

EFFECTS OF ADDITIVES IN REDUCING THE ODOUR CONCENTRATION EMANATING FROM WATER SCRUBBER IN RUBBER PROCESSING FACTORY

Mohd Ikram Mohammad¹, Nor Azieda Alias², Nur Fadhillah Idris¹ and Asrul Mustafa¹

¹Technology and Engineering Division, Malaysian Rubber Board (MRB), P.O. Box 10150, 50908 Kuala Lumpur, Malaysia

²Faculty of Applied Science, Universiti Teknologi MARA (UiTM), 02600 Arau Perlis, Malaysia

*corresponding author: ¹ikram@lgm.gov.my, ²aziedalias_93@yahoo.com, ¹fadhilah@lgm.gov.my, ¹asrul@lgm.gov.my

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ABSTRACT

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The paper describes the effects of additives incorporated into the scrubbing medium in reducing the odour concentration emanating from the water scrubber treatment system (WSTS) in Standard Malaysian Rubber (SMR) processing factory. Two different types of commercial WSTS additives were used in a lab scale simulation of a WSTS using water scrubber samples (WSS) as the scrubbing medium that were sourced from a local SMR processing factory. The WSS after incorporation of the additives were tested for odour concentration via olfactometry analysis. Total solid content, suspended solid, pH, UV-vis analysis and contact angle measurements of the WSS were also conducted. The results of olfactometry analysis indicated that each of the additives reduced the odour concentration level by 9.25% and 42.84%, respectively. The reduction in odour concentration was accompanied by an increase in total solid, suspended solid, pH and UV measureable compounds which may indicate an increase in the WSTS efficiency. The additions of additives were also shown to reduce the contact angle of the WSS that could plausibly be attributed to changes in the wetting properties of WSS. The work conducted has presented the likely effects of additives in the scrubbing medium or WSS of the WSTS in terms of its performance and properties.

Keywords: additives; water scrubber; odour concentration; SMR processing factory.

1. INTRODUCTION

Water scrubber treatment system (WSTS) is used to control air pollution in variety of manufacturing sectors. The treatment system uses water or liquid as the scrubbing medium to remove gaseous pollutants as well as particulate material that can contribute to air pollution towards the ambient environment. The most common type of WSTS used in raw rubber processing factories producing Standard Malaysian Rubber (SMR) is the vertical packed tower (Ming et al., 1985). The engineering design and operation of these WSTS may vary from one factory to another, but all share a similar purpose that is to minimize the gaseous pollutants particularly the obnoxious smell emitted during drying activities of SMR processing. Figure 1 shows a schematic diagram of a typical WSTS used in SMR processing factories. The WSTS normally consists of a cylindrical column with layers of packing material where the gaseous pollutant is passed through by facilitation of a suction fan. Water

is then sprinkled throughout the interior part of the WSTS using pressurized spray nozzles so that interactions can occur with the gaseous pollutants for collection of contaminants. The scrubbed gas is later passed through the demister situated at the outlet part of the WSTS before being discharged to the atmosphere in the state of reduced air emissions (Fatin, Nur-Fadhilah, & Ikram, 2015).

In the meantime, additives are sometimes used in the scrubbing medium or water scrubber samples (WSS) of the WSTS (Hutson et al., 2011). The use of additives in SMR processing factories is primarily for the intention of eliminating or reducing the malodour contained within the gaseous pollutants released from WSTS. The additives can also be referred to as malodour control substances that are usually implemented into the water holding tank of the WSTS. Usage of these additives have become widespread upon propositions by Malaysian Department of Environment (DOE) to impose the Odour Regulation in which malodour discharge limit should not exceed 25,000 ou/m³ at point source for SMR processing factories. Although the government has yet to gazette and impose the drafted Odour Regulation, its implementation is assumed important to avoid complaints being made towards SMR processing factories since the unpleasant smell is regarded as a public nuisance (Mohammadi et al., 2010).

