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Risk Assessment of Abrasive Blasting Environment in Pressure Vessel Fabrication Plants

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Abstract

Workers who are involved with abrasive blasting operations potentially have significant threats to their occupational safety and health (OSH) and environment from exposure to various types of occupational hazards and risks. For example, due to the abundant amount of dust generated from abrasive blasting, workers are exposed to possibility of respiratory illness and the inhalation of airborne contaminants may cause silicosis which often leads to fatality after a certain period of exposure. Concurrently, the control measures that currently exist in the standard operating procedures (SOP) for abrasive blasting operations at pressure vessel fabrication plant companies located in the southern region of Peninsular Malaysia are insufficient to remove or reduce the hazards and risks of OSH. In contrast, any possible harm during abrasive blasting may result in workers potentially experiencing occupational injury or illness. The purpose of this study is to describe and analyse the potential risk of abrasive blasting in pressure vessel fabrication plants. This comprehensive study was done using risk assessment tools such as Hazard Identification, Risk Assessment, and Risk Control (HIRARC). The study is designed to identify and analyse the potential risks that result from recommendations that are properly followed with control measures ranging from elimination, substitution, engineering controls, administrative control, to personal protective equipment (PPE). This would be beneficial in proposing improvements to SOP of abrasive blasting operations that comply with Malaysian requirements, standards and regulations.

Keywords: Abrasive blasting, Control measures, HIRARC, Pressure vessel fabrication plant, Risk assessment, Health, Safety and Environment

1 Introduction

These days, many organizations from various industries are eager to improve their workplace occupational safety, health and environment (HSE) policy to comply and meet with regulations [1,2,3]. Most organizations have realized and understood that the implementation of a good HSE produce benefits in return such as fewer cases of loss of personnel, productivity and material, reduced instances of receiving fines or penalties from local authorities, and enhanced company image and reputation. In contrast, if the employer fails to address the risk assessment properly, any existing and potential hazards cannot be identified and evaluated at the workplace as well as harmful sources or situations, illness or injury related to occupation, destruction to property or impact to the environment when exposed to workers.

The process of fabricating the pressure vessel involves many stages. It starts from receiving materials, forming and rolling, fit-up and welding, blasting and painting, and packing and shipping (Fig.1). It is the full responsibility of the employer to ensure that the HSE policy of their employee protects against hazards and to enable acts based on regulations and industrial codes of practice to be implemented [4,5].

Abrasive blasting operations are a common method for surface preparations that can generate high levels of airborne contamination from dust and contribute to serious HSE hazards as it may contain high levels of different toxic substances such as crystalline silica, lead, cadmium, chromium, and other compounds depending on the surfaces being blasted and type of abrasive media used, as highlighted by Conroy et al. [6]. Earlier studies show that crystalline silica causes respiratory illnesses and the inhalation of airborne contaminants is a serious health problem where approximately 2.2 million of United States workers have the potential of developing silicosis when exposed to silica dust contaminant. 100,000 of these workers are hired as abrasive blasters as can be seen in review papers by several authors [7,8,9]. The Malaysian regulations for permissible exposure limit (PEL) of mineral dust [10], provide guidelines where workers should not be exposed to mineral dust which contains free silica less than 1 percent (weight), breathable dust at concentrations of more than 5 milligrams per meter cube or total dust for eight hours of working not exceeding 10 milligrams per cubic meter.

Somehow, research regarding the exposure of crystalline silica done by Radnoff et al. [11] at Alberta, Canada across 40 work sites in 13 different types of industries has shown that the highest potential for exposure above PEL occurred in sand and mineral processing, followed by construction, aggregate mining and crushing, abrasive blasting, and demolition. A death case

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related to crystalline silica involved a 55 year old worker who worked in abrasive blasting for 10 years at a fabrication plant as an abrasive blaster. Another case involved a 49 year old non-smoker who also worked for 6 years as an abrasive blaster, who then came to a Louisiana hospital because of difficulty breathing, a bad cough, food aversion, high fever and immediate loss of weight but he died after 20 days of being admitted in hospital. These are some health hazard cases reported that are associated to abrasive blasting [12, 13].

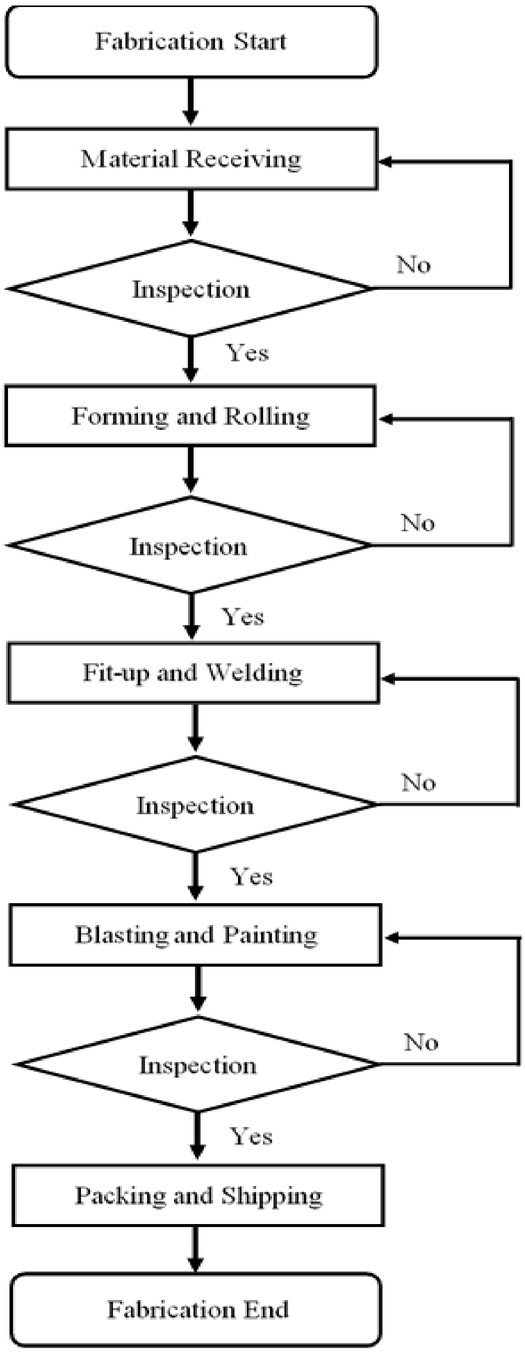

Figure 1: Fabrication of pressure vessel flowchart

The classification of hazardous levels depend on the types of potential air contaminants resulting from abrasive blasting airborne dust such as arsenic, beryllium, crystalline silica, lead, manganese, nickel, silver, titanium, and etc. mostly originating from the media types of steel, sand, and glass. For example, a study by Porter et al. [14] has shown that laboratory rats that are exposed to steel grit dust have significantly higher levels of arsenic, nickel, manganese and chromium, above the NIOSH recommended exposure limit concentrations and these elements are normally associated with cancer.

The most vital thing is that occupational silicosis disease does not develop overnight but depends on the severity of exposure and may clinically present as three types of silicosis known as chronic silicosis, accelerated silicosis and acute silicosis. The most common form of silicosis is classical or chronic silicosis which results from long-term and repeated exposure for more than 10 to 20 years to low levels of silica dust as addressed by Glazer et al. [15] and also as agreed by Khoza [16]. The silica dust causes inflammation in the lungs and chest lymph nodes and this may cause people to have trouble breathing. In addition, a study by Greenberg et al. [17] highlighted that symptoms of chronic silicosis may not develop even with exposure as long as 45 years but requires confirmation by radiographic examination to diagnosis the asymptomatic patients. The effects of continuous exposure are also incurable and irreversible.

