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Pharmaceutical Industry—Establishment

Pharmaceutical Industry
Plant Location
Plant Layout
Utilities and Services
Industrial Pollution and Control
Industrial Hazards and Safety

The development of a complete plant design requires consideration of many factors. The role of costs and profits is very important. The application of engineering principles in the design of individual equipment is equally important. In addition, many factors such as plant location, layout, operations and control, utility and safety should be considered.

PHARMACEUTICAL INDUSTRY

The pharmaceutical industry differs from most other industries in that there exist a considerable degree of specialisation in it. Since products are so varied, no firm engages in all aspects of pharmaceutical manufacture. The products can be classified arbitrarily on the following lines.

Crude and processed botanical drugs : India grows a large number of vegetable drugs and supplies them to manufacturing houses in India and abroad. There is a steady demand for drugs consumed by Ayurvedic and Unani Practitioners of medicine.

Fine chemicals and pharmaceuticals : In India, a large number of pharmaceutical manufacturing houses purchase fine chemicals and industrial chemicals from firms, which specialise in their manufacture, for converting them into tablets, ointments, capsules, injections and other pharmaceutical preparations.

Proprietary drugs : With the decline of dispensed medicines, the pre-packed products such as tablets, capsules and parenteral products,

are now prescribed and consumed in large quantities by hospitals and nursing homes. Hence, a number of firms engage in preparing proprietary drugs. Some manufacturers have built a name for the pharmaceutical industry and for themselves, by their research activities. Thus efforts are continued to develop better formulations of old drugs and discovery of new drugs. However, such manufacturers are limited in India.

Definitions of Manufacturers

Manufacturers are engaged in the mechanical or chemical transformation of inorganic and organic substances into new products.

The above definition also includes assembling of components or products. Pharmaceutical manufacturing has been divided into three kinds.

1. Biological products
2. Medicines and botanicals
3. Pharmaceutical preparations

The *biological products industry* includes "establishments engaged primarily in the production of bacterial and viral vaccines, toxins and analogous products (such as allergenic extracts), serum, plasma and other blood derivatives for human and veterinary use."

The *medicinal and botanicals industry* includes "establishments engaged primarily in the manufacture of bulk medicines, organic and inorganic chemicals, their derivatives and processing (grading, grinding and milling) of bulk botanical drugs and herbs."

The *pharmaceutical preparations industry* includes "establishments engaged primarily in manufacture, fabrication or processing into pharmaceutical preparations for human and veterinary use."

PLANT LOCATION

The selection of a location for the construction of a pharmaceutical or chemical plant is a vital decision to be taken, because it determines the balancing of investments and profits. Therefore, location of the plant has a strong influence on the success of an industrial venture. Care should be exercised in choosing the plant size. Primarily the plant should be located where the cost of production and distribution can be minimum. But other factors such as room for expansion and general living conditions are also important.

1. Fundamental (Primary) factors
2. Derived (Secondary) factors

Normally, primary factors exercise greater influence than secondary factors. However, it will be difficult to make a clear-cut decision between these types of factors. Sometimes, the secondary factors may have greater influence on location.

Fundamental or Primary Factors

1. Raw materials
2. Market
3. Energy availability
4. Transportation facility
5. Labour supply

1. Raw Materials : The availability of raw materials and cost of its transportation will be major determinants. Pharmaceutical industry uses the following types of raw materials.

(a) Crude drugs
(b) Inorganic chemicals
(c) Organic chemicals

It would be economical to locate the plant nearer to the source of raw materials particularly when they are consumed in large volumes. For example, raw materials for perfume industry are aromatic plants. These cannot be transported because important active principles may be lost and materials get spoiled. Hence, the industries undertaking extraction are located nearer to the place of cultivation as in Himachal Pradesh and hilly areas of UP.

If raw materials are not locally available or dangerous chemicals, the freight charges and risk of dangers increase enormously. If raw materials are stable, other factors take importance over this factor.

