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A Review on Effects of Hazards in Foundries to Workers and Environment

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Abstract

The working environment of foundries is hazardous and characterized by multiple simultaneous chemical, physical and mechanical hazards exposure, which would lead to injuries of foundry workers. Health risks from working in the foundry industry include exposure to molten metal fume (foundry fume), heat and spray mists. In addition to these hazards; some foundry workers work with dusts produced by casting sand, fettlings and kiln linings, which contain silica and, when dry, produce silica dust known as respirable crystalline silica (RCS). This paper provides an overview of foundry industry and hazards, health effects and safety measures. It presents the information currently available from different published research works and involves the group of people that can be affected by foundry hazards including foundry workers and nearby workers. It further indicates how the foundry industry contributes to environmental pollution. Through this review, it has been revealed from different studies that hazards in foundries are many and very dangerous both to foundry workers' health and to the environment which eventually affect the wider population.

Keywords: *Foundry, Health hazards, Workers exposure, Metal fumes, Pollution, Solid waste, waste water, Noise.*

1. Introduction

Foundries are integral part of the history of mankind. Foundries have been known for thousands of years [1]. Founding is the simplest of all metallurgical processes and one of the oldest of all industries. Two main procedures are carried out in a foundry: sand moulding and metal casting. The casting process consists basically of pouring liquid metal into a mould containing a socket in the geometry desired for the final part. The processes can be classified by the type of mould and model and by the force or pressure pair used to fill the mould with the liquid metal [2, 3].

This industry is diverse in terms of materials and processes, resulting in occupational exposures to a wide range of hazard substances or workplace activities that could cause diseases, injury, ill health or death [4]. Hazard is anything with the potential to cause harm [5]. It is a danger that includes the whole factors and accompanying occurrences which make harm to the human organism, property or environment. Very dangerous occur to be the disease risks that result from bad working conditions which do not meet the requirements of hygiene and environment [6]. Although many changes have occurred in foundry technology and materials, the basic processes and the associated hazards have remained much the same in many foundries. Some of the most common causes of injury and illness in these industries are: (i) exposure to silica; (ii) exposure to mineral wools and fibres; (iii) contact with hot metal; (iv) fire and explosion (v) extreme temperatures; (vi) non-ionizing and ionizing radiation; (vii) noise and vibration; (viii) inhalable agents; (ix) skin contact with chemicals [2].

In foundries, metals are extracted and produced from ores by various metallurgical processes and processes for moulding, melting and castings etc. are accompanied by evolution of heat, noise, dust fines, fly-ash, oxides of Nitrogen, Sulphur and metals. Particulate matters are generated in large quantities when preparing mould core sands and moulds melting metals, pouring metal, knocking out poured moulds and loading and unloading raw materials. Here metals are given a specific shape by metal castings for various engineering purposes [7]. Gaseous matters like gases, vapours, fumes and smoke are produced during melting and pouring operations. The major pollutants are emitted from various work areas in Foundry i.e. Pattern shop, Sand preparation, moulding and core making, mould drying and ladle heating, cupola, electric arc furnace, pouring and mould cooling, knockout, fettling, heat treatment etc. [7].

Many people are exposed to common air pollutants in their occupations e.g. smoke, dust, suspended particulate matters (SPM), respirable suspended particulate matters (RSPM), carbon monoxide, sulphur dioxide, oxides of nitrogen (NO_x), hydrocarbons, and heavy metals like Pb, Cd, Cr, As, Ni, Zn etc. Their prolonged exposure causes various health hazards. Heavy metals cause acute and chronic poisoning. The term "heavy metals" refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration [8]. Some disastrous episodes have focused attention upon air pollution as a health hazard [7].

Climate changes have a negative influence on water and food production but, on the other hand, they are necessary for human existence. Sustainable development is the basic approach to the environment in modern times. Energy consumption and environmental issues with climate changes are global problems, and industry influencing it is the foundry industry [4, 9]. The foundry industry can negatively impact the environment through its use of thermal processes and mineral additives. Managing its environmental footprint is therefore related mainly to acid gases and the recycling of mineral waste [4]. There are relatively permanent earth atmosphere components: O_2, N_2, CO_2, H_2O and other gases. However, emissions of pollutants of anthropogenic origin may drastically change proportions at the local and global level [4, 9]. The climate changes influence the food production, water quality, and pollution and it is necessary to develop an adequate strategy for protection [9].

