge

between the probe and dust particles is calculated. As the charge difference is so small it is amplified to produce an electrical output. The charge is usually measured in units such as picoamperes or nanoamperes.

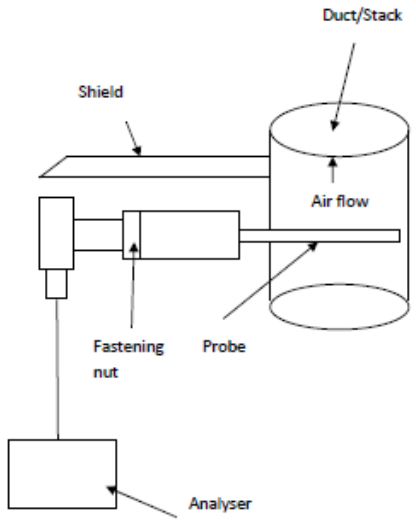


Diagram showing a Particle Charge Transfer Probe

Transmissometers (Opacity Monitors)

Jargon Buster

Transmissometers (or Opacity Monitors)

Are based on the determination of the optical transmission of a beam of light as it passes through an air stream containing particulate material. Due to scattering and absorption the light beam will be reduced in intensity.

The more particulate matter present in the air stream then the more opaque the air stream will be to light transmission (the more particulate matter present in the gas stream the less light will be transmitted) such that:

% transmittance = 100 - % opacity

Transmissometer-based devices can be either single or double pass types. In double pass types a reflector is placed at the opposite side of the stack or duct allowing light to be passed through the flue gas twice. Single pass designs may use two identical senders and receivers on both sides of the stack to allow transmission to occur alternatively so as to achieve greater sensitivity and decrease fouling of optics.

Light sources may include lasers, filament bulbs or light emitting diodes. Other additions may be air purge devices to keep optics clean and light modulation to compensate for light from other sources.

Transmissometers are not appropriate for measuring low particulate concentrations of small particles.

A variation on the traditional transmissometers is the light modulation beam transmissometer. These devices are based around the flicker of a beam of light during the transfer of dust particles through it rather than overall reduction in the beam intensity (as is used in standard transmissometers). As dust particles pass through the light, the receiver collects a modulating signal. Such fluctuations in received light are used to produce a ratio with the average intensity of light at the detector. This produces a signal that is proportional to the change in particulate concentration.

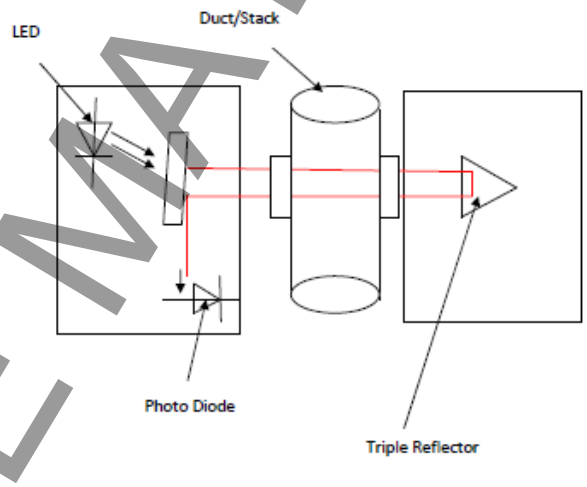


Diagram showing a Dual Beam Particulate Monitor

Beta Radiation Attenuation

Beta radiation attenuation devices draw flue gas through a sample inlet or probe with particulate matter being deposited onto a tape made from glass fibre filter paper. The tape is on a roll that moves sequentially such that a collection of particulate matter deposits on the tape over the length of time the tape is stationary. The tape then passes to a sensor consisting of a radiation source that emits high energy electronic or beta rays. The beta rays are absorbed and scattered by the particles that have collected on the tape, the absorption and scattering being dependent on the amount and concentration of particulates present. The radiation is measured by a detector such as a Geiger-Müller tube. A reference is taken by passing beta radiation through a section of the tape that has not been exposed to particulate matter. If the composition of particles is constant then the reduction in radiation can be used to determine the thickness of an area of particulate matter and therefore the mass of the material collected.

The system is not a truly continuous measurement as the particulate matter is collected on a tape for a period of time before moving to a sensor. As such only one minute average values are available.

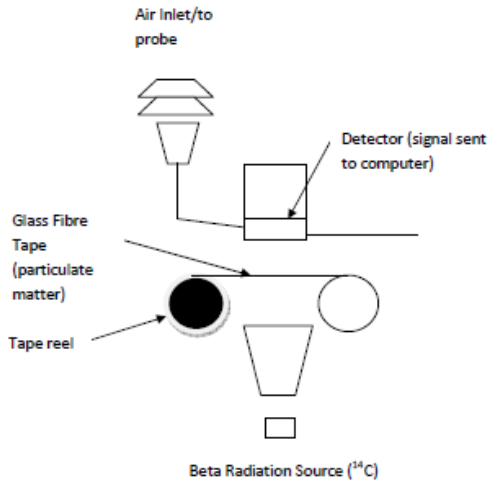


Diagram of a Beta Radiation Attenuation Device

CEGB Probe

The CEGB (Central Electricity Generating Board) device is made up of a miniature cyclone through which a flue gas sample is drawn on a continuous basis by a device operated by the suction in the flue. A detachable glass container is present at the base of the cyclone that receives the separated dust. The cyclone is encapsulated in a heating jacket to prevent condensation that would cause solid materials to be trapped in the cyclone rather than passing to the collection vessels. Samples are collected in the glass jar for weighing and analysis. This device operates continuously without moving parts.

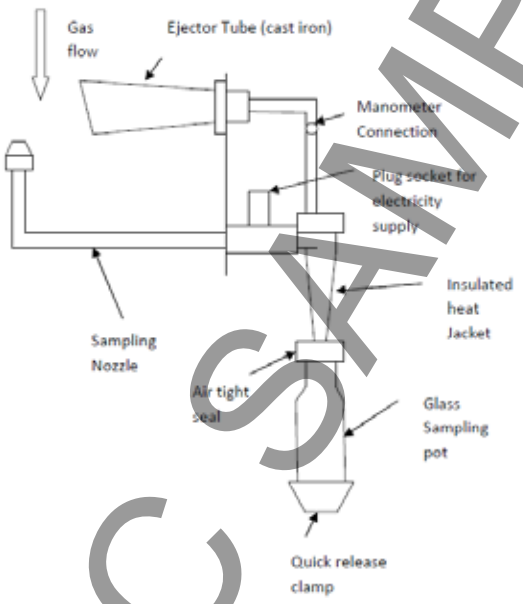


Diagram of a CEGB Probe

Deposition Gauges

A deposit gauge consists of a funnel supported by a glass bottle. The funnel includes a grooved stopper that allows water overflow during periods of heavy rain.

The stand for the gauge consists of a container that protects the contents of the bottle. The stand should also stop movement of the bottle during heavy wind and ensure that the funnel remains horizontal. During a sampling period particulate matter from ambient air is collected in the bottle with rainwater. The sample is then sieved to remove insects or leaves. The soluble and insoluble solids are separated by filtration and the weight of the dried insoluble matter gravimetrically determined. The mass of ash and combustible material is gained by incinerating insoluble solids. Soluble solids are determined from the filtrate. The mass deposition rate is calculated from the exposure period, the mass of the solids and the cross-sectional area of the collection funnel.

Such devices are relatively inexpensive and a simple approach to dust monitoring. They do not require any electrical power so can be left for long periods of time without maintenance. However, they do not provide day-to-day data on dust concentrations and it is therefore not possible to attribute data to specific events or changes in wind direction.

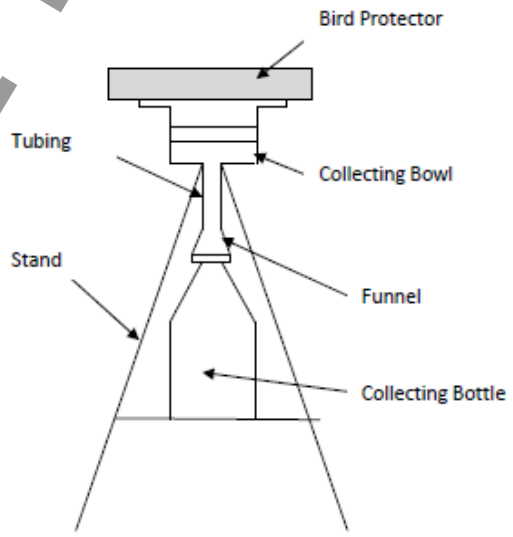


Diagram of a Deposition Gauge

Analysis Techniques

These include gravimetric analysis, microscopic analysis, gas liquid chromatography, mass spectrometry, atomic absorption spectrophotometry, chemiluminescence, electrochemical cells, atomic emission spectrophotometry, spectrophotometry and ultraviolet/ infrared spectrometry.

Jargon Buster

Gravimetric Analysis

Involves accurately weighing a sample before and after exposure to the dust or other pollutant. The gain in weight will represent the amount of pollutant collected over the period chosen.

Topic Focus

Gravimetric Analysis

Exposure of the sample filters will take place for a predetermined time, and the pre-weighed filters will be used to collect the requisite sample, which will then be weighed again. BS 1747-1:1969 deals with deposit gauges and dust gauges and other air pollutants such as SO_2 and O_3. The British Standard describes a deposit gauge for particulates. In this method, a collector bowl, protected by a bird guard, leads via a tube into a collecting bottle. Deposited material is washed off and the associated filters are measured gravimetrically.

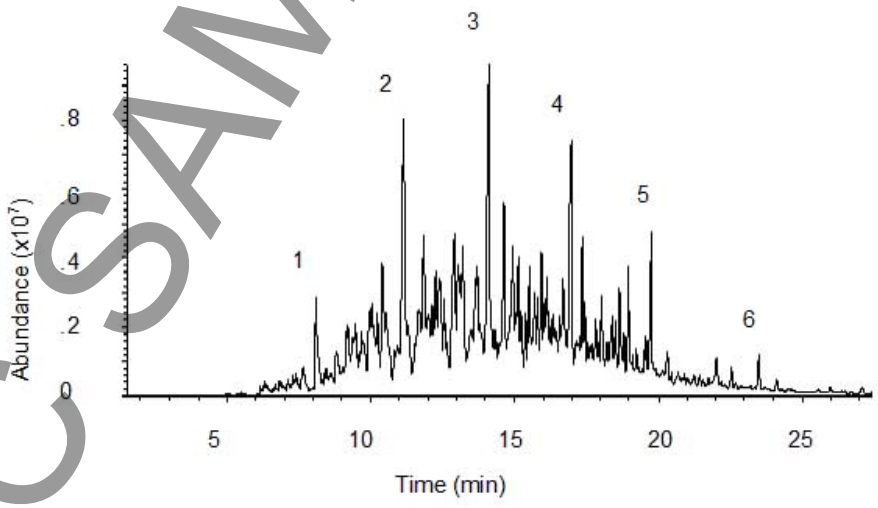
Extractive methods are also used. The Chartered Institute of Environmental Health 1995 method utilises the principle of air being drawn through a filter with the airflow rate regulated by an orifice or the rate of pumping. The sampling time is measured and the quantity of particles sampled, measured gravimetrically.

Microscopic Analysis

The actual physical examination of particles is carried out microscopically in certain cases. An example is in the examination of asbestos fibres. Both phase-contrast and scanning-electron microscopic methods are in use.

Gas Liquid Chromatography

Gas chromatography methods can be used for CO_2, CO, O_2, N_2, N_2O, H_2, sulphur, nitrogen, halogen compounds and light hydrocarbons. The gases to be analysed are drawn through a packed column containing a porous polymer mixture or molecular sieve, which absorbs the gases. An inert carrier gas, such as helium, is passed through the column. Each gas has a characteristic retention time.



Gas Chromatogram

(Continued)

Topic Focus

The technique for the analysis of liquid samples in aqueous solution produces similar characteristic spectra, and is the preferred method for anions such as sulphate, nitrate, chloride, bromide and sulphide. A similar procedure is used but a liquid, as opposed to a gaseous eluant is used.

Mass Spectrometry

This is an instrumental technique used for the simultaneous analysis of several gaseous components of a gas stream. The gas to be analysed is ionised by an electron beam, producing positively charged molecules and molecular fragments. These are separated on the basis of their mass to charge ratio using, for example, a magnetic sector analyser. The instrument can be set to analyse for one or more ions within a range of mass numbers. These instruments are very useful as they can measure 100% down to parts per million levels.

Atomic Absorption Spectrophotometry

This is the most widely used method for the analysis of metals, including heavy metals such as lead or mercury. It relies on the principle that each element has a characteristic wavelength when heated in a high temperature flame. A solution containing the substance to be analysed is excited through a high temperature flame, and a lamp of characteristic wavelength is shone through the gas stream. The resultant absorption pattern both identifies and quantifies the concentration of the metal being analysed. A separate light beam must be used for each element to be analysed, so the related technique of Atomic Emission Spectroscopy tends to be preferred.

Chemiluminescence

As the name implies, this is when a chemical reaction produces energy in the form of light. The technique can be used for the measurement of various substances and is commonly used for the measurement of nitrogen monoxide (NO) by introducing it to an excess level of ozone (O_3). The operation of direct-reading instruments for the measurement of NO/NO_2 is based on this principle. When using this technique for the measurement of gases, it is usually referred to as 'gas phase chemiluminescence'.

Ozone is usually generated by the measuring equipment and introduced into a reaction cell. The sample containing nitrogen monoxide is then added to the reaction cell. The two gases then chemically react and light, which is recorded by a photodetector, is emitted.

The equation shows the chemical reaction that would take place:

$$NO + O_3 = NO_2^* + O_2$$

$$NO_2^* = NO_2 + hv$$

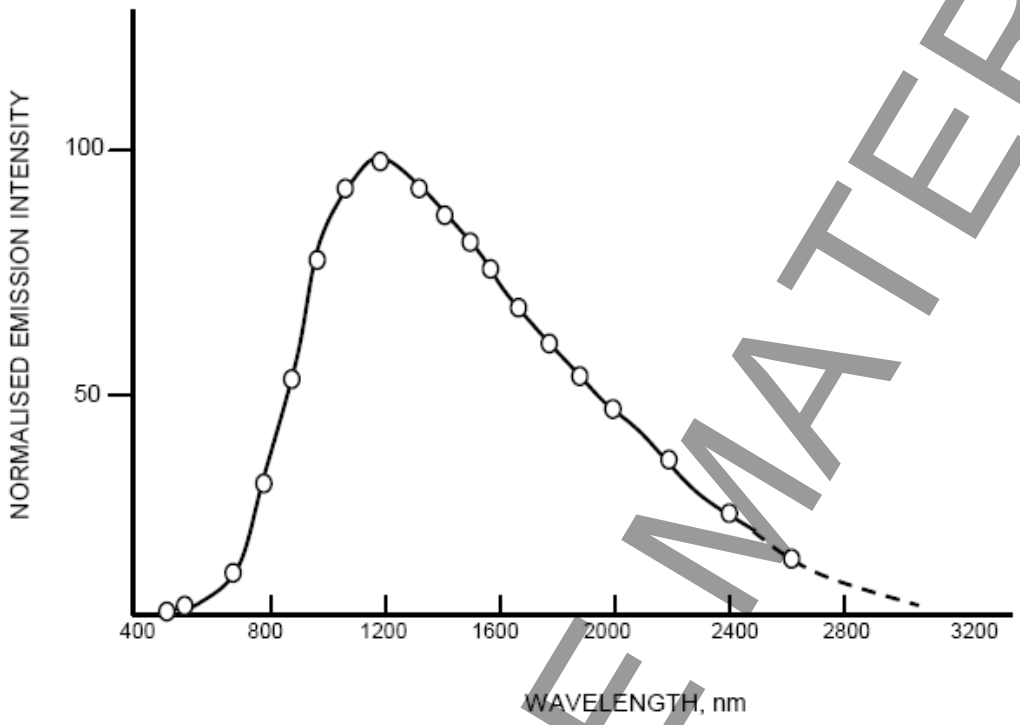
The nitrogen monoxide reacts with the ozone to produce oxygen (O_2) and nitrogen dioxide (NO_2) in an excited state (depicted by *). The excited nitrogen dioxide will naturally return to its ground state (i.e. 'unexcited') and by doing so, releases energy in the form of light (hv).

During the reaction, light is emitted between 600 nm and 2,400 nm, with a peak at about 1,200 nm, as shown in the following graph. The amount of light emitted is proportional to the amount of NO in the sample being measured.

NO_2 is measured using the same principle, but it is first reduced to NO before being reacted with the O_3. This is illustrated graphically as follows:

(Continued)

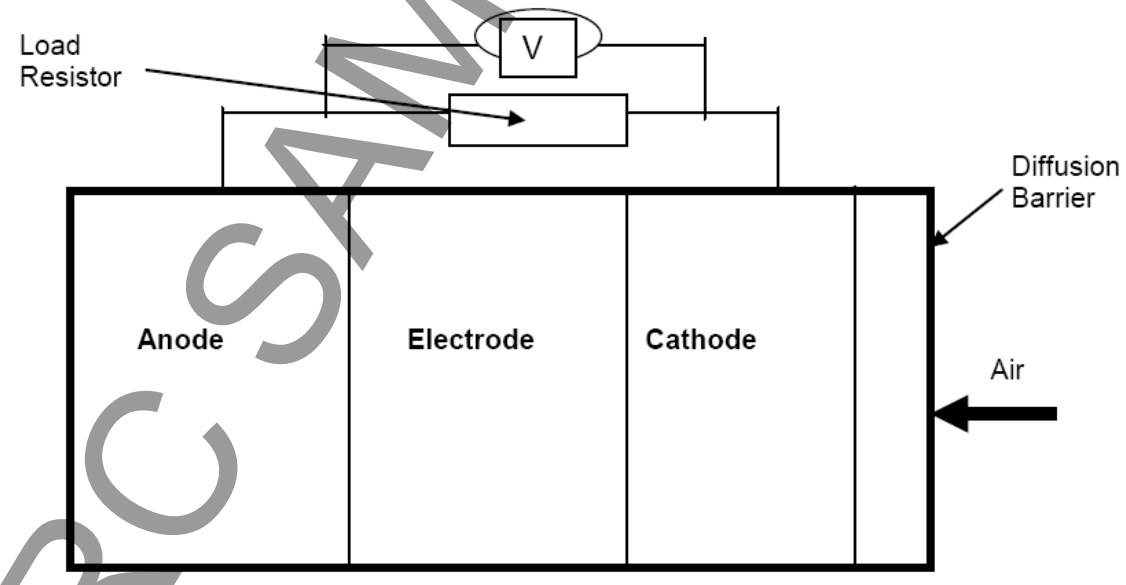
Topic Focus



Emission of Light

Electrochemical Cells

Many portable gas analysers utilise electrochemical cells. Oxygen can be monitored by their use, but they may also be used to analyse up to six gases simultaneously. The basis of the cell is a device with an anode, a cathode and an aqueous electrolyte. The gas sample is led through a thin Teflon membrane that allows the preferential diffusion of oxygen molecules to a cathode, where the oxygen is absorbed and then moves to the electrolyte, where it is ionised and can be measured. A typical cell is shown below.



Electrochemical Cell

(Continued)

Topic Focus

Atomic Emission Spectrophotometry

The material to be sampled is heated as before, but the Optical Emission Spectrum is recorded as a function of the wavelength. After calibration of the instrument, all the metallic elements can be analysed simultaneously.

Spectrophotometry

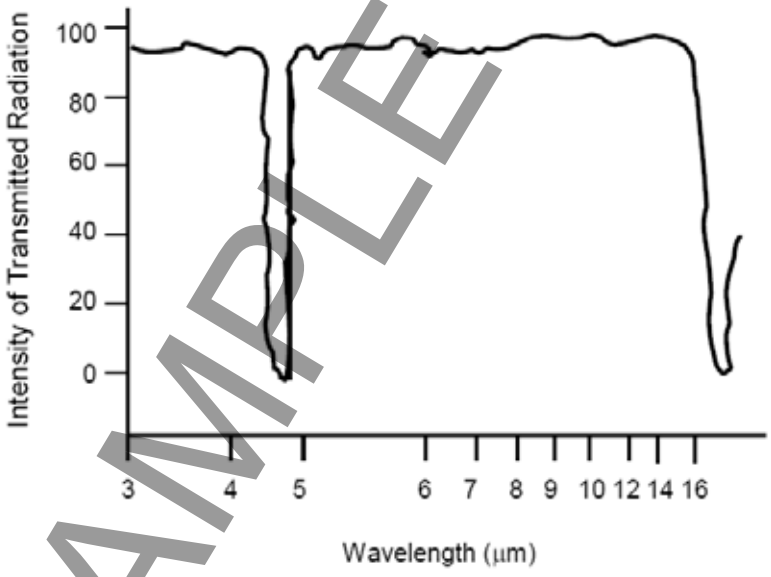
This uses specific frequencies of light to measure specific elements/gases. Three main frequencies of light are used: infrared (IR), visible and ultraviolet (UV).

The choice depends on which part of the spectrum the pollutant's characteristic absorption frequency lies. Sometimes they overlap and it is difficult to distinguish between pollutants.

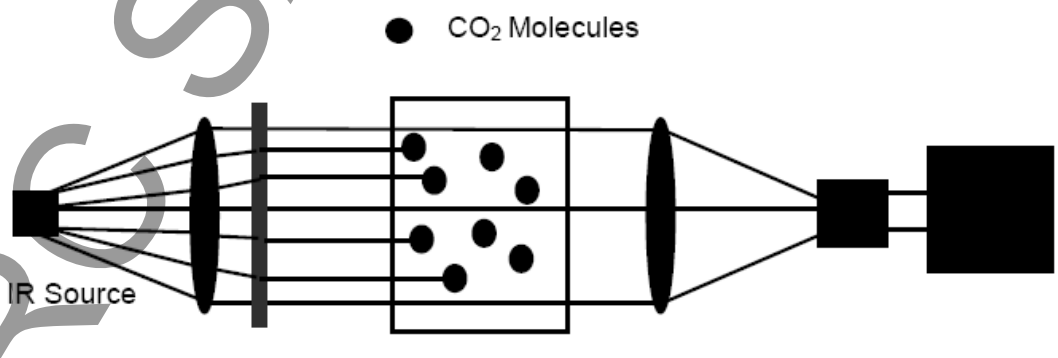
Ultraviolet/Infrared Spectrometry

Continuous monitoring of carbon dioxide, carbon monoxide and methane is usually undertaken by IR absorption. Molecules containing two or more dissimilar atoms display unique absorption characteristics in the infrared region, the intensity of the absorption being equal to the concentration. Many gases can be analysed by these methods, including carbon oxides, nitrogen oxides, ammonia, sulphur oxides, hydrogen chloride, etc.

Colorimetric techniques can be used by reacting the substance to be sampled with an organic dye and a quantified result obtained by measuring optical absorption in the UV or visible region.



Infrared Spectrum for Carbon Dioxide



Infrared Spectrometry

Revision Questions

5. When might a company be required to undertake sampling of a gaseous emission from its plant?
6. List methods for measuring particulates in a gas stream.

(Suggested Answers are at the end of this book.)

Control Strategies and Measures

Key Information

- Reduction at source is the most effective option for the control of gaseous pollutants.
- The behaviour of a discharge to air depends on factors such as the discharge rate of the pollutant gas, volume flow of the gas, temperature at release, height of the release, and location of the release relative to the environment, i.e. proximity to hills, buildings, other pollution sources and potential targets.
- Plume dispersion is complicated with many variables, such as the weather conditions, wind speed, temperature, ground conditions and the nature of the pollutant.
- The range of particle arrestment devices includes cyclones and other inertial separators, fabric filters, wet scrubbers and electrostatic precipitators.
- There are several types of gas and vapour control devices including absorption devices, adsorption devices, incinerators, coolers and chillers, and peat beds.

Background

Need for Control

Gaseous Pollutants - Reduction at Source

Our definition of environment was "surroundings", which covers both a global and local workplace scale. Reduction at source is the most effective option for the control of gaseous pollutants, and it should be considered as a global problem.

