CHAPTER - IV
DISCUSSION AND CONCLUSION

Despite rapid strides of mechanisation and automation in different industries in the country, muscular work still provides a major source of energy for production. Effective use of human energy for work, therefore, becomes a critical issue.

Modern foundry industry as we know it, might have started to make its beginning in India in 19th century. Since its modest beginning the foundry industry has registered tremendous growth, in volume and variety. The extent of this progress is apparent from the large number of foundries of all types that India has today, includes over 4500 iron foundries, producing in all over 6.9 MT castings. India ranks 4th largest country in the world. The industry directly employs about 500000 people and indirectly about 1,50,000 people and is labour intensive.

Growth of any industry at any phase of its development is dependent on the human resources. Foundry is no exception to this. The routes to human resource development are many but the success depends on the infrastructure and the strategy. Metal casting of foundry industry is a manufacturing process having a large dependence on the interactions between man, machine and material. In the present age, both machine and material have became highly sophisticated. To cope up with this sophistication the manpower needs to be appropriately geared up. Human resource development plays a key role in the economic development of an organization, it is necessary to recognize that human factor is an integral part of complex systems. Foundry industry
constitutes one of the largest industries in our country employing thousands of workers. It plays a key role in the economy of our state of Maharashtra also. Thousands of workers attend the foundry work at least 10 to 12 hours of the day. Their work comprises making pattern, making and assembling the mould, melting and refining the metal, pouring the metal into mould, and finally removing all adherent sand and surplus metal from the finished casting.

The work environment in the foundry is characterized by a multitude of concomitantly occurring exposures, such as silica dust, coal dust, metal dust, various chemicals, noise, heat, radiation etc. as well as strenuous physical work and poor work positions.

Although the health effects of many of these exposures are well known when they act alone possible nonspecific effects, caused by the interaction of the multiple stress factors and perhaps manifested as a change in the "normal" morbidity and mortality pattern, have not received much attention. Furthermore, many of the chemicals present in the air, including various products of pyrolysis, may have hitherto unrecognized effects. In order to get information about physiological responses of foundry workers during various work processes and to study the existence of stressors affecting the work efficiency of foundry workers.

Mostly the workers working in various foundry sections are of age ranging from 22 to 45 years. Height of workers ranges from 152 cms to 170 cms and the weight ranges from 44 to 65 kgs. The physical fitness score of workers indicates very poor performance after the long exposure time in foundry environment. The grip strength of the workers varies, between 24 kgs. to 43 kgs. for right hand, whereas for the left hand grip strength ranges from 22 kgs. to 42
kgs, Grip strength values of workers shows poor performance as compared to control values (More and Sawant, 2003). These have provided some insight concerning the patho-physiologic significance of the variations in the white blood cells in toxic states.

Variety of gases, fumes and vapours are reported in foundry environment where cupola furnaces are used. These foundries emit co, so$_2$ and particulate matter (dust). It was reported by Rao (1996). Air pollution in foundries was reported by Mathew et al., (1984). Air in the foundries contains irritants like formaldehyde, phenol and various amines. These contaminants are generated by core shell making and moulding process irritates the eyes and the respiratory tract. Visual disturbances occur among the workers exposed to triethylamine in foundry in Japan was reported by Tsutoma Yoshid et al., (2002). In our present study also, in moulding section and core shop, workers complain about visual disturbances and foggy vision as well as watering of eyes. These visual disturbances are due to triethylamine exposure; this has also been reported by Aakesson et al. (1986).

Various metal fumes are also generated during founding processes, especially during melting and pouring operations in ferrous foundries. Iron oxide is the major fume generated in iron and steel operation. "Metal fume fever", results from exposure to these contaminants. This is an acute illness of short duration which commences some hours after inhalation of the metallic fumes. The symptoms include muscular pain, dry throat, coughing, headache and nausea chills and sweating may occur later. In our study also workers complain about this fever, but they mentioned only warm body, muscular pain, irritation in throat and coughing.
In the foundry environment risk of physical injury is distinct. Serious burns may result from splashes of molten metal in the melting and pouring areas. Importance of flame retarded fabrics and protective clothing for foundry workers was reported by Mischutin et al., (1985).

In industrial environment, the workers are exposed to various physical and social conditions which have been found to affect their health and efficiency. Investigators in the field of ergonomics and occupational health have centered their attention in studying the effect of different individual factors as well as the effects of different combination of factors such as work environment, level of physical and mental fitness, age, sex, training, nutrition, work load, nature of manufacturing processes etc. It is well established from a number of experimental studies (Brouha, 1960), that when work is performed the displacement of physiological and psychological functions from resting level to a higher working level requires additional energy expenditure. The subjects of present study are found to be engaged in this type of work for 8-10 hours a day and for 25 years. Because of poor level of education and backward socio-economic conditions, the foundry workers accept the available working condition as given to them. They have no choice but they have to remain contented with what they have.

Concentration of silica dust and metal dust, fumes, dangerous noise and radiant heat are encountered in foundry. The respiratory impairments, high level of blood pressures, visual defects and several non auditory effects such as interference with communication, disturbance, stress, annoyance etc. are found to affect the performance. For identifying the adverse effects of occupational hazards due to workplace environmental factors, International Labor
Organization has adopted the conventions, concerning the protection of industrial workers against occupational hazards in the working environment. Foundries are unorganized and running without research, research is carried out with only mechanical point of view in order to increase productivity. The working conditions and work environment is extremely adverse and it is difficult to maintain optimum level of health status.