2. Market : Market exercises a strong influence on the establishment of industries. Where market is regional, the industry is located nearer to the market. The bulk drug industry is located in a place where drug formulation industries are located, since bulk drugs are the feed for the formulations and buyers are found nearby.

3. Energy availability : Fuel and power are the energy sources, which exert the same kind of influence as the raw materials. Now-a-days, electricity and diesel engines have been developed and are available at many places. In many cases, plants create power on their own for the smooth functioning of the industry. Therefore, industry can be located remote to the power generation plants.

4. Transportation facility : Transport is the lifeline of modern industry. Transport facilities are needed for bringing raw materials and distribution of finished products. An industry tends to be localised at places, which have a developed means of transport such as railway, road and seaport. These facilities are normally available in metropolitan cities or mega-cities such as Bombay, Calcutta, Madras, Hyderabad and Bangalore. Hence, most of the industries are located in these cities.

If the sale price of the finished product is very high, because of technical considerations as compared with freight charges, transportation may not outweigh other factors. The kind and amount of products and raw materials determine the most suitable type of transportation facility. There is also a need for transportation facilities for the personnel.

5. Labour supply : Low wages and abundant labour help in localisation of certain industries such as tea. However, pharmaceutical and chemical plants require skilled labour, who are better paid and often highly mobile. Therefore, industries can be located away from areas of labour concentration.

Consideration should be given to prevailing pay rates, restrictions on number of hours of work per week, competing industries that can cause dissatisfaction or high turn over rates among the workers, racial problems and variations in the skill and intelligence of the workers.

Derived (Secondary) Factors

1. Climate and soil
2. Government concessions
3. Water supply
4. Waste disposal
5. Site characteristics
6. Flood and fire protection
7. Community factors

1. Climate and soil : Climate and soil are very important for industries based on agriculture. For example, Ayurvedic drugs are mainly plant-based products. The soil and climate are suitable for cultivation of medicinal plants in the state of Kerala. These formulations are largely produced in that state.

In pharmaceutical industry, many operations have to be carried out in air-conditioned rooms, in dust free environment and under humidity control. A location which is very hot during summer would not be suitable as it is subjected to dust storms and drying up of water supplies. Further an area where the humidity is very high would not be suitable

from the point of cost, contamination, difficulties of maintaining laboratory animals in proper condition and the efficiency of labour and supervisory force.

Industries based on production of antibiotics etc. are normally located in a place wherein the microbial contamination in the environment is low and the ambient temperatures throughout the year are cool. For example, IDPL antibiotics plant is located in Rishikesh (in UP) and Karnataka Antibiotics and Pharmaceuticals Limited (KAPL) is located in Bangalore, Karnataka State.

If the plant is located in a cold climate, costs may be increased by the necessity of constructing protective shelters around the process equipment. Special cooling towers or a/c equipment may be required, if the prevailing temperature is high.

2. Government concessions : Government subsidies and tax concessions have been provided for the industries located in certain notified areas. These areas have been declared as industrially backward and the government offers incentives such as low wages, cheap power, tax concessions etc. Previously such areas were not economically feasible, but now due to government concessions, these areas are developing fast.

3. Water supply : The processing industries use large quantities of water for cooling, washing, steam generation and also as a raw material (liquid orals). The plant, therefore, must be located where a dependable supply of water is available. A study should be conducted regarding the supply position of underground water and/or surface water and their seasonal variations. The quality of the water is also very important in pharmaceutical industry, as purified water is consumed in large quantities.

The temperature, mineral content, silt or sand content, bacteriological content, cost of supply and purification treatment must also be considered while choosing a water supply. A detailed estimate of water requirements both for the present and future must be made.

4. Waste disposal : In recent years, many legal restrictions have been placed on the methods for disposing of waste materials from the processing industries.

(a) When organic or inorganic chemicals are manufactured, there may occur problems of noxious gases being produced and discharged in to the atmosphere or into the sea.

(b) If the industry is engaged in the manufacture of biological products from raw materials obtained from slaughter houses

or pathogenic organisms, the waste disposal does pose a problem, but a minor one, because the raw material handled is not in huge quantities.

