Part G

VULNERABILITY OF HUMANS AND THE ENVIRONMENT

Introduction

This is a reprise of Part F but is given in more detail as it is a complex subject.

In an earlier part it was pointed out that the human is very vulnerable to a series of physical and chemical assaults. This part is an expansion. The objective is obviously to prevent the harm at source but in line with the ***defence in depth*** it is necessary to protect the human against the finite but unlikely probability of failure of the first line of defence.

This section was located here as it is really a management issue so sits well just after the "management issues".

It is now been equally evident for over 100 years that humans have enormous potential to destroy the Environment as well as to cause injury. Initially the environment was considered to be "*air*" or "*water*", to a lesser extent "land" and the working conditions of "*heat and illumination*". The scope of the Environment now extends to longer term projections and includes "*noise*", "*visual impact*" and the effects on *flora and fauna*.

It is only in the last few decades that there is a realisation that the impact on the Environment has a significantly longer time frame or cycle than the impact on humans and that the changes are more subtle; there is no physical protection for the environment as there is for humans. For example it is not entirely clear if global warming is due to Carbon Dioxide alone or carbon dioxide and other parameters but assuming it only carbon dioxide it is a problem which has to be solved in the next fifty or so years. There is a reasonable assumption that the Carbon Dioxide load must be reduced over the next few decades but the Carbon Dioxide already in the atmosphere must also be reduced and that will take time. Total reliance on "*Renewable Energy*" is open to debate. Wave energy may be derived from the rotational energy of the earth (as is tidal energy), but there are no waves in Switzerland!! Stored energy is valuable for peak sharing but it can not be sustained. If Humans wish to have steady improvement in the quality of life and maintain the environment a more fundamental approach must be adopted to power generation and utilisation. This is called "***Sustainable Development***".

Most companies now have an Environmental Policy Statement and Environmental and Safety Targets are given in the Annual Report (HASWA requires a Safety Policy Statement). It is right therefore to discuss the Human and Environmental Assault together. They do not always pull in the same direction, the benefits to Safety may have an environmental impact and benefits to the environment may have a negative safety impact. It is prudent that all scientists/engineers to bear this in mind.

The time frame of the impact of events on humans and the environment are very complex and the following are an attempt to analyse of some of them. There are well recorded events which can be traced back by well meant events, none less than the use of CFCs which had positive safety benefits but we now know that they have had a serious impact on the environment. The following analysis is a serious one but is also a personal perspective.

Effects on the Human / Safety / Environment

The following are a brief analysis of Global Events and their effects on Humans and the Environment. G1/2

Table G.1 A brief analysis of Global Events and their effects on Humans.

Event and discussion	Immediate	Up to 10 years	Over 10 years
A Lake Nyos – Cameroon 21/8/86. Massive release of $CO/CO_2/H_2S$ from rotting debris in a volcanic crater lake, about 200,000 tonnes of gases was released.	About 17,000 deaths	Severe eye damage, skin damage from gases	As up to 10 years
B Minimata Japan – 1970s. Mercury effluent was released into the sea and entered the food cycle through the fish and then entered the human cycle with severe brain damage.	Nil	Localised severe brain damage in a small community	As up to 10 years
C Chernobyl (USSR) – April 1986.	2 immediate deaths and 27 delayed due to radiation	Hypo thyroidism and carcinoma	Up to 10,000 premature deaths
D Bhopal – India – Release of MIC to the atmosphere	2500 deaths in a few days	Total deaths of the order of 5,000. Serious eye and lung damage	15,000 Premature deaths due to pneumonia, severe impact on a society
E Chrome Processing 19th/20th Century	Nil	Cancer deaths	Cancer deaths
F Coal Gas Production	Real	Real	Possible Cancers
G Sea Empress – Milford Haven – about 50,000 tonnes of oil spilt	Nil	Health effects noted	Health effects, possible premature deaths (unknown)
H CFC 1970	Nil	Nil	Hundreds of Melanoma deaths
J Aswan Dam - Egypt	Positive	Positive	Fertile land becomes less fertile leading to potential starvation. Many metres of soil deposited behind the dams. Loss of soil feed downstream.

Table G.2 A brief analysis of Global Events (see table G.1 above) and their effects on the environment			
Immediate	Up to 10 Years	Over 10 years	Analysis
A Lake Nyos – Cameroon Negligible	Nil	Nil	This was caused by human migration towards water sources due to local population growth in a poorly developed area of the world. Humans were the main sufferers.
B Minimata Japan – 1970s. Nil	Nothing serious – fish become inedible	Nothing serious	Food sources become polluted by uncontrolled release of mercurous compounds.
C Chernobyl (USSR) – April 1986. Nil	Uncertain	Uncertain. Large area sterilised for human use	It is likely that the main impact will be on humans. As research is centred on humans the impact on animal/vegetable life is less certain.
D Bhopal – India – Release of MIC to the atmosphere Nil	Nil	Nil	The cause of the event is discussed elsewhere but was precipitated by the population explosion and human migration to a source of employment
E Chrome Processing Nil	Uncertain	Land sterilised for human use, vegetable growth stunted	Uncontrolled dumping of spent products, very expensive clean up – cost unpredictable
F Coal Gas Production Nil	Nil	As above	As above
G Sea Empress – Milford Haven – about 50,000 tonnes of oil spilt 1000s of sea birds killed	Negligible	Negligible	Very costly clean up short term major environmental pollution and effects. Possible delayed deaths in people living down wind
H CFC 1970 Nil	Negligible	Vegetative mutation	This is a potential time bomb
J Aswan Dam Egypt Loss of Historic Architecture	Degradation of fertile land	Loss of fertile line	The short term benefits are clear but the longer term effects are far less easy to predict

These tables are designed to show that S & E do not always pull together and that there is a complex relationship which must be recognised.

These examples of "disasters" are in no way complete and are only the tip of the iceberg. Particularly the evidence points to the fact that in the case of the human and environment assault the effects were poorly (if ever) predicted and that in retrospect the remedial costs more than outweigh the perceived benefits.

It would be wrong to think that there was a deliberate intent by our fore fathers to injure and kill people or to desecrate the environment. The real cause is the relatively slow learning curve and is also probably due to poor or little hindsight. This has been discussed in the introduction and is expanded in more detail here as means to urging caution and discretion.

Effects of the Environment

The damage/harm created by the use of Asbestos as an insulant is not disputed but no one could have predicted the effects on the lung nor was it reasonable to do the experimentation. Asbestosis and Mesothelioma was not immediately obvious and was probably diagnosed as lung cancer until more accurate diagnostic techniques were developed. Once it was recognised that there was a new tumour it was necessary to research its cause. Before the finger could be pointed at Asbestos there were two requirements - Medical Research and Social Research. This was also true for Black Lung or Silicosis in Miners. Once the pattern of lung damage/tumours was established it was not unreasonable to take the logical step of assuming that dusts, organic or inorganic, are potentially harmful. This does not help the hundreds of people who have died but the knowledge base has advanced such that face masks are far more common now than they were 20 or 30 years ago.