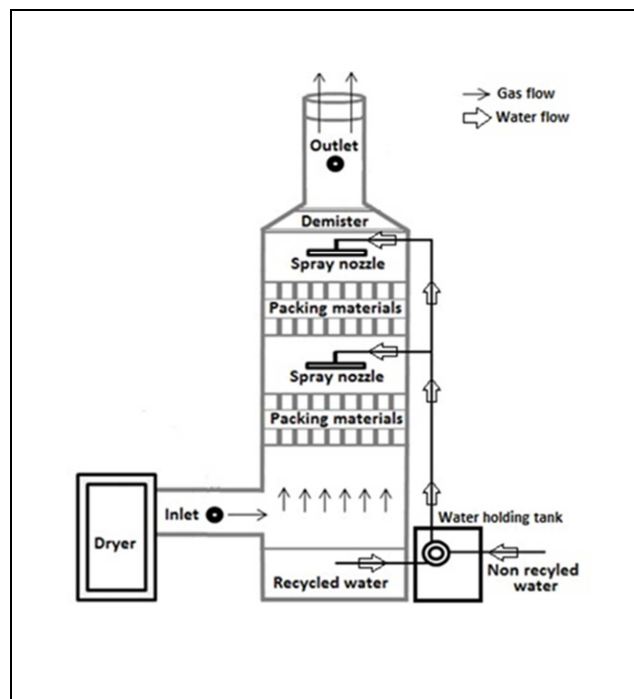


Figure 1: Schematic diagram of a typical water scrubber treatment system (WSTS)

Less is known regarding the effect or influence of additives used in WSTS to reduce odour concentration in SMR processing factories. Moreover the matter has rarely been described. Therefore, the present work seeks to investigate the usage of these additives in reducing the odour concentration. Further, the incorporation of additives was also highlighted in terms of

using different parameter measurements as an indication towards the likely effects that could occur.

2. MATERIALS AND METHOD

2.1 Sampling and simulation of water scrubber samples (WSS) for additive mixing and analysis

The WSS were obtained from a local SMR processing factory located in the state of Johor, Peninsular Malaysia. The WSS were collected directly from the water holding tank which is an integrated part and component of the WSTS and usually positioned below or perpendicular to the WSTS (Figure 1). Water scrubber samples were transferred into a 30 L airtight plastic container for transportation to the laboratory. Prior to analyses, the WSS were prepared for additive mixing. Figure 2 shows a schematic diagram on the general steps for additive mixing.