2. Foundry Industry

Foundries melt ferrous and non-ferrous metals and alloys and reshape them into products at or near their finished shape through the pouring and solidification of the molten metal or alloy into a mould. The foundry industry is a differentiated and diverse industry. It consists of a wide range of installations, from small to very large; each with a combination of technologies and unit operations selected to suit the input, size of series and types of product produced in the specific installation. The organisation within the sector is based on the type of metal input, with the main distinction being made between ferrous and non-ferrous foundries. The casting of metal is an ancient activity, dating back to more than 3000 BC [10].

Steel industry plays an important role in the industrialization and development of a country, as it has the input within all manufacturing sectors. However, one of the most important problems encountered in steel foundries throughout the world is the management of the dusts produced during melting [11]. Ferrous metals foundries require metal of controlled composition and temperature, supplied at a rate sufficient to match the varying demands of the moulding line. The metallic charge to be melted consists usually of foundry returns, iron scraps, steel scraps and pig iron with alloying additions such as ferrosilicon [12].

The castings of metals and alloys of copper, zinc, tin, aluminium, lead etc. come under the group of non-ferrous castings. Some of the prominent alloy castings are Brass, Bronze, Aluminium Bronze, Gun Metal etc. These castings are used for various purposes like bearing, bushes, automobile parts, textile parts, corrosion resistance parts, marine parts, impellers, clamps and connectors, over-head conductors etc. [13]. Non-ferrous castings are fast consuming items and the area of application for these items are vast. Due to certain inherent advantages of mechanical and chemical properties, the use of non-ferrous castings is increasing day by day. The consumption of these items is by Automobile Industries, machine manufacturing industries, textile industries, electrical industries and so on [13]. Fig. 1 presents a general foundry process fluxogram [10].

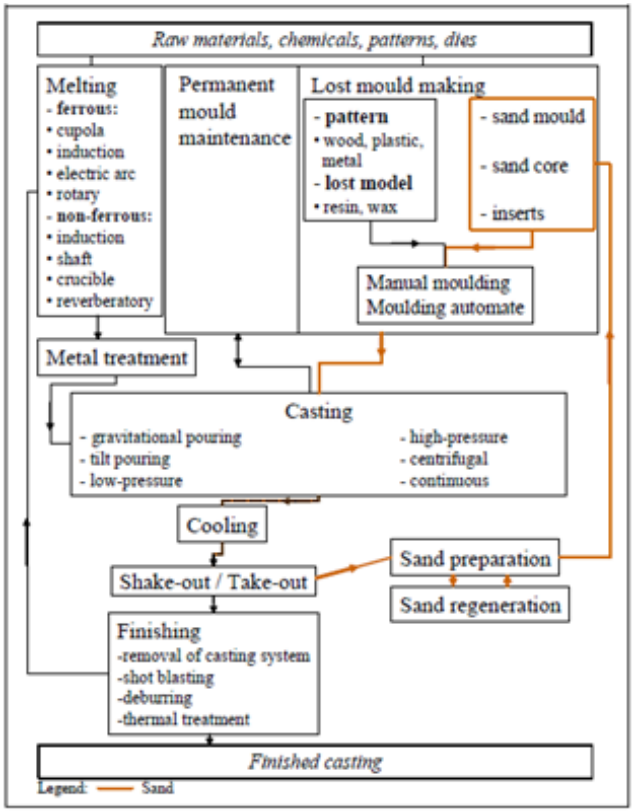

Fig. 1 The foundry process

3. Foundry Hazards, Effects and Control Measures

Major hazards in the foundry industry are: Working in heat; hazardous chemicals (incorporating hazardous substances and dangerous goods); airborne contaminants; manual tasks; noise; vibration; molten metal; plant and machinery and electricity [3, 14].

3.1 Heat Exposure

High temperatures and direct infrared (IR) radiation are common hazards in foundries [15]. Where the body is

unable to lose heat fast enough through the evaporative cooling process to maintain a steady core body temperature, it begins to experience physiological heat strain with different illnesses depending on the degree of heat stress [14, 16].