Many years ago it was common to clean tools in petrol and even to fill up car fuel tanks while looking into the filter pipe to watch for a rising level. Benzene is now recognised as a carcinogen and automatic cut offs in the filter are now standard practise (It is recognised that there are other reasons for this but it is also beneficial in preventing massive inhalation of Benzene vapours). Even now there is some uncertainty as to the tolerable levels of Benzene in the air and the ***Maximum Exposure Levels*** (MEL) is dropping year on year. Alpha Naphthylamine was produced up until the mid 1960s when there was irrefutable evidence of a link between bladder cancer and Alpha Naphthylamine (actually Beta Naphthylamine as a by-product). This effect was unexpected. Both of these incidents pointed strongly towards the link between Aromatics and Cancer and there are now biological screening tests for chemicals to determine if there are carcinogenic properties.

It is now fully recognised that many people have allergies to a variety of products about 10% are allergic to grass pollens (Hay Fever) others are allergic to house dusts and others to Nickel (amongst others). It has taken time for the research to realise that it is a two- step process. A low level dose will make them “sensitive” - “sensitising” - but then a higher dose creates the reaction “elicitation”.

It would be reasonable to assume that, as it is now recognised that “dusts”, Aromatics and nearly every other chemical could cause ill effects on humans but the problem is establishing the likelihood or link. This is best illustrated by Thalidomide, which was tested before introduction on laboratory animals and appeared to be safe. Unfortunately it is now known to be ***Teratogenic*** before the third month of pregnancy and there is now evidence that it is also ***Mutagenic*** - that is it genetically transmitted from those affected by Thalidomide. Increasingly it is being recognised that alcohol, smoking, aspirin and other nominally benign chemicals can be Teratogenic and in some cases be mutagenic if the foetus is affected in the first trimester. It is clear that correlation of product/chemical and effect requires detailed knowledge of exposure and timing. This to a degree is now being addressed in industry by the records required under the Management and Health and Safety at Work Regulations.

The final chilling fact that must be recognised is that animal experiments may not be accurate. The biochemistry and physiology must also be similar to humans. Experiments on rats may produce different responses between species of rats and that physiologically pigs are nearer to that of the human and for this reason pigs are being used for human organ donors.

It is clear from this brief analysis that there is a lead - time of about 20 years for the effects of many chemicals to become evident.

In the case of the environment it has taken about 20 years for the effects of C.F.C.s on the ozone layer to become evident and unfortunately the effects will not be reversed overnight and it could worsen for some years yet before a reverse trend is noted. In many cases the gross pollution of years gone by is being recognised and serious attempts are being made to arrest the effects in present processing industries but the historic residues are a major problem, which has not been resolved. It is now widely recognised that Volatile Organic Compounds (VOC) have a far greater "***green house effect***" than carbon dioxide. The "greenhouse" ratio CO_2: Methane is greater than 1:10. However there is still debate about the effects of flatus from bovine species, from termites and from methane seepage from old below ground carboniferous sources.

It is clear that there is an increasing understanding of the "environmental impact" of chemicals but there is a price, which has to be paid. In many cases the environmental "improvements" expose humans to a more immediate risk to life and in others there is a "trade off" of one environmental issue against another. This is illustrated by the cleanup of water in the offshore oil industry. The need to reduce visible pollution from produced water on the installation resulted in a trade off of <u>about</u> 500 kg of bio-degradable dispersed oil against the production of 200/Te per day of Carbon Dioxide. Which is the most damaging to the environment?

<u>Human Vulnerability</u>

While humans have strengths they also have weaknesses both physical and psychological. These limitations range from limited strength, reach, stretch, focal vision, and attention span through to unpredictable reactions under stress and unforeseen circumstances. These limitations impose serious problems for the designer, manager and supervisor which have to be addressed by design, training or sympathetic understanding. The study of the humans under stress is very complex and whilst fruitful it is still not fully understood.

<u>Physical access</u>

Access to equipment is an obvious problem which designers are expected to address but sometimes forget. There is no excuse for fitting an inaccessible valve beside platforms or walkways such that an operator has either to crouch or, even worse, to stretch over or through handrails to reach it. Both involve the operator being in a poor state of balance and leverage. Another example of difficult access may be the use of chain operated valves, these are mechanically inefficient and they are difficult to reach for a short operator and a potential "lasso" for a tall operator. (Said with feeling). There are other obvious forms of poor access such as the inclined valve which does not allow uniform leverage, the rising stem valve which juts out into the passageway and, of course, the vent or drains which always seem to be just out of reach.

Access ways should have a head clearance of at least 2 m and preferably 2.2 m. Too often it is forgotten that a safety helmet will add 5 cm to the height of individual and thermal insulation can remove another 5 cm clearance. Shoes add 2 to 3 cm and the peak of the helmet obscures upward vision - as a consequence collisions occur, the helmet usually preventing serious injury but can produce "whip lash" effects. Stairways should have adequate tread depth rise and stair angle. The arrangement should ensure that a toe is not caught on the tread while ascending or a heel caught on the tread while ascending. Sometimes it is necessary to install vertical ladders particularly up distillation columns; landings should be installed every 25 m for resting.

There are a number of important safety features associated with stairways and ladders:

Where stairs or ladders have to have a short riser it is better for this to be at the bottom of the flight and not at the top (for obvious reasons it is better to stumble at the bottom of a ladder rather than the top).

Ladders should have a safety cage above 2 m height and down to the grating level at handrails. Whatever the height of the ladder there should be a self- closing safety gate at the top of the ladder.

The exit from the safety cage MUST not open onto a handrail as people can stumble as they leave the cage and fall over that rail.

Handrails should be at least 1 metre tall and all overhead walkways should have a toe or kick board to prevent objects being knocked onto the unwary below.

All emergency exits should be duplicated, preferably at opposite ends of the walkway or structure. Escape ways should be at least wide enough for two persons to pass in comfort and if used regularly they should be a minimum of 1.5 m wide.

All stairs and landings should be sized so that stretchers can be manoeuvred without lifting them over the handrails.

Physical Ergonomics

Physical ergonomics of weights require skill and training. The straight back lift can be achieved with compact systems but it is not always possible with sacks or when lifting equipment within a crowded area, the load should not create excessive loads on the lower back. (Note: Manual Handling Regulations). Plant layouts should be examined at the design stage by operating maintenance personnel and mechanical handling experts to ensure suitable lifting equipment is available. Simple lifting frames and block and tackle arrangements supported from overhead runway beams will greatly ease mechanical handling.