Global Warming Gases - Carbon Dioxide

The upper atmosphere receives radiation from the sun which is composed of 5% ultraviolet, 52% visible and 43% infrared. The ozone layer and other upper atmosphere layers reflect and scatter the shorter wavelength ultraviolet radiation, allowing the visible and infrared radiations to reach the lower atmosphere and the Earth's surface. This radiation is received by the surface, and heats up. At night, the long wavelength radiation from the warm surface is re-radiated back into space. However, the water molecules and carbon dioxide in the atmosphere present a barrier to long wavelength radiation and slow heat loss from the surface. If this greenhouse effect were not present, the heat loss from the Earth's surface by re-radiation would reduce the Earth's surface temperature to around –18°C.

However, if the concentration of carbon dioxide and other so-called greenhouse gases increases significantly, this effect may be enhanced to the point where there are increases in the average global temperature. Even quite small increases in overall global temperatures can be significant and some studies claim that the additional carbon dioxide released into the atmosphere by industrial activity has already increased the temperature by 0.5°C.

In order to combat the increase of carbon dioxide release into the atmosphere, governments have agreed to legislate to limit the release of fossil carbon entering the atmosphere from coal, oil and petrol, from power stations and motor transport. In the UK, this is brought into effect through the **Environmental Permitting Regulations 2010** and through the Climate Change Levy and associated requirements.

Ozone Depletion and the Montreal Protocol

Ozone gas is composed of molecules containing three oxygen atoms. In contrast, the oxygen molecule contains two oxygen atoms. Ozone is formed in the stratosphere when solar ultraviolet radiation breaks down oxygen molecules into individual atoms and these combine with other intact oxygen molecules to form the ozone molecule. Ozone in the upper atmosphere is important because it absorbs most of the ultraviolet radiation from the sun and so prevents it penetrating to the Earth's surface, where it may cause skin cancer and cataracts in humans and adversely affect other animal and plant life.

In the mid 1980s, it was discovered by satellite imaging that the ozone layer at the South Pole was thinning and this was attributed to particular gases destroying the naturally-occurring ozone. Chlorinated and brominated gases such as chlorofluorocarbons (CFCs) and halons rise into the atmosphere, eventually reaching the stratosphere. They are then broken down by solar ultraviolet radiation to release chlorine and bromine atoms. Thus one single chlorine or bromine atom has the potential to dissociate relatively large numbers of ozone molecules and remain present in the upper atmosphere for decades.

The Montreal Protocol heralded restrictions and elimination of some substances known to be ozone

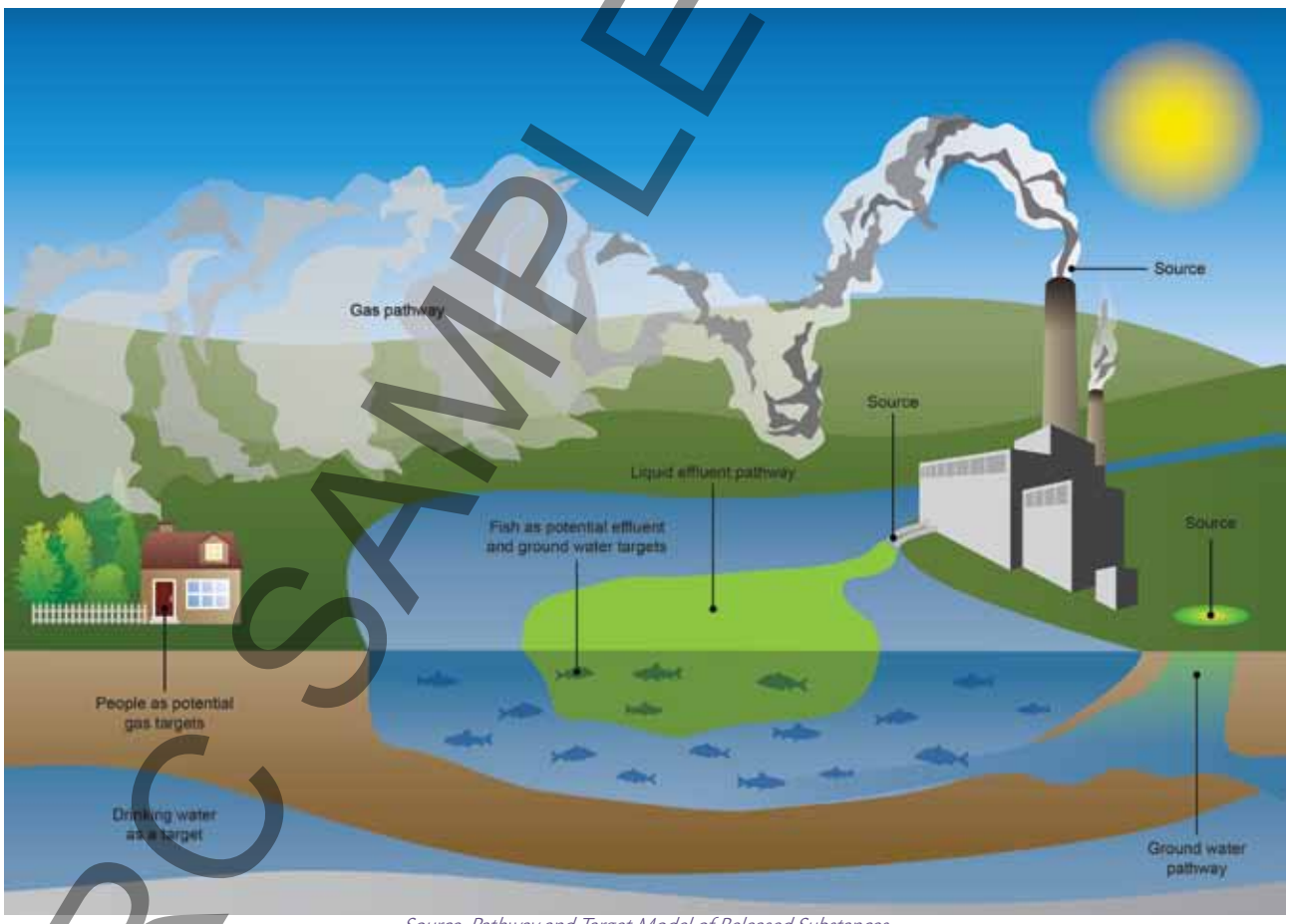
depleters. **EU Regulation 1005/2009** has brought the requirements of the Protocol into force throughout the EU and there is some recent evidence that, due to the restrictions on ozone-depleting substances made through the EU Regulation and other international legislation implementing the Montreal Protocol, the ozone holes are slowing in their rate of growth.

CFCs are relatively non-toxic and not flammable and therefore were widely used as refrigerants and in air-cooling systems, as blowing agents in flexible foam manufacture, and as propellant gases in aerosol cans. They are also widely used as solvents, particularly in the electronics industry. The brominated hydrocarbons or halons are also relatively non-toxic and not flammable and have been widely used in fixed installation fire-quenching systems in computer sites and in many industrial applications; they were also widely used in portable fire extinguishers.

Dispersion of Air Pollutants

Fate of Releases to the Environment

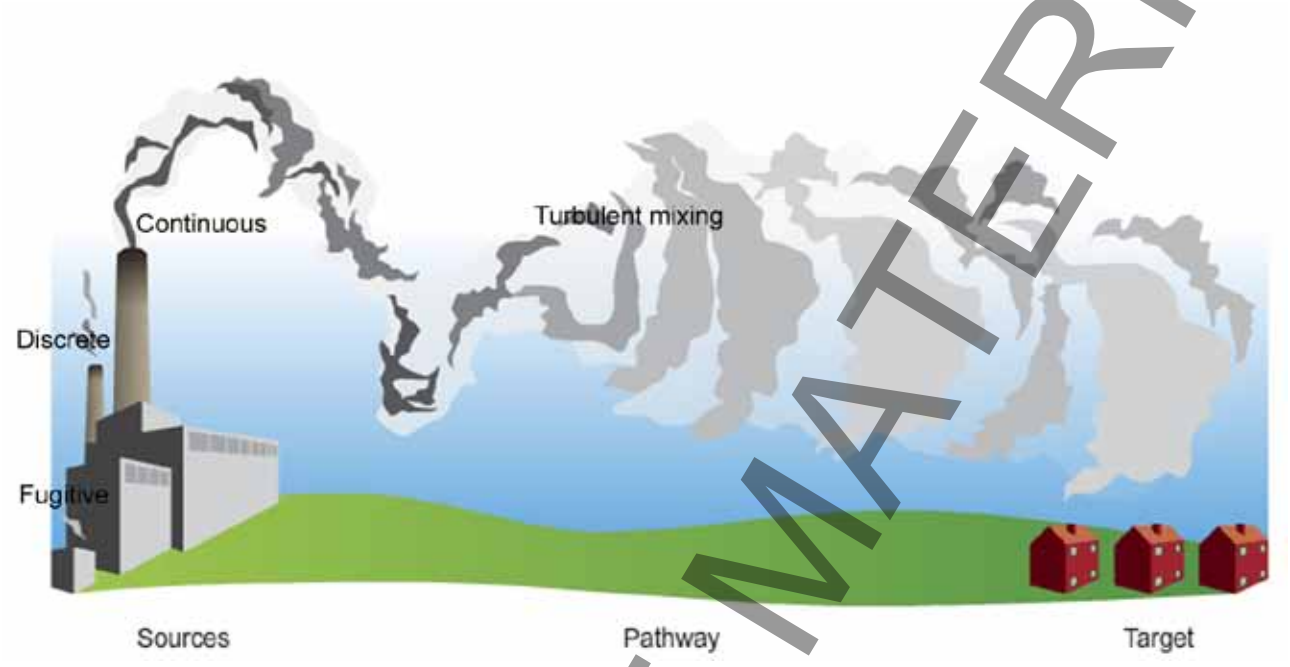
The same principles apply to air dispersion as to other forms of pollutant spread, as illustrated by the following figures.



Source, Pathway and Target Model of Released Substances

(Based on HMSO, Released Substances, 1996)

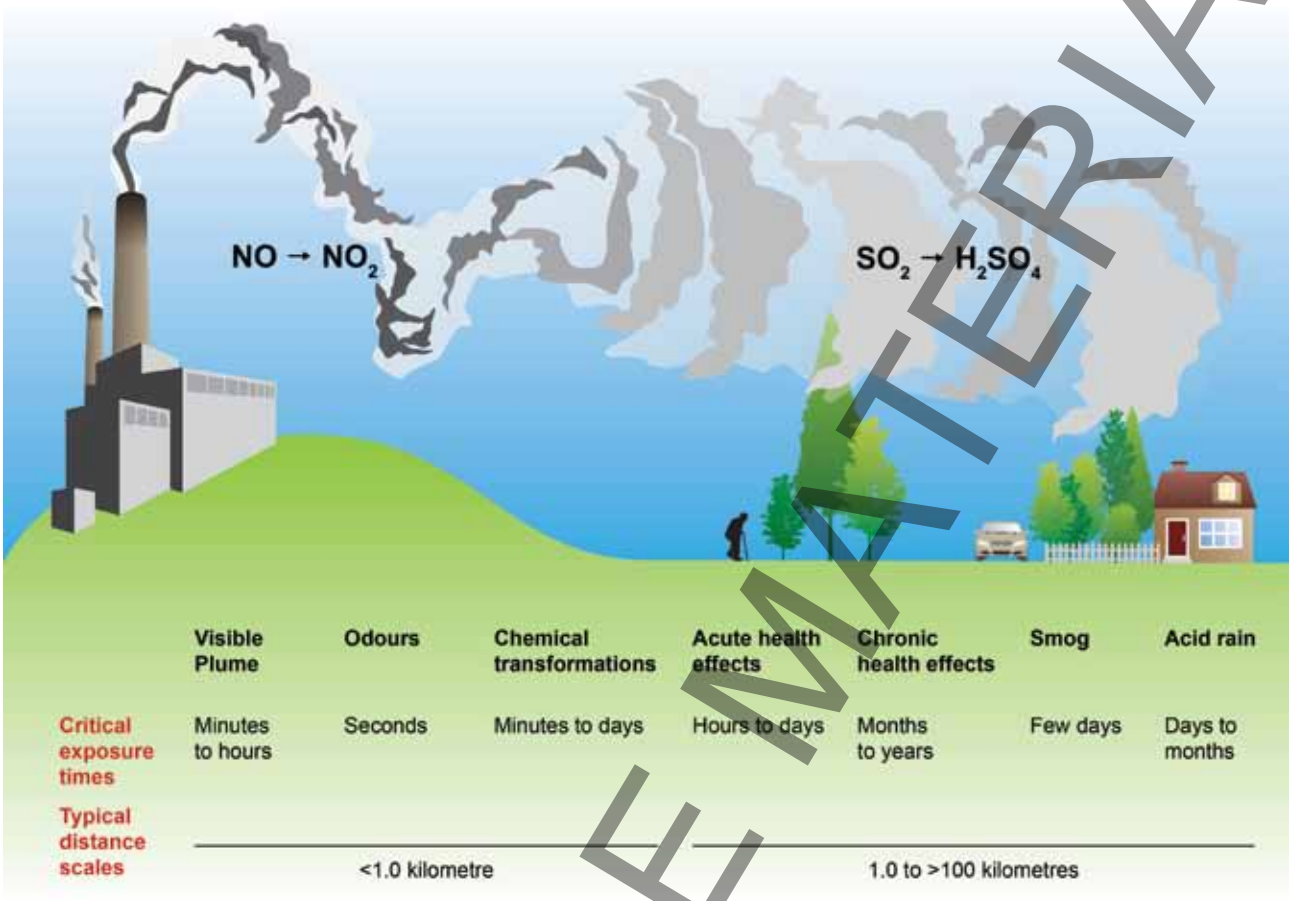
Emissions to air are illustrated in the next figure, which also shows the principal types of air emission, i.e. continuous, discrete and fugitive sources.



Emissions to Air

In order to define a discharge to the environment, the following should be taken into account and included in any emission inventory:

- The mass discharge rate of the pollutant gas.
- Volume flow of the gas, based on stack diameter and efflux velocity.
- Temperature at release.
- Whether the release is continuous or intermittent.
- Height of the release.
- Location of the release relative to the environment, i.e. proximity to hills, buildings, other pollution sources and potential targets.
- Presence of any fugitive emissions, e.g. from pipework or flanges.



Time and Distance in Air Emissions

Plume Dispersion and Pasquill-Gifford Categories

The physics of plume dispersion is quite complicated with many variables, such as the weather conditions, wind speed, temperature, ground conditions and the nature of the pollutant. The amount of mixing of the plume depends on the **stability** of the atmosphere. **Unstable** conditions are typified by a decrease in air temperature with height, so that close to the ground the air is warmer.

On sunny afternoons, the sun can cause large convective motion and plumes can loop, bringing pollutants to ground level. Conversely, at night with light winds and clear skies, the atmosphere may be **stable**; the ground may cool and the air temperature will increase with height. This means the vertical spread of the plume is limited. In between these two extremes, conditions are described as **neutral**, which is the most common in the UK and is typically overcast skies and moderate wind causing intermediate rates of plume mixing. The stability conditions (diffusion categories) have been described by a classification scheme known as the **Pasquill-Gifford scheme**:

- A-C Unstable conditions.
- D Neutral conditions.
- E-G Stable conditions.

The parameters involved are wind speed, solar radiation and/or cloud cover.

A pollutant plume emitted from a single source (e.g. a chimney) moves in the average direction of the wind. As it moves, it is acted on by the prevailing level of atmospheric turbulence. This causes the plume to grow in size as it entrains the (usually) cleaner surrounding air. Changes can occur to the gases in the plume, as shown in the diagram above. There are two main methods of generating atmospheric turbulence: **mechanical** and **convective**.

- **Mechanical Turbulence**

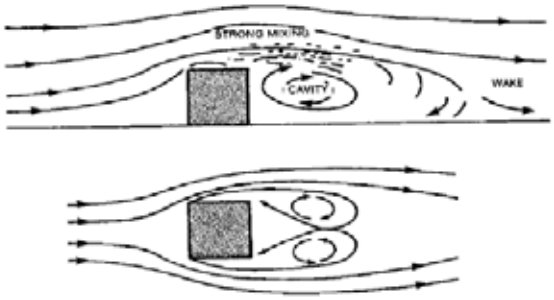
  This occurs when the air flows over obstacles on the ground, e.g. trees, hedges, buildings and hills. Turbulence increases with the surface roughness and decreases with the height above the ground.

- **Convective Turbulence**

  As heat from the sun heats the Earth's surface, the lower layers increase in temperature and convection begins. At night there is no solar heat and the Earth's surface cools, so there is little turbulence; on calm, clear nights when the surface is cooling rapidly there may be virtually no turbulence.

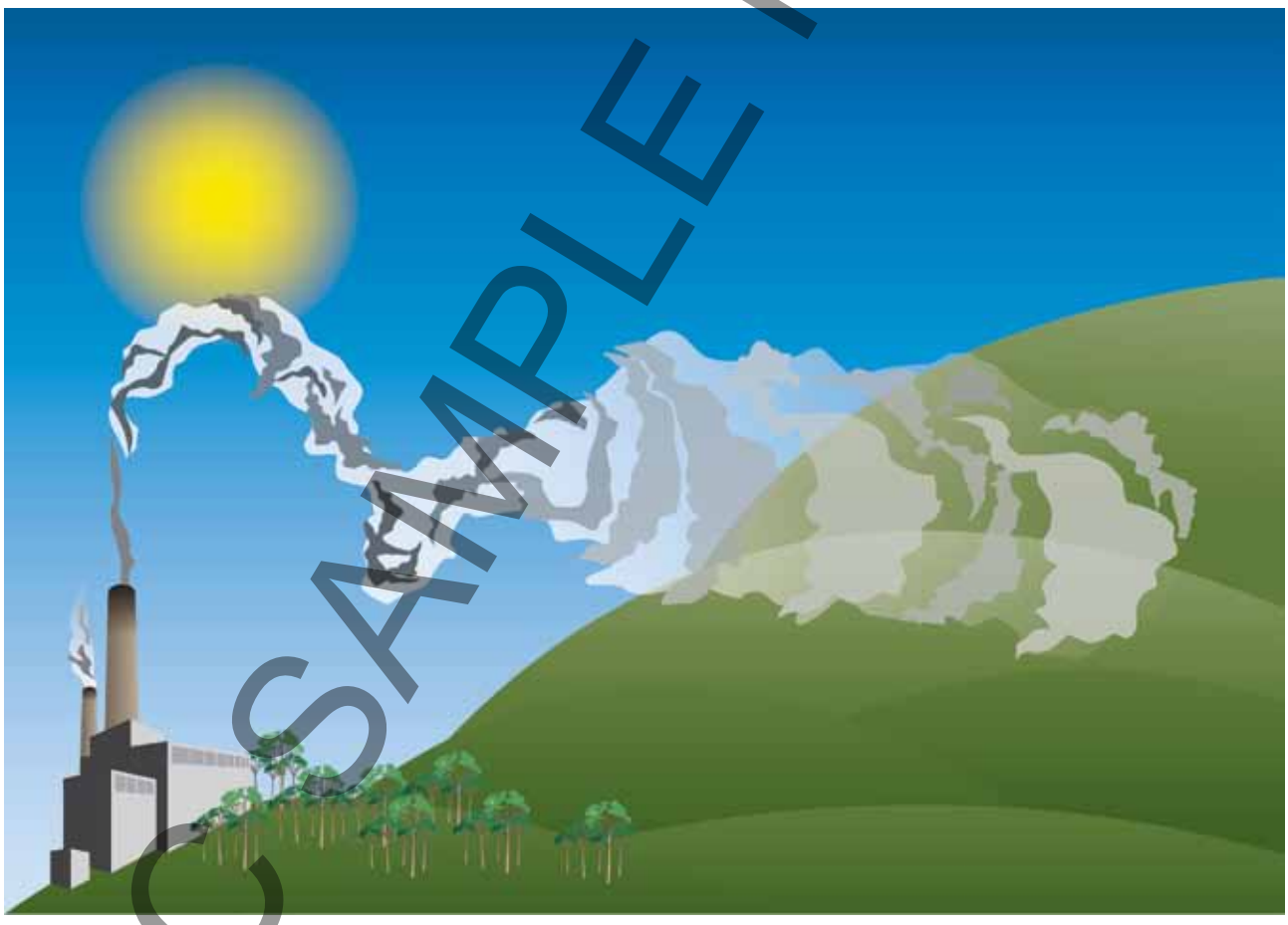
Building and Topographical Effects

Hills or buildings can have a significant adverse effect on plume dispersion, if their size is large compared to the size of the plume, or if they have a large effect on the flow of the wind as shown in the following diagram.



Air Flow Patterns around a Cubical Building

The following is an example of the interference of plume dispersion.



Plume Impact on a Hill under Stable Atmospheric Conditions

Similarly, in deep valleys it may be hard to disperse fumes from chimneys under certain meteorological conditions. This has given rise to widespread local pollution in the past, examples being Sheffield, Stoke-on-Trent and the South Wales valleys.

Chimney Height

At whatever height smoke and flue gases are discharged, gravity will eventually bring the larger particles of grit, dust and soot to the ground. Additionally, because of the natural turbulence of the atmosphere, a portion

of the gases and of the freely suspended fine particles will reach the ground although not affected by gravity. The higher the point of discharge and the greater the total heat content of the discharged gases, the more widespread and diluted the fine particles and gases will be by the time they reach ground level. Control of chimney heights enables local authorities to take into account a number of relevant factors, including the need to avoid downdraught or downwash created by the chimney itself, or by buildings or topographical features; to avoid the ground level concentration of combustion products becoming prejudicial to health or a nuisance; and in the case of smaller units, to prevent the flue gases from entering nearby buildings in too high a concentration.

The local authority must not approve the proposed chimney height unless it is satisfied that it will be sufficient to prevent, so far as is practicable, the smoke, grit, dust, gases or fumes emitted from the chimney from becoming prejudicial to health or a nuisance, having regard to:

- The purpose of the chimney.
- The position and descriptions of buildings near to it.
- The levels of the neighbouring ground.
- Any other matters requiring consideration in the circumstances.

The method used to calculate stack height is based on the need to limit local ground level pollution rather than long-range issues such as acid rain.

Guidance is available from local authorities and various computer modelling programs.

The first stage in determining chimney heights is to calculate a 'Pollution Index' for the pollutant gases and particulates being discharged. The Pollution Index is defined in terms of the discharge rate, the background concentration and the guideline safety concentration for each pollutant. The discharge stack height is then calculated using the Pollution Index and basic information about the discharge parameters, and the surrounding structures and buildings.

Chimney or process vents should be designed to achieve an exit or efflux velocity of 15 m/sec or more when a dry arrestment process is used, e.g. cyclones, bag filter plant or electrostatic precipitators. However, if a wet method is used such as a venturi scrubber, the system should be designed to ensure that the droplets are not carried over into the atmosphere. It is therefore recommended that the efflux velocity does not exceed 9 m/sec where wet arrestment systems are used.

When hot gases are being ducted to a stack, the ductwork and chimney should be insulated to prevent surface condensation leading either to accumulations of liquids, entrained dust in the ductwork or droplet ejection from the stack.