The site selected for a plant should have adequate capacity and facilities for correct waste disposal. Attention should also be given to potential requirements for additional waste treatment facilities.

5. Site characteristics : The topography of the land and soil structure should be considered, since both may have a pronounced effect on construction costs. The cost of the land, local building costs and living conditions are important. Future changes may make it desirable or necessary to expand the plant facilities.

6. Flood and fire protection : Many industrial plants are located along large bodies of water and there are risks of flood or hurricane damage. Before choosing a plant site, the regional history of natural events of this kind should be examined. In case of major fire, assistance from the fire departments should be easily available. Fire hazards in the immediate surrounding area of the plant site must not be overlooked.

7. Community factors : The character and facilities of a community can have quite an effect on the location of the plant. Cultural facilities of the community are important for sound growth. Churches, temples, libraries, schools, civic theatres, concert associations and other similar groups, if active and dynamic, do much to make a community progressive. If a minimum number of facilities for satisfactory living of plant personnel do not exist, it often becomes a burden for the plant to subsidize such facilities.

Special Provisions of Factory Premises—Location

The factory shall be located in a sanitary place remote from filthy surroundings. The factory shall be situated in a place which:

(a) Shall not be adjacent to an open sewage, drain or public lavatories.

(b) Shall not be adjacent to a factory, which produces disagreeable or obnoxious odours or fumes.

(c) Shall not be adjacent to a factory, which emits large quantities of soot, dust or smoke.

The factory shall not constitute undue danger to adjacent life and property. State laws and other related laws should be consulted.

No location can meet all the requirements ideally, but the best compromise has to be made by considering various points objectively and gathering relevant information. After considering all the above points, a project report has to be prepared. It becomes necessary for the entrepreneur to acquaint himself with all the legal controls, which are existing. A few such acts are:

Indian Factories Act.
Drugs and Cosmetics Act and Rules.

PLANT LAYOUT

Once the location of plant is decided, the problem of layout has to be tackled.

Plant layout is a coordinated effort to achieve the final objective to integrate machines, materials and personnel for economic production.

Layout can be described as location of different departments and arrangement of machinery in a department. A proper layout has the advantage from the point of workers, labour costs, other production costs, production controls, supervision and capital investment. Layouts are of two types.

(a) Process layout or functional layout
(b) Product or straight line layout

Process layout or functional layout : In this type, all machines of a particular class doing a particular type of work or process are arranged together in a separate department. For example, all cutting machines may be placed in one department, i.e., cutting department. The advantages of this type are:

(a) More effective supervision can be achieved.
(b) Division of labour or specialised work can be provided.
(c) Less disruption of production is possible.
(d) Good scope for expansion.

This type of layout may not be possible in the pharmaceutical and chemical industry, because a number of unit operations should be performed in a sequence.

Product or straight line layout : In this type, all machines doing various operations are arranged in a line. The advantages of this type of layout are:

(a) Facilitates quick and smooth processing of work.
(b) Reduces cost of material handling using conveyor.

(c) Reduces manufacturing time and speeds up the manufacturing cycle.
(d) Facilitates proper use of floor space.
(e) Reduces inventory of work-in progress.
(f) Reduces inventory of finished goods.

This type of layout is more suitable for the pharmaceutical and chemical industries. Some times, a combination of these two layouts is also used.

Procedures of Layout

The procedures of plant layout are shown in Figure 18-1. A proper layout in each case includes arrangement of processing areas, storage areas and handling areas for efficient coordination. The layout of processing units in a plant, the equipment within these units must be planned. Then detailed piping, structural and electrical design should be developed. This layout can play an important part in determining construction and manufacturing costs. Thus, these must be planned carefully with attention being given to future problems that may arise.

Some factors which guide the layout are:

(a) New site development or additions to a developed site.
(b) Type and quantity of products to be produced.
(c) Type of process and product control.
(d) Space available and space required.
(e) Operational convenience and accessibility.
(f) Economic distribution of utilities and services.
(g) Type of buildings and building code requirements.
(h) Health and safety considerations.
(i) Waste disposal problems.
(j) Auxiliary equipment.
(k) Possible future expansion.