In addition, the author also stated that accelerated silicosis develops in a relatively shorter period compared to chronic silicosis, as early 5 to 15 years after exposure to intense amounts of silica. It also shares certain clinical features with chronic silicosis such as swelling in the lungs, but it tends to progress rapidly and many cases of accelerated silicosis developed progressively even when exposure to silica was completely ceased promptly. Acute silicosis shows symptoms such as shortness of breath due to the respiratory failure due to a loss of pulmonary function and damaged gas exchange, low blood oxygen levels and other symptoms such as fever, fatigue, and weight loss. It can occur after short-term exposure to very high concentrations of silica dust as the damage to the lungs occurs quickly and as early as a few weeks to 5 years due to heavy silica exposure as addressed by several authors [18,19]. Concurrently, Liu et al. [20], reported that even low levels of silica exposure can contribute to the chances of silicosis and the author also stated having a smoking habit can deliberately elevate the likelihood of lung cancer together with silica exposure even if no silicosis develops.

In all forms of silicosis, the smallest silica particles end up in the air sacs of the lung after being inhaled. This causes inflammation and scarring that damages the sacs resulting in impaired gas exchange which then prevents a person from breathing normally. The primary hazard associated with abrasive blasting operations is the inhalation of airborne contaminants that may contain various kinds of highly toxic dust. Nevertheless, there are other HSE hazards that are present at the workplace such as extreme noise, working at heights, working in confined spaces, manual handling etc. These hazards that exist or arise from abrasive blasting operations also should be addressed properly and sufficiently as per standard operating procedures (SOP) by putting in place prevention measures to control the hazards and risks to employees. The development of a safe SOP for work activity procedures that describes the work tasks, identifies hazards and documents how the work task should be carried out in order to minimize the risks would be favoured by workers in any workplace.

An employer should clearly allocate and provide supervision in implementing a good SOP by ensuring that the procedures are followed accordingly and maintain precautionary action effectively. In contrast, any possible harm that occurs to the employees during abrasive blasting in the form of accident or health disease is not properly addressed in current SOP. By striving to comply further with the requirements and HSE legislations, this paper's objective is to assess the current situation for potential hazards and perform a risk assessment of abrasive blasting operations in a pressure vessel fabrication plant. The possible safety and health diseases that are involved in these practices will be included as well as recommendations for intervention strategies that use proper control measures which are available, practical and implementable in order to improvise the current SOP of abrasive blasting operations.

2 Methodology

An employer has the responsibility to assess the health risks at their workplace to ensure a safer workplace by eliminating or minimizing occupational hazards [21]. The important thing is to decide if an occupational hazard is significant and is adequately covered by control measures so that the risks are reduced, making it safer.

In order to perform an effective risk assessment process as highlighted by OHSAS 18001 [22], it is essential to have a clear understanding of the regulatory context and concepts, and periodically carry out a risk assessment of the related activities or every time a change is made in the workplace. The employer is probably carrying out countermeasures to protect their employees from any harmful HSE risks, but doing risk assessments systematically can help provide better coverage, as mentioned by Eccleston [23] who defines risk assessment as the process of identification, estimation, acceptance, aversion and management of risk. The risk assessment process starts by identifying hazards in the workplace by understanding the nature of hazards including safety hazards, health hazards and environmental hazards that can be found at the place of work. Once the hazards have been identified, the assessment of risks can be carried out before the appropriate risk controls are implemented. Related potential risks can be determined and assessed after associated risks have been identified using risk assessment tools which are Hazard Identification, Risk Assessment and Risk Control (HIRARC).

The HIRARC method is a popular structured tool in OSH for risk management and studies done by Hadi et al., Agwu and Ahmad et al. [24,25,26] have been effectively done using the HIRARC method for assessing risk. In addition, Ahmad et al. [26] stated that this tool is fundamental to planning practices, management and the operation of risk management where it helps to identify and evaluate a workplace's potential hazards and the methods used to control or eliminate the hazards identified. HIRARC is a tool used to recognize, evaluate, measure and control hazards and risks at the workplace. This risk assessment tool can determine the likelihood of the hazard or threat occurring, the level of risk and control measures to be implemented. In addition, Agwu [25] also highlighted that the implementation of HIRARC can determine the degree of compliance and performance efficiency of the organization by decreasing the accident or incident rates, enhancing safety practices at the workplace, increasing productivity and profitability and etc. Firm implementation of it can help eliminate, decrease and control the possibility of any coincidence or accidents happening at the workplace. The process flow of HIRARC [27] is as illustrated in Fig. 2. The benefits of using HIRARC include identifying any factors that may cause any harm to HSE, determining the probability of harm happening in certain circumstances and evaluating the possible severity of its impact. This would enable employers to plan and monitor control measures to ensure that the risk is controlled adequately.

HIRARC can help to prioritize risk levels to enable planning to control HSE risks by ensuring that the existing and potential risks are properly and adequately controlled. Using HIRARC involves certain steps, starting by classifying the work activities, identifying the hazards, conducting the risk assessments for each hazard by estimating the probability of occurrences and hazard severity, and applying preventive measures to the risk that is not acceptable. The most vital consideration in HIRARC is whether the control measure that is implemented is adequate in minimizing the hazard that is posing a risk to as a significant OSH threat. Hence, actions taken to improvise the HSE management system should be done by the employer and their employees by continuously and consistently reviewing their preventive action plans.

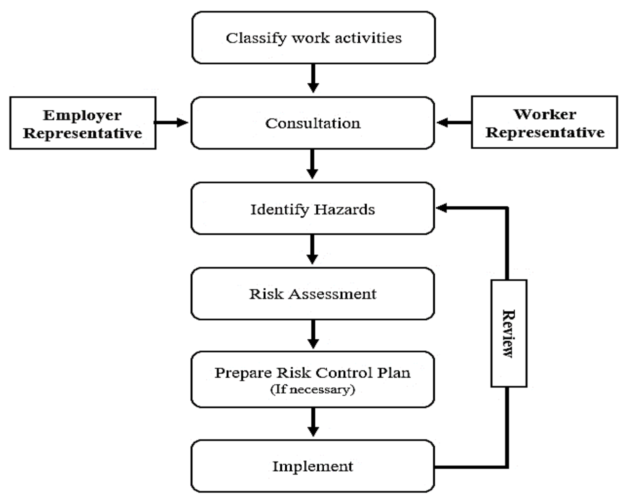

Figure 2: Flowchart for HIRARC process (DOSH, 2008)

2.1 Hazard Identification

Hazard identification can be defined as the process of determining if something, such as a condition, state, practice, or behavior, has the possibility of causing harm or destruction as well as impairment, illness, death, environmental damage, and damage to property and equipment. In addition, this process also requires each work area and work task to be investigated and analyzed persistently and periodically to recognize all related hazards and risks. A study was done by Saedi et al. [28] that suggest investigating any accident or incident at the workplace in order to find out the related factors that contribute to the unsafe condition. The author also highlighted that apart from investigation, there are other steps that need to be taken for hazard identification such as making a hazard identification checklist, carrying out workplace inspections and observation, doing job safety analysis or task hazard analysis, etc. Hazards can be classified into 3 main categories which are health hazards, safety hazards, and environmental hazards.

2.2 Risk Assessment

Assessing risk involves evaluating the level of risks to be considered for controlling risks that currently exists as well as potential risks. Risk evaluation is to be calculated with the likelihood that of hazardous incidents occurring within a period and under the circumstances of injury severity or damage (Table 1 and Table 2) based on the guidelines [26] for the OSH management system.

