The Performance Test on Local Exhaust Ventilation (LEV) System to Prevent Chlorine Gas Leakage in Water Treatment Plant

Nor Halim Hasan, M. R. Said, A. M. Leman and Anuar Mohd Mokhtar

Abstract—**Water is a necessity of life to humans and animals. In Malaysia, Government Link Companies (GLC) or Private Companies manages most of the water treatment plants. Chlorine gas is used as one of the water treatment media to treat raw water that will then be distributed for public or commercial usage. The large volume of Chlorine gases used and stored in these treatment plants has the potential to create a disaster if it leaks. Objective of this paper to highlight a result of Local Exhaust Ventilation (LEV) monitoring system and their performance test in controlling of air flow from the chlorine gas building to prevent leakage and spread to the surrounding environment. Methodology used follows the American Governmental Industrial Hygienist (ACGIH). The Chlorine Gas leakage system is checked and verified by using ACGIH Standard. Finally as a result, all the measured parameters (velocity, flow rate, face velocity and brake horse power (bhp)) show that the measurement and monitoring system of LEV are complied with ACGIH Standard and Local Law and Regulations.**

Index Terms—**Chlorine gas, local exhaust ventilation (LEV), American governmental industrial hygienist (ACGIH), occupational safety and health (OSH).**

I. Introduction

The geographical location of Malaysia (2°30 N 112°30 E) with total land area approximately 329,750 km² and coastline 4,675 kmis endowed with high abundant rainfall, averaging 3,000mm annually, and the equivalent of 990 billion cubic meters of water over the country, thanks to its equatorial climate. It is also blessed with an extensive river system consisting of more than 150 rivers that provide the country with more than 25,000 cubic meters of renewable water per capita per year. Renewable water is water that comes down as rain and flows down rivers every year. The amount of renewable water that Malaysia receives far exceeds that of many other parts of the world.[1] Processing company in Malaysia engaged in water treatment is subject to the Water Services Industry Act 2006. [2]

Chlorination is one of many methods that can be used to disinfect water. This method was first used over a century ago, and is still used today. It is a chemical disinfection method that uses various types of chlorine or chlorine-containing substances for the oxidation and disinfection of what will be the potable water source.

This paper discusses a local LEV measurement and monitoring which is done in a water treatment in Malaysia according to ACGIH Standard in compliance to the Malaysian Control of Industrial Major Accident Hazard (CIMAH) Regulation 1996 and the Use and Standards of Exposure of Chemicals Hazardous to Health Regulation 2000 (USECHH) under the Occupational Safety and Health Act (OSHA 1994).

The subsequent topics include the explanation of water treatment and the local legal requirement implied.

II. Water Treatment Process

Water treatment is a process that removes contaminants from raw water or concentration reduces to produce safe water for human use. Water should also be aesthetically acceptable, free of significant turbidity, odor and unpleasant color. Conventional treatment plant includes the following processes: screening, aeration, coagulation and flocculation, sedimentation, filtration, disinfection and pH adjustment. At the beginning, wood chips, leaves, aquatic plants and floating impurities are separated through the screening process. After the screening, a more compact suspended material will be removed to allow water to flow through the chamber where it will settle to the bottom. The raw water is pumped mixed with ventilation air. Aeration process to produce oxygen from the atmosphere to the oxidation of dissolved iron and manganese to insoluble forms for the purpose of eliminating them. This process also helps to remove taste and odor.

Coagulant, usually alum added to form microscopic particles in the water. It is then blended to allow small particles in the water colliding and merging to form settle able mud. Condensed sedimentation tank is allowed to flow through uniform as possible for a period long enough to enable him to settle. Clear water will be collected from the top. For soft mud, a different process is used. Minute air bubbles used in this process. Mud will stick to air bubbles and float to the top. Clear water will be collected from the bottom of the tank. This process is called Dissolved Air Flotation.

