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Assessment of safety control measures for centralized Chlorine gas system

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Abstract. As a glove manufacturing plant, the chemical is one of the most highly used materials. Some chemicals impact human health, environmental aspects, and physical hazards such as highly flammable gas. Chlorine gas is one of them. Besides the accidental release of chlorine gas incidents, ill-health issues are another aspect that should be taken care of. This study aims to determine the current chlorine concentration at a centralized chlorine gas manifold system in a rubber glove manufacturing plant and evaluate the existing safety control measures. A concept of safety by design, inherently safety, and the fail-safe system was considered during the study. The results show that the chlorine concentration level during drum replacement by the crew is at an average of 1.154 ppm and the standard deviation at 0.3478. The highest concentration was at 1.8 ppm. The wet scrubber assessment was done using the Industrial Ventilation and visual assessments and measurements within the system, including capture velocity, face velocity, and duct velocity or transport velocity. Other assessed parameters are total pressure, static pressure, and velocity pressure. The assessment found that the duct performance for all parameters complies with a minimum requirement of the American Conference of Governmental Industrial Hygienists (ACGIH) guidelines.

1. Introduction

Process operation for any organization is economical when it is inherently safer. All hazards able to mitigate the processes are known as basic safety. Inherently safer processes or operations also could be achieved by diminishing the hazards in the multi-component element during the design stage. The most challenging task for hazard reduction is during the design phases. The workers might be exposed to a single hazard and many hazards while performing ordinary work. Generally, the hazard can be classified as physical, electrical, chemical, biological, ergonomic, and psychological hazards [1]. Most of the manufacturing industry will have all those kinds of hazards. Generally, most of the activities concerning the glove-manufacturing process are highly involved in the chemical. Among those chemicals, chlorine gas is the most toxic used in operation.

Chlorine is highly irritating when inhaled and is standard toxic industrial gas causing tissue damage in the airways and an acute inflammatory response [2]. Chlorine solution for glove chlorination process generally can be produced either hydrochloric acid mixing with sodium hypochlorite or direct chlorine gas injected into a water bath or water feedline. The chlorination process is commonly used in latex dipped glove industries because it gives a smooth surface to reduced the friction between the glove and the hand while donning [3]. Generally, direct chlorine gas from a centralized chlorine gas manifold system is used for higher volume consumption. Chlorine is highly toxic and, if released accidentally, can kill or injure people in the vicinity of the storage tank [4]. Table 1 shows the chlorine properties. A chlorine release occurred during the loading and unloading operations and changing the chlorine drum during the glove chlorination process. Several recorded cases involve the incidental release of chlorine in the glove manufacturing plant in Malaysia. This incidence affected production activity, workforce losses due to emergency plant shut-down, and financial loss. Moreover, there are also reported accidents due to supply hose between chlorine gas cylinders to gas manifold failure, which was caused by poor installation after changing the cylinder.

Table 1. Chlorine properties [5].

Parameters	Range / Unit
CAS No	7782-50-5
Atomic weight	35.45
Chemical Formula	Cl_2
Melting point	-100.98°C
Boiling point	-34.05°C
Solubility in water	0.57g / 100g water
Odour detection	0.02 – 1.00ppm
Irritation	1 – 2 ppm
Eye irritation	1 – 3 ppm
Long term exposure with effect limited to minor changes in pulmonary function	0.01 - 1.4 ppm
Intolerance level	3 – 5 ppm
Immediate irritation of nose, throat, and eyes with cough and lachrymation	15 ppm
Immediate cough with a choking sensation and sense of constriction in the chest. Possibility of nausea and vomiting	30 ppm
Fatal level	50 ppm acute danger 400 ppm / 30 minute 1000 ppm / 5 minute

This research proposes the safety control measure for the centralized chlorine gas system in the rubber glove manufacturing industry. This study's more specific research objectives were to determine the current chlorine concentration at the centralized chlorine gas manifold system in the rubber glove manufacturing plant and evaluate the existing safety control measures.