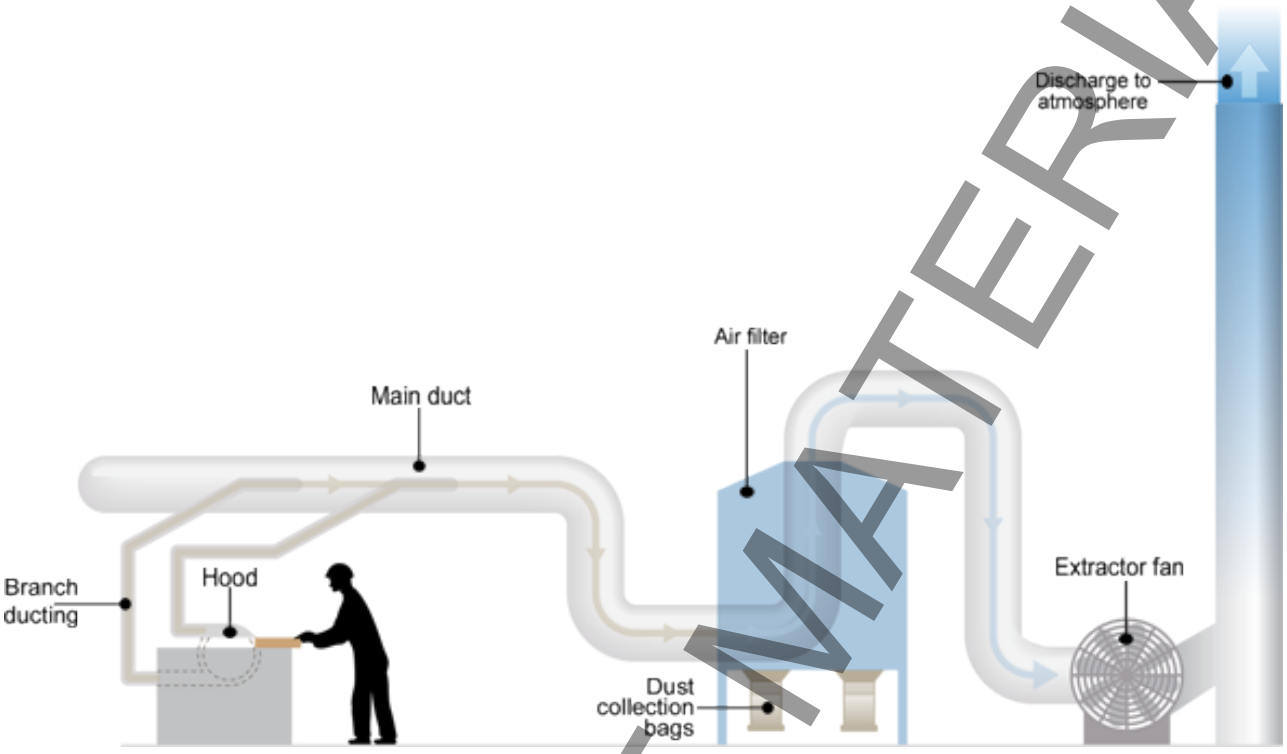
The current advice is that chimneys and other similar vents should not be fitted with cowls or plates as they impede the discharge flow and reduce efflux velocity. Efflux cones may be fitted to increase velocity in some circumstances.

The Range of Engineering and Procedural Control Measures and Strategies for Capturing Air Pollutants

In this subsection we shall consider the engineering and procedural control measures and strategies which can be applied to eliminate, or where not possible, reduce or render harmless emissions to the atmosphere. The control options which are appropriate for different types of substances will also be discussed.

Basic Principles of Air Pollution Control

Industrial air pollution control encompasses the design, process engineering and abatement techniques necessary to eliminate, reduce or render harmless the emission of contaminants into the atmosphere. The most cost-effective and efficient methods are those incorporated into the process design to reduce the total mass of contaminants in the waste stream. The engineering devices should be supplemented by management techniques, i.e. procedures, information, instruction and training.



A typical LEV system extracting sawdust from a bench-mounted circular saw

Many of the substances mentioned earlier in this element have the potential to harm the health of those people who may be working in the vicinity. Removal of such substances from the workplace may therefore be a requirement of the **Health and Safety at Work, etc. Act 1974 (HSWA)**, Section 2; and specifically, the **Control of Substances Hazardous to Health Regulations 2002 (COSHH)**.

Merely exhausting such harmful substances may cause other problems, e.g. they may affect people outside the workplace (an offence under **HSWA**, Section 3).

Another effect of exhausting harmful substances outside the workplace is that they may cause a "nuisance". Nuisance in common law and specifically statutory nuisances under the **Environmental Protection Act 1990**, Part III, Section 79, may be caused by a variety of issues, for example:

- Noise.
- Dust.
- Smoke.
- Fumes.
- Odour.
- Steam.
- Smell, etc.

The concept of nuisance is that it "spoils the enjoyment" of the use of someone's land or property. Therefore, there is no "minimum quantity" by which nuisance may be defined.

Waste air streams must be collected from the workplace and cleaned of harmful or nuisance contaminants before they are allowed to exhaust to the air.

Often monitoring, both of individual personnel and of the workplace, will also be required under **HSWA** to demonstrate compliance with **HSWA** and associated regulations.

The range of particle arrestment devices includes:

- Cyclones and other inertial separators.
- Fabric filters.
- Wet scrubbers.
- Electrostatic precipitators.

Cyclones

Jargon Buster

Cyclones

Are particulate removal devices which operate by forcing particles to the wall of the device through centrifugal forces. The particles then fall down and are collected at the base of the device.

Topic Focus

Cyclones operate by causing the airflow to change direction rapidly into a spiral, thus throwing the particles out of the air stream toward the walls of the device. The particles then fall down to the bottom of the device for collection. Cyclones are most efficient for large dense particulates; smaller, less dense particulates may be carried on through the cyclone.

Cyclones are used primarily for the following functions:

- Product recovery, e.g. wood dust.
- First stage air stream cleaning.
- Droplet removal.

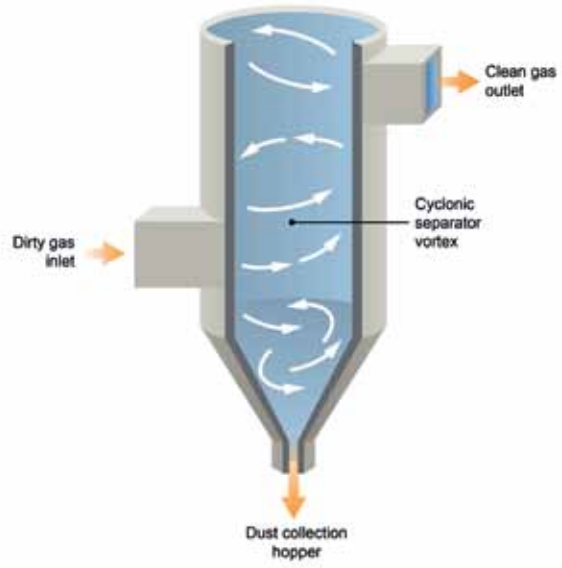
Single cyclones have no moving parts, so the running costs and maintenance requirements are low. However, efficiencies are much lower than fabric filters or electrostatic precipitators and generally they are not suitable for achieving current air emission standards. Common uses include wood dust collection in woodworking factories, and grinding and general metallic dust collection in light engineering plants.

Different design geometries are used to improve the efficiency, but at the cost of throughput capacity. For instance, as the diameter of the cyclone chamber increases, the volume of air which can be put through increases and the air cleaning efficiency decreases. With a constant resistance to airflow, the throughput of a cyclone is proportional to the square of body diameter.

The efficiencies of a cyclone are given by the following relationship:

$$\text{Efficiency} = \frac{\pi N P d^2 V}{9MW}$$

where N = number of turns made by the air vortex in the cyclone
P = particle density
d = particle diameter
V = gas velocity
M = gas viscosity
W = inlet width



Cyclone Schematic

The efficiency can be increased by decreasing the chamber diameter and increasing the chamber length and increasing the inlet velocities. However, this leads to a reduction in throughput. To accommodate this, cyclones may be arranged in groups and operated in parallel.

In some multiple tube cyclone designs, the vortex is induced by vanes at the entrance to the tube. However, there is a small pressure drop as air passes each row of tubes and this is compensated for by reducing the length of the cyclone body in each successive row. Collection efficiency can be improved by hopper evacuation, in which a small portion (about 15%) of the total gas flow is drawn off through the hopper. This reduces reintrainment of deposited dust and may increase collection efficiency by 50%.

Fabric Filters

Jargon Buster

Fabric Filters

Remove dust from a gas stream by passing through a fabric. The fabric must allow air to pass through it and remove the dust particles from the air.

Topic Focus

Principles of Fabric Filters

The filtration mechanism involves both the mechanical filtration of particles adhering to the strands of the fabric and the filtration properties of the dust particles which accumulate on the fabric surface. The layer of dust which accumulates on the fabric surface is called the filter cake. It may at first be thought that the particles which pass through the filter cake are those which are smaller than the spaces between the filter cake particles and the fabric weave. In fact, studies have shown that the particle size distribution leaking through into the exhaust air is similar to that in the original gas stream. The process involved may be visualised by imagining the slow build-up of particles on the clear fabric surface.

As the fabric pores are all open and unobstructed, the airflow through the fabric is uniform and at a relatively slow speed. As particles begin to adhere to the fabric strands, they form long chains due to electrostatic charging and begin to bridge the pores in the fabric. Large particles may actually block the pores altogether. With time, more and more pores are closed and the airflow through the remaining open pores increases. At some point, there are very few pores left open and the airflow through them may be several orders of magnitude higher than that through the pores when they were all open. The force of air through these pores prevents particles bridging and particles of all sizes are swept through the remaining pores. At this point, the pressure drop across the filter is very high and the fabric surface must be cleaned to allow airflow to continue.

(Continued)

Topic Focus

Fabric filters are generally more efficient at removing smaller particles from air streams than cyclones. Consequently, cyclones are often used as first stage air-cleaning devices to remove the larger particles from the air stream before it is passed into a fabric filter unit.

Fabric Filter Types

Fabric filters are normally designed with the fabric forming cylinders or bags. Usually there are several filter bags or filter elements grouped together in an enclosure; the whole air-cleaning device is called a bag house or bag filter plant. The types of bag filter plant are differentiated by the mechanism used to remove the filter cake from the surface of the bag.

There are three commonly used mechanisms:

- **Mechanically Shaken**

  The technique of using fabrics to filter particles out of dust-laden air streams dates back to the 1800s. In the early 1890s, bag-shaped filters were employed and these were shaken by hand to remove the filter cake. Modern bag filter plants employ mechanical shaking devices to vibrate the bag at frequencies between 10-100 cycles per second, for a few minutes. Generally the bag is open at the bottom and closed at the top. The dust-laden air enters the bag at the bottom and passes up and through the bag to leave the filter plant through vents at the top. Thus the filter cake accumulates on the inner surface of the bag. The cleaning cycle is operated at regular intervals to remove the filter cake before the airflow through the back is stopped and a slight reverse airflow is sometimes introduced to aid cleaning. The bags are shaken and the released dust is collected in hoppers at the base of the plant.

  The mechanical shaking of the bags induces friction and stresses the fabric, therefore the material of the filters must be chosen to tolerate this.

(Continued)

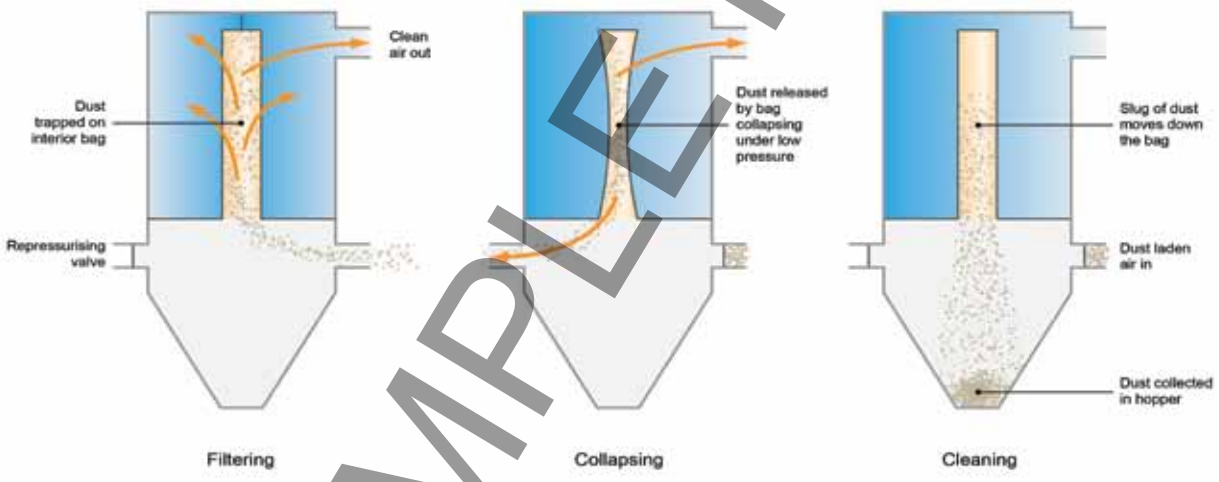
Topic Focus

- **Reverse Air Cleaning**

  Reverse airflow bag filter plants employ a cleaning technique which involves passing cleaned air through the bags in the opposite direction to the normal operating direction. In high- temperature operations the cleaned air is recirculated rather than using colder ambient air, which reduces the thermal stresses in the plant and prevents condensation.

  Generally, the reverse airflow is carried out in separate compartments of the baghouse to allow continuous operation of the plant. The reverse airflow fan is much smaller than the main baghouse fan. As with mechanically shaken systems, the dust-laden air enters the fabric bags which are open at the bottom and closed at the top. The filter cake accumulates on the inner surface of the bag. During the cleaning cycle, the normal airflow is diverted and a reverse air current applied to the outside of the bag. This change in pressure initially causes the bag to deform and the filter cake is dislodged and falls into a hopper. It is believed that it is deformation of the bag rather than the aerodynamic forces of the reverse airflow, which dislodges the filter cake. This method of cleaning involves less mechanical stress to the bags and so the strength of the fabric material is not so crucial.

  Sonic horns have been introduced into mechanically-shaken and reverse-flow bag filter plant designs to supplement the filter cleaning mechanisms.



Bag Filter Plant Reverse Air Cleaning

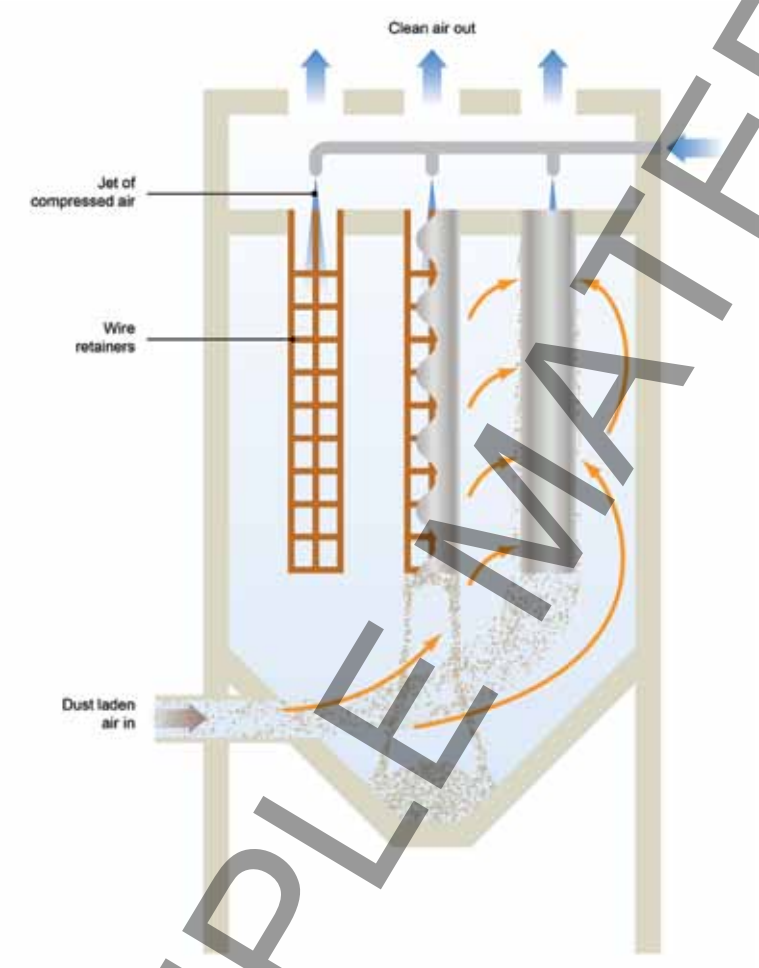
- **Pulse Jet Cleaning**

  Pulse jet bag filter plants employ jets of compressed air to remove the filter cake. In these plants, the bag filter elements are closed at the bottom and open at the top. The dust-laden air passes from the outside of the bag to the inside and up to vents at the top of the plant. The filter cake forms on the outside of the bag. To prevent the bags collapsing in normal operation, they are supported on the inside by metal rings or cages.

  During the cleaning cycle, the airflow to bags is redirected and air, from compressed air nozzles at the open tops of the bags, is directed into the bags. This positive pressure slightly inflates the bags and the deformation and outward flow of air dislodges the filter cake. The dislodged dust falls into a hopper and is removed from the plant.

(Continued)

Topic Focus



Pulse Air Jet Bag Filter Plant

Fabric Material

Probably the most important aspect of a bag filter plant is the choice of filter fabric. The material chosen must be able to withstand the dusts and gases to which it is subjected without damage and deterioration. Another critical factor is the temperature. Early bag filters used natural fibres such as cotton or wool and they are still used today. However, these materials are not suitable for high-temperature applications. Synthetic fibres such as acetates, acrylics, polyamides, polyester, polyolefins and polyvinyl chlorides have better chemical resistance and temperature characteristics. For high-temperature use, teflon, ryton and carbon fibre filters have developed with glass, ceramic and metallic fibres being employed for very-high-temperature applications.

The material may also be subjected to repeated flexing and abrasion within the fabric and between the materials and the supporting structure. The material chosen must be capable of withstanding this level of abrasion.

In selecting an appropriate bag filter material, the following characteristics must be considered:

- **Temperature**

  The material chosen must have a maximum continuous service temperature higher than the normal temperature of the application. If the temperature is likely to surge above the normal operating range, this must be taken into account when selecting the material.

- **Corrosivity**

  The ability of the material to resist physical degradation from the acids, alkalis, solvents and oxidising agents in the waste gas stream must be considered.

(Continued)

Topic Focus

- **Hydrolysis**

  The effects of the expected levels of humidity of the flue gases must be considered.

- **Dimensional Stability**

  If the material may shrink or stretch in service, the effects of this must be taken into account.

- **Strength**

  The resistance of the material to flexing and abrasion must be considered. A trade-off between the other factors may mean the selection of a material which must be replaced within shorter periods, thus increasing maintenance costs.

- **Release Characteristics**

  The material chosen must release the filter cake generated in the specific operational circumstances being considered. Poor release characteristics will rapidly degrade the plant efficiency.

Bag Filter Efficiency

Many of the design characteristics of bag filter plants have been carefully researched and documented. However, designers have been largely unsuccessful in predicting accurately bag filter plant efficiencies prior to installation. The method of measuring efficiencies involves measuring the particle concentrations in different size ranges and expressing efficiency as the percentage of mass concentration retained by the plant in each size range.

Specific characteristics are important in designing plants to deal with specific situations. The parameters include the gas to cloth ratio for particular materials. This is the measure of gas flow through a unit area of material. However, this measure considers only the material and not the filter cake. There are various theoretical equations for pressure drop across a porous bed and they are applied to material and filter cake combinations to determine the appropriate fan sizes and cleaning cycle frequencies.

Wet Scrubbers

Wet scrubbing techniques are used to remove particulates from waste gas streams. Gases will also be removed and the mechanisms involved are similar to those employed in absorption devices, such as packed columns whose main function is to remove soluble gases. However, wet scrubbing techniques employ higher energy systems and are normally employed under the following circumstances:

- Where the contaminant cannot be removed easily in a dry form.
- Where the waste gas stream contains both particulates and soluble gases.
- Where the particulates to be removed are soluble or wettable. They would adhere to the inner surfaces of a cyclone or bag filter plant and clog it.
- Where the contaminant will undergo some subsequent wet process, such as sedimentation, wet separation or neutralisation.
- Where the pollution control system must be compact.
- Where the particulates may ignite or explode if collected in a dry form.

Wet scrubbing is used to control sticky emissions which may block filter-type collectors, to handle waste gas streams containing both particulates and gases, to recover soluble dusts and powders and to remove metallic dusts such as aluminium, which may explode if handled dry.

Topic Focus

Principles of Wet Scrubbers

The principle of all wet scrubbers is that water droplets are generated within the device and particles are captured within the droplets. The droplets are then removed from the air stream which is now clean. The droplets are collected as contaminated water and transported out of the device for treatment or disposal. It is generally accepted that smaller droplets are required to capture small particulates and that the ideal case is to have a high concentration of fine droplets in contact with the dust-laden exhaust air stream.

There are three main particle mechanisms involved:

(Continued)

Topic Focus

- **Impaction**

  This occurs when the particle is moving at a much higher velocity than the target droplet and impacts directly onto the droplet. It happens when the particle has sufficiently high mass to overcome the aerodynamic forces exerted by the air stream flowing around the droplet and applies mainly to large or dense particles.

- **Interception**

  This occurs when smaller particles following the airflow around a droplet, touch the surface of the droplet and are captured in the droplet surface. It happens when the velocity of the particle is similar to the velocity of the droplet.

- **Diffusion**

  The collision of very small particulates with air molecules causes them to move in a random fashion known as **Brownian motion**. In a moving air stream, where there is little relative difference between the velocity of water molecules and particulates, the motion may be Brownian, but diffusion may cause particles to come into contact and be captured by the droplets.

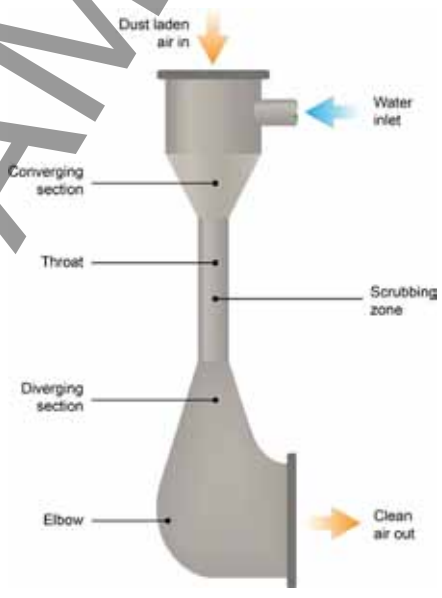
The scrubber design must be directed toward generating a high concentration of small droplets and mixing those efficiently with the dust-laden air stream. The methods for doing this include injecting water directly into the air stream and mechanically shearing the water into droplets, spraying the water into the gas stream and injecting water onto a spinning disc or fan. Different scrubber designs utilise different techniques or combinations of techniques.

Scrubber Designs

The designs may be considered as belonging to five basic types:

- **Venturi Scrubbers**

  These create atomised droplets by injecting water into the gas stream before accelerating the water through a high-velocity zone called a venturi throat. The water and the gas stream is then released into a low pressure area called the diverging section. The turbulence in the venturi throat breaks the water into tiny droplets and particle capture occurs toward the end of the venturi throat and at the beginning of the diverging section. Most venturi scrubbers have throat widths of 150 mm or less because large throat widths lead to inefficient mixing and areas where there are fewer droplets. To accommodate higher airflows, multiple venturis are often employed with throat widths of less than 30 mm.



Simple Venturi Scrubber

(Continued)

Topic Focus

- **Mechanically-Aided Scrubbers**

  These use spinning discs or fans to generate water droplets. Theoretical equations have been derived linking spinning disc speed to droplet diameter - the faster the disc speed, the smaller the droplet diameter. To increase the capture efficiency for small particles, smaller droplet sizes are required and the energy consumption of the scrubber increased.

- **Pump-Aided Scrubbers**

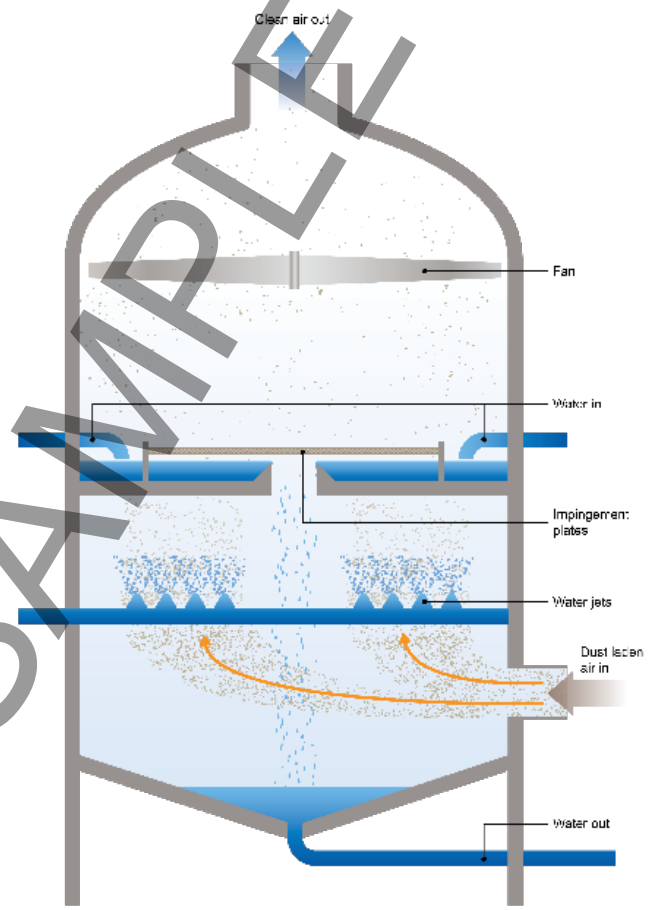
  These spray the water as droplets into the gas stream. In some devices, the droplet spray direction is counter to the gas flow direction, thus increasing the impaction mechanism efficiency. The atomisation of the liquid spray may be enhanced by compressed air.