Table 1: Indication of Occurrence Likelihood, L (DOSH, 2008)

Likelihood	Example	Rating
Most Probably	Most probably the hazard happened	5
Possible	Not uncommon but potential to happen	4
Conceivable	Capable of happening in the near future	3
Unlikely	Not known to occur after many years	2
Improbable	Never happened and almost impossible	1

Table 2: Severity Implication, S (DOSH, 2008)

Severity	Example	Rating
Disastrous	Many casualties, property destruction cannot be restored	5
Lethal	Major property damage with single fatality	4
Serious	Permanent impairment but no deadly injury	3
Insignificant	Disables but not lasting defects	2
Trivial	Minimal blisters, cuts, swelling, wounds, first aid injuries	1

Table 3: Risk Matrix (DOSH, 2008)

	Severity (S)				
Likelihood (L)	**1**	**2**	**3**	**4**	**5**
5	**5**	**10**	**15**	**20**	**25**
4	**4**	**8**	**12**	**16**	**20**
3	**3**	**6**	**9**	**12**	**15**
2	**2**	**4**	**6**	**8**	**10**
1	**1**	**2**	**3**	**4**	**5**

High **Medium** **Low**

The exposure levels such as the number of people who may be exposed to the risk can be considered when necessary and higher scores indicate a higher risk level. The degree of possible severity and the probability of the event happening are measured in order to prioritize the identified hazards and this is known as qualitative analysis. HIRARC will be used with the additional support of the risk matrix as shown in Table 3 [26]. This can be used in various ways in response to the results of the qualitative analysis to decide on the control of risks by selecting the necessary control measures.

The combination of likelihood (L) and severity (S) can determine the risk assessment as the calculation of risks can be formulated as L X S is equal to the risk matrix as shown in Table 3 where the results are presented in an effective way to enable communication between all levels of workers. The results for relative risk as shown in Table 4 are very important because it will have different consequences by influencing the management's response and the reporting required in order when addressing the control measure properly. A study done by Ahmad et al. [26], also suggested highlighting the critical operations of work that pose significant risks to a worker's OSH. This author also highlighted that depending on the level of risk that represents and is assigned to the existing or potential hazard, it is necessary for corrective and precautionary actions to be taken to eliminate or at least minimize the risk. A cumulative of potential risk can be considered as the chance of it actually happening to someone, and this can be evaluated by calculating the likelihood of occurrence and severity of the hazard.

Table 4: Relative risk (DOSH, 2008)

Risk	Description	Action
15-25	**High**	Demand prompt action to be taken sufficiently based on control hierarchy as level of risk is high
5-12	**Medium**	Planning is needed for medium risk level in controlling hazard and applying temporary prevention if needed
1-4	**Low**	Considered as acceptable and no further action to be taken because of low risk level

2.3 Control Measures

Hazards should be controlled in such a manner as to eliminate or minimize risks that pose a threat to OSH by controlling them at their source. When selecting a suitable control measure, there should be an evaluation of the selection for short-term or long-term control when reasonably practicable. The selection of control measures such as elimination, substitution, engineering control, administrative control and personal protective equipment (PPE) should be able to control the hazard at its source.

2.4 Monitoring and Review

By identifying, analyzing and coming up with a mitigation plan for risk control, the potential of a risk causing a severe impact on workers can be eliminated. In order to achieve effective implementation of a control measure, regular checks should be done during inspection and maintenance must be continuously evaluated. Monitoring and review can help to evaluate if the control measure is sufficient and adequate to solve the problem with significant risks, identify if there any hazards arising or if other measures are needed.

3 Results and discussion

The risk assessments that were conducted for abrasive blasting operations at the pressure vessel fabrication plant using HIRARC are summarized in Table 5. The related specific hazards are arranged from ones with the highest risk scores to the lowest risk scores. They are classified into different types of hazards based on three main categories, which are safety hazards, health hazards, and environmental hazards.

Table 5: Risk Scores for Abrasive Blasting Operational

No	Hazards	Risk Scores	Hazard Types
1	Respiratory illness and inhalation of airborne contaminants	16 (High)	Health
2	Working at heights	12 (Medium)	Safety
3	Confined spaces	12 (Medium)	Safety
4	Extreme noise	12 (Medium)	Health
5	Manual handling (Ergonomics)	12 (Medium)	Health
6	Particulate matter	9 (Medium)	Health
7	Explosion	8 (Medium)	Safety
8	Vibration	6 (Medium)	Health
9	Vision impairment	4 (Low)	Health
10	Electrical shock	4 (Low)	Safety
11	Skin irritation	4 (Low)	Health
12	Pollution (Air emission and waste)	4 (Low)	Environment
13	Extreme heat	4 (Low)	Health
14	Slips, trips and falls	4 (Low)	Safety
15	Equipment failures	4 (Low)	Safety
16	Psychological	2 (Low)	Health

Based on Table 5, the occupational hazards were categorized into three main groups which are safety hazards, health hazards, and environmental hazards where at least sixteen types of major hazards associated with abrasive blasting operations were identified thoroughly. Foreseeable hazards that have potential risks to occupational health are respiratory illnesses and inhalation of airborne contaminants, working at heights, confined spaces, extreme noise, manual handling (ergonomics), particulate matter, explosion, vibration, vision impairment, electrical shock, skin irritation, pollution (air emission and waste), extreme heat, slips, trips and falls, equipment failures and psychological risks. A comparison was made between potential occupational hazards obtained from the HIRARC study and control measures that currently exist in the SOP as illustrated in Fig. 3.

Based on Fig. 3, the control measures existing in the current SOP such as providing lifelines, air ventilation, and harness, timing blasting activity to be done when PTW has been issued by HSE, installing fully functional dead-man valve to hose and so on are obviously inadequate to remove or reduce all sixteen major hazards identified during abrasive blasting operations.

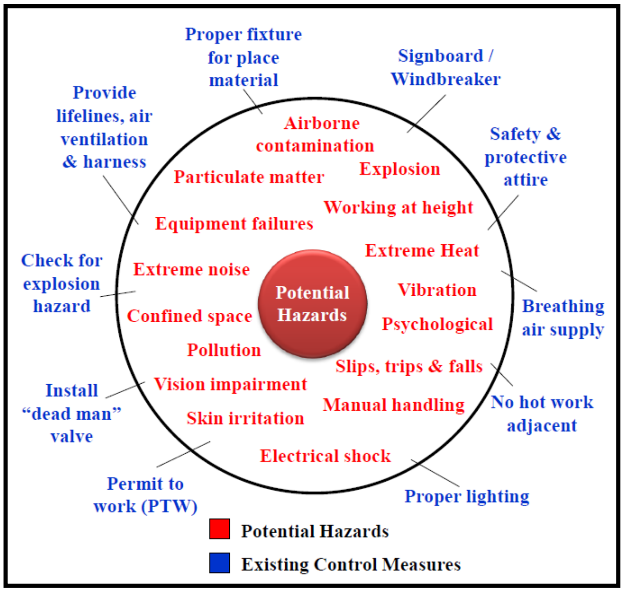

Figure 3: Comparison between potential hazards and existing control measures

Further action to provide additional prevention is essential to ensure a safe workplace for abrasive blasting activities. In addition, the existing SOP only provide control measures that can cover three types of occupational hazards namely as respiratory illness and inhalation of airborne contaminants, confined space, and manual handling. But somehow these hazards still evidently fail to be identified adequately enough to fully cover all possible control measures for related hazards and risks to achieve standards of safer practice that is required to manage OSH issues sufficiently.