2. Methodology

The operational framework of this study is started by determining the current chlorine concentration at a centralized chlorine gas manifold system in a rubber glove manufacturing plant. This includes chlorine exposure to the workers. Refer to Table 2 for research framework.

Table 2. Research Framework

RESEARCH OBJECTIVE	RESEARCH QUESTION	INSTRUMENT / TESTING POINT	SAMPLE / DURATION	DATA ANALYSIS
1. **To determine** the chlorine concentration at centralized chlorine gas system	1. What is the trend of chlorine concentration at centralized chlorine gas system which can lead to worker's exposure?	HYDRO chlorine gas sensor paired with SEFRAM DAS 220 data logger Testing point: chlorine room	Realtime monitoring, continous area monitoring for 1 month for each samle size.	Quantitative – numerical analysis : Std Dev, Avg, Mod and median.
2. To evaluate the existing safety control measures which available at centralized chlorine gas system at rubber glove manufacturing plant.	1. What is the safety control system currently available at centralized chlorine gas system in rubber gloves manufacturing plant?	Side inspection / walkthru evaluation	5 glove manufacturing plant	Qualitative – findings review
	2. How is the performance of wet scrubber system?	HYDRO chlorine gas sensor paired with SEFRAM DAS 220 data logger	5 sample group / system Data collection for 4 unit of scrubber. Sample taken during the scrubber running as normal operation	Quantitative – analysis for scrubber performance : capture velocity, face velocity transport velocity and for all pressue. Emission – stack analysis for scrubbing performance assessment
		Standard chlorine gas canister at 3 – 5 ppm concentration (to simulate the leakages)		
		Air flow meter – to measure capture & transport velocity (air flowrate)		
		Air emission / stack sampling		

After identifying and evaluating chlorine, the study focused on evaluating the existing safety control measures at a centralized chlorine gas manifold system (Figure 1) in a rubber glove manufacturing plant. A chlorine gas sensor was installed inside the chlorine room, incorporating a data logger. Real-time data was used to test the sample of air inside the room. All data of chlorine concentration inside the chlorine room, particularly during drum checking (daily task) and during drum replacement, was captured and analyzed. Data (chlorine concentration) was analyzed using statistical analysis, and the chlorine concentration that workers were exposed to while working was also measured. Chlorine concentrations were measured by a fixed chlorine gas detector near the landing valve or supply manifold header. Data was collected and recorded by a real-time recorder at the interval once every 10 seconds. Although the data is continuously logged by the data logger and plotted by the electronic chart, the chlorine data is analyzed when the crew is inside the room. The logged information was extracted by special software from the data bank. Statistical analysis was performed using Microsoft excel.

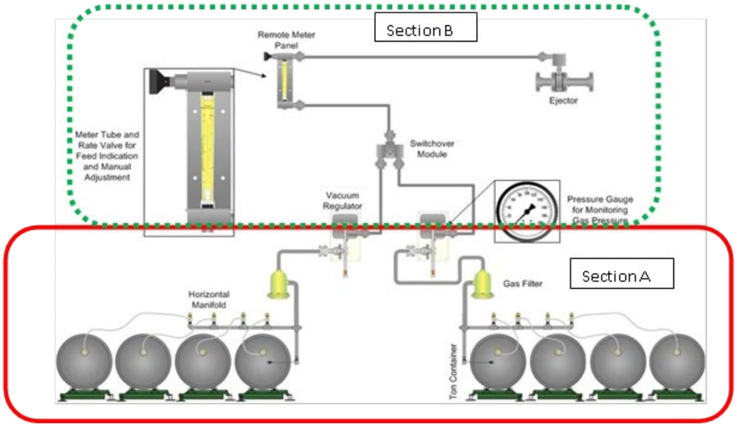


Figure 1. Typical Piping and Instrumentation Diagram (PID) for chlorine gas manifold system.

The data collected for the study were compiled from the monitoring data of chlorine gas concentration by using a chlorine gas detector with a data logger (Figure 2). To analyze the chlorine concentration, quantitative analysis was used. Chlorine gas sensor was used with a real-time data logger with a pre-set time interval of 10 seconds per reading for chlorine concentration (Model: HIOKI-LR 8431-20). Chlorine gas detector/sensors are calibrated to ensure the validity of the collected data.

