Overview on Safety Guidelines for Confined Space Working Environment

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ABSTRACT

The execution of constructional and repair activities at Confined spaces is challenging job nowadays. The hazard at confined space is very difficult to access and rescue. The first adverse problem that worker may experience is oxygen deficit, later physical and biological hazards may magnify the situation at work site. The present paper describes various problems experienced by workers at confined spaces and suggesting various guidelines to be followed to overcome such problems. The safe operation procedures must be followed in sequence order and should ensure safety of workers. Safeguarding of entry point, isolation of energy sources, utilization of warning signs are significant basic steps in rescue operation. The training of rescuers with periodic mock drills may effectively work in emergency plan of action and useful in rescue methodologies. As per OSHA three rescue operations have suggested during the emergency, they are self rescue, non-entry rescue and entry rescue. The rescuers should be provided with proper information and sufficient materials to save the affected person in time. The materials like first aid kit, oxygen supply equipment and Cardiopulmonary resuscitation [CPR] experts will help the persons in danger.

Keywords-- Confined space, Oxygen deficit, Environmental hazard, Toxic gases, Emergency action plan, Occupational safety

I. INTRODUCTION

The activities in the field of Construction sector has been increasing enormously in developing and undeveloped countries over the years because construction is key factor for the growth of any nation. With the increasing demand in construction sector a risk factor is also increased in the form of occupational fatalities in every country. The most common occupational fatalities are caused by four reasons, i.e., falls, being struck by an object, electrocutions, and being caught in between two objects, i.e., confined space[confined space 2017].

The Confined spaces may be possible in almost all fields of construction sector; hence, their identification is the basic step to prevent fatalities. According to Occupational Safety and Health Administration (OSHA)’s definition, it is large enough for an employee to enter fully and perform assigned work, has a limited or restricted means of entry or exit, is not designed for continuous employee occupancy. A confined space is an enclosed space that is not designed for human occupancy, has a limited entrance and can represent a risk for health and safety for anyone who enters into that place. The Confined spaces can be below or above ground and it can be found in almost any workplace. A confined space, despite its name, is not necessarily small [A guide to confined space 2017]. The types of confined spaces includes but are not limited to figure 1, it further extends to all places where a worker is unable to work freely such as vats, hoppers, Electrostatic precipitators (ESP), reaction vessels, sewers, pipes, access shafts, Ventilation and exhaust ducts, aircraft wings. The Ditches and trenches are also considered as confined spaces when access or outlet is limited [Confined Spaces 2017].

According to world globalisation and Indian Make in India movement, Indian industry is exposed to the latest trends in Occupational safety and health (OSH). The major occupational risks at confined spaces are accidents, silicosis, musculoskeletal injuries, chronic obstructive lung diseases, pesticide poisoning, asbestosis, workplace stress and so forth. The Director General of the Factory Advisory Services & Labour Institutes (DGFASLI) recorded 1,509 fatal cases and 33,093 non-fatal injuries in the year 2009[Shyam 2012].
The present paper highlights various causes of accidents in confined space entry and develops standard operating procedures [SOP] to be followed in general prior to the entry in confined space. The report will develop basic steps that are required by workers to be followed in any given job associated with confined space.

II. TYPES OF HAZARDS IN CONFINED SPACES

All types of possible hazards in regular workplace can also be possible in a confined spaces. normally, confined space is seems to be harmless but suddenly leads to life threatening under an unusual situations. The hazard assessment in confined spaces is very important and must be taken seriously each and every time of incident, especially in the inlet and outlet of the confined space [confined space 2017].

Self rescue and Rescue of the victim is more important considerations at confined spaces. Sometimes natural air and ventilation may not be sufficient to maintain favourable working conditions. The internal specification of the confined space does not allow easy movement of air circulation within it. A worker cannot assume that the space is safe for each entry, sometimes certain materials, conditions and factors may cause an immediate threat to the life or health of the worker entering the confined space. The hazard assessment is extremely important and must be taken very seriously each and every time. The types of hazards in confined space are classified into three categories, as shown in figure 2.