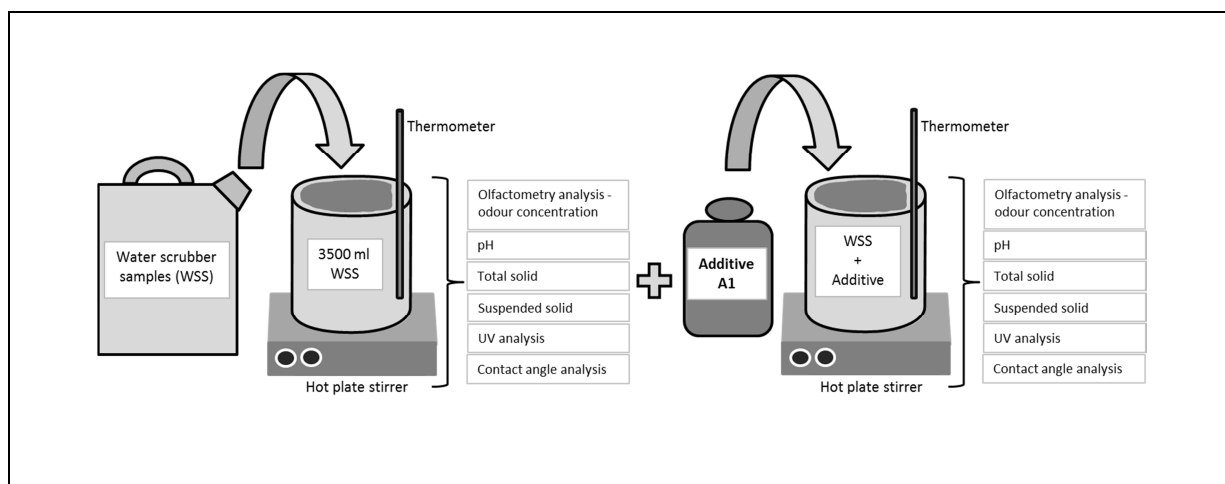


Figure 2: Schematic diagram on the general steps for additive mixing

Two different commercial WSTS additives were used and designated as additive A1 and A2. The additives were termed in alphabetical and numerical manner because disclosure of these commercial additives was restricted and not possible as to protect the legitimate concern and reputation of all parties involved. An amount of 3500 mL of the WSS taken were inserted into a 5 L glass beaker and covered at the top of the beaker with aluminium foil. The WSS were then heated until a constant 45°C temperature was attained using a hot plate stirrer and the temperature monitored using a mercury-in-glass thermometer. Agitation to the WSS was also applied constantly at 1000 rpm using a magnetic stirrer (Model Heidolph – MR Hei-standard). The temperature and agitation application was employed as to imitate the possible conditions of an operating WSTS throughout a lab scale setting. The WSS were then added with an additive (e.g. additive A1) in prepared portions such as that recommended and prescribed by the manufacturer of the different commercial additives utilised. The entire aforementioned procedure was again repeated separately using a different additive namely with additive A2.

The WSS were later tested for odour concentration, total solid content, suspended solid, pH, UV and contact angle at two different stages which is before (without) and after (with) incorporation of an additive. The WSS for before and after additions of an additive were assigned as (-) and (+), respectively. Water scrubber samples that were designated with (-) was merely used as the control sample. Collection of odorant gaseous samples for olfactometry analysis was done using PFA-HP (Perfluoroalkoxy-High Purity) flexible tubing and collected into a 5 L nalophon bag that was attached to a custom built-in vacuum pump eco-drum equipment where the lung principle was adopted. This was accomplished by inserting one end of the PFA-HP flexible tube into the head space of the beaker where odour was generated, for collection of odour samples by means of a vacuum pump suction. Detailed procedures for odour sampling can be referred in the Malaysian Standard (MS) 1963:2007.

2.2 Total solid, suspended solid and pH analysis

Determination of total solid content, suspended solid and pH in the WSS was done by outsourcing these various analyses to MRB (Malaysian Rubber Board), G-TAC_R (Global Testing and Consultancy for Rubber) Pollution Control Laboratory. The laboratory is accredited under the Skim Akreditasi Makmal Malaysia (SAMM) which meets the requirements of MS ISO/IEC 17025:2005 - "General requirements for competence of testing and calibration laboratories". Five hundred millilitres (500 mL) of the WSS were required for these analyses at a given stage of testing.

2.3 UV analysis

Water scrubber samples for UV analysis was transferred into a 3 mL quartz cuvette and analysis was conducted via a UV-Vis spectrophotometer (Thermo Insight, USA) at a scan speed of 1200 nm/min in the range of 200 nm to 500 nm. The WSS were filtered using a PTFE filter (0.45 μ m) and diluted 10 times with deionised water before analysis was conducted.

2.4 Contact angle analysis

Contact angles measurement was carried out with a Kruss Easy Drop Contact Angel employing the sessile drop method of liquid samples on a glass substrate. A drop of approximately 10 μ L of the obtained WSS was dropped onto the glass. The contact angles were recorded at five seconds interval until spreading of the dropped liquid reaches a state of equilibrium or when constant values of the contact angle measurements are achieved. Values that were taken in as results are the values of contact angle at equilibrium.

2.5 Olfactometry analysis

Odour concentration was measured by olfactometry method. The gaseous samples acquired were firstly diluted over varying concentrations with natural gas. The concentration of a gaseous sample of odorant was then determined by presenting the odour samples to a group of screened and trained panelists in order to determine the dilution factor at 50% detection threshold in an odour free environment. At that dilution factor, the odour concentration can be defined as 1 odour unit per cubic meter (ou/m³). The result of the analysis was subsequently expressed as a multiple (equal to the dilution factor at 50% detection threshold) of one Malaysian ou/m³ at standard conditions for olfactometry analysis (Malaysian Standard. MS

1963, 2007). Analysis was carried out in a confined odour control laboratory using DynaScent Dynamic Olfactometer. The olfactometer instrument applied the binary forced choice method throughout odour samples assessment by panelist. Sixty parts per million (60 ppm) of n-butanol was used as the calibration standard and control sample for the instrument. The accuracy and instability of the instrument was found to be smaller than 20% and 5%, respectively (Nor-Hidayaty, Nur-Fadhilah, & Zairossani, 2012). This inferred that the instrument was working at the optimum level of performance and conforming to MS 1963:2007.