Figure 2. HYDRO chlorine gas detector and Data Logger HIOKI-LR 8431-20.

This monitoring aims to determine the chlorine concentration that might be exposed to the chlorination operator while entering the chlorine room, particularly during cylinder or drum replacement. The study collected data from various chlorine gas installations from glove manufacturing plants that use chlorine gas for the glove treatment process. Preliminary data was collected from plant A (located at Rawang) – two (2) sets of chlorine gas bank and plant B (located at Kamunting Raya, Taiping) – two (2) sets of chlorine gas bank. All four gas banks use 930 kg chlorine drum capacity and have various capacities of the gas bank, from 6 drums per bank up to 14 drums per bank and using a centralized gas manifold system.

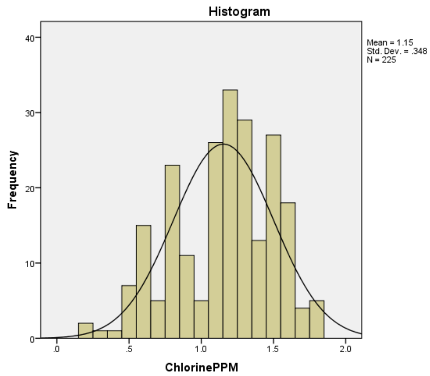
The chlorine concentration inside the chlorine room was assessed while the technical or production crew does the drum replacement. As a regular standard operation, the drum was replaced in the interval at once in 5 to 8 working days. The average time the crew spent inside the chlorine room is was also assessed and considered for the study. During drum replacement, the crew entered to chlorine room. All safety procedures such as entry permit until PPE compliance was complied with at all times before and during entering the chlorine room (Figure 3). Only trained and authorized crew was allowed to enter the room. The chlorine room was locked up all the time, and the access key was secured in the security control room.

Figure 3. Chlorine room and drum replacement in progress.

Before taking off the supply valve at the drum, the technical crew needs to close the landing valve to prevent the escape of chlorine gas. However, residual chlorine gas is left in the copper tube, which leads to free chlorine gas. The situation is becoming more severe in the event of the failure of the primary manifold valve. Chlorine concentrations were measured by a fixed chlorine gas detector near the landing valve or supply manifold header. The real-time recorder collected and recorded data at the interval once every 10 seconds. Although the data is continuously logged by the data logger and plotted by the electronic chart, in this study, the data of chlorine was analyzed when the crew was inside the room for drum replacement activities. The logged data was extracted by special software from the data bank.

3. Results and Discussion

From Figure 4, the analysis found that the crew's chlorine concentration level during drum replacement is at the average of 1.154 ppm and the standard deviation at 0.3478. The highest concentration was at 1.8 ppm. Based on schedule 1, Regulation 6 and 7, Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000, the eight-hour time-weighted average (TWA8) for the chlorine is 0.5 ppm. It shows that the workers are exposed to chlorine during drum replacement activities. Table 3 shows the safety control measures implemented by the rubber glove manufacturing plant.



Statistics

ChlorinePPM

N	Valid	225
	Missing	0
Mean		1.154
Std. Deviation		.3478
Minimum		.2
Maximum		1.8

Figure 4. Chlorine concentration analysis.

Table 3. Safety control measures for centralized chlorine gas system at rubber glove manufacturing.

