USc3CZ0027. Zoology:-21

Unit:- 4

Apiculture

Man had started the use of animal products since time immemorial even at the cost of animal's life. Honey has been under use in human civilization since prehistoric period as mentioned in our religious literatures like Vedas, Purans, Ramayan, Mahabharat and Charak Sanghita. Some foreign travellers like Fahiyan and Whenson had also discussed the use of honey as medicine. People were very much dependent upon honey for medicines and essential nutritive elements of the diet.

The highly evolved social organisation of bees had been established before the existence of human race. Bees teach us the lesson of work-work and work with co-operation. We can easily imagine about the hard-working of the bees, by the simple fact that for one pound of honey, a single honey bee travels about double the distance of the circumference of the earth's globe. Previously, the method of extraction of honey from the honey comb was very much crude but after the invention of artificial hive by Longstroth (1951), it became scientific and commercial. The bee keeping in United States, Canada, Australia and New Zealand has achieved out-standing success. In India people do not take interest in bee keeping from commercial point of view but only for their routine use. Since honey is produced by the honey bees, a detailed study of the biology of the bees is essential for successful implementation of apiculture programme.

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Honey Bee

Phylum ..... Arthropoda
Class ..... Insecta
Order ..... Hymenoptera
Family ..... Apidae
Genus ..... *Apis*

Habit and habitat

Honey bees are highly organised social insects reported from all over the world. Although they are active throughout the year but in winter season they do little work and do not rear the brood. In spring seasons *i.e.*, at the time of flowering they prepare a strong colony with honey rich combs.They exhibit polymorphism and good division of labour. The bee hives with thousands of individuals are observed hanging down from the branches of the trees and ceilings of houses. The workers communicate informations for the location of the food sources through the 'Waggle Dance', a phenomenon called as 'Language of the bees', by the eminent biologist Karl Von Frish. He has mentioned that the rate of dance is directly proportional to the distance of the food.

Species of Honey Bees

Four species of honey bees are reported.

1. ***Apis dorsata F.*** (Rock bee). This the largest bee, about 20 mm. in length, so named as GIANT HONEY BEE. SARANG and BOMBARA are other names of this bee which yields maximum amount of honey in comparison to other species. A single comb may yield 60 pounds of honey which is the maximum amount for a comb. The workers are very smart and active which may pollinate 12,000 flowers daily. But due to its ferocious and irritable nature, specific hive and migratory habit it is very difficult rather practically impossible to domesticate them for the bee keeping industry.

2. ***Apis indica F.*** (Indian bee). Commonly found in forest and plain regions of India. This is slightly smaller than *A. dorsata.* They prefer to live in dark places and construct several parallel combs about one foot across the protected places like cavities of tree trunks, mud walls, earthen pots, thick bushes, wells and walls of the buildings. This species is very gentle in nature, so can be domesticated easily. The production of honey is much less *i.e.*, 6 to 7 pound per comb.

3. ***Apis florea F.*** (Little bee). This is smaller than *A. indica* and yields very small amount of honey. The bees are not of gregarious nature and form a single comb. Due to its docile nature and rare stinging behaviour the combs can be removed easily for the honey extraction.

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4. ***Apis mellifera F.*** (European bee). Although this bee produces less honey yet it is found to be the best species from the commercial point of view. Due to their docile nature they can be domesticated easily and can be improved by breeding for several hundred years. Out of its several varieties, the Italian variety is reared every where in Europe and America in artificial hives for honey.

Social Organisation of Honey Bee

A highly organised division of labour is found in the colony of honey bees. A good and well developed colony of bees had 40 to 50 thousand individuals consisting of 3 castes *viz.*, QUEEN, DRONE and WORKER. The queen after fertilization lays fertilized and unfertilized eggs both. From unfertilized eggs male bees emerge which are known as DRONES whereas from the fertilized eggs worker bees are produced. The workers when feed on ROYAL JELLY, develop into QUEEN.

Queen. It is a well developed fertile female provided with immensely developed ovaries. Commonly one queen is found to be present in each hive and feeds on Royal Jelly. She is the queen in real sense as the Mother of the Colony, guarded by a number of attendants and never alloted any duty except egg laying. Egg laying is the sole function of the queen throughout her active life span. The queen is 15 to 20 mm in length and can be easily distinguished by her long tapering abdomen, short legs and wings. Structurally she is unable to produce wax or honey or gather pollen nector. By the combination of ovipositor-cum sting, a structure is developed which aids in egg laying. It is said that the queen gets mated only once in her life but in a single chance of mating, drone releases 2 crore sperms which are suffcient for the fertilization of the eggs at the time of laying by the female throughout her life span. In recent researches in U.S.A. it has been reported that out of 110 queens only 55 mated twice before egg laying. It is also a fact that queen lays fertile and unfertile eggs both in accordance to her will but the factors governing such selective activity are still not known. One queen lays about 1,500 to 2,000 eggs in a day depending upon the seasonal variation and other ecological factors. The total weight of 100 eggs is equal to her body weight. In the whole life span of two to five years a queen lays about 15,00,000 eggs. When the queen in a colony looses its eggs laying capacity, another worker of the same colony starts feeding on queen's diet *i.e.*, Royal Jelly and develops into a new queen and is provided with the facilities of real queen. At the same time old queen may be driven out but sometimes some workers object that as to why the mother of the colony be driven out so ultimately they also come out with the mother. Sometimes when 2 to 3 queens are developed in a colony, only one takes the position of the real queen and the others come out with some workers to establish new colonies.

Workers. Although the workers are the smallest of the three castes but they function as the main spring of the complicated machinery like honey bee

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colony. Like the queen, they are also produced from the fertile eggs laid by the queen and live in a chamber called as 'WORKER CELL'. It takes 21 days in the development from the egg to the adult and the total life span of a worker is about 6 weeks. The workers are atrophid female which sacrifice themselves for the well-being of the colony. The total indoor and outdoor duities of the colony are performed by the workers only. That is why they are provided with some special structures for particular work.

(1) Long proboscis for sucking the nectar.
(2) Strong wings for fanning.
(3) Pollen baskets for the collection of pollen.
(4) Powerful sting to defend the colony against any attack.
(5) Wax gland for wax secretion.

The workers which are engaged in outdoor duties, collect the nectar, pollen, gum and water which are received and stored properly by the house bees. The indoor workers are further sub-grouped for specific duties. Some of them which are very sincere, attend the queen while some others look after the nursery called as NURSERY BEE. Some produce wax for the formation of the new hive and are known as BUILDER. The repairing of the comb is done by the REPAIRERS. The dead body and other impurities are removed from the hive by the CLEANERS. The fanning in the hive is performed by the wings of the FANNERS. Several other functions like honey storage and ripening are also done by the workers. The guard bee always watches at the gateway. It is said that upto half of the life period workers perform indoor duties and later on become engaged in outdoor duties.

Drone. The drone is the male member of the honey bee colony which fertilizes the queen so called as KING of the colony. They take 24 days to develop from the egg to the adult stage. The sting and the wax glands are absent but in the males the reproductive organs are very well developed. They are reared from an unfertile egg in large DRONE CELL. Drone are totally dependent on the workers and have been seen begging for honey from the workers. The sole duty of the drone is to fertilize the virgin queen. At the time of swarming the drone follows the queen, copulates and dies after copulation.

Life History

After mating the queen generally lays one egg in one brood cell. The eggs are pinkish coloured, elongated with cylindrical body generally attached to the bottom of the cell. Larvae emerge out from both the fertilized as well as unfertilized eggs. Thus, the larvae from the unfertilized eggs form the drones while the workers are developed from the larvae of the fertilized eggs. Amongst the larvae of the workers one is fed on the royal jelly, a special diet secreted by the young workers in the colony, and becomes the queen of the colony. The royal jelly consists of digested honey and pollen, mixed with a glandular

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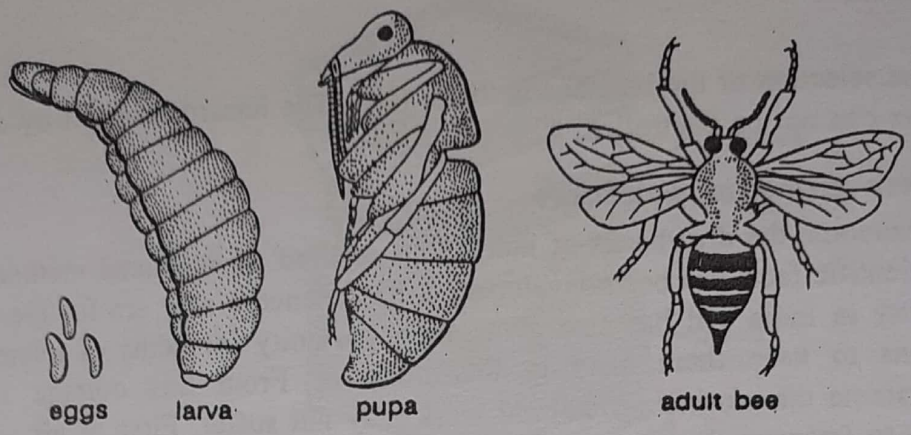

Fig. 1. Life history of *Apis indica*.

secretion into the mouth of the workers. After 5 days of feeding the cell is sealed and the larvae undergo pupation. It spins a thin silken cocoon and pupates completely. Emergence of the young ones takes place after three weeks and they get busy in the indoor duties for about 2 to 3 weeks. Later on they are sent for the outdoor duties. All the bees pass through a complete metamorphosis with the various changes in the life-cycle taking place within the comb (Fig.1).

Swarming. The process of leaving off the colony by the queen termed as swarming. It happens towards the end of spring or early summer but the real cause of swarming is still not well known. In summers when plenty of food is available and hive is overcrowded by the bees, the queen leaves the hive on a fine fore-noon with some old drones and workers and establishes a new colony at some other place. Now in the old hive a worker is given Royal Jelly and is converted into a new queen of the colony. This new empress of the colony never tolerates her successor, as a natural law in the hive, so she orders to kill the other sisters, if any, in the hive.

Supersedure. When the egg-laying capacity of the old queen is lost or it suddenly dies, a new young and vigorous queen takes the position of the old queen and is called as supersedure.

Absconding. The migration of the complete colony from one place to another takes place due to some unfavourable conditions of life, such as destruction of the comb by termites or wax-moths and scarcity of nectar producing flowers around the hive. This phenomenon is quite different from that of swarming.

Nuptial or marriage fight. The first swarm is led by the old queen but the second swarm is led by the 7 days old virgin queen which is followed by the drones and is called marriage flight. One of the drones starts copulating with the queen in the sky and fertilizes the queen and dies during the course of copulation. The queen receives spermatophores and stores in the spermatheca.

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Along with the queen, died drone falls on the ground and the queen reaches the hive.

Hive

The house of honey bees is termed as hive or comb. It consists of hexagonal cells made up of wax secreted by the worker's abdomen. These hives are hanging vertically from rock, building or branches of trees. Each hive has thousands of hexagonal thin walled fragile cells arranged in two opposite rows on a common base. The resins and gums secreted from the plants are used for the repairing of the hives. The young stages are generally occupying the lower and central cells in the hive which are the 'BROOD CELLS'. In *A. dorsata* broad cells are similar in shape and size but in other species brood cells are of 3 types *viz.*, WORKER CELL for workers, DRONE CELL for drones and QUEEN CELL for the queen. The queen cell can not be used again while the rest are used a number of times. There are no special cells for lodging the adults which generally keep clustering or moving about on the surface of the comb. The cells are mainly intended for the storage of honey and pollen specially in the upper portion of the comb while those in lower part are for brood rearing (Fig. 2).

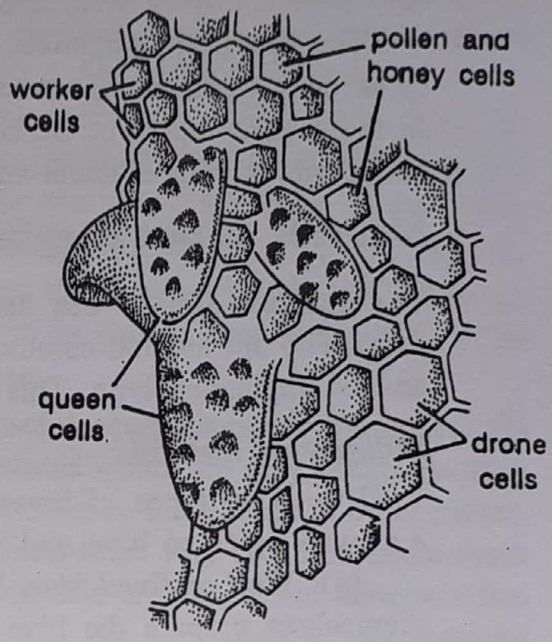

Fig. 2. Hive of *Apis indica* showing various cells.

Flora for Apiculture

Although honey bees can collect nectar and pollen from quite a long distance but the flora for apiculture is also important. The flora may be of wild or cultivated type. The more nectar yielding plants are neem, jamun, soapnut etc. The other plants like maize, rose and sorghum are good sources of pollen. Some plants like plum, cherry, apple, sheesham, coconut, guava, mustard etc., are good sources for nectar and pollen both.

Selection of Bees for Apiculture

For running a good apiary, selection of honey bee is of much importance, so the following should be kept in mind at the time of selecting honey bees for apiculture :

(1) Honey bees should be of gentle temperament.
(2) Honey bees should have capability to construct strong colony.

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(3) It should have ability to protect from enemies.
(4) Honey bee should have energetic and industrious workers.
(5) Workers can suck juice from numerous varieties of plants.
(6) Bees on the whole can produce more and more honey from its comb.
(7) Bees can from their comb easily at any place.

The apiculture scientists engaged in genetics are trying to find out such cross races which would not be of ferocious nature but be a good honey producer. In India, *Apis indica* is the best bee for apiculture industries due to its gentle nature and having efficient and prolific workers.

Methods of Bee Keeping

The ultimate aim of bee keeping is to get more and more honey in pure form. The old method commonly used by old apiculturists is very crude, cruel and of unplanned type. This old method is called as Indigenous method.

Indigenous method

1. Hive. Two types of hives are used in indigenous method of bee keeping *e.g.* wall or fixed hive and movable hive.

(a) ***Wall or fixed hive.*** It is purely natural type of comb because the bees themselves prepare the hive at any space on the wall or trees. There is an opening on one side through which bees come out of the hive.

(b) ***Movable hive.*** It comprises of hollow wood logs, empty boxes and earthen pots etc. placed in varandas of houses. There exist two holes, one is for entrance and the other for exit of the bees. The swarmed bees usually come to the box on their own accord. Some bee keepers use to take the clusters of the swarms from a tree and keep them in the hive.

2. Extraction of honey. For honey extraction, burning fire is brought near the bee hive at the night as a result of which bees are either killed or they escape off. Further the hive full of honey is being removed, cut into pieces and squeezed to get honey. Sometimes smoking is done so that the bees may escape from their hives.

3. Drawbacks of indigenous method. The indigenous method of bee keeping suffers from a number of drawbacks due to which it is not recommended by present day panel. These drawbacks are :

(i) Honey becomes impure because at the time of squeezing, the brood cells, pollen cells, honey cells and larvae are also extracted. (ii) The colony becomes weak due to killing of the eggs and the larvae at the time of squeezing. (iii) Formation of new hive by the escaped bees requires extra energy which effects the yield. (iv) The activities of the bees can be controlled. (v) The hivation of bees on the same place is only matter of chance. (vi) The honey robbers, like, rat, ant, wasp and monkeys may affect the hive easily. (vii) The race improvement programme may not be applied, so no possibility

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for the selection of the best bee is there. (viii) The hazards created by climatic factors can not be controlled.

Modern method of apiculture

To overcome the drawbacks of indigenous method an advanced method based on scientific facts has been developed. It has opened a new era for the cottage industry in India and has also given an opportunity for lakhs of unemployed persons to keep them busy in this business. From this cottage industry programme the routine agricultural work may not suffer. First of all care was taken to improve the texture of the hives and during this race hive patterns were introduced in India. The Newton model with 7 to 10 frames (21×14.5 cm) in the brood chamber with a shallow super (21×6.5 cm sized frames) has been most popular in south, east and central India. Longstroth hive containing 10 frames (44.8×23 cm) has been used as a standard hive in Himachal Pradesh, Jammu and Kashmir, and Punjab. In Uttar Pradesh another type of hive has been in use which was evolved at Jeolikote apiary and contained 8 frames (30×18 cm). After gaining experience from the above mentioned hives, Indian Standard Institute has standardized the hives of small and big sizes accommodating frames 21×14.5 cm and 31×20.4 cm respectively.

Now-a-days a typical type of movable hive is constructed which is capable of expansion or contraction according to the requirement of the place, season and climatic conditions.

Appliances for Modern Method

(1) Typical movable hive.
(2) Queen excluder.
(3) Honey extractor.
(4) Uncapping knife.
(5) Other equipments.

1. Typical movable hive. An artificial movable hive is constructed by wooden box based on bee space theory (Fig. 3). The size and number of frames are variable from hive to hive according to the need. A small space is enough to permit the entrance and exit of workers and drones but queen once placed in hive never comes outside the hive. The perforation size on zinc sheet is only of 0.375 cm but the thorax of the queen is 0.43 cm to 0.45 cm, so the queen can never pass through this pore. This typical hive consists of 6 parts as given below :

(a) Stand. It is the basal part of the hive on which the whole hive is constructed. The stands are adjusted to make slope for the hive. Due to this slope rain water comes down quickly.

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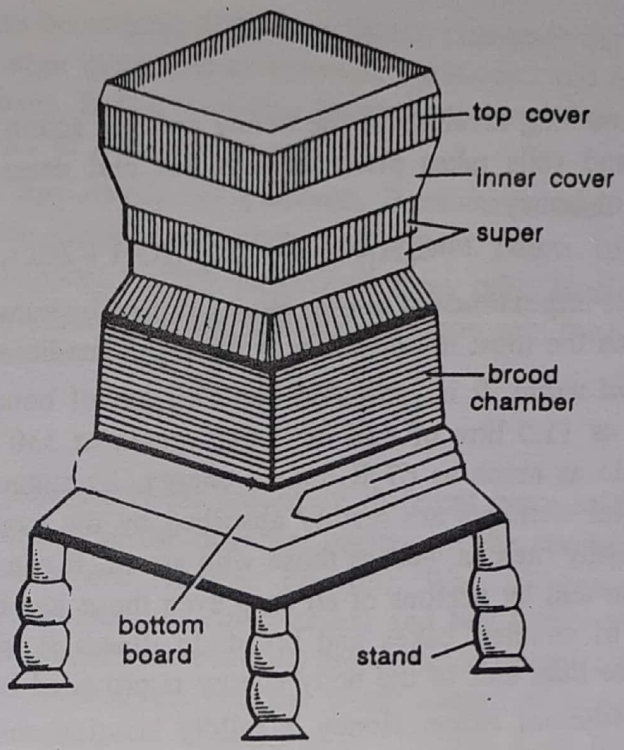

Fig. 3. Typical movable hive.

*(b) **Bottom board.*** It is situated above the stand and forms the proper base for the hive having two gates in the front position. One gate functions as an enterance while the other as exit.

*(c) **Brood chamber.*** The bottom board carries the brood chamber which is the most important part of the bee hive. It is large in size provided with 5 to 10 frames. In each frame a wax sheet bearing haxagonal frames is held up by a couple of wires in a vertical position. Along with the margin of every hexagonal mark, the bees start making wall and ultimately the cells. Here every sheet of the wax is known as COMB FOUNDATION which attracts the bees and provides the base for the comb preparation on both the sides. The frames are kept vertically in brood chamber which is covered over by other frames having a wire meshing through which the workers can easily pass. The comb foundation helps in obtaining a regular strong worker brood cell comb which can be used repeatedly. The Central Bee Research Station at Pune arranged the manufacture of a comb foundation mill which manufactures, different cell sizes required in several regions of the country. The brood chamber is covered by another chamber known as super.

*(d) **Super.*** It is also without cover and the base. Super is provided with many frames containing comb foundation to provide additional space for expansion of the hive.

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(e) Inner cover. It is a wooden piece used for the covering of the super. It has many holes for proper ventilation.

(f) Top cover. It is meant for protecting the colony from rains. It is fitted with zinc sheet which is plain and sloping.

2. Queen excluder. It consists of a wire-gauze, extrans guards and drone traps with individual wires placed 0.375 cm apart. It readily permits the workers to pass through it but keeps back the queen in the brood chamber.

3. Honey extractor. It is used for the extraction of the honey from the comb and functions on principle of centrifugal force. When combs are centrifuged by this device the pure honey is thrown out without any damage to the comb.

4. Uncapping knife. When all of the combs are filled with honey they are sealed by capping with the wax. So, before such capped combs are placed in the honey extractor, the wax sealing has to be removed with the help of an uncapping knife heated by steam before use.

5. Other equipments. Most of the useful equipments for the successful management of the bee are locally manufactured which are very cheap. As they are made locally, they may not be exactly similar to those made at other places. Thus, Indian Standard Institute has standardized some very common equipments for the production of uniform and interchangeable articles. Some materials like protective garments, gum cages, gloves, net veil, bee net, brush etc. are required for easy and well planned handling of the bees.

Advances of Modern Method

In the modern method of bee keeping there are several advantages which encourage the well planned bee keeping.

(1) A proper watch on the activities of the bees can be had.
(2) A strong colony can be developed by providing sugar, syrup, pollen substances to honey bees.
(3) Swarming of bees is checked by modern hive.
(4) The same hive is used again and again so the workers pay their attention more for the honey and not for the hive formation.
(5) Under adverse climatic conditions the hive can be transferred from one place to the other for the protection of the bees.
(6) Comb can be protected from the enemies.
(7) Pure honey in large quantity can be obtained.

Precautions. For the proper management of bee keeping programme following precautions should be taken :

(1) The hive should not be kept more than half a mile away from the place from where the bees have to collect the nectar and the pollen.
(2) People must know about the bee keeper for proper contact.
(3) The boxes must be kept under shade at cool places.

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(4) Industry should be near the road for proper transport facilities.
(5) Fresh water reservoir should be near the hive.
(6) Good flora for the collection of pollen and nectar should be there.

Products of Bee Keeping

The chief products of bee keeping industry are : (i) honey and (ii) bees wax.

Honey

It is truly an insect product of high nutritive value. The food value of honey may be estimated by the presence of about 80% sugar in it.

Production of honey. One should not be confused that honey is a direct plant product because the nectar, pollen and cane-sugar bearing secretions of flowers are ingested by honey bees, get mixed with the saliva and undergo certain chemical changes due to enzyme action. At this stage cane-sugar (sucrose) is converted into invert sugars *i.e.* dextrose and levulose. At this very time some ingredients of bees are also added to the mixture and reduce the water content. The whole mixture is then collected in the honey sac (crop) until the honey reaches the hive. As the honey bee reaches the hive this compound is regurgitated in the hive cell and is known as the honey. Now honey is concentrated by a strong current of air produced by the rapid beating of worker's wings, crawling over the cells.

Honey is very much sweet in taste and white to black in colour with variable smell in accordance with the juices collected from different flowers.

Chemical composition of honey. Honey is sugar rich compound having the following constituents :

(1) Levulose	—	38.9%
(2) Dextrose	—	21.28%
(3) Maltose & other sugars	—	8.81%
(4) Enzymes & pigments	—	2.21%
(5) Ash	—	1.0%
(6) Water	—	7.20%

Storage of honey. After long duration in the stored condition, the honey may be granulated and fermented.

(a) ***Granulation of honey.*** The stored honey becomes granular after long duration. Such type of granulation property is the best evidence of pure honey. It is considered that 10 parts of dextrose combine with one part of water, hence forms crystals. Due to less solubility levulose is not crystalised and gives cloudy appearance. Crystallization is mainly accelerated by the presence of minute air bubbles, colloids and pollens.

(b) ***Fermentation of honey.*** After crystallization honey is subjected to fermentation. Due to crystallization of dextrose 9% moisture is released, which

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dilutes the remaining levulose of the honey and the action of yeasts present in air, flowers and soils takes place on levulose and dextrose resulting in the fermentation of honey.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Economic importance of honey. Honey is used by human beings in different ways of which the most important is as food and medicine.

(a) Food value. It is estimated that 200 gm of honey provides as much nourishment as 11.5 litre of milk or 1.6kg cream or 330 gm meat. 2.1 gm of honey provide as much as 67 K. cal of energy. Its sugars, minerals, vitamins and other vital elements are readily absorbed by the systems. Honey may be taken by healthy men as well as those who are ill. It can be taken at any time in any season and by persons of all ages even those just born. It is used in the preparation of candles, cakes and bread. In illness it is preferred over milk because more than half of the body energy is provided burning of dextrose.

(b) Medicinal value. Honey is mildly laxative, antiseptic and sedative, generally used in Ayurvedic and Unani systems of medicine. It is quite helpful in building up of the haemoglobin of the blood and also used as preventive against cough, cold and fever, as blood purifier and as a curative for ulcers on tongue and alimentary canal. Its regular use is recommended after severe cases of heart attack for malnutrition, indigestion and diabetes. It is also found that typhoid germs are killed by honey within 48 hours, those of branchio-pneumonia in 4 days and of dysentry in 50 hours.

(c) Other uses. Other than food and medicine, honey is used in numerous ways. It is used in the preparation of bread, cake and biscuits. It enhances their preserving quality. Much amount of honey goes in making alcoholic drinks. In poultry and fishing industries honey is widely used. In laboratory, honey is used to stimulate the growth of plants, the bacterial culture, inoculation of seeds of cloves, in insect diet and in the preparation of poison baits for fruit flies.

Beeswax

Beeswax is a very useful by-product of bee keeping industry. It is yellowish to greyish brown in colour and insoluble in water but completely soluble in ether. Commonly it is a wrong impression to suppose that honey bees convert the pollen into beeswax because beeswax is also a natural secretion of the worker bees and is poured out in thin delicate scales or flakes. Chibnall (1934) has reported that all insect waxes are complex mixture of varying proportions of :

(1) Even numbered alcohols ranging from C_{24} to C_{36}.
(2) Even numbered normal fatty acids from C_{24} to C_{34}, and
(3) Odd numbered normal paraffins ranging from C_{23} to C_{37}.

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The various beeswaxes differ only due to change in the proportions of these constituents. Large quantities of beeswax produced and exported, come from *Apis dorsata* bees. Indian Standard Institutions have fixed standards for pure beeswax in order to facilitate its export.

Economic importance of beeswax. Beeswax is used in the manufacture of cosmetics, for Catholic churches, face cream, paints, ointments, insulators, plastic works, polishes, carbon paper and many other lubricant. It is also used in the laboratory for microtomy with the common wax for block preparation of tissues.

Bee Enemies

Enemies of the bees harm the colony in different ways so they have attracted considerable attention in the different regions of the country. The wax moths (*Galleria mellonella and Achroia grisella*), Wasp (*Vespa* spp. *and Palarus* sp.), black ants (*Camponotus compressus*) and bee eaters (*Merops orientalis*) and Kingcrow (*Dicrurus macrocercus*) are common enemies of the honey bee's comb and honey. Man is the last but worst enemy of honey bees.

Before 1958 bees were considered to be free from the diseases though suspected cases of NOSEMA from Punjab and Kashmir were known. But a parasitic mite-*Acarapis woodi* Rennie caused Acarine disease in the adult honey bee in Kulu valley in Punjab in 1956. It was later reported from Himachal Pradesh, Uttar Pradesh and Jammu and Kashmir. This disease was controlled by the scheme in co-operation with the United States of America at the college of Agriculture Ludhiana, Punjab. Now-a-days Indian honey bees are commonly free from any such disease. A strict quarantine measure is being taken to check the spread of any disease from foreign countries. But in European countries bees are commonly attacked by microsporadian which is injurious to bees.

Bee-keeping Industry

Bee-keeping has gained a good position as an industry in U.S.A., Canada and Australia but in tropical countries it is not growing as per need of the people. Before 1953 attention to bee-keeping was paid only by the State Governments but in the same year, all India Khadi and Village Industries Commission, started to pay attention to it and it was controlled by Union Government itself. Due to the functioning of the central organisation, bee-keeping industry was spread in South India and in some northern states also. Now-a-days bee-keeping industry is nation wide and is a good source of cottage industry. Till now limited research and development work has been done in this field which indicates that 'Apiculture' can be raised to the status of a viable occupation in tropical climates provided appropriate scientific and developmental efforts are generated. Because the tropical countries are very rich in bee fauna, the scientific development of apiculture may be helpful in agriculture and may

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contribute for providing nutrition, and employment to rural population and may help in raising the economic status of the people.