Water settles through the filter that traps particles and bacteria. Clean water eventually clear water tank. Filters are cleaned regularly using backwash through a combination of air and water mixture to ensure smooth operation. Disinfection / pH Adjustment is the process where water in the tank clear the infection to eliminate microorganisms that

Manuscript received January 3 2013; revised April 1, 2013. This work was carry out is part of the postgraduate study.

Nor Halim Hasan and M. R. Said are with the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia, Melaka (e-mail: irnorhalim@student.utem.edu.my, radzai@utem.edu.my).

A.M. Leman is with Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia (e-mail: mutalib@uthm.edu.my).

Annuar Mohd Mokthar is with Department of Occupational Safety and Health Malaysia (e-mail: anumokh@hotmail.com).

DOI: 10.7763/IJESD.2013.V4.386

remain in the water after the filtration process. Gaseous chlorine or chlorine compounds are commonly used for disinfection purposes. PH levels adjusted using lime or soda ash. Treated water will be collected and stored in a water tank for the purpose of distribution. Research conducted by Hend Galal-Gorchev in the use of chlorine for disinfection of drinking water has saved many lives, starting with a dramatic reduction in cases of typhoid and cholera that accompanied the introduction of this process in Europe and North America in the early 1900s. [3]

III. Local Legal Requirement

As part of the water treatment process, chlorine is used as a disinfectant. CIMAH Regulations, chlorine is regarded as a toxic substance that could pose a major hazard if the quantity available at site is greater than 10 metric tonnes. The overall amount of chlorine stored at any one time has already exceeded this threshold quantity. Hence, according to Regulation 16 (CIMAH Regulations) [4] an Industrial Activity Report is required to be made, revised and submitted to Department of Occupational Safety and Health (DOSH) Major Hazard Division every 3 years.

Compliance to the USECHH Regulation is an approach to reduce and maintain the exposure level of employees to chemicals hazardous to health below the permissible exposure limits or to the lowest practicable level.

Engineering Control Equipment in Regulations 2 of USECHH means any equipment, which is used to control exposure of employees to chemicals hazardous to health and includes local exhaust ventilation equipment, water spray or any other airborne chemical removal and containment equipment. The equipment shall be maintained and operated at all times while any machinery or plant is in operation, and for such time of Regulation 17 in same regulation.[5]

Hood and Ducting in Regulation 26 (3) stated that any hood, enclosure, canopy or shall be constructed so as to envelop, as far as practicable, the point of origin of the fume or dust so that a smooth and uninterrupted flow is maintained. In addition to this requirement the hood, enclosure, canopy, or ducting for the extraction of fume shall be constructed so as to maintain the air velocity at the surface thereof at a rate not less than one hundred and fifty (150) feet per minute.[6]

Design, construction and commissioning of local exhaust ventilation equipment. Regulation 18 of USECHH required any local exhaust ventilation equipment installed shall be designed according to an approved standard by a registered professional engineer and constructed according to the design specifications; and tested by a registered professional engineer after construction and installation to demonstrate that the equipment meets the design specifications. Regulation 17(1)(b) of the USECHH Regulations related with the DOSH compliance monitoring.[5]

IV. Case Study Description

The fourth periodic testing and evaluation of the LEV system was conducted on 20th March 2012 in raw water treatment plant at Sungai Layang, Johor. Generally, the purposed of the testing was done to obtain the actual airflow values of the existing systems to determine their performance. The testing and evaluation were done at the Wet Scrubber System in the plant.

The purpose of examination and testing of an LEV System to identify the effectiveness of the LEV as an engineering control measure so as to reduce the exposure of employees to chemical hazardous to health to below the permissible exposure limits or it is at the lowest practicable exposure level. The others purpose of examination and testing an LEV system is to prepare a periodic data for comparing it with the last monitoring data to determine the effectiveness of the LEV system by a hygiene technician at appropriate intervals of not more than 12 months after the last periodic monitoring.

This plant uses chlorine gas on average 1,200 kg / day for 315 MLD water production or 315,000 m^3. Chlorine gas tank storage capacity at the plant is of 40 tanks in one time with a net weight of chlorine gas in each tank of 930 kg. Chlorine gas utilization ratio and the volume of water per kilogram of chlorine gas are equivalent to 262.5 m^3 of treated water.