Control System	Control Point	Basic Principle	Limitation	References
Wet Scrubber (Engineering control)	Chlorine room	Emergency response – to remove chlorine gas during leaking / accidental release inside chlorine room.	1. Highly dependent on pollutant concentration (Cl_2) 2. Efficiency may deteriorate over time and is very much dependent on the maintenance programs.	Bashir et al. (2012)
Specially designated room to install chlorine which away from the main workstation (Isolation)	Chlorine room	The chlorine room was installed in a specially designated area away from the main workstation and with proper arrangement.	Difficult for those who have limitations with space.	Flexidynamic (2018)
Alarm System (Administrative control)	Chlorine room, Security Control Center	Emergency response – to notify any chlorine gas detected beyond the limit (2.0 ppm within 20 sec consecutively).	Passive system. Only for notification or alert of any dangerous situation that occurs.	Flexidynamic (2018)
Auto Shut Off valve (Engineering control)	Chlorine room	Active emergency response – drum supply valve will automatically shut off when chlorine concentration in the chlorine room reaches beyond 2.0 ppm for the time of more than 20 seconds.	1. Very expensive 2. Low usage by glove manufacturing plant (less than 1% from total glove manufacturing plant which using centralized chlorine gas system)	Malay Sino (2018)
Piping system – two segments (positive pressure & vacuum pressure)	Piping system	Safety by design. 1. Positive pressure – the shorter piping & tubing, the better safety condition. 2. Vacuum piping. Minimized the impact of the piping leaking.	Pipe material, the risk for leaking thru pipe connection.	Flexidynamic (2018)
Administrative safety control measures include safety signage, label, skill and competency of the workers, and monitoring of the present hazards.	Chlorine room	1. Notification of present hazards 2. Evaluation and assessment of hazard 3. Skill and competency of the works.	Passive system. Only for notification or alert of any dangerous situation that occurs. Improve awareness of workers to the presence of hazards.	Riverstone (2018)
Personal Protective Equipment	Workers	To minimize the impact when the workers are exposed to the hazards.	Lowest efficiency of protection in the hierarchy of control.	Malaysia (2000)

3.1 Wet Scrubber Assessment

The wet scrubber assessment was done using the Industrial Ventilation: A Manual of Recommended Practice 23rd Edition by American Conference of Governmental Industrial Hygienists (ACGIH), divided into two assessments. Visual assessments and measurements within the system include capture velocity, face velocity, and duct velocity or transport velocity. Other assessed parameters are total pressure, static pressure, and velocity pressure. The assessment found that the duct performance for all parameters complies with a minimum requirement of ACGIH guidelines.

The scrubber is designed to control toxic gas releases and human risk. Wet scrubbers use a liquid to remove pollutants or contaminants from an exhaust stream. In gaseous emission control applications, wet scrubbers remove contaminants by absorption. The driving factor for absorption is related to the amount of soluble gas in the stream and the concentration of the solute gas in the liquid film in contact with the gas. In this study, scrubber prevents toxic chlorine gas release from the chlorine system by immediate removal and treatment before discharge to ambient. Performance and effectiveness of scrubber need to assess. This assessment examines and tests the effectiveness of toxic gas removal, treated before it is released into the atmosphere. If the scrubber is inefficient, it may cause the toxic gas to fail to remove from the affected area or lead to environmental pollution. A list of equipment has been used during this assessment, as shown in Table 4.

Table 4. Scrubber assessment tools.

Equipment / tools	Purpose
TSI Digital Hot Wire Anemometer (Model: 9565-P)	To measure airflow, temperature, and humidity
Pitot Tube	To measure static and velocity pressure
Smoke tube	To identify the direction of airflow

There are a few parts or components for the scrubber system. Every part or component has a specific function. The process ensures the contaminants are captured or retained starting from the hood. The type of hood should be identified to determine the kind of reading that needs to be taken, face velocity or capture velocity, and capture distance. Besides that, the type of contaminant needs to be identified to match the standard capture velocity. The ideal scrubber system shall have an air-cleaning unit to be installed before the vacuum fan. The air cleaner is a device to remove the contaminants transported through the ducting. The air cleaner traps the contaminants by filtration method (absorption, adsorption, screen filter, or others) or by gravitational cyclone method. The static pressure can measure the effectiveness of the air cleaner before and after the air cleaner, and it will be compared to manufacturing specifications. The physical of the air cleaner has to be examined from any abnormal condition such as leakages or blockages.