- **Wetted Filter Scrubbers**

  These devices use a combination of water spray and a filtration element. Particles are captured by water droplets, as described previously. However, particles may also impact temporarily on the elements of the filter to be washed off by a film of water.

- **Tray or Sieve Scrubbers**

  Tray or sieve-type wet scrubbers have small holes in trays that accelerate the gas stream. Water is piped onto the trays to form a shallow layer of water. The airflow through the holes creates a froth which assists in capturing particles.



Impingement Tray Tower Scrubber

(Continued)

Topic Focus

Droplet Removal

The principle of wet scrubbers is the injection of fine droplets into the dust-laden air stream. It is crucial to the satisfactory operation of the scrubber that the droplets and associated mists are removed from the air stream. Many scrubbers use cyclonic separators or cyclones to remove droplets. Others use **chevron** droplet eliminators for either vertical or horizontal gas flow. Shaped like curved and parallel blades, the chevron introduces a surface against which droplets impact and accumulate as water and then drain off. The solids which accumulate on the surface are periodically washed off using water sprays.

For finer droplets, mist eliminators comprising a fine metal mesh are often used. A layer of wire mesh is introduced in the final duct and the mist accumulates on it and drops off. The mesh mist eliminators are also spray-washed periodically to remove any particulate build-up.

Operating Practice

There are certain useful principles which may be adopted in the design, selection and operation of wet scrubbing devices:

- Do not cool hot gas streams with water which has a high dissolved solids content. The water will evaporate leaving very small particles, which are difficult to remove.
- The order in which the contaminated air is treated can be important. The air should be saturated with water first, then the particulates removed. This will leave any contaminant gases which should then be taken out. If the air stream is not saturated, the water droplets will evaporate and drive the particles away from droplets. However, if the air is saturated, condensation on the particulates will aid particle capture. Particulates should be removed before gas absorption because gas absorption requires larger droplets, which are not efficient for particle capture.
- Condense the moisture in the contaminated air whenever possible. This helps sweep particles out of the air stream by creating submicron droplets around them. These small droplets are easier to collect.
- Allow for thermal expansion and contraction. As the temperature of the contaminated air- streams increases, the volume which they occupy increases. The scrubber capacity and velocity calculation must incorporate thermal expansion factors.
- Chemicals should be injected at points where they encounter the lowest particulate concentrations.
- Ensure that the scrubber can handle the maximum dust loadings envisaged. High dust loadings will result in greater particulate build-up on surfaces and require more cleaning and maintenance. Lower dust loadings will allow scrubbers with finer nozzles and perforations to be used.
- Take into account any airflow variations required because of batch production schedules. Airflow transients which may occur during abnormal or emergency situations must also be considered and the effect on scrubbing performance predicted. There is a statutory requirement to report to the enforcement authorities, emissions at twice the limit for that process.
- Arrange to remove sludges where the highest particle concentrations in liquid occur. Always design the scrubber to inject the clean liquid into the zone where the cleanest exhaust air is required. Avoid running liquids with high particulate concentration where the cleanest exhaust air stream is required, i.e. clean droplet eliminators with clean liquids. Avoid adding clean liquid into a dirty sump or scrubber tank.

Electrostatic Precipitators

Jargon Buster

Electrostatic Precipitator (ESP)

Is a particulate and droplet control device which uses electrical forces to remove particles from a dust-laden air stream.

Topic Focus

Principles of Electrostatic Precipitators

An area of ionised air molecules is established, usually around a wire, by maintaining the wire at a very high voltage, typically 20,000 to 100,000 volts. This region of ionised air molecules is called a **corona**. As dust particles flow through the corona, they collect the ions then they themselves become charged. Small particles around one micron may collect tens of thousands of ions. A plate, called the collector plate, is maintained at the opposite electrical polarity to the wire and the particles, so that the charged particles migrate toward the plate.

ESPs are normally arranged with a series of wires between rows of plates so that as the particles pass each wire, they collect more of a charge and drift progressively towards the plates. However, the turbulence in the gas tends to keep the charged particles uniformly mixed with the gas. The collection process is a competition between the electrostatic and dispersive forces. Eventually, the particles approach close enough to the plates so that the turbulence drops to lower levels and the particles are deposited.

(Continued)

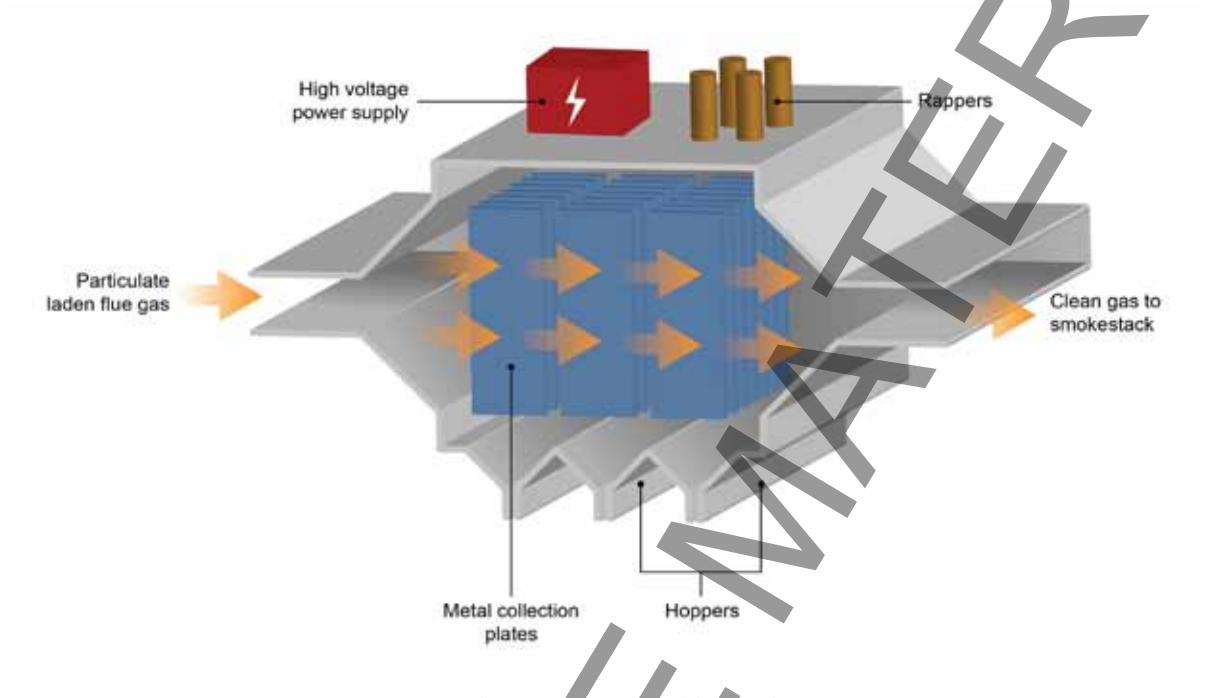
Topic Focus

An ESP would be a very high efficiency collection device, if all the particles could be removed efficiently from the plates. However, the removal of dust from the plates is often accomplished by rapping the top of the plates mechanically, using a hammer or piston. The released dust then drops or slides down the plate into a hopper. During this process, approximately 10% of the dust may re-enter the air stream. Most of this dust is recaptured, but dust released at the outlet of the device will escape into the exhaust air stream.

The dust deposited on the plates is not a solid cake, as in a bag filter plant, but a fragile deposit. Thus, there may be re-entry of the dust by the airflow over the plates. To prevent this, baffles are often included to reduce airflow over the plant surface.

(Continued)

Topic Focus



Electrostatic Precipitator (Plate-Wire)

Another major factor in ESP losses is the resistivity of the dust. Because the particles form a continuous layer on the ESP plates, all the ion current must pass through the layer to reach the ground plates. This current creates an electric field in the layer and it can become large enough to cause local electrical breakdown. When this occurs, new ions of the wrong polarity are injected into the plate-wire gap where they reduce the charge on the particles and may cause sparking. This breakdown condition is called **back corona**.

Types of Electrostatic Precipitators

There are four main types of precipitators:

- **Plate-Wire Precipitators**

  Plate-wire precipitators, as described above, are by far the most common type being used in a wide variety of industrial applications, including coal-fired boilers, cement kilns, solid waste incinerators, paper mill recovery boilers, petroleum refining and catalytic cracking units, sinter plants, basic oxygen furnaces, open hearth furnaces, electric arc furnaces, coke oven batteries and glass furnaces.

- **Flat Plate Precipitators**

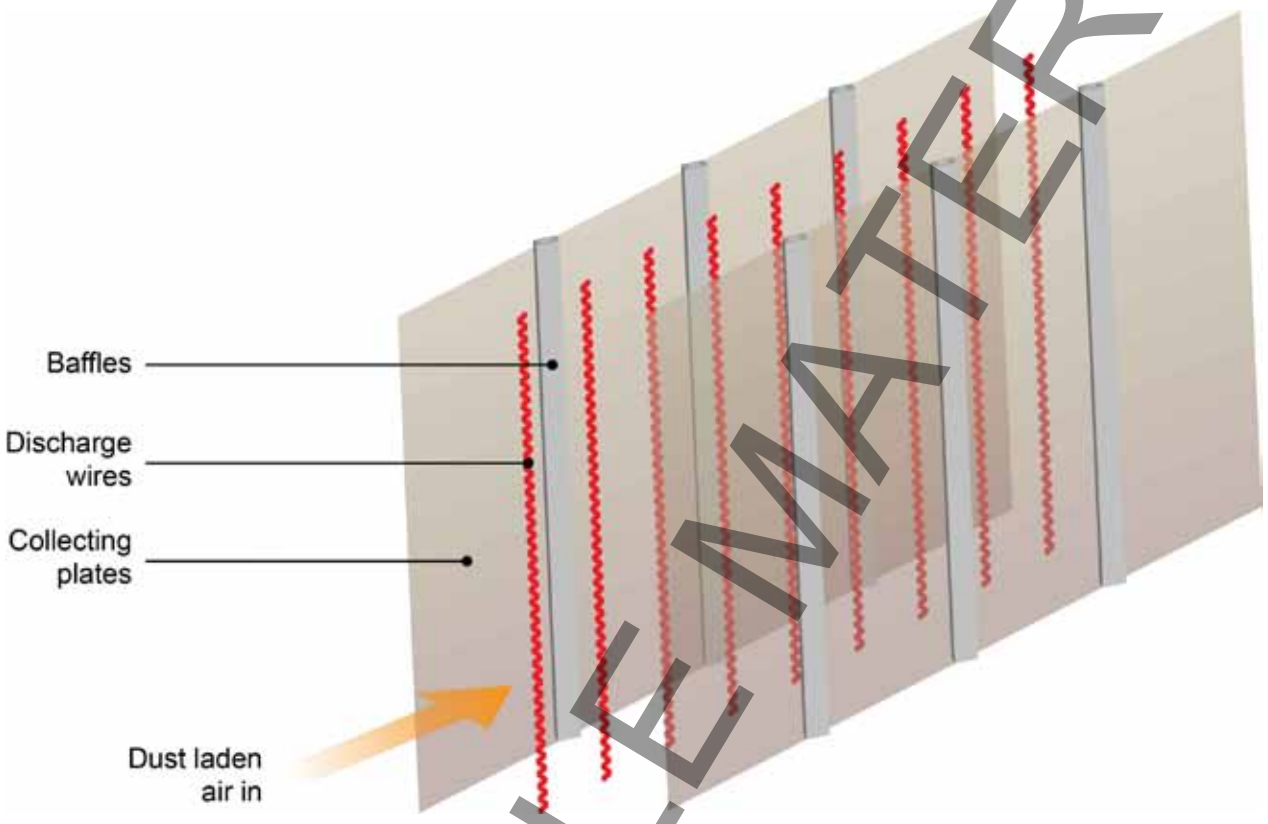
  These are used for smaller applications and utilise a central plate rather than a wire. The flat plates increase the average electric field, which can be utilised to collect the particles and provide an increased surface area for the collection of particles. Since a corona cannot be generated on flat plates, needle-like electrodes are located on the leading and trailing edges of the central plates.

  A flat plate ESP operates with little or no corona current flowing through the collected dust, except directly under the corona needles. This leads to a lower likelihood of back corona and, since there are two oppositely charged collection surfaces, particles of both polarities can be collected. However, because of the lack of current in the collected layer, the layer is less strongly attracted to the collection plates and this leads to high rapping losses.

  Flat plate ESPs have applications for small (less than one micron) particles with high resistivities. These applications are appropriate because electrical dislodging forces are weaker for small particles. A low air velocity is essential to avoid high rapping losses. This type of ESP has been used to collect fly ash.

(Continued)

Topic Focus



Flat Plate Electrostatic Precipitator

- **Tubular Precipitators**

  The early ESPs were tubular with the discharge wire running up the centre of the tube. In order to accommodate higher airflows, the tubes were often arranged in bundles. The tubes may be formed as a circular, square or hexagonal honeycomb and can be tightly sealed to prevent leaks of material. Consequently, while they are most often used in sulphuric acid plants, coke ovens, and iron and steel plants, they are often also employed to recover valuable materials or to control the release of hazardous material.

- **Water-Irrigated Precipitators**

  A water-irrigated precipitator may be of any of the design types discussed above, but with walls washed with water rather than the dry dust rapped from the surface. The water flow may be continuous or intermittent with the sludge collected in a sump below the plates. The use of a water wash system reduces the build-up of dust on the plates and so reduces the chance of back corona. However, it also generates slurry which is more difficult and expensive to dispose of than a dry dust deposit.

Typical Applications

Electrostatic precipitators are often used as the final stages in an air cleaning system. Where there are high dust loadings with large particles, a cyclone is often used as a first stage cleaning device to remove the coarse or large particles from the air stream.

Gas conditioning equipment to improve the ESP performance by changing dust resistivity is occasionally used as part of the original design, but more frequently it is used to upgrade existing ESPs. The equipment injects a chemical into the gas stream ahead of the ESP. Usually the chemical mixes with the particles and alters their resistivity to promote higher migration velocity and thus higher collection efficiency. However, the electrical properties of the gas may change rather than the dust resistivity. For example, cooling the gas will allow a higher voltage to be applied before sparking occurs. Important conditioning chemicals used include SO3, H2SO4, sodium compounds, ammonia and water, but the major conditioning chemical by usage is SO3.

Gas and Vapour Devices

There are several types of gas and vapour control devices utilising a variety of technologies. Some devices are designed to capture high volumes of particular gases and vapours, whereas others are designed to eliminate relatively small volumes of gaseous material which give rise to odours. There is considerable overlap between the technologies used to control large gas emissions and those designed to prevent VOC emissions and malodorous gases and vapours.

The technologies are as follows:

- Absorption devices.
- Adsorption devices.
- Incinerators.
- Coolers and chillers.
- Peat beds.

Absorption Devices

Jargon Buster

Absorption Devices

Remove pollutant gases by bringing them into contact with a solvent liquid (often water) so that the pollutants are absorbed by the liquid and removed from the air stream. A packed column is often used.

Topic Focus

Principle of Absorption Devices

These installations are designed primarily for removing pollutant gases from exhaust air-streams. In most industrial circumstances, the concentration of pollutant gas in the air- stream is low. The principle upon which these devices operate is to bring the molecule of the pollutant gas into contact with a solvent liquid, usually water, so that the pollutant dissolves in the solvent and so is removed from the air stream. The efficiency of the installation depends on the solubility of the pollutant gas in the solvent, the rate at which pollutant gas is dissolved, the contact time between the gas and the solvent and the degree of mixing. When the pollutant gas is distributed throughout the air stream, the pollutant molecules are evenly distributed. Thus, when one molecule of pollutant gas is dissolved in a droplet, either another molecule must move toward the droplet, or the droplet must move toward another molecule for absorption to continue. There must, therefore, be mixing and turbulence designed into the system.

Packed Columns

One of the most common types of absorption device is the packed column. These are usually vertical steel columns containing small elements over which water flows to coat each element with a thin layer of water. In most arrangements, the water enters from the top and trickles down while the polluted air stream enters from the bottom. The elements are designed with complex shapes to present a large surface area to the air- stream. As the air moves up the column, the pollutant gas is absorbed onto the water film which moves down toward the sump at the base of the column. As the air stream moves up the column, the air stream becomes progressively free of the pollutant.

(Continued)

Topic Focus

The upward movement of the air stream against the downward flow of water causes a resistance to the flow of water. Consequently, as more air flows through the column, the resistance to the water will increase and the flow of water will decrease. Eventually, a situation may be reached where the airflow is such that the water flow through the column is less than the rate of water delivered to the top of the column. At this point, the layers of water on the elements will increase and combine, and flooding of the column will occur, preventing the operation of the column. The column must be designed to have a maximum throughput of approximately 70% of flooding velocity.

The efficiency of the column is also dependent on the even distribution of water moving down through the column, so that the maximum surface area of water is presented to the air stream.

The water distributor is designed with spray jets to spray an even distribution of water onto the top of the packing. However, water tends to migrate toward the walls of the column. To reduce this effect, packing supports are incorporated into the column every three or four metres. These are plates which collect the water moving down through the packing and redistribute it evenly. There are many different elements which are used. There are also two basic packing strategies called random packing and stack packing.

- **Random Packing Columns**

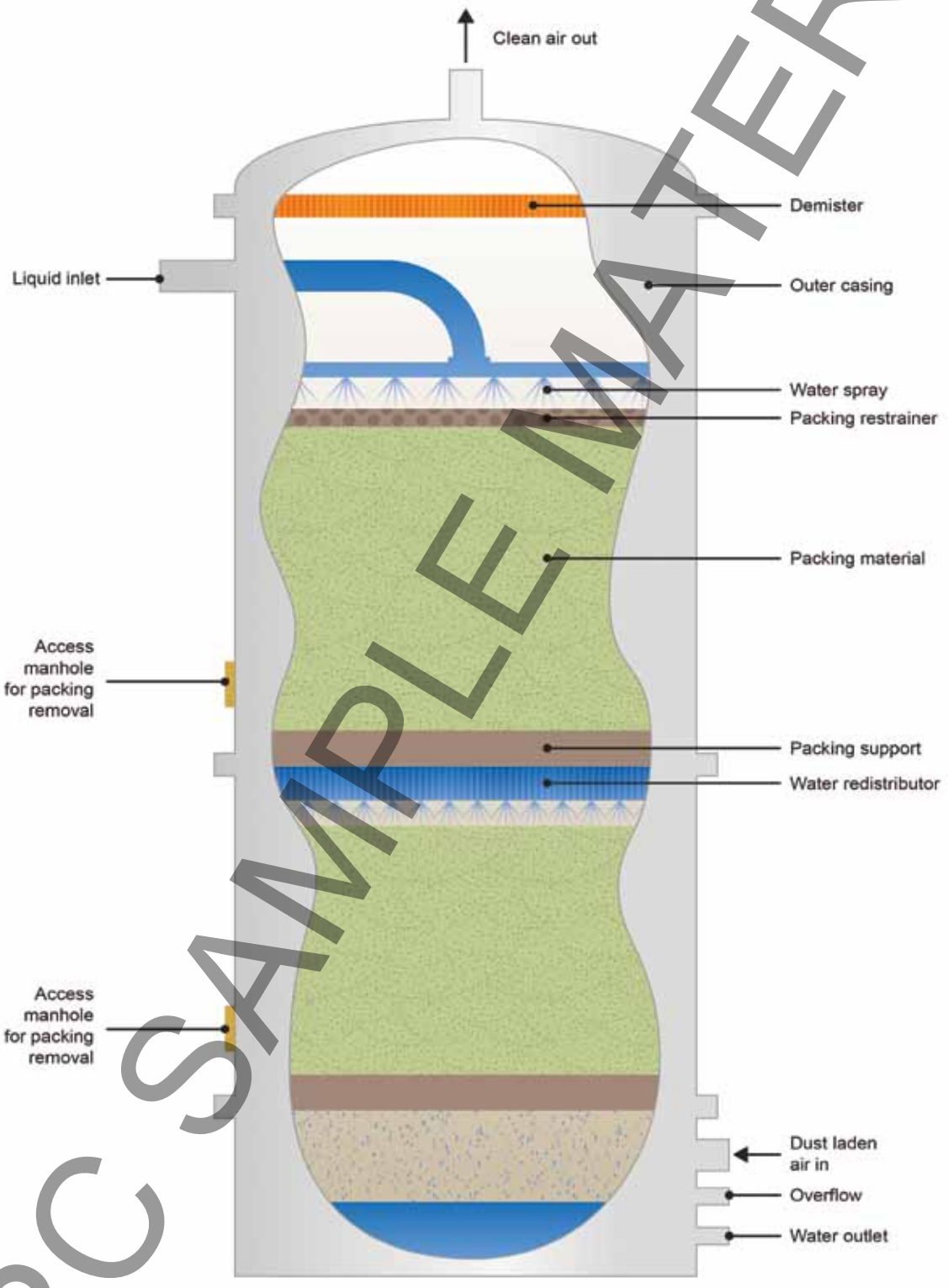
  In random packing columns, the elements are dropped in the column in a random way. To prevent damage to the elements, the column is filled with water and the elements are dropped in and allowed to take up the position in which they settle. After the first two or three weeks' operation, the packing will normally settle further and require to be topped up.

- **Stack Packing Columns**

  The elements in stack packed columns are manually placed in position. This creates vertical channels through which the water film can travel and maintain a more even distribution of water surface. It also leads to a lower pressure drop across the column.