2.1 Atmospheric Hazards

The atmospheric hazards are mainly describing the significance of atmospheric air quality and obnoxious gases, which have tremendous flammable or hazardous characters.
2.1.1 Oxygen Deficiency

Oxygen deficiency may be expressed in two types either by asphyxia or by hypoxia, the asphyxia is caused by an obstruction of air passage whereas in hypoxia inadequate supply or uptake of oxygen by tissues of the body. Oxygen deficiency at confined spaces may occur due to chemical or biological reactions which displace or consume oxygen from a confined space. Sometimes, the oxygen may be consumed during combustion of flammable substances such as in various mechanical operations like welding, cutting, or brazing. The aerobic bacterial decomposition of organic matter is also consuming oxygen as in the process. This type of Oxygen deficiency can be recognised at most of the confined spaces like manholes, garbage dumps and landfills. The containers like metal tanks, vats, silos etc., may consume Oxygen during the process or rusting. The table 1 describes the percentage of oxygen required for human reactions in a confined spaces[A guide to confined space 2017].

<table>
<thead>
<tr>
<th>SNo</th>
<th>Percentage of O₂ in atmosphere</th>
<th>Human Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.5</td>
<td>Abundant O₂ availability</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>Normal O₂ level</td>
</tr>
<tr>
<td>3</td>
<td>19.5</td>
<td>Minimum O₂ required for safety</td>
</tr>
<tr>
<td>4</td>
<td>12-16</td>
<td>Dyspnea, emotional instability, extreme tiredness after activity</td>
</tr>
<tr>
<td>5</td>
<td>10-11</td>
<td>Weak heart beat, agitation, dizziness</td>
</tr>
<tr>
<td>6</td>
<td>6-10</td>
<td>Nausea and vomiting, inability to move, semi unconsciousness</td>
</tr>
<tr>
<td>7</td>
<td>6 and low</td>
<td>Gasping, respiratory arrest, heartbeat stops after few min</td>
</tr>
</tbody>
</table>

2.1.2 Flammable Atmospheres

The various biological and mechanical operations release certain gases like methane and other flammable gases. The flammable atmosphere is the result of vaporization of certain liquids, by-products of atmospheric compounds and excessive oxygen availability [Worker deaths 2017]. The in flammability is depends on mixture of fuel and oxygen and it will vary from gas to gas within a fixed range. The lower flammability limit is represented as LFL where as the upper flammability limit is represented as UFL. As per OSHA standards the methane concentrations below 5% explosive range is represented as LFL is 5%, and concentrations above 15% i.e., UFL is 15% is to support combustion. If a confined space contains 27% methane and forced ventilation is started, the introduction of air into the confined space may dilute the methane in air, taking it into the explosive range. Oxygen levels higher than 21% in atmosphere will cause inflammable to various materials, such as cloths, hair and so forth. Hence, we should not use pure oxygen for ventilating a confined space. [Confined space programme 2017].

2.1.3 Toxic Gases

The gases and chemical deposits are produced in confined spaces during the period of time and those are absorbed into the walls and give off secondary pollutants. These toxic gases will be released widely when cleaning the deposits of a stored product or toxic gases. We can find foul smell of hydrogen sulphide gas while cleaning septic tanks or removal of sludge from a sedimentation tank. The engineering operations like welding, cutting, brazing, painting, scraping, sanding, degreasing, etc., are responsible for the release of toxic gases or hazardous vapours. Most of toxic vapours produced by various activities can enter and accumulate in confined spaces. The cleaning solvents widely used in many industries for leaning or degreasing are very toxic in a confined space. The table 2 describes types of various toxic gases generating from industrial operations. Some toxic gases such as phosgene or carbon monoxide are particularly insidious because of their poor warning properties. Toxic gases which have been reported to cause death in workers in confined spaces include carbon monoxide, hydrogen cyanide, hydrogen sulphide, arsine, chlorine, oxides of nitrogen, and ammonia [confined space programme 2017].