The human body can perform many awkward and unnatural movements for a limited time, but continuing these for prolonged periods may exceed the workers physiologic limitations. Now days it is recognized that many injuries are result of the cumulative stress of repetitive lifts of heavy or bulky objects, where twisting is involved so lifts can be adjusted to make it less stressful.

In foundry industry workers are lifting and carrying maximum load manually. In core shop workers are stoving cores, for that frequent lifting and carrying the heavy core box is carried out. In moulding section also workers are lifting and carrying the mould boxes and ladles. In fettling shop also lifting and carrying of castings for finishing purpose takes place.

When lifting and carrying loads, working efficiency and the prevention of damage to the spine should both be considered. As well known spine curves like an inverted ‘S’. For reasons at present unknown occupational disease of the outer part of the inter vertebral discs frequently occurs. A sudden lift of heavy load can cause the rupture of the tissue so inter vertebral disc burst and press on the spinal cord or on the nerves leaving it. Due to that pain and paralysis and muscular disorders like stiff necks, lumbago, sciatica etc. are observed. These occupational diseases are common in the 20-30 age groups. The workers in
certain occupations like heavy manual work, agriculture dock workers etc. suffer from disc.

It has been observed that, though in the working environment of foundry, radiant heat is present, but workers do not show increase in body temperature. Due to heavy work load workers sweat profusely hence the body temperature at surface declines and there is no significant increase in the central body temperature of workers. Excessive sweating indicates that there is stress on thermoregulatory systems of body.

For industrial operations, measurement of pulse rate is the most direct simple method available for evaluating stress of job on body of workers Narayane (1986). Due to daily hard work, pulse rate and blood pressure values are not much affected. But according to work exposure, heat stress, high concentration of dust, intensity of work as well as duration of work and intensity of noise, the cardiovascular responses are affected. The cardiovascular responses well correlate with the age of workers and exposure to working environment.

Pulse rate responses of individual workers in a group are different. A number of workers indicated a steady state of pulse rate and recovery time is shorter indicating good physical fitness. The postural strain is another important factor of physical strain on foundry workers, leading to low back pain, pain in joints and in some workers even vertebral dislocation (Sawant and More, 2003).

The work load in the foundry industry is higher. A significant observation for the physiological responses like heart rate, blood pressure (diastolic and systolic) and body temperature of worker is that heart rate comes to normal level quickly; but blood pressure shows increase according to work exposure. Body
temperature was found to be normal. It was due to acclimatization to specific working conditions.

A study of lung function shows that there is significant decrease in peak expiratory flow rate, vital capacities, forced vital capacities, total lung volumes and forced expiratory volumes in one second, during work. The FEV$_1$ values of workers indicates acute ventilatory impairment of workers (More and Sawant, 2003).

Respiratory illness and other intermediate type of respiratory illness, due to occupational environment among foundry workers has been reported in coal mining, quarrying, foundry, metallurgy and refractory brick industries. Dust problem in silica refractories, which leads to lung abnormalities was reported by Nair et al., (1988). The study of lung cancer mortality among iron foundry workers was carried out by S. Tola (1979) and also by R. S. Koskela et al., (1989). Concentration of silica dust in agate grinding units was reported by Ghodasara et al., (1997). Silicosis in sand blasting section under primitive conditions in foundries in Turkey was reported by Cimrin et al., (2003). Workers are not aware about the occupational hazards pay little attention towards the personal hygiene and health care. Indian study related to silica dust exposure and incidence of silicosis in unorganized factories was reported by various research scientists such as in stone cutters and grinders by Sikand and Parmara (1949), in foundry operations by Pandya et al., (1977), in ceramic industry by Ghodasara (1984), in quartz crushing industry by NIOSH (1986). No specific study to the health hazards in foundry industry except the preliminary medical survey has been carried out in India. Hence, comprehensive environmental monitoring was carried out to assess the dust exposure risk.
Respiratory illness observed in the foundry workers is due to dust particles of silica, coal and metal, which can freely fly in the foundry work environment. Dust particles less than 7µ size are respirable, that is it can enter into the lungs, while the dust particles more than 7µ are known as inspirable, that is it can not enter the lungs. Nature has provided an efficient filter mechanism for the dust particles that enter the human body. All particles greater than 7µ size (inspirable dust) are likely to be trapped either in the nose or high in the throat, while the particles smaller than 7µ size (respirable dust) enter the trachea and lungs. Due to presence of respirable silica dust in the workplace environment, it becomes significant source of adverse physiological impact on the exposed individuals.

Foundry workers are found to develop pulmonary fibrosis and typical silicosis. Silicosis is a chronic fibrotic disease of lungs resulting from prolonged and intense exposure to free crystalline silica. Chronic silicosis occurs with moderate exposure and lesions are usually nodular and tend to be more prominent in the upper lobes, these nodules lead to pulmonary impairment. Silicosis may be complicated by the formation of massive fibrotic lesions, usually in the upper lobes. Acute silicosis is a rare form of silicosis occurring in individuals with heavy exposure to dust, with very high concentrations of silica. The disease usually develops over a period of 1 to 3 years and progresses rapidly leading to death from respiratory failure. It was also observed that mortality rate in foundry environment was higher. It was shown by S. Tola et al. (1979) that there is an increased risk of lung cancer among foundry workers. The study showed lung cancer is common cause of death among workers, engaged in foundry work environment. Not only the cancer of lung but also cancer of trachea and cancer of larynx were recorded.
Foundry environment contains polycyclic aromatic hydrocarbons, some of them are reported as having carcinogenic effect.

The physiological responses of workers are found to change due to different occupational stresses like noise, light, and heat, variety of fumes and concentration of dust in foundry unit. The questionnaire study shows that occupational stresses are prevalent among foundry workers. It is observed that majority of workers complain about lower back pain, pain in joints, chest pain, watering of eyes, irritation in nose, problems in hearing and warm body. In all probabilities these complains are mainly due to intensity of heavy workload as well as due to environmental stress factors.