Potential health effects for persons under increasing levels of heat stress include: discomfort; heat fainting; heat stroke; prickly heat; irritability, dehydration; reduced concentration or attention; heat rash; reduced tolerance to chemicals and noise exposure; heat cramps; heat exhaustion; Heat cramps, heat exhaustion and heat stroke are the most serious forms of heat illnesses. Heat stroke is a life threatening condition and may result in permanent damage to the heart, kidneys and brain. The effects of heat stress are most likely to increase during the hot season [14, 16]. Exposure of the skin to strong IR may lead to local thermal effects and even serious burns, especially if the exposure covers the whole body [17]. Eliminating situations that could lead to heat related illnesses is the ***best form of control strategy***. This can be done by: eliminating unnecessary sources of radiant heat; eliminating sources of water vapour in the workplace (i.e. leaks from steam valves, evaporation of water from wet floors, etc.) [14, 16]. Where exposure to heat cannot be prevented or reduced by any other form of control, all exposed persons must be provided with PPE. PPE may be used in addition to other control measures. The PPE are: eye wear, such as ultra-violet glasses and radiant energy reflective face shields; non-flammable and heat reflective clothing and equipment; water cooled bodysuits/vests and other equipment; protective gloves and footwear- Metatarsal safety shoe with Heat resistant soles [14, 15, 18, 19,].

3.2 Hazardous Chemicals

Hazardous chemicals (which incorporate hazardous substances, dangerous goods and combustible liquids) are widely used in the foundry industry. The Regulation also requires manufacturers or importers of a hazardous chemical to prepare a Safety Data Sheet (SDS) for each hazardous chemical dealt with and for suppliers to provide a current SDS to any person that is likely to use or be affected by the hazardous chemical. Hazardous chemicals common to the foundry industry include: amines; benzene; hexachloroethane; ammonia; epoxy resins; formaldehyde; furfuryl alcohol; isocyanates; mould release paints; protective coatings; phenol; crystalline silica etc. [3, 14, 20]

Health Effects of Hazardous Chemicals: Hazardous chemicals can enter the body through inhalation, skin contact or by accidental ingestion. Different hazardous chemicals can create different hazards including fires or explosions as well as short and long term effects on specific organs of the body. Prolonged exposure to hazardous chemicals may result in the following health effects: headaches; nausea; fatigue; irritant or allergic dermatitis; asthma; bronchitis; chemical burns; irritation of the nose, eyes and respiratory tract; adverse effects on the central nervous system and other bodily systems, including the lungs, kidneys and liver [3, 14, 21]. ***Work activities that are not essential should be eliminated wherever practical.*** For example: use a physical process to clean an object (e.g. ultra-sound) instead of using a chemical process; use clips, clamps or bolt instead of adhesives; purchase supplies of a material in a ready-cut and sized form rather than carrying out a dust producing cutting process on site, the area should be well ventilated [14, 21].

3.3 Airborne Contaminants

This is a contaminant in the form of a fume, mist, gas, vapour or dust, and includes microorganisms. Significant concentrations of airborne contaminants (e.g. gases, vapours, fumes and dusts) may be encountered in all facets of foundry operations. Metal fumes are formed by the evaporation, condensation, and oxidation of metals in air. These contaminants may be encountered in many areas including pattern making, core making, mould making, furnace, fettling and sand plant sections. Hence, in foundries furnace tenders, melters, casters, ladlemen, pourers, and crane operators are exposed to the smoke and fumes during melting [14, 22]. In foundries, airborne contaminants may be released by, or generated from: the handling of scrap - receiving, unloading, storage and conveying; scrap preparation using heat and solvent degreasers - carbon monoxide; the melting process - carbon monoxide, sulphur dioxide, nitrogen oxides, chloride and fluoride compounds; the treatment and inoculation of molten metal before pouring; core and mould making processes during sand reclamation, sand preparation and sand mixing; mould and core forming processes including core baking and mould drying from additives, binders and catalysts; cooling of casts causing decomposition of organic binders; casting knockout and shake-out; and fettling [3, 14, 23, 24,].

Health Effects of Airborne contaminants: Other gases may indicate their presence by various irritating effects such as respiratory irritation, coughing, asthma, acidic taste and eye irritation. The inhalation of wood dusts causes a slowing of dust clearance and alteration to the structure of the mucous membrane lining of the nasal cavity. This may be accompanied by the risk of cancer of the nasal cavity and sinuses. Some wood dusts also act as sensitisers that

may manifest itself as a skin rash, inflammation or as an asthmatic condition. The inhalation of heavy metal dusts may produce diverse health effects depending on the specific metal dust involved. For example: iron dust may accumulate in the lungs and cause siderosis; aluminium dust irritates the respiratory system and may result in chronic non-specific lung disease; beryllium dust irritates the lungs and may result in tracheobronchitis, pneumonitis and beryllosis, and may also be a possible carcinogen; lead dust results in systemic poison effects; manganese dust irritates the lungs and may have a chronic effect on the nervous system; nickel dust irritates the respiratory tract and some nickel exposures may result in lung or nasal cancer [14, 23, 15].