A. Approach

The main process activities of this plant are screening, pre-chlorination, pre-liming for pH adjustment, coagulation with alum, injection of Poly Aluminum Chloride (PAC) for phenol adsorption, taste and odor control, injection of polymer as coagulant aid, flocculation and clarification, possible intermediate chlorination, rapid gravity sand filtration, final disinfection with chlorine, fluorination using sodium silicofuride and finally neutralization with lime slurry to produce clear quality drinking water.

Basically, a LEV system was installed at the Chlorination Building to remove all the chlorine gases in case of gas leakage. In this context it is LEV system, control hazards immediately to control contaminants that are exposed are engineering controls. However, the best known is the type of administrative controls to reduce exposure of workers rotation. [7] Chlorine gas detectors are strategically placed inside the Chlorination Building to detect and automatically activate the LEV system in any event of chlorine gas leak in the chlorination system.

B. Purposes

The existing LEV system has been examined and tested for the performance and functioning, whether it was acceptable to engineering practice (ACGIH) and legal requirements (USECHH Regulations 2000). The impact from leakage of Chlorine Gases without any control and not timely evacuated, these staff will be poisoned and resulted in casualties.[8] It is important to note down the test data such as static pressure, velocity pressure and total pressure at the appropriate points of the LEV system. Measurements are made to analyze and determine whether the LEV system is performing effectively to capture, treat and remove the airborne contaminants from the workplace. Also to determine if the LEV system has any abnormal operation conditions so that the recommendation of maintenance, servicing, repairing and improvement could be made.

Preparation of a periodic data for comparison with the baseline examination and testing data, by the hygiene technician and check if the design is according to an approved standard by a registered professional engineer and constructed according to the design specifications. At last check if a registered professional engineer has tested the LEV system after construction and installation to demonstrate that the equipment meets with the design specifications.

C. Instrumentations

The equipment used in the course of this study, namely as recommended in the ACGIH guidelines. Explanations of the use of each instrument are as follows. Airflow Meter is used for airflow measurements. Thermal Anemometer is used for airflow and temperature. Smoke Tube is used for identifying the direction of airflow and duct leakages. Thermo hygrometer is used to measure temperature and humidity. Tachometer is used for determining the fan and motor speed (rpm).

Vane anemometer is used for airflow measurements. A measuring tape is used to measure the length and distance. To cover-up the holes on the duct, Adhesive Tape are used. Pitot tube is used for pressure measurements. Clamp Meter to measure current and voltage. Manometer is used for airflow measurements.

D. Methodology

The testing of LEV system was carried out in accordance with the methodology given in the handbook of the ACGIH [9]. An LEV system consists of five main components, i.e. hood, duct, air cleaner, motor & fan and stack.

Hood

The types of hood should be identified in order to determine the type of reading that need to be taken, face velocity or capture velocity and capture distance.

Duct

Static pressure is taken to determine whether there is any negative pressure while the velocity pressure is taken to obtain the transport velocity, where it will then be compared against the standard (ACGIH) values.

Air Cleaner

The measurement of static pressure should be taken before and after the air cleaner in order to determine the effectiveness of the air cleaner as compared to the manufacturer's specifications, if any.

Motor and fan

The equations for calculate Fan Static Pressure (FSP) against Static Pressure (SP) and Velocity Pressure (VP) and Fan Total Pressure (FTP) and Brake Horse Power (BHP) are found in the ACGIH guidelines.

$$FSP = SP(outlet) - SP(inlet) - VP(inlet) \quad (1)$$

$$FTP = [(SP(outlet) - VP(outlet)] - [SP(inlet) + VP(inlet)] \quad (2)$$

$$BHP = \frac{Q \times FTP}{6356 \, X \, ME} \quad ; \text{Where } ME = 0.60 \quad (3)$$

Stack

The physical condition of the stack should always be examined to detect any abnormal condition or leakage.