<table>
<thead>
<tr>
<th>SNo</th>
<th>Industry/operation</th>
<th>Type of toxic gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manufacturing process</td>
<td>Polyvinyl chloride, hydrogen chloride</td>
</tr>
<tr>
<td>2</td>
<td>Biological or chemical processes</td>
<td>Hydrogen sulphide, methane</td>
</tr>
<tr>
<td>3</td>
<td>Welding</td>
<td>Oxides of nitrogen, ozone, and carbon monoxide</td>
</tr>
<tr>
<td>4</td>
<td>Acids for cleaning</td>
<td>Hydrogen sulphide</td>
</tr>
</tbody>
</table>
2.1.4 Effect of Solvents

Many solvents are used as a mixing agent for Industrial operations. These solvents are found under a variety of trade names. They are used in the form of Adhesives, Cleaning and degreasing materials, Inks and ink removers, Pesticides, Paints and varnishes, Paint removers, Toiletries etc. The Hydrocarbon solvents are more popular as degreasing agents in industries. These hydrocarbons show effect on central nervous system and causes unconsciousness. The chlorinated hydrocarbon solvent is most popular as chloroform, have been used as anaesthetic agent, but these fluorinated hydrocarbon solvents are most dangerous to the heart and have been associated with sudden death in confined spaces. The popular solvent methylene chloride can metabolize in the body to carbon monoxide in the confined spaces. These solvents may enter into human body by various paths such as breathing, come into contact with our skin or swallowing of liquid solvents. These solvents may show Short-term effects such as eye irritation, lungs irritation, skin irritation, headache, nausea and dizziness. At high concentrations of vapours unconsciousness and even death can result from exposure [Solvents 2017].

III. PHYSICAL HAZARDS

Physical hazards are also most common at confined spaces and these hazards include with various technical operations associated with mechanical, electrical, and hydraulic energy, engulfment, communication problems, noise and size of openings into the confined space [Worker deaths 2017].

3.1 Mechanical hazards

The various mechanical operations in confined spaces may cause hazards to the worker due to limited space. These hazardous mechanical operations are basic in varying combinations to almost all machines and identifying them is the prime requirement step to protect worker from the hazard. Dangerous Mechanical Hazards Occur at different areas in confined spaces mainly cutting, shaping, boring and etc. The components of power transmission apparatus such as flywheels, pulleys, belts, connecting rods, couplings, cans, spindles, chains, cranks, and gears are also susceptible for hazards [Worker deaths 2017]

3.2 Electrical hazards

The electrical hazards in a confined space may cause a blistering explosion by releasing huge radiant energy. The sudden arc flash is the most common hazard when working with electrical equipment. The arc flash may be ignited by a simple workplace incident such as dropping of metal items or operation of fused switches. The arc flash may produce a sudden blast wave which shoot-up the temperature even up to 5,000 degrees Fahrenheit. This effect may causes damage to loss of hearing, loss of vision, severe burns and even death [electrical hazards 2017].

3.3 Noise hazards

Noise hazards are common in confined spaces because the inner surfaces may cause resound effect which leads to higher sound levels than those found in normal environment. This excessive noise increases the risk to loss of hearing to workers. The Noise levels may also interfere in verbal communication between the workers during the emergency situation in confined space. The use of various tools and materials may produce high noise levels, which may lead to permanent hearing loss. The various operations in a confined space like abrasive blasting, use of high pressure steam or water guns, grinding, scaling are responsible for severe hazards [confined space programme 2017].

3.4 Radiation hazards

The radiation hazard may be caused by radioactive substances or thermal radiation. A thermal radiation caused by excessive heat may lead to heat exhaustion, heat cramps, heat stroke, loss of consciousness, or even death. Workers in a confined space must be ready for any hazards from heat with proper personnel protective equipment [PPE], heat-producing equipment to protect from temperature related illnesses [confined space programme 2017].