Respirable crystalline silica (RCS) dust presents one of the greatest risks to the health of foundry workers. Fine silica dust is produced in foundries by the rubbing, abrading or mechanical action on quartz and which is primarily composed of crystalline silica. The major foundry operations which produce RCS dust are mould and core making, shakeout, cleaning of castings, furnace and ladle repair, sand reclamation and sand preparation. The principal health effect associated with silica dust is silicosis, which is stiffening and scarring of the lungs. Silicosis is a chronic disease, and usually takes a number of years for the symptoms to appear. It results in increasing shortness of breath, coughing and chest pain. The effects are irreversible, and lead to degeneration in the person's health, invariably resulting in the premature death of the worker. Silica is also now classed by the International Agency for Research on Cancer as an occupational carcinogen, where excessive exposures can lead to irreversible lung cancer [14, 23, 25, 26].

There are a number of control options that can be used alone, or in combination, to prevent or minimise exposure to the risk. The risks from airborne contaminants may be controlled by substituting a hazardous process or material for a safer one. For example: using wet (with caution for recycled sands) or vacuum methods or brushes to remove loose dust or sand in the mould making process rather than compressed air to minimise dust creation and using chromite sand instead of silica sand. Engineering controls may involve the use of plant or processes which: minimise the generation of a contaminant; suppress or contain a contaminant; limit the area of contamination [14, 20]. Administrative controls largely involve the development and training of workers in safe work practices and procedures that should be used in combination with other control measures for airborne contaminants. For example: use of continuous monitoring devices to monitor the levels of carbon monoxide in the work area; systematic monitoring to ensure airborne contaminants do not exceed the exposure standard; training in safe work practices [14] and use and maintenance of personal protective equipment. Personal protective equipment that can be used in the control of airborne contaminants includes: face and eye protection; respiratory protection appropriate to the contaminant; respirators with organic vapour filters for organic vapours [14, 18].

3.4 Manual Tasks

This is a task that requires a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any person. Manual working is a major source of hazards and problems for industrial workers worldwide. Tasks which are performed manually constitute a considerable proportion of work done in industries around the globe, especially in developing areas. Manual carrying is defined as the unaided moving of objects, often combined with twisted and awkward postures, contributing to musculo-skeletal disorders (MSDs) [27, 28, 29, 30]. These tasks are part of nearly all work done by workers. They include any activity where workers grasp, manipulate, carry, move (lift, lower, push, pull), hold or restrain a load. Workers in most areas within a foundry would perform manual tasks. The areas that involve frequent performance of manual tasks include pattern and core making, moulding, fettling shops, stores and dispatch, inspection and surface coating area [14].

Health Effects of Manual Tasks: Over a period of time, damage to the low back, upper back or shoulder can gradually build up through: frequent lifting with the back bent or twisted, or pushing/pulling loads; working in a fixed position with the back bent, continuous sitting or standing, or driving vehicles for long periods; repetitive work with the hand or arm, and having to grip tools or loads tightly; working with the neck, shoulders and arms in a fixed position (e.g. using tools and handling heavy loads). **Manual handling risks may be removed** by redesigning equipment or work practices; reduce the amount of force required to carry out the tasks by utilising conveyor system, hoists, cranes or forklift trucks, trolley systems and position tasks at comfortable working height. Administrative controls involve task specific training; work organisation; preventive maintenance programme [14] and personal protective equipment (PPE). To prevent a decrease in work efficiency or an increase in injury potential, consider the following: Clothing which restricts the ability to move freely should not be worn; when gloves have to be worn provide different sizes so the right size can be selected and cover only the area of the hand necessary to protect the worker; provide knee protectors

for work involving kneeling to reduce stress on the knee [14, 18].