V. Field Measurement

For the locations of the data measurement points, refer to Fig. 1 of LEV System at Chlorination Building and Fig. 2 of photo of LEV System outside the building. Locations taken are Hood (H1, H2, H3 and H4), Branch Duct (CSH 1, CSH2, CSH3 and CSH 4), before scrubber (CS1.3) and before and after fan (CS1.2 and CS1.1).This location of test point are selected at sufficient points which performance can be measured also recommended in Design of Industrial ventilation Systems by John [10]. The material for ducting used are FRP round duct. Two fan & motor are provided to ensure no fail in the process of remove chlorine gas for any leakage. The experiment and measurement are taken from point located with running of fan number first and followed by the second. The results are measure and discussed.

A. Current Data

Measurement and inspection on LEV system is to collect the data for the use of fans and motors for no 1 and no 2. This is for performance comparison if any of the fan and the motor does not reach the required level.

Fan 1 and Fan 2

Table I show that the velocities of all open-end ducts were above the recommended values. The value of tested velocity for both fans more than 200 percent higher for 8 in diameter hood and 6-diameter hood in from ACGIH recommended values are 1,000 fpm for velocity. Meanwhile tested flow rate value against recommended calculation for diameter 6 in and 8 in hood are double. Therefore, all the open-end ducts would be effective to remove most of the airborne contaminants from the workplace if there was any gas leakage in the Chlorine Building.

Table II show that the velocities in a ducting were above the recommended values except at location CSH 4 but still above the minimum standard recommended by ACGIH i.e. between 1,000 to 2,000 fpm. Therefore, the ducts would be effective to remove most of the airborne.

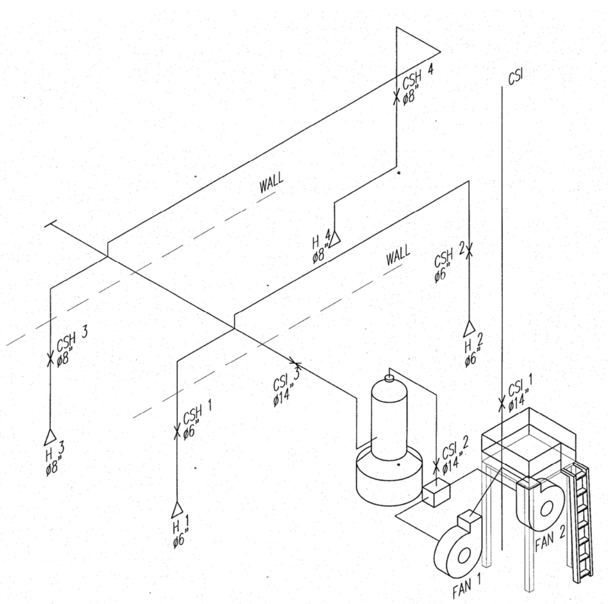

Fig. 1. LEV System (Chlorination Building) of Schematic Diagram

Fig. 2. LEV System (Chlorination Building) of Photo outside the Building.

From the observation to the fan condition found that was running with minimum vibration and motor conditions was warm (39°C) with measured amperes that were low and quite balanced. Its can concluded that fan was in good working condition. As a result, in Table III show comparison test value to design the motor speed, Fan Static Pressure (FSP) and flow rate are no significant different, while value of Brake Horse Power (BHP) reduce almost halve compare to design for both fan tested.

B. Previous Data

Previous measurements of velocities of all open-end duct for fan no 1 and fan no 2 for year 2011 in Table I was above the recommended values. It presents no different compare to current performance.

Data shows in Table IV that the velocities in a ducting were above the recommended values except at location CSH 3 and CSH 4 but still above the minimum standard set by ACGIH. Therefore, the ducts would be effective to remove most of the airborne contaminants from the workplace if there was any gas leakage in the Chlorine Building.

Following are measurement and calculation of fan rating curve and comparison with design LEV system and show in Table III for previous year (2011).