3.5 Environmental Hazards

The Environmental hazards associated with work in a confined space may cause severe harm to workers. The various environmental conditions such as high temperature or cold temperature, dampness, are more likely to pose danger in confined spaces. The other possible environmental hazards due to limited space are slips, trips and falls. The Workers in confined spaces may expose to slippery working surfaces on ladders, moist walls and leads to tripping hazards. Fall hazard is an environmental hazard causing of workplace fatalities. The sudden fall hazard is happening mainly from floor openings, open holes or bore wells, from ladders and scaffolding [confined space programme 2017].

IV. BIOLOGICAL HAZARDS

Biological hazards in confined spaces are mainly originated from contaminated water in that area. The most of the diseases will spread through various biological agents such as bacteria, viruses, fungi, molds and other microorganisms. The workers at confined space expose to such biological agents may suffer with serious viral diseases. Mold is fungi, is another form of biological agent found everywhere. The spores of mold float continually in the air. These Molds can grow on any substance, as long as moisture and oxygen are available into and releases millions of spores into air, water, or on any other vectors. These spores have negative effects on human health. People have higher risk with allergies, asthma, sinusitis, and also affect the immune system of the workers [mold 2017].
V. WORKING GUIDELINES AT CONFINED SPACES

The confined spaces should identify and evaluate authorized space before allowing employee entry. The worker must have through knowledge in all existing or potential hazards in each confined space of the worksite. The first guideline is to test atmospheric conditions in the authorised space before entering into the work. Test environmental conditions from outside the space. According to OSHA recommendations, O-F-T tests are required to identify atmospheric hazards. The O-stands for oxygen test, F-stands for flammable gases monitoring and T-stands for testing of toxic atmospheric conditions [Confined space programme 2017].

5.1 Safe operational procedures

All procedures at confined spaces must be followed in sequence order and should assure complete safety of workers. All workers involved in confined space operations should follow the given procedure. The detailed flow chart on safe operational procedure steps are shown in figure 3.

5.1.1 Safeguarding Entrance or Exit

The confined spaces should be provided with safe entry and exit points. Standard rescue operations, methods and equipment should be used by the worker whenever enters a confined space. Each entry and exit point must be monitored for safe operation. Mechanical gadgets, supporting tools, oxygen supply equipment with masks should be available to recover workers from vertical type confined spaces like bore wells, mines etc. The entry team members must have through training and experience to work in such areas and situation and they must have good coordination with emergency responders [confined space programme 2017].

5.1.2 Isolation of Energy Sources

All energy sources such as electrical, thermal, hydraulic, radioactive, mechanical and chemical - are hazardous to the entry persons, so care must be taken safely before workers are entering into the confined space. Isolation technique prevents sudden shock, heat and release of toxic gases and liquids from entering the confined space. Lock-out or tag-out procedures are to be adopted to safeguard employees from the unexpected release of energy. Under this procedure a worker should turns off or disconnects the energy source before performing service. They should lock or tag the energy-isolating equipment to prevent the release of hazardous energy [confined space programme 2017].

5.1.3 Warning Signs and Symbols

All confined spaces must have warning signs or boards to explain about seriousness of the work. The Signs and symbols should be maintained in a clear visible condition. All sign boards must contain a clear warning that a prior permission is required before entry. We must place clear warning signs like DANGER, NO ADMISSION, PERMIT-REQUIRED CONFINED SPACE etc that prevent the people entering confined spaces [confined space programme 2017].