In the study the hematological parameters of fifty foundry workers exposed to silica dust have been assessed. These include haemoglobin and differential leukocyte count. Most of the workers have haemoglobin levels above 10.0 g/dl (the minimum normal value of haemoglobin taken in Indian epidemiological studies).

A significant observation in the previous study it was that in foundry industry, only in fettling shop, significant changes in the WBCs were observed. Neutrophil count in fettling shop was decreased, but in other sections neutrophil count remained normal.

These observations are similar to the animal model used for the study of noise stress by Sembalingam et al., (1998). In fettling shop noise level was higher (102-105 dB) and metal dust and silica dust was also observed in this section. In fettling shop the behaviour of other WBCs was typical i.e. eosinophil and basophil number was found to be increased while in other sections values of
eosinophil and basophil were normal. Lymphocytes and monocytes showed negligible change in various other sections of foundry.

In foundry noise is generated due to grinding, fettling, shot blasting and while blowing the furnace i.e. fettling shop and in furnace section, production of high intensity noise takes place so workers in these sections are exposed to high level of noise. The threshold limit value is 85 \( \text{db} \) for foundry workers.

The noise level in fettling shop ranges from 102 to 105 dB. The noise level of above 100 dB can cause permanent hearing loss Agarwal (1987). Noise level above 100 dB results in headache tinnitus and temporary deafness; it was reported by Ravichandran et al., (1999). In the present study also workers from fettling shop and furnace section are found to make similar complaints. The health effects due to excessive noise have been well established. Exposure to noise of sufficient intensity for long period of time can produce detrimental changes in the inner ear and seriously decreases the ability to hear. Severe exposure to noise may cause structural damage that leads to rapid breakdown of the processes necessary to maintain the life of the cells of the organ of corti. Such injury is called as acoustic trauma. A standard was proposed to highlight the exposure of noise levels to which workers were subjected. The Williams-Steiger Act, known as Occupational Safety and Health Act (OSHA) of 1970, clearly shows that for sound level 102-105 dB the exposure limit is 1.5 to 1 hours only but workers working in fettling shop are exposed for 8 hours per day. Noise level in the office ranges about 57 to 60 \( \text{db} \), so it does not make any harm to office persons.

Light is an important environmental factor, about 80% impressions are carried through gate way of vision. During foundry processes, appropriate light
intensity is essential. It has been observed that due to inadequate illumination there was poor coordination of eyes and hands with brain, irritation and watering of eyes makes the situation more complicated and worker complaints about visual strain.

Section 17 of Factories Act suggests that minimum intensity of illumination for workplace should ranges from 1000 to 2000 Lux. It has been observed that intensity of light is inadequate in sand plant and moulding section. Illumination levels at different sections in foundry ranges from 190 lux to 1000 lux i.e. in the office 1000 lux while in the sand plant 190 lux, in core shop 510 lux, in moulding section 230 lux in the furnace section 750 lux, and in fettling section 560 lux. Poor illumination level in sand plant and moulding section affects the working capacity leading to visual fatigue.

Heat stress is another important environmental stress factor which affects the health status of workers. It was observed that environmental conditions in foundry are too hot, near the core furnace and cupolas furnace, the physiological responses of workers in foundry are mostly affected due to climatic heat and artificial thermal stress in various sections of foundry environment.

Cardiovascular responses i.e. pulse rate and systolic blood pressure as well as diastolic blood pressure, when observed, pulse rate does not show significant change but the blood pressure shows higher values due to heat stress.

The body temperature remains normal due to heat acclimatization. Acute heat stress can also lead to dehydration and loss of electrolytes, which was reported by Bandopadhyay et al., (1989). Hot environment increases oxygen
consumption (Vo$_2$) pulmonary ventilation and decreases work performance, as reported by Gupta et al., (1981).

Alterations in the white blood cells count and in the relative proportions of the various white blood cells have been recognized as measures of the physiological reactions of the body to noxious agents. In many instances, these alterations give useful indications of the nature of the pathological process.

Main functions of the WBCs are accomplished in the tissues and that, these cells in the blood, evenly normal persons, are in transit from the site of production, or storage, to the tissues. From this, it is evident that variations in the blood concentration of each white blood cell can result from changes in the flow of cells into the blood, the egress of cells from the blood, the distribution of cells within the vascular compartment, or due to the combinations thereof. Furthermore, these changes may be of short duration and thus, easily missed or they may persist for days or weeks. Quantitative measurement of such changes in the distribution and in the inflow and egress rates has been possible only in recent years.

Earlier studies conducted on the foundry workers indicates, very poor physical fitness, increased heart rate, increased blood press are according to increased exposure period, decreased peak expiratory flow rate decreased total lung capacity and acute ventilatory impairments, Sawant and More (2003) similar results as well as other intermediate type of respiratory illness related to occupational exposure in foundry environment have been reported by Tanaka et, al; (1960), Johnson et, al; (1985), Low et, al; (1985), Rao et, al; (2010), Kakooeil et, al; (2004), Gomes J. et, al; (2001), Koo J. W. et, al; (2000) Mendonca E. M.C. et, al; (2006).
One of the significant observation noticed regarding foundry workers is that as the work in foundry environment is also responsible for development of systemic sclerosis in several foundry workers. During physical examination of palm of foundry workers from core shop. It was noticed that there are white spots on the palm and particularly on finger tips and claw like flexion. [Plate II ] Similar results have been observed by McCormick Z. D. et al., (2010). He demonstrated that occupational silica exposure is risk factor for scleroderma (Systemic sclerosis). In the foundry environment dust contains silica particles, metal dust, coal dust and other toxic fumes.