Meanwhile, the percentages of related main hazards are presented in Fig. 4, where occupational health is the highest percentage with 56.25% which is 9 times higher compared to environment hazards and almost 2 times higher compared to safety hazards. This is followed by safety hazards at 37.5% and the lowest percentage at 6.25% is contributed by environment hazards. Thus, it indicates that almost more than half of the occupational hazards from abrasive blasting operations in fabrication plants can contribute to various types of occupational health issues. Examples of the related occupational health hazards for abrasive blasting operations are respiratory illness and inhalation of airborne contaminants, extreme noise, manual handling, particulate matter, vibration, vision impairment, skin irritation, extreme heat, and psychological risks.

In addition, the only hazard that requires immediate action for control measures to eliminate or minimize the risk is respiratory illness and inhalation of airborne contaminants that scores 16 for high risks and contribute to 6.25% as shown in Fig. 5. As the risk of respiratory illness and inhalation of airborne contaminants is categorized as high-risk based on HIRARC, an employer has the responsibility of taking immediate action and implementing adequate corrective or preventive measures to eliminate or minimize any related hazard that poses a significant threat to employees who are working in abrasive blasting.

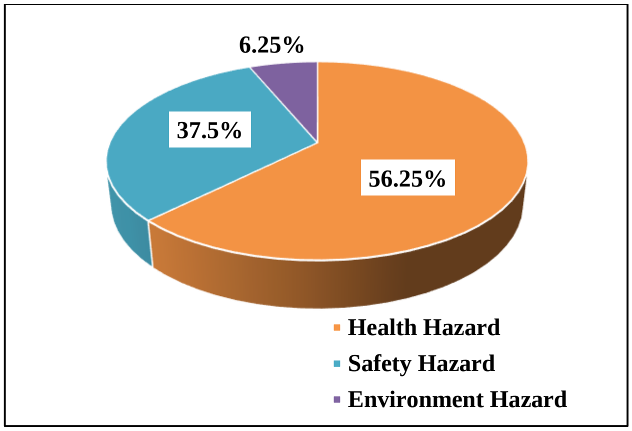

Figure 4: Percentages of the main hazards of abrasive blasting in the fabrication plant

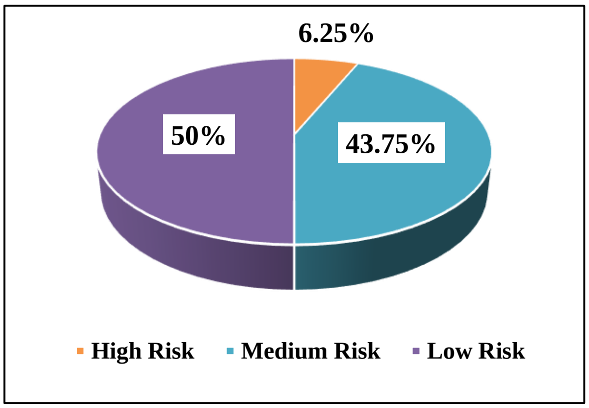

Figure 5: Percentages for risk scores of abrasive blasting in the fabrication plant

Moreover, a medium risk requires controlling the hazards by a planned approach and temporary measures are to be applied at 43.75% with scores of 12, 9, 8, and 6. The highest scores for medium risk are the hazards of working at heights, confined space, extreme noise, and manual handling. The rests have a score of 9, 8, and 6 rated for particulate matter, explosion, and vibration respectively. The rest of percentage indicates 50% for risk score of 4 for vision impairment, electrical shock, skin irritation, pollution of air emission and waste, extreme heat; slips, trips and falls, and equipment failures; while psychological risk was scored as 2. According to Fig. 6, the correlation of main hazards and risk scores at fabrication plants for operations of abrasive blasting shows that health hazards are the main threat to occupational hazards compared to safety hazards and environment hazards, where the only hazard that scored as high risk is the health hazard. Health hazards also contribute 57.14% of the medium-risk category and 50% of the low-risk category. This result proves that health hazards are the main threat to occupational safety if not addressed properly using control measures especially for those workers who are engaged with abrasive blasting operations in the fabrication plant. Meanwhile, for safety hazards had a result of 42.86% for medium risk and 37.5% for low risk but no risk rated as high was observed. Somehow, hazards related to the environmental indicate 12.5% for low risk only. Hazards rated as medium risk still require approaches to minimize the hazard in order to prevent any unsafe conditions at the workplace as hazards should be contained from its origin or source. Once the hazard was ranked, preventive measures such as elimination, substitution, engineering control, administrative control and PPE should be implemented accordingly based on reasonable, practical actions to eliminate or minimize the occupational risk.

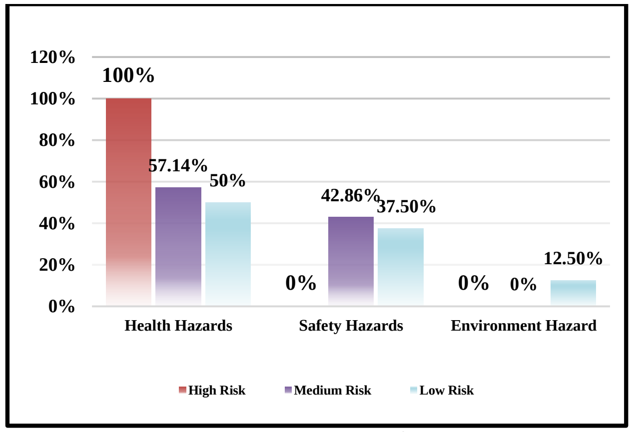

Figure 6: Correlation between main types of hazards and risk scores

3.1 Control Measures

The hazards and risks involving occupational safety, health and environment for abrasive blasting operations in fabrication plants have been identified and assessed accordingly using the HIRARC method. Any control measures for existing and arising hazards associated with abrasive blasting operations that had not been addressed properly and sufficiently in the existing SOP were approached for sufficient improvements. The prevention action measures for controlling the hazards and risks accordingly are as per the following: -

3.1.1 Respiratory illness and Inhalation of Airborne Contaminants (High Risk)

Even though abrasive blasting cannot be eliminated as surfaces need to be cleaned prior to painting, the risks can still be controlled by substitute methods such as using less hazardous abrasive media or using abrasive media that generates less dust by checking the concentration of impurities on the Material Safety Data Sheet (MSDS) such as chilled iron steel grit, sodium bicarbonate blasting and reusable sponge abrasives. It can also be substituted by different surface preparation techniques such as wet abrasive blasting, high pressure water jetting, centrifugal wheel blasting and dry ice blast cleaning. For smaller jobs that do not require a high-level of surface preparation, alternative techniques can be considered such as chemical strippers, heat gun, power tools, and manual scraping. When it is practical to do so, abrasive blasting should be carried out using a blasting cabinet or blasting chamber as an isolation method to eliminate or reduce the hazards of airborne contamination. Nevertheless, both blasting cabinets and blasting chambers are not practical if the product that fabricates it is larger. In this case, using temporary enclosures by means of curtains or sheeting is the best option when the object to be blasted not possible or too large to be transported to where it can help dust and airborne contamination from spreading. On the other hand, when using temporary enclosures for abrasive blasting operations, they must be equipped with dust collection systems and exhaust ventilation.

Administrative control can also help reduce the threat of inhaling airborne contaminants by establishing an exclusion zone to protect workers and other people in the vicinity with proper warning signs. The size of exclusion zone should be determined to be sufficient enough to protect workers in the vicinity especially those who are not wearing respiratory protective equipment appropriate for abrasive blasting operations. Moreover, they can also establish a rotation system for work related to abrasive blasting; schedule or shift blasting activity to outside normal hours or alternatively by stopping and clearing away other workers while abrasive blasting is taking place. Another administrative control would be to limit access to the abrasive blaster for only authorized and appropriately trained personnel who can cease or control abrasive blasting in windy conditions, as this increases chances of minimizing airborne contamination. Depending on the levels of airborne contaminants, the employer can establish medical surveillance and conduct periodical health monitoring of their workers using chest X-rays, pulmonary function testing and yearly tuberculosis assessments to ensure their health status is within safe levels. It is also vital to establish and conduct periodical biological monitoring to measure their blood levels to ensure it is within safe limits compared to the employee's medical history.