(Continued)

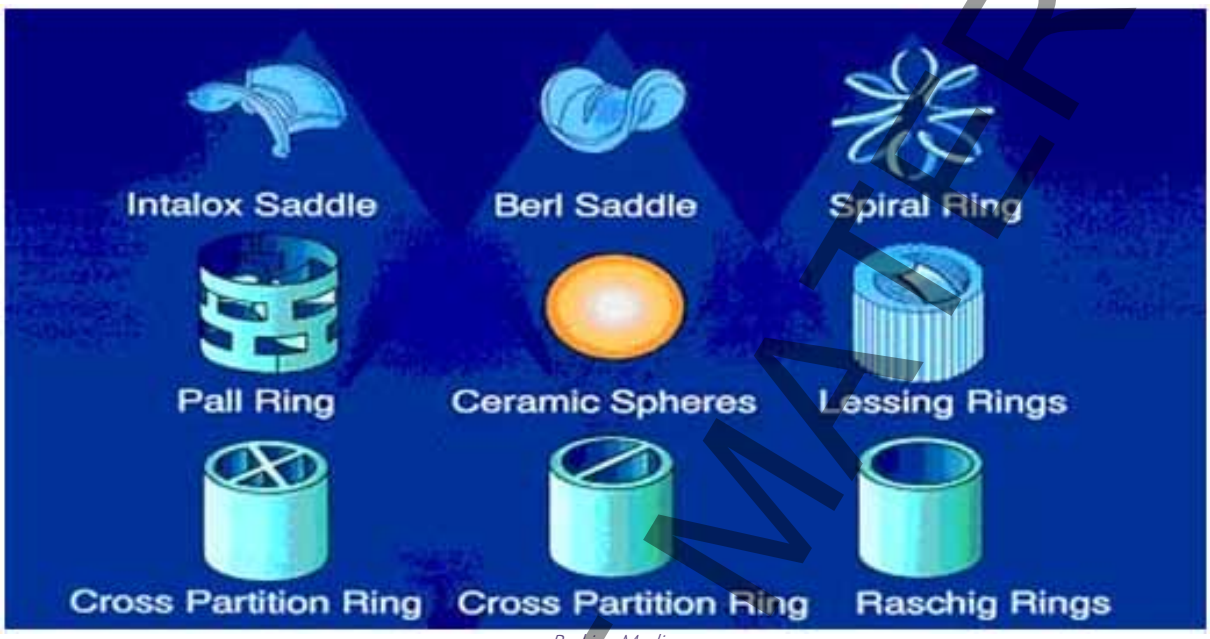
Topic Focus



Counter-Current Random Packed Column

(Continued)

Topic Focus



Packing Media

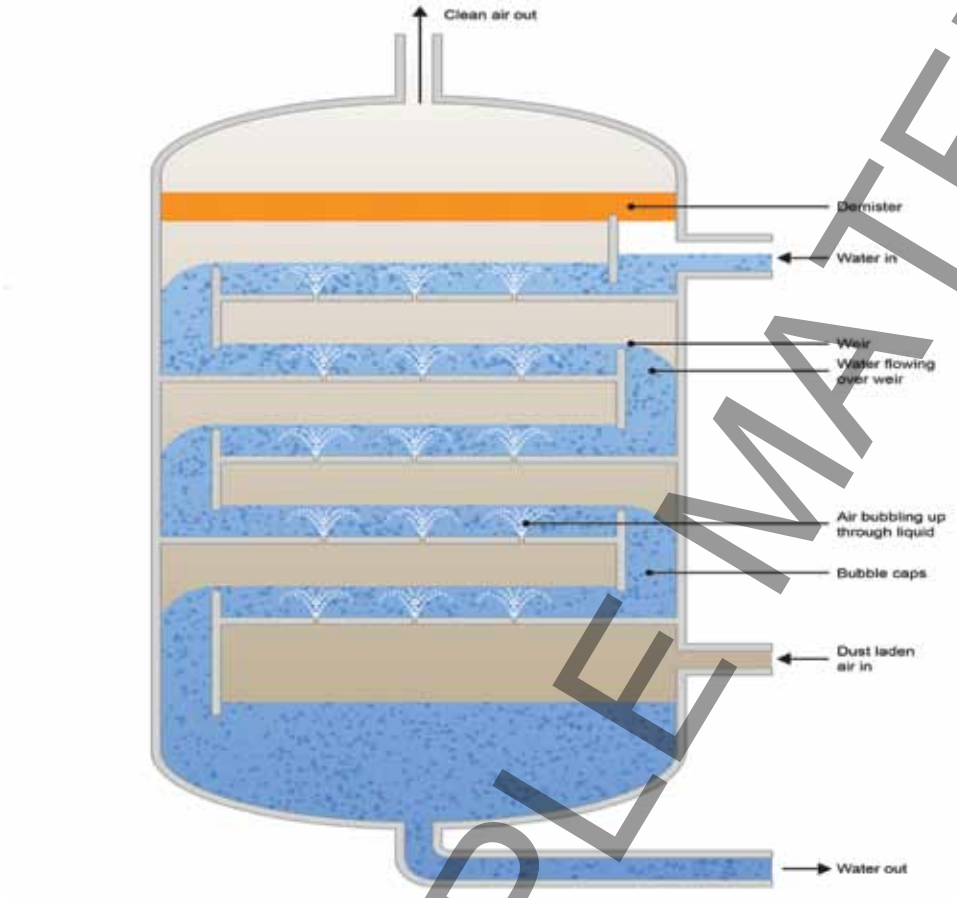
Plate Columns

Another mechanism used to mix pollutant gases in an air stream with a solvent is to bubble the air up through water held on plates. These devices are called plate columns. There are two basic designs, bubble-cap plate columns and sieve air-perforated plate columns. As the air bubbles through the holes in the plates, the pollutant gases are dissolved into the water. In order to extend the contact time with the water and allow mixing of the pollutant gas and the air, these devices have several stages, or plates. The contact between polluted gases and liquid is also increased by creating bubbles or froth. In the bubble plate system, the plates are approximately 500 mm apart, with holes on top of which perforated caps are fixed to generate a frothing action. These are called bubble caps.

The plates in the perforation plate column are closer together, about 300 mm, and the holes between 5 mm and 25 mm in diameter. The liquid resting on the plate flows off over a weir and into a down caster to the plate below. The action of forcing the airflow through the small holes and into the liquid again creates bubbles or a frothing effect which increases the gas liquid surface area. Increasing the depth of liquid through the gas bubbles increases efficiency. However, it also increases the pressure drop, which increases the energy consumption of the device.

(Continued)

Topic Focus



Bubble-Cap Plate Column

Application

These devices each have several features which present advantages in particular situations. The total weight of a plate column is normally less than the equivalent packed column. The pressure drop of the gas through a packed column is lower than that through a plate column. The plate column can function on lower water-feed rates as the water stands on the plates. However, the packed columns must have a minimum water-feed rate to maintain a water film on all of the elements. The arrangement of water flowing off the plates also means that a plate column can accommodate higher water-feed rates at levels which would normally flood a packed column.

In addition, the plate column design is less likely to have the water distribution problems presented by a random packed column. The contact between the gas and the water is better. If the air stream contains particulates, they will deposit on the internal surfaces of the columns. With packed columns they may plug or clog the elements. While back flushing may remove some sediments, gross contamination is difficult to clear. In plate columns, the plates may be cleaned manually provided access manholes have been incorporated into the design. Where the absorption processes involve heating or cooling of the liquid, this can be achieved by incorporating heat exchange systems on the plates of plate columns. However, heat exchange elements are more difficult to incorporate into a stack column design. In addition, temperature changes are more likely to damage a packed column than a plate column.

Where the air stream contains highly corrosive pollutants, a packed column is simpler and cheaper to construct, the ceramic elements are less prone to corrosion and easier to replace. Packed columns are also preferred for liquids with high foaming characteristics.

Jargon Buster

Adsorption

A process involving the retention of a gas or vapour molecule on the surface of a particle or droplet.

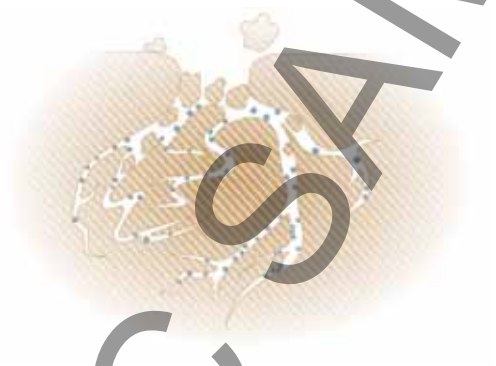
The phenomenon is essentially a surface reaction as opposed to absorption, which involves the complete encapsulation of a molecule which is then dissolved in a liquid droplet.

Topic Focus

Principles of Adsorption

There are two adsorption mechanisms: a physical action involving intermolecular **Van der Waals** forces and a chemical action involving activated adsorption.

The physical adsorption utilises the surface forces present on the surfaces of most solids to attract gas molecules. When these surface forces are stronger than the intermolecular forces between the pollutant gas molecules and the air molecules, the pollutant gas molecules will adhere to the surface of the solid. Some solids with many pores and crevices present extremely large surface areas to gases and so are the most appropriate adsorbents. These include activated carbon, activated alumina, silica gel and molecular sieves - see following illustration.



Adsorption on a Solid with Many Pores

(Continued)

Topic Focus

Adsorbents

Several factors must be considered in selecting an adsorbent. A high relative surface area is important to maintain a large contact area for adsorption, while maintaining the maximum possible space between the adsorbent granules for maximum airflow rates. Relative affinity for polar and non-polar compounds varies between adsorbent media with activated charcoal, which is non-polar, having an affinity for organic compounds to the exclusion of polar gases, including water vapour. Silica gel and alumina are polar and have increasing affinity for higher polarity gases. Clearly, the adsorbents must not be chemically reactive with the gases to be retained, unless chemical adsorption is desired.

- **Activated Carbon**

  Activated carbon is charcoal which has been heated in the absence of air. At one time wood was heated to produce charcoal, but later developments include the use of coal, coconut shells, peat and other substances.

  After heating, the carbon is activated to remove the volatile components. In the case of coal, high temperature steam is used. However, zinc chloride, magnesium chloride, calcium chloride and phosphoric acid have also been used as activating agents.

- **Activated Alumina**

  Activated alumina and hydrated aluminium oxide is produced by special heat treatment of aluminium ore or bauxite. Activated alumina is mainly used for drying gases under pressure. It selectively adsorbs polar and higher molecular weight compounds and, like all polar adsorbents, has an affinity for water.

- **Silica Gel**

  Silica gel is an amorphous form of silica, derived from the interaction of sodium silicate and sulphuric acid. As with alumina, the polarity of the adsorbed compound determines the binding strength, hence compounds of high polarity will displace compounds of lesser polarity.

(Continued)

Topic Focus

- **Molecular Sieves**

  A carbon molecular sieve sorbent is the carbon skeletal framework remaining after pyrolysis of the synthetic polymeric or petroleum pitch precursors. The result is a spherical macroporous structure. The choice of starting polymer or pitch dictates the physical characteristics of the sieve, such as particle size, shape and pore structure. Carbon molecular sieves are most commonly used to collect non-polar organic compounds.

Operational Mechanisms

Adsorption systems are designed either to remove pollutant gases and vapours from air streams, to prevent the emission of these pollutants to atmosphere, or to collect those vapours to return them to the process. In either case, there are four phases in the process:

- Contact between the polluted air stream and the adsorbent under conditions which allow adsorption of the pollutant.
- Removal of the cleaned air stream from the adsorbent.
- Regeneration of the adsorbent to recover the pollutants and reuse the adsorbent.
- Reuse or disposal of the pollutant.

The adsorbent most often used is activated carbon.

- **Static-Bed System**

  In simple systems, granulated activated carbon is held in a vertical column and solvent-laden air is passed down through the column. The solvent is progressively adsorbed on the carbon and the cleaned air passes out of the column to the atmosphere. After a predetermined period, set to ensure that the carbon is not completely saturated with solvent, the airflow through the column is shut off and the carbon is regenerated. This may be achieved by lowering the gas pressure on the carbon to cause desorption of the solvent, or by increasing the temperature. Of the two, thermal desorption is the most widely-used method. In many cases, hot dry steam is passed through the column in the opposite direction to the previous airflow. Thus, desorption occurs first at the end of the column with least adsorption and the released solvent is passed over the areas of most adsorption, which reduces the likelihood of re-adsorption during the regeneration cycle.

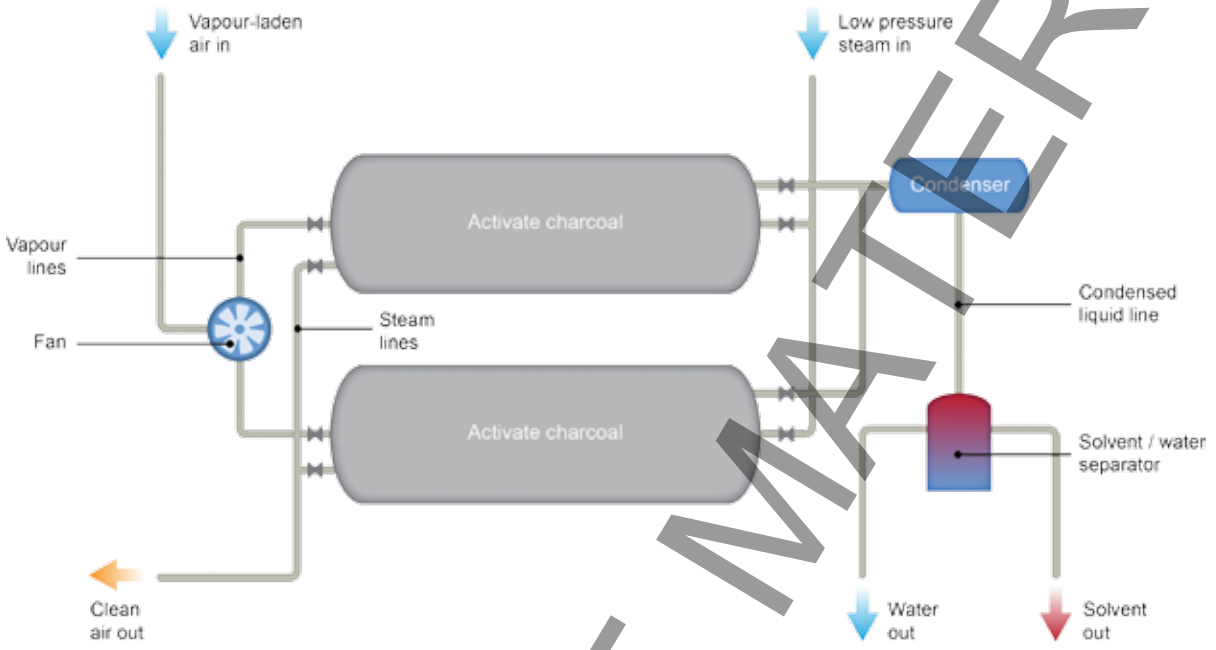
  Steam consumption per litre of solvent recovered varies with strip time and with the particular solvent adsorbed. As the steam strip time is extended, more steam per litre of solvent recovered is required and a point is reached at which expended steam cost exceeds the solvent recovery benefits. Hence, it is more economical to operate the strip cycle to recover only part of the adsorbed solvent, leaving a **heel** of solvent within the bed. The resultant steam solvent mixture passes into a condenser and then into a single gravity separator. In cases where the recovered solvent is miscible in water, fractional distillation may be necessary.

  After the solvent is steam-stripped, the carbon beds are hot and saturated with water. The beds are normally opened and air-dried, allowing the water to evaporate to atmosphere. Where the polluted air stream contains more than one pollutant, the lighter molecular weight solvents will be adsorbed first, but may then be displaced by higher molecular weight solvents. Thus different percentages of chemical species may be present at different parts of the column.

  Although the time taken for regeneration of the carbon and recovery of the solvent or gas is usually much less than the period when air cleaning or adsorption is taking place, in some cases the industrial process is such that it cannot be stopped. Multiple systems are therefore common where two or more columns are used. This allows some columns to be in the adsorption part of the cycle, while others are in the regeneration part of the cycle, as in the following illustration.

(Continued)

Topic Focus



Simple Activated Carbon Solvent Recovery System

- **Rotary Bed Systems**

  In order to provide more efficient utilisation of the carbon bed, continuous rotary bed systems have been developed. These consist of a rotating drum containing activated carbon. The drum has a hollow central core along the axis of rotation and the space between the inner and outer walls of the drum is divided into radial sections. Vapour-laden air enters the drum in one section, at one end of the drum. It then travels along the length of the section and the vapour is adsorbed in the carbon. The cleaned air leaves through the central core from the far end of the drum.

  Once that section is saturated with vapour, the drum rotates to the next section. At another vapour-saturated section of the drum, steam is pumped up a pipe in the central core, to enter the section at the far end of the drum. The steam passes through the vapour-saturated carbon to exit as a steam and solvent mixture at the front end of the drum. Thus, there is always adsorption and regeneration is progressive within the drum.

Process Controls

Before a carbon bed adsorption system is considered or designed, careful consideration should be given to modifying existing processes and procedures to reduce the quantities of VOCs in the exhaust air streams:

- Consider whether the use of the solvent is necessary or whether a water-based system or detergent degreasing system could be used.
- Consider the substitution of the solvent for a lower volatility solvent, or a less toxic solvent, or one with a lower environmental impact.
- Minimise the ventilation rates and volumes in the process to reduce evaporation rates.
- Establish working procedures for increasing free board zones, increasing transit times, avoiding splashing and solvent carry over. Train workers to comply with the procedures. Maintain a cold air condensation zone above tanks with either chilled water coils or direct expansion refrigeration. Do not vigorously boil the sump or agitate the solvent with compressed air.
- Provide well-designed local exhaust ventilation systems with hoods and tank enclosures.

(Continued)

Topic Focus

- Provide a parts-drying chamber within this process if possible, with internal recycling.
- Cover tanks when not in use.
- Perform solvent spraying in a vapour zone, preferably with a gentle flush rather than an atomised spray.
- Do not use compressed air drying techniques.
- Do not direct ventilation fans onto solvent baths, containers or uncontrolled drying areas.

Maintenance and Operation

The surface area of carbon granules must be protected against dirt and other particulates entering the bed. It is common to have a fabric filter or bag filter as a primary air- cleaning device located upstream of the carbon bed. Some solvents entering the adsorption bed will degenerate or polymerise. Such substances must not be allowed to enter the bed as they will progressively reduce the working surface area of the carbon.

Many local exhaust ventilation systems have been introduced to satisfy occupational hygiene requirements. Poor hood and enclosure design and leaking ducts have often been compensated for by higher ventilation velocities and volumes, which are not consistent with efficient final air-cleaning characteristics. Careful consideration should be given to improved design characteristics which deliver lower ventilation velocities and volumes. This will lead to lower space heating energy requirements, more efficient final air cleaning, lower atmospheric emissions and lower fan and system maintenance costs.

Working bed capacities vary considerably, depending on the particular solvent being reclaimed and its regeneration characteristics. To maximise the performance of the carbon bed, the duration of the adsorption cycle should be extended to just below the breakthrough points of the bed. Breakthrough can be determined using organic vapour analysers simultaneously on the inlet and outlet streams of the adsorber bed. Breakthrough history can be determined on the particular process being controlled and regeneration can be initiated when appropriate.

Incinerators

There are three types of incineration devices generally referred to: flare stacks, thermal incinerators and catalytic incinerators.

Topic Focus

Incineration Devices

- **Flare Stacks**

  These are usually employed in the petrochemical industry and are seen as tall stacks with visible flames on top. When operating efficiently, the flame should be blue or colourless. Yellow flames indicate incomplete combustion. The oxidation reaction occurs at the burner at the top of the stack and is almost instantaneous.

- **Thermal Incinerators**

  These devices are used primarily for oxidising organic compounds to prevent their release into the atmosphere. For simple organic compounds containing only carbon and hydrogen, the products of combustion are carbon dioxide and water. However, where more complex compounds are involved containing sulphur or halogens, the incineration process may produce sulphur dioxide, hydrochloric acid, hydrofluoric acid or phosgene. These pollutants may have to be removed using a scrubber, before they are released to the atmosphere.

  Combustion occurs when the waste gas is raised to a sufficiently high temperature for the molecules to react with oxygen. For this to happen the conditions must be established in terms of temperature and time. The higher the temperature, the more rapid the reaction rate and so the shorter the time involved.

  Most incinerators comprise a chamber containing a burner unit. The burner unit, fuelled usually with natural gas, raises the temperature of the waste gas to the point where it reacts with the oxygen in the air. The chamber size and waste gas flow rate is designed to achieve a given residence time of the waste gas in the chamber. Since the cost of the fuel gas is a critical parameter in the economics of incinerator operations, a balance between operating temperature and residence time is reached.

  Most hazardous waste gas incinerators operate at temperatures of between 950°C and 1,200°C, although the thermal destruction of most organic compounds occurs at around 600°C. Residence times are of the order of one or two seconds. One of the major considerations in operating waste gas incinerators is complete incineration of the waste gas stream. Operating at higher temperatures assists this, but thorough mixing of the incoming waste gases with the hot gas around the burner zone is critical. For this reason, the chamber is designed to induce turbulence in the burner zone. Some designers say that the most important design features are Temperature, Time and Turbulence, or the three Ts.

- **Catalytic Incinerators**

  Since the cost of fuel gases used to maintain high temperatures in incinerator operation is so high, devices have been developed to achieve oxidation at lower temperatures. Catalysts such as finely divided platinum in the form of surface-coated pellets, honeycombs and meshes are in common use. However, there are other catalytic surface coatings such as oxides of copper, chromium, vanadium, nickel and cobalt.

  The use of a catalyst allows the oxidation reaction to take place at much lower temperatures, around 400°C. While this allows economies through fuel gas costs and less substantial structures due to the lower pressure and temperature demands, there are penalties in the initial cost of the catalyst. In addition to this, the surface of the catalyst can be poisoned by halogens and particulates containing metals such as zinc, arsenic, lead and mercury. This requires the catalyst surface to be regenerated periodically using steam. The necessity of keeping the catalyst surface clean also means that particulates may have to be removed from the polluted air stream before entering the catalytic incinerator.

Both thermal and catalytic incinerators can achieve destruction efficiencies in excess of 95%. They are widely used for the control of VOCs and where odour control is important.

Coolers and Chillers

VOC vapours condense when their temperature is reduced or pressure increased. In most air pollution control applications it is more practical to reduce the temperature of the vapour. There are two methods which are used to reduce vapour temperature. One involves spraying cold water into the gas stream and cooling by direct contact. Devices which use this principle are called **contact coolers**, or **contact condensers**. Devices which present the vapour with a cold surface are called **surface cooler**s.

Topic Focus

Contact and Surface Coolers

- **Contact Coolers**

  The most simple form of contact cooler is a chamber fitted with sprays. The vapour enters the chamber and is sprayed with chilled water. Another variant involves a chamber containing trays onto which chilled water pours from tray to tray down the chamber. The vapour rises through the chamber condensing as it makes contact with the chilled water.

  In contact coolers, there is clearly intimate contact between the vapour being condensed and the cooling medium. Thus, the cooling medium becomes contaminated and is seldom suitable for reuse. This may in fact present significant waste disposal problems.

- **Surface Coolers**

  In surface cooling or surface condensing devices, the cooling water is circulated within pipes similar to a heat exchanger. The vapour-polluted air stream flows over the pipes and the vapour condenses on the pipes, leaving the air stream.

Neither contact nor surface coolers are high-efficiency devices and are generally used for pre-treatment to reduce the total vapour volume being passed into more efficient devices, such as carbon adsorbers or incinerators.

Peat Filter Beds

These were being developed in the mid-1980s as an inexpensive technology to remove from air streams, simple organic compounds which were not toxic but did present odour problems. The beds were typically large steel or concrete containers containing natural peat. The peat was treated with micro-organisms and supplied with water and nutrients to encourage their growth. High-volume, but low-velocity air streams could then be treated by passing them through the peat beds to remove the organics which generated the odours.

The General Philosophy and Application of Emission Standards and Air Quality Standards Relevant to Air Quality Management

The UK's policies for achieving improvements in air quality are included in the **Environment Act 1995**. The Act provides a legal framework for implementation of the Air Quality Strategy and requires local authorities to undertake a review of air quality to determine whether air quality standards and objectives are being met. If an area does not meet such standards then the local authority is required to designate an **air quality management area (AQMA)**.

Air quality management is generally achieved by:

- Emissions monitoring.
- Air quality monitoring.
- Standards and guidelines.
- Air quality modelling.
- Public information.
- Alert procedures.
- Land use planning.
- Transport integration.

Local authorities have the main responsibility for this, with the co-operation of bodies such as the Environment Agency.

The most significant air pollutants are monitored at various urban and rural settings within the UK. Pollutants monitored include nitrogen oxides, particulate matter, sulphur dioxide, hydrocarbons (e.g. benzene and toluene), carbon monoxide, lead and ozone. Guidelines and standards by the UK or by international organisations provide a benchmark to which UK levels of air pollutants can be compared and assessed. At present there are six sets of standards and guidelines that are mainly referred to in the UK and Europe. These include:

- UK National Air Quality objectives.
- Expert Panel on Air Quality Standards (EPAQS) recommendations.

- UK air quality bands.
- European Community Directives Limit and Guide Values.
- World Health Organisation guidelines.
- United Nations Economic Commission for Europe critical levels.

Information on air quality in regions and cities in the UK can be found at the following website: http://uk-air.defra.gov.uk/.

Revision Questions

7. Describe two devices which can be used for the capture of particulates; sketch an outline of each device.
8. Describe how an emission of a solvent could be captured for reuse.

(Suggested Answers are at the end of this book.)

Summary

Key topics covered in this element:

- Air pollutants may be classified as fumes, smoke, dust and grit, vapours, mists and droplets.
- Legal standards for smoke emissions class smoke as dark or black by reference to a shade on the British Standard Ringelmann Chart.
- Installations are required to control emissions to air under the Environmental Permitting regime.
- The **Clean Air Act** prohibits emission of dark smoke from chimneys.
- Ozone-depleting substances are controlled through the **Environmental Protection (Controls on Ozone-Depleting Substances) Regulations 2002**.
- There are various standards to ensure the quality of air emissions monitoring.
- Measurement devices for air pollutants include particle charge transfer probe, transmissometers (opacity monitors), beta radiation attenuation, CEGB probe and deposition gauges.
- Methods of sample analysis include gravimetric analysis, microscopic analysis, gas liquid chromatography, mass spectrometry, atomic absorption spectrophotometry and chemiluminescence.
- Plume dispersion is quite complicated with many variables, such as the weather conditions, wind speed, temperature, ground conditions and the nature of the pollutant.
- The range of particle arrestment devices includes cyclones and other inertial separators, fabric filters, wet scrubbers and electrostatic precipitators.
- There are several types of gas and vapour control devices including absorption devices, adsorption devices, incinerators, coolers and chillers, and peat beds.