Occupational exposure to silica occurs in a large number of industries and settings, such as mines, stone quarries and granite production, ceramic and pottery industries, foundries and many other. At least 1.7 million U.S. workers are exposed to reparable crystalline silica in a variety of industries and occupations (NIOSH 2009). There are other diseases that may be associated with occupational crystalline silica exposure such as autoimmune diseases, including rheumatoid arthritis, systemic lupus erythematosus and scleroderma.

Scleroderma or systemic sclerosis is a multisystem disease characterized by tissue thickening and fibrosis often with involvement of internal organs.

Hand involvement is often the first clinical manifestation of systemic sclerosis. In this disease chronic inflammation observed which is characterized by widespread micro vascular damage and excessive deposition of collagen in the skin and internal organs. Among potential risk factors for systemic sclerosis, occupational exposures of silica have received very little attention. Generally lesions start at ventral side of the palms at certain locations.
Particularly more significantly on the finger tips. Calcification occurs at these locations in the pulps of fingers. Involvement of skin on the palm consists of dermal thickening through the process of fibrous replacement of normal dermal structures. This thickening extends in to subcutis and gradually increases rigidity of the skin with tightening and atrophy of the overlying epidermis and fingers become hard, rigid, reddish and shiny.

Laboratory animals have been used for studies in toxicology, microbiology, nutrition, immunology etc. In experimental medicines certain physiological and psychological processes in human can be studied using models, but hypothesis about abnormality and spread of disease in human body can not be tested directly. Therefore, animal models are required for the study of both physiological processes and evaluation of toxicity. The WHO has also recommended that toxicological and biochemical studies should be carried out in animals prior to use of drugs and chemicals in human body. The rat is ideal species for toxicological studies. Much information is known about its physiology, anatomy, genetics, and behavior. So meaningful results were obtained in rats which can be predictive to human beings.

Male albino rats (*Rattus norvegicus*) have been exposed to different sections of foundry and physiological reactions on exposure with various time intervals to this environment. To correlate and conform the adverse effects of work place environment in foundries and find out the etiological agent (s) if any. It has been found that in the foundry environment excess heat, noise, vibrations, illumination and foundry dust containing silica, metal dust and coal dust was present, More and Sawant (2003).
In the present investigation priority has been given to the physiological studies and responses of animal model, albino rats (*R. norvegicus*) on exposure to different sections in the foundry environment for various time intervals.

The study of physiological responses of the animal model have mainly focused on toxic stress of foundry dust as well as other stressors prevailing in foundry environment on the behavior, hematologic parameters, serologic parameters on various organ systems including trachea, lungs, liver, kidney and adrenal gland. The multifactorial mode of alterations in the physiological status of the rats on exposure to foundry environmental toxic stress is studied.

In the present study both experimental as well as clinical methods have been employed to record to the adverse effects of work place environment. In the present investigation, it has been observed that the rats exhibited several behavioral changes and responses which includes defecation, urination, scrubbing of nose, scratching of fur sneezing, high activity, tiredness, deep breathing sitting in wet areas, entire face wetting infrequent hiccups, frequent piloerection, (hairs become erected) finally motionless and sleepy posture after 30-50 minutes. Piloerection has been seen during exposure and post exposure. Plate No. III illustrates the physiological responses and behavioral changes observed as well as studied by introducing the rats in the Animal Activity Monitor. All these responses and behavioral changes are the result of exposure of rats in the adverse working environment of foundry.

There is slight decrease in the body weight of exposed rats. This decrease in body weight of rats immediately after post exposure maybe due to excess heat, dehydration desiccation as animals consume scarce food and water.
It has already been observed that the foundry dust not only contains silica but also metal dust, coal dust, toxic elements and toxic fumes.

The external morphological and internal anatomical changes as well as microscopic observations show various changes in the organs. Trachea, kidneys, adrenals are moderately enlarged, as well as lungs shows nodular changes on the surface.

These changes indicate increased physiological demand and activation of stress response under and influence of the toxic foundry stresses.

The blood comprising the plasma and the formed elements are of crucial importance for maintenance of internal functions within the body any alteration with respect to their biochemical composition, structural integrity and their internal constituents can occur under pathological condition.

Studies of the hematological parameters of rats and exposure to foundry environment indicate that the complete blood count (CBC) profile shows significant alterations in all the formed elements of blood. The RBC count was increased in all the sections except 24 hours exposure in core shop (S-5). The haemoglobin level was also increased except 24 hours exposure in core shop and furnace section (S-4). The PCV, MCV, MCH and MCHC values were increased as compared to normal. The WBC count shows fluctuations it decreases initially in sand plant, moulding section, and core shop and then showed elevation in all the sections except core shop.

The differential cell count indicates an increase in neutrophil percentage after initial decline. The eosinophil percentage has also seen to increase than
normal value. The monocyte percent value was initially increased and as period of exposure increases these values are decreased.

The neutrophil shows ring formation of nucleus and also hyper segment nuclear forms. There is significant decrease in total platelets count in experimental animal than control.

A significant increase in total RBCs and haemoglobin concentration may because of release of erythropoietin which stimulates the bone marrow and spleen to release more erythrocytes in blood circulation. Similar observation in RBC count, hemoglobin concentration in albino rat has been observed after sub lethal electroduction, Mitra and Dash (1991).

The total platelets count was significantly decreased in the present study. This decrease may be due to the effect of adverse foundry environment on immunological set of animal body. This is possible suggestion. Exact underline mechanism for this decrease in platelet count needs to be further investigation.