Recent Efforts

An international conference on 'Apiculture in Tropical Climates', organised by the 'World Crops' in collaboration with the International Bee Research Association (IBRA) was held at London in 1976. In this Conference it was recommended that the research and development of apiculture should be taken on priority basis in the tropical areas. The Second International Conference on Apiculture in Tropical climates was organised by the Indian Council of Agricultural Research in Collaboration with the Khadi and Village Industries Commission, Department of Science and Technology and Indian National Science Academy at New Delhi in 1980. In this Conference Eminent National and International scientists and experts realised the importance of apiculture and suggested further research development as a device for raising the industrial status of apiculture.

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Lac Culture

Lac insects and their products have been known to naturalists since very early times. The lac has been referred in ancient Sanskrit works *viz.*, Atharva-Veda (Dave, 1950; Hora, 1952) and was called as 'Luxa'. It is mentioned in Mahabharat that 'Luxa Griha' was made up of lac which was prepared by Kaurava for Pandavas. Abul Fazal (1590) in his famous book 'Ain-i-Akbari' has mentioned in detail about the lac industry in India. Mahdihassan (1950, 1952), has referred about the lac insect and its products in China. The first scientific reference regarding the lac and lac insect is the report of Kerr and Glover in 1782. Subsequently, much work has been done by various workers on the organization, distribution, taxonomy, host plants, culture, production, enemies, chemistry and technology.

Three products from lac insects, viz., the lac-dye, lac-wax and lac (resin) have been items of trade and commerce.

Distribution

India has its monopoly on the production of lac. Other countries like Africa, Australia , Brazil, Burma, Sri Lanka, China, Formosa, France, W. Germany, Japan, Malaya, Nepal, Spain, Thailand, Turkey, U.S.A. and some others also produce lac. But in Thailand, Malaya, Burma and Nepal the lac producing industries are increasing day-by-day. Thailand has become the main competitor of India in export of lac. In India major lac producing places are Assam (Kashi Hills), Bengal (Calcutta, Jangipur, Murshidabad, Mathrapur, Malda), Bihar (Manbhum, Palamau, Ranchi, Santhal Pragana), Delhi, Gujarat,

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Hyderabad, Kashmir, Madhya Pradesh (Damoh, Champa, Bilaspur, Rewa, Umaria), Chennai, Coimbatore, Mysore, Orissa (Cuttak, Mayurbhanj), Punjab (Hoshiarpur, Shahpur), Rajasthan (Indergarh, Kota, Jaipur, Jhallawar, Karauli), and Uttar Pradesh (Ghazipur, Mirzapur, Agra) etc.

Lac Insect (Lakh ka-kira)

Phylum ..... Arthropoda
Class ..... Insecta
Order ..... Hemiptera
Sub-order ..... Homoptera
Super-family ..... Coccidae
Family ..... Leciferidae
Genus ..... *Tachardia*
Species ..... *lacca*

Lac insect (*Tachardia lacca*) previously known as *Laccifer lacca* is a minute, resinous, crawling scale-insect which inserts its beak into plant tissues, sucks juices and grows, and secretes lac from the hind end of the body. Its own body ultimately gets covered with lac in the 'CELL'. Lac is actually secreted for its protection and not for the food of the insect. The commercial lac is produced in large quantities by female as a protective covering of its body which is injurious to the host plants.

Male. Male is red in colour and 1.2 to 1.5 mm in length. It secretes bright creamy lac. It has reduced eyes and ten segmented antennae. The mouth-parts are of piercing and sucking type. Thorax bears three pairs of legs and one pair of hyaline wings. The abdomen is eight segmented and terminates into a short, chitinous prominent general sheath containing penis. On either side of this genital sheath a white elongated caudal seta is found.

Female. Female is larger than males and measures about 4 to 5 mm in length. The pyriform body of the female is enclosed in a resinous cell. The head, thorax and abdomen are not clearly distinct. The mouth-parts are of piercing and sucking type. The antennae are clearly visible and degenerated. The posterior end of the body has a median and two lateral processes. The legs are in degenerated form.

Life History

Each mature female just after fertilization lays about 200 to 500 eggs in a cell in which she is enclosed. The oviposition takes place into the incubating chamber which is formed by the contraction of the body of the female in forward direction inside the lac cell. The eggs are laid in the months of October and November. After six weeks of laying, the eggs are hatched into first instar nymphs in the months of November and December. When nymphs emerge they are in quite large number. This mass emergence of the nymphs is known as 'SWARMING' (Fig. 1).

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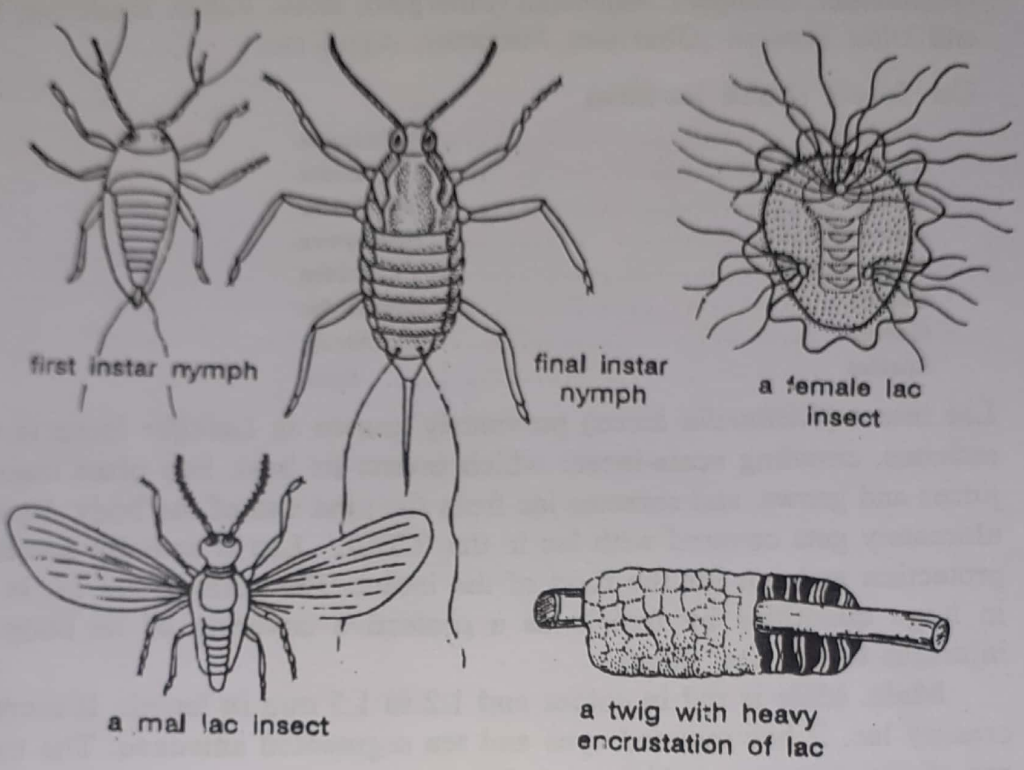

Fig. 1. Life history of *Tachardia lacca*.

Nymph. At the time of emergence the nymphs are about 0.5 mm in length, red coloured and boat-shaped. The head bears paired antennae, ocelli and ventrally situated piercing and sucking type of mouth-parts. The mouth-parts are provided with proboscis. The three segmented well developed thorax contains two pairs of spiracles and only one pair of walking legs. The abdomen contains two pairs of legs and terminates into a pair of long caudal setae. The active nymphs can crawl to a considerable distance so, just after emergence they start moving in search of food and reach their host plants, preferably on young and succulent shoots because the young nymphs are unable to settle and feed on hard twigs. These nymphs settle very close to each other on the twig of the host plant which further collapses completely and forms a continuous covering even on the lower surface of the twig. The number of nymphs that settle per square inch area is about 150 to 200. Settled nymphs suck the sap from the twig of the host plant and start to secrete the resinous substance by special dermal glands which are located all over the body. As the resinous secretion comes in contact with air, it soon becomes hard and forms a coating over the body of nymph and is called as 'CELL'. Within this cell various life processes like growth of the nymph, morphological changes and lac secretion take place.

The male 'Cell' is elongated and cigar-shaped having two holes *i.e.*, anterior and posterior. From the posterior hole which is covered by a flap or operculum,

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the male insect comes out by pushing open the operculum. After six to eight weeks of stationary life the nymphs are metamorphosed as a result of which some (30%) active winged males and maximum (70%) emerge in the form of females which are wingless. The females get fixed on the host plant in resinous mass. The males walk over the encrustations of females and fertilize them within their oval cells through anal opening. The males leave the parent cell after fertilizing the female. One male is capable to fertilize many females. The female nymph once settled never moves but undergoes 3 moults inside her cell loosing its eyes and legs, and with rudimentary antennae only. The fertilization of female is followed by a rapid growth of the female body till it begins to lay eggs in October and November. From these eggs male and female emerge in February to March. The male fertilizes the females of this generation and the fertilized female lays eggs in months of June to July and dies secreting lac all the time. Thus, the life cycle reoccurs twice in one year on the same host plant.

Due to short life period males do not take major part in the secretion of lac but female secretes lac throughout her life and its life span is longer than males. Major quantity of lac is secreted from females. The life cycle period depends mainly on ecological factors of the region.

Host Plants

The lac insects have more than one host plant. The selection of suitable host plant for the cultivation of lac is of much importance. To establish the lac industry one should know well about the topographic and climatic conditions for the growth of host plants suitable for that particular region. Brun (1958) has mentioned that 113 varieties of host plants are found in the geographical Indian regions including Pakistan and Burma. Out of these 113 host plants only 14 are very common in India which are as follows :

1. Kusum	—	*Schleichera oleosa*
2. Babul	—	*Acacia nilotica*
3. Ber	—	*Zizyphus mauritianas*
4. Palas	—	*Butea monosperma*
5. Ghont	—	*Zizyphus xylopyra*
6. Khair	—	*Acacia catechu*
7. Peepal	—	*Ficus religiosa*
8. Gular	—	*F. glomerata*
9. Pakapi	—	*F. virens*
10. Putkal	—	*F. globella*
11. Mango	—	*Mangifera indica*
12. Sal	—	*Shorea robusta*
13. Shisham	—	*Dalbergia sisso*
14. Fig	—	*Ficus carica*

The quality of lac is directly related with the quality of host plant. So far, no artificial product has been able to replace the lac. Khair, Kusum and Babul give better quality of lac when sown directly in the field. But Palas, Ber and

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Ghont give good crop when they are first sown in nursery and then transplanted to the lac growing field. Palas and Ber produce a particular type of lac which is called as 'KUSUMI LAC'.

Cultivation of Lac

Lac cultivation is a complicated process, so the cultivators should know well about the inoculation, swarming period and harvesting of lac.

Inoculation

The first procedure in the lac cultivation is the inoculation of lac insect. Inoculation is the process by which young ones get associated properly with the host plant. Inoculation is of two types—

1. Natural inoculation. The inoculation taking place in normal routine or in natural way is very simple and common process during which the swarmed nymphs infect the same host plant again and start to suck the juices from the twigs. The natural incubation of swarmed nymphs has some drawbacks which are as follows —

(a) Incomplete nutrition. Lac insects with their piercing and sucking mouth-parts, pierce into succulent twigs and suck the cell sap of the same host plant for nutrition. If the cell sap of the same host plant is further sucked out by the swarmed nymphs of the second crop continuously, the growth of the host plant would be retarded. In this way lac insect may not be able to get enough nutrients from the same host plant. The lac insects due to lack of sufficient nutrients lose their proper development, thereby affecting the production of lac also.

(b) Irregular inoculation. During the natural inoculation it is not sure that uniform sequence of inoculation takes place. If inoculation is not of continuous fashion, a regular crop of lac may not be obtained.

(c) Unfavourable climatic conditions. At the time of swarming a number of factors like high intensity of sunlight, heavy rainfall, flow of wind etc. affect the proper inoculation of nymphs. These natural environmental factors may also affect the host plant at the same time and may cause a gap of inoculation resulting in irregularity of the lac crop.

(d) Multiplication of parasites and predators. Lac insects have certain enemies in the form of parasites and predators. If the crop is not harvested in time and lac is allowed to remain on the same twig, the multiplication of parasites and predators takes place which hampers the population growth of lac insects.

Thus, keeping in view the above drawbacks the natural procedure of inoculation is avoided and certain devices have been developed to ensure artificial method of inoculation.

2. Artificial inoculation. The main idea behind the artificial method of inoculation is to check all possible drawbacks of natural inoculation.

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In this method first of all host plant should be pruned in January or June. The twigs bearing insect nymphs which are about to swarm, or just before swarming are cut in sizes ranging between 20 to 30 cm in length. Then the cut pieces of these twigs are tied to fresh trees in such a way that each stick touches the tender branch of the tree at several places which form bridges for the migration of the nymphs. After swarming, these twigs should be removed and separated from the host plant. The following precautions should be taken in artificial inoculation :

(i) One must ensure that the twigs, which are going to be tied on fresh host plant, are having good number of nymphs or eggs. It is also possible that from many of the twigs nymphs have swarmed out, thus inoculation would prove unsuccessful. (ii) The twigs provided with eggs or nymphs should be without any parasite and predator. (iii) The eggs or nymphs present on the twigs should be healthy and about to swarm so that one has not to wait for longer period and thus save time. (iv) For the uniformity of inoculation. 3 to 4 twigs should be utilised. (v) Host plants should be changed from time to time for the proper nutrition of the nymphs.

These insects are very small and if they move to a long distance there are chances of mortality of the nymphs. Due to maximum contact of twigs, swarming nymphs have not to move for long distance and find suitable places to establish on the host plant.

Inoculation period

In India two types of crops *viz.*, Rangini and Kusumi are grown in a year. The Rangini crop is of two types called as Kartiki and Baisakhi crop which produce Kartiki and Baisakhi lac respectively. The Kusumi crop is also of two types *viz.*, Agahani and Jethi which produce Agahani and Jethi lac respectively.

Thus, the inoculation periods of all the four types of crops are different. The inoculations of Kartiki, Baisakhi, Agahani and Jethi crops are recommended in months of June to July, October to November, July and January to February respectively. But if continuously four crops are taken, the plant would not get any rest which may cause less production of lac.

Swarming

It is very important phase in the life history of lac insect. So one should have accurate knowledge about the actual date of the swarming. At the time of swarming, the upper surface has yellow spot on the anal region. At this stage muscle contracts and insect gets detached from the place of attachment. Thus, it leaves a hollow cavity which later on gets covered with wax also. When these eggs are to be hatched out they become orange coloured. Thus, it is an indication that swarming has taken place. Thus, by trials and learning

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methods *i.e.*, by practice one could know about the exact date of swarming by looking at the colour of the eggs.

Harvesting of lac

The process of collection of ready lac from host tree is known as harvesting. In common practice the harvesting is of two types.

1. Immature harvesting. The harvesting of the lac before swarming is called as immature type of harvesting and the lac thus obtained is known as 'ARI LAC'.

2. Mature harvesting. The collection of crop after the swarming is called as mature harvesting and the lac obtained is known as 'MATURE LAC'.

The harvesting of lac before the swarming has some drawbacks because the lac insects may be damaged at the time of harvesting which would affect the population of lac insects and ultimately result in great economic loss to the cultivators. But in case of palas lac (Rangini lac) it is found that Ari lac gives better production. Therefore, Ari lac harvesting is recommended in case of palas only. In all other cases immature harvesting should be discouraged. It is also found that in cold areas mature crop yields better quality of lac.

Harvesting period. The harvesting periods of different crops are quite different in accordance with the inoculation of crops. Kartiki crop is harvested in October to November whereas, Baisakhi crop in May and June. The other crops like Agahani and Jethi are harvested in January to February and June to July respectively.

Recent Plan for Lac Cultivation

With the increasing number of lac industries some advanced plans have been recommended for the better cultivation of lac crops. Two types of planning are used now-a-days.

1. Ceupe system. All the trees of host plants of a definite area are not used under continuous cultivations process of lac crop because if all host plants of a farm would be under continuous attack of lac insects, 100% plants may not get any rest and thus the production of the lac would be affected due to deficiency of nutritive cell sap to the swarmed nymphs and adults. So, the plants of a farm are numbered into 5 groups of plants. This artificial division or marking of trees is called as ceupe system of crop cultivation. In this system when one group of host plants is under the process of cultivation of lac, other groups of host plants would be under rest.

2. Alternation of plant. In this system the variety of host plant is changed after one crop. So, swarmed nymphs are inoculated on the tree of other variety of host plant. In this way every host plant can get enough rest resulting into better production of lac.

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Processing of the Lac Industry

When the crop matures fully most of the lac is harvested and some part is left on the host plant. For the proper cultivation, the host plant should be pruned in January every year.

The twig bearing the lac alongwith eggs is called a BROOD LAC STICK and lac is known as BROOD or STICK LAC. The processing starts with the scraping of the stick lac from the twig. The scraped lac is subjected to removal of many impurities like dead parts of the lac insects, eggs and colouring matter, and finally crushed by hand-operated mortars. Then the material is air dried and obtained in the form of granules which is known as SEED LAC. This seed lac is soaked in water, washed, dried in sun light, bleached and heated to melt on charcoal fire in cloth bag of 3 to 4 metre. At the time of heating the bag is twisted and the lac is squeezed out of the bag. The impurities of the lac are left out in the bag, and are called as KIRRI LAC. The squeezed lac is now allowed to cool and solidify around the button-shaped forms which is now called BUTTON LAC or PURE LAC. This pure lac when stretched into thin sheet is called as SHEET LAC. This sheet lac when dissolved in water, produces white or orange coloured lac which is called as SHELL LAC. Shell lac is, in fact, prepared by boiling the seed lac with yellow arsenic in a certain proportion. Thus the shell lac is most purified form of lac.

The quality of lac depends upon the host plant. Kusumi lac is said to be the best lac while Dhak is supposed to be the worst and cheapest one. The quality and colour of the lac is variable according to the presence of gum and resins in the host plants.

Composition of lac

Lac is a complex substance having large amount of resins, together with sugar, water and other alkaline substances. The percentage of various constituents are as given below :

(1) Resin	—	68 to 90%
(2) Dye	—	2 to 10%
(3) Wax	—	6%
(4) Albuminous matter	—	5 to 10%
(5) Mineral matter	—	3 to 7% and
(6) Water	—	3%

Properties of lac

(1) Lac is not soluble in water but easily soluble in alcohol. This property of lac has great value for insulation of electrical connections.

(2) Lac is easily fusible on heating.

(3) Lac has adhesive quality.

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(4) It has binding property when mixed with alcohol.
(5) Lac is also soluble in weak alkali like ammonia.
(6) Lac is a bad conductor of heat.

Enemies of Lac Cultivation

Lac cultivation is destroyed by biotic and abiotic factors :

1. Abiotic enemies . These are high intensity of light, high temperature, high humidity, heavy rainfall and flow of wind.

2. Biotic enemies. The main biotic enemies of lac cultivation are mammals and insects. Krishnaswami et. al. (1957, 59), and Gepulpure et. al. (1963), have reported that squirrel, rats, and monkeys cause great damage to the lac crop.

The insects are very powerful enemies of lac crop. Annual loss due to the insect enemies is to the tune of about four lakh maunds.The insects damage the crops in different ways.

1. Parasites. The lac insects are parasitised by eight species of chalcidoid parasites like, *Parenchthrodryinus clavicornis, Erencyrtus dewitzii, Tachardiaephagus tachardiae,Tachardiaephagus tachardiae* var. *somervilli, Eupelmus tachardiae, Coccophagustschirchii, Mariettajavensis* and *Tetrastichus purpureus.* These parsites lay their eggs into lac insects and parasitised 4.8 to 9.9% of lac insects per year and 1/3 of the parasitised cells are males. Thus, it may be concluded that parasitization is not a major cause of the damage to the lac cultivation.

2. Predators. Predators cause very severe damage to lac cultivation and 35% of the lac cells are damaged by two predators *viz., Eublemma amabilis* Moore (Lepidoptera : Noctuidae) and *Holocera pulverea* Meyr (Lepidoptera : Blastobasidae). Female lays eggs near encrusted twigs from where larva emerges and feeds on lac insects.

Precautions

(1) Twigs for inoculation should be cut just before the swarming to get healthy brood.
(2) Twigs used for inoculation should be free from predators and parasites.
(3) Twigs tied for inoculation should be removed from inoculated host plants after a maximum period of 20 days.
(4) Lac left on the host tree for swarming should be removed in October and November.
(5) The brood lac after swarming should be destroyed along with predators and parasites on it.
(6) The lac scraped from the tree should be taken away from the area of lac infected trees.
(7) Fumigation and water immersion of lac, before removing from twig, should be done.

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Lac Industry in India

India used to produce about 97 per cent of the total lac output in the world but at present it has come down to 50-60 per cent. The cultivation of lac has been good source as an earner of foreign currency. About 50 per cent of the total lac produced in India is obtained from Chhotanagpur area. States like Orissa, Punjab, Madhya Pradesh, W. Bengal, Uttar Pradesh, Gujarat, Rajasthan, Assam etc. are increasing the production of lac now-a-days. On a very small level lac producing is also reported from Delhi and Kashmir. The average yearly yield of lac in India is about 15,000 metric tons. A lac research institute 'Indian Lac Research Institute' Namkum, Ranchi had been established in 1925 which is producing good quality of white lac. The Indian white lac is supposed to be better than red or other coloured lac because they produce stain or spots at places where they are kept. This is mostly small scale industry with around 350 factories, mostly located in Bihar. In Mirzapur district alone there are about 40 factories. Out of total lac produced in India about 85 to 95 per cent is exported specially to Britain, U.S.A., Russia and West Germany.

Economic Importance

In 19th century lac dye was in more use than lac resin. Presently due to availability of a better and cheaper annaline dyes the use of lac as a dye has been discarded. The manifest uses of lac is one of the Nature's standing gifts. The various used to which it is put are —

(1) It is utilized in the preparation of gramaphone records. Previously this industry utilized major part of the lac produced annually. But now a days to a great extent plastic is being used in this trade.

(2) It is of utility to Jewellers and Goldsmiths who use lac a filling material in the hollows in gold ornaments like bracelets, armlets and necklaces etc.

(3) It is an essential gradient used extensively for making polishes, paints and varnishes for finishing wooden as well as metal furnitures and doors etc.

(4) It is utilized for the preparation of toys, buttons, in pottery and artificial leather.

(5) It is used in the manufacture of photographic material, lithographic ink and for stiffening felt and hat materials.

(6) It is used as an insulating material for electrical goods.

(7) It is also used in confectionary trade as antifowling for applying on ship bottom, grinding stone industry and for ammunition and fire works.

(8) Last but not the least used commonly as sealing wax.

Thus, it is of great use and considered to be as one of the cash crops for the cultivators and also to the Government as source of foreign exchange earners which amount to crores of rupees annually.

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Sericulture

For more than 35 centuries countless generations of silkworms are continuously breeding, feeding on mulberry leaves, spinning their cocoons and dying, an everlasting sacrifice to the demand of human-beings for decoration. For the first time in 2697 B.C. Lotzu Empress of Kwang-Ti discovered the fancy origin of beautiful silk in the form of threads. Thus, the technique of cloth preparation from the cultivated silk was known to Chinese people for more than 2,000 years ago. The art of silk preparation was kept as top secret as national policy and any one, who attempted to send the eggs of silkworm out of the country, was hanged to death. It is said that silk was as valuable as gold and ultimately gold was flowing into China from all parts of the world. But in the year 555 A.D. this secrecy was opened and the eggs of silkworm and sericulture technique were smuggled by two monks sent as spies to China and thus, sericulture was introduced into Europe. Later on it was introduced in Mediterranean and Asiatic countries. Now-a-days sericulture has become one of the most important cottage industries in a number of countries like Japan, China, Rep. of Korea, India, Brazil, Russia, Italy and France.

The experimental and systematic study on sericulture was started in Japan in 1911 after establishment of the Sericulture Experiment Station and in 1979 the National Sericulture Experimental Station was set up in Tokyo.

In India first of all Lefroy (1905-1906) started investigation on the silkworm and sericulture at Pusa Institute, New Delhi. He set up a sericulture stall in an 'All India Exhibition' organised by the Government of Uttar Pradesh at Allahabad

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in 1901-1910 to draw the attention of scientists and general public towards the sericulture industry.

Silk Moth

The silk producing machine is an insect called as silk moth locally in Hindi 'Resham-ka-kira'. Although a number of species are found producing silk but only few species are used for sericulture industry.

Systmatic position

Phylum ..... Arthropoda
Class ..... Insecta
Order ..... Lepidoptera
Family ..... Bombycidae and Saturniidae

Species of Silkworm

1. Mulberry silkworm. *Bombyx mori.* It belongs to the family Bombycidae. China is the native place of this silkworm but now it has been introduced in all the silk producing countries like, Japan, India, Rep. Korea, Italy, France and Russia. Since the natural food of this worm is mulberry leaf, it is called as mulberry silkworm. The silk produced by this moth is white in colour.

2. Tasar silkworm. *Antheraea paphia.* It belongs to the family Saturniidae and common in India, China and Sri Lanka. The caterpillar feeds on ber, oak, sal and fig plants. The cocoon p oduced by this moth is hard and of hen's egg size which produces reelable brown coloured silk. Though it had been only a wild variety of silk moth since long, now, by cross breeding, it has been possible to produce such varieties which are reared any how and domesticated. But the domestication of tasar caterpillars is not so easy, so the cocoons have to be collected from the forest. The moths do not easily breed in captivity. Since breeding is not well controlled, the tasar silk industry has not reached up to mark as the mulberry silkworm industry.

3. Muga silkworm. *Antheraea assama.* It also belongs to the family Saturniidae and semi-domesticated in nature. The native place of this species is Assam where, it has now become a good source of cottage industry. The caterpillars of this worm feed on *Machilus* plant and the silk produced by this moth is known as Muga silk.

4. Eri silkworm. *Attacus ricinii.* It also belongs to the family Saturniidae and produces silk in East-Asia. In India sericulture scientists are trying to produce silk in East-Asia. Sericulture scientists are trying to produce such cross breeds which can provide good quality of silk and can be reared easily. It feeds on castor leaf. Cocoons cannot be reeled as in mulberry cocoons, therefore, it has to be spun. Its life history resemble with that of mulberry worms. The cocoons of this worm have very loose texture and the silk produced is called as 'Arandi silk' locally. The threads are not glossy but much durable.

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5. Oak silkworm. *Antheraea pernyi.* It belongs to the family Saturniidae and is found in China and Japan. *A. roylet* of the Himalayas and *A. yamamai* of Japan have been reared for centuries. They produce good quality of silk.

6. Giant silkworm. *Attacus altas.* It belongs to the family Saturniidae and is found in India and Malaysia. It is the largest of the living insects reaching upto eleven inches in wing-span.

Out of the above species only four are of common use for sericulture *viz., Bombyx mori, Attacus ricinii, Antheraea assama* and *Antheraea paphia.*

Mulberry Silkworm

The perusal of literature reveals that much advanced work has been done by sericulturists and scientists on *Bombyx mori* because of its total domesticated nature. Various varieties of silkworm are produced by genetical crossing and they are producing 2-7 generations in India but in some countries like Europe and Russia where the duration of winter is more than the summers only one generation is produced per year. The race of silkworm by which only one crop is taken in one year is called UNI-VOLTINE, producing two crops in a year is called BI-VOLTINE and producing more than two crops in a year is called MULTI-VOLTINE races. Now- a-days , for commercial purpose only approved races are reared by conducting national trial of silkworm races offered by various research institutions. Different crosses are generally chosen for spring and autumn rearing.

Life History of Mulberry Silkworn., *Bombyx mori* (L)

The adult of *Bombyx mori* is about 2.5 cm in length and pale creamy white in colour. Due to heavy body and feeble wings, flight is not possible by the female moth. This moth is unisexual in nature and does not feed during its very short life period of 2-3 days (Fig. 1)

Fertilization. Fertilization is internal preceded by copulation. Just after emergence, male moth copulates with female for about 2-3 hours and if not separated they may die after few hours of copulating with female.