From the observation to the fan condition found that was noisy and with minimum vibration and motor conditions was warm (38.2°C fan no. 1 and 44°C fan no. 2) with measured amperes that were low and quite balanced. Its can concluded that fan was in good working condition

VI. Discussion

Static Pressure (SP) and Total Pressure (TP) can either be positive (+ve) or negative (-ve) depending on whether the measurements are made upstream or downstream of the fan. Both are negative upstream and positive downstream. Positive pressures mean the pressures are above atmospheric pressure whilst negative pressure mean below atmospheric pressure. SP acts in all directions and measurements are usually taken perpendicular to the duct. Velocity pressure (VP) acts in the direction of airflow and is always positive. TP is a measure of the energy content of the air stream is the sum of the SP and VP, become more negative in moving towards the fan and is most positive as it exits the fan.

A. Current Measurement for Fan 1

Site inspection conducted found that housekeeping at the scrubber and chlorination building was satisfactory. The scrubber, main and branch ducts' physical condition was good without any abnormal condition from the observation. Smoke Tube test for the purposed of any leaking detection and was detected no leakage at the duct joints during the short running test. It shows that air suction was in good order.

TABLE I: Hood Velocity and Flow Rate Measurement.

Point	Airborne Contaminants	Velocity, V (fpm)					Hood			Flow rate, Q (cfm)				
		Rec. Value	Tested Fan 1		Tested Fan 2		Type	Size (in)	Area (sq. ft.)	Rec. Value	Tested Fan 1		Tested Fan 2	
			2012	2011	2012	2011					2012	2011	2012	2011
H1	Chlorine Gas & Vapors	1,000	3,041	2,799	2,938	2,844	Open End Duct	Dia. 6	0.196	196	596	549	576	557
H2	Chlorine Gas & Vapors	1,000	3,035	2,876	2,817	2,948	Open End Duct	Dia. 6	0.196	196	595	564	552	578
H3	Chlorine Gas & Vapors	1,000	2,659	2,826	2,706	2,897	Open End Duct	Dia. 8	0.349	349	928	986	944	1,011
H4	Chlorine Gas & Vapors	1,000	2,160	2,609	2,725	2,719	Open End Duct	Dia. 8	0.349	349	754	911	951	949

TABLE II: Transport Velocity and Flow rate Measurement for Branch Duct (2012)

Point	Duct Size (in)	Duct Area A (Sq. ft.)	Velocity Pressure VP (in wg)		Velocity V (fpm)		Flow rate Q (cfm)		Remarks		Static Pressure SP (in wg)		Velocity Pressure VP (in wg)		Total Pressure TP (in wg)	
			Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2
CSH 1	6	0.196	0.418	0.515	2589.3	2874.1	508.5	564.4	Above	Above	-1.018	-1.125	0.418	0.515	-0.600	-0.610
CSH 2	6	0.196	0.449	0.375	2683.6	2452.6	527.0	471.6	Above	Above	-0.814	-1.036	0.449	0.375	-0.365	-0.661
CSH 3	8	0.349	0.269	0.265	2077.2	2061.7	725.2	719.8	Above	Above	-0.660	-0.815	0.269	0.265	-0.391	-0.550
CSH 4	8	0.349	0.168	0.136	1641.6	1477.0	573.1	515.6	Within	Within	-0.709	-0.865	0.168	0.136	-0.541	-0.729
CS 1.1	14	1.069	0.537	0.415	2934.9	2580.0	3137.8	2758.5	Above	Above	0.079	0.175	0.537	0.415	0.616	0.590
CS 1.2	14	1.069	0.427	0.425	2617.1	2610.9	2798.1	2791.5	Above	Above	-5.328	-5.106	0.427	0.425	-4.901	-4.681
CS 1.3	14	1.069	0.283	0.296	2130.6	2179.0	2277.9	2329.6	Above	Above	-2.657	-3.055	0.283	0.296	-2.374	-2.759

Recommended transport velocity for chlorine gases (1,000 to 2,000 fpm)

TABLE III: RESULT CALCULATION USING EQUATION (1), (2) AND (3)