Question

(a) **Describe** the main environmental effects that may be caused by emissions of oxides of nitrogen (NOx) into the atmosphere. (14)

(b) **Describe TWO** methods that could be used to quantify NOx emissions from chimneys. (6)

Approaching the Question

For part (a) a description of the main effects of nitrogen oxides being released to atmosphere is required. Nitrogen oxides are common pollutants that have numerous effects on a wide range of receptors. Part (b) requires a description of two techniques that may be used to obtain a quantitative reading of nitrogen oxide emissions. Diagrams may be used to help describe the two techniques chosen.

Have a go at the question as you would in the exam, writing in full sentences to the necessary detail as indicated by the action word ('Describe' in this case). Ensure that you write a plan, etc. This time try to stick to the 36 minutes you would have to answer this question in the exam.

Remember you can contact your tutor if you have any queries.

Suggested Answer Outline

Now you have completed your answer, compare it to the following suggested answer.

Plan

(a) Ground level, respiratory problems, photochemical smogs, odour, acid deposition (wet and dry), effects (damage to vegetation, release of metals, damage to monuments and buildings, aquatic system).

(b) Description of any two of the following: chemiluminescence; infrared spectrometry; colorimetry; gas chromatography.

Answer

(a) The main environmental effects of emissions of nitrogen oxides into the air include direct damage to human health if air quality standards are exceeded. NOx emitted at a low level through car exhausts, for example, can be breathed in by people and combine with water in mucous membranes of the respiratory system (e.g. lungs and throat) causing acid formation. This will result in irritation of the lungs. Emissions of NOX at a low level are also implicated in the formation of low level ozone, which again is another respiratory irritant. NOx and other substances are broken down with the aid of sunlight and form low level ozone (photochemical smog) which is inhaled by people.

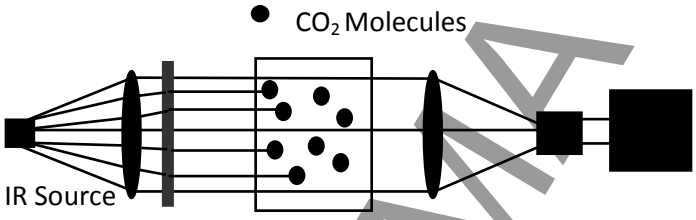
Emissions of oxides of nitrogen are also odorous in large quantities, causing a nuisance problem to those who may live or work close to the source. Emissions of NOx from combustion and other activities can also be involved in the process of acid deposition. Acid deposition can be of two types - wet and dry. Wet deposition occurs when NOx is released to air in the atmosphere and combines with water in clouds to form acids. Such clouds can be blown long distances and the lowered pH of the precipitation can cause damage to vegetation both directly (corrosive action on the plants' structures) and by removing essential minerals from the soil, leaving the plant open to disease and attack by parasites. Acid rain may also release harmful heavy metals such as aluminium from certain areas into groundwater and surface water used for drinking. Such metals can have significant effects on people's health. Additionally, acid rain can cause damage to buildings and monuments, particularly those constructed from more vulnerable types of building materials such as limestone and metals. Acid rain may also decrease the pH of rivers and lakes and as such reduce the biodiversity of such habitats, as organisms that can tolerate the lowered pH will thrive whereas those that cannot will disappear. Fish, plants and macroinvertebrates could also be affected depending on their tolerance to the increased acidity of the water. Acid deposition can also occur from dry deposition. This is when acidic particles or gas are removed from the air through gravitational forces. Depending on where the particles land, this can have similar effects

to acid rain such as release of heavy metals from soil, damage to buildings and monuments, etc.

(b) Two of the following:

Chemiluminescence occurs when a chemical reaction produces energy in the form of light. It can be used for the measurement of various substances including nitrogen compounds. The operation of direct-reading instruments for the measurement of NO/NO_2 is based on chemiluminescence. When using this technique for the measurement of gases, it is usually referred to as 'gas phase chemiluminescence'.

Continuous monitoring of nitrogen compounds and others is usually undertaken by infrared absorption. Molecules containing two or more dissimilar atoms display unique absorption characteristics in the infrared region, the intensity of the absorption being equal to the concentration.



Infrared Spectrometry

Colorimetric techniques can be used. This works by reacting the substance to be sampled with an organic dye and a quantified result is obtained by measuring optical absorption in the UV or visible region.

Gas chromatography methods may be used. This works by the gas to be analysed being drawn through a column packed with a porous polymer mixture or a molecular sieve, which absorbs the gases. An inert carrier gas, such as helium, is then passed through the column. Each gas has a characteristic retention time.

IEMA Introduction to Environmental Management Systems

Element 1: Overview of the Background to EMAS and the ISO 14000 Series

RRC TRAINING

Contents

Learning Outcomes

After completion of this section you will have an appreciation of:

- The background on the development of EMAS and the ISO 14000 series.
- The benefits of implementing an EMS.
- The aims & objectives of each EMS.
- The key differences.
- The administration structures and agencies relevant to each EMS.
- The latest developments with the ISO 14000 series and EMAS.
- How to incorporate biodiversity into an EMS.

Hints and Tips

Before you begin, please make sure you have read your 'Welcome to your Course' and read, signed and returned your Learning Agreement.

Background on the Development of EMAS and the ISO 14000 Series

An environmental management system (EMS) provides a structured framework for making continual improvements in environmental performance. EMSs are voluntary and provide a system to manage environmental impacts associated with an organisation. This organisation can gain external certification of their EMS to a recognised standard, such as ISO 14001, if it fulfils the relevant criteria.

Jargon Buster

Environmental Management System (EMS)

An EMS is the name given to a structured management system put in place to improve the environmental performance of an organisation.

Development of EMS Standards

The first nationally recognised environmental management system dates back to 1992 when the British Standards Institution (BSI) first published BS 7750. Following the publication of BS 7750 a number of new national standards were developed in other countries. The standards did not all follow the same requirements, some even contradicting standards from other countries. In order to assist international trade, it was decided that an international standard would be developed.

The ISO 14001 series of standards emerged primarily as a result of the Uruguay round of the GATT negotiations and the Rio Summit on the Environment held in 1992. This led to the creation of the **Strategic Advisory Group on the Environment** (**SAGE**). SAGE determined the requirement for international environmental management standards and recommended that ISO continue with their development. In 1996 the first version of EMS standard ISO 14001:1996 was published which replaced many of the national standards that had been developed around the world, including BS 7750. The latest version of the ISO 14001 standard was published in 2004, with minor changes to the initial version of the standard being made.

In addition to the international EMS standards, regional EMS legislation was developed. The **Eco-Management and Audit Scheme** (**EMAS**) was adopted by the European Union (EU) in 1993. EMAS is a European regulation that enables industries to voluntarily implement formal environmental management systems. As we will see later, there are various differences between ISO14001 and EMAS, but these mainly stem from the level of detail involved. In 2001 EMAS II was born and included numerous updates to the original EMAS regulation, such as opening up the regulation to all public and private sector organisations. In January 2010 the second revision of EMAS came into force and made several improvements aimed at strengthening rules on reporting, raising the attractiveness for participating companies and increasing user friendliness of the scheme.

The Benefits of Implementing an EMS

There are many benefits that can result from implementing an EMS, these include:

- **Increased profits**

  Good environmental management can result in increased profits. Cutting waste and energy costs, for example, can result in large cost savings. Environmental monitoring may also identify production inefficiencies, and result in better process control, therefore conserving resources and increasing profitability. Minimising waste and reducing water and energy use all help to conserve the baseline and keep the cost of production or services delivery down. Lower environmental taxes may also be payable, e.g. landfill tax.

- **Workforce**

  Effective management of a prescriptive environmental system will also help improve both commitment and morale of the workforce, improve health and safety and encourage the recruitment and retention of motivated employees.

- **Customers**

  Customers may pressure an organisation to achieve a recognised EMS standard, such as ISO 14001. This can help in gaining approved supplier status and lead to preferential treatment over non-certified organisations (competitive advantage). It may be even more significant if an organisation sells its products or services internationally.

- **Shareholders**

  Shareholders may be concerned about environmental practices of an organisation leading to bad publicity and so lowering share prices. Conversely, publicising good environmental practices could be used to increase the value of shares in a company.

- **Local community**

  The local community may have raised concerns about the environmental practices of an organisation. Implementing an EMS that is externally certified to a recognised standard means that an organisation can demonstrate commitment to good environmental practices locally.

- **Insurers and lenders**

  An organisation that has an externally certified EMS can be seen to present less risk and be better managed (e.g. good practice contributing to lower

costs) and therefore receive better rates.

- **Regulators**

  Regulators such as the UK Environment Agency may be more lenient to those businesses that have a recognised system of environmental management in place. They may also offer reduced rates for environmental permits to companies which achieve this standard.

The Aims & Objectives of Each EMS

ISO 14001

It is useful to consider the overall aims and objectives of EMSs before we look in detail at their requirements. In **ISO 14001:2004** the stated overall aim of the standard is:

> *"...to support environmental protection and prevention of pollution in balance with socioeconomic needs. It should be noted that many of the requirements can be addressed concurrently or revisited at any time."*

Although this definition is quite general, it gives some idea of what to expect from an ISO 14001 EMS. Such an EMS aims to protect the environment and prevent pollution from occurring, but this must be done in a balance with the needs of society and the economy – it alludes to a sustainable approach.

EMAS

In EMAS it is stated that:

> *"The objective of EMAS, as an important instrument of the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan, is to promote continuous improvements in the environmental performance of organisations by the establishment and implementation of environmental management systems by organisations, the systematic, objective and periodic evaluation of the performance of such systems, the provision of information on environmental performance, an open dialogue with the public and other interested parties and the active involvement of employees in organisations and appropriate training."*

This objective is much more detailed but by picking out some of the key phrases, and considering them in more detail, it can tell us what a good EMAS system should achieve:

- **Continuous improvement** - an integral part of the EMAS and ISO 14001 standards, it is a requirement to make changes on a regular basis over time, rather than just make a few improvements and then stop.
- **Environmental management system** - this is defined further as structures of the organisation, planning, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy and managing the environmental aspects. It is the overall system for controlling or reducing environmental impacts.
- **Evaluation of the system** - some kind of check on the system is required, to see if it has been implemented correctly and is effective.

The Key Differences

There are many similarities between ISO 14001 and EMAS. In fact, EMAS requires that an EMS meets the requirements ISO 14001 and many organisations progress from ISO 14001 to EMAS (as it has extra requirements) and maintain certification/registration to both. As with ISO 14001, the EMAS aims to provide the organisation with a structured management framework for identifying environmental impacts and evaluating and improving environmental performance.

There are however a number of differences between the two standards, these include:

EMAS	ISO 14001
EMAS is a European standard.	ISO 14001 is an international standard
It is mandatory that an initial environmental review is completed.	An initial environmental review is recommended (but not mandatory).
A publicly available, environmental statement is provided and validated by an independent body to ensure that it accurately states the environmental performance of the organisation.	Only the environmental policy must be made publicly available.
An open dialogue must be established between the organisation and the public.	An organisation must respond to communications from external interested parties.
Organisations must demonstrate that they comply with environmental law. Breaches of law may result in EMAS registration being withdrawn.	There is only a commitment to comply with applicable legal requirements.
The audit interval is no longer than 3 years, during which all areas should be verified at least once.	No explicit audit cycle is specified.

The Administration Structures and Agencies Relevant to Each EMS

ISO 14001 Administration Structures and Agencies

For the ISO 14001 standard the following administration structures and agencies are important:

- **International Organisation for Standardisation** (**ISO**) - is responsible for the development of the ISO 14000 series of international environmental management standards.
- **Certification bodies** - external bodies which certify an organisation to the ISO 14001 system by undertaking audits of the organisation's EMS against the requirements of the ISO 14001 standard.
- **Accreditation bodies** - the accreditation body for the UK is UKAS. UKAS provide an accreditation service for certification bodies ensuring that they provide a high quality certification service.

EMAS Administration Structures and Agencies

A number of organisations are responsible for implementing and promoting the EMAS Scheme. The European Commission develops, supervises and promotes the scheme across Europe, in addition to setting up the EMAS helpdesk to respond to requests from companies and the public. Member states are responsible for the creation of national registration and certification schemes, and competent bodies, verifiers and accreditation bodies play the key role.

- **Competent bodies** - issue registration numbers (for organisations that provide a validated environmental statement), collect registration fees, refuse, suspend and delete organisations from the EMAS register and respond to enquiries regarding organisations on the member states' own EMAS register. In the UK, the Institute of Environmental Management and Assessment (IEMA) is the competent body.
- **Verifiers** - ensure that organisations wanting to gain registration are in compliance with the requirements of EMAS. This includes ensuring the organisation has a compliant EMS and that the information and data in the environmental statement is reliable, credible and correct. Accredited EMAS verifiers can undertake verification activities in any members state. There are numerous verifiers in the UK, including the British Standards Institute (BSI) and Lloyds register of Quality Assurance (LRQA).
- **Accreditation bodies** - are designated by individual member states and responsible for the accreditation and supervision of environmental verifiers (as required by the EMAS regulation). They establish and update a list of national verifiers and the scope of accreditations. The UK designated accreditation body is UKAS.

The Latest Developments with the ISO 14000 Series and EMAS

The last revision of the EMAS regulation was in November 2009 and the requirements came into force in January 2010. The new regulation is known as **Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS)**. The standard was changed to increase participation in EMAS.

The last revision of ISO 14001 took place in 2004, following the initial release of the standard in 1996. Relatively minor changes to the original standard were made, including:

- Greater level of alignment with ISO 9001:2000.
- Specific clause to evaluate legal and other compliance.
- Fewer documented procedures are required.

ISO 14005 is also being developed which will cover the phased implementation of environmental management systems. This standard covers an approach where an organisation can gain credit for implementing a smaller EMS than required by ISO 14001, but build a system that is compatible with ISO 14001 over time.

ISO 14001 is the key standard in the ISO 14000 series other standards in the series include:

Standard	Title
ISO 14004:2004	Environmental Management Systems – General Guidelines on Principles, Systems and Support Techniques
ISO 14015:2001	Environmental Management – Environmental Assessment of Sites and Organizations (EASO)
ISO 14020:2000	Environmental Labels and Declarations – General Principles
ISO 14021:1999	Environmental Labels and Declarations – Self-Declared Environmental Claims (Type II Environmental Labelling)
ISO 14024:1999	Environmental Labels and Declarations – Type I Environmental Labelling – Principles and Procedures

ISO 14031:1999	Environmental Management – Environmental Performance Evaluation – Guidelines
ISO 14040:2006	Environmental Management – Life Cycle Assessment – Principles and Framework
ISO 14044:2006	Environmental Management – Life Cycle Assessment – Requirements and Guidelines
ISO 14050:2009	Environmental Management – Vocabulary

Table 1: Examples of Other Standards in the ISO 14000 Series.

The standard ISO 19011:2002 "Guidelines for Quality and/or Environmental Management Systems Auditing", although not classed as being in the 14000 series, also includes requirements for EMS auditing.

How to Incorporate Biodiversity into an EMS

Biodiversity continues to decrease at an alarming rate. In the UK, for example, over 100 species are estimated to have been lost since 1900. Factors that threaten biodiversity include climate change, taking land for urban and industrial development, and the spread of invasive and none-native species.

Jargon Buster

Biodiversity

Term that is used to describe the variety of different types of plant, animals and other organisms on earth. It includes the variety of different species and genetic variation within species. For example, a rainforest has a very high level of biodiversity whereas as very cold areas, such as the north pole, have a low level of biodiversity.

Biodiversity is not often included within the scope of a formal EMS, although this represents a missed opportunity. Easy ways of incorporating biodiversity into a formal EMS could be:

- State a commitment to address biodiversity in the environmental policy of the organisation.
- Identify environmental aspects that state the interaction of the organisation's activities, products or services with biodiversity.
- Objectives and targets should be in line with those that are stated in the biodiversity action plan (BAP).

  The BAP, if present, should be included within the EMS structure where it will be audited to ensure legal compliance. The BAP should be within the 'normal' structure of an EMS (in much the same way as waste management is often included).
- Purchasing may also be important and should consider biodiversity – the origin of the raw materials that are components of a procured product should be investigated.
- Using the management review to consider whether activities products or services have an impact on wildlife, land, habitats, etc. This will help ensure that measures are implemented and maintained to protect biodiversity.

Although biodiversity is different from the usual issues that are covered by an EMS (such as pollution, waste, energy reduction, etc.), biodiversity can be easily included.

More...

http://www.defra.gov.uk/environment/biodiversity/documents/bbpg2007.pdf

IEMA Foundation Certificate in Environmental Management

Element 1: Sustainable Business Thinking

RRC TRAINING

Contents

Learning Outcomes

After completion of this section you will understand and have an appreciation of:

- The key environmental issues and their relevance to business, e.g. climate change, greenhouse effect, acid rain, ozone depletion, pollution of land, air and water, loss of biodiversity, deforestation, population growth and consumption, non-renewable resource use and desertification.
- The importance of integrating environmental issues into the business process and the potential business benefits of doing so.
- The driving forces leading to the introduction of environmental management systems into an organisation and their potential benefits.
- The principles and benefits of effective resource use.

Hints and Tips

Before you begin, please make sure you have read your 'Welcome to your Course' and read, signed and returned your Learning Agreement.

Key Environmental Issues

Definition of the Environment

Before we consider the key environmental issues, it is worth considering what the environment actually is. Although there are many definitions of the term 'Environment' the environmental management system (EMS) standard ISO 14001 and the **Environmental Protection Act 1990** define the environment as:

> *"...the surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation. 'Surroundings' can extend from within an organisation to the global system".*
>
> **ISO 14001 - 2004**

> *"The "environment" consists of all, or any, of the following media, namely, the air, water and land; and the medium of air includes the air within buildings and the air within other natural or man-made structures above or below ground".*
>
> **Environmental Protection Act 1990**

We shall now consider some of the key issues that have an impact on the environment.

Global Climate Change

A large proportion of the solar radiation that hits the earth's surface is reflected back to space. Carbon dioxide (CO_2), methane, water vapour, chlorofluorocarbons (CFCs) and other gases are present in the atmosphere. These allow visible light (shortwave radiation) to pass through them but absorb the infrared radiation (long wave radiation) that is formed and reflected when the visible light hits the surface of the earth. The process retains the heat from the sun. It is commonly called the **greenhouse effect** as the system works in similar way to a normal greenhouse (with the greenhouse gases acting as the glass). The greenhouse effect is essential and without it the earth would not be hot enough for life, including us, to exist.

Although there are many greenhouse gases, the chief offender is CO_2. CO_2 is both a pollutant and natural component of the air. It is produced from the burning of fossil fuels, when animals breath and when plants undergo decomposition.

Other common greenhouse gases include methane released from vehicles, homes and factories; CFCs released from refrigeration, aerosols, etc.; and water vapour.

The effect that this man-made warming may have on the earth includes:

- Ice caps and glaciers melting - leading to increased sea levels, causing flooding of low lying areas.
- Hazardous weather - e.g. hurricanes and tornadoes, becoming more frequent.
- Tropical diseases - occurring in areas where they did not previously.

Ecosystems and agriculture may also be severely affected.

Global Warming

Rather than using the term '**global warming**', the term '**global climate change**' is perhaps more accurate. Global warming implies an equal warming in all places on the planet. By altering the earth's climate, global climate change may even lead to cooling in some areas, although the earth will heat up on average.

The **Kyoto Protocol** is an international agreement that was developed in Kyoto, Japan in 1997 to reduce man-made greenhouse gas emissions. Under the Kyoto Protocol, developed countries pledged to cut the annual emissions of greenhouses gases by different amounts adding up to average reduction of 5.2% by 2012 in comparison to 1990 levels.

The Kyoto Protocol is now coming to an end and discussions are occurring as to what will replace it. These started with the development of the Copenhagen Accord, following a meeting in Copenhagen in late 2009.

To reduce fossil fuel burning (mainly in power stations and road vehicles) we must:

- **Decrease energy consumption**, e.g. improve insulation, double-glazing, attention to heating.
- **Increase efficiency of energy use**, e.g. use of fuel-efficient vehicles (diesel gives 30% better performance than petrol-driven vehicles, on average).
- **Use alternative energy sources**, e.g. nuclear energy and renewable alternatives.
- **Burn fuels which release less CO_2**, e.g. compared to coal, natural gas (methane) produces more than twice as much energy (per kg) and releases less CO_2.

More...

http://www.decc.gov.uk/

Acid Deposition

Acid deposition can occur in two forms.

- **Acid Rain** - results from the combustion of coal and oil from activities including power generation, industrial operations and vehicle emissions. The acidic nature of rain arises from sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) in the air combining with water to form acid rain. The rain can be blown many hundreds of miles from the source. Impacts associated with acid rain include damage to vegetation; acidification of soil and rivers, with resultant damage to aquatic life; and release of harmful metals in soils (e.g. aluminium) which can contaminate drinking water.
- **Dry Deposition** – acidic gases, such as sulphur dioxide and oxides of nitrogen, fall back to earth under the influence of gravity - usually more local to the source, causing similar problems to acid rain.

Ozone Depletion

The ozone layer is a screen of ozone gas in the lower stratosphere (around 25 to 40km above the earth), which filters out the harmful ultraviolet (UV) rays from the sun that can cause skin cancer, cataracts and crop failure. In 1985 British scientists detected significant ozone layer depletion over the Antarctic. Ozone levels have declined further since.

Certain chemicals have been identified as having a significant effect on the rate of ozone depletion.

- **Chlorofluorocarbons** (CFCs) can exist in several forms and in a variety of products, e.g. foams, aerosols, refrigeration, solvents and air-conditioning. They have the highest ozone depletion potential.
- **Halons** contribute to ozone depletion. The two main halons are bromotrifluoromethane (halon 1301) that was used in total flooding applications, and bromochlorodifluoromethane (halon 1211) that was used in fire extinguishers.
- **Carbon tetrachloride** is traditionally used as a solvent.
- **1,1,1-Trichloroethane** (methyl chloroform) is a non-flammable solvent with low toxicity and is often used for cleaning metal.
- **Hydrochlorofluorocarbons** (HCFCs) are transitional substances and may be used to replace CFCs. Although less potent, they do have some depletion potential.
- **Methyl bromide** is widely used as a fumigant to kill pests in soil and stored crops.

See the full page picture in the Appendix to this Element, which demonstrates ozone depletion in action.

Following this scientific evidence of damage to the stratospheric ozone, the **Montreal Protocol** was set up. Its parties have agreed to phase out man-made ozone-depleting chemicals as quickly as possible (e.g. CFCs are now banned and HCFCs are being phased out by 2015). It is postulated by some scientists that following the introduction of the Montreal Protocol, and compliance with its requirements, the ozone layer will return to its natural state by about 2050 to 2075.

Pollution of Land, Air and Water

Jargon Buster

Pollutant

A pollutant can be anything that causes harm in some way to humans, animals, ecological systems or even buildings.

In addition to the air pollutants we have already discussed, pollutants can also cause harm to rivers, streams and other watercourses through:

- Deoxygenating materials, e.g. sewage and other organic wastes, such as waste from a number of heavily polluting industrial processes (e.g. food processing and production of textiles, paper and dairy products).
- Nutrient enrichment, by such things as fertilisers, which may give rise to eutrophication. This causes an accelerated growth in plants and algae and leads to a decline in water quality.
- Solids which may impede or block out light for growth.
- Toxic materials, such as heavy metals, pesticides or nitrates, are toxic to humans, animals, plants, or all three (depending on the dose they receive).
- Materials which cause an impact on amenity, e.g. car tyres or shopping trolleys which can prevent a lake or river being used for pleasure purposes such as boating or fishing.
- Disease carrying agents, such as bacteria.
- Heat, which may reduce biodiversity and deoxygenate water.

The effect of any pollution will vary according to the size, temperature, rate of flow and oxygen content of the receiving water, as well as the presence of other pollutants and any resulting synergistic effects.

Pollution can also affect land. The term "contaminated land" defines the presence of substances on a site (usually in the soil), in concentrations that are above

background levels, which can often cause harm (directly or indirectly) to humans, animals, vegetation or structures.