Egg laying. Just after copulation, female starts egg laying which is completed in 1-24 hours. One moth lays 400 to 500 eggs depending upon the climatic conditions and the supply of food material to the caterpillar from which the female moth is obtained. The egg laying is always in form of clusters and covered with gelatinous secretion of the female moth which helps them in proper attachment.

Eggs. The eggs laid by the female moth are rounded and white in colour. The weight of the newly laid 2,000 eggs comes to about 1 gm. With the increase in time after laying, eggs become darker and darker day-by-day. Two types of eggs are generally found *viz.,* DIAPAUSE type and NON-DIAPAUSE type. The diapause type of eggs are laid by the silkworm inhabiting in temperate regions, whereas, silkworms belonging to subtropical regions like India lay

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non-diapause type of eggs. During diapause all the vital activities of the eggs cease.

Hatching. The eggs after ten days of incubation hatch into a larva called as caterpillar. Hatching is the most important phase of silk moth's life. After hatching, caterpillars need continuous supply of food because they are voracious feeders. If proper supply of mulberry leaf is not possible the development of caterpillar would not be in proper course. Sometimes, due to lack of food material, young caterpillars die causing great loss to the sericulture industry. It is recorded that in uni-voltine race hatching of eggs takes one month after laying.

Caterpillar. The newly hatched caterpillar is about 0.3 cm in length and is pale, yellowish-white in colour. The caterpillars are provided with well developed mandibulate type of mouth-parts adapted to feed easily on the mulberry leaves. The caterpillar is twelve segmented and the abdominal region has ten segments having five pairs of pseudo-legs. It is also provided with a small dorsal horn on the anal segment. Because of its being very much tender, the Ist instar larva can feed only on very soft leaves of mulberry plants. As they are voracious feeders, they grow rapidly which is marked by four moultings. After Ist, 2nd, 3rd and 4th moultings caterpillars get changed into 2nd, 3rd, 4th and 5th instars respectively. It takes about 21 to 25 days after hatching. The full grown caterpillar is 7.5 cm in length. It develops salivary glands, stops feeding and undergoes pupation. The time taken for the full growth of the caterpillar from young to the well grown stage varies with regard to the temperature, humidity, food supply and type of race. Weight of the full grown caterpillar varies from 4 to 6 gm.

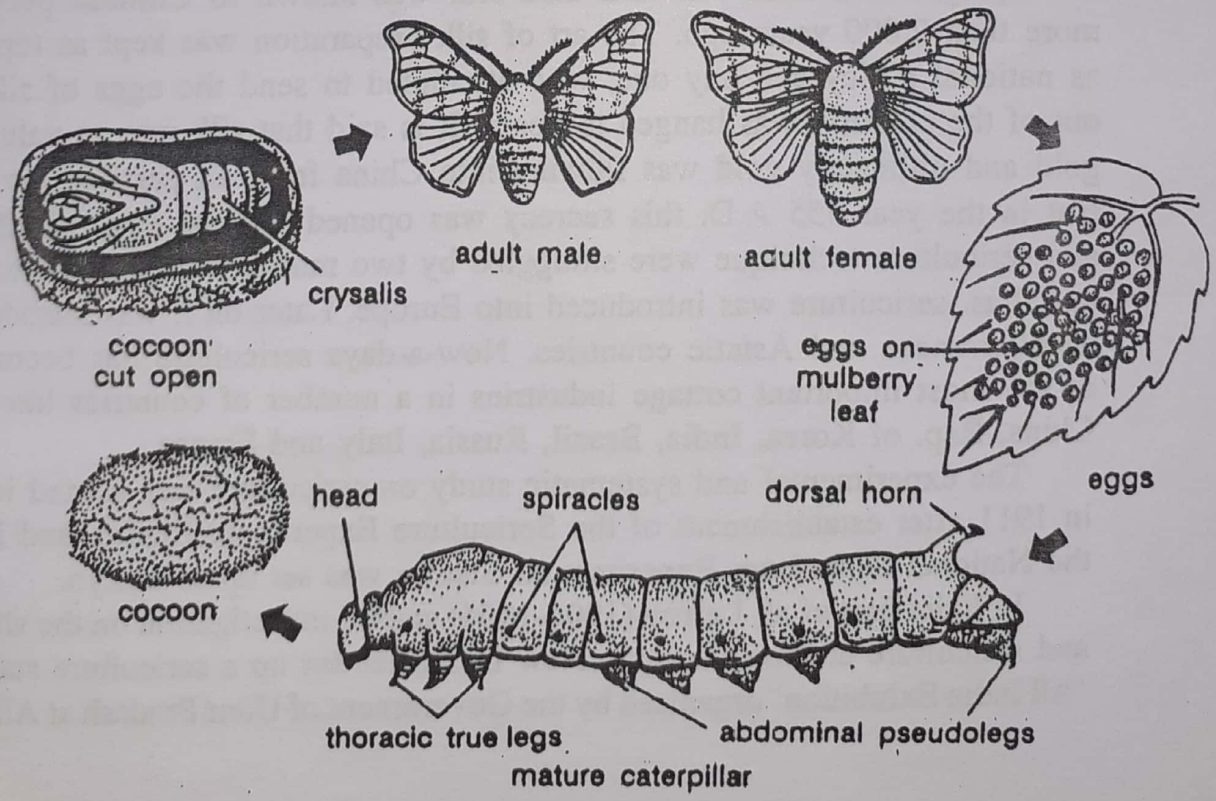

Fig. 1. Life history of *Bombyx mori*.

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Pupa. The caterpillars stop feeding and move towards corner among the leaves and secrete a sticky fluid through silk gland. The secreted fluid comes out through spinneret (a narrow pore situated on the hypopharynx) and takes the form of long fine thread of silk which hardens on exposure to the air and wrapped around the body of the caterpillar in the form of a covering called as COCOON.

Cocoon. Cocoon is the white coloured bed of the pupa whose outer threads are irregular while the inner threads are regular. The length of continuous thread secreted by a caterpillar for the formation of cocoon is about 1000-1200 metres which requires 3 days to complete. The threads is wound around the cocoon in concentric manner. The binding of threads round the cocoon is very interesting and quick going phenomenon achieved by the constant round motion of the head of the caterpillar from one side to the other at the rate of 65 times per minute. Now the silkworm pupa is covered within a thick, oval white or yellow silken cocoon. It is estimated from the data obtained by practical application that one pound of silk can be obtained from 2,500 cocoons. The weight of one cocoon is about 1.8 to 2.2 gm and the weight of the cocoon shell only is 0.45 gm. The size of the thread is 2.0 to 2.8 denier. The pupal period lasts for 10 to 12 days and the pupae cut the cocoon and emerge into adult moths.

Emergence of imago. Due to active metamorphic changes during pupal period the abdominal pseudo-legs disappear and two pairs of wings develop. The silkworm within the cocoon secretes an alkaline fluid to moisten its one of the ends. As a result of this the moistened end becomes soft where the threads are cut open (hydrolysed) by the silkworm. Finally a hole is formed through which a feeble adult moth squeezes out of the cocoon.

Sericulture Industry

The production of silk from the silkworm by rearing practices on commercial scale is called sericulture. Although silk is very beautiful and fancy gift of nature but its commercial production is very much complicated and a tough job which requires heavy man power. Before going into the details of the sericulture industry it is essential to have an idea about the major steps and requirements of sericulture. Improved race of *Bombyx mori* and good nutritive type of mulberry plantation is the sole need for the industry. Other than these some of the other requirements are given below —

(1) Machana : The proper place for rearing the silkworms.
(2) Rearing trays : For keeping the laid eggs alongwith the mulberry leaves.
(3) Spinning or Chandrakis tray : For keeping the caterpillars at the time of full grown stage ready for pupation.
(4) Dalas : For fetching the mulberry leaves.
(5) Chopping knife : For cutting the mulberry leaves into smaller pieces.
(6) Baskets : For the distribution of mulberry leaves.

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(7) Hygrometer : To know the % humidity in the atmosphere.
(8) Thermometer : To take the reading for the room temperature.
(9) Oven : To regulate the different stages of life cycle at different temperatures.
(10) Freez : For the storage of eggs (seed) for next generation.

Selection of races of *B. mori*. Although a number of races have been developed for the purpose, care should be taken to select only those which would be fit for a particular locality keeping in view the climatic condition of that area. According to rearing season *viz.*, spring, early autumn and late autumn different crosses are chosen for successful rearing.

Mulberry. The whole sericulture industry is based on the best utilization of the mulberry leaves as it is the only food of this insect. In Japan more than thousand varieties of mulberry exist including as many as 130 natural species out of which only a few are in commercial use.

Mulberry is a deciduous medium sized tree belonging to the family Moraceae. Its species are given as below :

***(a) Morus alba* Linn.** It is of white type and locally called as Toot, Tootri etc. This is widely used for rearing the silkworm and also for fruits.

***(b) Morus indica* Linn.** It is locally called as 'shahtoot' and is Indian in origin. It is also used for fruits and for rearing of silkworms.

Climate. Although, mulberry is a plant of temperate zone but some varieties have been developed by cross breeding which can grow well in tropical and subtropical zones also. According to the climatic conditions different varieties of mulberry are being used throughout the world.

Soil. For a good crop and nutritive type of leaves, soil should be of loam type and not with stones etc. Soil with neutral pH is best suited for proper growth of mulberry plants.

Plantation. It is of two types as given below —

(a) Seed. In December and May seeds of mulberry are sown and the seedlings grow very quickly which can be transferred either as whole plant or a stump in months of June, July and November. Seed beds should be mixed with ash, lime and white arsenic.

(b) Cutting. Cutting should be done in months of July and August. The size of each cut piece should be 20 to 25 cm in length and 2 to 3 cm in thickness. The cut pieces should be planted in slanting position in the pits (50 × 50 × 50 cm) having 1 kg. superphosphate, 30 gm B.H.C. and 25 kg farm-yard manure.

The plantation is performed in December-January or July. The plantation is mainly of 2 types *viz.*, single row and multiple row plantation. (i) In single row plantation 400 plants can be placed around the boundary of one hectare plot at the distance of one metre from plant to plant. (ii) In multiple row plantation scheme the whole of the plot is used only for sericulture programme. About 10,000 plants are placed at the distance of 1 × 1 metre per hectare.

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Weekly irrigation is most preferred for bumper growth of mulberry leaves.

Fertilizers. The months of December to January are the best time for manuring the crops. Although the real dose of any fertilizer can be fixed after proper soil testing and according to the fertility of the soil but a generalized recommended dose of manuring is given below (S.S. Sagwal and O.P. Katna, 1981).

Table. **Dose of manures and fertilizers per plant.**

Age of Plant (Year)	Farmyard manure (Kg.)	Kisan Khad (gm)	Super phosphate (gm)
1	10	500	250
2	20	1,000	500
3	30	1,500	750
4	40	2,000	1,000
5	50	2,500	1,250

Pruning and thinning. December and January are best suited months for pruning and thinning. After 4 to 5 years of plantation mulberry plants get ready for the rearing of silkworms.

The white mulberry *(Morus alba)* or Kashmir white or black mulberry or white Philippine early variety are preferred. In India white Philippine early variety is most preferred because this grows easily.

Rearing of Silkworm

The word rearing does not mean only the feeding of caterpillars as often understood but a continuous care from egg laying through aestivation, hibernation, incubation, early stage larval care, late stage larval care to the production of cocoon. So, for proper and step-wise study of rearing one should proceed from Grainage Technology.

Grainage management

The aim of the establishment of grainage is to provide good quality of seed to rearers and maintenance of original quality of races. For this purpose due care should be taken of the 'crop of silkworm' for seed production from the very beginning *i.e.* the caterpillar stage, by providing them with proper nutrition and protection from the attack of diseases. Keeping these points in view initial selection is made on the basis of percentage of dead pupae during normal development. If it is above the limit seed should not be purchased for seed production. First selection is made by separating out dead cocoons and next selection in the grainage.

After final selection, cocoons are subjected to sex separation by cutting one end of the cocoon either manually or through Nagahara (in Japan) cocoon openers. The Nagahara machine can cut 10,000 to 15,000 cocoons per hour. For the

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production of commercial eggs loose forms of cocoons are used and collective mother examination is done, either through mass pebrine detecting machine or general microscopic observations. They are then kept for mass emergence.

1. Emergence of moth and fertilization. When kept for emergence at room temperature, mass emergence of adults takes place. As per their nature, just after emergence, male moth starts moving around the female. Males are very much active whereas the females which are loaded with eggs are incapable of flying. If not separated atonce in cages males start copulating with the females but the eggs obtained from this female mated from the male of the same stock is useless for the seed. So the males and the females just after emergence have to be separated into separate cages without their mating. Now one female of one lot is kept with the male of the other lot and atonce they form pair and copulate for about 3 hours. After completion of mating, males should be separated and may be used for the fertilization of other females. But one male can not fertilize more than two females. Now fertilized females are subjected to egg laying.

2. Egg laying. Just after fertilization, female starts egg laying and in the duration of 24 hours it completes egg laying process. The eggs laid by one female are about 400 to 500 varying according the different races. Female dies after egg laying. These eggs are called as SEED. These eggs are kept in sterilized trays and stored at 4° C under laboratory conditions or sometimes kept at hill stations in diapause conditions.

The stages of egg (seed) production is of 3 types *viz*., production and supply of grand parent eggs, production and supply of parent eggs, rearing of parent eggs and production of commercial F_1 seed. The grand parent and parent eggs are produced by recognised and reputed organizations. This commercial seed is supplied to the rearers.

3. Hatching. This is an important phase of sericulture industry because as soon as the larvae are hatched they start feeding voraciously. So only those sericulturists who would be able to supply sufficient amount of fresh mulberry leaves to the young hatched larvae, could perform successful sericulture programme otherwise young ones will die resulting great loss to sericulture industry. This is why the hatching has to be controlled, accelerated or postponed by artificial treatments under refrigerated conditions. For proper hatching of seeds (eggs) advanced techniques have been developed in which eggs are collected and kept with mulberry leaves, working as stimulant for hatching in shady places on white sheet of paper in insect proof trays on a stool. For this purpose the legs of stool must be kept in water so that insects may not crawl and damage the hatching eggs. It is also notable that if the eggs are placed in the same position in which they are laid, hatching will not be 100 per cent. So it is advisable that the eggs kept in trays should be moved with the help of feather. The group of caterpillars hatched at various stages should be kept

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separately. Thus, one should be careful that hatching must be coincided with the best season of the mulberry.

4. Experimental data of egg laying and hatching. (i) If after 120 minutes of oviposition eggs are kept at 10° C for 24 hours then transferred to the oven at 16°C for 4 days and further soaked in hydrochloric acid (15% at 46° C) for 5 minutes, the diapause condition is broken easily. (ii) To get the homozygous stock of female silk moth, eggs are taken from 24 hour old moth and treated with hot water (46° C) for 18 minutes then kept at 15 to 17° C for 4 days, treated with acid at 46° C and then kept for incubation. When such eggs are reared carefully a homozygous stock is obtained. (iii) If the female moth is kept at 5°C for 24 hours just after mating and for egg laying at normal room temperature, 70 per cent eggs are laid in the first hour after incubation and 20 per cent eggs are laid in 2nd hour. This data is very much useful for grainage technicians from the point of view of uniform hatching of eggs.

Supply of seed to rearers and commercial rearing

After grainage management the next step is the supply of seed or caterpillars to the farmers. The supply is of two types depending on the knowledge of rearers *i.e.*, supply of eggs and 2nd instar larvae.

The old rearers who are well versed with the rearing technique may purchase eggs for the rearing but new and untrained rearers knowing nothing about the rearing should always be given 2nd instar caterpillars for this purpose. Much care should be taken for the rearing of 1st, 2nd and 3rd instar caterpillars and 4th and 5th instar caterpillars are mostly reared either on hanging trays often with nylon nets or on the floor.

It is essential to clean the bed of the caterpillars once in a day for 3rd, 4th and 5th instars.The principle of rearing should be the production of healthy caterpillars with uniform development.The mulberry leaves supplied to the 1st and 2nd instar larvae should be young and well chopped because they are very tender in nature. The 3rd instar larvae may feed even on chopped hard leaves but 4th and 5th in star larvae can feed easily on leaves also.

The taste of mulberry leaf is lost due to rapid loss of moisture, so rearer should be careful to stop or reduce the loss of moisture from the leaf after harvesting. For this purpose 60 to 70% humidity of the room is needed otherwise it affects the health of silkworm. So, it is advisable to keep the leaves wrapped in wet clothes. The overcrowding of worms causes under-nourishment and checks proper development. If a large number of rearers in the same village take the worms from same lot, spinning of silkworm of all the rearers starts on the same day if proper supply of mulberry leaves is there.

Now full grown 5th instar larva stops feeding, undergoes pupation and settles to a corner among the mulberry leaves and starts to secrete sticky fluid.

Thus, an improved technique of rearing of silkworm has resulted in the production of cocoons of good quality. The temperatures best suited for the

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rearing of 1st, 2nd, 3rd, 4th and 5th instar larvae are 27, 27, 25, 24 and 23° C respectively.

Spinning of cocoons

This is the period when the caterpillar stops feeding and starts to secrete a pasty substance from the silk gland. In this condition worms should be picked up and transferred to the spinning trays and kept in a position of slope (slanting) to the sun for a short period. Within three days spinning is over and the cocoon is formed and this is the last phase of the rearing of silkworm.

Quality of cocoon. The quality of cocoon is dependent on the raw silk yield, filament length, reelability and splitting.

Marketing of cocoon. The price of cocoon is fixed during every season of the rearing. This price is, however, watched by the Government and cocoons are purchased by the rearers.

Post-cocoon processing

The method of obtaining silk thread from cocoon is known as post-cocoon processing. This includes STIFLING and REELING.

1. Stifling. The process of killing the cocoons is termed as stifling. Sericulturists should be very much careful that before the emergence of silkworm (The cocoons which do not have cut holes) good sized cocoons of 8 to 10 days old are selected for further processing and dropped into hot water or subjected to steam or dry heat, sun exposure for 3 days or fumigation. In this way pupae or cocoons are killed. The killing of the cocoon in boiling water helps in softening the adhesion of the silk threads among themselves and loosening of the outer threads to separate freely, facilitating the unbinding of silk threads.

2. Reeling and spinning. The process of removing the threads from the killed cocoon is called as reeling. Four or five free ends of the threads of these cocoons are passed through eyelets and guides to twist into one thread and wound round a large wheel from which it is transferred to spools. Thus the silk obtained on the spool is called as RAW SILK or REELED SILK. The waste outer layer or damaged cocoons and threads are separated, teased and then the filaments are spun. This spunned silk is called as 'SPUN SILK'.

The raw silk is further boiled, stretched and purified by acid or by fermentation and then carefully washed over again and again to bring about the well-known lustre on the thread.

The modernization of the reeling and spinning process by autolization and various labour saving process has opened a new way to this cottage industry in the world. One autolizer can yield 3.715 kg silk per basin in 8 hours in Japan.

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Silk

Silk is a pasty secretion of the silkworm produced by the silk gland. The silk glands are actually modified salivary glands which are long and sac like. As this pasty secretion comes in contact with air, it becomes hard and forms strong and pliable silk strands. This secretion forms two cores of fibroin : (i) a tough elastic insoluble protein consisting of 75% of the fiber's weight and cemented together with sericin from the middle region of the silk gland at the time of secretion, and (ii) a gelatinous protein which is easily soluble in warm water. Some quantity of wax and carotenoid pigments are also detected. The diameter of the silk fibers is 0.0045 to 0.0082 cm. Its elasticity is found to be 20%.

Diseases of Silkworm

The Sericulture Industry suffers from a number of diseases in Tropical regions of South East Asia. The maggot disease, pebrine, polyhedrosis and flacherie are the diseases which cause severe damage to this industry. The poisoning by tobacco and Muscardines is also reported to be harmful but is not very common.

[I] Maggot disease

This disease is caused by *Tricholyga sorbillans,* a fly belonging to the order-Diptera and Family-Tachinidae. It is distributed throughout India, Japan, Korea, China, Vietnam and Thailand. The presence of milky white cylindrical eggs on the skin of silkworm larvae is a symptom of this disease. The number of eggs laid by the fly on a silkworm larva varies from several to more than fifty but usually they are two to three. After 30-40 hours of egg laying, maggot is formed inside the egg shell. Now this maggot makes a hole on the ventral side of egg shell and on the skin of the silkworm. Thus, maggot penetrates into the body of silkworm larvae and starts eating the tissues of larvae. When the maggot penetrates into the larval body, the big black mole is formed on that part of the skin. The segments in which maggot exists, swell up and bend as a result the attacked larva becomes inactive and loses appetite. Usually fourth and fifth stadia are attacked by the maggots. The larvae, attacked up to the fourth stadia die before making cocoon, whereas, those attacked in the fifth stadium make cocoons but usually do not attain the pupal stage.

A number of natural enemies like parasitic insects, fungi etc. are known to control the population growth of *T. sorbillans.* The avoidance of entry of this fly into the rearing room of silkworm is the only means for the prevention of this disease for which nets are fixed around the windows.

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[II] Pebrine

This is one of the worst diseases of silkworm. Sericulture was once damaged by this disease in all the countries involved in this industry but some countries have overcome this disease and succeeded in getting pebrine-free-silkworm-eggs for reeling cocoons. *Nosema bombycis* Nageli, belonging to Microsporida, is the casual micro-organism of this disease. The infection takes place through the mouth of larvae at the time of feeding or through the mother's ovary. When new spores are formed in the tissues of alimentary canal of silkworm, they are discharged with the faeces and make a source of infection. When the spore enters into the digestive tract of silkworm, two nuclei, contained in the sporoplasm, are divided into four nuclei and at the same time the polar filament projects and penetrates into the cells of the alimentary canal. Further, they enter into the blood and swim in it. They are distributed throughout the host body, attacking various tissues, specially the fat bodies and organs, excluding chitincus tissues and nucleus of cells. When the hypoderm is attacked and its cells die, the affected part becomes black due to the formation of melanin. Inside the body, the milky white spots or marks are observed on the silk gland or on the surface of the alimentary canal. In case of severe infection of the eggs the whole of yolk nearly gets filled with the micro-organisms resulting in their (eggs) death. Whereas, in case of slight infection the eggs hatch but the larvae carrying infection die at the third moult without making cocoon.

The diseased larvae show little inclination towards food and exhibit irregular and differential growth resulting in the formation of small larvae of different sizes. They become tardy, shrunken or moult quite late and finally die.

Counter measures against pebrine. If the infection occurs at the embryo stage, the larvae die in the third moulting stage as already mentioned. So, during the rearing of reeling cocoons it is very important that the pebrine free eggs are used. The infection by pebrine should be strictly avoided at any stage of the life history of the silkworms for rearing seed cocoons in order to get the healthy eggs. Therefore, it is essential for the prevention of pebrine that the tools used and the rearing houses should be kept free from pebrine germs. The following measures may be applied.

1. Examination of mother moths. All the mother moths producing eggs should be carefully examined one by one, and eggs laid by healthy moths only be taken for further use. The unqualified eggs should be burnt away.

2. Forecasting and correcting examination. In order to make the pebrine examination more reliable, the forecasting and correcting examinations are carried out for the eggs of the seed cocoons.

The materials employed for forecasting examinations are the excrement of mature larvae, late moulting larvae, dead larvae, cocoons or pupae and moths accelerated to emerge out of cocoons. For the correcting examination a few

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eggs of each reproductive egg-batch are taken and incubated and thus, emerged larvae are used as the material for examination of pebrine germs.

3. Removal and disinfection of pebrine germs. The spores of pebrine may survive for a number of years in an ordinary type of rearing room if the environmental condition is humid. Therefore, rearing rooms, tools and other utensils should previously be cleaned and washed to remove the pebrine diseased eggs, carcases of infected larvae, pupae, moths and dead cocoons, faeces of diseased larvae and so on. The pebrine spores can be destroyed by treatment with 2% formalin for 30 minutes, 0.5% sublimate for 5 minutes, 5% chlorinated lime for 30 minutes, current steam for 30 minutes and sun shine in the summer for 7 hours.

4. Care on rearing silkworms. The tendency of the infestation by the pebrine spores has been observed to occur more when silkworms are reared in dry and cool conditions than in the hot and wet conditions. If the larval period becomes longer, the infection of pebrine is severe, so care should be taken on these points during the course of selection of the seed cocoons by the rearers.

[III] Polyhedrosis in silkworms

Three types of polyhedrosis are found in silkworms.

(1) Nuclear polyhedrosis.
(2) Intestinal cytoplasmic polyhedrosis.
(3) Intestinal nuclear polyhedrosis.

1. Nuclear polyhedrosis (Grasserie, Jaundice). It is caused by a kind of virus which forms polyhedra in the nuclei of the cells of fatty tissues, dermal tissues, muscles, tracheal membranes, basement membrane, epithelial cells of midgut and blood corpuscles. The polyhedra are commonly hexagonal and rarely tetragonal in shape, containing large number of virus in them. The polyhedra form the white pus after they are released into the body fluid. The virus present inside the polyhedra maintains its pathogenic power for a number of years in the rearing room but the isolated virus loses its pathogenic power in a period of short time.

The larvae infected by this virus become inactive and lose appetite, and the membrane between segments swell up. Further, the whole body swell up showing the loose skin. In the last phase of the disease the body becomes purulent and the skin becomes tender from which pus leaks out. The larvae in this phase crawl around up and down and finally die. The infection of grasserie occurs through the mouth of the larvae, the wounds of skin and induction under extremely adverse conditions (cold treatment, heat treatment, chemical treatment).

Countermeasures. (1) The rearing rooms, tools and utensils should be washed, cleaned and disinfected.

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(2) The highly nutritive mulberry leaves should be given sufficiently to the infant larvae. The fresh air should be circulated in the rearing room especially in fifth stadium.
(3) The high temperature, low temperature and high moisture content should be avoided especially during the infant stages to maintain good health.
(4) The diseased larvae or dead bodies should be removed and the room disinfected completely by 2% formalin.
(5) The silkworms should be reared carefully, so that they may not suffer from the wound of skin.

2. Intestinal cytoplasmic polyhedrosis. This type of polyhedra are formed in the cytoplasm of midgut cells but in a few cases they are formed in the goblet, too. The polyhedra of this disease contains plenty of virus. The infected cells of midgut rupture and polyhedra are released into the gut. Thus the faeces, excreted becomes whitish, containing plenty of polyhedra.

The symptoms of this disease are the occurrence of translucent cephalothorax and shrinkage of body size but in the advanced phase the larvae excrete white coloured loose faeces. The body fluid of the diseased larvae remains in the normal condition.

The mode of infection of this disease and countermeasures are similar to those of the nuclear polyhedrosis.

3. Intestinal nuclear polyhedrosis. In this disease the virus makes polyhedra inside the cytoplasm and nucleus of the midgut cylindrical cells. The polyhedra formed in this disease are large sized. The translucent cephalothorax, shrinkage of body and diarrhoea are the symptoms of this disease also. The mode of infection and countermeasures are similar to those of nuclear polyhedrosis.

[IV] Flacherie

Flacherie is the genetic name of some kinds of silkworm diseases, carcases of which rot due to the attack of bacteria. Flacherie may be divided as follows :

1. Infectious flacherie caused by a kind of virus. The various symptoms of flacherie are loss of appetite, translucent cephalothorax, vomiting and diarrhoea but the real diagnosis can be made after the microscopic observation of the virus.

The pathogen of this disease is a spherical virus which does not form polyhedra in the body of silkworm larvae. The virus multiplies in the tissues of midgut and is released into the gastric juice and is excreted alongwith faeces which is the source of infection. The virus infects the larvae of silkworm orally.

Countermeasures. (1) Resistant silkworm races should be selected.
(2) The rearing room, tools and utensils should be well disinfected.
(3) In order to maintain the good health of silkworm, high quality mulberry leaves should be provided.

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(4) Favourable conditions like temperature and humidity should be maintained in rearing rooms.
(5) The faeces, diseased larvae and dead bodies should be piled in the compost.
(6) Some of the chemicals like hydrochloric acid, formalin, chlorinated lime may be used as disinfectants for this virus.