See also Manual Handling Operations Reg.

Control Room Panel and VDU Screen Layouts

Panel layouts have been the subject of much study and analysis not only in real situations but also under experimental conditions. Typically, the eye has a very limited cone of sharp vision, possibly only two letters in a word. However, the peripheral vision is very useful for picking up moving or flashing data. The ear is the primary warning device, as indeed it is with most animals. Reading data is most easily done at eye level but if any head movement is required it is easier to look up than to look down. Assuming an analogue control panel is vertical and some 2 m high only the top half is of any real use. The typical panel layout is shown below.

Height below top of panel (m)	Zone	Depth of Zone (m)
0 - 0.25	Zone A	0.5
0.25 - 0.75	Zone B	0.5
0.75 - 1.25	Zone C	0.25 - 0.5
Below 1.25	Zone D	1.00 - 0.75

Table G.2 Typical Layout of a Control Panel

Zone A will usually contain alarms and visual warning devices which are only required occasionally.

Zone B will contain the most important data and controllers with all of the main controllers set at about eye level. At the top of this zone will be indicators, which do not require adjustment.

Zone C is an area at waist sight and can be used for the less important controllers. The lowest part may only be of use for simple data points.

Zone D is of no real use to the operator as it is difficult to see and probably requires stooping or bending to view the instruments.

Increasingly control rooms are moving to TDC and touch screen displays. These notes are intended to show some of the problems that have existed and still exist but in as different form in modern control rooms.

Some control panels have inclined aprons at waist level, which, increase the effective visual zone but severely limits the reach of the operator, affecting his ability to cancel or adjust controllers in the vertical section. The final design of the panel is complex and may vary from plant to plant and company to company.

The same analysis can be applied to VDU screens. The lean towards computer- controlled plants requires careful architecture of each "page" or display on the screen. Although the layout on the screen is an essential safety feature, no less important is the order with which the pages are recovered and the data displayed on that page. In traditional analogue instrument panels all data was visual and the operator could "scan" different panels rapidly by eye, however only a limited amount of data can be stored on each "page" of a computer screen. The analysis of the plant using a Hazard and Operability Study will help the control systems designers to devise the best and most informative displays. The prudent screen designer should consult the operator to ascertain what key parameters should be visible on all screens so as to assist in diagnostics and prompt fault diagnosis. The effects of VDU screens also have to be considered. (Note also, Display Screen Equipment Regulations).

<u>Stress and Unpredictable Behaviour</u>

The design of control rooms and plant instrumentation must take into account human frailty. If too much data is fed to the operator he/she will become confused and make irrational decisions (information overload). The repeated sounding of alarms during upset conditions can either distract the operator so that he/she fails to take effective control or may ignore important alarms and block the mind to additional incoming data. Eventually the operator may panic and carry out irrational acts. There are no hard and fast rules for dealing with this situation but the following are some practical suggestions.

<u>Training</u>

The better the operator's understanding of the plant the better will be their ability to control it. This should not only be ***cause and effect*** training but also the ***dynamics*** of the process. This knowledge can be achieved through on-line and off-line training using simulators. The more practised the operator the more likely he/she is to take the correct action when the need arises.

<u>Operating Instructions</u>

Well prepared instructions can help the operator understand what is happening in the plant, if warnings are added the operator will understand the need the work within a tight operating "envelope". This will also give the operator confidence and will also show the operator that management are operating in a responsible manner.

Avoid Information Overload and Mind-set

Alarms should also be fitted if they are essential and should be calibrated so that set points are at reasonable levels outside the normal operating envelope. The worst situations occur when alarms are frequently sounding in the control room. Operators then become engrossed in the task of control and alarms are ignored, alternatively operators try to respond to alarms and forget about the main task in hand which is control. The opposite can also be true on stable and simple plant, operators may ignore changes in variables which experience shows do not usually change, vessels may drain or fill and no action be taken even to the point of alarms being ignored.

Control instruments should have some form of supplementary "check indicators" or other diagnostics. These should be simple, easy to read and readily accessible to the operator. The simple expediency of recording control values and actual values on record sheets or data loggers will show if instruments are drifting or giving false readings. This will assist the operator to make the correct deductions. It may be necessary to install additional diagnostics to assist the operator; these will usually be identified during a Hazard and Operability Study. Modern controls can incorporate a warning element for the rate of change or drift.

Experience/Confidence

A competent operator with a depth of experience is worth his/her weight in gold. It may take years to train this person but if management are never seen to give help and guidance, operators will lose their confidence.

In summary, good operating instructions, good management, good training, good plant design and good control room layout can go a long way to overcoming stress. Ultimately the final protective system will be the Emergency Shut Down (ESD) system, which will put the plant into a "safe" condition and allow the operator to restart in an orderly manner.

"**SAFE" was put in inverted commas as the very act of shutting down and re-start carries some risks due to thermal cycles or upsets.**

Personnel Protection

One of the objectives of safe design is to avoid the need for personnel protection. This is a form of *intrinsically safe* design. There are some obvious exceptions to this principle for example; exposed moving parts on machinery should be fitted with guards. It must not be forgotten that ties, cuffs and long hair may slip between the guards. Management will normally supply overalls for machine minders and require the use of hair -nets where necessary. More detailed guidance on Personnel Protection is available from a number of sources.

The most vulnerable parts of the human are, starting at the top: head; eyes; ears; lungs; hands and feet. Various forms of protection are available; however these are not total or absolute and have limitations. The following sections discuss their benefits and limitations.

The Brain

This has already been outlined in Part E. It is a topic that must be given a high priority so has been repeated in this part. Attention to the mental pressures of plant and office are key to safety.

Information Overload

In Information overload the brain has TOO MUCH information and can not sift the critical or top level information from the low level unimportant information. In effect the reasoning powers are swamped by essential and trivial information and so the outcome is that nothing is done. This can be analogous to a juggler - there is an absolute limit to the ability to handle objects and beyond that limit things get dropped.

The concept of Information Overload can be dealt with by two strategies. At one level the operators have sufficient resources to handle all of the workload and at the other, the information is filtered and presented on a clear and unambiguous form. In process plant it is not only the information but the size of the plant. On a small plant where the transit time may be small the supervisor may be able to handle more as there is less time used in moving from A to B to C in data collection. Above all the presentation of clear unambiguous data with the appropriate diagnostics in a Control Room is fundamentally important. The human can only accept a limited amount of information at any one moment and the message must be clear and unambiguous. This argument could also apply to an office environment where that are pressures to achieve targets.