Scale drawings indicating complete description with elevation can be used for determining the best location for equipment and facilities. Elementary layouts are developed first. By analysing all the factors that are involved in the plant layout, detailed recommendations can be presented finally. Drawings and elevations including isometric drawings of the piping systems can be prepared.

In the recent years, three-dimensional models are often made for making proposed plant layouts. These have the advantage of indicating errors in a plant layout easily. In addition, models are useful in

improving the layout during plant construction. Models are also useful for instruction and orientation purposes after the plant is completed.

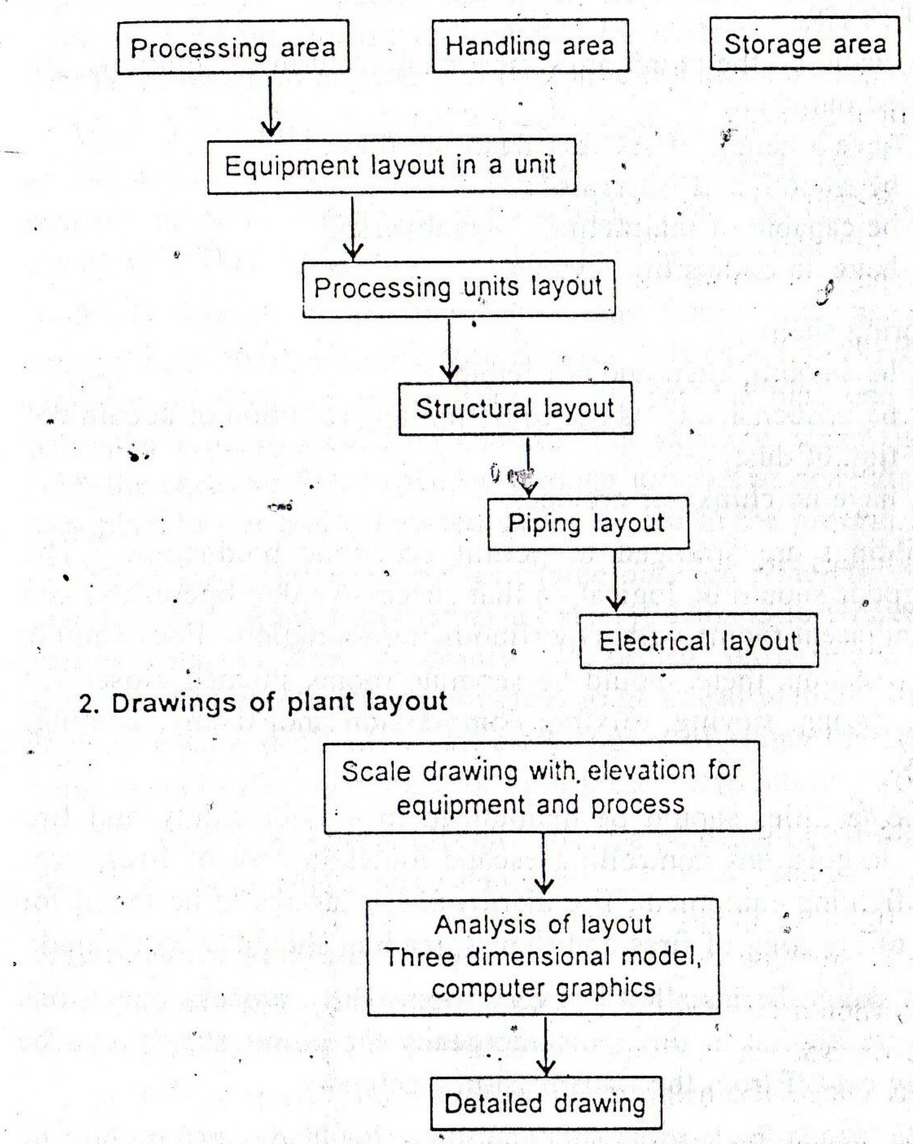

Figure 18-1. Flow diagram of procedures for an appropriate design of plant layout.