2. Gastric injury caused by physiological disturbance of silkworms followed by the multiplication of bacteria. Due to the supply of bad quality of mulberry leaves the digestive physiology of the silkworm is disturbed and multiplication of bacteria in the gastric cavity takes place. Thus, the combined action of physiological disturbances and bacterial activity in the gut are major causes of this disease. In unfavourable climatic conditions, the bacteria like *Streptococci* sp. *Coli aerogenous bacilli* or proteus group bacilli attack the weakened silkworms.

The control measures against this disease is to keep healthy conditions of rearing silkworms.

3. Bacterial intoxication. This disease is caused by a toxin of some bacilli, *Bacillus thuringiensis* Var. The larvae attacked by this toxin become unconscious, later soften, become darkish and finally rot off. The infection occurs orally and can retain the toxicity as long as for seven years in some cases.

The countermeasures are the disinfection of the rearing room and instruments.

4. Septicaemia. This disease is caused by infection of some bacteria as *Bacillus megatherium, B. proteus, B. prodigiosus, B. pyocyones* in the blood of silkworms. This disease is rare in the larval stage but it causes severe damage to the pupae and the moths during the period of egg production. The infection is caused through the wounds on the skin.

Countermeasures. (1) The rearing tools and rearing houses should be kept sterilized.
(2) The diseased cases should be kept away and put into the fermenting compost.
(3) During the period of egg laying the temperature and humidity of the room should be maintained in proper order specially at lower range of humidity.

[V] Green muscardine

It is a fungal disease of silkworms. There are a number of muscardine in silkworm but only green muscardine (*Spicaria prasina*) has been noticed to affect the larvae of silkworm in Vietnam.

The infection may be observed at the third and fourth stadia of silkworm. In the beginning stage a big black spot is observed on the ventral side.

The green-tubes of fungus develop into mycelia in the blood and bear cylindrical spores which are separated from mycelia and further form mycelia which bear cylindrical spores again. Thus, all the organs of silkworm are attacked

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by this fungus disturbing their normal functioning. As a result the diseased larvae do not moult and finally die.

Countermeasures. (1) The rearing room, tools and utensils should be disinfected.

(2) The diseased larvae and their faeces should be piled into compost to kill the germs.

(3) The rearing bed should be kept dry as much as possible to prevent the germination of conidia of fungus.

Economic Importance of Silk

The raw silk is used in the manufacture of woven materials and the knitted fabrics for the preparation of garments, parachutes, parachute cords, fishing lines, sieve for flour mills, insulation coil for telephones and wireless receivers, and tyres of racing cars. Fabrics for garments in various weaves, plain, twill, stain, crepe, georgette and velvet, knitted goods such as vests, gloves, socks, stockings, dyed and printed ornamented fabrics for saries, jackets, shawls and wrappers are made out of this material.

Status of Sericulture Industry in India

At the root of the social, economic, cultural and political progress of India, there are 6.5 lacs villages where 75% of the population of the country lives. The real progress of our country is definitely on the development of these villages. For the economic independence of the villages it is most important to check the flow of ingenious people from the villages towards cities so that the villages also may get a chance for advancement and progress. Even today the main source of earning livelihood, in villages, is agriculture and agriculture based industry on which 70% of the population depends. Majority of the village population even today lives below poverty line. It is believed that small scale and cottage industries are only in small and under developed countries but this assumption is only partially correct because in developed countries like USA, Germany, France, Britain, Russia, Switzerland and Denmark cottage industries occupy a special importance in their economy. In such countries where there is derth of capital but ample labour power, small scale and cottage industries also have great importance. When we discuss the economic policy of India, one doubt always haunts our mind, wheather on the strength of small and cottage industries only, would it be possible for us to face the challenges in the international economic competition. Gandhi's economic philosophy provides solution to this doubt that small cottage industries and modern and large industrial units have to be free from mutual competition, then only, all round development of the nation can be possible.

In the back ground of the industrial growth of past few years and their popularity and distribution of cottage industries it is apparent that the silk industry

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has developed as a popular cottage industry in which all big, middle, marginal and small farmers in their own way in their limited resources can start silkworm rearing. Even the landless labours with the cooperation of farmers can get mulberry leaves and rear silkworms. This industry neither needs any large equipment, big capital nor specialized technical know how for its start. Although sericulture is practised in India since long even much before independence, yet because of more capital involved at that time and low quality production it could not achieve required success. In any region for achieving success in sericulture industry there are some basic factors which should be surveyed. It is most important to have additional knowledge of the climate, soil, previously developed small industry, if any, and economic and social structure of that region. In case the soil and the climate of the region is suitable for rearing of silkworms, proper arrangement for irrigation, availability of labour etc. have also to be thought of. In short it must be fully ascertained wheather this new industry of silkworm rearing would be definitely profitable in contrast to the traditional farming or other small and cottage industries, if any, prevelant in that region before embarking on this new project. The idea of the capital investment involved and the average income per acre should also be calculated so that the farmer be told that it would be profitable to them. If finally decided to undertake this venture then for selecting the race of silkworm for rearing, the climate, soil and irrigation facilities should again be kept in mind so that the rearers may not face any technical difficulty later on.

In the country due to the efforts of sericulture research and investigation cum training centres and other production programmes, there has been a good improvement in the production and quality both of the silk cloth during the last 25 years. In a number of regions new varities of mulberry with close spacing and proper instructions have proved to be much fruitful in some regions but a number of rearers are still unaware of the proper cultivation technique and use of fertilizers for the mulberry plants. By efforts of systematic researches it has been possible to improve the nutritive quality and growth of mulberry leaves from 15,000 to 35,000 kg per hectare. The new mulberry varieties K_2 and M_5 are giving 65% more yield than the local crop. Now some strains are capable of giving 100 per cent increase in the yield of mulberry leaves. Sericulture research stations and grainages have evolved techniques for handling of young leaves easily with respect to temperature, humidity, quality, quantity and frequency of feeding, spacing, aeration and protection against diseases. A number of techniques have developed which has resulted in the improvement of the maintenance of silkworms.

Although India occupies second position after China in silk production yet the production in India is one fourth of the total production in China. The increasing demand of silk cloth in India and its decreasing production in Japan has placed China as the biggest market of silk in the world. The ever growing

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interest shown by Japan in the manufacture of electronic goods has left Japan much behind in silk production. Central Silk Board was established in 1949 in India and since then, through development and research plans, silk industry got a great encouragement. But in 1989, with the cooperation of 'World Bank', 'National Silk Project' has doubled in silk production in seven years and in the next five years the production may be still doubled from the present quantity. 85% of the silk cloth manufactured in India is utilized in the country itself. India imports raw silk for its industry from China. Out of the total silk cloth woven here, 65% is woven by handloom, 30% by powerloom and only 5% in mills by modern machine. In India the export quality of silk can only be produced by using threads manufactured by modern machines only. At present 3.5 lacs hactare of land is under mulberry cultivation in India. In Karnataka, Andhra Pradesh and Tamil Nadu the interest of the farmers in silk production is continuously increasing day by day. In the country to day silkworm rearing programme is providing whole time and part time employment to 75 lacs of people.

Distribution of silk industry in India

Of the 6.5 lac villages in India sericulture is practised in about 75,000 villages. The production of mulberry silk is confined to the five traditional states like Andhra Pradesh, Karnataka, Tamil Nadu, West Bengal and Jammu and Kashmir. Now it has also been initiated in other twelve states like, Kerala, Maharashtra, Bihar, Madhya Pradesh, Orissa, Gujarat, Rajasthan, Punjab, Haryana, Uttar Pradesh, Assam and Himachal Pradesh and gaining success in some other states. The traditional states produce about 99 per cent of the total mulberry raw silk in the country. The major production of tasar raw silk is achieved from Bihar, Orissa, Madhya Pradesh, Andhra Pradesh and West Bengal, while Maharashtra and Uttar Pradesh are producing tasar raw silk on a small scale The eri raw silk production is being achieved from major eri silk producing states like Assam, Bihar, Meghalaya and Manipur while it is also produced in Arunanchal, Mizoram, Tripura, Nagaland and Orissa at small scale. Manipur, Nagaland, Mizoram and Arunachal Pradesh are the oak tasar silk producing states. The production of muga silk is mostly confined to the states of Assam but now-a-days this silk is also produced in Mizoram, Meghalaya and Nagaland.

National sericulture project (NSP)

For the rapid development of mulberry sericulture industry in India, a five year programme. 'National Sericulture Project' of Rs. 555 crore was launched in 1989 by the World Bank and the Swiss Development Corporation under the supervision of Central Silk Board. This project was implemented by the department of sericulture in five traditional mulberry silk producing states like, Andhra Pradesh, Karnataka, Tamil Nadu, West Bengal and Jammu and Kashmir. Twelve pilot projects in the 12 states like, Assam, Bihar, Gujarat, Kerala,

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Haryana, Himachal Pradesh, Madhya Pradesh, Uttar Pradesh, Punjab, Maharashtra, Rajasthan and Orissa were implemented by the Central Silk Board to create additional facilities for the silkworm seed production, training, maintenance of germplasm and extention programmes as well as research and Development facilities.

The broad objective of NSP was the introduction of mulberry sericulture in non-mulberry silk states, and expansion of this industry in mulberry silk producing states. The other important objectives of this project were generating employment opportunities for an additional one million people, increasing raw silk production, improving quality of silk produced, strengthening the infrastructure for research, extension, seed production, silk processing and development of market support for raw silk and cocoons. In addition to the above objectives the financial support to rearers, reelers and twisters, increased participation of private sectors, involvement of Non-Governmental Organisations and improved participation of women were also the priorities of NSP.

The specification of National Sericulture Project in Traditional and Pilot states was of different nature on the policy as well as application level. In traditional states the main thrust was towards consolidating the status of progress already achieved by strengthening the existing infrastructure and by providing additional facilities for further expansion. The development of water management technique, evolvement of rainfed technology for mulberry, promotion of smokeless chulhas in reeling units, establishment of grainage, basic seed farms, quality control measures, women welfare and sound Research and Development facilities were the main features of NSP. The Central Silk Board has strengthened the already existing research facilities at various centres like Central Sericulture Research and Training Institute (CSR and TI) Berhampore, Central Sericultural Research and Training Institute (CSR and TI) Mysore, Central Silk Technological Research Institute (CSTRI) Bangalore and a number of Regional Sericulture Research Station (RSRS). Central Silk Board has also established three new research institutes like Seribiotechnology Laboratory (SBL), Silkworm Seed Technological Laboratory (SSTL) and Silkworm and Mulberry Germplasm Station (SMGS) during the tenure of NSP in traditional states.

Before the launching of the NSP in 1989 mulberry sericulture was already growing in small pockets of some non-traditional NSP states like Uttar Pradesh, Bihar, Assam, Orissa and the North- East but no integrated developmental effort were taking place in absence of infrastructural facilities. The pilot projects of CSB under NSP in pilot states provided comprehensive packages right from basic seed production to the yarn production. The CSB has invested Rs. 660 million in non traditional states from 1989 to 1994. The pilot activities were restricted to one district (in some cases more) in each non-traditional state to ensure the achievement of the target. The district taken under pilot project were Akola and Buldana (Maharashtra); Ambala (Haryana), Bastar (Madhya Pradesh),

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Dehradun and Saharanpur (Uttar Pradesh); Hoshiarpur (Punjab), Jorhat and Sibsagar (Assam); Koraput (Orissa), Palakkad and Idukki (Kerala); Purnea, Kishanganj and Araria (Bihar); Solan (Himachal Pradesh); Surat and Valsad (Gujarat) and Udaipur and Banswara (Rajasthan).

Sericulture industry and women welfare

It is a reality that spite of all efforts the status of women in the industrial sector is not significant because there are so many constraints for a women to participate freely in the industrial activities. Sericulture is such an agro-based cottage industry in which there is involvement of interdependent rural, semi-urban and urban based activities in which the estimated participation of women is about 60 per cent. Thus, in contrast to other agro-based profession the role of women in sericulture industry is dominating which will be helpful for improving the status of women in family enterprises. In the light of women welfare through sericulture industry the Central Silk Board has established a special component of 'Assistance to Women and NGO's' into the National Sericulture Project. For the women welfare sericulture should lead to formulate positive additions to rural women's awareness, participation in decision making and proportional control over resources and income. For achieving improved status and recognition of their value and importance to household, community and society as a whole, group formation should be encouraged among the women involved in sericulture industry.

Central Silk Board (CSB)

Central Silk Board, a statutory organisation under the administrative control of the Ministry of Textiles, Government of India, was constituted in 1949 under an act of the Parliament. After its constitution, Central Silk Board has taken overall responsibility for the intensive development of growing sericulture industry in India. The Board is constituted by 36 members including the Chairman, Vice-Chairman, Member Secretary, representative of both the Houses of Parliament, Central and State Government's nominees, Rearers, Reelers, the Trade and Industry. The head quarter of CSB is in Bangalore.

Function of Central Silk Board. (1) Proper development of sericulture industry in the country through promoting necessary measures.

(2) To promote and encourage scientific, technological and economic research for further advancement of sericulture industry.

(3) To develop healthy silkworm seed and ensure their proper distribution.

(4) To devise advanced means for the improvement of mulberry cultivation, silkworm rearing, reeling of silk and spinning.

(5) To search and establish the means of standardisation and quality control of silk and silk products.

(6) To stabilise the prices of silk cocoon and raw silk, and rationalise the marketing.

(7) To collect the statistics regarding sericulture industry.

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(8) To prepare and furnish the relevant reports on sericulture to the Central Government.

(9) To give proposal and advise to the Central Government for the intensive development of sericulture industry in the country.

Co-ordination of Central Silk Board with states. Being a state subject in the concurrent list, the schemes for the proper development of sericulture industry are formulated and implemented by State Governments. For performing this work, additional money is allocated to the State Governments on the basis of the annual plans approved by the planning Commission. Besides coordinating the sericulture developmental activities in states and advising the Central Government in policy making programmes, the CSB is also directly concerned with the sericulture research activities, sericulture Post Graduate Training programmes, basic seed production, distribution of raw silk, inspection of silk goods and standardisation and quality control.

The Central Silk Board has established 5 'Regional Offices' and 7 'Regional Development Offices' in different parts of the country. The Regional offices are Bangalore (Karnataka), Mumbai (Maharashtra), Calcutta (West Bangal), New Delhi (Delhi) and Srinagar (Jammu and Kashmir). The Regional Development offices are Bhubaneswar (Orissa), Guwahati (Assam), Hyderabad (Andhra Pradesh), Lucknow (Uttar Pradesh), Chennai (Tamil Nadu), Maheshmati (West Bengal) and Patna (Bihar). Special attention for promoting sericultural programmes in North-eastern region has been paid by CSB and an office of the Director (NE) is functioning at Dispur in Assam.

Silk development and research

Though the sericulture is one of the ancient industries in India yet it remained inadequate from technological know how and productivity. The establishment of Central Silk Board in 1949 has been proved to be the backbone for developing sericulture industry in India which is providing the much needed research and developmental support to this growing industry. Within the span of five decades the achievement of CSB is encouraging particularly in the field of research and training programmes. To meet this requirement 'Central Sericultural Research and Training Institute was established in Mysore in 1962. Further, the status of Central Sericultural Research Station, Berhampore, established in 1943, was upgraded into a research institute. In 1972 the Regional Tasar Research Station on Temperate Oak Tasar came into existence. The state research stations were taken over by the CSB and two Regional Research Stations were established at Titabar and Majra. The establishment of International Centre for Training and Research in Tropical Sericulture (ICT RETS) in Mysore initiated international cooperation in sericulture development. For conducting research on silk reeling, spinning, weaving and processing of silk the first institute of its kind in the world, Central Silk Technological Research Institute,' was set up in Bangalore in 1983. There is a wide network

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of extension centres carrying extensive work for the transfer of sericulture technology from lab to land through out the country. Now a days a number of Research Institutes and Regional Research stations are actively engaged in sericulture research activities. The list of these institutes and stations is as under :

Silk -Research Institutes

(1) Central Sericultural Research and Training Institute (CSR and TI) Mysore (Karnataka).
(2) Central Sericultural Research and Training Institute (CSR and TI) Berhampore (West Bengal).
(3) Central Tasar Research and Training Institute (CTR and TI) Ranchi (Bihar).
(4) Central Silk Technological Research Institute (CSTRI) Bangalore (Karnataka).

Regional Silk-Research Stations

A number of Research Centres have been established in different parts of the country for carrying out research in mulberry, oak tasar, muga and eri silk :

Mulberry Silk-Research Station

(1) Bangalore (Karnataka)
(2) Chamaraj Nagar (Karnataka)
(3) Salem (Tamil Nadu)
(4) Coonoor (Tamil Nadu)
(5) Kalimpong (West Bengal)
(6) Dhule (Maharashtra)
(7) Pampore (Kashmir)
(8) Anantpur (Andhra Pradesh)
(9) Jorhat (Assam)
(10) Ranchi (Bihar)
(11) Koraput (Orissa)
(12) Mothabari (West Bengal)
(13) Majra (Uttar Pradesh)

Oak Tasar Silk Research Station

(1) Batote (Jammu and Kashmir)
(2) Bhimtal (Uttar Pradesh)
(3) Imphal (Manipur)

Muga Silk Research Station

(1) Boko (Assam)

Eri Silk Research Station

(1) Mendipathar (Meghalaya).

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Prawn Fishery

Apart from fishes some of the aquatic crustaceans are also included among the fisheries of economic importance. In India most important crustacean fishery is of prawn. The prawns constitute highly nutritive diet for human-beings. The prawn fishery of India is next to that of U.S.A. in the world. In certain areas, particularly on west coast , prawn catches are exceeding than those of fishes of any single group. Prawn production in Kerala State and Maharashtra coast is 92.4% of the total of all India prawn catch.

The export earning from prawn and prawn products has increased from about rupees 17 million in 1960 to over rupees 950 million in 1975. In terms of weight the total prawn catch in India, during the last 25 years, has increased from about 68,000 to 5,20,000 tons. For steady supply of raw materials it is essential to explore fresh grounds outside the conventional inshore regions and intensity prawn culture operations.

Types of Prawn Fishery

According to the quality, topography and nature of water, prawn fishery may be studied under four headings :

1. Shallow water prawn fishery. It is located on the west coast where fishing is restricted to shallow water near the coast, rarely exceeding 18 meters in depth. During monsoon months of June to August the shoals come near the Malabar coast and fishermen are enabled to catch prawns with cast-nets.

2. Estuaries and back water or saline lake prawn fisheries. The principal areas of production are the back waters extending along the southern half of

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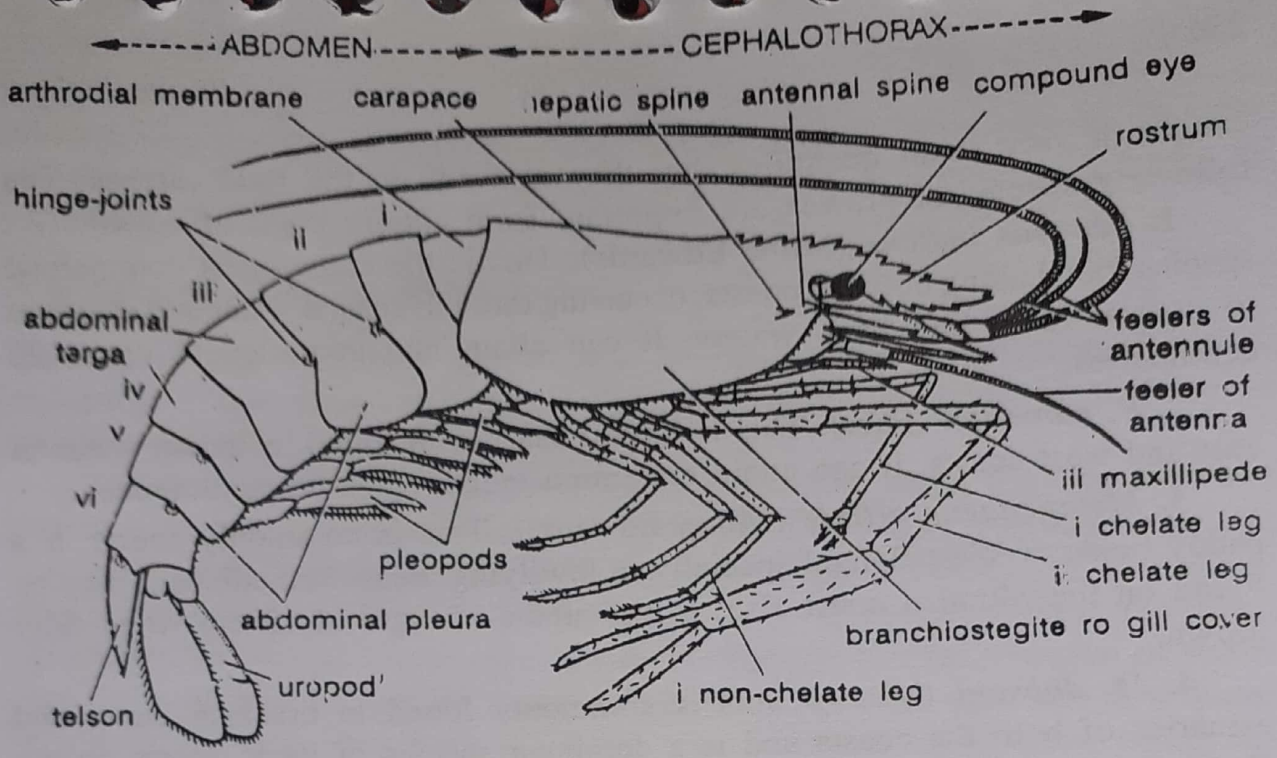

Fig. 1. Adult prawn (*Palaemon*).

Kerala coast and the mouths of numerous hill streams in the Malabar area. Ennur, Pulicat, Cellair and Chilka lakes, and Estuaries of Ganges and Brahmputra rivers on the east coast are also important fishing areas. Chilka lake is much rich in prawn production.

3. Fresh water prawn fishery. Prawns are caught from the rivers, lakes and other fresh water areas throughout the country. Some species are also caught from Brackish water lakes during certain months when the salinity is low, and the prawn migrates into them temporarily, chiefly for breeding.

4. Marine prawn fishery. Most of the marine prawns caught along the Indian coast belong to the family Penaeidae. Three genera like *Penaeus* Fabr., *Metapenaeus* Wood Mason and *Parapenaeopsis* Wood Mason are commonly found to be present. Marine prawns are fond of warm shallow seas and swarm, both in their larval and adult stages, in muddy waters such as those found in deltic regions.

Species of Prawns

A number of species of prawns are found distributed in water resources and are of different sizes (Fig. 1). Only those prawns which are of good size and weight, available in plenty and easily culturable, are commonly selected for prawn culture on commercial basis. The prawns belonging to the families Penaeidae, Pandalidae, Hippolytidae, Sergestidae and Palaemonidae are vrey much important. Some species are good for culture while several others are

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caught in very small quantities, but they also add to the total catches. The following species of prawns are important from culture point of view.

1. ***Penaeus indicus*** (Milne Edwards). This is the commonest commercial species found along both the coasts, occurring through coastal water and estuaries to coastal lakes and back waters. It can attain maximum length up to 20 centimetres.

2. ***P. monodon*** (Fabr). This is largest sea prawn found in Indian water of east and west coasts. It can attain maximum length up to 30 centimetres.

3. ***Metapenaeus affinis*** (Milne Edward). This is commonly found in a paddy fields of West Bengal specially in low lying areas. Sometimes it may be found on the Mumbai coast also. It can attain a length of 13 cm when fully grown.

4. ***M. dobsoni*** (Miers). This is commonly found in brackish water and estuaries of both the coasts and is a dominant species of back waters on the Kerala coast and fished throughout the year. It can grow up to a maximum length of 11 cm and its life span is found to be of 3 years.

5. ***M. monoceros*** (Fabr). This is found throughout the entire coast line. It is also common in estuaries and back waters and can attain a maximum length of 17 cm.

6. ***Parapenaeopsis sculptilis*** (Heller). This is found on both the coasts but good catches are obtained in Mumbai and West Bengal particularly in Hoogly river. This is also found in Chilka lake. The maximum length attained by this prawn is 14 cm.

7. ***P. stylifera*** (Milne Edwards). This is found on the west coast and fished maximum in Kerala State in the months of December to May. This can grow up to a maximum length of 11 cm and the life span of this prawn is of 2 years.

8. ***Palaemon fluminicola*** (Kemp). This prefers to inhabit fresh or brackish water and is reported to ascend the river Ganges to a distance of 1,127 Km.

9. ***P. styliferus.*** (Milne Edwards). This inhabits brackish and marine waters and contributes good catch of the Gangetic delta and Mumbai coast.

10. ***P. tenuipes*** (Henderson). This is found commonly on the west coast and is caught in large number from Mumbai coast.

11. ***Macrobrachium carcinus*** (Fabr)). This is freshwater prawn and migrates to brackish water for breeding. This can attain a maximum length of 30 cm and is available in good number for over 3 months in the year. This prawn is highly demanded species for freezing and eventual export.

12. ***M. idac*** (Heller). This is commonly found in Kerala back water during months of September to December.

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13. ***M. malcomsoni*** (Milne Edwards). This is migratory species generally found in Chilka lake towards the close of Monsoon and fished in large number. This can attain a maximum length of 15 cm.

14. ***M. mirabilis*** (Kemp). This is an important prawn catch in the upper reaches of West Bengal estuaries.

Food of Prawn

The prawns feed on living organisms, vegetable matters and also on dead organic materials. Prawns with the help of their chelae of thoracic legs catch the food material and take to the mouth. The maxillipedes cut the food and pass into the mouth for proper mastication by the mandibles and then it is swallowed. The food of *Macrobrachium malcomsoni* mainly comprises of small insects, sea weeds, algae and mosses. After analysis of the stomach of well fed prawn, *Panaeus indicus* it was found that prawns of different size and age groups prefer to feed on varying quality of food material *viz.*, vegetable matter, crustaceans, detritus and other organisms of their surrounding. The comprehensive survey of prawn food suggests that they have wide adaptability for their feeding habits and accommodate themselves to feed on planktonic diatoms : *Coscinodiscus, Pleurosigma, Rhizosolenia,* alage *(Trichodesmium),* cuttings of sea weeds, crustaceans (copepods, decapods, amphipods) and non-crustacean (molluscs, hydroids, nematodes, foraminiferans, echinoderms, trematodes). Sometimes sand particles were also recorded in the food of prawns. It is interesting to note that the bigger prawns never feed upon the healthy smaller ones under normal conditions but once the smaller prawn becomes weak or dies the bigger ones will feed on them. The behaviour of food selection is also important factor for the distribution of prawn in different types of water resources. Prawns even collected from the same environment show different tastes of food preference. From a number of data obtained from different localities regarding the analysis of food constituent it is found that prawns have food preference for Crustaceans > Molluscs > Algae and in case they are not getting any of these, they feed on other items. It is a fact that environmental conditions and the availability of particular food in a definite area play major role for the feeding habit and food of prawns.

Culture of Fresh Water Prawn (*Macrobrachium rosenburgii*)

Macrobrachium rosenburgii is a big sized palatable prawn found in abundance in rivers, fields and low salinity areas of estuaries. Ever since unplanned commercial export of prawns started, their number has depleted to a great extent. Ling (1969) had suggested the plan to operate a hatchery to produce annually 1 million youngs or *M. rosenburgii* for stocking and culturing. The

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prawns collected from ponds, rivers or fields are transferred to the tanks which are particularly aerated. The transport of these collected prawns should be performed in plastic bags with oxygen or in bamboo with aquatic plants.

For the purpose of fertilization one pair (one male and one female) of prawn only should be kept in an aquarium of 60 litre capacity. After sometimes mating takes place and the female starts egg laying for about 24 hours. For commercial exploitation the spawning has to be planned. Spawning tanks of different sizes should be prepared *viz.*, 200 × 100 × 40 cm, which would be suitable for 10 pairs and 300 × 150 × 40 cm for 24 pairs. The proper aeration of the spawning tanks is most important. At the same time proper care for the cleanliness of the tanks is also to be taken.