Another critical component of the scrubber is the exhaust fan. The function of the exhaust fan is to drive or transport the contaminants along with the ducting in the system. The technical personnel require regular servicing and proper maintenance of the fan to ensure the fan is running at the best performance. Finally, the last component of the scrubber is the chimney. It is located at the end of the system, where the air is drawn out to the atmosphere. The emission sampling will be there. The wet scrubber assessment was done using the Industrial Ventilation: A Manual of Recommended Practice 23rd Edition by ACGIH, divided into two assessments. Visual assessments and measurements within the system include capture velocity, face velocity, and duct velocity or transport velocity. Other assessed parameters are total pressure, static pressure, and velocity pressure. The assessment found that the duct performance for all parameters complies with a minimum requirement of ACGIH guidelines.

3.2 Visual assessment
Visual assessment was carried out by observing the overall scrubber system. A smoke test kit was used to determine the effectiveness of the suction provided by the system. Besides the smoke test, visual inspection to identify any structures such as pots and a wall near the hood's opening that could interfere with the airflow into the hood was also made. Visual inspection was also carried out to observe ducting system. A smoke test was also used to determine any leakage at junctions or connections.

3.3 Measurement within the system
There are a few parameters taken into consideration in this aspect. Firstly, is capture velocity, representing the minimum induced air velocity that captures and conveys the contaminant into the hood. The captures velocity may vary according to the different distances and locations from the hood.

The capture velocity also depends on the type of contaminants and the hood's design. Besides, face velocity is measured at the face opening of the hood. The reading represents the airflow at the beginning of the hood into ducting. The face velocity will reduce if the hood size is increased. The face and capture velocity must be within the recommended value by ACGIH, as stated in Table 5 below.

Table 5. Range of capture velocities recommended by ACGIH.

Condition of dispersion of contamination	Example	Capture Velocity, m/s
Released with practically no velocity into the quiet air	Evaporation from tanks, degreasing, etc.	0.25 – 0.5
Released at low velocity into moderately still air	Spray booth, intermittent container filling, low-speed conveyor transfer; welding; planting; pickling	0.5 – 1.0
The active generation into the zone of rapid air motion	Spray painting in shallow booths; barrel filling; conveyor loading; crushers	1.0 – 2.5
Released at high initial velocity into the zone of very rapid air motion	Grinding; abrasive blasting; tumbling	2.5 – 10.0

Speed or velocity inside the ducting is known as ducting velocity and transport velocity. It can be measured by using a standard pitot tube. Duct velocity measured along the duct at a uniform distance (Minimum at a distance of 2 Diameter (2D) to a maximum length of 8 Diameter (8D) of the chimney from bending. Duct transport velocity must at least achieve the minimum recommended transport velocity by ACGIH, as stated in Table 6 below, to avoid settlement of contaminant inside the ducting, which can contribute to duct blockage or flow disturbance.

Table 6. Range of minimum duct design velocities recommended by ACGIH.

Nature of Contaminant	Examples	Design Duct Velocity, m/s
Vapors, gases, smoke	All vapors, gases, smoke	5 – 10
Fumes	Weldings	10 – 13
Very fine light dust	Cotton lint, wood flour, litho powder	12 – 15
Dry dust & powder	Fine rubber dust, bakelite molding powder dust, jute lint, cotton dust, shavings (light), soap dust, leather shavings	15 – 20
Average industrial dust	Grindings dust, buffing lint (dry), wool jute dust (shaker waste), coffee beans, shoe dust, granite dust, silica flour, general material handling, brick cutting, clay dust, foundry (general), limestone dust, packaging, and weighing asbestos dust in textile industries.	18 – 20
Heavy dust	Sawdust (heavy & wet), metal turnings, foundry tumbling barrels and shake-out, sandblast dust,	20 – 23

	woodblocks, hog waste, brass turnings, cast iron boring dust, lead dust	
Heavy or moist dust	Lead dust with small chips, moist cement dust, asbestos chunks from transit pipe cutting machines, buffing lint (sticky), quick-lime dust	23