Description	Speed (rpm)		FSP (in wg)		FTP (in wg)		BHP (HP)		Flow Rate, Q (cfm)	
	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011
Designed	1900		5.000				7.5		2,650	
Tested Fan 1	1957	1961	4.980	4.685	5.516	5.270	4.04	4.20	2,795	3,040
Tested Fan 2	1957	1957	4.980	4.725	5.273	5.190	3.86	4.01	2,789	2,948

TABLE IV: TRANSPORT VELOCITY AND FLOW RATE MEASUREMENT FOR BRANCH DUCT (2011)

Point	Duct Size (in)	Duct Area A (Sq. ft.)	Velocity Pressure VP (in wg)		Velocity V (fpm)		Flow rate Q (cfm)		Remarks		Static Pressure SP (in wg)		Velocity Pressure VP (in wg)		Total Pressure TP (in wg)	
			Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2	Fan 1	Fan 2
CSH 1	6	0.196	0.464	0.465	2,728	2,731	535	535	Above	Above	-1.195	-1.195	0.464	0.465	-0.635	-0.735
CSH 2	6	0.196	0.414	0.415	2,577	2,580	505	506	Above	Above	-1.084	-1.085	0.414	0.415	-0.332	-0.665
CSH 3	8	0.349	0.225	0.225	1,900	1,900	663	663	Within	Within	-0.765	-0.765	0.225	0.225	-0.545	-0.545
CSH 4	8	0.349	0.105	0.105	1,298	1,298	453	453	Within	Within	-0.836	-0.835	0.105	0.105	-0.725	-0.725
CS 1.1	14	1.069	0.585	0.465	3063	2731	3242	2917	Above	Above	0.065	0.135	0.585	0.465	0.645	0.605
CS 1.2	14	1.069	0.505	0.474	2846	2760	3040	2948	Above	Above	-5.125	-5.065	0.505	0.474	-4.901	-4.681
CS 1.3	14	1.069	0.355	0.345	2386	2352	2548	2512	Above	Above	-3.126	-3.016	0.355	0.345	-2.774	-2.675

Recommended transport velocity for chlorine gases (1,000 to 2,000 fpm)

During measurement and observation of the hood, the open-end ducts physical conditions were good. The four points tested was satisfactory as all were showing flow rates more than twice the recommended value set by ACGIH. The air suction at the open-end ducts was strong to trap and exhaust most of the airborne contaminants from the workplace if there was any minor gas leakage. Both sizes of ducting (Diameter 6" and 8") and fans use are measured and physical condition of the main and branch duct was good. The transport air velocities measured at the main duct were above the recommended values.

For the reading obtained from the air cleaner section the static pressure drop across the scrubber was approximately 5 in wg indicating that the scrubber was clean. The scrubber still needs normal preventive maintenance to be cleaned and serviced to maintain or improve its efficiency.

The motors were warm with measured ampere that was low and quite balanced. So, we could deduce that the motors were in good condition.Stack with no visible ducts could be seen emitted from the stack into the outside atmosphere. The stack was high and the efflux air velocity was above the ACGIH recommended values and the stack was effective to disperse and dilute most of the airborne contaminants into the outside atmosphere.

Airflow measurements, visual assessments and other tests conducted, the overall performance of the Wet Scrubber System was found to be satisfactory using fan 1.This shows that the LEV system was effective in removing most of the airborne contaminants from the workplace in the event of any minor chlorine gas leakage at the Chlorination Building. Overall, the airflow performance of the Wet Scrubber System was quite similar as compared to the last monitoring.

B. Current Measurement for Fan 2

Measurement and observation the hood, the open-end ducts' physical conditions were good. Where the four points are tested above 2,000 fpm for velocity and double for flow rate measured compare with recommended value by ACGIH. The air suction at the open-end ducts was strong to trap and exhaust most of the airborne contaminants from the workplace if there was any minor gas leakage. Both sizes of ducting (Diameter 6" and 8") and fans use are measured and physical condition of the main and branch duct was good. The transport air velocities measured at the main duct were above the recommended values.

Air cleaner section from the reading obtained, the static pressure drop across the scrubber was approximate 4 in wg indicating that the scrubber was clean. The scrubber still needs normal preventive maintenance to be cleaned and serviced to maintain or improve its efficiency.