Training and background knowledge all help to reduce the potential for information overload as also does practices. There are no solutions or fixes; an understanding is required as well as the open mind and eye. The key question must be:

"How could I handle the problem/problems professionally and without error?"

Mind set

The person has a fixed idea and can not be convinced that there may be an alternative explanation or idea. It could also be called "tunnel vision". Nothing but nothing will convince that person that there may be an alternative explanation.

Cognitive Dissonance

This is quite difficult to explain. The mind tries to fix the evidence into a picture. Some does not fit so is rejected , reasoned away or refined to fit the rest of the evidence. The brain is quite convinced that the evidence is now consistent but ignores the fact that some key evidence may have been rejected or distorted due to some erroneous logic.

Panic

The person just can not make any decisions and could take the wrong actions!

The Body General

The Head

The design intent of a safety helmet is to arrestor to deflect light dropped objects and to deflect the head away from beams, fittings, brackets, etc. It does not protect the head from sharp falling objects but should protect the head from serious injury from, say, a dropped spanner. The oblique impact loads when hitting low beams/piping can lead to "***whiplash damage***" to the neck. The wearer may however be knocked out by the impact. Safety helmets are a necessary protection on congested plant but are not particularly comfortable, they are hot and "sweaty", the peak obscures upward vision and can be the causative agent for impact on low beams; as a result staff cannot be relied to wear them under all circumstances. Maintenance areas should therefore be roped off and "No Entry" signs displayed. Periodic housekeeping tours should be carried out to identify and remove loose objects. Guards should be fitted around head hazards and if necessary they should be painted in visible colours (usually black painted and yellow) and warning signs fitted. While the designer must try to avoid poor design features, some instances may exist and the good manager should try to protect the operator wherever possible.

Eyes

Many types of eye protection are available (glasses, goggles, visors). Some protect the eyes from wind-borne dust or chemical and, others from high levels of light or other forms of radiation. Goggles can become uncomfortable and "sweaty" or "mist up". For people not used to wearing glasses can find them a nuisance in the rain. Goggles by nature of their design restrict peripheral vision and make the operators' task more difficult. The fit of the goggle round the face and particularly round spectacle frames is not good and drops of chemicals can still penetrate so face visors may be appropriate. In non-hazardous plant it may be desirable to supply industrial glasses with toughened glass and side shields to protect the eye against dusts.

Ears

High noise levels - over 85 dB (A) for 8 hours exposure per day and sharp impactive noises (as in sheet metal works) can lead to hearing damage. Noise induced hearing loss is rarely obvious until the damage is quite advanced. Only then is it noticed that conversation becomes difficult to follow in noisy rooms. In particular the sounds which result in high frequencies (s, d e and such are most distorted. Eliminating noise at source is a task for specialists but personnel protection may still be necessary. Table G 3 gives a typical indication of noise levels. Ears can be protected by means of ear plugs, which cut out the most destructive high frequencies, however they must fill well. Equally ear muffs or ear defenders can be used but these must be fitted correctly and have a good seal round the edge. This can create problems with beards, long hair and for wearers of glasses. Ear muffs can become uncomfortable and "sweaty" after prolonged use and are again not popular with operators. Ear plugs are more comfortable but a less efficient protection, as noise can be transmitted through the facial tissue and still cause damage to hearing.

Ear protection is not an ideal solution to high noise levels as sound energy can still be transmitted to the ear through body tissues. Also, ear defenders may "leak" sound and communication is made difficult, if not impossible. Sound attenuation at source or better still designs which are inherently low sound emitters is much better. Noise at work is covered by regulation in the UK.

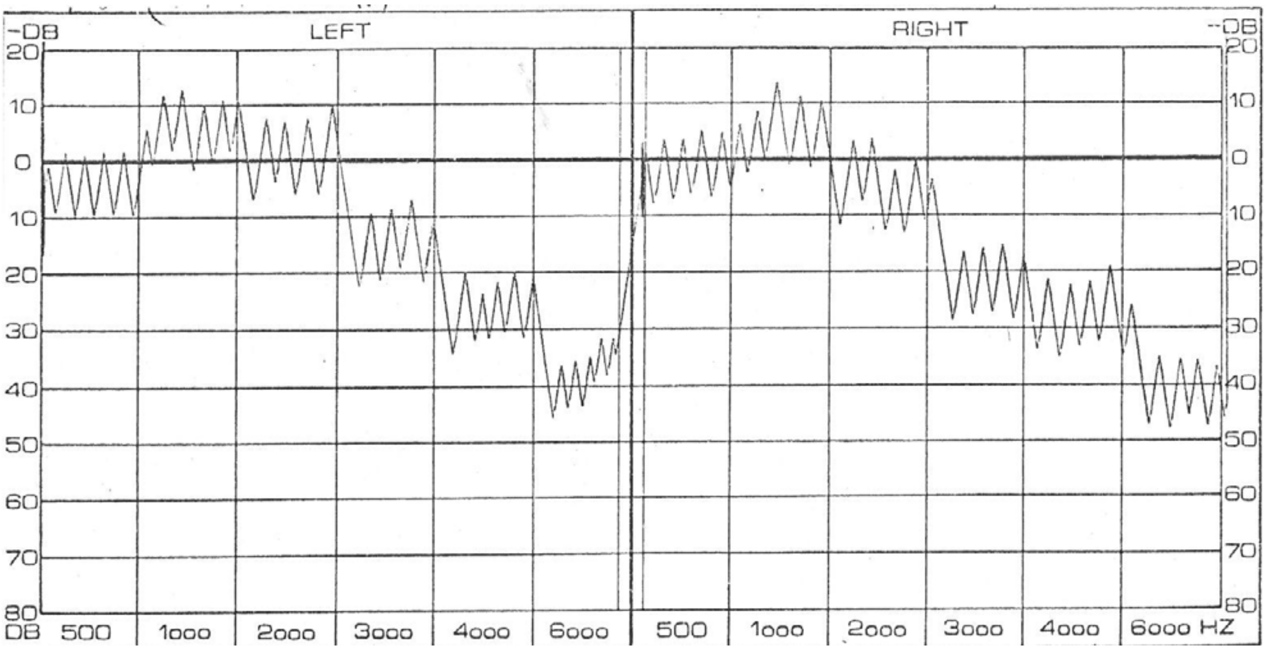
Table G.3 Noise Levels and equivalents

Approximate sound pressure level, dB (A)	Source	Distance from source, m
200	Moon rocket at takeoff	300
140	Jet aircraft at takeoff	25
100	Very noisy factory	
90	Large diesel lorry	7
80	Alarm clock	1
75	Inside a railway carriage	

70	Inside a saloon car at 50 km/h	
65	Busy office with typewriters Normal conversation	1
40	Quiet office	
35	Quiet bedroom	
25	Still day in the country	

The audiogram shown below was taken of a person in his early 30s. He had been subject to high noise levels for about 8 months and received “2,500 noise excess units” without adequate hearing protection. He suffered from tinnitus. This is equivalent to 2,500 hours at 93 dB or 1250 hours at 96dB.

