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OVERVIEW ON PERFORMANCE OF WATER SCRUBBER SYSTEMS IN REDUCING ODOUR AT RAW NATURAL RUBBER PROCESSING FACTORIES IN MALAYSIA

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ABSTRACT

The upcoming Odour Regulation enforcement by the Department of Environment (DOE) sets an odour discharge limit at point of emission of not more than 25,000 ou/m3 at all times for all raw rubber processing factories. The major source of malodour is from the release of volatile organic compounds (VOCs) via exhaust gas during the drying activity and is presently controlled by using water scrubber treatment systems. In the present study, the operating conditions and performances of a scrubber from a local Standard Malaysian Rubber (SMR) factory was evaluated to find factors affecting high odour discharge levels. Poor performance of scrubbers was due to low scrubbing efficiency and this was attributed by the acidic pH levels of scrubbing liquid and high air flow rates. High odour concentration levels of the drier's exhaust gas were due to high volatile content in the raw rubber. Some design recommendations made include suggestions in installing gauges to monitor and control contributing factors hampering scrubber performance.

Keywords: *Odour concentration; scrubbing efficiency; Standard Malaysian Rubber (SMR); water scrubber treatment system; volatile organic compounds.*

1. INTRODUCTION

The natural rubber (NR) industry is among the leading commodity sector in Malaysia and has contributed significantly to the economic, social and technological development of the country. However, the processing activity of raw rubber has been known as a nuisance to surrounding communities due to the malodourous pollutants discharged, mainly from Standard Malaysian Rubber (SMR) processing factories. The major odorous and offensive volatile organic compounds (VOCs) emitted by the gases from natural rubber factories has been identified as low molecular weight volatile fatty acids (C2-C5) such as acetic, propionic, butyric, isobutyric, valeric and isovaleric acid (Niramol 2014). Other volatile organic contents verified based on characteristic ions of mass spectra included carbonyl compounds, low molecular weight compounds containing nitrogen or sulphur and aromatic compounds (Vipavee 2003). These odorous components are the by-products of non-rubber components which had undergone microbial breakdown during storage or thermal degradation during processing. During the processing of block rubbers, the malodorous VOCs, which are trapped in the cup lumps, are volatilized due to high temperature at the drying stage and released to the environment via the drier's exhaust gases (Zaid 2005).

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The most common method used by SMR processing factories to overcome the malodour problem is by installing a packed bed water scrubber system. Water scrubbers or 'wet scrubbers' is the generic name of an air pollution control device that uses the process of absorption to separate the water soluble pollutants from a gas stream. The process allows the gas stream carrying the malodorous VOCs to come into intimate contact with droplets of scrubbing liquid and this will enable the VOCs to become dissolved into the liquid which is further channeled into a water treatment plant to be treated before being released into the public sewerage system.

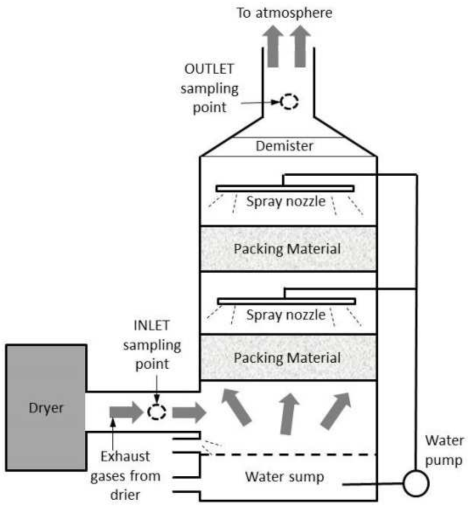

Figure 1: Schematic diagram of standard water scrubber treatment system

Figure 1 shows a schematic diagram of a packed bed water scrubber systems used by local SMR processing factories. It basically consists of a main cylindrical scrubber chamber containing two to three layers of packing materials held in place by mesh retainers. Packing materials are the medium to provide a large surface area for liquid-gas contact to encourage the absorption process. Water is distributed evenly onto the packing materials via the spray nozzles. The demister placed at very top functions as a mesh-type separator to prevent scrubbing liquid droplets from escaping the scrubber chamber and the water sump is used to hold and supply the scrubbing liquid (Wayne 2000). Previous study found that the water scrubber's malodour removal efficiency by this system can range from 48 % to as high as 92 % (Kamalruzaman 2012).