For the development of eggs under proper conditions, the mixing of sea water with fresh water is well suited. With the increasing time of the egg development as indicated by the change in the colour from orange to light gray, some amount of sea water should again be added to make the concentration upto 5%. The eggs hatch into larvae which should be transferred immediately to other tanks made up of cement (200-300 × 50-70 × 25 cm) filled with the water of spawning tank and sea water (2/3 : 1/3 v/v). The temperature should be maintained almost in between 24°C to 30°C. The pH of this tank should be 7 to 8. The tanks under shade provide good environment for development. Moulting of the larvae takes place and the first and second stages are found without loss of organs. The prepared food like steamed egg custard, fish ball and fish eggs should be given to the young hatched larvae. The supply of artificial food is continued 4-5 times a day till the larvae are 2 to 3 days old up to the metamorphosis. Now they should be transferred to fresh water tanks for acclimatization and to be fed on artificial diet.

It is found that the young ones of 5 cm length (about 60 days old) can be reared in fresh or slightly brackish water at 22°C to 32°C in properly oxygenated ponds, partitioned canals or rice fields. The artificial pond of 50 × 20 × 1.5 metres is best for operation and can be managed economically. One should be careful to remove the predators and excess of aquatic vegetation from the pond.

The provision for natural food for the proper growth of prawns in their natural habitat can be made by providing 200 kg cow dung mixed with 10 kg lime per hactare per month. Gentle circulation of water current has proved to be a better stimulant for proper development of the prawns. For the supply of food in the form of living organisms small pieces of waterfish, insects, earth-worms and plant food *viz.*, spoiled paddy, broken rice and fruits is to be managed for each pond. Under proper natural conditions the prawn can develop up to 20 cm in length with about 100 gms in weight within 6 months. Two crops of prawns can easily be harvested per year. In paddy fields with 12 cms water, young prawns of 3 months age group can be introduced so that they may attain maturity when paddy is harvested. In the fields where insecticides are

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applied, the stocking of prawns should not be done because prawns are very much sensitive to the insecticides, so great hazard of prawn population may be caused in such field.

Culture of Marine Prawn

Several factors determine the success of marine prawn farming of which selection of site, water and soil quality, availability of seed and preparation of farm are more important.

1. Selection of site. The most suitable location is along the tidal flats and marsh lands adjacent to brackish water estuaries. The site of irregular shape and uneven bottom contours are not fit as they reduce the efficiency of harvesting. The sites located too close to the beach are likely to be subjected to the threat of erosion. In the sublittoral zone, the main criterion for the selection of site is that there should be smaller range of variation between high and low water levels. At the same time there should be enough circulation of water within the farm enclosure at neap tides.

2. Water quality. The regular supply of good quality clean water must be available to fulfil the water lost through evaporation, seepage and drainage during the course of management operations. The water should be free from hydrogen sulphide pollutants and other contaminations. The dissolved oxygen and nutrients should be sufficient. The temperature and salinity conditions of water must suit the physiological state of the species to be reared.

3. Soil quality. The soils having clay composition with a pH range of 6.5-7.5 are usually suitable as they tend to hold water. The clay particles absorb calcium and potassium salts from the sea water making the oil rich in minerals. There should not be more than 50 cms of silt on the bottom since for unknown reason the heavy silting reduces the production of prawns.

4. Availability of seed. The naturally occurring species in a given locality would most likely dictate the species to be suitable in that area. The prawns suitable for farming include those species which can be reared from egg up to the adult stage in captivity and the young ones of which must be obtained from natural habitat.

5. Other factors. For the commercial and economic farming, the surface area should not be less than 5 hectares. The site should be accessible by road at all times to the culturist as well as to the market for the effective disposal of catches.

Preparation of Farm

For the preparation of ponds for algal growth and for the subsequent stocking of prawns it is essential to drain off the water and sundry the bottom followed by light tilling if possible. During this period agricultural lime should be applied

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(400 kg. per hactare) to absorb the excess of carbon dioxide and supply the calcium required by the prawns during moulting. The algal growth may be further accelerated by the addition of commercial fertilizers. Variety of organic fertilizers like rice bran, poultry and cattle dung, night soil and sewage wastes are used to increase the fertility of soil. It would be desirable to drain the pond completely once in a year to increase the rate of the production of microbenthos. It may be mentioned here that the considerations given are only of general nature. So, there may also be some biological and physical problems related to the locality for prawn culture for which the points mentioned above should be taken into consideration.

Methods of Prawn Fishing

The Indian coastal region of 4,500 kms with a huge area of continental shelf has great scope for fishing operation throughout the year either for fishes or prawns. In shallow water areas, fishing may be possible only with the help of gears, but in deep water reservoirs like rivers, lakes and sea, fishing requires craft and gears both. Since ancient times various types of traditional local made craft and gears are being used for the fishing of crustaceans and fishes while some are specially suitable and used for prawn fishing. In recent years a number of mechanised crafts and gears have been introduced for fishing in India. Till now the mechanised as well as non-mechanised crafts and gears are being used side by side in India and probably would be in use for several years.

[I] Crafts (Boats)

The crafts used for the prawn fishing in India are of several types in commensurate with the flow of water, depth of water, habit of prawn, flora and fauna of water reservoir. etc. The boats used are described below in brief. In Kerala, Vallom (8.3 to 10.6 metres) is used which is operated by 5 to 6 persons while Thanguvallom (12.6 to 14 metres) is operated by 10 to 11 persons. From Kakinada to Masulipatam, Masula (8.5 to 12 metres) is used and operated by 8 to 12 persons while Nava (6.4 to 10.7 metres) is operated by 5 to 6 persons. The boat used in Maharashtra is called as Machwa (9.0 to 14 metres) and operated by 7 to 9 persons. In Orissa boat Dinghi (10.4 to 13.3 metres) is used and operated by 8 to 10 persons. The boat used by the fishermen of West Bengal is Nauk (10.4 to 13.2 metres) which is operated by 8 to 10 persons. It is found that for the operation of boats in any part of India generally 5 to 10 persons are needed which may solve unemployment problem for some technical persons.

[II] Gear

Boats are the only means to be used on the surface of water for catching out the prawns. But for the act of catching of prawns a number of devices

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are employed *viz., nets, traps* and *hooks.* Before the preparation of these appliances for prawn catching it is essential to have an idea about the behavioural trends *viz.*, feeding behaviour, swimming, breathing, rest phase etc. of prawns because some prawns are bottom dwellers, some crawling over the surface of water can jump on disturbance and some are attracted towards light. Thus, keeping in view the various behaviours nets, traps and hooks should be utilized for easy catch. The adult and sexually matured prawns prefer to live in sea but juveniles prefer to live in shallow estuaries and back waters.

[III] Nets

Generally, nets are made by cotton, nylon, hemp or in combination of these. The spaces of nets should be specially kept in view so that the prawns may not be able to pass through them. If selective fishery is under fishing programme, nets should be prepared with care so that only adult prawns may come under the catch and smaller or young ones may pass out from the net.

The simplest type of net used is CAST NET which is operated by single person only by throwing the net over the water surface and later on drawn off with the aid of rope attached at one end of the net.

Some nets are bag like and so are called as BAG NETS.

The nets either with bag or without bag when tied to stake, the operation is in stationary phase, are called as STAKE NETS.

When bag nets are towed by the crafts which are under movement and prawns are caught by themselves in the bags, they are called as DRAG NETS or TRAWL NETS.

When the upper margin of the mouth of the drag nets is fixed to the beam and the lower margin is free hanging, this net is called as BEAM TRAWLS.

In sea water where tides are of usual occurrence, nets without bags are fixed to the stakes for a long distance to check the escaping of catched prawn along with the back currents, such types of nets are called as BARRIER NETS.

The local names of different types of nets are based on the local names in linguistic regions of the fishing area.

1. Fixed bag nets of the west coast. ***(a) Dol.*** Used throughout the year in Mumbai sea shore area. It is made up of hemp and cotton and set against current. Prawns like *Acetes indicus, Hippolysmataensirostris, Palaemon tenuipes* and *Metapenaeus affinis* are caught there. The smaller nets are called as BOKSHI-JAL.

(b) Gholu jal. It (Golva, Dor, Dol) is used generally after Monsoon up to February in Kathiawar region. It is made up of hemp with coir, set against tide on muddy grounds. Prawns caught are *Metopenaeus kutchensis, M. monoceros, Parapenaeopsis sculptilis* and *Penaeus indicus.*

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(c) Onnivala. It (Valuvala) is used throughout the year in the back water in Kerala region. It is made up of cotton and coir yarn and set against water current. The prawns caught are *M. dobsoni, M. monoceros* and *Penaeus indicus.*

2. Fixed bag nets on east coast. ***(a) Thokavala.*** (Gidasavala). It is very important for fishing in tidal estuaries of Godavary and Krishna deltas in Andhra region. It is made up of cotton and coir and set against current. The prawns caught are *Metapenaeus brevicornis, M. monoceros,. Penaeus indicus* etc.

(b) Behundi jal (Bhim Jal, Thor Jal). This is used in the estuaries of W. Bengal, in Hoogly and Malta regions. This is made up of hemp and coir rope and set up against the current. The prawns caught are *Metapenaeus brevicornis, Palaemon styliferus. P. tenuipes, P. flumicola, Macrobrachium mirbilis, M. carcinus, M. lamarrei. Penaeus indicus* etc.

3. Barrier nets of west coast. *Patti.* This is used in creeks and tidal inshore area Gulf of Kutch and south Gujarat. It is made up of cotton. The prawns caught are *Metapenaeus brevicornis,* and *Penaeus indicus.*

4. Barrier nets of east coast. ***(a) Moolakattuvala.*** It is used in Kakinada Bay and back waters connected to Godavary estuary. It is made up of cotton. The prawns caught are *Metapenaeus brevicornis, Penaeus merguiensis, P. monodon* etc.

(b) Char-pata jal. This is used in winter month in 24 paragnas during spring tides. It is made up of cotton, hemp, jute or combination of all. The net is kept folded on the ground. The prawns caught are *Palaemon styliferus, Macrobrachiun lamarri M. radis, M. scabriculum.*

5. Boat-seinnes of west coast. ***(a) Kolliyala*** (Sultanvala, Paithuvala). This is used in Kerala coasts during August to October when prawns migrate upwards. It is formed of cotton or hemp. The prawns caught are *Metapenaeus dobsoni, M. monoceros, Penaeus indicus, P. monodon* etc.

(b) Madivala (Thattuvala). This is used in Vizhinjam, South-West coast in months of April to October. This is made up of cotton and coir. The prawns caught are *Metapenaeus monoceros* and *Parapenaeopsis stylifera.*

6. Boat seines with bags on east coast. *Irgali* (Irgaljalo, Pedda or Bada Irgali and Sanna). This is made up of hemp and is used in Ganjam coast by Telgu fishermen. The prawns caught are *Penaeus indicus, P. semisulcatus, Metapenaeus dobsoni, M. monoceros, M. affinis* etc.

7. Shore-seines of the west coast (Without bag) *Rampan* (Rampani). It is used in inshore regions in premonsoon months. It is made up of cotton or hemp. The prawns caught are *Metapenaeus affinis, M. dobsoni, P. indicus, Parapenaeopsis stylifera.*

8. Shore-seines of the east coast (Without bag). *Aliviala* (Pedda Alivi, Chinna Alivi). This is used in November to March in Andra coasts. This is made up of cotton and the net is carried out in a nava and is laid in sea. The

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prawns catches are *Metapenaeus affinis, M. brevicornis, M. dobsoni, M. monoceros, Palaemon tenuipes* etc.

9. Shore-seines of west coast (With bags). *Kamba vala*. This is used in the inshore-areas during October and May. This is made up of cotton or coir. The prawns caught are *Metapenaeus monoceros, M. affinis* and *Penaeus indicus*.

10. Shore-seines of east coast (With bags). Periyavalai. This is used in Chennai, Andhra and Orissa and made up of cotton and hemp. The prawns caught are *Metapenaeus monoceros* and *Penaeus monodon*.

11. Drag nets. These are operated in shallow areas and back waters.

(a) Kondavalai. This is used in shallow coastal area. This is prepared from cotton. The prawn caught are *Metapenaeus dobsoni, M. monoceros, Penaeus carinatus, P. Indicus*.

(b) Bari. This is used in Gujarat coast during monsoon, when other fishing is not possible. This is made up of cotton. The prawns caught are juveniles, *Metapenaeus kutchensis, M. monoceros* etc.

12. Drift nets. *(Kanthavala).* This is used in Bottom drift net in North Kerala and Kanara in November to April. The materials used are cotton, hemp or nylon. The prawns caught are big sized *Metapenaeus affinis, Penaeus indicus, P. merguiensis.*

13. Cast net. *(Veesuvala).* This is used in shallow coast lines, back waters, estuaries and rivers where the bottom is without any rocky projections. Prawns caught are *Macrobrachium* spp. and *Palaemon* spp., *Metapenaeus* spp. and *Penaeus* spp.

[IV] Traps

Traps have been oldest devices for prawn catching in some regions to cover the prawns from above and some traps are used for catching the prawns when passing through current of water. The traps used are, Ottal, Gutta guli, Uduka, Muchu, Uted, Thapa, Chhapa, Polo and Poluha at different places.

Spoilage of Prawns

After fishing, prawns are subjected to spoilage if proper protective measures are not taken. There are mainly two types of spoilage. One is the chemical spoilage in which the tissue contents of the body like free amino acids are leached out resulting in loss of taste, nutritive value and the weight. Other type of spoilage is bacterial contamination in which free fatty acids are released from the muscles by enzymatic hydrolysis of triglyceride and phospholipids, essential constituents of lipids, which later undergo auto-oxidation producing carbonyl, and thereby affecting the quality of prawn by introducing rancidity.

The spoilage starts in the boat where prawns are stored for 6 hours without ice because prawns deteriorate more than the fishes. Upto 4 hours, at 28°C,

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praws keep up their original quality, but after that deterioration is rapid and in 8 hours they may become unfit for eating. So, just after fishing prawns should be processed for preservation.

Preservation and Processing of Prawn

Prawns, after fishing, are taken to the ma ket for local consumption as soon as possible by keeping them in ice layers. For the supply, prawns are frozen in different forms for the purpose of export. The preservation of prawns is of following types :

(1) Peeling and deveining (2) Peeling, deveining or cooking, (3) Cooking and peeling, (4) Headless (Shellon).

[I] Peeling and deveining

The fresh water prawns are beheaded, peeled, deveined and washed thoroughly with water. After removal of shell parts and other tissues, the pulp is placed in freezing trays or in a waxed cardboard lined inside with polythene sheets. Now ice-water is added in the box containing prawns, kept in freezer at 30 to 40°F for about 3 to 4 hours. If prawns are frozen in trays the sticky hard matter obtained are dipped in ice water for glayzing because glazing protects the frozen material from dehydration, oxidation etc. and is performed at 10 to 15°F. The slabs after glazing are wrapped in polythene sheets and packed into a waxed cardboard and stored in frozen storage room at -10°F till shipped.

[II] Peeling, deveining and cooking

First of all the prawns are peeled, deveind and washed with water and cooked in 3% to 5% brine for about 3 to 5 minutes. After cooking they are cooled and placed in trays and processed for freezing as mentioned above.

[III] Cooking and peeling

In this method fished prawns are cooked in 7 to 10% boiling brine for about 2 to 3 minutes then cooled in ice-cold water containing 3 to 5% salt. After cooling, prawns are peeled and washed in 20 ppm chlorinated water. The washed meterial is then placed in cardboard or trays, frozen and glazed with 50 ppm chlorinated water.

[IV] Headless (Shellon)

In this method of prawn preservation only the head of the prawns are removed and the rest of the body is covered with its shell. Now headless prawn is processed for freezing as in case of peeled and deveined prawn.

At the time of prawn freezing only fresh prawns are taken and sufficient amount of ice used under strict hygeinic conditions.

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Export of Prawn

The prawns have become an important source of earning foreign currency because of their export to various parts of the world. They are exported in the form of frozen prawn, canned prawn, dried prawn, prawn pickles, prawn powder, prawn bits, prawn curry and prawn meal.The frozen prawn is exported to Australia, Belgium, Canada, Denmark, France, Japan, Kuwait, Netherland, South Arabia, Switzerland, Sweden, U.K., U.S.A. and Germany. The canned prawns are exported to Australia, Belgium, Canada, Denmark, Germany, France, Greece, Italy, Muscat, Oman, Netherlands, Newzealand, Puerto-Rico. Sweden, Switzerland, Singapore, U.S.A., U.K., Germany and Yugoslavia. The dried prawns are exported to countries like Australia, Canada, France, Hong Kong, Japan, Netherland, Singapore, Spain, Trinidad, U.S.A. and U.K. The other prawn material 'Prawn pickles' is exported to Canada, Dubai and U.K. The prawn powder is sent to Australia, Netherland, U.K. and Germany.

Thus, it is clear if India can produce more and good quality prawns and prawn products, it would be a very good source for raising the economy of the Nation as foreign currency earner.

Pollution and Prawn Fishery

Now-a-days degradation of fresh water and sea water resources, due to water pollution, have become a serious problem for the entire world. The prawn fishery is also badly affected by the water pollution due to indiscriminate discharge of industrial effluents, sewage, domestic wastes, pesticides, fertilizers, distillery, electroplating, detergents, silt tanning, thermal power, radio-activity and oil, into the rivers, lakes, streams and ultimately into the sea.

The critical study of the effect of these effluents and pollutants has been tried on some species of prawns and some results have been achieved. It is obvious that the pollutants which affect the fish population almost affect the prawn fishery also. Although vast studies have been made on fish culture with respect to pollution problem but no such comprehensive work has been done on the pollution problem with particular reference to prawn culture.

The studies made in Bihar and Mysore have shown that the effluents of paper mills consisting of cooking solutions, cellulose constituents of the bamboo and the chemical mixture of a number of sulphur compounds, some amount of alkali sulphides, acetic acid and formic acid with a high percentage of sugars, the gaseous discharge in the form of sulphur dioxide, methyl alcohol, ammonia and some aromatic oils are heavily discharged into nearby rivers.

The wood distillation plant of Mysore discharges its effluent into Bhadra river. Its effluent comprises of tar particles, phenolic bodies and acetic acid. It is found that the suspended particles at the time of slow flow of river settle on the bottom and form a sticky layer on the bottom of river. When the wastes of

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paper mills and wood distillary were discharged into a river, a large number of prawns were found dead or some had escaped away.

It has been studied that due to various types of effluents discharged into the Ramgarh lake of Gorakhkpur (Uttar Pradesh), the prawn fishing is dwindling gradually every year. The effect of pesticides and heavy metals on the prawn have been studied which showed an adverse effect on prawns and prawn fishery.

Oil is a common pollutant in rivers, estuaries and sea and it is increasing day-by-day as new oil wells are being added in the world of fuel for energy resources. Oil forms, at present, 50% of the ship cargo of the world. It is found in a number of cases that there was no recovery even after 4 years of oil pollution due to oil spill. According to U.S. Scientific Survey "the effect to the spill will be felt for another decade..... it will be visible to the untrained eyes for at least five years and to the trained eyes for another ten years."

In India the industrial enterprises and oil drilling activities are on continuous increase. The studies regarding proper safeguards against effluents on the prawn culture are going on. It is found that if the effluents before discharge into water can be treated or diluted, they would be without danger for the aquatic life. Although it will be extra expenditure to the mills and factories but in the interest of the welfare of the water fauna and flora, the suggested measures should be applied.

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Pearl Culture

A large number of molluscs are found on the land and in the water reservoirs like sea, fresh water and brackish water. They are used for food, for shells and in pearl industries. Pearl is a white, highly shining globular concretion found within the shell of an Oyster (a kind of shell-fish). It is also called as 'Moti' or Muktaphal'. Since antiquity, pearl has been reputed as one of the rarest gems and was previously imagined as the tears of moon but the reality, is far away than imaginary flight of poets. It Sanskrit literature it is mentioned that during 'Swati Nakshtra' when a drop of water falls in between the mantle and the nacre layer, pearl develops which seems to be more reasonable. The rare occurrence of pearl in the nature is due to its peculiar mode of formation which may not happen frequently in the natural conditions. Pearl is known to Chinese since 2300 B.C. Kautilya and Shakespeare in their literature have mentioned about the pearl in detail. The researchers engaged in pearl culture organisation have planned to stimulate this natural phenomenon and have succeeded in producing cultured pearls exactly of the same substance as the natural pearl.

History of Industry

For the first time the idea of pearl industry was evoked in Japan which was carried out in the Bay of Japan located at South coast of Hansoo. But in Japan, pearl culturists feel difficulty due to unfavourable climatic conditions. Kokichi Mikimoto (1858-1954) is referred to be the father of pearl industry in Japan. In 1890 an exhibition on Annual Domestic Industrial Promotion

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was organised in Tokyo where among a number of industrial products pearls were soid at very high prices. Mikimoto came to know that pearls can only be formed in nature and not by artificial devices. This exhibition encouraged him to manipulate the oysters to do what they did in nature. In 1890 he established a pearl farm on small Island of Taba and began to culture oysters but could not get success for two years. In the third year due to a red-tide his farm was destroyed completely except for a batch of some oysters which survived. Subsequently on 11th July 1893, his wife Uma when opened an oyster shell to her surprise and joy she found a pearl duly formed in it. It was a memorable day for them. Then in 1896 he got a patent for pearl culture. Tokichi Nishikawa, a Govt. scientist of Misaki Marine Biological Laboratory of Tokyo University, was the first person to get spherical artificial pearl.

Pearl Producing Molluscs

Although a number of bivalves have ability to produce pearl under suitable climatic conditions but high quality of pearls are obtained from pearl oysters of Genus *Pinctada roding* belonging to class—Bivaliva, family—pteriidae. A number of species of this Genus like, *P. vulgaris* (Schumacher), *P. chemnitzi* (Philippi), *P. margaritifera* (Linn.), *P. anomioides* (Reeve) and *P. atropurpurea* (Dunker), are found in Indian water resources. *P. vulgaris* is a common oyster distributed in the gulf of Kutch, gulf of Mannar and the Pak bay.

Apart form the true pearl oyster belonging to the genus *Pinctada* a large number of other marine and a few fresh water molluscs are also found to produce pearls or pearl like concretions. These are Ear-shell (*Haliotis* Linn). Sea muscle (*Mytilus* Linn) and windowpane oyster (*Placuna blacenta* Linn). *P. margaritifera* and *P. maxima* are giant species and produce pearls of bigger size but of inferior quality.

Pearl Producing Sites in India

Mostly the pearl oysters are inhabiting on the ridges of rocks or dead corals (secreted by many species of polyp), forming extensive pearl banks or at the depth of 18 to 22 metres at a distance of 19 km from the shore. The pearl oyster beds of the east coast are more extensive and productive than those of the west coast. These pearl beds produce best quality of pearls called as 'Lingha Pearl'. The pearl oysters are obtained from the reefs in the gulf of Mannar, gulf of Kutch, Pak bay and Baroda.

Pearl Formation

Pearl formation is an interesting phenomenon for protection against foreign invaders, parasites, sand grain, small broken twigs of sea-seeds or a small insect accidently entering the body of the oyster which happens to adhere to a part of its mantle (Fig. 1). The mantle epithelium at once encloses it like

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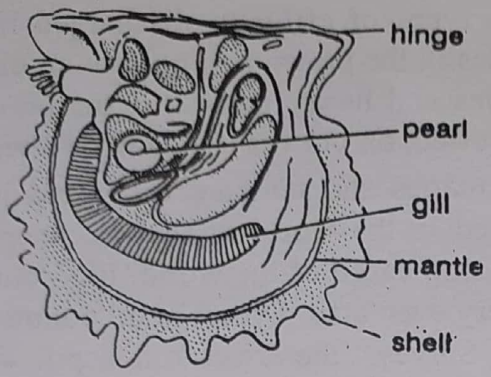

Fig. 1. Diagrammatic sketch showing site of pearl formation in Mytilus.

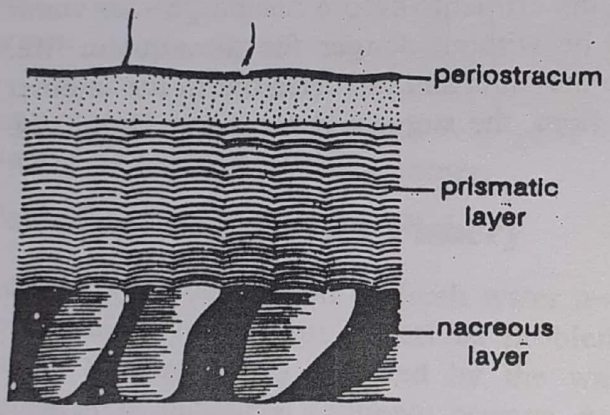

Fig. 3. Vertical section through the shell.

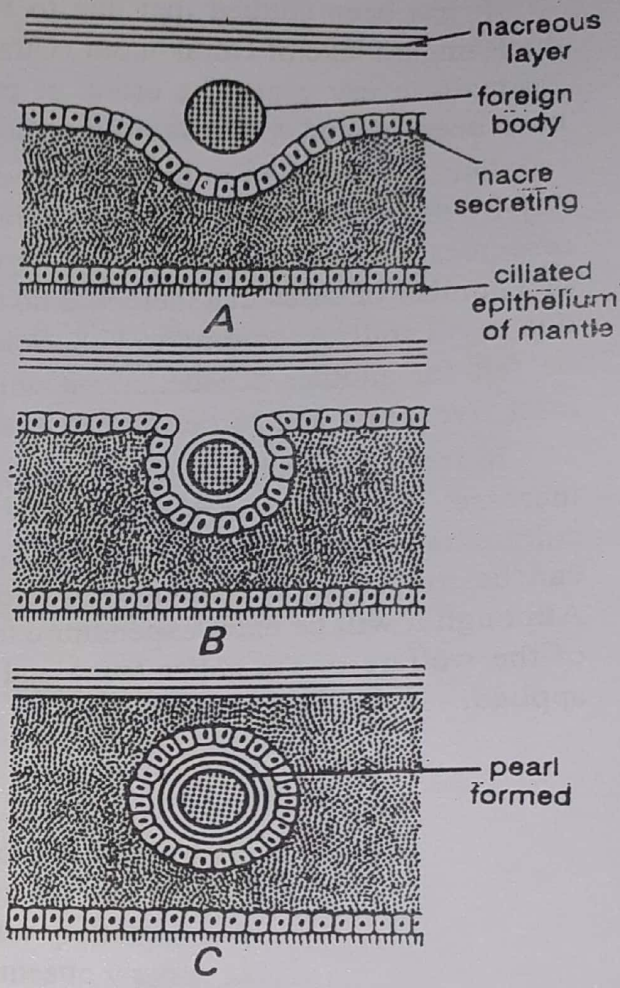

Fig. 2. Stages in pearl formation : A. Primary stage ; B. progressive ; C. Final stage.

a sac and starts to secrete concentric layers of nacre around it from defence point of view and completely encloses it gradually. Nacre is secreted continuously by the epithelial layer of the mantle and deposited around the foreign particle in the form of several layers and ultimately the pearl is formed (Fig. 2).

For a detailed information, vertical section of the shell if cut, shows that it consists of three layers (Fig. 3).

1. Periostracum. It is an outer layer formed of a horny conchyolin which is a substance related to chitin. On its inner side the next layer is found which is known as prismatic layer.

2. Prismatic layer. It consists of a small prism-like deposit of calcite (Burnt ash) separated by thin layer of conchyolin. This layer is followed by the third layer known an nacreous layer.

3. Nacreous layer. It is the inner-most layer formed of calcium carbonate and called as 'Mother of the pearl'. It consists of alternating layers of calcium

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carbonate and conchyolin arranged parallel to the surface. This nacreous layer is secreted by the entire outer surface of the mantle, while the first two layers are secreted only by the edge of the mantle.