In addition, it is important to establish and conduct safety campaigns to increase the level of awareness of workers associated with hazards and risks of abrasive blasting operations. Safety campaigns do not necessarily focus on the threat of inhalation and respiratory inhalation of airborne contaminant, but it can be the main issue of OSH. This is because the purpose of a safety campaign is to promote positive fundamentals as a guide for better OSH culture and the values of a positive safety culture can be improved by behaviour through leadership and involvement of workers. It can help to deliver motivation to improve their safety culture and as well as introduce elements that are required to improvise a positive culture. Lastly, a control measure that would help prevent the harms of airborne contaminants from abrasive blasting operations is PPE. Workers who are engaged in abrasive blasting as blasters should be supplied with and wear respiratory protection with airline positive pressure hoods and protective suits that have shoulder capes with high visibility. When using the respirator helmet, the helmet should be fitted with an inner bib and supplied with breathing air of an adequate quality. Concurrently, an air purifying respirator should be used by the pot attendants or workers within the vicinity of abrasive blasting operations. In order to keep out the dust, the PPE worn should be of the leather type with elastic straps at the wrist and ankles as well as overlapping flaps at all closures of the suit. If the disposable clothing type is used, clothing should be appropriately disposed after use. There should be daily or periodical cleaning, inspection, testing and maintenance of PPE especially on the breathing air quality in order to identify any worn or defective component so that it can be repaired and replaced immediately.

3.1.2 Working at Heights (Medium Risk)

Abrasive blasting operations in the pressure vessel can be up to 8 meters of height from the ground and it is not an easy task to complete as scaffolding needs to be erected around the workplace area and the temporary enclosure that needs to be covered. Working at heights of more than 10 feet can result in serious impact injuries or fatalities especially when using steel framework. For instance, avoiding heights whenever possible and doing work as much as possible from the ground using extended tools or equipment because the risks of working at heights is that it can result in injuries to the neck or spine, leading to permanent disability or paralysis and multiple fractures, apart from fatalities. In case the abrasive blasting operational need to be performed at height, some control measures should to be implemented. For example, the structure of scaffolding must be rigid and strong. Use substitute methods by using only material from steel tubes with the coupler to replace main frame types. Replace steel tubes with aluminium tubes which are 3 times lighter to reduce the burden during erection and installation but maintain almost the same strength as normal steel.

Implementing engineering control can reduce risk factors by having competent personnel to assemble and qualified personnel with knowledge and skills to do an inspection after assembling is done. These competent and qualified personnel can ensure that scaffolding is installed in a proper way which is fit to be used. Regular inspection, testing, and maintenance for the material condition for wear and corrosion is necessary and once its condition is not fit for service, it must be replaced immediately. A good design is also vital when working at heights so that the strength and stability of the material can serve and withstand its purposes.

Establishing tags after an inspection is essential for evidence and as information for the other workers to understand whether it is safe or not for them to start work. The green tag would signal that it safe to use and red tag would mean that it is unsafe to work or not ready to be used. Placing signs wherever visible for workers can also be another administrative effort because when working at height, there is also the risk of falling objects or materials. The level of awareness of employees associated with hazard and risk of working at height during abrasive blasting operations is also important, thus the employer should establish and conduct training and briefing for working at heights for workers to increase their level of awareness, establish emergency and rescue plans and establish a permit to work (PTW) for any activity related to working at height. The last defence in preventing falls while working at heights is PPE where only compliant falling protection is used and regularly inspected to be calibrated and be fit for services. Any findings such as damage or wear and tear should be reported and replaced immediately.

3.1.3 Confined Space (Medium Risk)

Working in a confined space is not necessarily done for all abrasive blasting operations of internal pressure vessels considering that sometimes the project requirements do not involve surface preparation and painting works. But if entering a confined space in the pressure vessel cannot be avoided, a safe system to work in the confined space should be implemented. There should be an isolation area to establish a barrier and barricade. Only the related workers will be entering the confined space with isolated area from a power source and all movable parts should be locked (Lockout and Tagout - LOTO). The levels of oxygen and airborne contaminants can significantly impact the risks of working in a confined space. Thus, the air quality inside the confined space should be tested by qualified personnel before any first entry worker can start working in the confined space. In addition, these qualified personnel should continuously monitor the air quality periodically. Using a mechanical ventilation system would dilute any potential toxic gases and providing sufficient lighting to improve vision would be ideal because working in a confined space will result in vision impairment.

An implementation by administrative control would be to develop a permit to work (PTW) before abrasive blasting can be started with a designated authorized entrant (AE) and a standby person (SP) during confined space activity. Maintain effective communication between SP and AE at all times. Additionally, in case of emergencies while working in confined spaces, employers should develop and establish documents for confined space emergency and response plans that provides training and briefing about working in confined space. A safety campaign should be conducted in order to increase the levels of workers awareness about response during an emergency. Moreover, signage with clear information should be placed at confined space areas to alert workers in the vicinity and provide the confined space attendant (CSA) with details about those entering confined space work areas such as names, time entered, time out, etc.; where the badge of the person entering is to be left at the entrance before entering and recollected after coming out as a way of tracking the people who are working in the confined space. Lastly for administrative effort, conduct pulmonary function tests in all workers who will be working in a confined space to ensure they are fit to work.

Wearing PPE for working in confined space is essential as well as ensuring safe levels of oxygen and safe levels of airborne contaminants. Proper PPE should be provided and worn in all situations including a compliant respirator and breathing apparatus, full body harness, protective clothing, head protection, eye and face protection and lifeline. Employers also need to provide equipment and tools for emergencies and response situations such as self-contained breathing apparatus (SCBA), while maintaining all equipment and tools for confined space in good shape and condition.

3.1.4 Extreme Noise (Medium Risk)

Abrasive blasting operations can generate various high noise levels that exceed the standard of noise and may cause permanent hearing loss when exposed to workers that engage with abrasive blasting especially the blaster. People who are working in the vicinity also may cause gradually experience hearing loss over a period of time. The impact of risk from extreme noise can be minimized by isolating other unprotected workers who are not wearing any hearing protectors from the source of noise by using barriers or enclosures. Using engineering control can be done in the blasting chamber if possible. If it cannot be done, they have to reduce the amount of pressure used during blasting, fit silencers to compress the air exhaust and air blowing nozzle, and also improve their mufflers and silencer systems. The noise that is generated from blasting equipment also can be reduced by regular maintenance and inspection of equipment periodically. Scheduling time for performing abrasive blasting out of normal working hours will minimize the noise exposure to other workers and using a rotation system for work or working in shifts to minimize exposure of noise to the abrasive blaster can help to minimize the risk of noise exposure from an administrative effort. It also can be done by limiting the time workers spend in noisy areas. Noise sources are not only generated from the air supply inside the operator helmet but can originate from the impact of abrasive media on the surface blasted, the noise of abrasive media being discharged from the blasting nozzle, noise from an air compressor and noise from the exhaust of the ventilation system. Thus, unprotected workers who are working in the vicinity of abrasive blasting operations should be limited to noise exposure. Whenever abrasive blasting operations are taking place, signage should be placed at noisy areas where the exceeded permissible exposure limit (PEL) may cause temporary loss of hearing, deafness from prolonged noise exposure and tinnitus. The hearing of each employee should be subjected to an audiometric test for exposure monitoring during hiring and audiometric monitoring and testing should be provided at intervals at least annually. Personal hearing protectors can be used such as hearing protective helmets, ear plugs, ear canal caps, earmuffs, etc by related workers and only use compliant types of ear protection based on the level of noise exposure as well as regular maintenance of hearing protection for damage and wear and tear.