Despite the reported effectiveness of water scrubber systems, increase in public complaints due to malodour release from SMR factories has urged the Malaysian Department of Environment (DOE) to propose an Environmental Quality (Odour) Regulation to regulate the odour limit on the gas emitted from these water scrubbers. The regulation draft stipulates an odour discharge limit at point of emission of not more than 25,000 ou/m3 (odour units per cubic meter) at all times. Although this draft has yet to be gazette, it has already raised concern among the SMR industry because currently most factories are unable to comply with the proposed discharge limit using the present system (Kamarulzaman 2012) due to variations in standard operating procedures, maintenance and scrubber designs.

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This study aims to look at determining the factors causing the poor performance of the scrubber operating at Factory X and suggestions on how to improve them.

2. MATERIALS AND METHODS

2.1 Data Sampling

A scrubber unit from Factory X, an SMR processing factory with a total daily production of 170 tonnes of various block rubber SMR grades (eg. SMR 10/20/10CV/20CV/5GP), was evaluated. Selection was made based on the scrubber's accessible design structure and also due to the location of factory from odour testing lab which allowed samples to be sent directly for testing at the end of each day to achieve result validity as depicted by standards (CEN 2003).

For the evaluation of the scrubber performance, the following parameters were measured;

i. Odour concentration of the drier's exhaust gas before and after scrubber treatment (measured in ou/m3);
ii. pH of scrubbing liquid inside water tank;
iii. Air flow rate of gas stream at scrubber outlet (measured in L/s); and
iv. Volatile matter (VM) of shredded raw rubber.

A total number of three days were spent at the factory to monitor and gather the data for the performance of one operating water scrubber unit. Odour samples and raw rubber samples were collected three times a day at 9 am, 1 pm and 4 pm, whereas on-site readings such as water pH and air flow rate were recorded on an hourly basis using a portable pH meter and an anemometer respectively. Qualitative evaluations were also carried out through questionnaires to obtain information on water scrubber operations, housekeeping and maintenance practices.

2.2 Odour Test and Analysis

Odour testing services were carried out by Malaysian Rubber Board's Pollution Control Laboratory via dynamic olfactometry. The olfactometer employed in this study was DynaScent Olfactometer by EnvironOdour Australia Pty. Ltd with a dilution range of 22 - 218. This method is in accordance with MS 1963:2007 Air Quality: Determination of Odour Emission by Dynamic Olfactometry adapted from the European standard, EN 13725 (2003) where it measures the odour concentration within a volume of air in terms of odour units per cubic meter (ou/m3) (Kamarulzaman 2012).

The exhaust gas was sampled from two points; the inlet and outlet of the water scrubber treatment system (refer Figure 1). The gases were each collected into 10 L nalophan bags using a vacuum pump attached to an eco-drum. Samples had to be analysed within 30 hours prior to sampling as required by the standard.

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2.3 Scrubbing Efficiency

Scrubbing efficiency or odour removal efficiency measures the performance of the water scrubber system to remove malodorous components from the gas stream.

Scrubbing efficiency was calculated from the results obtained by using the following equation:

$$\text{Scrubbing efficiency} = (A-B)/A \times 100\%$$

A = Odour concentration at inlet (before undergoing scrubbing treatment); (Unit: ou/m3)
B = Odour concentration at outlet (after undergoing scrubbing treatment); (Unit: ou/m3)