Programming of Pearl Industry and Artificial Insertion of Nucleus

Although pearl industry may be established only on natural basis of pearl formed by oysters in the natural conditions but an artificial device to insert the nucleus as foreign particle in the shell of oyster has proved useful for the production of pearls in greater number. This whole process is very much complicated, technical and time taking and can be managed as given below—

[I] Collection of oysters

The oysters are collected from the bottom sea by the divers particularly women divers in Japan who are called as 'AMA' which in Japani means 'the girls of Sea.' The divers usually have got training for proper diving into the sea water since their childhood for the search of sea shells or sea weeds. The well protected suits of cotton with cap are used at the time of diving. Each diver has a small hand net at the time of diving when she goes upto 5 metre depth. The net helps in the collection of oysters from the bottom. The oysters collected by nets are stocked in the wooden bucket attached to the diver's left wrist by a cord and the diver with bucket comes up on the surface of water. An experienced diver can remain under water up to about one and half minute and can collect 2 to 10 oysters per dive. The best time for diving is from the early morning to mid day. The best period for the collection of the oysters is of two months in the summer season when the water is nearer and the sea is calm.

During diving in deep sea water the divers operate directly from the side of boat and a rope remains tightly fitted to the diver's wrist through which the operating boatman pulls the diver out with force up to the surface after receiving any signal from the partner. Thus, the whole collected oysters are stored and stored out. The oysters of same age group are segregated and two years old are kept in shallow water for future. Three years old oysters are sent to shallow water and in the months of April and May they are taken out. For pearl industry and proper supply of oyster, its eggs are incubated artificially which solves the problem of obtaining oysters for pearl culture.

Oysters are also caught by special type of cages (84 × 54 × 20 cm) by covering a heavy wire frame with two centimetre wire mesh. This cage is dipped into hot coltar as a measure against corrosion. Now this cage is dipped into the sand-cement mixture providing rough surface to the cages to which free swimming sopts get easily struck up. These cages are suspended at a depth of

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6 metre from July to November where spots are easily available. These collected oysters are now transferred to rearing cages.

[II] Rearing of oysters

The collected oysters are stocked and reared in special type of cages called as rearing cage. These cages are almost similar to those of collection cages except that they are further devided into 4 to 6 smaller chambers and lack the diagonal sub-divisions. They are also covered with metal mesh and with netting of cotton. These cages are well protected from natural enemies of oysters like Octopus, Eel, Devil fishes etc. The collected oysters are first cleaned and then placed into the culture cages for a period of about 10 to 20 days to recover the strain due to excessive handling and for the physiological adjustment to the shallow water conditions.

[III] Insertion of nucleus

The insertion of nucleus as foreign particle is very much technical process and is of great importance for pearl industry. A number of methods are devised but most practicable and efficient method is one adopted by Nishikows. In this method a piece of mantle of living oyster is cut off and inserted together with a suitable nucleus inside the living tissue of another oyster. Following steps are taken for the insertion of nucleus.

1. Fitness of oyster for operation. The selected oysters for the insertion of nucleus should be healthy and strong enough to over come the shocks during operation. It is suggested that if the ovary and testis of oysters are got rid off they would be more resistant to the shocks of operation. For this purpose oysters are dipped into cold and warm current of water alternately which initiates them to eject their sperms and eggs in case of males and females respectively. Before operation, oysters are kept under stress of suffocation as a result they start to open their shells and at once a bamboo peg (piece) is inserted between the gap of two shells due to which shells may not be closed again.

2. Preparation of graft tissue. The piece of tissue which is inserted inside the mantle is called as 'GRAFT' tissue. A strip of about 7 × 0.75 cm is cut from the edge of mantle of healthy oysters by sharp knife. This piece is smoothed, cleaned and washed off the adhering muscus and again wiped off by wet sponge. The border of gill piece is removed by sharp scalpel. Now this tisssue is trimmed to 2 to 3 cms long narrow strip and again cut transversely into small squares according to the size of the nucleus for insertion. These squares are kept in sea water at 22°C where they can survive for about 48 hours. The outer edges of these graft squares must be known because nacre secreting cells are found only on the outer surface of the mantle so it is essential to keep the outer surface in contact with the inserted nucleus.

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3. Preparation of nucleus. Although any small particle may function as nucleus to initiate the pearl formation but it is reported that calcarious nucleus is the best because the deposition of nacre was found to be more satisfactory on calcarious nucleus as compared to any other particle. Best nucleus is formed by the shell of molluscs with heavy deposition of calcarious shells. Such type of molluscs are easily available in India but Japan depends on U.S.A. for good quality of calcarious shells. It is also notable that spherical nucleus is best for the formation of good quality of spherical peral.

4. Insertion of nucleus. For the insertion of nucleus, oysters are fixed in a desk clamp in the position of right valve facing upward. Mantle folds are smoothly touched to expose the foot and the main body mass, followed by an incision into the epithelium of the foot and a slender channel into the main mass. Suddenly one graft tissue piece is placed into the channel and the nucleus is placed over the graft tissue which functions as a bed for the nucleus. Now the bamboo peg is quickly removed and oyster shells are closed automatically. For the insertion of the second nucleus similar operation is performed from the left side in the gonadial tissue and third insertion should never be tried. In Japan one trained girl can operate 25 to 40 oysters per hour and these girls are called as 'TOMARINE SON' means 'Miss Nucleus Pusher'. The operation period should not increase beyond 30 minutes and the oysters can not survive beyond one hour of the operation period. So operation and insertion of nucleus should be performed by experienced persons.

5. Post operational care. Nucleated oysters are placed into cages and suspended into sea water and attached with floating rafts to a depth of 2 to 3 metres for about 6 to 7 days to recover from the shocks due to operation. This period of 6 to 7 days is known as 'RECOVERY PRRIOD.' Now oysters are examined properly and dead individuals are removed from cages. Sometimes, few oysters expel out the nucleus from the body due to heavy shock. Now-a-days it is examined by X-rays whether oysters are having inverted nucleus or not. About 3000 to 3600 nucleated oysters are kept in different cages suspended in sea water at 2 to 3 meters depth for 3 to 6 years and undisturbed except at the time of clearing and inspection. The pearl oysters grow best in warm shallow waters generally not more than 14 metre deep.

[IV] Harvesting of pearl

Pearls are harvested in the month of December to February which may slightly vary according to the climatic conditions of the industrial area. After the completion of 3 years of the insertion of nucleus, pearl oysters are harvested from the sea and the pearls are taken out from the shell.

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[V] Clearing of pearls

After taking out the pearls from the oysters shell they are washed properly, cleared with the soap solution, but pearls should not be rubbed much.

Composition of Pearl

Pearl comprises of water, organic matter, calcium carbonate and the residue.

(1)	Water :	2-4%	(2)	Organic matter :	3.5-5.9%
(3)	Calcium carbonate :	90%	(4)	Residue :	0.1-0.8%

Quality of pearl

The pearls obtained are of variable shapes and sizes. They may be white, or cream red or pink red in colour. The spherical pearls of rainbow colour are rarely found. The best quality of pearl is known as 'LINGHA PEARL' and obtained from marine oysters. Pearl obtained from freshwater bivalves are not as valuable as those obtained from the marine oysters (Mishra, 1961).

Problems of Pearl Industry

Theoretically pearl culture appears to be very much easy but practically several problems crop up during culture. Number of enemies like eel, octopus, devil fishes etc, destroy the oyster. The lethal cold water, low salinity of water, turbidity of water and high range of temperature variation hamper the pearl industry by affecting the proper rearing of the oysters.

Suggestions for Pearl Industry

(1) During pearl fishing the nets used should be of such size from which smaller than a limited sized pearl may not be caught but should pass through the net to get a chance to grow.
(2) The fishing of pearl oysters should not be much so as to exhaust the stock soon.
(3) During the breeding season, oysters should not be distrubed by fishing, rather allowed to breed freely. This period may be declared as close season for any fishing.

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Meghna Toxicology. unit 2-3

પાર્થ ગેરોક્ષ
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Toxicology :

Toxicology is a Greek word - toxin or toxicum or toxicon = poison + logus = discourse or knowledge, i.e, "the science of poison." In other words "the branch of pharmacology which deals with the various aspects of poisons and poisoning is known as toxicology". Poison may be defined as a substance which, even in small dose, produces adverse effect in the metabolism of an organism and consequently, may cause death.

Presently, toxicology is not restricted to the study of poisons only. Rather, it is the study of the nature and mechanism of toxic effects of substances on living organisms and other biological systems. Toxicology also deals with the quantitative assessment of the severity and frequency of these effects in relation to the exposure of the organisms. Along with other sciences, toxicology contributes to the development of safer chemicals used as drugs, food additives, pesticides etc.

Disciplines of Toxicology :

Modern toxicology is regarded as a multidisciplinary science. It is subdivided in to four principal disciplines - Environmental, Economic, Clinical, and Forensic toxicology.

1. Environmental Toxicology :-

The environmental degradation due to the presence of various pollutants is referred as environmental toxicology. Thus environmental toxicology is the study of causes, conditions and effects of such chemicals on the living system and biosphere

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2. Forensic Toxicology:

Detection of causes of mortality due to any toxicant (poison) via medical examination is an allied aspect of toxicology and refered as Forensic toxicology. Therefore, forensic toxicology deals with the poison, its type, symptoms and possible treatment. In precise form, forensic toxicology is concerned with the medicolegal aspects of deleterious effects of chemicals on human and other animals.

3. Economic Toxicology:

Subjects classified under this head - food, drinks, drugs, etc. - are directly and indirectly involved in the economics of the country e.g. pure food contributes to good health and is of real value in the commercial export market. In other words, economic toxicology is directly or indirectly related to the economics of the nation. It deals with the harmful effects of chemicals which are intentionally administered for the purpose of achieving a specific effect in the biological system.

1. Clinical Toxicology:

It deals with diagnosis and treatment of the effects of harmful diseases caused by toxic substances of exogenous origin i.e, xenobiotics. These include accidental and intentional abuse of chemical substances, including therapeutic agents; undesirable excessive and non-therapeutic drug effects, injurious interaction of xenobiotics, accidental exposure to toxic substances in house and industry, intentional and inadvertent food additives, environmental contaminants, and naturally occurring toxic hazards. Clinical toxicology is closely related to forensic toxicology. The application of antide

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tal substances to prevent the toxic actions of poiso are also important aspects of clinical toxicology.

5. Mechanistic Toxicology:

It is a branch of toxicology which is associated with the elucidation of mechanisms by which xenob -otics exert their deleterious effects on living bein

6. Biochemical Toxicology:

The study of changes at the cellular and subce -llular levels as a result of toxic action of chemical is designated as biochemical toxicology.

7. Regulatory Toxicology

It is a branch of toxicology which deals with the imposition of certain restrictions on the entry of chemicals in the environment with the help of law. For this purpose, legislations are framed and passed by the government (State and Central) and regulatory agencies enforce these legislations.

8. Industrial toxicology:

It deals with the study of the nature and type of chemical substances emitted by the industries in ambient air and water, and possible effects of such contaminants on the living biota including human beings. It is much close to environmental toxicology. It also considers the suggestions regarding proper measures to treat hazardous substances released from the industries and, thus, to minimize their release in to the environment.

9. Genetic Toxicology:

It deals with the study of deleterious effects of xenobiotics, if any, on chromosomes and, more specifically, upon the genetic constitution of indivi

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-als. It is closely related to the mechanistic as well as biochemical toxicology.

10. Preventive Toxicology:

This branch deals with the evaluation and recommendation of suitable measures for the protection of environment and its living resource

11. Behavioural Toxicology:

It is chiefly concerned with the study of alterations in the behaviour of organisms followir exposure to specific toxicant.

12. Systemic Toxicology:

This branch deals with the adverse effects of chemicals on a particular system of organisms, viz respiratory system, immune system, nervous syst cardiovascular system etc.

13. Comparative Toxicology:

This branch deals with the study of relative toxicities of xenobiotics to various organisms,

14. Toxinology:

Toxinology is the study of toxins in the restricted sense (poisons produced by micro-organisms, viz., bacteria and viruses etc.).

15. Wildlife Toxicology:

It involves the study of the effects of toxicants of any origin on wildlife, in exactly the same way as the veterinary toxicology is related to domestic animals.

16. Ethnic or Geographical Toxicology:

It is a recent area concerned with the puzzling phenomenon that certain toxic dru

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reaction seems to be more frequent in particular countries or in one continent. It analyses various factors (Climate, nutritional practices, genetic factors and other environmental influences) which might account for these differences in responses of the human body to a xenobiotic.

* Principal aspects of Toxicology:

The following are the principal aspects of toxicology.

→ 1. Toxicometrics: It is the study of measurement of poisons.

→ 2. Toxicodynamics: It deals with the biochemical and physiological effects of xenobiotics and mechanisms of their action.

→ 3. Toxicokinetics: It deals with the absorption, distribution, biotransformation and excretion of xenobiotics.

* Scope and Importance of Toxicology:-

Toxicology incorporates a very broad scope. It is primarily concerned with the identification of deleterious agents and, secondly, with the treatment of these agents for detoxification, i.e. removal of the toxin. Apart from this a toxicologist is also concerned with the character, properties, signs and symptoms and the chemical detection of the toxin, where offensive intent is suspected.

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Actually, toxicology has its impact on human life from the day of conception in the womb till the last moments of life. Nevertheless, certain toxicants are even deleterious for the sperms and the ova.

Toxicology deals with the toxicity studies of chemicals used.

1. In medicine for diagnostic, preventive and therapeutic purposes.
2. In food industry as direct and indirect additives.
3. In agriculture as pesticides, growth regulators, artificial pollinators, and animal food additives.
4. In chemical industry as solvent, component and intermediates of plastics and many other types of chemicals.
5. Toxicology is also concerned with the health effects of metals (as in mines and smelters), petroleum products, paper and pulp, toxic plants and animals toxins.

The study of toxicology may be system-wise and also agent-wise. In this way, we may have systemic toxicology involving toxicology of central nervous system, hepatic system, respiratory system ophthalmic system etc. The study would include defences of each of these systems against assault from foreign chemicals, responses and reactions as also injuries caused through excesses.

An agent-wise study would take up drugs, pesticides, food additives, chemicals, heavy metals,

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trace elements, polymers, radiation, chemical carcinogens, teratogens. There is hardly much of generalization which can be made and many of the agents have to be studied individually in different species before being precisely conclusive.

Application of toxicology for practical purposes ca be broadly divided in to three areas which are, however, flexible and overlapping:

1. Forensic toxicology where medical science has a role.
2. Economic or industrial toxicology which includes drugs, pesticides, food additives, containers (like cans and packing materials) etc.
3. Environmental toxicology which includes pollution-al studies, residue analysis, industrial hygiene and occupational health.

Besides, many other divisions and names are also given by different scientists.

When standard procedures may not be able to predict the toxicity in human, then the predictions have to be based on chemical and physical propertie molecular structure, biological activity relations, pharmacokinetics etc. This is termed as speculative Toxicology and is based up on certain speculative studies.

Usefulness of the study of toxicology to human beings may be described in the following points:

→ 1. Toxicology may be helpful in the development of:
   (i) Suitable and safer food additives.
   (ii) Suitable and safer pesticides

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(iii) Suitable drugs against any specific disease.

→ 2. The data on ~~acute~~ acute toxicity tests for various xenobiotics against different fauna may be valuable in following ways:

(i) Provides an idea of toxic dose of a specific toxicant for specific animal.

(ii) Makes certainty of sublethal doses of the toxicant for specific animal.

(iii) Provides precise idea about maximum permissible limits for the pollutants in the ambient air or the drinking water.

(iv) Assists in evaluation of maximum acceptable daily intake of specific chemical.

(v) Aids in determination of sensitive species.

(vi) Aids in ascertaining sublethal dose of any chemical for long-term toxicity tests.

→ 3. The data on long-term toxicity tests provides reliability for:

(i) In evaluation of safer levels of xenobiotics.

(ii) In determining the most sensitive stage of a particular target animal against any toxicant.

(iii) In elucidation of mode of toxicity of chemicals

(iv) In rational therapy of intoxication.

(v) In establishment of sensitive predictive tests useful in achieving information for risk assessment.

→ 4. Toxicology may be helpful in the antidotal therapy

→ 5. It may be helpful in the monitoring of environmental pollution.

→ 6. ~~Toxicology may be helpful in mono monitoring~~ of risk assessment.

→ 7. An understanding of the mechanism of toxic

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action also contributes to the basic knowledge o pharmacology, physiology, biochemistry and cytology.

→ 8. Analytical toxicology provides suitable procedu to evaluate the presence or absence of differe types of substances and their levels in the env -ment.

→ 9. It also contributes an idea about the permissil limit of any toxicant in any segment of the env -nment.

→ 10. Comparative toxicology is concerned with the study of different species of animals exposed to chemical stresses to evaluate how close these a to human systems.

→ 11. It gives an idea about the factors affect in the toxicity of any toxicant.

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Pesticides:

Various pesticides viz. insecticides, fungicides, herbicides, molluscicides, and other biocides cause pollution directly or indirectly.

Effects of Pesticides:

Some adverse effects of pesticides present in soil are:

1. Pesticides may adhere to soil particles causing harm to vegetation.
2. Pesticides like DDT, BHC and other organochlorin retained in soil concentrate in vegetables, crops cereals and ~~fo~~ fruits. Consequently, these recyc in the food chain. DDT, If accumulated in huma may cause impotency besides other disorders.
3. Persons who used vegetables contaminated with 0.5 gm or more PCBs developed darkened skin, eye damage and severe acne.
4. Pesticides like DDT, endrin, dieldrin, heptachlor etc are known to slip gradually through soil into grou -nd water and eventually contaminate public dri -king water supplies.
5. From the pesticides-contaminated soil, when irrigated water evaporates, it may also spread pes -ticide molecules in to the atmosphere, indirectly causing ill-effects on human health.
6. Long-lasting effects of pesticides are visible in animals and man where they affect the tissues and interfere with normal metabolic activities by disturbing the enzymatic functioning in the body.
7. Herbicides and chlorinated insecticides are very

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potent pollutants of the soil and affect soil texture and function of the ecosystem. Many c these have long-lasting effects and if used inc -criminately may be suicidal for people. Even c -tain herbicides - such as dioxan - has been fou to cause congenital birth defects in offspring of experimental female rodents who have ingested inhaled certain concentration of dioxan at cri periods.

8. Organophosphate insecticides cause extreme muscular weakness, tremor and dizziness in poisoned animals.

9. Many hunting birds feeding on grains, partic -rly contaminated with high levels of DDT, ar threatened with extinction. It has also been i -licated as the cause of thin and fragile eggs because of inhibition of enzymes and interfere with hormones which regulate calcium metab -sm. Vultures declining population may be due this reason.

10. Excess intake and consequently absorption pesticides may lead to greater accumulation acetylcholine in the body. Chronic absorption damages liver and kidney causing malfun tioning, excess of amino acid in blood and u blood abnormalities and cancer.

Fertilizers :-

The synthetic fertilizer urea (NH_2CON required for the boosting up of agriculture crops also cause pollution.

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Effects of Fertilizers:

Modern agricultural practices i.e., the use of fertilizers, pesticides etc. are employed to increase the soil fertility and crop production. In fact, the fertilizer-enriched soil can not support microbial flora, hence there remains poor humus in the soil.

Salient adverse effects of the use of fertilizers are:

- Fertilized soil produces larger sized vegetables and fruits, which are more prone to pests.
- Excessive use of nitrogenous fertilizers in land leads to accumulation of nitrate in the soil, which are transferred to human through plants.

Nitrates, being highly soluble, proceed in to drinking ground water and become deleterious when this concentration exceeds 90 ppm, causing diarrhea and cyanosis (blue jaundice) in children. In human body these nitrates or nitrites may be converted to nitrosoamines and other nitros compounds, which are suspected to cause stomach cancer.

Recent reports reveal that nitrogenous fertiliz has raised NO_3 levels in soils to dangerous amounts The danger appears to be acutely severe, particularly to infants (less than 4 months old) who are more susceptible to fatal disease called methemoglobinemia or blue baby syndrome where nitrates interfere with O_2-carrying capacity of blood. It also damages respiratory and vascular system causing ultimately death in infants.

- Potassium fertilizer in soil decreases the ascorbic

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acid (Vitamin C) and carotene in vegetables and fruits.

Researches reveal that there is a 25-30% declin in protein content when corn, maize, gram and wheat crops were grown on soils fertilized with N fertilizers. Moreover, the subtle balance of amino acids with the protein molecule is also disrupted, degrading the carbohydrate and protein quality leading to malnutrition.

4. Excess use of fertilizer intensively reduces th ability of plants to fix nitrogen.

5. Fertilizers get contaminated with other synthe organic chemicals, there by polluting the soil wa These fertilizers enter the aquatic system contribut to eutrophication.

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Automobile Emissions

Meghna

SYNOPSIS

Introduction, Kinds and sources of pollutants emitted by automobiles, Effect of important automobile pollutants on human health, Photochemical pollution, Control of vehicular pollution.

NICE Automobiles

Introduction

assign on AE.

Alarming level of pollution has shrouded the cities due to motor vehicles. In big cities of India like Delhi, Mumbai, Kolkata, Kanpur, Chennai we have now an automobile culture and we find roads and nearby places full of exhaust toxic gases. Out of the automobiles the major pollution is done by two-wheelers and three-wheelers which burn a mixture of petrol and oil and emit about 9-10 times more harmful gases than cars. Besides the emission of harmful gases, automobiles also increase the problem of noise pollution. As vehicular air pollution in this country is not monitored efficiently, it is difficult to estimate precisely the extent to which they contribute to the pollutants in the air. However, it is believed that in three metros in our country, vehicles-contribution towards air pollution is as follows :

Delhi = 64%

Mumbai = 52%

Kolkata = 30%

A study indicates that 97% of HC and 76% of CO emissions in Delhi are from vehicles running on petrol. About 70% of HC and 48% of CO in India come from vehicles having 2-stroke engines. In general, most two-wheelers and three-wheelers run on 2-stroke petrol engines. In spite of the advantages of 2-stroke engines (light, easy to manufacture, less cost, high specific output, easy cold start, and easy to maintain), the 2-stroke engines are considered to be emission-inefficient, However, NO_x emission in 2-stroke engines is only 1/3 as compared to 1/4 in 4-stroke engines. The present chapter, however, deals with the types of pollutant emitted by automobiles and their deleterious effects, particularly on human health.

Kinds and Sources of Pollutants Emitted by Automobiles

The composition and nature of air-borne pollutants produced by automobile exhaust has been reviewed by Sherwood and Bowers (1970). Although the exhaust gas, the chief culprit, pollutes the air but evaporative losses from the fuel tank and carburetor and also losses from the crank case account for a significant proportion of the hydrocarbons emitted (Fig. 10.1). If the petrol is completely oxidized in the environment, only the H_2O and CO_2 will be produced in an internal combustion engine, which can hardly be considered as pollutant, although there is considerable anxiety about the build-up of CO_2 in the environment and its possible effect on the climate. In practice, it is rather difficult to achieve 100% oxidation and, thus, CO is formed in considerable quantity.

Besides, some of the fuel remains unchanged and some is converted into other organic components. Apart from these products of incomplete or partial combustion most petrols contain lead and

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lead compounds which are also present in the exhaust. Further, the conditions in the combustion chamber favour the oxidation of the nitrogen in the air so that oxides of nitrogen are also formed in the engine. All these chemical products are expelled as exhaust gas. It is observed that the diesel exhausts also contain some carcinogens like benzopyrine.

The important pollutants present in the exhaust gas produced by automobiles are :

Water vapour
CO_2
Unburnt petrol
→ Not considered to be pollutants

CO
Nitrogen oxides
Lead compounds
Sulphur oxides
Carbon particles (Smoke)
Organic compounds
→ Considered to be serious pollutants

The world average of the transport sector's share in polluted air is :

- CO → 85%
- NO_x → 47%
- HC → 45%
- SO_x → 3%
- CO_2 → 20%

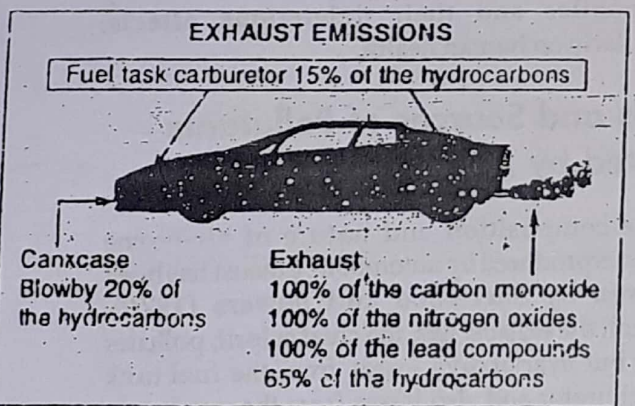

Fig. 10.1 : Pattern of emissions from an uncontrolled vehicle

It shall not be out of place to mention that under certain circumstances the products emitted by automobiles can react with each other to produce unpleasant secondary products. This frequently occurs.

Although petrol engines and diesel engines both produce similar products in their exhausts, the relative proportions present are very different — as shown in Table 10.1.

The exhaust of diesel engines contains significantly lower concentration of pollutants than the exhaust gas from petrol engines. However, to offset this, diesel engines are very liable to emit smoke and a nauseating smell if they are incorrectly operated and/or not properly maintained. Under such conditions the amount of CO and hydrocarbons produced is also increased; the CO content may then rise to 2,000 ppm. Diesel, high in sulphur content, is also responsible for high SO_2 concentration in traffic junctions of big cities.

From the above discussion, it can be concluded that another major source of air-borne pollutants, through the combustion processes, is the automobile. Poilution occurs each time a motorist presses his brake pedal. Thus vehicles on road serve as mobile sources of air pollution, contributing such pollutants as CO, nitrogen dioxide, smoke, organic vapours and incompletely burnt hydrocarbons (Table 10.2). Their contribution to air pollution is minimum, and the combustion process is nearly complete, when vehicles are driven at constant speeds, with minimum stops and start. Of course, other factors such as the engine design and the type of gasoline used also determine the quantity and profile of poliutants emitted by a car.

Table 10.1 : Comparative Composition of Exhaust Gases in Maintained Vehicles (concentrations in ppm by volume)

Type of engine	*Pollutant*	*Idling*	*Acceleration*	*Cruising*	*Deceleration*
Petrol Engines	CO	69,000	29,000	27,000	39,000
	Hydrocarbons	5,300	1,600	1,000	10,000
	Nitrogen oxides	0	1,020	680	20
	Aldehydes	30	20	10	290
Diesel Engines	CO	Trace	1,000	Trace	Trace
	Hydrocarbons	400	200	100	300
	Nitrogen oxides	60	350	240	30
	Aldehydes	10	20	10	

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Table 10.2 : Average Emission Factors of Pollution for Automobile Exhausts	
Types of emission	*Kgs/1,000 liters of gasoline used*
Carbon monoxide	300.00
Hydrocarbons	25.00
Oxides of nitrogen	14.00
Particulates	1.50
Oxides of sulphur	1.00
Aldehydes	0.50
Organic acids (acetic)	0.50
Benzo(a)pyrene*	0.06

Nickel may be emitted from the Ni-added to gasoline and Ni-containing parts of automobiles. Zinc and cadmium come from the lubricating motor oils, tires and galvanized parts of the vehicles. Cadmium concentrations range from 0.07 to 0.10 ppm in diesel oils and 0.20 - 0.26 ppm in lubricating oils; cadmium in automobile tires ranges from 20 to 90 ppm. It is amazing to know of the various chemicals and materials involved in the manufacture of automobiles and keeping them on road. When discarded, several of them contaminate the environment (Table 10.3) :

Table 10.3 : Automobile Parts and Pollution Problems associated with them	
Parts	*Problems*
Battery	Contains lead and HCl
Bumper	Wastes include cyanide, chromium and other heavy metals
Brake shoes	Contains asbestos
Engine	Waste per tonne of castings, 0.3 tonnes — mainly slags with some toxic contaminants
Exhaust	Contains several air pollutants : 63% lead, 20% NO_2, 23% hydrocarbons and 45% CO.
Seat textiles	Wastes include dyes, acids, solvents, greases and waxes
Gasoline tank	Serves as a source of benzene and hydrocarbon emission during fueling
Plastic components	Toxic chemical used in the production include vinyl chloride, formaldehyde, phenols
Tyres	Toxic chemicals used in production include amines, thiurams, nitrosamines and solvents

Bond and Straub (1972) reported that diesel vehicles are important sources of nitrogen oxides, hydrocarbons and particulates (Table 10.4). Regulations proposed in the early eighties called for a reduction in particulate emission from 0.35 g/km to 0.12 g/km, and restricted the nitrogen oxide emissions from 1.2 g/km to 0.6 g/km. It had been a problem to achieve the simultaneous control of particulate and NO_x emissions efficiently.