Similar alternations in certain immunological and hematological parameters in abinorats due to acute heat stress have also been recorded by Joseph et al., (1991).

In the present investigation it has been observed that the values of total WBCs count in blood of rat on exposure to foundry dust was found to be decreased up to 16 hours exposure and after that found to be elevated. The polymorphonuclear leukocyte in blood smear of rat was also elevated after 16 hours exposure.

Hogg and Doevschuk (1995) observed significant migration of PMNs from the vascular space in to the lung tissues with macrophages required to
clear foreign materials. The current concept PMNs endothelial interaction have been dominated by studies shows that leukocyte first gathered to endothelium of capillary by transient adhesion that mediated by members of selectine proteins.

Three families of molecules mediate leukocyte endothelial cell adhesion i.e. immunoglobulin selectins and interleukin-1, so large number of PMNs adhered to endothelium of capillary from blood stream and their number found to be decreased.

The leukocyte migration also occurs in response to stimuli that arise in air space, which gives rise to bronchitis, bronchiolitis, and inflammation of alveolar tissue. The factors determining which neutrophils migrate and whether the migrating neutrophils represent a defined subset of neutrophil population are present in the circulation remains to be determined Plate No. V.

Microscopic observations in nasal lavage smear of rat exposed to foundry environment reveals, shedding of nasal epithelial cells, large amount of mucus, and after 24 hours exposure heavy exfoliation of epithelial cells, cellular debris and more significantly pyknosis of nuclei with particularly irregularity of nuclear outline as compared with that of control.

Garciduenas et al., (1994) demonstrated that human nasal mucosal changes after exposure to urban pollution exhibit large amount of cellular debris, epithelial cells with pyknotic nuclei, cell ghosts after 42 hrs. exposure.

In our study, the changes in nasal lavage smear observed may be mostly because of higher concentrations of fly dust, which mixture of silica, coal and metal particles.
The bronchoalveolar lavage smear of experimental rats reveals that there is marked infiltration of polymorphonuclear leukocytes, increase in number of macrophages and epithelial shedding (Plate VI). Similar results were also observed in guinea pigs exposed to zinc oxide, Conner et al., (1988). Zhongyi Z, et, al; (2001). Also studied the effects of carbon fiber and carbon fiber composite dusts on bronchoalveolar lavage component of rats and observed similar results.

In present investigation, it has been noted that, there is marked increase in megakaryoblast cells and megakanyocytes (Plate IV) cellular debris and polymovphonulcar leukocyte number also increased which correlates with period of exposure to foundry dust in rat. Similar observation showed in Guinea pigs after combined exposure to cigarette smoke and industrial dust, Rylander (1979).

Inhalation of dust alters the morphometric and histopathologic structure of proximal and distal airways. The changes in the organ system occur because of effects of foundry dust particles.

It has been demonstrated that, thickening of mucosa, thickening of cartilage, peritracheal edema, fibrosis below mucus layer and in some areas of hyaline cartilage observed in rat on exposure in the different sections of foundry.

Using morphometric approaches, increase in thickness of tracheal wall, bronchi, particularly in mucus gland hypertrophy, hyaline cartilage and musculature of upper respiratory tract also observed Plate No. VII.

Histopathological observations of lung of rat exposed to foundry environment shows that, thickening of alveolar wall, thickening of mucosa in bronchiole, thickening of wall of blood vessels, alveolar congestion peribronchial
edema, and inflammatory cells was more surrounding the blood vessels and fibrosis between bronchial wall Plate No.VIIIA and B.

Takayoshi K et, al; (2007) observed effect of particle size of intratracheally instilled crystalline silica on pulmonary inflammation, which causes changes in blood, bronchoalveolar lavage fluid and pulmonary tissues we have also observed similar changes in experimental animals exposed to foundry environment.

Yasho M.et al., (2005) was documented expression of clara cell secretary protein in the lungs of rats exposed to crystalline silica in vivo he showed that haw clara cell secretion protein plays role in regulating the acute inflammatory response in the lung. Hiroko N et al., (2006), observed expression of hem oxygenase-1 in the lungs of rats exposed to crystalline silica, the levels of Ho-1 were increased following intratracheal instillation of crystalline silica, which increases alveolar macrophages, which indicates Ho-1 is related to lung injury.

Kodavanti et al., (1998) find extensive edema, thickening of inter alveolar septum and wall of blood vessel which results in pulmonary hypertension after inhalation of Monocrotaline (MCT) and Residual oil fly Ash (ROFA) and on chronic exposure to MCT and ROFA which results in cardiopulmonary impairments.

In present study, pulmonary edema, RBCs, congestion, patchy fibrosis in alveolar wall, alveolar congestion observation was that the wall of blood vessel shows thickening and reduction lumen of blood vessel (Plate VIII A and VIII B ). This may result in cardiopulmonary impairments. These changes may be responsible for migrations of PMNs from blood stream to lung tissue.
Exposure to environmental stress factors can accentuate the risk of liver damage and lead to hepatocellular injury known as environmental hepatotoxicity. In the process of detoxification, some changes occur in the components of liver, most of the hepatotoxins enter through respiratory mucosa and via blood reach to liver. The hepatotoxicity may be accompanied by damage to other tissues like skin, lungs, bone marrow and immune system and such hepatotoxicity shows reflection in liver function tests.

The liver function test in the present investigation indicates that significant alterations occur in bilirubin level, serum proteins level and significant alterations in alkaline phosphatase in blood of rat on exposure to foundry environment. Sood (1990), showed that level of bilirubin were found be increased in excessive red cell hemolysis, hepatocellular injuries, bile duct injury and also may be due to less intake of food during exposure and environmental stress.