3. RESULTS AND DISCUSSION

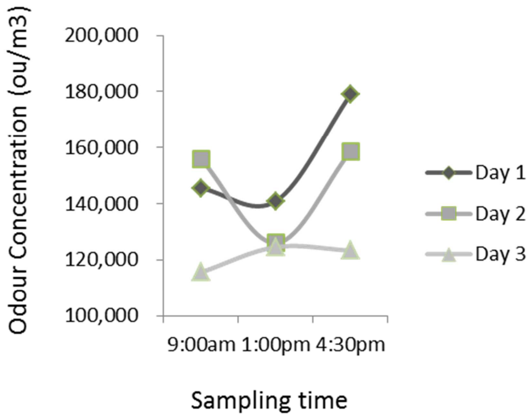

Figure 2 (a): Three-day profile study of before treatment (BT) odour concentration results taken at Factory X's scrubber inlet

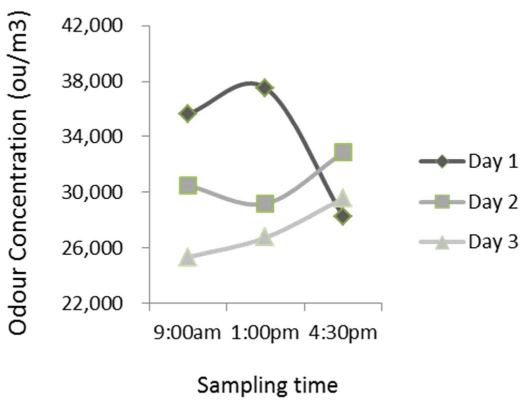

Figure 2 (b): Three-day profile study of after treatment (AT) odour concentration results taken at Factory X's scrubber outlet

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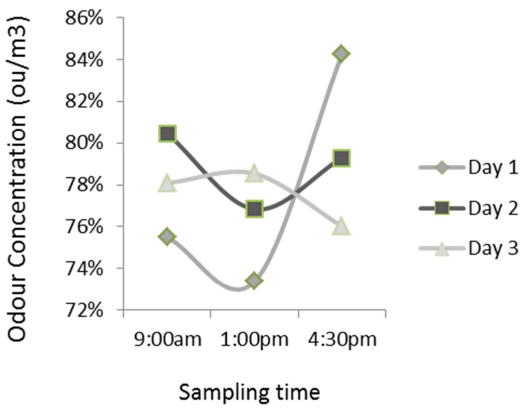

Figure 2 (c): Three-day profile study of scrubbing efficiency of Factory X's scrubber system

Figure 2(a), 2(b) and 2(c) shows the various performance of Scrubber No. 2 at Factory X throughout the 3-day evaluation.

In Figure 2(a), odour concentrations levels at the inlet of the scrubber ranged between 115,631 ou/m3 to 179,049 ou/m3 while Figure 2(b) shows odour concentration levels after scrubbing treatment ranged from 25,247 ou/m3 until 37,517 ou/m3. Day 2 showed the overall lowest release of malodour from the drier. On the other hand, the scrubber's odour removal efficiency was found to vary between 73 % until 84 % (Figure 2(c)), where the lowest and highest efficiency achieved both to have occurred on samplings carried out on Day 1. Efficiency patterns were not consistent throughout the three days. Further analysis is required to determine the cause for each of this.

3.1 Effect of pH Level of Scrubbing Liquid on Scrubbing Efficiency

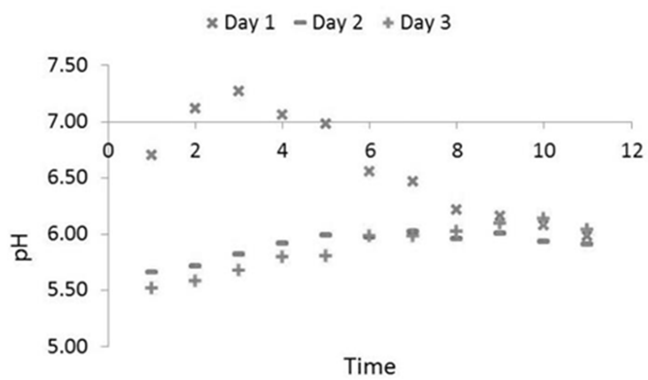

Figure 3: Daily pH profile of scrubbing liquid in water sump

Figure 3 shows the daily pH profile of scrubbing liquid at water sump. Readings were recorded 11 times throughout the day from 9 am until 5 pm for three consecutive days. The initial pH readings taken from sampling 1 to 7 on Day 1 showed relatively higher pH levels compared to those measured on Day 2 and Day 3 ranging from pH 6.7 to pH 7.3. The slight alkaline reading on Day 1 was due to the addition of an alkaline-base detergent applied into the water as a cleaning agent. The detergent created an alkaline solution in the scrubbing