Another parameter is required to measure its pressure during the assessment, measured in Pascal (Pa). There are 3 types of pressure: total pressure, static pressure (SP), and velocity pressure (VP). Static pressure can determine any blockage or leakage along with the ducting and the efficiency of the air cleaner unit and the fan. However, velocity pressure can be used to determine the transport velocity. Velocity pressure results from air movement, and it is always positive. It can be measured by using a Pitot tube. The usual method is to make two traverses across the diameter of the solid round duct at right angles to each other. Readings are taken at the center of the annular rings of equal area. For ducts, less than 150mm, at least six traverses points should be used. Ten traverses points should be employed for a round duct of more than 150mm. Whenever possible, the traverse should be made 7.5 duct diameters or more downstream from any significant air disturbance such as an elbow, hood, branch entry, or any fittings. The total pressure is the algebraic sum of static pressure and velocity pressure. Table 7 shows the general data of the scrubber. Whereas Table 8 is the assessment data of the scrubber. The result indicates that the minimum duct transport velocities were achieved as per ACGIH guideline and adequate to transport the contaminant from the suction source of generation to discharge at the point of release (chimney).

Table 7. Scrubber general data.

Scrubber ID	**SC1 / PA**	**SC2 / PA**	**SC9 / PB**	**SC6 / PB**
Location	Chlorine room	Chlorine room	Chlorine room	Chlorine room
Type of contaminant	Chemical vapors	Chemical vapors	Chemical vapors	Chemical vapors
Humidity	55.7% RH at 29.2°C	60.2% RH at 30..2°C	52.8% RH at 29.2°C	68.8% RH at 31.1°C
Barometer readings	760.0 mHg	760.0mHg	760.0mHg	760.0mHg
Average Face Velocity	0.74 m/s	0.76 m/s	0.83 m/s	0.68 m/s

Table 8. Result of measured; transport velocity (TV) and flow rate (FR).

Scrubber ID	**SC1 / PA**		**SC2 / PA**		**SC9 / PB**		**SC6 / PB**	
Point	**TV (m/s)**	**FR (m^3/s)**	**TV (m/s)**	**FR (m^3/s)**	**TV (m/s)**	**FR (m^3/s)**	**TV (m/s)**	**FR (m^3/s)**

D1	5.83	0.10	5.66	0.10	6.05	0.11	7.23	0.13
D2	5.92	0.10	5.74	0.10	6.33	0.11	7.31	0.13
D3	6.22	0.99	5.98	0.10	6.42	0.11	7.45	0.13
D4	6.33	1.01	6.18	0.98	7.08	0.13	8.04	3.94
D5	6.38	1.01	6.00	0.96	7.20	3.53	8.21	4.03
D6	NA	NA	6.31	1.00	7.31	3.58	8.47	3.20
D7	NA	NA	NA	NA	7.64	2.48	NA	NA
ACGIH Specification			**TV (m/s)**			5 – 10 m/s		

Further assessment, particularly for treatment performance, was conducted for four units of the selected scrubbers. The purpose of the evaluation is to assess the efficiency of the scrubber treatment before the contaminant air is discharged to the ambient. The isokinetic stack emission measurements were performed using the following equipment: Microprocessor-Based Advance Stack Monitoring System (Brand: POLYTECH; Model: PEM SMS-4). The system directly measures the linear velocity of the gas stream in the stack, compotes, and continuously regulates the sampling flowrate to meet actual isokinetic sampling conditions at all times during measurement. Table 9,10, 11 and 12 shows assessment data for stack emission. In addition, all measured parameters and sample volume are corrected to STP. The systems meet Malaysia Standard MS1596;2003 and Environmental Protection Agency of USA. The system uses methodology according to Malaysia Standard MS 1596:2003 and the USA Environmental Protection Agency (EPA) Code of Federal Regulations 40 Part 60.

Table 9. Result of stack emission sampling-Scrubber 1.

Test Parameter	Test Method	Result	Malaysian Clean air Regulation
Dust Concentration-	MS1596:2003	11.95 mg/Nm3	50 mg/m3
Oxides of Nitrogen, NOx	USEPA Method 7E	ND < 0.0001mg	700 mg/m3
Sulfuric acid, H2SO4	USEPA Method 8	ND < 0.0001mg	5 mg/m3
Hydrogen sulfide, H2S	USEPA Method 11	ND < 0.0001mg	7.5 mg/m3
Hydrofluoric, HF	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Hydrogen Chloride, HCL	USEPA Method 26A	ND < 0.0001mg	200 mg/m3
Chlorine, gas	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Copper, Cu	USEPA Method 29	ND < 0.0001mg	1 mg/m3
Zinc, Zn	USEPA Method 29	ND < 0.0001mg	N/A
Arsenic, As	USEPA Method 29	ND < 0.0001mg	0.2mg/m3

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Table 10. Result of stack emission sampling-Scrubber 6.