3.5 Noise

Hazardous noise is unwanted sound that may damage a person's hearing. The amount of damage caused by noise depends on the total amount of energy received over time. This means as noise becomes louder, it causes damage in less time. In the foundry industry, hazardous noise levels are produced in many operations. The noise created by foundry machinery is complex due to the wide variety of noise sources and whether it is constant or intermittent. These noise sources include: machinery used in pattern making; moulding machinery; core-making machinery; furnaces; shake-out and knockout of castings; machinery used in tumbling, grinding and cleaning of castings; fettling and dressing of castings [14, 15, 31, 32].

Health Effects of Noise include: temporary threshold shift which occurs immediately after exposure to high noise levels, condition may last for minutes to hours; noise induced hearing loss that occurs from long term exposure to high noise levels, irreversible; tinnitus which is ringing in the ears that sometimes accompanies noise induced hearing loss; acoustic trauma resulting from explosions or extremely loud impulsive noise which may destroy the cilia hair cells and ear structure. In addition high noise levels may cause difficulties in verbal communication and in hearing warning signals or emergency commands. The following **control measures** are listed in order of the most effective way of managing risks from noise: elimination by: replacing the machine or its operation with a quieter alternative with equal or better efficiency; replacing noisy machinery with newer equipment designed to operate at lower noise levels; correcting the specific noise source by design changes (e.g. replacing metal components with plastic). The engineering noise control measures for managing noise levels are treatment of: the source; the noise transmission path and treatment at the receiver. Administrative control measures include: Sign posting noisy areas; providing quiet rest areas for food and rest breaks; limiting the time workers spend in noisy areas by moving them to quiet work areas before their daily noise exposure levels are exceeded etc. [14, 31, 33]. Workers should be supplied with personal hearing protectors as ear plugs; ear muffs and ear caps [14, 18, 25, 20].

3.6 Vibration

Exposure to noise in industry is often accompanied by exposure to vibration which is classified as: whole body vibration (1 to 80 Hz), or hand-arm or segmental vibration (8 Hz to 1 kHz). Foundry workers may be subject to whole-body vibration during shake out processes, sand-slinging and from forklift truck, conveyor, overhead crane, pneumatic ramming operations and jolt-squeeze machines. Hand-arm vibrations occur when using hand-held power grinders, chippers and other pneumatic tools [14, 33].

Health effects of vibration: Vibration disease may develop after several years of exposure and result from either whole body vibration or segmental (hand arm) vibration. The main effects of whole-body vibration include: blood pressure and heart problems; nervous disorders; stomach problems; joint and spine damage, influence on speech, shortness of breath, chest pain. The factors that influence the effect of vibration on the hand and wrist include: vibration frequency; level of insulation; duration of exposure etc. The symptoms include: blanching and numbness in the fingers (white finger disease); decreased sensitivity to touch, temperature and pain; loss of muscular control and discomfort and/or pain in the joints, such as the wrists, elbows and shoulders. [14, 34] The **control measures** of vibrations are: tools with vibration dampers should be used. They should weigh as little as possible to reduce muscular effort and have handgrips that do not involve twisting the hand away from a normal position while using the tool [14, 35]; Machinery must be designed and constructed in such a way that risks resulting from vibrations produced by the machinery are reduced to the lowest level [34]. Administrative controls involve the development of safe work practices and procedures like labelling equipment to warn workers of potential hazards; avoiding prolonged use of vibrating equipment etc. [14, 35]. Where exposure to vibration cannot be prevented or reduced by any other form of control, PPE should be provided like: protective gloves and provision of vibration absorbing materials [14, 18].

3.7 Molten Metal

Molten metal is a major hazard in foundry melting and pouring areas. Workers, who perform tasks with or near molten metal, may come into contact with metal splashes and be exposed to electromagnetic radiation. Extreme caution must be taken to prevent metal and metal slag from coming into contact with water or moisture, as this may result in an explosive reaction or ejection of molten metal with catastrophic consequences. Electromagnetic radiation is emitted from molten metal in the furnaces and pouring areas. Foundry workers are mainly exposed to infrared and ultraviolet (UV) radiation [14].

Health effects of molten metal: Serious burns may result from splashes of molten metal and radiant heat at any time

in the melting and pouring areas. Sparks from molten metal may also damage the eyes. Exposure to infrared and UV radiation may result in eye damage including cataracts. To **control molten metal exposure,** barriers and other suitable shields, including mobile shields should be used or installed to protect workers against molten metal splashes and electromagnetic radiation; restricting visitors and workers from wearing synthetic clothing, including undergarments when entering the furnace and pouring areas; keeping melting and pouring areas free of combustible materials and volatile liquids using: heat resistant protective clothing as footwear, headgear, face shields, fire retardant spats, aprons, coats and gaiters; eye protection with side shields; special UV and infra-red glasses [14].