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liquid which, theoretically, should have made it an effective absorption solution against the acidic VOCs. Nevertheless, as shown in Figure 2(b) and Figure 2(c), the scrubber showed relatively high outlet odour concentration level and low scrubber efficiencies respectively on the first sampling of Day 1.

It was suspected that there are two main factors causing this low scrubber efficiency despite the alkalinity advantage. Firstly, among the detergent's properties was to emit a citrus smell with the intention of masking obnoxious odours from the scrubber. However, this masking smell had ultimately contributed to additional odour units on top of the discharge odour units emitted from the drier. Thus, this increased the overall odour concentration level of the gas sampled from the scrubber exhaust and analysed via the olfactometer test. Secondly, the use of detergents in water would decrease its surface tension and show hydrophobic effects thus hamper the water's ability to absorb the malodorous compounds thus also reduce scrubbing efficiency (Breslow 1991).

Figure 3 shows that as Day 1 continued, without any further addition of detergent, the pH level of the water began to reduce towards saturation at pH 6 by the end of the day due to the acidity of the pollutants being absorbed. The pH profile of Day 2 and Day 3 were comparable without the dose of detergents and the pH level of the water remained acidic throughout the day between pH 5.5 to pH 6.2.

3.2 Effect of Air Flow Rate on Scrubbing Efficiency

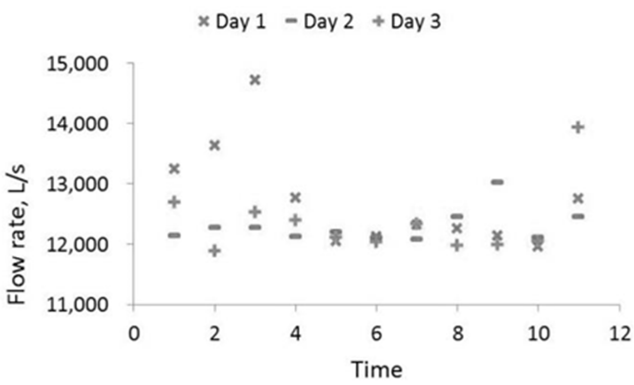

Figure 4: Daily flow rate profile of gas stream at scrubber outlet

From the daily air flow rate profile of the gas stream passing through the scrubber outlet shown in Figure 4, the air flow rates were seen to be fluctuating throughout the three days, mainly between 12,000 L/s to 13,000 L/s. Fluctuating air flow rates could be caused from varying pressure difference within scrubber or skewed water-gas flow which are both indicators for clogging of packing materials, demister or spray nozzles (Wayne 2000).

In contrast, Day 1 started with a relatively higher air flow rate reaching up to 15,000 L/s. Although the cause of this was not determined, nonetheless, the rapid flow would have resulted in insufficient contact time for absorption to occur between gases and liquid that would have also contributed to the low scrubbing efficiency earlier that day as shown during the 9 am and 1 pm sampling of Day 1 in Figure 2(c).

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3.3 Effect of Volatile Matter of Raw Rubber on Odour Concentration Levels of Drier's Exhaust Gas

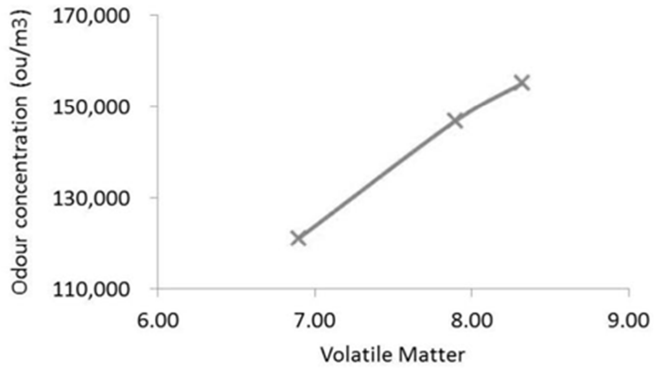

Figure 5: Odour concentration at scrubber inlet against volatile matter of raw rubber before drying