*gram/1,000 liters

Table 10.4 : Emission Factors for Diesel Engines	
Types of emission	*Emission levels (Kg/1,000 liters of diesel)*
Oxides of nitrogen	27
Hydrocarbons	17
Particulate matter	14
Carbon monoxide	7
Oxides of sulphur	5
Organic acids	4
Aldehydes	1
Benzo(a)pyrene*	0.1

Excessive and visible smoke is always inexcusable and is the result of bad engine maintenance. Odour, however, is a more difficult problem. No single component is responsible for exhaust odour, and complex synergisms undoubtedly occur.

Hydrocarbons are undoubtedly responsible for a considerable part of the odour, and oxygen-containing materials may also contribute. Compounds of sulphur and nitrogen may also contribute to odour although the sulphur contents of exhaust are generally so low that they are present but not detected. The concentration at which a material in the atmosphere is detected varies greatly from compound to compound — a list of these 'odour thresholds' for some materials is given in Table 10.5 :

Table 10.5 : Odour Thresholds of Possible Exhaust Components	
Material	*Odour threshold level (ppm)*
Hydrocarbons	
Benzene	4.700
Cyclohexane	300.000
Styrene	0.050
Toluene	2.100
0-Xylene	0.200
p-Xylene	0.500
Oxygen-containing compounds	
Acetaldehyde	0.200
Acetone	100.000
Acrolein	0.200
p-Cresol	0.001
Formaldehyde	1.000
Phenol	0.050
Sulphur-containing compounds	
Dimethylsulphide	0.001

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Effects of Important Pollutants Produced By Automobiles or Human Health

1. Unburnt Fuel and Secondary Products Produced from Fuel

Unburnt fuel is emitted into the environment by evaporation losses from the fuel tank and carburetor, a high proportion of the hydrocarbons in the crank-case blown and exhaust gases also contain unburnt fuel. In fact, the constituents of petrol are not regarded to be deleterious but few of them have very slight anesthetic effects in fairly high concentration.

The gaseous products released from the fuel and emitted through exhaust gases contains over 100 compounds. Most of these are hydrocarbons, acetylenes, olefins, paraffins, aromatic hydrocarbons and aldehydes. These components produce irritant action on the eyes, mucus membrane and respiratory system. Apart from the gaseous products, various polynuclear aromatic compounds are also emitted with the exhaust gas as very fine particles and these may persist in the air for long periods. Such particles are injurious to health and are known to be carcinogenic, e.g., benzopyrine.

Benzene is a constituent of crude oil; when unleaded fuel is produced, benzene is added or maintained at high levels to enhance the fuel's anti-knock property. Benzene is highly soluble in fat, and settles conveniently in fat-rich adipose tissues and bone marrow. Even a small amount of benzene can cause cancer and leukemia. On the other hand, PAHs are quickly absorbed into the gut and lungs — and thus increase the risk of being affected with bladder cancer — among truck drivers and delivery personnel by 50%. PAHs are formed during incomplete combustion of fuel; exhaust of diesel engines particularly contains high concentration of PAHs.

2. Carbon Monoxide (CO)

It is deemed as a serious toxic pollutant emitted from the engines. It has a tendency to combine with hemoglobin in the blood to form carboxy-haemoglobin (COHb) :

$$CO + Hb \rightarrow COHb$$

As a matter of fact, CO has a greater affinity for hemoglobin than O_2 and is easily absorbed even in small concentration.

Table 10.6 : Signs and Symptoms at Various Concentrations of Carboxyhemoglobin

Percent COHb	*Signs and symptoms for normal man*
0 - 10	No signs or symptoms (toxicity zero)
10 - 20	Slight headache; dilation of the cutaneous blood vessels; tightness across the forehead
20 - 30	Headache and throbbing
30 - 40	Weakness; severe headache; dizziness; dimness of vision; nausea; vomiting.
40 - 50	Syncope and increased pulse and respiratory rate; greater possibility of collapse and others as above i.e., (30 - 40%)
50 -60	Syncope; increased pulse rate; coma; intermittent convulsions, and Cheyne-Stokes respiration.
60 - 70	Coma; intermittent convulsions; depressed heart function and respiratory rate, and possibly death.
70 - 80	Weak pulse; very slow respirations; respiratory failure and death within few (4-6) hours.
80 -90	Death in less than an hour
90 +	Death within few minutes

The deleterious effects of CO is measured by the percentage of COHb formed in the blood. Table 10.6 shows the signs and symptoms at different concentrations of carboxyhemoglobin.

3. Nitrogen Oxides

Both nitric oxides (NO) and nitrogen dioxide (NO_2) are produced in the automobile exhausts. NO is produced in much larger quantity. However, NO_2 is produced in less quantity (about half of NO), but is relatively more toxic. The maximum allowable concentration for industrial exposures of 8 hours for NO is 25.0 ppm and NO_2 5.0 ppm. Normal level in city street is under 1 percent of these values. Nitrogen dioxide finally ends up as HNO_3, nitrates, or organic nitrogen compounds (under conditions of photochemical smog) :

$$3NO + HOH \rightarrow 2HNO_3 + NO$$

In the stratosphere (12-50) km above earth, NO_2 also reacts with hydroxyl radical to from HNO_3:

$$HO^- + NO_2 \rightarrow HNO_3$$

Little is known about the deleterious effects of oxides of nitrogen on human health. However, their effects are adverse and permanent than the CO.

Dogs and rabbits exposed to a concentration of 0.5 ppm for 90 days gained weight less than normal, and monkeys, when similarly exposed, lost weight.

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Mice exposed at this concentration for 3, 6 and 9 months and then exposed to *Klebsiella pneumoniae* had higher mortality rates than the control groups.

4. Lead Compounds

It has been reported that some three thousand tons of lead are emitted with the exhaust gases of automobiles, especially cars, in UK each year. This has been found to accumulate in the vegetations and soil along roadside verges. Lead could possibly enter food chains and have damaging effects far from the source of pollution.

In humans, lead enters the body either through the mouth, with things eaten or drunk, or breathed in through the nose. Far more lead is likely to be ingested than inhaled, but ingested lead is less absorbed than that which is inhaled. Poisoning by lead at high concentration has been known for a very long time.

The most common form of lead poisoning seen today is the disturbance of the gastro-intestinal system known as *lead colic*. Its symptoms are excessive tiredness; continued headaches; loss of appetite, muscular pains and nausea. These symptoms are produced only when the lead level in the blood increases above 80 mg per 100 ml of blood. As most lead in ambient air is in the form of fine particles, children are the worst sufferers of lead poisoning.

5. Smoke

The smoke emitted by automobiles consists mainly of very fine particles of carbon formed due to incomplete combustion of fuel. Smoke formation is actually related with diesel engines. Carbon particles may act as nuclei both for haze formation and in the absorption of gases e.g., CO_2 and nitrogen oxides. It has been observed that where this occurs, it is likely to cause damage to lungs.

6. Other Particulate Matters

In addition to the finely divided carbon and aromatic compounds in the exhaust, road traffic is also responsible for finely divided rubber from the tyres and for asbestos dust from the brake-linings and clutch-plates. Prolonged exposure to asbestos dust gives rise to *asbestosis* and some varieties are carcinogenic. However, the proportion produced from road vehicles is small and there is no evidence that it is a hazard to human health.

Photochemical Pollution

'Smog', as experienced in Los Angeles, is a classical example of photochemical pollution.

As initiated by sunlight, the series of atmospheric reactions between hydrocarbons and oxides of nitrogen, which lead to the formation of new products, is a most complex system. Among these products are substances termed 'oxidants' which are chemical entities detrimental to biological systems and destructive to certain materials.

In the original sense, the term 'oxidation' represents chemical reactions in which certain atoms combine with oxygen to form carbon dioxide — a typical example of an oxidation reaction.

Presently, the term 'oxidation' is more usually applied to describe the loss of one or more electrons by an atom, ion, or molecule. Conversely, a gain of electrons is referred to as *'reduction'*. Oxidation-reduction reactions cannot be separated since, in any reaction, one of the reactants is oxidized while the other is reduced. For example, in the combustion of carbon in air, carbon is oxidized while oxygen is reduced.

The combustion of coal and petroleum products such as natural gas, gasoline, and fuel oil — termed 'fossil fuels' — is an oxidation-reduction reaction which is responsible for most of the air pollution in urban atmospheres. Fossil fuels are composed principally of hydrocarbons (RH or HC) which, upon complete combustion, produce two oxides; carbon dioxide and water. These two oxides are not considered to be air pollutants, since they are relatively non-toxic and are normal constituents of the atmosphere.

The other byproducts of combustion in exhaust gases and the products of incomplete combustion lead to localized air pollution problems. Since combustion processes are normally less than 100 percent efficient, the exhaust gases contain minor amounts of the original fuel as well as minor amounts of partially oxidized fuel. Carbon monoxide, aldehydes, and unsaturated hydrocarbons (those which contain less than the maximum number of hydrogen atoms as a result of the presence of double or triple bonds) are examples of partially oxidized fuel. Small amounts of nitrogen (a major constituent of air) are oxidized — at the high temperatures characteristic of combustion processes — to nitric oxide; sulphur compounds — also found in varying quantities in fossil fuels — are oxidized to sulphur dioxide. Therefore, the combustion processes produce emission which pollute the air with oxides of carbon,

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nitrogen, and sulphur; also a large variety of hydrocarbons and partially oxidized hydrocarbon fragments.

When these contaminants have been released into the atmosphere, they may react chemically to produce other contaminants quite different from those originally released. Sunlight-induced oxidation processes, termed photo-oxidation, are especially important in some community air pollution problems. During day, for example, nitric oxide in polluted atmospheres is rapidly oxidized to nitrogen dioxide. Similarly, the oxidation of sulphur dioxide to sulphur trioxide is accelerated and olefins and alkylbenzenes are oxidized to form aldehydes and ketones. Formation of ozone is also observed, as well as formation of a family of compounds identified as peroxyacetyl nitrates ($RCOONO_2$). Researches suggest the presence, in such atmospheric mixture, of peroxybenzoyl nitrate, hydrogen peroxide and alkyl hydroperoxides.

Various pollutants formed during the photochemical reaction process are termed oxidants — atmospheric substances which oxidize certain reagents not readily oxidized by oxygen. Products of the photochemical air pollution process, these substances are often termed photochemical oxidants. For detail about photochemical smog, refer Chapter 12.

Control of Vehicular Pollution

Catalytic converters are recommended for the reduction of vehicular emissions. Such a converter is placed near the exhaust pipe in cars to chemically convert engine emission into environmentally benign gases. Three-way converters promote reactions which oxidize HC and CO and simultaneously reduce NO_x emission.

Such converters work best when a chemically correct mixture or fuel and air is consistently maintained by the introduction of a closed loop air-fuel ratio control system. However, no Indian manufacture, at present, uses this system, and converters become non-effective during the start up, i.e., when the emissions are maximum. Catalytic converters also require unleaded fuel.

It should be appreciated that the existing vehicular pollution is due to combined effect of :

- Bad vehicular technology
- Poor fuel quality (accounts for 30% of the problem of vehicular emission)
- Poor vehicular maintenance, and
- Non-existence of traffic planning.

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To control automobile pollution vehicles need engine redesign. Emission efficiency of the vehicles should be increased. But quality of the fuel that are being supplied by the state-owned refineries has also to be improved. Crude oils, high in sulphur content, are usually cheaper, and are imported by the refineries. This results in an increase in the sulphur and carbon content in the fuel. Improvement in fuel quality would result in immediate improvement in air quality.

Experts suggest that maintenance alone can reduce emission by 40%. But only efficient traffic management, as practiced in many large cities elsewhere, can reduce the vehicular air pollution in India metro cities. The only way out of jammed road, slowly moving cars and increased emission seems to be a tough traffic management. Introduction of a Mass Rapid Transport System like Metro Rail or Suburban Rail System, control of entry of vehicles on busy roads or crowded areas, banning of old and polluting vehicles from city roads, and withdrawal of subsidy from diesel could be some of the strategies for a cleaner environment.

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Heavy Metals

13

Toxic Metals

SYNOPSIS

Introduction, Toxicology of Arsenic, Lead, Mercury, Cadmium, Chromium, Copper, Zinc, Aluminium and Manganese.

Introduction

Some 65 of the known 92 elements are metallic in nature. The term 'metal' designates an element that is a good conductor of electricity whose electrical resistance is directly proportion to absolute ^{0}T. In addition, metals share some distinctive characteristics such as high thermal conductivity and high density. Metallic elements are intrinsic components of the environment. Erosion of surface deposits of minerals, forest fires and volcanic activity are some of the natural causes of environmental pollution with the toxic metals. The processes involved in the extraction of metals from the ores and their extensive use resulting from improved technology are also responsible for their dispersion in the biosphere. With the increasing use of a wide variety of metals in industry and in our daily life, problems arising from toxic metal pollution of the environment have assumed serious dimensions. Further, their use without appropriate recycling has also precipitated the prospect of exhausting these non-renewable resources.

Trace elements generally found in coal fly ash are Ba, Be, Cd, Cr, Co, Cu, F, Ga, Ge, La, Pb, Li, Mn, Mo, Hg, Ni, Sc, Se, Sr, Sn, V, Yb, Zn and Zr. These trace elements are transferred during combustion to particles that range in size from less than 0.1 μm to greater than 100 μm. Some elements also present in traces are As, Bi, Ce, and Ti.

Toxic metals, to a large extent, are dispersed in the biosphere through industrial effluents, organic wastes, refuse burning, transport and power generation (Fig. 13.1). They can be carried to places many kilometers away from the source of origin by the winds depending on their physical state, viz., whether they are in the gaseous form or as particulates. Metallic pollutants are ultimately washed out of the air by rain onto land or the surface of the waterways. Thus, air becomes a major route for the contamination of the rest of the living environment. Industrial smoke containing arsenic, antimony, copper, managanese, nickel, etc. is a potential source of contamination of air. The inhalation of these elements at enhanced levels can produce adverse physiological effects. Metals from the air are accumulated by mosses and lichens since these plants depend on the atmosphere for their mineral supply. The levels of copper and zinc in plants have also been found to be high near the copper smelter plants.

National Institute of Occupational Health, Ahmedabad (Gujarat) recently has collected baseline data on metals in blood and urine of Indian population. Twentysix occupationally unexposed human volunteers from Ahmedabad city were investigated for lead, manganese, zinc, cobalt, nickel, copper, chromium and cadmium contents in blood and urine. The contents of most of these metals were almost similar to values reported from abroad;

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however, the nickel content in the blood was found to be on the higher side. This relatively higher content of nickel was assumed to be due to the consumption of vegetable ghee or due to use of stainless steel vessels in cooking.

Metal containing industrial effluents constitute a major source of metallic pollution of the hydrosphere. Metal containing industrial effluents when discharged into coastal waters are, of course, eventually dispersed and diluted in the ocean. In polluted coastal waters there is a possibility of concentration of toxic elements within the food chain in the marine ecosystems. This may seriously affect life of birds and mammals which are dependent on sea for their food.

Mercury-containing effluents are being discharged into waterways by some of the industries in India which can possibly create problems similar to Minamata disease in Japan. Reports on fish from coastal waters of Mumbai reveal that all varieties of fish, except salmon, contained about 100 ng/gm of mercury on fresh weight basis. The greater part of the metal load emitted into the environment is transported by water, lead being an exception.

such as smelting and mining of ores, releasing industrial wastes, use of metallic compounds in pesticides, fertilizers, textile, paper, cosmetics, medicines, detergents, war weapons and in the production of vehicles and aeroplanes have released a large number of toxic metals and their salts in to the environment.

General Principle of Metal Toxicity

The toxicity of metal increases with the increase in atomic number and electropositivity. Among metal salts the toxicity rises from Nitrates < Chlorides < Bromides < Acetates < Iodides < Perchlorates < Sulphates < Phosphates < Carbonates < Fluorides < Hydroxides < Oxides.

A number of metals and metalloids, for example Arsenic, Chromium, and Nickel, and their compounds are carcinogenic in animals. Some of them are considered to be carcinogens in human also. Arsenic was thought to be an exception in that it is carcinogenic in humans but not in animals. Nickel is a biologically active metal which can produce allergy and lung cancer (Sunderman, 1973). Exposure to Ni has been reported to produce nasal

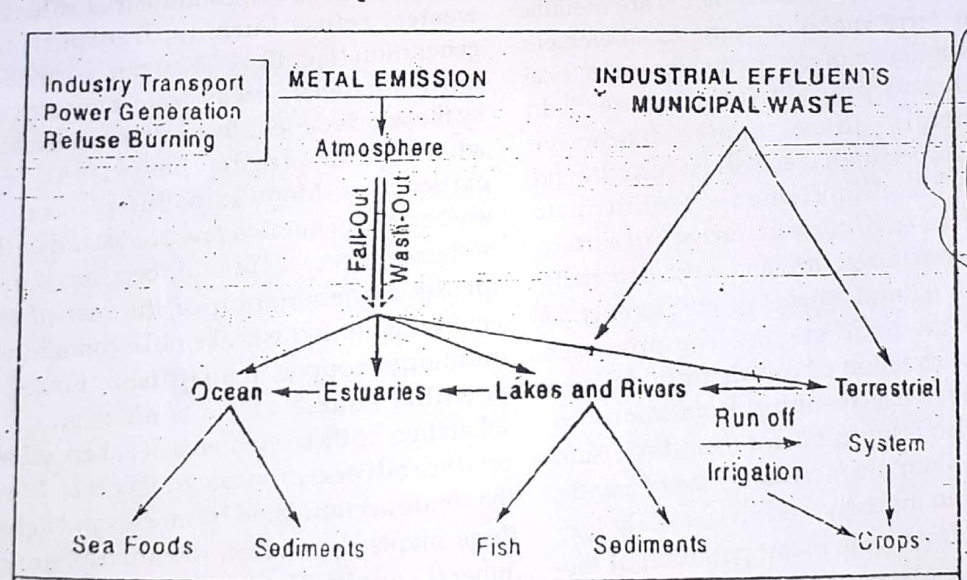

Fig. 13.1 : Dispersion of Metals in Environment

Actually toxic metals are present in small quantities in the earth's crust; hence these are called trace metals. Trace metals by definition are those that occur at less than 1,000 ppm levels in the earth's crust. These are further classified as heavy and light metals based on their densities being over or under 5 g/cm³.

The toxic heavy metals are present at < 0.1% levels in the earth's crust but anthropogenic activities

sinus cancer in refinery workers and in experimental animals. The most important hazard in the nickel-using industry arises as a result of inhalation exposure to nickel carbonyl even in extremely low concentrations. Two phases of acute poisoning are described. Headache, dizziness, nausea and vomiting appear in the first phase and chest pain and tightness, dry cough, dyspnea, cyanosis and extreme weakness in the second phase.

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Important Toxic Metals

The following are the important toxic metals of global concern :

1. Arsenic
2. Lead
3. Mercury
4. Chromium
5. Cadmium
6. Copper
7. Zinc
8. Aluminium
9. Manganese.

Manganese is of special interest to India because of the position occupied by the country as one of the leading exporters of manganese ore. The demand for manganese by our steel and chemical industries has also risen.

1. Arsenic

Arsenic is particularly difficult to characterize as a single element because its chemistry is so complex and there are many different arsenic compounds. It may be trivalent or pentavalent and is widely distributed in nature. The most common inorganic trivalent arsenic compounds are arsenic trioxide, sodium arsenite, and arsenic trichloride. Pentavalent inorganic compounds are arsenic pentoxide, arsenic acid, and arsenates, such as lead arsenate and calcium arsenate. Organic compounds may also be trivalent or pentavalent, such as arsanilic acid, or may even occur in methylated forms as a consequence of biomethylation by organisms in soil, fresh water, and sea water. Arsenic trioxide (As_2O_3) is known as white arsenic. It constitutes about 97% of all arsenic produced and used in end-product manufacturing. Arsenic has been known to mankind from ancient times. Already in the 8th century its compounds were known to Arabian chemists, while in the 9th century Avicenna described arsenous anhydride in his works. T. Paracelsus (1493-1541) was the first to use arsenic compounds for medical purposes. Arsenic and its compounds in small doses are valuable drugs having a tonic effect on an organism. They improve the state of an organism and increase metabolism. A solution of potassium arsenite, KA_sO_2, called Fowler's Solution, is used in medicine.

Uses and Pollutional Sources

Natural Sources : Mine wastes and land erosion.

Anthropogenic Sources : Inorganic arsenic is released into the environment from a number of anthropogenic sources which include primary copper, zinc, and lead smelters, glass manufacturers that add arsenic to raw materials, and chemical manufacturers.

The arsenical compounds are used as :

(i) *Pesticides* : Lead arsenate; sodium arsenite; calcium arsenite etc.

(ii) *Herbicides* : $NaAsO_2$.

(iii) *Wood Preservatives* : Monosodium arsenite; Dimethyl arsenic compounds like fluorochrome arsenate phenol (FCAP) and chromated copper arsenate (CCA).

(iv) *Chemotherapic Agents* : Methylated Arsenic acid ($CH_3AsO(OH)_2$ and cocydylic acid $(CH_3)_2AsOOH$.

(v) Lead and copper based alloys to increase hardness and heat resistance.

(vi) *Warfare* : Lewistios ($CH_3CH = CH\,As\,Cl_2$).

Researches (Pandey and Shukla, 1982) reported release of arsenic as its trioxide from HPC Tower of Urea manufacturing plants.

Environmental Fate of Arsenic

Sequential methylation of arsenic by certain soil microbes (fungi and bacteria) releasing dimethyl and trimethyl arsine has been reported.

Toxicokinetics of Arsenic

Actually arsenic is a metalloid and not a metal. The toxicity of arsenic in trivalent state is greater than pentavalent state. It is because the arsenites bind strongly with the -SH-groups of proteins resulting in enzyme inhibition, whereas the arsenates neither bind to-SH-groups nor inhibit enzyme systems. However arsenates inhibit ATP synthesis by oxidative uncoupling of certain reaction. To sum up, As (III) is most potent, followed by As (v), monomethylarsenate, and dimethyl-arsenate (Kreppal et al, 1993). In fact, ingested arsenite gets oxidized to arsenate and the latter is reduced to arsenite again. Both these inorganic forms are partly methylated to form monomethyl arsenic acid and dimethylarsenic acid (also called cacodylic acid). The formation of methylated forms is regarded as a detoxication mechanism, as far as arsenic toxicity is concerned.

Excretion of absorbed arsenic is mainly via urine. The biological half-life of ingested inorganic arsenic is about 10 hours and 50 to 80% is excreted in about 3 days. The biological half-time to methylated arsenic is about 30 hours.

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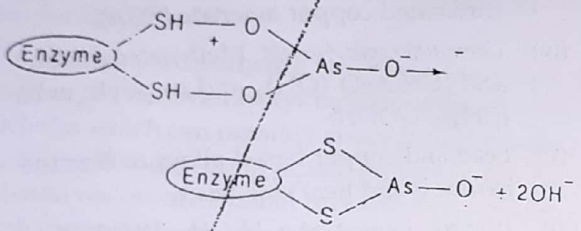
When low chronic doses of arsenic are ingested, it tends to accumulate in lipid-rich tissues. It also concentrates in nails, hair and skin. Arsenic in nails produces Mee's lines (transverse white bands across finger nails) Human milk contains about 3μg/liter of arsenic. Inhaled arsenic may retain in the lung tissue for relatively long periods of time.

Arsenic crosses placental membranes and is a known animal teratogen. It induces skin lesions and may lead to skin cancer. Inorganic arsenicals are known lung carcinogens in humans.

Trivalent arsenic exerts its toxic action by attacking -SH-groups of an enzyme, thereby inhibiting enzyme action :



The enzymes which generate cellular energy in the TCA cycle are adversely affected. The inhibitory action is based on bioactivation of pyruvate dehydrogenase by complexation with As (III). whereby the generation of ATP is presented.

As (III) compounds at high concentrations coagulate proteins, possibly by attacking the sulphur bonds, maintaining the secondary and tertiary structures of proteins.

Arsenic affects mitochondrial enzymes and impairs tissue respiration (Brown et al, 1976), which seems to be related to the cellular toxicity of arsenic.

Arsenic compounds are inducers of metallothionein in vivo. Potency depends on the chemical form of arsenic.

Toxic Effects of Arsenic on Humans

Large doses of arsenic (70-180 mg) ingestion may be fatal. Symptoms of acute illness possibly leading to death consist of fever, hepatomegaly, melanosis, and cardiac arrhythmia. Other feafures include peripheral neuropathy, gastrointestinal, cardio-vascular and hematopoietic effects. Sensory loss in the peripheral nervous system is the most common neurological effect.

Chronic exposure to inorganic arsenic compounds may lead to loss of appetite and weight, diarrhea and neurotoxicity of both the peripheral and central nervous system. Neurotoxicity usually begins with sensory changes, paresthesia, and muscle tenderness followed by weakness. Liver injury is also a characteristic of chronic exposure to arsenic.

Arsenic may induce skin, liver, blood, nasopharyngeal, kidney and bladder cancers in human only but not in any experimental animal. Presence of 0.6-0.8 ppm concentration of arsenic in drinking water in Latin (U.S.A.) caused endemic poisoning and the *Black-foot disease* (WHO, 1972).

Toxic Effects on other Animals

Chronic exposure reduces growth of fingerlings of freshwater fishes (Pandey and Shukla, 1982). Shukla and Pandey (1984, 86, 87) reported impairment in spermatogenesis, oogenesis, nucleic acids (DNA-RNA), and protein metabolism in nature tropical fresh water fishes. Fish liver dysfunctioning at 1-20 mg/l cone has also been observed. Chronic effects in mammals produce skin damage, liver damage and other pathological effects.

2. Lead

Lead is the most ancient industrial toxicant known to man. Earth contains about 0.00002% of lead by weight. It occurs in nature as its sulphide (galena), cerrusite (lead carbonate), and anglesite (lead sulphate). The average lead content of mined ores ranges from 3-8%. Lead smelting and refining are probably the most hazardous operation in regard to exposure to lead with recorded mean concentration of lead in air of 80-4,000 $\mu g/m^3$.

Chemical Forms

Lead occurs in two valence states i.e., +2 and +4. Lead in inorganic formulations normally exists in the divalent (+2) state; but in the +4 form occurs in lead acetate and tetra alkyl lead (R_4Pb) compounds.

Uses and Pollutional Sources

Lead is extensively used in printing, manufacture of paints, water pipes, storage, battery manufacture, pottery and soldering operations, etc. Besides, it is used as an antiknock agent in gasoline. Lead in gasoline, accounting for 20% of lead used by makind, is responsible for about 96-98% of the pollution problems caused by lead. Lead arsenate is used as pesticide.

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Toxicokinetics

Air-borne lead of small particle size is readily absorbed through the lungs. About 50% of inhaled particle lead (size < 0.9 μm) is absorbed; as much as 90% may be absorbed when the size is still smaller (< 0.1 μm). About 90% of lead particles in ambient air that are deposited in the lungs are small enough to be retained. Absorption of retained lead through alveoli is relatively efficient and complete.

Net absorption of lead in the alimentary tract is very low (5-15%) because of its low solubility. More then 90% of the lead in blood is in R.B.C. Lead in bone may contribute as much as 50% of blood lead. Mobilization of lead from maternal bone is of particular concern during pregnancy and lactation and may be mobilized in later years in persons with osteoporosis (Silbergeld et al, 1988). The total lifetime accumulation of lead may be as much as 200 mg to over 500 mg for a worker with heavy occupational exposure. Most of the lead intake by a typical city dweller is from diet (about 200-300 μg/day), air and water adding a further 10-15 μg/day each. Of this total intake, 200 μg of lead is excreted while 25 μg is stored in the bones each day. Renal excretion of lead is usually with glomerular filtrate with some renal tubular resorption. Lead also crosses the placenta. Possibility of lead poisoning in Indian women who apply *sindoor* (red lead) to the scalp (hair parting) and forehead has also been reported.

Toxic Effects of Lead on Human

The major toxicological effects of lead is its interference with heme synthesis, which leads to haematological damage. Lead inhibits several of the key enzymes involved in the overall process of heme synthesis whereby the metabolic intermediates accumulate as shown in Fig. 13.2.