![Figure 3 Flow chart for confined space operations](image-url)
5.1.4 Training for workers

All workers should undergo training to acquire through knowledge and skills necessary for the safe performance of their job in confined spaces. The workers responsible in various activities such as supervision, planning, working in confined space and rescue operations must be trained in their specified duties before executing the task. Training should be provided to each worker to know about proper usage of PPE and other safety equipment necessary for entry into confined spaces. They should be trained to recognize symptoms of air contamination and methods for alerting other workers. All workers should undergo training on the proper use of monitoring and testing equipments. They should have through knowledge on concentration levels of contaminants permissible exposure limit [PEL] and threshold limit value [TLV]. The Training should include Rescue plan and procedures for each model of confined space with through knowledge on First aid and Cardiopulmonary resuscitation [CPR] technique which restore instantaneous blood circulation and breathing. The Periodic training assessment will give the effectiveness of workers standard and capability [confined space programme 2017].

5.1.5 Hazard Re-evaluation

The Supervisor or safety officer should ensure the hazards based on deviations in their job activities and other environmental conditions. The Job Safety Analysis [JSA] at confined space should be routed through the Departmental Safety review before changing the plan of operation. The JSA should identify the stages of work to be carried out in the confined space. The anticipated hazards and control measures to be implemented for the minimization of hazards to permissible level. Nobody allowed until the hazard assessment has been reviewed properly with the right authorities engaged in the job. Personnel who enter confined spaces must have through knowledge on hazards associated with the confined spaces [confined space programme 2017].

VI. EMERGENCY RESPONSE PLAN

A confined space emergency is an incidence occurred inside or outside the workspace, which may create dangerous condition to the workers in that space. As per records, most of the emergency cases rescuers died instead of workers. It is due to taking of unnecessary chances, due to improper plan of action, lack of rescue training and by emotions.

Time is the important factor during emergency situation, in Oxygen deficit environment people can survive only four minutes without oxygen, under these situation worker will experience asphyxiation and death may causes due to brain damage [Mainwaring and Conroy, 1990]. The rescuer should have proper calculation before entering into confined space for emergency. The rescuer should analyse distance, space restrictions, general obstruction and time requirement to perform his action.

6.1 Rescue methodologies

As per OSHA, three rescue operations have suggested during the emergency, they are self rescue, non-entry rescue and entry rescue. The self rescue method is preferred during minor emergency conditions. This method is effective when worker recognize their critical condition and unfavourable environmental atmosphere; they should escape from the confined space as quickly as possible. Since they are Conscious and alert, physically able to escape more fast than to wait for help. Whereas Non-entry rescue operation is suitable when self-rescue is not sufficient. In this process material and other rescue aids are provided to assist in removing endangered workers. In the last method, Entry rescue, supporter entering the space to rescue the worker with emergency assistance such as first aid, oxygen supply and Cardiopulmonary resuscitation [CPR] as per the requirement. A proper entry rescue plan needs to be established during the training period by anticipating similar emergency situation.

The rescuers should be provided with proper information like reasons for accident, number of victims at the location, time period of suffering, and climatic conditions. The plan of rescue should be positive approach, initially they have to cover the location with proper fence and restrict the entry of people, provide proper ventilation for air circulation and lighting facility at confined space. The rescuer should Keep ambulance and other emergency requirements at the location and also take support from similar kind of experience from other rescuers. It is advisable to keep onsite rescuers at working site and rescuers must be trained to use PPE and other equipment such as Ladder, rope, Stretcher, medical kit, oxygen supply equipment etc [confined space programme 2017].

VII. CONCLUSION

The operational and maintenance works execution at confined spaces is more critical than regular works. The physical, atmospheric and biological hazards are more common in confined spaces. A lot of workers lost their lives for not following the basic instructions. In most of confined space fatalities two-thirds of fatalities are from rescuers. The pre-planning of confined space operation in the form of training is essential to save the victims of hazards. Risk assessment is an important procedure to recognise the relevant hazards and possible injuries, diseases to the worker. Permit to work is an essential document before workers enter a confined space. The regular usage of personnel protective equipment is another option for controlling hazards. In an emergency plan
proper procedures should be developed along with a rescue team. These people must be trained and should have a regular practice with the mock drills along with emergency devices.

REFERENCES