Figure 5 shows the relationship between the odour concentration level measured at scrubber inlet and the volatile matter (VM) of raw material before drying. Apparently, as VM reading increases, the odour concentration level released by the drier also increases. The VM reading indicates the volatile content within the raw rubber, suspected to mainly represent the volatile organic compounds (VOCs) produced from bacterial activity trapped inside the cup lumps. These VOCs are released into the atmosphere through volatilization during the drying process and produces the obnoxious smell of the drier's exhaust. Thus, it would explain how raw rubber with high VM value would produce a drier's exhaust gas with high odour concentration levels.

3.4 Evaluating Factory X's Compliance to DOE Regulations's Discharge Limit

As illustrated in Figure 2(b), all nine scrubber outlet's odour sampling results show that the scrubber failed to reduce the discharge odour to the suggested compliable limit of 25,000 ou/m3 despite reaching a scrubbing efficiency of up to 84%. This is due to the high odour concentration levels of the exhaust gas coming from the drier which ranged between 115,631 ou/m3 to 179,049 ou/m3 as shown in Figure 2(a). Therefore, in order to comply with the regulation limit, asides from focusing on the improving scrubber performance, focus should also be looking into ways to reduce the odour concentration at inlet which means controlling the VOCs released from the drier's exhaust gas. This would include finding ways to reduce volatile content in raw rubber, improve the cleanliness of drier and trolleys to reduce odour build-up, and to avoid the use of masking agents on cup lumps during storage as this would contribute to additional odour being picked up during odour sampling.

4. CONCLUSION

It was found that in order for raw rubber processors to comply with DOE's proposed odour discharge regulation, they would need to work on increasing their scrubber's efficiency and also reducing the odour concentration level of their drier's exhaust gas before it enters the scrubber system.

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The factors affecting scrubbing efficiency were found to be the pH of scrubbing liquid, solubility of pollutant into scrubbing liquid, additives contributing to additional odour units and the gas flow rate of gas stream while the factor contributing to high odour concentration levels of drier exhaust gas was due to the amount of volatile content in the raw rubber. Operator's lack of competency in handling scrubber operations and poor maintenance practices also affected the consistency of the overall scrubber performances.

Design of water scrubbers need to consider ease of monitoring and control of the each scrubber parameters to be able to achieve a more optimum scrubber performance. It is recommended to install instrumentations that would allow operators to control and monitor;

i. pH levels of water to observe scrubbing liquid acidity levels;

ii. Chemical dosing pump to adjust pH of water to become alkaline;

iii. Water flow rate to ensure undisrupted water supply is going into scrubber and to indicate plugging of spray nozzles;

iv. Air flow rate/pressure drop to monitor any indication of plugging in packing materials or demister;

v. Filtration system for sump to separate solid particles from entering sump that could cause clogging of nozzles and packing materials.

To improve maintenance work, design also needs to consider ease of parts removal and ease of access into areas that require frequent inspection, cleaning and/or replacement especially for the packing materials, spray nozzles, demister, water sump and dryers.

With regards to the high odour concentration level of the drier's exhaust gas, due to recent shortage supply of raw material it has resulted in closures of multiple SMR factories across the country. This has caused rubber block production to become centralized at the few remaining factories which leads to increase in these factories' production rate. This has led to current scrubbers not being able to treat the high odour concentration level resulted from the increasing production capacity of the factories. To address this issue, installation of an additional pre-treatment system should be considered to help reduce the odour levels before the exhaust gas is being further treated by the water scrubber system.

There are also considerations to include an adsorption column to remove any hydrophobic compounds that are not being removed by the scrubber system but may be contributing to high odour concentration levels.

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