3.8 Plant and Machinery

Special care should be taken with plant and machinery used in foundry environments. For example, the elevated temperature in a foundry creates greater stress on crane components and may dramatically reduce a crane's working life. Continuous vibration of some equipment results in increased mechanical stress on nuts, bolts, chains and cables, which may eventually lead to equipment failure. This in turn may result in major explosions, fires, spills and burns. Atmospheric particulate matter also increases wear through contamination of lubricants and ingress to bearings [14].

Health effects of plant and machinery: Improper maintenance, repair, guarding and use of plant and machinery in foundries may result in significant increases in the risk of injury to operators and nearby workers. The injuries are: cuts and lacerations; amputations; foreign bodies in eyes; crush injuries; fractures; burns and manual handling injuries. To **avoid plant and machinery injuries**: Redesign can be carried out which involves changing the design of the workplace, equipment or work process. It involves thinking about ways the work could be done differently to make the plant safer such as modifying equipment, combining tasks, changing procedures, changing the sequence of tasks. Administrative measures involve: ensuring that purchasing specifications for new equipment incorporate all required safety features, for example, safety devices and guards and "fail safe" design; carrying out routine and preventive maintenance programs at regular intervals; PPE should be used as: eye protection; hearing protection; safety helmets, and skin protection - gloves, barrier creams [14, 18, 36].

3.9 Electricity

Electrical risks are risks of death, electric shock or other injury caused directly or indirectly by electricity. Electricity can cause death or serious injury. Foundry workers who may be exposed to the risk of injury from electricity include those who work with or around electrical equipment in areas such as the pattern shop, fettling shop, and the furnace section. The common **electrical hazards** and causes of injury can be broken into three broad categories: Electric shock which can cause injury or death [14, 37]; Table 1 shows the effects of current on the human body. Arcing, explosion or fire that cause burns and Toxic gases causing illness or death. There are a number of **control measures** that can be used alone, or in combination, to reduce the level of risk of injury from electricity:

Table 1: Effects of current on the human body [38]

Current (mA)	Duration (ms)	Effect
0 - 0.4	unlimited	No effect
0.4 - 20	unlimited	Usually no harmful physiological effects
20	< 500	
30	< 400	
50	< 100	
100	< 30	
200	< 10	
20	> 400	Muscular contractions and pain Difficulty in breathing Burns
50	> 100, < 1 000	
100	> 30, < 500	
200	> 10, < 400	
50	> 1 000	Severe burns
100	> 500	Cardiac and breathing arrest
> 500	any duration	Risk of ventricular fibrillation, increasing with current and duration

Turn off the power: it is not allowed to work on electrical equipment where there may be a risk of exposed live parts; removing covers on equipment to access mechanical parts may also expose live electrical parts. Employers have a duty to ensure their business is conducted in a way that is electrically safe, including that all electrical equipment is safe. Safety switches and regular maintenance of electrical equipment are good ways of controlling electrical safety risk [14, 37, 38].

4. Environmental Issues

Today pollution has become big challenge around the globe [39]. The major terms of pollution are air pollution, water pollution, soil contamination, plastic pollution. Air pollution comes from both natural and man-made sources. However, globally human made pollutants from production, combustion, construction, mining, agriculture and welfare are increasingly significant in the air pollution equation. Adverse air quality can kill many organisms including humans. Pollution prevention and waste minimization are

most desirable than pollution control. The pollution control devices used commonly are dust collection systems, scrubbers, and sewage treatment, industrial wastewater treatment, vapour recovery systems and phytoremediation [40]. The environmental issues associated with foundries primarily include air emissions, solid waste, wastewater and noise [40].