Test Parameter	Test Method	Result	Malaysian Clean air Regulation
Dust Concentration-	MS1596:2003	12.35 mg/Nm3	50 mg/m3
Oxides of Nitrogen, NOx	USEPA Method 7E	ND < 0.0001mg	700 mg/m3
Sulfuric acid, H2SO4	USEPA Method 8	ND < 0.0001mg	5 mg/m3
Hydrogen sulfide, H2S	USEPA Method 11	ND < 0.0001mg	7.5 mg/m3
Hydrofluoric, HF	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Hydrogen Chloride, HCL	USEPA Method 26A	ND < 0.0001mg	200 mg/m3
Chlorine, gas	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Copper, Cu	USEPA Method 29	ND < 0.0001mg	1 mg/m3
Zinc, Zn	USEPA Method 29	ND < 0.0001mg	N/A
Arsenic, As	USEPA Method 29	ND < 0.0001mg	0.2mg/m3

Table 11. Result of stack emission sampling-Scrubber 9.

Test Parameter	Test Method	Result	Malaysian Clean air Regulation
Dust Concentration-	MS1596:2003	12.79 mg/Nm3	50 mg/m3
Oxides of Nitrogen, NOx	USEPA Method 7E	ND < 0.0001mg	700 mg/m3
Sulfuric acid, H2SO4	USEPA Method 8	ND < 0.0001mg	5 mg/m3
Hydrogen sulfide, H2S	USEPA Method 11	ND < 0.0001mg	7.5 mg/m3
Hydrofluoric, HF	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Hydrogen Chloride, HCL	USEPA Method 26A	ND < 0.0001mg	200 mg/m3
Chlorine, gas	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Copper, Cu	USEPA Method 29	ND < 0.0001mg	1 mg/m3
Zinc, Zn	USEPA Method 29	ND < 0.0001mg	N/A
Arsenic, As	USEPA Method 29	ND < 0.0001mg	0.2mg/m3

Table 12. Result of stack emission sampling-Scrubber 2.

Test Parameter	Test Method	Result	Malaysian Clean air Regulation
Dust Concentration-	MS1596:2003	11.74 mg/Nm3	50 mg/m3
Oxides of Nitrogen, NOx	USEPA Method 7E	ND < 0.0001mg	700 mg/m3
Sulfuric acid, H2SO4	USEPA Method 8	ND < 0.0001mg	5 mg/m3
Hydrogen sulfide, H2S	USEPA Method 11	ND < 0.0001mg	7.5 mg/m3
Hydrofluoric, HF	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Hydrogen Chloride, HCL	USEPA Method 26A	ND < 0.0001mg	200 mg/m3
Chlorine, gas	USEPA Method 26A	ND < 0.0001mg	5 mg/m3
Copper, Cu	USEPA Method 29	ND < 0.0001mg	1 mg/m3
Zinc, Zn	USEPA Method 29	ND < 0.0001mg	N/A
Arsenic, As	USEPA Method 29	ND < 0.0001mg	0.2mg/m3

Generally, for isokinetic stack and air emission monitoring results for the selected scrubber unit, the dust concentration and another contaminant, particularly chlorine level emitted, stuck to be well below the Malaysia Environmental Quality (Clean Air) limits Regulations 2014 during the sampling period. In other words, scrubber performance is accepted for chlorine handling.

5. Conclusion

The chlorine exposed to the workers during drum replacement activities is above TWA_8. Wet scrubber performance is crucial for minimizing the health risk to the workers. Appropriate control measures strongly believed that the workplace of a glove manufacturing operation regarding chlorine system could be better and safer for all relevant personnel.

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