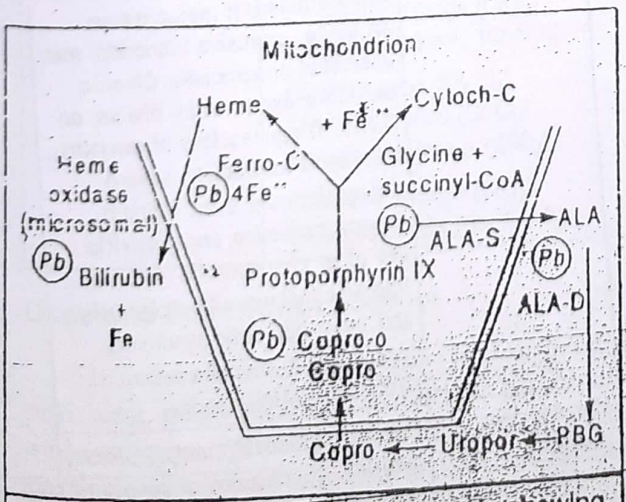

Fig. 13.2 : Scheme of heme synthesis showing sites where lead has an effect

CoA. Coenzyme A : ALA-S aminolevulinic acid synthetase : ALA-S-aminolevulinic acid : ALA-D. aminolevulinic acid dehydratase; PBG. Porphobilinogen; Uropor, Uroporphyrinogen : Copro, coproporphyrinogen : Copro-O, coproporphyrinogen oxidase; Ferro-c, ferrochelatase; Cytoch-C, cytochrome c; Pb, site for lead effect.

Since lead interferes with the synthesis of heme, anemia appears to be the first symptom of its chronic poisoning in animals in general and humans in particular.

Chronic exposure to lead causes weight loss, constipation, and loss of teeth.

Lead also damages liver, kidney and central and peripheral nervous system.

Kidney dysfunction occurs due to the impairment of energy metabolism, leading to the expression of *Fanconi Syndrome* (characterized by an increased loss of amino acids, glucose and phosphate in the urine due to the inability of the damaged tubular cells to resorb these substances). Lead is a renal carcinogen in rodents but whether it is carcinogenic to human kidney is unclear.

An increase in blood pressure is probably the most sensitive adverse health effect from lead exposure occurring in the adult human population.

Lead is also a carcinogen (IARC, 1987). The most common tumours found in people working in lead industry is of the respiratory and digestive systems, not the kidney.

Lead is now a well-known teratogen leading to embryo toxicity. Due to lead intoxication, the rate of abortions goes up and it may also lead to low birth-rate, brain damage and low reproductive ability. In higher concentration, it tends to accumulate in foetal bone and liver and leads to deformity and physiological malfunctioning. Adverse effects of lead intoxication enhances due to iron deficiency. Cases of lead poisoning have also been noticed in India after the consumption of acidic beverages stored in glazed pottery.

Toxic Effects on Other Animals

In fishes lead inhibits liver enzymes, causes muscle tremors, reduces haemoglobin production. Chronic exposure to lead produces renal carcinoma in mammals.

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3. Mercury

Mercury is a well-known toxic metal which came to the limelight after the incidence of "Minamata Disease" in 1953-1960 in Japan (For Minamata Disease refer Chapter 5). No other metal better illustrates the diversity of effects caused by various chemical species than does mercury. On the basis of chemical speciation, there are three forms of mercury (i) elemental (ii) inorganic, and (iii) organic compounds, each of which has characteristic toxicokinetics and health effects as shown in Table 13.1.

Uses and Pollutional Sources

In the environment, mercury occurs as metallic mercury and as HgS and $HgCl_2$ in the earth's crust. Anthropogenic sources consist of mining, smelting, paper pulp, paints, batteries, lamps, switches, caustic soda, medicine and instruments. Twenty five percent of the total production of mercury is consumed by the chlor-alkali plants, rest is used in electrical equipments, paints, in measurement and control like thermometers, sphygmomanometers, in dental practice and in agriculture. Methyl and ethyl mercury have been extensively used in seed dressings. Mercury is released into the environment during its production and by human activities like combustion of fossil fuels, waste disposal and industrial activities. Annual production of mercury in the world is estimated to be about 9,000 tons. About 50% of which is estimated to be lost into the environment. As per WHO (1971) standards, the maximum permissible limits of mercury in drinking water should not be more then 0.001 ppm.

Environmental Fate of Mercury

Inorganic mercury released into the environment is converted into more toxic methyl mercury compounds by the action of certain anaerobic bacteria present in the sediments and bottom muds of waterways. The major source of exposure to methyl mercury for people in general population is from the consumption of fish.

Toxicokinetics

Metallic or elemental mercury volatizes to mercury vapour at ambient air temperatures, and most human exposure is by inhalation. Mercury vapour readily diffuse across the alveolar membrane and is fat soluble so that it has an affinity for R.B.C. and the central nervous system. Metallic mercury is very slowly absorbed by the alimentary tract (0.01%).

Inorganic mercury salts may be divalent (mercuric) or monovalent (mercurous). Kidneys contain the maximum concentrations of mercury following exposure to inorganic salts of mercury and mercury vapour, whereas organic mercury has greater affinity for the brain, especially the posterior cortex. All forms of mercury cross the placenta to the fetus in experimental animals.

Elemental or metallic mercury is oxidized to divalent mercury after absorption which is mediated by catalases. Also inhaled mercury vapour absorbed into R.B.C. is transformed into divalent mercury. Methyl mercury may undergo biotransformation to divalent mercury compounds in tissues by cleavage of the CH_3 bond. Formation of any organic form of mercury, however, in mammalian tissues has not yet been reported.

Within cells, mercury may bind to a variety of enzyme system producing non-specific cell injury or cell death.

Toxic Effects of Different Species of Mercury on Humans

As mentioned above, the toxicity of mercury depends upon its chemical species which may be represented in tabular form :

Table 13.1 : Toxicity of Different Species of Mercury

Sl. No.	Species of Hg	Toxic Effects
1.	Elemental Mercury (Hg vapour)	Elemental Hg is relatively inert and nontoxic but vapour highly toxic when inhaled. It may produce an acute, corrosive bronchitis and interstitial pneumonitis. Chronic exposure exerts major effects on C.N.S. It causes loss of memory, increased excitability, severe depression and even delirium. Severe salivation and gingivitis are other characteristic features. Sporadic instances of proteinuria and even nephrotic syndrome may occur in persons with exposure to Hg vapour.
2.	Mercuric salts (Example — Mercuric chloride)	Severe abdominal cramps, bloody diarrhea, suppression of urine, circulation collapse, renal failure etc. HgS is trapped in soil.

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3.	Mercurous Salts	Loss toxic than mercuric salts because of less solubility. In excess it may cause acrodynia or Pink Disease in children. It causes fever, pink coloured rash, swelling of the spleen, lymph nodes and fingers in children.
4.	Methyl Mercury	Highly toxic, causes severe neurotoxic effects viz., paresthesia; ataxia; neurasthenia; vision and hearing loss and finally coma and death in adults. Also causes genotoxic effects resulting in chromosomal aberrations. **Special** : Methyl mercury interacts with DNA and RNA and binds with sulfhydryl groups, resulting in changes of the secondary structure of DNA and RNA synthesis.

Toxic Effects on other Animals

Inhibits enzymes and protein synthesis in fishes. In mammals it reduces DNA synthesis.

4. Chromium

Chromium is generally an abundant element at about 100 ppm levels in the earth's crust and occurs in oxidation states ranging from Cr^{2+} to Cr^{6+} as shown in Table 13.2, but only trivalent and hexavalent forms are of biological significance.

Table 13.2 : Valency states of chromium compounds

Valency State	Examples
0	Metallic chromium
+ 2	Chromous chloride ($CrCl_2$) Chromous sulphate ($Cr\ SO_4$)
+ 3	Chromic oxide ($Cr_2\ O_3$) Chromic chloride ($Cr\ Cl_3$) Chromic sulphate ($Cr_2(SO_4)_3$)
+ 6	Chromium trioxide (CrO_3) Dichromate salts ($Na_2\ Cr_2\ O_7$)

Uses and Pollutional Sources

Chromium is extensively used in electroplating, polishing, paint-pigment industry. Chromium in ambient air originates from industrial sources, particularly ferrochrome production, ore refining, chemical and refractory processing, and combustion of fossil fuels. Cement-producing plants are another potential sources of atmospheric chromium. The potential sources of chromium in aquatic environment are effluents from tanneries and textile mills.

Tannery wastes contain 10-50 ppm of chromium. Its permissible limit in drinking water is 0.05 ppm.

Toxicokinetics

Chromium (+3) is the most common form found in nature and in biological components. Now report is available that trivalent chromium is converted into hexavalent forms in biological systems. However, hexavalent chromium readily crosses cell membranes and is reduced intracellularly to trivalent chromium. Trivalent chromium compounds are considerably less toxic than the hexavalent chromium compounds.

The excretion of chromium increases with the duration of exposure.

Toxic Effects on Human

Chromium (III) is considered an essential trace nutrient serving as a component of the "glucose tolerance factor". No conclusive evidence exists on the toxic effects of chromium in its trivalent state. The adverse effects of chromium are attributed to the hexavalent forms which are highly toxic to humans. Hexavalent chromium is corrosive and causes chronic ulceration and perforation of the nasal septum. It is because chromium (VI) is a powerful oxidant which can easily penetrate the cell membrane and irritate cells. Chromium (III) is neither irritating nor corrosive. Chromium (VI) is a teratogen and also carcinogenic (inducing bronchogenic cancer).

Studies of chronic exposure on animals to Cr (VI) have not revealed evidence of toxicity.

Toxic Effects on other Animals

Fishes as well as mammals are far less susceptible to the toxic effects of chromium.

5. Cadmium

Cadmium is a toxic heavy metal belonging to the same family as zinc and mercury from toxicology view point. It is relatively rare but toxic to all systems and functions of animals and humans at high levels of exposure.

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The occurrence of free metallic cadmium in nature is rare but it exists in close association with other metallic ores. It occurs mainly with zinc (in the ratio of 1 Cd : 200 Zn in zinc sulphide ores) and is obtained as a byproduct from the refining of zinc, copper and lead.

Uses and Pollutional Sources

Cadmium has been used in a number of industrial processes, as in electroplating, in the manufacture of pigments and paints, as a stabilizer in plastics and in welding electrodes. As copper-cadmium alloy, it is used in automobile radiators and cadmium may serve as an electrode component in alkaline accumulators.

It is of interest to note that an extremely wide range of cadmium concentration have been reported in foodstuffs from many parts of the world. In water, cadmium is found mainly in the bottom sediments and suspended particles. Pollution of drinking water with cadmium can occur as a result of leaching from solders containing the metal in fittings of water heaters, coolers and taps. Cadmium in the ambient air occurs mostly in the particulate form. Smoking tobacco may be an important route of exposure for the general population. Both water-borne and air-borne cadmium can cause an increased concentration of cadmium in soil. The use of cadmium containing sewage sludge and superphosphate fertilizers lead to contamination of the soil. Cadmium present in the soil is taken up by plants. It has been observed that more then 50 percent of the soil samples from Punjab and Haryana were sandy with low organic matter, low pH and were deficient in zinc; these conditions are favourable to promote cadmium uptake by the plants. Fertilizers like superphosphate, rock phosphate, diammonium phosphate etc. used in Punjab contained cadmium. Sea water from Bhavnagar, Gogna and Mandapam used for preparation of salt contained cadmium more than the recommended permissible limits. Studies carried out on flyash produced by casal burning power plants during electricity generation shows that the dust contains high contents of cadmium (Hayes et al, 1980).

Respiratory absorption of cadmium is about 15 to 30 percent. Workplace exposure to cadmium is particularly hazardous where there are cadmium fumes or airborne cadmium. Most airborne cadmium is respirable. A major nonoccupational source of respirable cadmium is cigarettes. One cigarette contains 1 to 2 μg cadmium, and 10 percent of the cadmium in a cigarette is inhaled (0.1 to 0.2 μg). Smoking one or more packs of cigarettes a day may double the daily absorbed burden of cadmium.

Toxicokinetics

Of various heavy metals present in the aquatic environment, cadmium pollution is especially a problem because it is not only highly toxic to the organisms but its toxicity is also cumulative.

Alimental absorption is less than respiratory absorption and is about 5 to 8 percent. Absorption is actually enhanced by dietary deficiencies of calcium and iron and by low protein diets. Low dietary calcium stimulates synthesis of calcium-binding protein, which enhances cadmium absorption. Women with low serum ferritin levels have been shown to have twice the normal absorption of cadmium (Flanagan et al, 1978). Zinc decreases cadmium absorption, probably by stimulating production of metallotheionein.

Cadmium is transported in blood by binding to erythrocytes i.e., red blood cells and large-molecular-weight proteins in plasma, especially albumin. A small fraction of blood cadmium may be transported by metallotheionein. Blood cadmium levels in adults without excessive exposure is usually less then 1 μg/dL. Newborns have a low body content of cadmium, usually less than 1 mg total body burden. The placenta synthesizes metallotheionein and may serve as a barrier to maternal cadmium, but the fetus may be exposed with increased maternal exposure. Human breast and cow's milk are low in cadmium, with less than 1 μg/kg of milk. About 50 to 75 percent of the body burden of cadmium is in the liver and kidneys; its half-life in the body is not exactly known, but it is many years and may be as long as 30 years. With continued retention, there is progressive accumulation in the soft tissues, particularly in the kidneys, through ages 50 to 60, when the cadmium burden in soft tissues begins to decline slowly. Because of the potential for accumulation in the kidneys, there is considerable concern about the levels of dietary cadmium intake for the general population. However, presence of higher concentrations of zinc in water may reduce cadmium toxicity.

Principle of Cd Toxicity

Once absorbed into the body, cadmium has a strong affinity for the imidazole moiety of histidine,

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phosphates, sulfhydryl groups and inhibits a number of enzymes. About a third of the cadmium absorbed is stored in the kidney, which constitutes the principal target organ. Also lung is the major target organ effected by air-borne Cd. The symptoms are the development of severe tracheobronchitis, pneumonitis, emphysema and pulmonary edema (Goyer, 1986). Sampson et al (1984) reported development of pulmonary fibrosis. Cadmium is proved immunosuppressive as indicated by IgG mediated rosette formation (Hadley et al, 1977).

Toxic Effects on Human

The symptoms of acute poisoning in man are vomiting, abdominal cramps and headaches. After inhalation, shortness of breath, general weakness and respiratory insufficiency occurs. Chronic exposure to cadmium results in respiratory disorders, kidney damage, osteoporosis, i.e., decalcification of the skeleton, liver dysfunction, anaemia and hypertension. It has also been found to be highly toxic to the gonads of experimental animals.

Cadmium has recently been accepted as a pulmonary carcinogen (IARC — 1994) in human and rat.

Since the kidney is the principal target organ for cadmium toxicity, the following disorders have been recorded in kidney of human :

1. Aminoaciduria	Excretion of amino acids in the urine.
2. Glucosuria	Excretion of blood sugar in the urine.
3. Hypercalciuria	Excretion of excess calcium in the urine.
4. Proteinuria	Excretion of proteins in the urine.

Itai-Itai Episode

Rice, as in India, is the staple food in most of the regions of Japan. Normally, people living in uncontaminated parts of the globe ingest about 25-60 μg of cadmium daily. However, the reports reveal that the people living along the banks of *Juntsu river* in northern Japan were ingesting 100-1,000 μg of cadmium every day. It was because of the fact that the rice they consumed were grown with such irrigation water supplies (effluent from zinc smelter) that contained 0.35-3.5 ppm of cadmium. It caused about one hundred deaths until the end of 1965. As a result of the analyses carried out by Jun Kobayashi at Okayama University, it became apparent that cadmium intake was the causative factor. The victims accumulated 500 mg of cadmium in their body over the lifetime. This disorder was termed 'Itai-Itai' (literally meaning "ouch-ouch") characterized by renal malfunction (reduced ability to reabsorb water), drop in the phosphate level of blood serum, loss of minerals from the bone and osteomalacia, a ricket-like condition characterized by pathological bone fracture and intense pain. Actually the onset of symptoms occurs only several years after the consumption of cadmium. Nogawa (1987) reported that serum 1, 25 $(OH)_2$ Vit. D levels were lower in Itai-Itai diseased patients.

Toxic Effects on other Animals

In fishes, Cd accumulates in muscle, liver, gills and bones where it produces toxicity. Cadmium chloride can produce acute but reversible effects on ovarian tissue in sexually immature rats. The ovarian stimulation induced by $CdCl_2$ was manifested as follicular maturation and corpora lutea formation but did not seem to lead to the production of sex hormones. A single intraovarian injection of this salt (1 to 3 mg/kg) sterilized adult goats, all the germinal elements and corpora lutea were destroyed. The stromal tissue with vasculatures was also damaged. Similar changes have also been observed in other species of animals. The change commenced with damage to the vascular structure indicating the primary role of vascular injury in producing acute degeneration of the tissue.

6. Copper

Copper (Cu) is an essential element and is widely distributed in nature. Substantial copper deposits in India are known to occur in Rajasthan. It occurs primarily as its oxide or sulphide ores. Copper deficiency is characterized by hypochromic microcytic anemia resulting from defective hemoglobin synthesis. Oxidative enzymes viz., peroxidase, catalase, cytochrome oxidase and others also require copper.

Uses and Pollutional Sources

Next to iron and aluminium, copper is the third most important metal used in the industries. It is

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second to silver in its thermal and electrical conductivities, hence it finds use as a conductor in many alloys. It is also used in paints and ceramics. Copper sulphate is used medicinally as an emetic and also as an antihelmintic. Copper sulphate mixed with lime has been used as a fungicide.

The environmental contamination with copper primarily results from its discharge from the industrial plants producing non-ferrous metals. Additional sources comprise wood combustion and steel production. Copper mining and metallurgical operations contribute to contaminations of aquatic environment. Some of the copper salts are used as algicides and fungicides. Apart from these, copper is also used as antifouling agents in paints. Most of the paints contain 100-200 g copper oxide/liter. Fertilizer production and disposal of industrial/municipal sewage wastes represent minor sources of copper in the environment.

Toxicokinetics

Alimental absorption of copper is generally regulated by body stores (Sarkar et al, 1983). It is transported in serum bound initially to albumin and later more firmly bound to ceruloplasmin, where it is exchanged in the cupric form. The normal serum level of copper is 120 to 145 μg per liter. The bile is the normal excretory pathway and plays an initial role in copper homeostasis. Most copper is stored in liver and bone marrow where it may be bound to metallothionein. The amount of copper in milk is not enough to maintain adequate copper levels in the liver, lungs, and spleen of the newborn. Tissue levels gradually decline up to about ten years of age, remaining relatively constant thereafter. Brain levels, on the other hand, tend to almost double from infancy to adulthood. The ratio of newborn to adult liver copper levels shows considerable species difference : human, 15 : 4; rat, 6 : 4, and rabbit, 1 : 6. Since urinary copper levels may be increased by soft water, under these conditions concentrations of approximately 60 μg per liter are not uncommon.

Copper is an essential component for various enzymes, including tyrosinase, involved in the formation of melanin pigments, cytochrome oxidase, superoxide dismutase, amine oxidase (involved in the formation of two proteins — elastin and collagens) and uricase. It is essential for the utilization of iron. Iron deficiency anemia in infancy is sometimes accompanied by copper deficiency. Molybdenum also influences tissue levels of copper. The recommended daily intake of copper ranges from 2-3 mg/day. The impairment of the ability to absorb copper resulting in its deficiency is called Menke's Disease whereas Wilson's Disease is its opposit (i.e., excessive accumulation of copper).

Toxic Effects on Human

Acute poisoning resulting from ingestion of excessive amounts of oral copper salts may produce death. The ingestion of 15-75 mg of copper causes gastrointestinal disturbances. Further increase in amount may cause hemolysis, hepatotoxic and nephrotoxic effects.

Inhalation of airborn copper causes irritation of the respiratory tract and metal fume fever and ultimately lung cancer after chronic exposure.

Toxic Effects on other Animals

Reduces growth, survival and rate of reproduction. It also causes necrosis of kidney cells and brain haemorrhage.

7. Zinc

Zinc is a nutritionally essential trace metal to all organisms, as it is necessary for the normal functioning of various enzymes. More than 200 metalloenzymes require zinc as a cofactor.

Zinc is ubiquitous in the environment so that it is present in most foodstuffs, water and air. The important ores of zinc are : Willemite (Zn_2SiO_4), Zincite (ZnO), Zinc Blends (ZnS), Smithsmite ($ZnCO_3$), etc. Zinc forms about 40 mg/kg of the earth's crust. Atmospheric zinc levels are higher in industrial areas.

Uses and Pollutional Sources

Zinc is used in dry batteries, construction materials, pigments and printing processes. It is also used for protective coatings on iron, steel, brass and alloys.

Smelting of ores contributes appreciably to the atmospheric levels of zinc. Municipal refuse and automobiles serve as additional pollutional sources. Agricultural use of $ZnSO_4$ — containing pesticides and fungicides, for example — Manozeb (16% Mn and 2% Zn), Zineb and Ziram (1-18% Zn) may be yet another source of Zinc in the environment.

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Toxicokinetics

Approximately 20-30% of ingested zinc is absorbed. Its absorption is generally influenced by prostaglandins E_2 and F_2 and is chelated by tryptophan derivatives like picolinic acid. Zinc concentration in tissues varies widely. The liver receives up to about 40% zinc. It is bound there to metallotheionin. The greatest concentration of zinc in the body is in the prostate, probably related to the rich content of zinc-containing enzyme and phosphatase.

It is interesting to note that Zinc is necessary for the normal functioning of the cell, viz., protein synthesis, carbohydrate metabolism, cell division and growth. Recommended daily dietary allowances of zinc are at 15 mg for adults and 10 mg for children over a year old. The average dietary intake of zinc in India is about 12-15 mg, mostly from food.

Toxic Effects on Human

Zinc at concentration over 15 mg/m^3 in air may produce metal fume fever. Large doses of zinc salts (220-440 mg of zinc as $ZnSO_4$) cause gastrointestinal disorders including vomiting and diarrhea. There is no evidence of zinc being teratogenic or mutagenic. Zn shows no hematological, hepatic or renal toxicity.

Toxic Effect on other Animals

In fish zinc causes decrease in O_2 consumption. It also damages gills, decreases growth and fecundity.

8. Aluminium

Aluminium (Al) is one of the most ubiquitous elements in the environment. It is the third most abundant element in the earth's crust (about 8-15%). In industrial societies it is the second most important metal. Bauxite, the principal ore source of aluminium, is widely distributed in India. The most important deposits are found in Bihar, M.P. and Maharashtra.

Uses and Pollutional Sources

Aluminium is a non-ferrous metal, chiefly extracted from bauxite. It is extensively used for canning, food packaging, and as foil for covering and preserving foodstuff. Beverage cans and cooking utensils constructed of Al are extensively used around the world.

Contamination of the total environment with Al may result from the indiscriminate disposal of Al-containing products and wastes. Workers in the mining and manufacturing industries may be exposed to aluminium particles. Human exposure to Al comes from foods and drinking water as well as pharmaceuticals.

Toxicokinetics

Average daily intake of Al by human has been reported to be 18-20 mg/day through foods and drinking water. In plasma 80-90% of Al binds to transferrin, an iron-transport protein for which there are receptors in many body tissues.

Aluminium at higher levels of exposure interferes with phosphate metabolism. It reduces the bioavailability of ATP and casein, and inhibits certain active enzymes by complexing them.

Bone and lung have the highest concentration of aluminium. Actually bone may be a "sink" for aluminium. It does not normally accumulate in blood to any great extent.

Aluminium compounds may affect absorption of other elements in the alimentary tract and alter its motility by inhibition of acetylcholine-induced contractions. Aluminium has been found to inhibit fluoride absorption and may decrease the absorption of calcium and iron compounds. Al may cross the placental barrier. Al in its dissolved form in water is much more toxic than suspended form.

Toxic Effects on Human

Generally, human beings are least affected by aluminium; however, inhalations with aerosol produce pneumonia. In general, Al binds with bone and causes osteomalacia. Al competes with or alters calcium metabolism in several organ systems including the brain. Calcium rises in brain tissue following Al exposure and disrupts neurotubular integrity and transport.

Toxic Effects on other Animals

In fishes, Al causes gill hyperplasia and mortality.

9. Manganese

Manganese (Mn) is an essential trace element and is a cofactor for a number of enzymatic reaction, particularly those involved in phosphorylation, fatty acid and cholesterol synthesis. It is toxic at higher concentrations. The most important commercial

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source of manganese is Pyrolusite (MnO_2) containing 60-63% manganese. India ranks third in the production of manganese. About 75% of Mn is produced in Orissa, Karnataka, M.P. and Maharashtra.

Uses and Pollutional Sources

Besides export, indigenous demand for this metal is constantly increasing with the growth of the steel industry. Manganese is also used for the manufacture of ferromanganese alloys and in non-ferrous industries. MnO_2 is utilized in dry cell batteries as a polarizer; metallic manganese is coated in the electrodes in welding rods and fluxes for iron and steel. Manganese is also used in the production of zinc by electrolysis, manufacturing pigments, paints, ceramics, photographic material, as a wood preservative and in fertilizers. Organic manganese compounds are used as additives in gasoline, fuel oil and diesel.

Burning of fossil fuels (coal, oil) is the principal source of Mn in the environment. Industrial processes of battery, glass and steel manufacture provide additional input of Mn into the environment. The use of Mn in some fertilizers contributes further to air and water pollution.

Chemical Forms

Manganese can exist in seven possible oxidation states : 0, +1, +2, +3, +4, +6 and +7. Of these, only two valence states, +2 and +4, are encountered commonly from toxicological view-point.

Toxicokinetics

Mn is present in all living organisms. Vegetables, the germinal portions of grains, fruits, nuts, tea, and some spices are rich in manganese. A daily allowance of 2.5-9.0 mg of Mn is recommended for humans. But when exposed to higher levels of Mn, approximately 1-4% of it is absorbed, retained, and accumulated — chiefly in kidney, liver, and bones. Gastrointestinal absorption is less than 3-4%. Mn concentrates in mitochondria so that tissues rich in these organelles have the maximum concentration of Mn, including the pancreas, liver, kidneys and intestines. Biological half-life of the manganese in the body is 37 days. It readily crosses the blood-brain barrier and its half-time in the brain is longer than in the whole body. The principal route of its excretion is with feces.

Toxic Effects on Human

Evidence of occupational Mn poisoning was reported for the first time as early as 1837 in France in a few workers engaged in the grinding of manganese ores.

A definite relationship was established only in 1919. Since then several cases of chronic manganese poisoning have been detected in miners, steel plant and foundry workers, welders, workers employed in dry cell battery manufacturing industries and in families consuming water with high manganese contents. Industrial toxicity from inhalation exposure, generally to manganese dioxide, in mining or manufacturing, is of two types : The first, manganese pneumonitis, is the result of acute exposure. Men working in plants with high concentrations of manganese dust show an incidence of respiratory disease 30 times greater than normal. Pathological changes include epithelial necrosis followed by mononuclear proliferation.

The second and more serious type of disease resulting from chronic inhalation exposure to manganese dioxide, generally over a period of more than 2 years, involved the central nervous system. Chronic manganese poisoning (*manganism*) produced a neuropsychiatric disorder characterized by irritability, difficulty in walking, speech disturbances, and compulsive behaviour that may include running, fighting and singing. If the condition persists a masklike face, retropulsion or propulsion, and a Parkinson's Disease-like like syndrome develops. To sum up, the symptoms of neurological syndrome of manganese poisoning are usually insidious and progressive. An initial phase of psychomotor excitement is followed by asthenia, somnolence, imbalance while walking, slurred speech, difficulty in fine movements, impotence, etc. Established cases show tremors, paresthesia, memory loss, difficulty in walking and swallowing. Bradykinesia, impaired postural stability, diminished associated movements, gait disorder described as "Cock-walk", retropulsion and masked faces are also observed.

Victims of chronic manganese poisoning tend to recover slowly, even when removed from the excessive exposure. The oral absorption of Mn is increased by iron deficiency.

Toxic Effects on other Animals

Mn is neuro- and pancreotoxic to fishes and mammals.

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