Dust and particulate matters are generated in each of the process steps with varying levels of mineral oxides, metals (mainly manganese and lead), and metal oxides. Dust emissions arise from thermal (e.g. melting furnaces) and chemical / physical processes (e.g. moulding and core production), and mechanical actions (e.g. handling of raw materials, mainly sand, and shaking out and finishing processes) [41, 42]. Metal emissions should be controlled during the melting and casting processes. Metal emissions may be emitted through volitization and condensation of metals during molten metal pouring into moulds. Particulates in ferrous foundries may contain heavy metals, such as zinc (mainly if galvanized steel scrap is used), cadmium, lead (e.g. from painted scrap), nickel, and chromium (these last two in alloy steel casting production) depending on the steel grade being produced and scrap used. Particulates associated with nonferrous metal production may contain copper, aluminum, lead, tin, and zinc. The presence of metal in particulate emissions can be especially significant during alloying activities and during the introduction of additives. For example, the addition of magnesium to molten metal to produce ductile iron may result in a reaction releasing magnesium oxides and metallic fumes. Dust, fumes and particulate emission can be controlled by using high-efficiency dust abatement techniques [40, 41].

Solid waste streams include sand waste, slag from desulfurization and from melting, dust collected within emissions control systems, refractory waste, and scrubber liquors and sludges. General techniques to manage the waste generated by foundries include the selection, design and construction of storage areas for metals, dust waste from filters, refractory waste, slag, and sand waste, with due consideration of site geological and hydrogeological conditions to prevent potential contamination from potential heavy metal leaching [41]. Disposal by landfill of spent sands is becoming an increasing problem as legislation is getting tighter and economic as disposal cost by current practices increases rapidly [43]. According to a foundry industry survey, approximately 9.4 million tons of non-hazardous spent foundry sand (SFS) is generated annually in the United States. Of this, 28% is beneficially used in construction fill, as a component of concrete and asphalt, in road construction, and/or in soil mixes. As of 2002, 18 states had implemented programs to encourage and regulate the beneficial use of SFSs [44, 45] as an alternative friendly solid waste disposal. Zanetti and Fiore [46] report that in Europe, because of the different rules and economic factors that exist in different countries, a solution that can be valid for the reuse of foundry wastes in one country might not be acceptable in another country. However, a knowledge of the possible solutions could lead to choosing modifications that might be acceptable. Silica sands for foundry products in the different European countries are commercialised at different prices: in Italy the price is about 0.04 €/kg while in Belgium and Netherlands the same product is sold at about 0.01 €/kg. These differences and the landfilling costs justify the different solutions adopted in European countries for green moulding sands (recycling or reuse): recycling in Italy, re-use as capping for landfills and concrete production in Sweden, re-use for road construction in Belgium and so on.

The most significant use of water in foundries is in the cooling systems of electric furnaces (induction or arc), cupola furnaces, and in wet dedusting systems. In most foundries, water management involves an internal recirculation of water resulting in a minimal effluent volume. Use of wet dedusting techniques may increase water use and consequent disposal management. In core making, where scrubbers are used, the scrubbing solutions from cold-box and hot-box core-making contain biodegradable amines and phenols. In high-pressure die-casting, a wastewater stream is formed, which needs treatment to remove organic (e.g. phenol, oil) compounds before discharge. Wastewater containing metals and suspended solids may be generated if the mould is cooled with water. Wastewater with suspended and dissolved solids and low pH may also be generated if soluble salt cores are used. Wastewater may be generated by certain finishing operations such as quenching and deburring, and may contain high levels of oil and suspended solids. Prevention techniques for effluent streams from foundries include: installation of closed loops for cooling water to reduce water consumption and discharge; recycle tumbling water by sedimentation or centrifuging followed by filtering; store scrap and other materials (e.g. coal and coke) under cover and / or in bunded area to limit contamination of storm water and facilitate drainage collection; process water treatment [41]. Industrial operators must ensure that waste generated at the premises is not discharged into any waters or onto land where it is reasonably likely to enter any waters (e.g. by seepage, runoff or infiltration) [47].

The foundry process generates noise from various sources, including scrap handling, furnace charging and electric arc furnace melting, etc. The recommended noise management

techniques include: enclosing the process buildings and / or insulate them; enclosing fans, insulate ventilation pipes and use dampers; implement management controls, including limitation of scrap handling and transport during night time [14, 41].

5. Conclusion

A review on effects of hazards in foundries to workers and environment has been conducted where the general overview on foundry industry and the associated hazards was carried out. Major hazards in the foundry industry, the effects and control measures were presented. In the study, various hazards were identified and elaborated which are heat exposure, hazardous chemicals, airborne contaminants; manual tasks; noise; vibration; molten metal; plant and machinery and electricity. Finally the effects of hazardous materials to environment and their control were looked at. It has been revealed that hazards in foundries are many and very dangerous both to foundry workers' health and to the environment which eventually spread and affect the wider population.

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