Special Provisions of Plant Layout

The premises should be suitable for the purpose of drug manufacturing. It means that all possible measures should be taken to prevent confusion or mixing-up of substances or materials and contamination. The building for the factory shall be constructed so as to permit the production under hygienic conditions. They shall conform to the conditions laid down in the Factories Act, 1948 (63 of 1948).

1. The part of the building used for manufacture shall not be used as sleeping place.
2. No sleeping place adjoining the building shall communicate therewith except through open air and through an intervening open space.
3. The walls of the room in which manufacturing operations are carried out shall
   (a) have a height of six feet from the floor.
   (b) be smooth and waterproof.
   (c) be capable of maintaining cleanliness.
   (d) have no chinks or crevices.

The flooring shall:

(a) be smooth, even and washable
(b) be in such a way as not to permit any retention or accumulation of dust
(c) have no chinks or crevices.

The buildings are arranged to permit economic production. The routing of goods should be logical so that successive unit operations can be done in adjacent rooms with superfluous transportation. For example in the tablet section, there should be separate rooms situated closer for granulation, drying, sieving, mixing, compression and, if any, coating, successively.

Adequate facilities should be maintained to provide safety and fire protection. Regulations controlling escape routes in case of fires, providing fire fighting equipment, fire alarms and measures to be taken for prevention of breaking of fires and their spreading should be complied.

Devices should be installed in every room where process operations are carried on, so that in times of emergency the power supply can be immediately cut off from the transmission machinery.

Building meant for storing and handling should be segregated and isolated. These satisfy the provisions of the act.

UTILITIES AND SERVICES

Utilities

The basic utilities required for an industrial plant are power and water.

The primary sources of energy for the supply of power are heat of combustion of fuels. Fuel burning plants are of greater industrial

significance than hydro-electric fuels, because the physical location of fuel burning plants is not restricted.

In chemical industries, power is supplied primarily in the form of electrical energy. Agitators, pumps, hoists, conveyers, compressors and similar equipment are usually operated by electric motors. Sometimes, internal combustion engines and hydraulic turbines are employed.

When a new plant is being set up, a decision must be made on either to use purchased power or to set up its own power unit. It may be possible to obtain steam as a by-product from the self-generation of electricity. This factor may influence the final decision.

Power can be transmitted in various forms, such as mechanical energy, heat energy and pressure energy. It is essential to recognise the different methods for transmitting power and the best one to suit the particular process should be chosen. For example, steam is generated from the cheapest fuel expanded through turbines to generate the necessary plant power and exhausted steam is used in the process heat.

Water for industrial purposes can be obtained either from the plant's own source or from a municipal supply. If demand for water is large, it can be obtained from the plant's own drilled wells, rivers, lakes, dam streams. Before the company agrees to go ahead with any new project, it must ensure itself of a sufficient supply of water for all industrial, sanitary and safety demands for both present and future.

The water used in manufacture shall be pure and of drinkable quality, free from pathogenic microorganisms.

Maintenance Services

Many of the problems involved in maintenance are due to the faulty design and layout of plant and equipment.

Sufficient space and facilities for maintenance work must be provided in the plant layout. It is essential to consider maintenance regulations while making decisions on equipment. Too often the design engineer is conscious only on installation costs and fails to recognize the maintenance costs. On several occasions, the maintenance costs can easily nullify the advantages of a cheap initial installation. For example, a compact system of piping, valves and equipment may be cheap and convenient for the operator's use, but maintenance of the system may be costly and involves time consuming dismantling operations.

Instruments are used in the chemical industry to measure process variables such as temperature, pressure and density. Automatic control

has been accepted as the best and the resultant savings in labour combined with improved ease and efficiency of operations has more than offset the added expense for instrumentation (Use of high speed computers). In general, one centrally located control room is used for the recording and regulation of the process variables.