Note the drop-off in acuity above 2kHZ. This is the first sign of noise induced hearing loss. It can not be repaired. 40 dB hearing loss at 6kHz is significant as hearing, particularly of speech becomes distorted. A repeat taken some 30 years later showed the same drop-off but the whole audiogram was 15 dB lower. This is age hearing loss.



Plot G.1

Hands

Gloves with rubber studs can be very useful for preventing loss of grip on handrails. Hands can be injured by sharp objects, hot surfaces, chemicals, and of course dropped objects. The usual protection is gloves, be these “heavy duty” or gauntlets. They should be appropriate to the protection required. They are not popular with operators who lose their “touch”; generally gloves are “clammy” or “sweaty”. The primary objective must be to protect the operator *at source* but in some cases this will not be possible, furnaces will always have hot surfaces and sheet metal sharp edges or “rags”. Remember to fit the gauntlets **INSIDE** the external body protection to avoid ingress of harmful fluids into the gauntlet.

Feet

Feet are vulnerable to impact through scuffs and dropped objects as well as hot fluids. The typical industrial shoe or boot protects the foot against glancing impact or sharp objects and light dropped objects (10 kg m), they cannot be fully protected against dropped heavy objects and a higher level of protection may be required. Industrial footwear will also protect the foot against hot fluids provided they do not enter the footwear by fitting then inside the body protection. In many cases, the safety footwear must have electrical insulating properties. Remember to fit the boots **INSIDE** the external body protection to avoid ingress of harmful fluids into the boot.

Lungs

Lungs can be severely affected by dusts or toxic gases. The simplest protective device is a dust mask, which fits over the nose and mouth and filters out solids. The life of this type of mask is limited and the seal round the face is important, beards generally reduce efficiency. Face masks for toxics may use either activated charcoal absorbents, a compressed air supply will offer the great protection but once again the seal against the face is important, beards MUST be shaved off. A better solution is to ensure that hazardous fluids do not leak out by avoiding leak sources such as flanges, packings and seals. Face masks would then only be required to combat the effects of mechanical failure. An alternative approach is to ensure good ventilation and close monitoring of the environment either automatically or by “policing”. There is, however, an increasing trend, for environmental reasons, towards containment at source and it will be increasingly important to prevent any leakage of material. All welded piping is a possible solution but this has its own problems when maintenance is required!

Face masks or breathing systems can be used to protect against the effects of toxic gases. These are generally suitable for emergency situations or some difficult forms of maintenance work. It is unacceptable to expect process plant workers to use gas masks on a routine basis they must only be used in an emergency.

General Body Protection

Toxic chemicals, particularly acids and alkalis may attack the skin. In a well-run plant chemical leaks should not occur on a day-to-day basis but drops may leak from glands etc. When carrying out maintenance, fluids may be released and, for hazardous materials, it is necessary to specify fully body protection. In some instances process materials may be so hazardous that full body protection is required at all times in case a leak suddenly occurs.

A full visor or, a headpiece and visor can protect the face. The body can be protected by a total enclosed suit made of impervious fabric. The seal between the parts of the suit and, of course, boots and gauntlets require careful consideration; the top half must overlap the lower half. Similar the overlap between body protection and boots and gauntlets must be tight.

In some industries, for example offshore oil production, it is becoming standard practice for all personnel to wear overalls of fire resistance material.

Balance

Consider the benefits of harnesses and fixed anchor points where the operator might be exposed to the extremes of weather or work in a precarious position such as a window cleaner.

Muscle Damage

This is best dealt with by affording good access, proper lifting facilities and the use of good, well trained ergonomics. Do not allow stretching or operation at an angle to the body. This is equally applicable to an office where back problems probably dominate the injury profile.

Control of the Working Environment (Airborne Materials)

Some plants - particularly enclosed plants which handle dust or toxic fumes - will require ventilation, this can be in or one of two forms:-

1. Removal of the materials to avoid affecting the employee.

2. Dilution of the contaminant to acceptable levels.

In the first case the equipment is either enclosed in a booth so at to contain the material or is located under an exterior hood. In both cases air is drawn from the hooded area and discharged into a safe location where the material may be recovered in dust cyclones, scrubbers or discharged to the atmosphere where it is diluted by normal dispersion mechanisms.

In the specific case of degreasing vats, where volatile organic compounds may be released, more sophisticated ventilation; possibly involving the use of refrigeration may be required. This is a specialized study in itself.

Summary

At best protection is uncomfortable and unpopular. It must be fitted properly and used with due recognition of its limitations; every effort MUST be made to prevent the potential for harm to the operator at source. When there is no way of avoiding the hazard such as head or eye hazards the use of protective measures must be rigorously enforced by Management through example and a policy of policing.

Not only must protective clothing, etc be provided, it must be suitable for the task in hand. There have been many cases where incorrect protective equipment has been used with tragic results. Manufacturer's representatives can usually provide the necessary information and, of course reference to appropriate standards should be made. (See also PPE)

Toxicology

Many chemicals are potentially harmful to humans and other life forms. The degree of harm depends on the form of the substance, it concentration, its method of ingestion, the animal species concerned and a number of other factors. The term ***toxicology*** refers to the study of harmful effects caused by the presence of chemicals, other than those, which occur naturally.

The main sources of access for toxic materials to the human body are by nose; mouth and, of course, skin. The concentrations, durations and effects are specific to the material itself and the effects may be specific to the site of entry to the body. There is often difficulty in determining safe levels of exposure to chemicals as the effects are difficult to measure and the response will vary from one individual to another. Much of the available data has been obtained from animal tests where the animals' metabolism differs from humans. There can therefore be difficulty in translating the results of laboratory tests into useful guidance. For example, some materials are especially harmful to women of childbearing age and may cause abnormalities to their children. Toxicology is therefore a very specialized subject. It is, however, useful to have an indication of the most common terms used and these are given below:

Exposure:	Amount of **toxic** substances to which an individual is exposed. This may be present the amount ingested, absorbed or inhaled or it may refer to the integral of concentration with time in the immediate environment. Where ambiguity may arise the basis used to define the exposure should be specified.
Dose:	Used as a synonym for *exposure*.
Toxic:	The property of substances which, when introduced into or absorbed by a living organism, destroy life or injure health.
Poison:	Common term for a *toxic* substance.
Corrosive:	In the context of *toxic* substances a *corrosive* substance is one, which may, on contact with living tissues, destroy them.
Acute:	Immediate, short-term. Relating to *exposure*: conditions, which develop rapidly and may cause harm within a short time. Relating to effects: which appear promptly after exposure.
Chronic:	Persistent, prolonged and repeated. Relating to *exposure*: frequent, or repeated, or continuous *exposure* to substances. Relating to effects: when physiological affects appear slowly and persist for a long period or with frequency recurrences.
Carcinogen:	A substance which produces cancer.
Toxicity:	The relative power of a *toxic* material to cause harm.
Irritant:	A non-corrosive material which may, through immediate prolonged or repeated contact with the skin or mucous membrane, cause pain, discomfort or minor injury, or injuries as such.
Asphyxiation:	Endangering life by causing a deficiency of oxygen.
Long Term exposure Limit	A time weighted average concentration, usually averaged over 8 hours, which is appropriate for protecting against the effects of long-term **exposure**.
Short Term Exposure Limit	A time weighted average concentration, usually averaged over 10 minutes, aimed at avoiding **acute**

	effects.
Threshold Limit Value – Time Weighted Average (TLA-TWA)	The time-weighted average concentration for a normal eight**-hour** workday or 40-hour workweek to which nearly all workers may be exposed, day after day, without adverse effect. (To be superseded by the term **Control Limited).**
Threshold Value Ceiling (TLV-C)	The concentration which should not be exceeded even instantaneously.
Lethal Dose (LD50)	The quantity of material administered orally or by skin absorption, which results in the death of 50% of the test group within a 14-day observation period.
Lethal Concentration (LC50)	The concentration of airborne material, the four-hour inhalation of which results in the death of 50% of the test group within a 14-day observation period.
Immediately Dangerous to Life or Health (IDLH)	Conditions such that an **actual exposure** will lead to **acute** or **chronic** effects.

The following further definitions are also of use:

Mutagen: A compound causing genetic damage.

Sensitizer: A compound which generates an immune response.

Teratogenic: A compound that causes birth defects when the developing foetus is exposed.

This list of definitions may appear bewildering; however, they are all necessary and specific. They help to differentiate the effects of different chemicals, the site of access, the consequence and immediacy of the effect.

It should be understood that the toxic effects and concentrations are often derived by experimentation on animals with a very limited amount of inferred data from industrial incidents. The animals tend to be rabbits, rats and mice. While experimentation *in vivo* is unpopular with the public as a whole, it is an unpleasant necessity. There are potential hazards with this experimentation as the physiology and biochemistry of the subject has to be a close match to that of Homo Sapiens. There are a number of readable summaries concerning toxicology and the limitations of this form of experimentation. Bridges gives the following note-worthy warning:-

"Assessment of the lethal effects of chemicals is usually conducted only in rodents yet findings in a rodent may be a poor indicator of toxic hazard to man. Large interspecies differences are also common. Since the Seveso Directive is based on an incident in which Dioxin (2, 3, 7, 8 - tetrachlorodibenzo-p-dioxin-TCDD) was released into the atmosphere it is appropriate to use this as an illustration. Ingested Dioxin is about 100 times less acutely toxic to mice than to guinea pigs, and the Syrian hamster is about

600 times less susceptible than the guinea pig. Differences of this magnitude between three species make extrapolation from animals to man somewhat problematical. In an attempt to identify whether one species is more predictive of lethal properties in chemicals in man than another, Krasovskii analysed the scientific literature on the acute toxicity of some 260 chemicals in man and other mammals. Krasovskii concluded that man was usually more sensitive than the commonly used tested species to the acute toxic effects of chemicals.

If no data exists to identify, for a particular chemical, which species is likely to be the most appropriate representative of the human response the findings from the most sensitive species must be adopted for hazard assessment purposes.

Differences in LC50 and LD50 also commonly occur between animals of different ages, sex, and between strains of animals of the same species. Other factors include timing of observation, housing conditions and diet may also contribute to variability of results".

The LC50 and LD50 refer to an average healthy human. There may be significant differences between healthy subjects and ones with bronchitis or other health problems. The values quoted must be treated with caution and the data source checked carefully for applicability and authenticity. The history of Thalidomide is a warning against the blind acceptance of experimental data derived from animals. One particular problem is to be found with carcinogens which have long induction periods and where the history of exposure may be limited, particularly in a migrant working population. There are a number of sources describing the toxic effect of chemicals, the best known being Sax N I and Lewis J R, 1989, 'Dangerous Properties of Industrial Materials'; Van Nostrand Reinhold, New York, USA, and Bretherick L, 1985, 'Handbook of Reactive Chemical Hazards'; Butterworths, London.

The HSE publish short term and long-term exposure limits under their Occupational Health Series.

Toxic Doses

The toxic doses of a mixture of gaseous chemicals to achieve certain effects, for example in a gas plume, are often described by:

$$Dose = \int C^n t \qquad \textbf{(G.1)}$$

Where:

C = concentration - ppm

n = chemical dependent factor of 1.6 to 2.8

T = time- s

This equation has to be treated with care as the concentration in the plume is not constant and may vary by a factor of 2 to 3. Most dispersion programs give time weighted average concentrations - not necessarily dose values and once again there must be uncertainty as to the calculated value with the time varying concentration inherent in the dispersion process.

Alternatively the effect may be described by a probit equation of the form

$$\mathbf{P = K_1 + K_2 \ln (Dose) K_3} \qquad \textbf{(G.2)}$$

Where:

P = probit (relationship to the probability of fatality)

$\mathbf{K_1, K_2, K_3}$ and **n** are constants for any specific gas

Dusts

There are many examples of the harmful effects of dusts. The classic cases being silica in mines, which leads to pneumoconiosis and asbestos and, leading to Asbestoses and Mesothelioma. Wood dust can also lead to damage to the lung.

Metals

Many metals are toxic, including cadmium, chromium, mercury and lead, all of which can gain access to the lung in the vapour phase. Low-level concentration, for example ingested in food, can also cause serious health problems.

Noise

All process plant has the potential to produce noise; the frequency and strength of the noise may come from many sources. Frequencies produced are quite specific, for example electric motors will produce frequencies, which are multiples of 25 Hz or 50 Hz. Gearboxes emit frequencies at shaft speed and multiples of these and also the gear mesh frequency. Noise due to the flow of fluids is typically in the range of 1 kHz to 20 kHz, with leaks producing even higher frequencies. Turbines, control valves and ejectors also produce noise at high frequencies. Noise and vibration can be considered as synonymous. Low frequency noise has relatively low energy and is less damaging to human hearing but noise above 1 kHz is potentially damaging to the inner ear. (see the audiogram plot G.1)

By convention, noise is defined in Decibels (dB) by:

$$\mathbf{20 \log_{10} (P_2/P_1)} \qquad \textbf{(G .3)}$$

Where:

$\mathbf{P_2}$ **=** pressure of signal

$\mathbf{P_1}$ = reference pressure -2 x 10^{-5} N/m^2.