The motors were warm with measured ampere that was low and quite balanced. So, we could deduce that the motors were in good condition. Stack with no visible ducts could be seen emitted from the stack into the outside atmosphere. The stack was high and the efflux air velocity was above the ACGIH recommended values and stack was effective to disperse and dilute most of the airborne contaminants into the outside atmosphere.

Fan 2 from the airflow measurements, visual assessments and other tests conducted, the overall performance of the Wet Scrubber System was found to be satisfactory. This shows that the LEV system was effective in removing most of the airborne contaminants from the workplace in the event of any minor chlorine gas leakage at the Chlorination Building. Overall, the airflow performance of the Wet Scrubber System was quite similar as compared to the last monitoring.

C. Compared with Previous Data

Current and previous data show not significant different between them for fan 1 and fan 2. Both the reading is more than what has been prescribed and recommended by the ACGIH for contaminants such as chlorine (i.e. 1,000 to 2,000 fpm). Based on the two fan readings performed compared to previous data can be said of this LEV system is in very good condition and ready to absorb the chlorine in the event of a leak.

For Fan Rating Curve (FRC) comparison between the current and previous readings showed no significant different. Value is equal to the design speed of around 1900 rpm fan.

Fan Static Pressure value is almost equal to the value of design from the calculation. Brake Horse Power (BHP) comparison between design values and different measurement almost 50 percent of the total. Design flow rate value is almost equal to the current value of the performed measurement.

VII. Conclusion

The airflow measurements, visual assessment and other tests conducted, the overall performance of the Wet Scrubber System was found to be satisfactory. At this present working condition, the scrubber system was effective to trap and scrub most of the airborne chemical contaminants from workplace and exhaust cleaner air into the outside atmosphere in the event of any chlorine leakage. Therefore, the workplace was clean and safe for the workers to work for longer hours without any serious exposure to the chemical hazardous to health.

The airflow performance of the LEV system was quite similar as compared to the last monitoring. The management is advised to practice the following steps to maintain/ improve the systems performance. The Scrubbers shall be serviced regularly to maintain / improve its performance. Maintenance and servicing schedules should be followed regularly to maintain the performance and detect early sign of deterioration of the systems.

Air cleaner to be inspected, maintain and serviced at least once a month and replace worn out packing, clear the dirt in the strainer and service the valve, water circulation and spray nozzles. Lastly, recommended to carry out inspection for any gas leakage at switching system. Yearly evaluation of LEV system by any DOSH Registered Hygiene Technician and the management must kept the LEV report for 5 years for any further action.

As a result with both fan measured and compare with previous data and design calculation show that LEV system performance are good and ready to remove in any cases of leaking of Chlorine Gas at water treatment plant. Measurement and monitoring showed that the LEV system are comply with both regulation enforced by the Department of Occupational Safety and Health Malaysia i.e. CIMAH Regulations 1996 and USECHH Regulation 2000 and followed according to the American Conference of Governmental Industrial Hygienists (ACGIH) Guidelines.

Acknowledgment

The authors would like to acknowledge the following organizations and individual for their contributions and supports: Government of Malaysia, Department of Public Services, Department of Occupational Safety and Health Malaysia, Faculty of Mechanical Engineering, University of Technical Malaysia, Melaka. University Tun Hussien Onn, Malaysia and officials from the water treatment plant also assist in providing information to this study.

References

[1] *Compendium of Environment Statistics 2010*, Department of Statistics Malaysia. Putrajaya: Department of Statistics Malaysia, 2010.

[2] *Water Service Industry Act 2006*, Malaysia: Percetakan Nasional Berhad, Department of Environment Malaysia, 2006.

[3] H. G. Gorchev, "Chlorine in water disinfection," *Pure & Appl. Chem*, vol. 68, no. 9, pp. 1731-1735, 1996.

[4] *Control of Major Accident Hazard, Regulation 1996.* Kuala Lumpur: MDC, Dept. Of Occupational Safety and Health Malaysia, 2006.