3.1.5 Manual Handling - Ergonomics (Medium Risk)

The nature of the working position during abrasive blasting operations require workers to perform difficult and awkward positions for long durations of time such as bending their legs, raising their upper arm more than 90°, rotating their wrists, etc. where these postural will introduce stress in the certain parts of body and may result in Musculoskeletal Disorder (MSDs) problems.

Some control measures can be implemented to reduce the risk of MSDs include purchasing the abrasive media in a smaller bag that requires less energy to lift and using a bulk storage hopper to refill the blasting pot. Other control measures include using engineering control such as redesigning a workplace to minimize the amount of energy required to perform a task and reducing intrusions and distances for material and equipment to be moved. Another effort that can be implemented is placing abrasive blasting media, blasting equipment and tools close to trolleys, overhead cranes, hoists, forklifts or any mechanical means that can help to perform a task. Risks can be reduced by providing a flag point for the maximum weight that can be performed by a person in a range is safe without the risk of back injury, providing training and educating the workers about the safe limit and lifting techniques for working in manual handling especially in awkward, twisting and bending positions. Lastly, another administrative control is job rotation or frequent rest to minimize the amount of repetitive movements.

3.1.6 Particulate Matter (Medium Risk)

Employees are at risk during abrasive blasting operations where a small piece or particle from abrasive mediums or material being blasted can cause death or common injuries such as severe lacerations, skin penetration, eye damage and burns. The risk of particulate matter is increased when the activity is carried out in a confined space and performed in an elevated place and position. In order to minimize the risk of particulate matters, isolate other workers while abrasive blasting activity is taking place or schedule the activity out of normal working hours. Stop the activity when the direction of an abrasive stream cannot be controlled in a windy state and only allow appropriate highly trained and skilled abrasive blasters to do the job. Abrasive blasting activities also can be done using blasting chambers if practical or temporary enclosures integrated with a guard to reduce the potential of hitting the abrasive blaster and other workers. In order to able stop the flow immediately or cut-off abrasive media, abrasive blasting equipment must be fitted with an instant self-actuator. Implementation of administrative control such as placing signage at abrasive blasting areas to remind of the dangers of particulate matter, and always remind workers that the nozzle should only be pointed at work all the time and provide abrasive blasters with sufficient training. An employer also should provide compliant and suitable PPE to protect against high velocity flying abrasive particles such as eye protection, protective footwear, gloves and clothing, and maintain all PPE and tools in good shape and condition.

3.1.7 Vibration (Medium Risk)

Abrasive media in high-pressure force when discharged from the blast hose will spread vibrations to the blaster's hands and arms. Continuous and extended long exposure may lead to the condition of white finger or dead finger. In order to minimize the risk of vibration exposure to the blaster, engineering control can be implemented by using vibration isolating handles on blasting nozzles. Limit or use job rotations by minimizing the amount of time that a blaster is needed to operate a blast nozzle, regular inspection and maintenance of related equipment can help to minimize the level of vibration, and employers should provide anti-vibration and shock dampening types of work gloves to reduce vibration exposure.

3.1.8 Explosion (Medium Risk)

Explosions during abrasive blasting operations are very rare and exceptional but can occur when in contact with any sources of ignition such as open fires, static electricity or sparks. In some cases, it can occur from a cloud of dust from abrasive medium being used in a closed area. Prevention measures can be applied by minimizing the quantity of dangerous substances and ignition sources at the abrasive blasting areas, always using a dust collector to minimize dust clouds, and keeping ventilation system to produce sufficient air flow in the direction of extraction. Administrative control can help to provide training and safety campaigns to increase the level of workers awareness and employers should develop and establish documents and procedures for explosions or fire emergencies and response plans by providing proper fire or explosion suppression relief equipment at any time.

3.2 Comparison between the Improved SOP and Existing SOP

Based on the earlier discussion about the existing SOP for abrasive blasting operations, it is clear that a new SOP is needed to establish and improve the effectiveness of control measure program. The HIRARC study shows that there are at least sixteen major occupational hazards associated with abrasive blasting operations that need to be addressed properly through counter measures to ensure safer practices at the workplace for employees, while the existing SOP only identified three hazardous conditions of abrasive blasting namely respiratory inhalation of airborne contaminants, confined space and manual handling. Nevertheless, the prevention measures instructions for those identified hazards in the existing SOP are still insufficient to eliminate and minimize the hazards and risks that may potentially cause occupational illness or injury. In contrast, the HIRARC study helped to recognize and rank the hazards to prioritize based on the level of risks that may pose a significant impact to OSH and the effectiveness of any program of controlling the hazards or control measures is subject to the risk level and adequately recognizing the hazard as shown Appendix A. Appendix A shows the comparison between the improved SOP and existing SOP for abrasive blasting operations. The evaluation has shown that the existing SOP was clearly insufficient to ensure safety at the workplace because the preventive measures were inadequate and ineffective in controlling associated hazards. For example, in order to eliminate or minimize the hazards of respiratory illness and inhalation of airborne contaminants, the action of having a rotation system for workers by scheduling or shifting abrasive blasting activity outside of normal hours can help to reduce the risk posed by toxic dust towards workers. Another example would be to conduct periodical health monitoring in workers and periodical biological monitoring to measure workers blood levels, but somehow the existing SOP provides instruction and direction that are too minimal to be control measures. In addition, the existing SOP also failed to identify related hazards other than respiratory illness and inhalation of airborne contaminants, confined space and manual handling. Thus, the improved SOP that is obtained from the HIRARC study is more consistently relevant and applicable. The appropriate documentation needs to be amended to propose an improved SOP for with abrasive blasting operations.

4 Conclusion

One of the factors that contribute to workplace incidents, either occupational injuries or illnesses, is the failure to recognize or identify the existing hazards during an activity or operation. Generally, the identification of hazards imply that a risk assessment has been performed. The main purpose of performing a risk assessment in this study is to implement the necessary control measures effectively and adequately for OSH protection in abrasive blasting operations at pressure vessel fabrication plants. The hazards associated with abrasive blasting in a pressure vessel fabrication plant were identified based on HIRARC techniques and were separated into three main groups which are safety hazards, health hazards, and environmental hazards. At least sixteen types of major hazards associated with abrasive blasting operations had potential risks to occupational health, including respiratory illness and inhalation of airborne contaminants, working at heights, confined space, extreme noise, manual handling (ergonomics), particulate matter, explosion, vibration, vision impairment, electrical shock, skin irritation, pollution (air emission and waste), extreme heat, slips, trips and falls, equipment failures and psychological risks.

As prevention measures in the existing SOP are unable to eliminate and diminish the hazards and risks that may potentially cause occupational illnesses or injuries, HIRARC aids to distinguish and rank the hazards to prioritize them based on the level of risk that it poses and the significance of its influence on OSH. Correction actions are then prioritized based on information about of risk levels, the likelihood of occurrences and the severity of hazards. High levels of risk require immediate action to implement control measures that are reasonably practical to prevent workers from being exposed to the risk. While for medium risks such as working at heights, confined space, extreme noise, manual handling, etc., controlling the hazards require planning and if required, a temporary measure can be applied. When a hazard is ranked as low risk, it can be assumed as acceptable and no further action is necessary.