With the development pressure on green belt land, and with great importance being placed on inner city regeneration and urban renewal, there has been the need to redevelop land which was formerly utilised for industry, mining, waste disposal or other potentially contaminating uses. There is now great pressure to develop such sites, for commercial, industrial or housing uses. For example, a large number of former town gas production sites are now available for redevelopment as a result of the nationalisation of the gas industry and the replacement of town gas with natural gas. Estimates of the extent of contaminated land range from 10, 000 hectares to a possible 100, 000 hectares.

Jargon Buster

Pollution

The **Environmental Protection Act 1990**, describes pollution as:

"*...pollution of the environment is due to the release (into any environmental medium) from any process of substances which are capable of causing harm to man or any other living organisms supported by the environment.*"

Harm

Harm in this context is defined as being:

"...harm to the health of living organisms or other interference with the ecological systems of which they form part and, in the case of man, includes offence caused to any of his senses or harm to his property."

Pollution of River

Loss of Biodiversity

Biodiversity (or biological diversity) is the variety of plants, animals and other organisms that are present on the earth. The term can be used for different scales, from the biodiversity within a local area, to that in a country or continent.

Human activities have lead to biodiversity being reduced at a increasing rate due to many reasons. These include climate change, developments in agriculture, poor choices of land for industrial and urban developments and the spread of non-native invasive plant and animal species. Examples of the losses of UK biodiversity include:

- "Farmland bird populations fell by almost half between 1977 and 1993 – though have been relatively stable since.
- By the 1980s, unimproved lowland meadows had declined by 97% over the previous 50 years. Declines have continued since at a rate of 2-10% per year.
- By 1980, over a quarter of upland heathland had been lost in England, with losses of 36% in Cumbria. Widespread declines in the condition of the remaining habitat still continue.
- Between 1978 and 1998 the diversity of plants in infertile grasslands in England and Wales declined by 20%.
- Water voles have disappeared from 94% of the sites where they were previously recorded."

Source: Working with the Grain of Nature: A Biodiversity Strategy for England, DEFRA, 2002 (http://www.defra.gov.uk/publications/files/pb7718-biostrategy-021016.pdf)

Most plant or animal species are adapted to live in a specific habitat or environment that best meets their survival needs. Without such a habitat the species may not survive. Habitat destruction may be caused by single events such as oil spills, road building or deforestation, or by cumulative incidents such as gradual air or water pollution. Both cumulative and single events have destroyed or damaged available habitats.

Jargon Buster

Biodiversity

Biodiversity (or biological diversity) is the variety of plants, animals and other organisms that are present on the earth.

Deforestation

Deforestation is the removal of naturally occurring forests by human activities, such as logging or burning of tress. Deforestation may occur for a number of reasons including:

- Clearing land for cattle, settlements or agricultural plantations.
- Use of wood or charcoal by humans or as a commodity.

The removal of trees without sufficient replanting leads to numerous problems, including damage to habitat, biodiversity losses and soil erosion. It also removes a key carbon sink and so increases the amount of carbon dioxide in the air. Some deforested areas can also suffer from significant soil erosion which allows fertile soil to be washed into rivers, leaving behind wastelands.

Deforestation on a large scale tends to occur as a result of a lack of enforcement of relevant environmental laws or poor forest management. A report by the United Nations Food and Agricultural Organisation has estimated that the total area of the world's forests is decreasing at a rate of about 13 million hectares a year.

Deforestation

Population Growth and Consumption

Overpopulation does not just refer to the size of the population, but the ratio of population to sustainable resources that are present and the way the resources are used and distributed within a population. Overpopulation can result from an increase in birth rates, decrease in mortality rates (due to medical advances), increase in immigration and unsustainable use of resources. This makes it possible for very sparsely populated areas, such as the Sahara desert, to be over populated due to the limited capacity of the environment.

Jargon Buster

Overpopulation

Overpopulation occurs when the population exceeds the carrying capacity of the environment.

When considering the ability of the environment to sustain a population, factors such as clean water, clean

air, warmth, food and shelter, etc. should be taken into account.

The vast increase in human population over the twentieth century has raised concerns about the earth's ability to sustain such large numbers of people. Current estimates suggest that the earth's population is around seven billon, with the population projected to grow to around nine billion by 2050.

With increased population comes increased pressure on the environment in areas such as pollution, biodiversity and habitat degradation. Of particular concern is the development of large countries, such as China and India, in a similar way as has occurred in other nations. The Worldwatch Institute has postulated that if China and India were to consume the same level of resources per person as the USA or Japan, then by 2030 their new way of life would require the resources of the whole world to sustain them.

More...

http://www.worldwatch.org/

Non-Renewable Resource Use

Natural resources are grouped into two categories; renewable and non-renewable. A renewable resource is one that may be replaced over time by natural processes, such as softwoods, or is inexhaustible, such as wind energy. It is extremely important that renewable resources are not consumed faster than they are replaced.

Non-renewable resources are those that are in limited supply, that cannot be replaced, or can only be replaced over extremely long periods of time. Non-renewable resources include fossil fuels (coal, gas, etc.) and mineral ores (e.g. gold, iron, etc.). Non-renewable resources must be used sparingly and reused or recycled wherever possible.

Examples of estimated resources remaining (at current consumption rates) are:

- Coal – 160 years.
- Oil – 40 to 80 years.
- Natural gas – 59 years.

Almost all our energy is currently obtained from non-renewable resources (oil, gas and coal). Energy production and consumption leads either directly or indirectly to emissions of carbon dioxide, sulphur dioxide and oxides of nitrogen. These all contribute to global warming and acid rain.

In addition to the generation of pollution, the cost of energy relating to process operation, general heating and transport represent the most significant environment-related costs for the majority of organisations.

Desertification

Desertification describes the deterioration of land in arid

and sub-humid areas as a result of loss of soil moisture and vegetation. The main causes are overgrazing, taking groundwater and diversion of rivers for industry and drinking water. Its root cause is commonly overpopulation.

According to the United Nations Environment Programme approximately nine to eleven million hectares of agricultural land is becoming desertified each year. An example of desertification is the dust bowl era of the 1930s in the Great Plains of the USA where prolonged drought and poor agricultural practices caused crops to wither and die, with large areas turning into dry dirt. Winds swept this fertile topsoil into massive dust storms carrying it to other areas far away from the source.

Desertification

Environment and Business

Business Benefits of Good Environmental Management

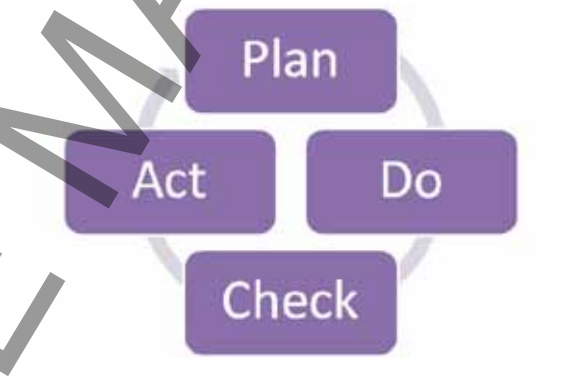
It is important that environmental issues are integrated into the management of the business. As we will see later, this is often achieved by the development of a formal environmental management system (EMS) to a recognised standard such as ISO 14001. Organisations that take their environmental responsibilities seriously tend to enjoy the following benefits:

- Minimised energy and water costs.
- Decreased waste management costs.
- Increased corporate image, which in turn leads to many business benefits.
- A decrease in the likelihood of an accident occurring and causing significant damage to the environment.
- Better defence should an accident occur.
- Reduced insurance premiums.
- Improved recruitment of staff.
- Better compliance with environmental law.
- Improved sales, as a result of improved environmental performance of products.
- Better relations with local communities.

Introduction to Environmental Management Systems

An EMS gives a framework for making continual improvements in environmental performance. EMSs are voluntary and provide a system to reduce and control environmental impacts associated with an organisation. The organisation may gain external certification of their EMS to a standard such as ISO 14001, but this is optional.

EMS models (including the ISO 14001) are constructed on the "**Plan, Do, Check, Act**" (PDCA) model introduced by Shewhart and Deming. This model is based upon the concept of continual improvement.



Plan-Do-Check-Act Cycle

ISO 14001 describes an EMS that is based on the PDCA model. It is a process of continual improvement which can be defined under five categories; environmental policy, planning, implementation and operation, checking and corrective action and management review. (We will look at this in more detail later.)

Resource Efficiency

Resource efficiency is defined as maximising the output of a product or service from a given level of energy and materials. It is all about making or doing more with the same or lesser quantity of materials. Generally, resource efficiency involves making improvements in raw material utilisation, in addition to reducing general and hazardous wastes.

Typically, improvements in resource usage will increase productivity and generate more profit or cut operating costs – equivalent to between 1% and 3% of business turnover. It will also give more control over the environmental costs of processes, products and services. Other benefits include:

- Helping the company identify and plan for environmental factors affecting the business.
- Making it easier to comply with environmental regulations.

- Improving the company's reputation with insurers, regulators, investors, shareholders, employees, customers and neighbours, who will all react more positively to a company that can demonstrate that it is aware of its environmental impacts and is taking steps to improve performance.

Jargon Buster

Resource efficiency

Resource efficiency is maximising the output of a product or service from a given level of energy and materials.

The process of becoming more resource efficient can be categorised into a number of steps:

- **Step 1 – Assessing scope for savings**
  Determining the potential for savings by estimating resource costs.
- **Step 2 – Gaining management commitment**
  Gaining support of management is key and will allow the scheme to be fully implemented and operated.
- **Step 3 – Mapping of activities/processes**
  Enabling a good understanding of what actually goes on at the business and a more detailed estimate of where savings can be made. To create a process map, a flow diagram of the activities that occur at an organisation should be developed – from where the raw material enters the site, to where the final product leaves.
- **Step 4 – Quantifying and cost determination**
  Considering purchasing records for raw materials, and bills, etc. such as:
  - Production data.
  - Electricity and gas invoices.
  - Water and effluent invoices.
  - Waste disposal transfer notes.
  - Raw material invoices.
  - Stock information.
  - Meter readings.

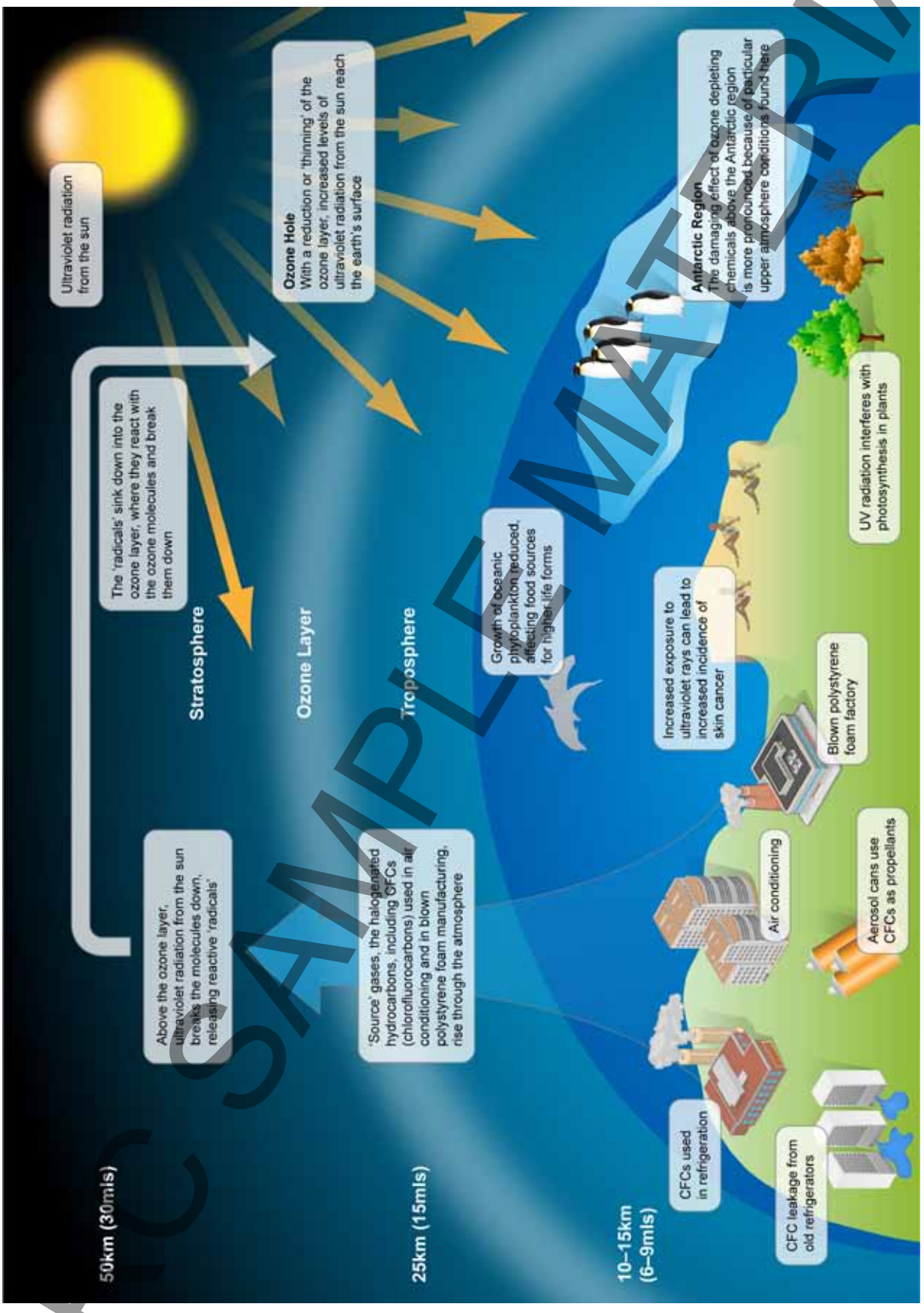
  The true cost of waste should be determined (hidden waste costs can include treatment, abatement costs, staff time, PPE, monitoring costs, additional utility costs, etc.).
- **Step 5 – Understanding and generating options**
  Considering how to go about reducing inefficient use of resources or waste production. Brainstorming with staff is useful as are guides produced by Envirowise and the Carbon Trust
- **Step 6 – Opportunity assessment**
  Determining whether the improvements are technically or economically feasible.
- **Step 7 – Project implementation and maintaining momentum**
  An action plan should be developed, implemented and communicated.

More...

http://www.envirowise.gov.uk

http://www.carbontrust.co.uk

Appendix



Ozone Depletion in Action

IEMA Associate Certificate in Environmental Management

Element 2: Background to Environmental Law

RRC TRAINING

Contents

Learning Outcomes

After completion of this element you will have the skills and abilities to:

- Identify types of instruments available to achieve change and the role they play (e.g. information, financial and legislative instruments and voluntary measures).
- Understand in general terms the UK regulatory framework: relationships between UK, EC and international law, civil and criminal law and the regulators.

Hints and Tips

Before starting work on each element, take a look at the Contents page – this will help you see how the different topics relate to one another.

Instruments to Achieve Change

Key Information

- There are a number of instruments that can be used to bring about improvements that benefit the environment. These instruments can be broadly categorised as information, financial, voluntary and legal.

There are a number of instruments that can be used by governments and others to try and bring about improvements that benefit the environment. Legislation is one possible mechanism for change which we will consider in detail in this module but there are others including information, financial or voluntary.

Information

The provision of information regarding the environment plays a part in environmental improvements. Many environmental laws that have been developed require that legal information regarding a site is placed on a public register, e.g. permit applications, the permits themselves and other information must be made available for inspection by the public.

Identifying and making information available regarding best practice will also assist organisation in making environmental improvements. Indeed this is an approach that has been adopted by the Envirowise programme that produces numerous company specific case studies on how organisations have become more resource efficient. Other types of information sources, such as labels, will provide consumers with information and enable them to compare the environmental performance of similar products.

More...

http://envirowise.wrap.org.uk/

Financial

Taxation can also be another type of measures that is sometimes implemented to activate change. The **Landfill Tax** for example is a levy on the disposal of waste to landfill and was implemented as a method of reducing waste production and increasing waste recycling and recovery. Similarly the **Climate Change Levy** is a tax on the use of energy that has been produced from the combustion of fossil fuels.

Away from taxation, as we saw in the previous module, a more sustainable business operation can result in significant financial savings. Government grants can also be issued to those organisations who decide to implement efficient technology on their site, such as those made available by the **Carbon Trust**.

More...

http://www.carbontrust.co.uk/

Voluntary

Initiatives can also be voluntary, sometimes in the face of the government threatening to implement laws. Examples include voluntary agreements covering the use of pesticides and the motor industry agreeing emission reduction targets for vehicles within the EU.

Background to UK Law

Key Information

- Common law and statute law are both sources of UK law.
- Criminal law is based on crimes against the state being committed. Breaches result in fines or imprisonment.
- Civil law is based around the results of past cases. When a case is successful, compensation is usually awarded.
- Acts of parliament and regulations are both types of criminal law.
- The tort of nuisance and tort of negligence are type of civil law.
- Nuisance is concerned with the unreasonable interference with the legitimate use/enjoyment of land.
- Negligence describes a failure to undertake an action that would be expected (an omission) or undertaking careless behaviour (an act).
- Numerous defences are available against the torts of nuisance and negligence. These include no breach of duty, necessity and prescription.

Law can best be described as the set of rules that regulate and control the conduct of citizens; it is laid down by those in authority and enforced by its agencies.

The two main sources of UK law are Statute Law and Common law.

- **Common Law** is based on case law (past cases) it is dependent on the accumulation of decisions by courts hearing cases with similar issues. Case law is based on the principle that a lower court must follow the judgement of a higher court when applying the law. This has advantageous in that judgements are based on practical experiences, however the law is uncertain until a case is heard in court.
- **Statute Law** is law that is produced by the government. Examples of statute law include Acts, Regulations and Orders. Statute law is written down and states a legal and binding code of conduct.

The law in the UK is developed into two branches criminal law and civil law.

- **Criminal Law**

  Criminal law is based on crimes which are classed as offences against the state. Criminal law is closely allied to statute law. It has the objectives if punishing, deterring or reforming - usually through the imposition of fines and/or prison sentences. Prosecutions are brought by the state. In the environmental case this would include the Environment Agency, Procurator Fiscal (Scotland only with assistance of the Scottish Environmental Protection Agency) or local authorities. For a case in criminal law to be successful, evidence must be proved 'beyond reasonable doubt'.

- **Civil Law**

  Civil law is based around the duties and rights of individuals to each other. It was introduced into the UK in 1066 with the Norman Conquest. The main source of civil law is common law. In fact civil law is a codified version of common law, based around torts (civil wrongs) or delicts as they are known in Scotland. Breaches of civil law often involve financial compensation for harm that has occurred to an individual or group of individuals. This compensation is designed to return a person back to the position they were in before the damage occurred. Cases in the civil court have to be proved 'on the balance of probabilities' (a lower degree of proof than in criminal courts).

Civil	Criminal
Offences by individual	Offences against society
Based mainly on common law	Based mainly on statute law
Individual brings action	Action brought by state's enforcement bodies
Mainly result in compensation	Result involves punishment (e.g. fine, prison sentence)
Tort (civil wrong)	Crime
Can insure against civil actions	Cannot insure against criminal actions
Loss must be proved	No loss can occur
Standard of proof - balance of probabilities	Standard of proof - beyond reasonable doubt

Differences between criminal and civil law.

Both legal systems can and often are applied to the same incident. For example, polluting a river may result in a prosecution under the **Environmental Permitting (England and Wales) Regulations 2010** by the Environment Agency, however the owner of the river may also sue the polluter for cost of fixing the damage to the river such as removing contaminated sludge or stocking the river with fish.

Criminal Law

Types of Offences

In criminal law there are three types of offences:

- **Summary Offences**

  These tend to be minor offences that are heard in a Magistrates' Court (England and Wales) or the District Court, or Summary Division of the Sheriff's Court (in Scotland).

- **Indictable Offences**

  These are more serious offences. A formal document called the indictment illustrating the case against the accused is developed. Initially the decision to commit the case to the crown court is taken in the Magistrates' Courts who determine whether sufficient evidence exists to commit the accused for trial. The Sheriff's Court holds committal proceedings in Scotland.

  Trials for indictable offences are heard before a judge and jury in the Crown Court in England and Wales, or, in Scotland, the Solemn Division of the Sheriff's Court or the High Court of Judiciary. Fines and prison sentences available tend to be higher for indictable offences.

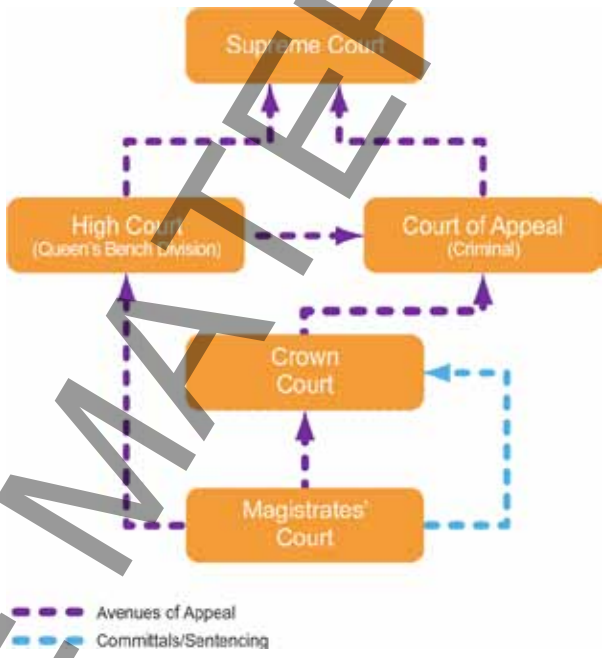
- **Triable Either Way (Hybrid)**

  These are offences which can be heard in a Magistrates' Court or Crown Court. Most environmental offences are hybrid offences.

Criminal Courts

Criminal Courts in England and Wales

The structure of the criminal courts can be seen in the following figure.



Criminal Court Structure (England and Wales)

Damages/Penalties

The maximum fine will be set out in Acts or Regulations. As a guideline:

- **Magistrates' Court** - may impose a fine of up to £50,000 and/or 12 months' imprisonment (some offences attract lower sanctions than this).
- **Crown Court**- on indictment in a Crown Court, this rises to an unlimited fine and/or five years' imprisonment. Costs may also be charged to the company in a crown court.

Types of Criminal Law

There are two key types of criminal law:

- **Acts of parliament** - these are developed by parliament and tend to be framework acts in that they set out a wide framework for action rather than imposing a specific set of rules. Their aim is broad and they go through a long and rigorous debating process in Parliament prior to becoming law. Well known environmental acts include:
  - **Environmental Protection Act 1990.**
  - **Environment Act 1995.**
  - **Pollution Prevention and Control Act 1999.**
  - **Water Industries Act 1991.**
- **Regulations** - these are secondary legislation that supplement primary legislation by providing the more detailed and technical content of the relevant regulatory regime. These are developed by ministers

and placed before Parliament for a limited period of time. Well known environmental regulations include:

- **Environmental Permitting (England and Wales) Regulations 2010.**
- **The Environmental Protection (Duty of Care) Regulations 1991.**
- **The Producer Responsibility Obligations (Packaging Waste) Regulations 2007.**
- **Control of Pollution (Oil Storage) (England) Regulations 2001.**

Framework Acts are the opposite of the **prescriptive Acts** described above. They set out a broad framework for action rather than imposing a detailed set of rules. All the principal modern Acts (primary legislation) are set out in this form and the detail is to be found in secondary legislation (e.g. regulations or commencement orders) set within the broad framework. The definitions are broad, often needing clarification by the Courts.

Civil Law

A tort in English law is a civil wrong, a breach of civil duty imposed by law (the Scottish equivalent is known as a delict). Examples of torts are defamation, nuisance and trespass. For environmental issues the **tort of nuisance** is most commonly applied.

Tort of Nuisance

There are two types of civil nuisance, private and public.

- **Private Nuisance** - is concerned with the unreasonable interference with the legitimate use/ enjoyment of land (e.g. noise or odour). A claim for damages may be made or an injunction. The claimant must normally be the owner or tenant of the land. The complaint must be reasonable (people who are sensitive have no greater protection).
- **Public Nuisance** - these must have a significant and direct effect on the general public (including definable groups). Actions can be taken by an individual, local authority or the Attorney General.

As we will consider later, many civil nuisances have been made into criminal law nuisance under Part III of the **Environmental Protection Act 1990**.

Tort of Negligence

Negligence describes a failure to undertake an action that would be expected (omission) or undertaking careless behaviour (act).