[5] *Use and Standards of Exposure of Chemicals Hazadrous to Health, Regulation 2000.* Kuala Lumpur: MDC., Dept. of Occupational Safety and Health Malaysia, 2006.

[6] *Factories and Machinery (Safety, Health and Welfare) Regulation.* Kuala Lumpur: MDC, Factories and Machinery (Safety, Health and Welfare) Regulation, 2009.

[7] D. K. Nims, *Basics of Industrial Hygiene.* New York: John Wiley & Sons, Inc., 1999.

[8] L. Jianfeng, Z. Bin, and L. Wenmoa, "A typical small-scale chlorine leak and dispersion simulation in industrial facilities," *International Journal of Energy and Environment*, vol. 2, no. 6, pp. 1039-1052, 2011.

[9] *Industrial Ventiltion: A Manual of Recommended Practice for Operation and Maintenance.* Cincinnati: ACGIH, American Conference of Govenrnmental Industrial Hygienists, 2009.

[10] J. L. Alden and J. M. Kane, *Design of Industrial Ventilation Systems.* New York: Industrial Press Inc., 1982.

Nor Halim Hasan was born on 29 August 1969 in Melaka, Malaysia. He joined Department of Occupational Safety and Health (DOSH) Malaysia since 1994 and latest position as Deputy Director at DOSH Johor. He earned Bachelor of Chemical Engineering (UTM-1992) and Masters in Industrial Safety Management (UKM-2006). Registered with Board of Engineer Malaysia as a Professional Chemical Engineer since 2004. Currently, he pursues his doctorate with Faculty in Mechanical Engineering at Universiti Teknikal Malaysia, Melaka. He is conducting research in the field of mechanical engineering with a focus on Local Exhaust Ventilation (LEV) for the industry that contributed much to the health problems of workers.

M. R. Said is a professor in the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka. He was born on 10 August 1958.

He earned his Diploma in Mechanical Engineering from Universiti Teknologi Malaysia. His B.Sc. (Hons) from Sunderland Polytechnic, U.K, CNCAA. His M.Sc. in Applied Mechanics, Stress Analysis and Impact Energy Absorption from University of Manchester Institute Science Technology (UMIST), U.K and His PhD in Stress Analysis and Impact Energy Absorption from UMIST. U.K.

Prof M.R Said has serves in various posts in the University Science Malaysia (U.S.M) and Universiti Teknikal Malaysia, Melaka (UTeM). Previously he is a Dean on The Faculty of Mechanical Engineering, UTeM.

A. M. Leman is an associate professor in the Department of Plant and Automotive Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia. He was born on 1977 in Klang, Selangor, Malaysia. He earned a B.Sc. in Mechanical Engineering (Manufacturing) from Universiti Teknologi Malaysia (UTM), and his M.Sc. in Emergency and Response Planning) from Universiti Putra Malaysia (UPM). His PhD from Universiti Teknologi Mara (UITM) and he attach in Daegu University, South Korea. His teaching and research interest is Safety Engineering, Indoor Air Quality (monitoring) and Industrial Hygiene, For the administration position, he has serves as a Head of Thermal Environment Laboratory from 2011 and a coordinator of INSEP program.

He is a full member of MIHA, MSOSH and member of ISDS.

Anuar Mohd Mokhtar is a senior occupational safety and health officer. He is currently the deputy director (Technical Services) at the Department of Occupational Safety and Health (DOSH), Selangor branch. He was born on 9th September 1959 in Gopeng, Perak, Malaysia.

He earned his first degree in Chemical Engineering from the University of Manchester Institute of Science and Technology (UMIST), United Kingdom in 1982. He graduated with Master in Occupational Hygiene from the University of Newcastle, United Kingdom in 1990.

He is professional chemical engineer registered with the Board of Engineer Malaysia. He is a full member of the Malaysian Industrial Hygiene Association (MIHA) and also a senior Occupational Hygienistin DOSH and has chaired a number of technical committees drafting or reviewing Malaysian regulations and guidelines pertaining to chemical management.