For comparison, the existing SOP only identified three potential occupational hazards which are respiratory illness and inhalation of airborne contaminants, confined space and manual handling. It is clearly inadequate in providing safer work practices to workers. Furthermore, the existing SOP failed to provide guidelines and directions for hazard control for at least five types of hazards which were ranked as medium risk such as working at heights, extreme noise, particulate matter, explosion, and vibration. Nevertheless, the application of PPE as the only preventive measure to prevent OSH risks is not enough. As a matter of fact, the risk of respiratory illness and inhalation of airborne contaminants should be controlled from its source which is toxic dust. For example, the sources of airborne contamination can be controlled by using less hazardous abrasive mediums, using abrasive mediums that generate less dust, conducting blasting activity using different techniques than abrasive mediums such as wet abrasive blasting, dry ice blasting and high pressure water jetting, as well as having a dust collection system together with exhaust ventilation during blasting activities.

In conclusion, a proposal to improve current SOP associated with abrasive blasting operations is suggested and it can be a guideline for establishing a safer working environment by preventing or minimizing the risks to OSH at the workplace. A proposal to improve current SOP associated with abrasive blasting operations is compulsory as current control measures in the existing SOP are clearly insufficient to eliminate and minimize occupational hazards in a comprehensive manner. The improved SOP that was accomplished from the HIRARC study is more reliable and can be a guideline for a safer working environment by preventing or minimizing the risks to OSH at the workplace. Somehow, the implementation of these control efforts and actions demand full support and commitment from the management. In demonstrating a commitment, the employer should actively get involved in health and safety issues, invest time and money in managing obligations for safer practices at the workplace and clearly understand the responsibility of the management in safety and health issues. Nevertheless, the new and improved SOP must be regularly reviewed to ensure effectiveness by the management such as accountability for safety and health being clearly and sufficiently allocated. To ensure that the related procedures are followed, maintained, reviewed, and analysed when any OSH injury or illness occurs, before any changes of work procedure, it needs to be proven and justified to show that the available control measures indicate that it may no longer be effective and relevant.

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Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing

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Appendix A: Comparison of Improved SOP and Existing SOP

No	Potential and Level of Hazards	Improved SOP	Existing SOP	Control Measures	
				Improved SOP	**Existing SOP**
1	Respiratory illness and Inhalation of Airborne Contaminants - High Risk	✓	✓	**1. Substitute** - Using less hazardous abrasive media that generates less dust. Using different surface preparation techniques such as wet abrasive blasting, high pressure water jetting, centrifugal blasting and dry ice blast cleaning. **2. Isolation** - Using blasting cabinets/chambers, temporary enclosures **3. Engineering Control** - Equipped with dust collection systems, using exhaust ventilation, and using sheeting when there is a risk of dust spreading.	**1.Engineering Control** - Dead-man valve should be installed to hose and functioning **2.Administrative Control** -Adequate signboards and windbreaker to be placed at a vicinity of blasting location. - No blasting activity without PTW issued by HSE
1	Respiratory illness and Inhalation of Airborne Contaminants - High Risk (continue)	✓	✓	**4. Administrative Control** - Exclusion zones (buffer zones) to protect workers and other persons in close proximity with proper warning signage. - Establish a rotation system for workers related to abrasive blasting by scheduling/shifting blasting activity outside normal hours. Stopping abrasive blasting when conditions are windy, clearing adjacent workers while abrasive blasting is taking place, and only authorized and appropriately trained abrasive blasters can work - Establish and conduct periodical health monitoring in workers and periodical biological monitoring to measure blood levels to ensure safety -Establish and conduct safety campaigns to increase level of awareness of workers **5. PPE** - Using respiratory protection with airline supplied and positive pressure respirator and respiratory helmet supplied with breathing air of adequate quality and with inner bib - A pot attendant and vicinity worker shall use protection from air purifying respirator type. - Wear protective suits/ clothing to keep out dust and the clothing should be appropriately disposed after use (disposable type). - Daily/ periodical cleaning, inspection, testing and maintenance of PPE especially on the breathing air quality (respiratory equipment) in order to identify wear or damage and any worn or defective component to be repaired or replaced	**3. PPE** - Workers shall wear recommended PPE when working in the affected areas - Used only approved type of breathing air supply for blaster
2	Working at Height – Medium Risk	✓	**None**	**1. Elimination** - Avoid whenever possible by working from the ground or using extended tools or equipments **2. Substitute** - Only use material from steel tube with coupler to replace mainframe types and replace steel tubes with aluminum tubes (3 times lighter) **3. Engineering Control** - Have competent personnel assemble and qualified personnel with knowledge and skills to do inspection after assembling is done - Regular inspection, testing, and maintenance for material condition for wear and corrosion. - Redesign scaffolding that withstands its purpose	**None**
2	Working at Height – Medium Risk (continue)	✓	**None**	**4. Administrative Control** - Establish tags after inspection is done where green tag is safe to use and red tag is unsafe to work or not ready to be used. - Place signage whenever visible to worker s - Establish and conduct safety campaigns to increase level of awareness of workers and give training and briefing for working at height to workers - Establish emergency and rescue plans and permit to work (PTW) **5. PPE** - Use only compliant falling protection and regularly inspect for calibration to ensure it is fit for service	**None**

No	Potential and Level of Hazards	Improved SOP	Existing SOP	Control Measures	
				Improved SOP	Existing SOP
3	Confined Space - Medium Risk	✓	✓	**1. Isolation** - Isolate area with established barrier/ barricade, only related workers will enter confined space and isolate from power source, lock all movable parts (Lockout and Tagout -LOTO) **2. Engineering control** - Dilute any potential toxic gases by using a mechanical ventilation system with air quality inside confined space to be tested by qualified personnel before first entry - Continuous monitoring of air quality periodically and improve visually by providing sufficient lighting **3. Administrative control** - Establish a permit to work (PTW) and establish an authorized person and standby person during confined space activity. - Establish related procedures for confined space emergency and response plan by providing training and briefing to workers in confined spaces and safety campaigns to increase levels of workers awareness - Signage to be placed at confined space areas and establish confined space attendant (CSA) for those entering confined space work areas and maintain an effective communication between the standby person and entry person all the time - Conduct pulmonary function tests on all workers who will be working in confined spaces to ensure they are fit **4. PPE** - Use a compliant respirator and breathing apparatus, full body harness, protective clothing, head protection, eye and face protection and lifeline. - Provide equipment for emergency and response situations such as SCBA. - Keep and maintain all equipment and tools for confined spaces in good shape and condition	**1. Engineering control** - Ensure all process lines are blanked off **2. Administrative control** Check for explosion hazards, toxic materials, adequate oxygen content, and provide proper lighting. - Before entry, provide lifelines, air ventilation, harness, and standby someone outside.
4	Extreme Noise - Medium Risk	✓	**None**	**1. Isolation** - Isolate other workers from the source of noise using barriers or enclosures **2. Engineering control** - Reduce the amount of pressure used during blasting by fitting silencers to compress air exhaust and air blowing nozzles and improving silencer system. - Regularly maintaining equipment **3. Administrative control** - Abrasive blasting operations can be done after normal working hours - Use rotation system for working in shifts to minimize exposure to noise for abrasive blasters and limit the time workers spend in noisy areas - Place signage at noisy areas which exceed PEL - Provide audiometric monitoring and testing periodically **4. PPE** - Using only compliant types of ear protection based on noise level exposure and maintaining hearing protection regularly.	**None**
5	Manual Handling (Ergonomics) - Medium Risk	✓	✓	**1. Substitution** - Order the abrasive media in smaller bags that use less force/energy to lift and use a bulk storage hopper to refill blasting pot **2. Engineering control** - Redesigning workplaces such that a minimum amount of force/energy is required to perform tasks and reduce intrusions/disturbances and distance for materials/equipments to be moved such as being close to trolleys, overhead cranes, hoists, forklifts, etc. **3. Administrative control** - Provide a flag point for a maximum weight range that is safe with job rotations or frequent rest breaks	**1. Engineering control** All material to be put on proper fixtures which should be 2 feet higher from the ground