Storage

1. Adequate storage facilities for raw materials, intermediates, recycle materials, rejected materials and fuels are essential for the operation of a processing plant.
2. Bulk storage of liquids is generally handled by a closed spherical or cylindrical tanks so as to prevent the escape of volatile material and minimizing contamination.
3. Liquids with vapour pressures above atmospheric pressure must be stored in vented tanks. Flame arrest mechanisms must be installed in all openings.
4. Gases are stored at atmospheric pressure in wet or dry seal gasholders.
5. High pressure gases are stored in spherical or horizontal cylindrical vessels under pressure.
6. Solid products and raw materials are either stored in weather tight tanks with sloping roofs or in out door bins and mounds.

INDUSTRIAL POLLUTION AND CONTROL

Thermal Pollution and Control

Various off-stream cooling systems are required to handle thermal discharges from processes because:

1. Changes in temperature cause potential damage to the aquatic environment.
2. High temperature causes reduction in the assimilative capacity of organic wastes.
3. Federal enactments are more stringent regarding water temperature standards.

Cooling towers are most often considered for this service followed by cooling ponds and spray ponds in that order.

1. In *wet cooling towers*, the condensed cold water and ambient air are intimately mixed. Cooling results from the evaporation of a portion of water.

2. In *dry cooling towers*, the temperature of the condensed water decreases due to conduction and convection for the transfer of heat from the water to the air.
3. *Cooling ponds* are generally considered for heat removal when suitable land is available at a reasonable price. It is normally assumed that heat discharged to a cooling pond is lost through the air water interface.
4. *Spray ponds* provide a viable alternative to cooling ponds when land costs are too high. It is estimated that a spray pond required only about 5 to 10% the area of a cooling pond due to the more air water contact. In addition, drift losses and corrosion problems are less severe than in cooling towers.

Water Pollution Abatement

The problems of handling a liquid waste effluent is more complex than handling a waste gas effluent. The waste liquid may contain dissolved gases/solids or it may be slurry in either concentrated or diluted forms. Because of this complexity, priority should be given to the possibility of recovering part or all of the waste products for reuse or for sale.

Frequently, it is economical to install recovery facilities rather than waste treatment equipment. If product recovery is not capable of solving the waste disposal problem, waste treatment should be done. One of the functions of the design engineer is to decide which treatment process or combination of processes will best perform the necessary task of cleaning up the waste water effluent. This treatment could be physical, chemical or biological in nature, depending upon the type of waste involved and the amount of removal necessary.

Physical treatment : Large floating or suspended particles are removed first. Sedimentation and gravity settling methods are employed using circular clarifiers with continuous chain sludge scrapers. Adsorption process is employed using activated carbon for the removal of refractory organic substances, toxic substances and colour. Three different membrane processes, viz., ultrafiltration, reverse osmosis and electro-dialysis are used as the final treatment and for in-plant recovery systems.

Chemical treatment : Chemical methods are generally used to remove colloidal matter, colour, odour, acids, alkalis, heavy metals and oil. Such a treatment is generally brought about by coagulation, flocculation, emulsion breaking, precipitation and neutralization.

Biological treatment : If common bacteria are found in water, many organic materials will be oxidized to form carbon dioxide, water, sulphate and similar materials. This treatment consumes oxygen that is dissolved in water and may cause a depletion of dissolved oxygen.

Air Pollution Control

Air pollution control can essentially be classified into two major categories.

- Those suitable for removing particulate matter.
- Those associated with removing gaseous pollutants.

Air pollutants are removed by chemical and physical means in the following manner.

1. Coarse diameter particulate matter can be removed with low-energy devices such as settling chambers, cyclones and spray chambers.
2. Sub-micron particles must be removed with high-energy units such as bag filters, electrostatic precipitators and venturi scrubbers.
3. Intermediate particles can be removed with impingement separators or low-energy wet collectors.
4. Gaseous pollutants can be removed from air streams either by absorption, adsorption, condensation or incineration.