Geubel et al., (1991) observed that, drug induced hepatic fibrosis and cirrhosis results in alteration of liver function test, i.e. elevation of AST, ALT, Bilirubin and ALP and in advanced cases serum hypoalbuminemia and hyperglobulinaemia.

Lieberman et al., (1999) demonstrated the level of bilirubin also elevated in inflammatory lesions of lung and liver necrosis in mice after intraperitoneal injection of cyclosilohexane.

Ogunbileje J.O. et, al; (2010) demonstrated that immunoglobulin classes (IgG, IgA, IgM and IgE) and Liver Function Tests in Nigerian cement factory workers shows higher level of IgG, and IgE and elevated alkaline phosphate and bilirubin levels which may suggest hepatotoxic effect of foundry dust in our study.
An alteration in the composition of serum proteins occurs in various physiological and pathological states. Analysis of relative distribution of serum protein fraction gives valuable information in hepatitis, nephrosis and other conditions such as exposure to environmental stresses. Studies on serum protein pattern has grown most rapidly in the field of occupational medicine because of evidence of many toxic compounds serum proteins and gamma globulin abnormalities observed mostly in liver insufficiency and by toxic substances at low dosage levels.

It has been found observed that, the level of total proteins, albumin and globulin was found to be altered in rats on exposure to foundry dust. Among total proteins, serum albumin level found to be decreased in most of the sections while the level of globulin slightly elevated up to 24 hours exposure to foundry dust.

Gardiner et al., (1979), observed that total lung proteins found to be increased in rat after injection of paraquate dichloride.

The serum enzyme analysis widely used for the diagnosis and confirmation of clinically suspected disease of varying etiology, embracing disorders of the liver, the hepatobiliary system, the heart, the kidney, the liver, the muscle and other organs. The most common response to pathophysiological condition consists of elevation of serum enzyme values. The cause of such increase usually due to efflux of enzymes from damaged organs in to the circulation.

The level of serum alkaline phosphatase in experimental rat was found to be increased on foundry dust exposure, such concentration at alkaline
phosphatase increased in liver lesions, osteoblastic activity, osteomalacia, healing fractures, granuloma, abscess observed by Henry (1991).

Shevehenko et al., (1992) also demonstrated that, the level of alkaline phosphatase significantly increased in serum with chronic poisoning by dust from mineral wool made of ferronickel slag.

The liver function tests shows significant alteration on short term exposed rats to foundry environment; further studies will be needed to address the explanation of mechanism of toxic stress of foundry dust on long term exposure.

In present investigation the level of CPK and CKMB were found to be significantly increased on exposure to foundry dust in foundry environment.

Qamar Rahman et al., (2001) observed development of chronic obstructive pulmonary disease and cardiopulmonary impairment on chronic exposure to fumes and dust in workplace of isocynates, heavy metals and mining activities.

The level of CPK and CKMB in serum significantly increased in myocardial infractions, neurologic, muscular dystrophy, excessive exercise and pulmonary impairments.

Kodavanti et al., (1998) found that in brown Norway rat, the cardiopulmonary diseases typically are diseases that involve heart, lung and also their respective vasculature. Any loss of vascular integrity may results in organ dysfunction. The pulmonary vascular dysfunction have relationship with the cardiac impairment as the entire cardiac output must be pumped through the pulmonary vasculature, chronic pulmonary impairment frequently involves pulmonary hypertension and right ventricular hypertrophy which when advanced
indirectly alter left ventricular function. Each of these conditions may sensitize the lung of heart to the effects of inhaled toxicant.

In the present investigation, it has been demonstrated that level of serum enzymes shows significant alterations in the SGOT, SGPT and serum proteins. The SGOT and SGPT values shows increase to highly significant values indicating 2-3 fold increase from the control value. The level of serum transaminases were elevated in inflammatory lesions of liver and liver cell necrosis after interaperitonal injection of cyclosilohexane, Liebraman et al., (1999). Increase in SGPT and SGOT, in albino rats, due to induced stress was reported by Nagaraja et al., (1999). Increase in SGPT and SGOT are better marker for hepatic functional status as they indicate parenchymal liver damage also result of cortisol induced gluconeogenesis in liver under stress conditions, Rosen et al., (1958).

Gubel et al., (1991) have observed drug induced hepatic fibrosis and cirrhosis results in elevation on SGOT and SGPT and in advanced cases serum hypoalbuminemia and hyperglobulinaemia.

In the present study, the liver structure and function of rat shows significant alterations due to exposure to foundry environment. The liver histopathologic picture shows focal hypoxic necrosis, mitosis of hepatocytes in perillobular region with few multinucleated giant cells and entire liver lobule shows multinucleated giant cells, ground glass hepatocytes, vacuolated giant cells, ground glass hepatocytes, vacuolated cytoplasm, ghost of anuclear cells, typical eosinophilic bodies, eosinophilic changes in cytoplasm, and necrotic cells with nuclear pykinosis. Also haemosiderin in the hepatocytes at the periphery of liver lobule Plate No.IX.
Significant changes were also observed in adrenal gland and kidney. There was increase in the size of the gland, it may be due adrenal hyperplasia and hypertrophy. Stress induces adreno medullar response in man (Wortman et al., 1984). Adrenaline in turn stimulates $\beta_2$ receptors on the pituitary gland causing greater release of ACTH (Reisine et al., 1983). The experimental data of present study indicated that industrial stresses in foundry induce hyperplasia and hypertrophy of adrenal cortex Plate No.XI. These alterations could be due to excessive secretion of ACTH. Sound stress induces hypothalamo pituitary axis and sympathetic system stimulation, resulting in liberation of catecholamines and adrenocorticoids (Gehlot et al., 1997). Lesion observed in zona fasciculata region might be due to overactivity of this region with increased exposure period there was increased damage of cortical cells. Medullary cells hypertrophid, in order to secrete more and more epinephrine and norepinephrin. Localized hemorrhage might be due to increased blood pressure. Epinephrin increases the pulse rate and cardiac output and thus the systolic blood pressure. (Labhart, 1974).