As noise is measured on a logarithmic scale a doubling of the sound level is equivalent to an increase of 3 dB. As some frequencies are more damaging, the various frequency bands are given a loading factor to average out the damage potential, lower frequencies have a lower loading factor than the higher frequencies. The result of this “normalising” is the *A scale,* dB (A).

Exposure to noise is measured by a dose relationship; with the unit of measurement call the ***Leqs***. The current action level of exposure in the UK is 85 dB (A) for 8 hours but different levels may apply elsewhere. Noise above this level requires exposure to be below a full eight-hour period, for example:

88 dB (A) for 4 hours

91 dB (A) for 2 hours

Exposure to 88 dB (A) for 2 hours + 85 dB (A) for 4 hours constitutes the daily dose so it is normal to require the use of hearing protection within any area where the noise level is over 85 dB(A). If there are high noise levels on the plant it is necessary to establish the employees' base line hearing level and then regularly monitor for hearing loss. Apart from the use of noise doses ***Leqs***, there are overriding limits for impact noise as sheet metal works. Special considerations may be necessary during construction and demolition activities. For example during pile driving or steam blowing pipelines.

Note that noise is not numerically additive, two sources of 45 dB (A) equate to one source of 48 dB(A) and NOT 90 dB(A). Noise from motors, control valves and piping can add up rapidly to a significant overall noise level. The public may justifiably complain if these factors are not adequately taken into account. The planning consent for a new green field site may impose strict noise limitations and, of course, the addition of new plant on an existing site may require extensive noise abatement across the site. Noise reduction is a specialist activity, which often makes use of the techniques in table G 4.

Table G. 4 Noise Sources and Possible Solutions

Noise Source	**Design Solution**
Piping	Heavy wall pipe Dense insulation Flow velocity
Control valves	Silent trims Silencers Booths and insulation
Fans	Silencers Low Noise Fans
Compressor/Turbines	Acoustic booths Limit blade tip velocity
Gearboxes	Design Acoustic booths Low gear mesh velocity
Intakes/exhausts	Silencers Diffusers
Flare stacks	Design

<u>Vibration</u>

Vibration, generally at low frequency, can cause a variety of problems including injury to bones, joints and tissue. The best-known vibration problem is ***white finger*** and has been a problem for personnel working with machinery such as pneumatic drills, riveting guns etc. It usually takes many years for damage to become apparent and is usually irreversible.

Lighting

Process plant must, obviously, be adequately lit to ensure safe operation and easy reading of instruments. It is essential that the work place is adequately illuminated however shadows on the plant and glare are optional problems. Emergency lighting is also essential to allow operators to escape from the site if there is a power failure.

It is sometimes found that scaffolding may screen normal lighting and additional temporary lighting may be necessary, this must conform to the appropriate electrical area requirements. It is necessary to monitor the illumination of the worksite on a routine basis to check that the lights do, in fact, work.

It is also necessary to consider the effect of light on the surrounding environment during the hours of darkness. Flares, for example, may cause problems to local residents, even at a distance.

Uses of nucleonic

Nuclear devices are becoming of increasing use in industry and life in general.

The following are just some.

Table G.2. Some Uses of Radioisotopes, Non intrusive techniques

Technique	Application
Pulsed Isotope Injection	Flow measurement in pipes Flow measurement in reboilers
Drip Feed Injection	Leaks in heat exchangers Tracing underground pipes or drains
Absorption (Neutron)*	Density measurement
Absorption*	Level measurement Interface measurement/control
γ - Rays Scans*	Scanning vessels for solids build up Scanning distillation columns for (a) tray damage (b) flooding (c) tray performance

γ - Rays/X-Rays*	Inspecting welds and castings for defects Inspecting filters, on line, for build up or foreign Inspecting non return valves for damage/performers in flowing conditions Monitoring equipment for corrosion

Nuclear Risks - Ionising Radiation

Obviously, there are special precautions needed in their application but under proper control and supervision their use both in control and as a diagnostic tool is a potent addition to the safety armoury. . Ionising radiation is totally invisible, within the UK; its use must be under the control of a ***Registered Responsible Authority***, prescribed by Regulation.

Naturally, the source strengths have to be powerful enough to penetrate metal and fluids in vessels this in turn may require the evacuation of an area. It should be recognised that ionising radiation exists naturally. It is present in air, rock, food, and cosmic rays and also from medical investigations and traces from residual radiation from atomic weapon tests

Definitions

Four basic types of radiation exist; their effects and penetration ability differ significantly:

Alpha Particles: are essentially charged Helium atoms - they have relatively little energy and can be stopped by a layer of dead skin. Their damage potential from external exposure is low - but internally it is high.

Beta Particles: are essentially charged electrons. They have sufficient energy to penetrate approximately one centimetre under the skin surface.

Neutrons: are uncharged. They are highly penetrating but can be arrested.

Gamma Rays: are electromagnetic waves such as X-rays. They are highly penetrating and are very difficult to arrest. Dense layers of lead and/or concrete are needed.

In summary: Alpha particles are relatively safe when received externally but they can be dangerous if received internally. Beta particles are potentially dangerous if received externally but Neutrons and Gamma Rays are very dangerous if received externally or internally.

Dose

The absorbed dose is called a ***Gray*** (Gy) and is measured in terms of energy density. One Gray is equal to one Joule per metre squared (J/m^2). The damage potential for the four types of radiation differs and the damage potential is normalised into a dose equivalent, called a ***Sievert*** (Sv).

Radiation

The rate at which radiation is produced is called the ***Becquerel*** (Bq). A Becquerel is equivalent to the decay of one radio nuclide per second.

Working with Radioactive Materials

Operators who use radioactive substances are designated, in the UK as ***Classified Workers*** by law, and are subject to:

Periodic Health Checks

Radiation Dose Monitoring (Film Badges)

Detailed Record Keeping

Radioactive sources must not be used indiscriminately. Where they are used, the area must be restricted and cordoned off; this cordon must extend all around the site, over and below, as well as horizontally. Clear visible warning signs must be displayed at all edges of the cordon. Further the area round the site must be monitored for radiation leakage. Sources should be registered with the appropriate regulatory authority then held in a safe on the site when they are out of the safe a record of their movement must be kept.