INDUSTRIAL HAZARDS AND SAFETY

Toxic and corrosive chemicals, fire, explosions and plant personnel falling to accidents are the major health and safety hazards encountered in the operations of plants in processing industries.

Chemical Hazards

Tough many common substances are apparently innocuous, prolonged breathing and/or skin contact produce irritation and may bring about permanent impairment of health or even death.

Many chemicals can cause severe burns, if these come into contact with living tissue. Living tissue may be destroyed by chemical reactions such as:

(a) Dehydration by strong dehydrating agents.
(b) Digestion by strong acids and bases.
(c) Oxidation by strong oxidizing agents.

Eyes and mucous membranes of the throat are particularly susceptible to the effect of corrosive dust, mist and gases. In addition, many chemicals are very toxic, flammable or detonable.

Chloroform, benzene, chlorinated hydrocarbons, low-boiling fractions of petroleum are some of the common solvents used in pharmaceutical industry. Solvents used in the extraction of plants, purification of synthetic drugs and in chemical analysis should be handled with care.

In pharmaceutical industry, most of the dermatitis can be attributed to synthetic drugs, especially to acridines and phenothiazine compounds. It has been noticed that fair people are generally more susceptible to skin irritation than dark people. The only protection from skin reactions is to observe cleanliness and to remove the people from the areas as soon as the first sign of skin reactions is noticed. Wherever practicable, application of barrier creams before commencing the work has been found useful in protecting individuals.

While grinding vegetable drugs, dust evolved is irritating. For example, capsicum and podophyllum affect the eyes and irritation is painful. Therefore, goggles are to be worn. Some individuals are so sensitive to ipecacuanha that they develop symptoms of asthma, when exposed even to minute traces of its dust.

Tolerance levels for toxic chemicals have been set by Federal Regulations. Flammability and detonability of chemicals are available in most handbooks. Hazards due to industrial chemicals can be minimised if there is strict observance of safety regulations and protective measures of good house-keeping principles, besides their full and intelligent cooperation in the handling of dangerous chemicals and drugs.

Dust Explosion

In pharmaceutical industry, a number of grinding operations is employed. If iron or stone pieces get into the disintegrator or other similar grinding mills, sparks are emitted, which might bring about explosion with some easily combustible materials. Therefore, suitable precautions against accumulation of dust should be taken. It has been found that in pharmaceutical and ancillary factories, dust of starch and dextrin besides organic substances are extremely hazardous.

The methods used for controlling dust in the pharmaceutical industry are:

(a) Filtration
(b) Inertial separation
(c) Electrostatic precipitation

Filtration : In this method, air which contains dust is sucked or blown through a suitable mechanical barrier whose pore size is sufficiently small to retain particles. Materials used for this purpose include paper, felt, wool, cotton-wool and nylon. The filters often take the form of pads or panels fitted to the walls and windows of building. A large variety of filter bags are available, which can be attached to a particular machine where dust is produced.

Inertial separators : Example is a cyclone separator. In this method, air is allowed to circulate in a spiral manner through a cone-shaped vessel. Due to centrifugal force, particles of drugs are thrown outwards to the walls of the cyclone separator. They slide down to a hopper, which can be subsequently withdrawn. Cyclone separators are particularly suitable for attaching to machines. These can form an integral part of the design of certain mills and mixers.

Electrostatic precipitators : It consists of a number of earthed tubes. Fine metal wires are stretched between the tubes. Several thousand volts of direct current is applied on metal wires. The high potential difference between the tubes and the wires ionizes the dust particles that are carried by air stream. The dust is deposited on metal plates from which it is collected periodically.

Fire and Explosion Hazards

A single fire or explosion can spread to adjoining units. Careful plant layout and judicious choice of constructional materials can reduce such events. Hazardous operations should be isolated by conducting them in separate buildings or by the use of brick firewalls. Brick or reinforced concrete walls can limit the effects of an explosion, particularly if the roof is designed to lift easily under an explosive force.

Equipment should be designed to meet the specifications and codes of recognized authorities such as Indian Standards Association, American Petroleum Institute (API) and American Society of Testing Materials. The design and construction of pressure vessels and storage tanks should follow API and ASME codes.