No	Potential and Level of Hazards	Improved SOP	Existing SOP	Control Measures	
				Improved SOP	Existing SOP
				- Provide training and educate the workers about safe limits and lifting techniques for working in manual handling especially in awkward, twisting and bending positions.	
6	Particulate Matter – Medium Risk	✓	**None**	**1. Isolation** - Isolate other workplace activities using blasting chambers, temporary enclosures, exclusion zones, etc. - Stop/ isolate other workers while abrasive blasting is taking place and scheduling/ shifting blasting activity outside of normal hours. When in uncontrolled windy conditions, stop abrasive blasting - Only appropriate highly trained and skilled abrasive blasters can work	**None**
6	Particulate Matter – Medium Risk (continue)	✓	**None**	**2. Engineering control** - Use incorporate guards to reduce possibility of the particulate hitting the abrasive blaster/other workers. - Abrasive blasting must be fitted with fast acting self- actuating that permits immediate stop of abrasive flow. **3. Administrative control** - Place signage at abrasive blasting area - Nozzle only pointed at work all the time, and when in use, blast hoses must not be uncoiled. - Abrasive blaster must be provided with sufficient training **4. PPE** - Use compliant and suitable PPE to protect against high velocity flying abrasive particles such as eye protection, protective footwear, gloves and clothing. - Keep and maintain all PPE and tools in good shape and condition	**None**
7	Explosion – Medium Risk	✓	**None**	**1.Isolation** - Isolate and reduce the quantity of dangerous substances and ignition sources. **2.Engineering control** - Using dust collectors to minimize dust clouds and keep ventilation systems to produce sufficient air flow in the direction of extraction - Fully enclosed area to prevent source of ignition **3.Administrative control** - Provide explosion/fire suppression relief equipment - Develop and establish document/procedure for explosion/fire emergency and response plan and provide training and safety campaign	**None**
8	Vibration – Medium Risk	✓	**None**	**1. Engineering control** - Using vibration isolating handles on blasting nozzles or with support in order to reduce vibration exposure. **2. Administrative control** - Job rotation by minimizing the amount of time an abrasive blaster is required to operate a blast nozzle. - Levels of vibration can be minimized by regularly inspecting and maintaining related equipment **3. PPE** - Using anti vibration and shock dampening work gloves to reduce vibration exposure	**None**
9	Vision Impairment – Low Risk	✓	**None**	**1. Engineering control** - Keep ventilation systems in order to produce sufficient air flow so that it can minimize clouds of dust using dust collection and keep lighting system sufficient **2. PPE** - Replace vision glass when it becomes scratched from abrasive impact, using the mylar film type instead of normal vision glass	**None**

No	Potential and Level of Hazards	Improved SOP	Existing SOP	Control Measures	
				Improved SOP	Existing SOP
10	Electrical Shock – Low Risk	✓	**None**	**1. Isolation** - Isolate from power source, lock all movable parts (Lockout and Tagout -LOTO) **2. Engineering control** - Static electricity charge from the blast nozzle can be removed by grounding object that being blasted - Electrical supply and installation must be comply with relevant standards **3. Administrative control** - Place signage or posters to alert to dangers of electrical shocks to humans and hiring competent and qualified electricians	**None**
11	Pollution – Low Risk	✓	**None**	**1. Substitute** - Change to different surface preparation techniques such as wet abrasive blasting, high pressure water jetting, and dry ice blast cleaning that can eliminate or minimize level of dust **2. Engineering control** - Enclose the area to be blasted to minimize dust spreading such as in a blast chamber or by using sheets to avoid any dust from spreading and contaminating the surface of the ground and water - For wet abrasive blasting, setup a bund and containment system or use an appropriate drainage system - Avoid sweeping and hosing the floor surface with water after abrasive blasting operations are completed but use a vacuum cleaner for cleaning purpose. Equip with dust collection systems and exhaust systems for ventilation and incorporate warning devices in the filter arrangement to help alert if filters fail - Any element used for abrasive blasting operations such as abrasive media, filter cartridges, wastewater, and PPE should be treated as a waste and securely stored and disposed. **3. Administrative control** - Usage of proper signage to collect all used abrasive and other debris with securely storage for disposal purposes.	**None**
12	Pollution – Low Risk (continue)	✓	**None**	**3. Administrative control** - Keeping the doors closed for sufficient time after abrasive blasting operations stop in order to give time for residual dust to be completely collected by dust collector. - Label waste container clearly based on types of waste and keep at safe and convenient areas and keep records of abrasive media purchased and the total amount that is disposed - Establish and conduct safety campaigns to increase levels of awareness of workers associated with pollution - Establish and develop environmental management systems	**None**
12	Skin Irritation – Low Risk	✓	**None**	**1. Administrative control** - Provide decontamination facilities that allow abrasive blasters to shower after completing their work. - Increase level of workers knowledge about the importance of personal hygiene prior to eating and drinking. **2. PPE** - Using provided appropriate full PPE all the time while working as abrasive blaster to avoid contact directly with dust	**None**

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Potential and Level of Hazards</th><th rowspan="2">Improved SOP</th><th rowspan="2">Existing SOP</th><th colspan="2">Control Measures</th></tr>
<tr><th>Improved SOP</th><th>Existing SOP</th></tr>
<tr><td>13</td><td>Extreme Heat – Low Risk</td><td>✓</td><td>None</td><td>1. Engineering control
- Blast helmets to be fitted with air cooling device systems and keep ventilation systems producing fresh air flow to minimize radiant heat
2. Administrative control
- Provide periodical rest breaks in order to cool down the body temperature and prevent from dehydration
- Provide training related to risks and symptoms of heat stress
3. PPE
- Using suitable PPE clothing that can minimize the build-up of the heat and wearing cotton undergarments</td><td>None</td></tr>
<tr><td>14</td><td>Slips, Trips, and Falls – Low Risk</td><td>✓</td><td>None</td><td>1. Isolation
- Keep minimum number of workers, only person who actually performs a task is barricades area.
- Using a dust collector and having sufficient lighting system
2. Administrative control
- Keep workplace area clean and tidy from water or liquids on the ground with regular housekeeping and minimize number of sharp edges
- Keeping access way at workplace clear from any obstruction, keep hoses straight, and return any tools and equipment to initial places
3. PPE
- Always wearing a compliant PPE</td><td>None</td></tr>
<tr><td>15</td><td>Equipment Failures – Low Risk</td><td>✓</td><td>None</td><td>1. Engineering control
- Use valves with same ratings as safety relief valves to be installed at air compressor and air supply system and work below working pressure only
- Dead man control shall be fitted near blast nozzle as an automatic cut-off device and never modify, remove or substitute part by mean for free movement of control handle
- Only use hose with anti-static rubber types and always kept as straight as possible and use and fit hose with hose coupling safety locks
2. Administrative control
- Adequate maintenance of equipment with regular inspections, nozzle linings and thread must be checked for damage and wear and tear signs periodically
- Provide adequate training for blasters and establish safety campaign to increase levels of workers awareness
- Never point blasting nozzle towards a person but only to work object, should uncoil blast hoses during blasting
3. PPE
- Always wearing a compliance PPE</td><td>None</td></tr>
<tr><td>16</td><td>Psychological – Low Risk</td><td>✓</td><td>None</td><td>1. Engineering control
- Control access and work area design with video surveillance and alarm system
2. Administrative control
- Improve management policies to prevent any discrimination
- Limit working overtime and fatigue management and offer workers psychological counseling and help
- Enable training to improve work related skills by providing communication and additional support
- Adequate security and secure environment</td><td>None</td></tr>
</table>