The tort of negligence can be described as a breach of a duty of reasonable care towards other persons that caused some kind of identifiable loss. There is a great amount of case law that defines who is owed a duty and the ways that breaches may occur.

Three things must be satisfied in order for a case in the tort of negligence to be successful:

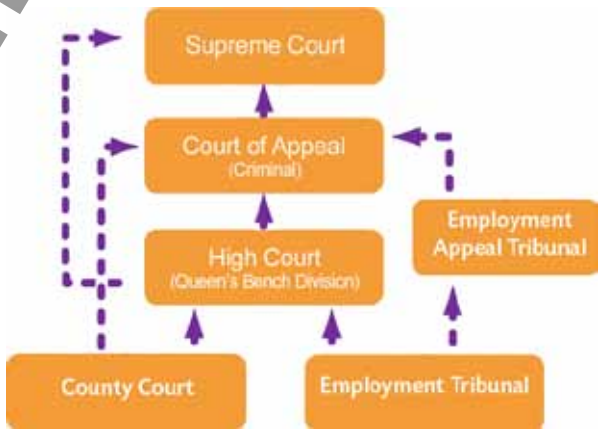
- The defendant owed a duty of care to the claimant.
- There was a breach of that duty.
- That as a direct result of the breach, the claimant suffered harm which was not too remote from the breach.

A commonly quoted environmental case of negligence is that of ***Scott-Whitehead v. National Coal Board (1987)***:

- The defendant poured chlorinated solvent into a river.
- The river was in drought so there was not enough water to dilute the solvent.
- The claimant was a farmer who was abstracting water downstream to irrigate crops.
- Not surprisingly, the water abstracted from the river caused damage to his crops.
- The second defendant in this case (the local water authority) was found liable for negligence for not informing the farmer of the dangers of the discharge to his crops.

Civil Courts

The civil court structure is different to that for the criminal courts. It is illustrated in the following figure.



Civil Court Structure (England and Wales)

Damages

Damages in civil courts can be for the following:

- Monetary loss.
- Non-monetary loss.
- Injunction (to prevent the continuation of the wrongdoing) or
- Abatement.

Defences

There are a number of defences that can be used in civil courts, for negligence these include:

- **No Breach of Duty** - if no breach occurred, then the defendant was not negligent.
- **No Duty Owed** - if it was not possible for the defendant to have reasonably foreseen that the action would result in the condition that led to the loss suffered by the claimant.
- **Breach by a Third Party** - if the breach was not committed by the defendant.
- **Breach Did Not Lead to the Damage** - if there is not a direct connection between the breach and the damage/injury.
- **An Act of God** - if the damage occurred from an act of God, the defendant is not responsible.
- **Lack of Foreseeability** - if the incident was unforeseeable then the defendant is not liable.
- ***Volenti Non Fit Injuria*** - this phrase means 'that no injury can be done to the willing'. As far as the law of torts is concerned, no person who has consented to the infliction of an act on himself can expect to find a legal redress for the consequences of that act.
- **Necessity** - in certain situations it is reasonable to assume an abnormal risk. An example would be the causing of pollution to prevent a larger pollution incident occurring.

Defences for private nuisance include:

- **Consent of the claimant** - i.e. the claimant has agreed to the nuisance but, just as with *volenti* above, it has to be true consent.
- **Prescription** - implied consent because the defendant has carried on the nuisance for a long time without complaint from the claimant.
- **Statutory authority** - the nuisance is being caused in the exercise of a statutory power.

International Influences on UK Law

Key Information

- UK Law can be influenced by International law.
- There are numerous environmental international agreements that countries must comply with, e.g. Kyoto Protocol.

As many significant environmental problems are global, and the activities of one country can have an effect on another, there is a need for laws at an international level. Example issues include climate change or ozone depletion. International law can be described as consisting of:

- International agreements to which sovereign states consented; such as treaties, conventions, or protocols. (This is the main type of international law and is usually developed by the Unites Nations.)
- General legal principles.
- International case law.
- The written analysis and comments of eminent academics and judges.

States only have obligations under international environmental law when they have consented to them. This is achieved by signing and ratifying international agreements. Others who participate in the development of international law include non-governmental organisations (NGOs), multinational companies and inter-governmental organisations.

International law is usually implemented into the legal system of each compliant country. For members of the European Union, a common way of implementing an international environmental agreement is by the development of a European Directive which provides a framework. This must be implemented directly into a member state's law.

Examples of international laws that have been developed are provided in the following table.

Title	Subject	Year in Force
MARPOL Convention	This is the main international convention covering prevention of pollution of the marine environment by ships, from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively, and updated by amendments through the years.	1973
Geneva Convention on Long-Range Transboundary Air Pollution	This convention was concerned with long-range transboundary air pollution throughout Europe. It provides a framework for the development of international law concerned with protecting human health and the environment. Further protocols have extended the original agreement since 1983.	1979
Helsinki Protocol	This protocol was concerned with the reduction of sulphur emissions by 30%. The UK was not a signatory to the original agreement.	1985
Sofia Protocol	This protocol was concerned with retaining nitrogen oxide emissions at 1987 levels and was ratified by the UK.	1988
The Montreal Protocol on Substances that Deplete the Ozone Layer	This protocol was concerned with reduction in the use and availability of those substances known to deplete the stratospheric ozone layer. 155 countries ratified the agreement, including the UK.	1989
International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC)	This deals with the adoption of a global framework for international co-operation for combating major incidents or threats from marine oil spills.	1990
Geneva Protocol	Concerned with reducing VOC emissions. Ratified by the UK, where a 30% reduction in emissions by 1999 (over 1988) was agreed.	1991
OSPAR Convention	The Convention on the Protection of the North Sea and NE Atlantic. Deals with pollution of the sea, conservation and repair of marine ecosystems, and reduction of eutrophication.	1992
Framework Convention on Climate Change	The convention was launched at the Earth Summit in Rio de Janeiro in 1992, and came into force two years later. It was concerned with the reduction in those gases considered to contribute to the phenomenon of global warming. The treaty was ratified by 180 countries, including the UK.	1994
Oslo Protocol	Further reduction in sulphur emissions; different countries agreed to different levels of emissions. The UK was a party to the sulphur emission reductions.	1994
Convention on Marine Pollution by Dumping Wastes and Other Matter, 1972	Prohibits the dumping of certain hazardous materials and introduced a permit system for the dumping of other materials.	Now replaced by the 1996 Convention
Convention on Marine Pollution by Dumping Wastes and Other Matter, 1996	The convention adopted a cautionary approach to permitted dumping at sea. The aim was: *"To individually and collectively protect and preserve the marine environment from all sources of pollution and take effective measures, according to their scientific, technical and economic capabilities, to prevent, reduce and where practicable, eliminate pollution caused by dumping or incineration at sea of wastes or other matter".*	1996

Title	Subject	Year in Force
Convention on the Protection and Use of Transboundary Watercourses and International Lakes	Requires parties to prevent, reduce and control releases of hazardous, acidifying and eutrophying substances into the aquatic environment.	1996
Kyoto Protocol	This protocol is concerned with global warming gases. It introduced individual, legally binding targets to cut global warming gases by 2008-2012, including a cut of up to 5% over 1990 levels. The Kyoto Protocol has not been ratified by many of the major producers of global warming gases, including the USA and Australia.	1997
Aarhus Protocol	This protocol was concerned with reducing cadmium emissions, particularly from incineration and combustion processes. The UK has not yet ratified this protocol. A second Aarhus Protocol concerned persistent organic pollutants (11 pesticides, two industrial chemicals and three by-products) and has not yet been ratified by the UK.	1998
Protocol of Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances	The HNS Protocol follows the principles of the OPRC Convention and was formally adopted by states already party to that convention at a diplomatic conference held at the International Maritime Organisation headquarters in London in March 2000.	2000
Protocol on Civil Liability for Pollution of Transboundary Watercourses	Individuals affected by the transboundary impact of industrial accidents on transboundary watercourses will be able to claim compensation. Operators covered by the protocol will need to have adequate financial insurance.	2003
Gothenburg Protocol	This protocol concerned the abatement of ground level ozone, acidification and eutrophication.	2005

Influence of European Union Law

Key Information

- EU Law is a major influence on UK law.
- Law in Europe is mainly made as Directives which must be implemented into a member state's own legal system.
- EU Regulations are law as and when they are agreed.

European law may further implement an International Agreement or may be developed solely by the EU. There are two main types of law made at a European level these include:

- **Directives**

  Directives normally leave member states with a certain amount of leeway as to the exact rules to be adopted. They generally provide a framework of what should be achieved rather than providing exact details to allow for a member state's specific conditions. They must be implemented into a member states own legal system. Directives are the most common mechanism of developing EU environmental law.

  EU environmental directives include:

  - **Packaging & Packaging Waste Directive (94/62/EC).**
  - **Waste Electrical & Electronic Equipment Directive (2002/96/EC).**
  - **Control of Major-Accident Hazards Directive (96/82/EC).**
  - **Integrated Pollution Prevention and Control Directive (2008/1/EC).**

- **European Regulations**

  European Regulations are immediately enforceable as law in all member states simultaneously, they do not have to be implemented into a members state's own legal system. This is a relatively rare form of European Environmental law one example being **Regulation (EC) No 1005/2009** on substances that deplete the ozone layer.

The European Union plays an important role in determining legislation in member states. The extent of control it has with regards to UK environmental law making include:

- The UK is able to determine the subject, content and form of its national legislation.
- The UK can enact its own legislation independent of the EU, provided it does not contradict a Directive.
- As a consequence, the UK tends to respond only to the EC Directives and does not formulate its own laws when the EU may well issue a later Directive that requires something different.
- Directives are implemented in the UK by Acts or Regulations. The Directives are binding on the result to be achieved, so that gives the UK some leeway in interpretation and enactment to suit UK law.

To redress the balance, the UK as an EU member state can influence the European law making process.

More...

http://ec.europa.eu/environment

Regulators

Key Information

- Environmental regulators include Environment Agency/Scottish Environment Protection Agency, local authorities and water companies.
- Criminal notices for breaches of environmental law include enforcement notices, abatement notices, suspension notices, remediation notices and revocation notices.
- Civil sanctions include compliance notices, restoration notices, variable monetary penalties, enforcement undertaking, third party undertaking, fixed monetary penalties and stop notices.

Environment Agency/Scottish Environment Protection Agency

The **Environment Act 1995** created the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA). Both the EA and SEPA are the key regulatory bodies for environmental law in the UK. In Northern Ireland the equivalent body is known as the Northern Ireland Environment Agency. The powers of the bodies are broadly similar including:

- Preventing pollution.
- Water resources and quality.
- Contaminated land (special sites).
- Waste management.
- Flood defence.
- Fisheries and navigation of inland waterways.
- Recreation and conservation.
- Advice and the promotion of good practice.

One of the key duties of these agencies is their role in the environmental permitting of industrial and other sites. For example Part A(1) installation permits under the **Environmental Permitting (England and Wales) Regulations 2010** are regulated by the EA, whereas all IPPC permits in Scotland are regulated by SEPA.

More...

http://www.environment-agency.gov.uk/

http://www.sepa.org.uk/

http://www.ni-environment.gov.uk/

Local Authorities

The environmental health departments have responsibility for regulating Part A2 and Part B installation permits in England and Wales. They also have duties to regulate the statutory nuisance regime. Additionally they are required to administer and enforce the clean air provisions of the **Clean Air Act 1993**, which controls the emission of smoke, and they have duties for local air quality under the **Environment Act 1995**. Local authorities are also required to undertake duties with regards to contaminated land.

The planning departments have the responsibility of considering applications for planning permission for new developments. They will also require that an environmental impact assessment is carried out for certain developments.

Water Companies

The Water Companies, although private companies, also have a role as an environmental regulator. They are involved in issuing and regulating discharge to the foul water system under the **Water Industries Act 1991.**

Powers of Inspectors

EA/SEPA and local authority Inspectors have significant powers that enable them to prevent pollution and investigate incidents. These include the power to:

- Enter premises at any reasonable time or at any time when it is considered that there is an immediate risk of serious pollution of the environment.
- Direct that all or part of the premises, or anything in them, be left undisturbed as long as is reasonably necessary for the purpose of any investigation.
- Take samples of any articles or substances found.
- Dismantle or test any article or substance found.
- Take possession of any article or substance and retain it.

- Require any person to answer such questions as the inspector thinks fit to ask, and to sign a declaration of the truth of their answers and take witness statements.
- Require the production of any record which is required to be kept.
- If they have reasonable cause to believe that an article or substance is the cause of immediate danger or serious harm, seize it and cause it to be rendered harmless (whether by destruction or otherwise).
- Be accompanied by a police officer, should obstruction be likely. (The police officer is there to ensure that the SEPA/EA/LA officer is not obstructed in their duty and has a power of arrest should such an obstruction take place.)
- Make any investigation as necessary including measurements, taking samples, photographs and questioning individuals.
- Carry out experimental borings, and install and maintain monitoring equipment.
- Serve notices - prohibition, enforcement, abatement, suspension, revocation, variation and remediation.
- Apply to the courts for a summons (to start the prosecution process).
- In cases of emergency, gain entry at any time, with force if necessary.

Option for Enforcement

The Environment Agency and local authorities (regulating authority) have powers to enforce environmental legislation and regulations. They have a number of options available to them to deal with environmental offences. These can be generally classed as providing advice, issuing a criminal notice or civil sanction and prosecution.

The types of enforcement notice are detailed in the following table.

Criminal Notice Type	Details
Enforcement Notices	• Served under the **Environmental Permitting (England and Wales) Regulations 2010.** • When a permit condition has been, or is likely to be, contravened. • Remains in force until the appeal is heard.
Abatement notices	• Served for offences of Statutory Nuisance under **Section III** of **EPA 1990.** • Served on a person when a nuisance is likely to occur or reoccur (or the owner or occupier of the premises when the person causing the nuisance cannot be located). • Right of appeal. • Failure to comply is an offence that makes the person issued with the notice subject to prosecution.
Suspension Notice	• Served under the **Environmental Permitting (England and Wales) Regulations 2010**. • Suspends the activities covered by the permit whether a permit condition applies or has been infringed or not. • Right of appeal. • Remains in place until the appeal is heard.
Remediation notices	• Served under **Contaminated Land Regulations 2006.** • Requires the appropriate person(s) to remediate the area of land (i.e. restore it to its previous condition, prior to the contamination). • Failure to comply with a remediation notice will usually result in prosecution. • Right of appeal. • An appeal suspends the notice.
Revocation notice	• Served under the **Environmental Permitting (England and Wales) Regulations 2010.** • Permit conditions are being breached, or the activities covered by a permit are causing, or likely to cause, serious harm to the environment or human health. • Agency may serve a notice stating that it intends to partially/completely revoke a permit.

The **Environmental Civil Sanctions (England) Order 2010** and the **Environmental Sanctions (Miscellaneous Amendments) (England) Regulations 2010** make civil sanction available for various offences for use by the EA and Natural England.

These were recently introduced as there was found to be no middle ground between issuing a warning and undertaking criminal proceedings. Also damage occurring to the environment was not always being put right.

The laws compliment the current powers of the regulators and are used to fill gaps in regulation that have occurred from laws that have mainly been historically developed. Civil sanctions can only be used where the Act, Regulation or Order allows, such as parts of the following:

- **Environmental Protection Act 1990.**
- **Water Resources Act 1991.**
- **Water Industries Act 1991.**
- **Environment Act 1995.**
- **Control of Pollution (Oil Storage) (England) Regulations 2001.**

The civil sanctions that may be used by regulators include:

- **Compliance notice** - issued to ensure that a person takes steps, within a specified time period, to ensure that an offence will not continue or happen again.
- **Restoration notice** - requires an individual to take steps to restore harm that has been caused by non-compliance, such that the position is restored to what it would have been (or as close as possible) if the offence had not taken place.
- **Variable monetary penalties (VMP)** - monetary penalties that can be used by regulators for cases of more serious non-compliance where the regulators decide that a prosecution is not in the interest of the public.

- **Enforcement undertakings** - these are voluntary agreements made by a person to take steps that would make amends for non-compliance and its impacts. It is the regulator's decision whether to accept it in a particular case.
- **Third party undertakings** - when a person receives a notice that the regulator plans to issue a compliance notice, restoration notice or variable monetary penalty, they may offer a third party undertaking (TPU). This involves taking action that benefits a third party who has been affected by the offence.
- **Fixed monetary penalties** - low-level fixed penalty that the regulator can impose for specific minor offences. It is a stand-alone sanction that cannot be used with any other sanction. Various activities where an FMP could be used include failure to monitor or document activities as requested by the regulator.
- **Stop notices** - prohibit a person from undertaking an activity that is causing (or is likely to cause) serious harm. Also prohibit situations that present (or are likely to present) a significant risk of causing serious harm until the person has undertaken specified steps stated in the notice to remove the risk of serious harm or to return to full compliance with the law.

Prior to issuing a compliance notice, restoration notice or VMP the regulator is first required to issue a **'notice of intent'** detailing what is proposed. If the regulator makes the decision to impose a compliance notice, restoration notice and/or VMP then a **'final notice'** must be submitted.

An appeal can be made for civil sanction and must be made to General Regulatory Chamber of the First-tier tribunal within 28 days of the date when the sanction or other decision was received.

Jargon Buster

Civil sanctions

Civil sanctions are available as a form of punishment for organisations that break the law. They fill gaps in regulation that have occurred from laws that have mainly been historically developed.

Prosecution

The penalties that occur for breaches of environmental law can include a fine and/or prison sentence. The maximum fine will be set out in the legislation (as discussed previously).

Overreaching Criminal Environmental Law

Key Information

- The **Environmental Protection Act 1990** contains provision for waste, contaminated land, statutory nuisance and other issues.
- The Environmental Permitting Regime requires a permit for mobile plant or installations, waster operations, waste mobile plant, mining waste operations, radioactive substance activities, waster discharge activities and groundwater activities.
- Installation Permitted activities must use the Best Available Techniques to control emissions and other environmental aspects.

In this section we will consider important pieces of criminal environmental law.

Environmental Protection Act 1990

The **Environmental Protection Act (EPA) 1990** is an important and broad piece of environmental legislation. It was developed to be legislation that included a number of environmental issues into a single framework Act. The **EPA 1990** has nine parts as we can see in the following table:

Part I	Integrated Pollution Control and Local Authority Air Pollution Control (Now replaced by the **Pollution Prevention and Control Act 1999** (**PPC Act**) and the **Environmental Permitting (England and Wales) Regulations 2010 (EP Regulations)**, made under that Act)
Part II	Waste on Land
Part IIA	Contaminated Land (inserted by the **Environment Act 1995**)
Part III	Statutory Nuisances and Clean Air (includes noise, dust, smell, accumulations/deposits)
Part IV	Litter
Part V	Radioactive Substances - now repealed and replaced by the **EP Regulations 2010**
Part VI	Genetically Modified Organisms
Part VII	Nature Conservation
Part VIII	Miscellaneous, including pollution at sea, control of dogs and straw burning
Part IX	General, including offences by bodies corporate, European Community and other international obligations, offences and application of the Act to the Crown

Pollution Prevention and Control Act 1999 and Environmental Permitting (England and Wales) Regulations 2010

The **PPC Act** has little information on actual implementation. It is an enabling act that allows further, more detailed, secondary regulations to be made.

The **PPC Act** implements many European directives in UK law such as Directive **2008/1/EC** on Integrated Pollution Prevention and Control (the **IPPC Directive.** For England and Wales, the most significant piece of legislation made from the Act is the **EP Regulations 2010.**

The **EP Regulations 2010** require that an environmental permit is needed if a regulated facility is operated. Regulated facilities include:

- **Mobile plant or installations undertaking an A(1), A(2) or Part B activity** - installations are classed as stationary units that undertake an activity listed in Schedule 1 of the Regulations. The risk-based grading system (i.e. A(1), A(2) and Part B) for installations is described below.

  Note: Part A permits provide for control of a wide range of impacts on the environment such as air, land and water emissions, waste minimisation, raw materials consumption, noise, heat, vibration and preventing accidents. **Part B** permits only provide control of activities that produce emissions to air.
- **Waste operations** - these include waste recovery or disposal activities that are not specifically mentioned in Schedule 1 of the Regulations. They also do not include exempt waste activities.
- **Waste mobile plant** - this is classed as any plant that is mobile that is used for a waste operation.
- **Mining waste operations** - the management of extractive wastes such as handling, treating, storing and disposing of extractive wastes. Extractive wastes

are defined as wastes from the extracting, treating or storing of minerals in addition to wastes produced from activities undertaken at quarries.

- **Radioactive substances activities** - including keeping of radioactive substances and wastes at a site.
- **Water discharge activities** - including the discharge into controlled waters of polluting materials, discharges into the sea.
- **Groundwater activities** - discharge of hazardous substances and non-hazardous pollutants either directly or indirectly into groundwater.

Regulators for the EP regime are the **EA** and **local authorities**. The EA regulates the following:

- Part A(1) installations.
- Part A(1) mobile plant.
- Waste operations.
- Radioactive substances activities
- Water discharge activities
- Groundwater activities

The relevant local authority will regulate:

- Installations identified in Schedule 1 of the Regulations that are:
  - Part A(2) installations.
  - Part B (Local Air Pollution Prevention and Control).
  - Part A(2) and Part B mobile plant.
  - Waste operations undertaken as part of the Part A(2) or Part B installations or Part A(2) and Part B mobile plant.

Note: In Scotland, under the IPPC permitting system, SEPA is the sole regulator.

Installation regulated facilities must under the **EP Regulations** prevent or, where that is not possible, reduce pollution from a number of industrial and other installations and operations, by means of a permitting process which is based on Best Available Techniques (BAT).

The constituent parts of BAT are as follows:

- **"Best"** means, in relation to techniques, the most effective in achieving a high general level of protection of the environment as a whole.
- **"Available"** techniques means those techniques which have been developed, on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the cost and advantages, whether or not the techniques are used or produced inside the United Kingdom (as long as they are reasonably accessible to the operator).
- **"Techniques"** includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

Assistance on determining BAT can be found in **EP Regulations 2010 Guidance Notes** produced for numerous relevant industrial sectors.

More...

http://www.environment-agency.gov.uk/business/topics/permitting/36419.aspx

Part A(1) and A(2) installation permits take a wide range of environmental impacts into account, these include those that are considered in an integrated manner:

- Emissions of pollutants to air, water and land.
- Energy efficiency; waste management.
- Consumption of raw materials.
- Noise and vibration.
- Site restoration and decommissioning.
- Accidents and incidents affecting the environment.

Installation permits under the **EP Regulations 2010** are required by a number of different activities (see schedule 1 for the full list), e.g.:

- Energy industries.
- Production of metals.
- Chemicals manufacture.
- Recovery processes, e.g. waste oils and incinerators.
- Tanneries.
- Surface treatments, e.g. paint and printing using solvents.
- Slaughterhouses.
- Large food and drink manufacturers.
- Intensive rearing of poultry and pigs.
- Dyeing of fibres and textiles.

There are three types of environmental permit that can be issued by regulators:

- **Standard permit** - requires operators to comply with a single set of rules and is used for low to medium risk activities such as waste transfer station operations or material recycling sites.
- **Bespoke permit** - consists of a set of site-specific conditions for activities that have a potentially high impact on the environment. Such permits may include more than one regulated facility on a site.

- **Consolidated permit** - a combination of more than one permit into a single permit provided they are regulated by the same regulator.

More...

http://www.netregs.gov.uk/

Summary

- Instruments used by governments that may bring environmental change can be categorised as information, financial, voluntary and legal.
- Common law and statute law are both sources of law.
- Breaches of criminal law may result in fines or imprisonment, breaches of civil law often results in compensation.
- Types of criminal law include Acts of Parliament and Regulations. Civil law torts include nuisance and negligence.
- Nuisance is defined as unreasonable interference with the legitimate use/enjoyment of land.
- Negligence is defined as failure to undertake an action that would be expected (omission) or undertaking careless behaviour (act).
- UK law can be influenced by both international and European law.
- Environmental regulators include Environment Agency/Scottish Environment Protection Agency, local authorities and water companies.
- Criminal notices for breaches of environmental law include enforcement notices, abatement notices, suspension notices, remediation notices and revocation notices.
- Civil sanctions include compliance notices, restoration notices, variable monetary penalties, enforcement undertaking, third party undertaking, fixed monetary penalties and stop notices.