Adequate venting is necessary and it is advisable to provide protection by using both spring-loaded valves and rupture discs. Possible sources of fire are reduced by eliminating the unnecessary ignition sources such as flames, sparks, heated materials, matches, smoking, welding, cutting and static electricity. Spontaneous combustion and non-explosion proof electrical equipment are the potential ignition sources. The installation of sufficient fire alarms, temperature alarms, fire-fighting equipment and sprinkler systems must be specified in design.

Every type of mechanical device should be examined periodically by a competent person.

Noise Abatement

The design engineer should include noise studies in the design stage of any industrial facility.

To attain efficient, effective and practical noise control, it is necessary to understand noise sources in the process, their acoustic properties and characteristics and how they interact to create the overall noise situation. Table 18-1 presents typical process design equipment providing high noise levels and potential solutions to this problem.

TABLE 18-1

Equipment Noise Sources, Levels and Potential Control Solutions

Equipment	*Sound level in dBA at 3 feet*	*Possible noise control treatments*
Air coolers	87-94	Aerodynamic fan blades, decrease revolutions per minute, increase pitch, include tip and hub seals, decrease pressure drop
Compressors	90-120	Install mufflers on intake and exhaust, enclose the machine with casing, vibration isolation and lagging of piping system
Electric motors	90-110	Acoustically lined fan covers, enclosures and motor mutes.
Heaters and furnaces	95-110	Acoustic plenums, intake muffiers, lined and damped ducts.
Valves	<80-108	Avoid sonic velocities, limit pressure drop and mass flow, replace with special low noise valves, vibration isolation and lagging.
Pipes	9-105	Inline silencers, vibration isolation and lagging.

Safety Regulations

Safety must be a paramount consideration in the design of pharmaceutical industry. The factories Act, 1948 is very comprehensive. It includes provisions on cleanliness, ventilation, lighting and heating and the prevention of over-crowding.

The intention of the Occupational Safety and Health Act (OSHA) of 1970 is "to assure so far as possible every working man and woman in the nation safe and healthy working conditions and to preserve our human resources." Two of the standards directly related to workers health and important in design work are:

(1) toxic hazardous substances.
(2) occupational noise exposure.

The first factor concerns with the normal release of toxic and carcinogenic substances carried via vapour, fumes, dust fibres or other media. Compliance with the act requires the designer to make calculations of concentrations and exposure time of plant personnel to toxic chemicals during normal operation of a process or a plant. Their release could emanate from various types of seals, control valve packing or other similar sources. Normally, the designer can meet the limits set for exposure to toxic substances by specifying special valves, seals, vapour recovery systems and appropriate ventilation systems.

The Federal Register should be examined closely for the list of materials declared hazardous, acceptable material exposure time and concentration before beginning the detailed design of a project.

The occupational noise exposure standard requires well planned timely execution of steps. It is best to prepare two noise specifications during plant design itself. One to define the designers own scope of work and the other to set vendor noise-level requirements for various pieces of equipment.

Other standards in the safety area most often cited by OSHA are the National Electric Code and Machinery and Machinery Guarding, which must be considered in detailed designs.

Personal Safety

Every attempt should be made to incorporate facilities for health and safety, protection of personnel in the plant design. This includes (but it is not limited to) protected walkways, platforms, stairs and work area. Any unavoidable physical hazards must be clearly defined. In such areas, means for exit must be unmistakable. All machinery must be guarded with protective devices. In all cases, medical devices and first aid must be readily available for all workers.

QUESTION BANK

Each question carries 5 marks

1. What are possible industrial hazards? How can they be controlled?
2. What methods are employed for preventing the hazards of handling and use of poisonous chemicals in industry?
3. Explain industrial pollution and control.
4. What methods are employed for preventing the hazards of handling and use of poisonous chemicals in industry?
5. Write a note on plant location.

Each question carries 10 marks

1. Describe the factors that should be considered regarding plant location and layout.