Environmental Vulnerability

From historic evidence it is possible that there are as yet unknown aspects of the environment and also ways of causing further damage and some may be occurring even now. It takes time for them to be fully identified and it is not possible to redress the balance or eliminate the causes overnight. This also takes time.

The main-routes of assault are

Land

Air

Water

Visibly

Audibly

Flora

Fauna

The last two are sensitive in themselves and there are strong arguments to suggest that there is a strong negative influence on them from many industries. The main objective with SHE is to eliminate the problem or effect and it follows that any process that produces any effluent or waste is not environmentally acceptable (tolerable, possibly). The design or specification of the process equipment must therefore address the environmental issues:

1a) What are the gaseous emissions - fugitive or deliberate?

1b) How can these by contained, recovered and eliminated?

2a) What are the liquid releases - accidental or deliberate?

2b) How can these be contained recovered or eliminated?

3a) What are the solid residues/wastes?

3b) How can these be disposed of in a 'safer' manner with no long-term impact, or eliminated?

4a) What is the visual impact?

4b) How can it be reduced/disguised?

5a) What is the audible impact?

5b) How can it be reduced at source/attenuated?

6) What is the impact on the flora/fauna?

7) How will the process equipment be recycled or disposed of in a 'safe' manner?

It will be noted that no answers are given to 6 and 7.

Note: any release should be logged so as to assist in site restitution. Many old "Towns Gas" works and steel works have left tracts of land that are not fit for human habitation.

It is not always possible to eliminate all sources of release or to ensure that they have no environmental impact. However, attention to the detail of the design and the operational procedures may go a long way towards controlling the releases.

Plants are now becoming subject to Environmental Impact Assessments with set "***consent limits***" for release of effluents. The consent may have limits on:-

Total release per year

Maximum 'concentration'

Maximum 'average concentration'

The topics covered for water may include:-

Temperature

pH

Chemical oxygen demand

Biological oxygen demand

Oil in water (soluble and insoluble)

Solids concentration (suspension)

Concentration of chemicals, e.g. phenol or heavy metals

The topics covered for air may include:-

CO_2 / SO_x / NO_x

Solids (size/weight/concentration)

Other gases/chemicals specified

Colour

It is self-evident that for Green Field sites a 'background' monitor of the 'before' must be taken so that the impact can be monitored and tracked. This requires a tracking programme such as measurements of flow/concentration/quality on a continuous basis.

It may not be possible to eliminate the source of the pollutant, and effluent treatment is the ultimate resort. This is often called 'end of pipe' and very often it is the only approach. Some techniques for the control of gaseous effluents include the following:-

V.O.C.	Volatile Organic Compounds are often removed by ventilation systems with absorption processes in the ventilation process or by combustion processes
SO_x	So_x can be reduced by hydrodesulphurisation or by scrubbing processes using lime.
NO_x	NO_x can be catalytically converted.
Solids	Solids can be reduced by cyclones, electrostatic precipitation or direct filtration

Likewise for liquid effluents:-

pH	pH can be adjusted at source but must be done with care.

Oxygen Demand	Effluents can be oxygenated to reduce the demands for oxygen.
Solids	Solids can be flocculated and skimmed from the system.
Oil	Oil can be biologically digested.
Chemicals	Chemicals can be removed by biological treatment or by precipitation and physical separation.
Incineration	Where appropriate, recovered organic compounds can be incinerated in a registered process.

Likewise for solids:-

The processes will usually involved disposal at a registered site.

In the first few words of this unit, a warning was made for the future. Already it is recognised that rivers can be 'killed' by oxygen depletion and that agricultural run-off (nitrogen and phosphates) can produce toxic algal blooms in late summer. Even the decomposition of organics/chemicals requires oxygen and the oxygen depletion produces sterile rivers. The longer-term effects of poisoning a river are uncertain - there could be an accumulation, leading to silting up of the watercourse. Even now, it is clear that recovery of flood plains for human usage in many countries is a potential time bomb. Concerns are being expressed for the potential for flooding along the River Thames and changes to enhance navigation on the River Rhine have allowed flood water to reach the lower reaches of the river due to by-passing or the elimination of "***flood plains***" have resulted in flooding in areas which hitherto have not experienced these effects. Changes in the River Mississippi resulted in higher flooding in New Orleans in 1994.

Visual light pollution is evident in Britain - there are reasons for good illumination but is it in the interests of the environment? Noise pollution from aircraft is being addressed - but slowly. Certain aero-engines are to be prohibited within a few years, but the noise from roads is increasing steadily

Many experience noise impact from roads.

The noise from chemical process produces a low frequency 'throb' as the higher frequency sources are more attenuated by distance than low frequency sources. The increase in noise levels in previously 'rural' areas can produce significant environmental impact.

Visual impact is to be seen in many areas, the visual pollution is often personal, but must NEVER be ignored.

Most developments require Environmental Impact Assessment, which may also require both a base-line measurement of flora and fauna, an assessment of the restitution of the site, the routine monitoring of the near and far field environment and of changes in flora and fauna.

The migration of gases and solids once released into the environment can be assessed by other models.

The migration of liquids into soils and water courses is complex and can be assessed using mathematical models in the same was as gases dispersion. At the first level the liquids may fall onto the surface water and rapidly run off the surface into the local watercourses. At the next level it will enter the ground water and eventually enter the water table where it will be diluted to a degree before reaching the watercourses such as streams and rivers before reaching the sea (or worse still reservoirs).

Flora and Fauna

Much has been written on the effects of ***Flora and Fauna***. The effect of Acid Rain is fairly well proven as are the effects of "mankind" on hedgerows and draining marshland. Soil erosion is now wide spread in the developing countries and various species of flower/animal and birds are under threat from mans influence. The whole ecosystem is in very fine balance and a small change can have a major effect in the long term.

If I was to give a series of examples, I run the risk of being accused of being biased or unbalanced. The history is there for us all to see and even with the best "scientific evidence" H.S. seems to have an unnerving ability to get it wrong!

- The history of the dust bowl in Central USA due to the removal of hedges in the prairie Corn Belt earlier in 19th century is well documented.

- The effects of D.D.T. on bird life in U.K. are well documented but in Africa D.D.T. did produce beneficial effects in the suppression of the Malarial Mosquito and its use was justified. (Silent Spring)

- The recovery of land near rivers for human habitation reduced flood plains and enhanced flooding downstream. Although to improve the navigation of the Rhine produced flooding as the river flowed more freely and created flooding at its estuary.

- In the Sahara, aquifers were tapped for irrigation purposes - unfortunately salts accumulated in the soil and the vegetation died in a few years.

If H.S. can get the macro modules so badly wrong how can H.S. be expected to solve the Micro models of a localised Environmental Impact Study!! But legislation and Environmental Pressure says we must start.