Kidney sections showed swelling and flattening of tubular epithelium it could be due to increased load of reabsorption and tubular epithelium under the influence of aldosteron Plate NO. X. Various stresses might be causing hyper functioning of adrenal cortex (Kventnansky, Richard 1973, Kirillov et al., 1971). Accumulation of edematous fluid might be due to increased salt and water retention, under the control of ADH and Aldosteron. In heat stress there is increased secretion of ADH (Marya et al., 1988).

Thus the present investigation reports significant alterations in motor activity behavior of PMNs, structural alterations in trachea, lung liver, kidney,
adrenal gland, hematological parameters including profile of serum proteins, serum enzymes and liver function tests, indicating severe stress and pathophysiologic changes. The structural and functional integrity of the above said parameters/ organs has been significantly compromised at the expense of the exposure inside the hazardous foundry environment. These changes must be the synergistic effect of foundry dust and other stresses like heat, noise, vibrations, toxic fumes, gases metal dust, coal dust etc. prevailing in the workplace.

Complementing the human studies, animal research has also shown that responses to various aversive physical stimuli may have pronounced effects on the immune status.

Environmental stimuli can induce changes that can have tremendous effects on the physiology of the organism and hence, have severe impact on the immunologic function. It is significant to note that the rats do not show any reversibility in the damage. Undergone by the respective organs even with recovery periods post exposure. Physiologically it is unclear whether these extra pulmonary responses are triggered by the response of lung, or whether these repairable particles in foundry environment may become extra pulmonary to directly exert the effect. An Unitrin approach is suggested were by the tropic activity of the immune cells outside their known function can be studied to understand the basic mechanism regarding the damage.

The present study indicates the severity of the pathophysiologic changes occurring under the influence of occupational stress in the albino rats, on exposure in the foundry environment. Since the albino rats are small mammals the rapidity and extent of pathologic findings are more pronounced in
comparison with that of human, nevertheless the finding propose the multifactorial mode of disease causation and or the involvement of the immune system as the possible factor for alterations in the various organs systems and the use of unitarian approach to study them.

The animal model rat will be instrumental in finding on the susceptibility as well as suitability of animal models of occupational disease for providing basic information regarding the mechanism of disease induction, with conservative interpretation of data and provide toxicologists with another tool to investigate occupational diseases.
RECOMMENDATIONS:

The workplace environment and the working conditions in the foundry were quite adverse. It was difficult to maintain optimum level of health status of these workers. Excess ventilation, high concentration of dust, inadequate light, and high intensity of noise was some of the important stress factors faced by the foundry workers. Physical work strain also adds to the severity.

Based on the observations it is recommended that the foundry workers are advised to use mask to avoid inhalation of foundry dust. Where radiant heat is excessive, near the furnaces special goggles, screens and protective clothing must be provided. They should be advised to drink cool water frequently to replace sweat loss. This would help to reduce heat stress. Heat proof and flame retarded clothing should be used by the workers, working near the furnace. Workers in the fettling section should be provided with earplugs, earmuffs and protective goggles. Arrangements should be made to increase the air velocity in the workplace, which will be much beneficial to the workers to reduce the physiological strain due to heat.

Similarly work rest cycles are introduced, which will be much beneficial to reduce the fatigue among workers. Due to frequent lifting and carrying in furnace section, sand plant, fettling section and in core shop worker shows musculoskeletal stress. To reduce this stress workers are advised to reduce time spent on lifting, carrying and putting down loads. By preventing use of these workers in difficult tasks involved in the manual transport of loads. For heavy loads mechanization will be beneficial to protect spine damage of workers. To prevent workers from back injuries, proper training and correct kinetic techniques in lifting and carrying have been recommended. To prevent excessive back stress following principles should be adopted.
I. Before lifting removing all obstacles.

II. The maximum height for gripping the load should be 40cm above the floor.

III. Where the load has to be lifted from floor level, mechanical aids (hooks or pulleys) are advisable.

IV. The load to be lifted should be kept as near as possible to the body.

V. The back should be held straight with a rounded back the danger of “slipped discs” is much greater.

VI. Initially the knees should be bent and the trunk kept as up right as possible, with the back straight.

The periodic health monitoring is very much essential for the comfort and maintenance of health of foundry workers, which will help to increase the productivity rate.

CONCLUSION:

While concluding the present treaties on the physiological studies of rats exposed to foundry dust it should be mentioned that practically all the objectives with which the present investigation was taken up have been satisfactorily fulfilled. Thus, the present thesis describes in detail the physiological reaction of rat due to the exposure to foundry environment. Modern physiological and clinical techniques have been employed for the elucidation of the alterations in the structure and functions of some of the vitally important organ systems. Not only the present investigation gives reliable information on the physiological responses of man and experimental animals exposed to foundry environment but also give information regarding suitability of animal models for comparison and prediction of occupational health hazards in foundry environment. Such a
comparisons, predications and resultant similarities and differences have been only commented upon and interpreted in the last chapter of general discussion.

In India large numbers of foundries of all types are present. Totally 5000 foundry units are present in India. More than 95% of them are in small sectors, with wide variation in sizes, products, technology standards and work culture. In India of all foundry units having an installed capacity of approximately 7.5 million tons per annum amongst which around 95% of them fall under small scale industry in India is its geographical clustering. Each foundry duster in known for catering to some specific end use markets. Five major clusters in India are at Belgaum, Batala or Jalandhar, Coimbatore, Kolhapur and Rajkot.

India is 6th largest producer of casting in the world after U.S., China, Japan, Russia and Germany. This industry directly employs about 5,00,000 people and indirectly about 1,50,000 people and is labor intensive.

The various types of castings which are produced are ferrous, nonferrous, Aluminum Alloy, steel, Cast iron etc for application in Automobiles, Railways, Pumps, Compressors and valves, Diesel engines, Cement/ Electrical/ Textile Machinery, Aero and Sanitary pipes and fittings, etc.

In the foundries, the workers are exposed to host of occupational health hazards and stress factors. Occupational hazards in the foundries are found to arise due to silica dust, metal dust, coal dust, excessive noise, heat, vibrations, light and moving machinery. Thus thousand of workers attend the foundries for 8-10 hours of the day in the hazardous environment.

Thus the occupational health problems, in foundry industry are enormous due to variety of stress factors such as high concentration of silica dust, coal
dust, metal dust, heat, noise vibrations, and inadequate illumination. In many foundries in Kolhapur cupola furnace is used and old machineries produce noise and vibrations. In foundries dust particles (respirable small particles <10µ) produced, during various processes in different sections. These dust particles freely fly in the air. It has already been reported previously from our laboratory that these small respirable dust particles cause serious respiratory impairment in workers. It has been reported by several workers that the foundry workers, due to continued inhalation of silica dust over a period of time, results in a respiratory disease known as silicosis. After large studies on population exposed to silica dust also leads to pneumoconiosis, this disease in caused by combination of silica plus another dust such as iron oxide.

Studies involving rat as an experimental model has offered on important advantage of control over both host and environmental variables of course the results obtained by use of animal model requires careful interpretation for the extrapolation to the human situation. Animal models of human diseases have been used extensively in investigation of disease pathogenesis and potential pharmacology intervention. However, their application in ascertaining altered susceptibility to toxicants has been spotty and has yet to gain popularity. In the present study though the efforts have been made for the development of Rat as an experimental model it is essential to study all the basic physiological responses of the animal in foundry environment and efforts should be made to find out the possible mechanism of occupational and or toxic stress on individual organ systems and / or an animals as a whole leading to occupational diseases.

As it is observed in the present investigation, etiological agent in the form of silica dust and toxic fumes and gases all are major factors responsible for
pulmonary and other reactions leading to impairments in respiratory system. The experimental animal rat used in the present study is found to mimic several physiological responses febrile and pulmonary reactions similar to those foundry workers. It can be seen that there are multiple in-vivo effects of foundry dust in man (Foundry workers) and experimental animals, which may result in occupational health hazards. Development of a workable animal model of occupational disease is essential provocative inhalation challenge studies in persons suffering from occupational disease like silicosis. With careful monitoring of physiological responses of individual organ system of animal model and finding out underlying etiology and pathogenesis would help to answer some of the questions regarding mechanism of silicosis.

Several possible mechanisms may prove to be operative but yet, they remain to be evaluated. Among these are in depth studies of possible cellular and sub cellular effects of pure silica dust. Study of mechanism of release and effect of cell activating factors. Such studies will, however, are only possible when development of well characterized animal model.

Recent trend in the study of occupational physiology concerns with investigation of combined effects of environmental factors. These investigations mostly deal with the exposure of a worker to a complex unfavorable environment. The aggregate effect of these factors is determined by their interaction. But most of the researchers have not studied the physiological mechanism in the combination of factors like noise, heat, vibrations, dust etc. Only the final effect on this or that system or on the individual as whole is studied. Therefore, it will be interesting to study epidemiology of the long term effects of silica dust, toxic fumes, heat, noise and vibrations.
The improvement of hygienic norms on dust, heat, noise, vibrations and toxic fumes as most wide spread stressful factors of occupational environment is necessary for the maintenance on the health status of workers and for creation of the environment for productive and qualitative labour.

India totally produces 6.9 million tons of castings of different types. Foundry technology in India had made significant advancement during last decade. Foundry industry gives direct employment to about 25% of all industrial labour. It is important to note that foundry industry is running without research or innovation of any kind. The working conditions and work environment is extremely adverse and it is very difficult to maintain a high level of health status. It seems that, a sweating toiling human mass, menaced by a grim struggle for existence is in search of an anchor which would help them in escaping the drift of hunger and distress. Thousand of foundry workers enter in the industrial area to fulfill the casting requirement of various industries of the nation at the cost of their health and lives. Hence it is necessary to take genuine measures for their health protection and this will be only possible, if one undertakes the extensive research in foundry industry.

Although much has been learned, several research gaps remain. First more mechanistic information with regard to cellular information and cytokine control is necessary such information is required if effective treatments are to be developed for the treatment of silicosis. For example, the acute reaction to inhalation of inorganic dust is pulmonary inflammation. Would anti-inflammatory drugs be useful or would they inhibit clearance and prolong adverse effects of respiratory impairments? Second information is required concerned chronic responses of animal models to foundry dust inhalation. Do acute reactions
progress to chronic disease? Can progression to chronic disease be inhibited? Are current animal systems useful in modeling chronic occupational disease? The work in these lines is in progress in this laboratory.

In light of present observations in the interest of protection of foundry workers during work possible recommendations have been suggested at the end of discussion. These recommendations should be practiced by the management of the foundries.