3. RESULTS AND DISCUSSION

3.1 Total solid, suspended solid and pH

Table 1 depicts the total solid content, suspended solid and pH of the WSS A1 and A2, before (-) and after (+) the addition of two different additives. It was found that the incorporation of additives had increased the total solid and suspended solid content of both the WSS A1(+) and A2(+) as compared to WSS A1(-) and A2(-), respectively which are the WSS before additives were added. This increment might be an indication on the improvement of the scrubbing efficiency that may have transpired. During drying activities of SMR processing, streams of gaseous pollutants are emanated from the dryer and subsequently directed into the WSTS. The gaseous pollutants is then channelled outwards where it is forced through layers of packing material that function primarily to provide sufficient retention time and surface area while being washed down counter current with water. The action allows good gas-to-liquid contact being established in which the gaseous pollutants is collected into the water through absorption and eventually drained out of the WSTS as wastewater. Hence, the higher total solid and suspended solid content obtained could demonstrate an increase in the removal of gaseous pollutants via the WSS in addition to achieve a higher scrubbing efficiency. The pH of WSS A1(+) and A2(+) in comparison to WSS A1(-) and A2(-), respectively was also found to increase after incorporation of these additives. The increment was indicative of the presence or the use of alkaline constituents within the additives. It is worthwhile to note that for WSTS additive A2, its ingredient mainly consisted of sodium hydroxide (NaOH) among others. Alkaline substances such as caustic soda are the few common additives used in WSTS that aid in the absorption capacity for removal of gaseous pollutants by rendering the pH of the scrubbing medium or WSS. It was reported in the literature that slightly alkaline conditions favour the efficiency of the WSTS in lead smelters where lime was used to adjust the pH (Rabah, 2013). Further, in order to improve WSTS efficiency, SMR processing factories have been advised to increase pH of the water used for scrubbing by adding dilute solutions of caustic soda or calcium hydroxide (Devaraj et al., 2013). Nonetheless, the approach at present is often neglected in these SMR processing factories because it is deemed costly and due to poor maintenance of the WSTS components that strings to faulty chemical dosing equipment and pH monitoring devices utilized in the adjustment of pH.

Table 1: Results (mean \pm standard error) of total solid ($N = 3$), suspended solid ($N = 3$) and pH ($N = 3$)

Water scrubber samples (WSS)	Total solid (%)	Suspended solid (%)	pH
A1(-)	2567 \pm 2.9	83 \pm 1.2	7.58 \pm 0.02
A1(+)	2795 \pm 3.5	187 \pm 1.8	7.70 \pm 0.01
A2(-)	2584 \pm 3.3	130 \pm 1.5	7.98 \pm 0.02
A2(+)	5568 \pm 2.6	237 \pm 2.6	12.35 \pm 0.04

Symbols in parentheses represent (-) before - without additives and (+) after - with additives

3.2 UV analysis and contact angle

UV analysis in wastewater treatment has been widely accepted and applied in the monitoring of water quality. The monitoring of water quality using UV/UV-vis techniques is able to provide measurements such as nitrate, turbidity and organics (Broeke, Langergraber, & Weingartner, 2006). At the wavelength of 210 nm, nitrate absorption usually predominates although direct measurements are presumed to have certain interferences and a method of correction is required (Armstrong, 1963). Figure 3 shows the typical UV absorbance obtained for the WSS investigated. It was shown that the WSS strongly absorbed UV in the region of 210 nm to 220 nm.

Meanwhile, contact angle is the measurement of the angle at which a liquid comes into contact with a solid substrate surface. In general, contact angle can be visualised as the physical angle of contact that a droplet of liquid makes when at rest on the substrate where in the case of this investigation is a glass slide. The wetting properties of a liquid drop are associated to its surface tension and the changes in the liquid's surface tension can be indirectly inferred by comparing the liquid drop on a similar set of glass substrate. Low value of contact angle indicates a good wetting of the substrate by the liquid drop. Figure 4 illustrates a typical graph of contact angle against time for a drop of liquid with an inserted picture showing the shape of the liquid drop on a substrate in the measuring of contact angle. The importance of contact angle is to comparatively measure the changes of contact angle in the WSS before and after incorporation of the additives. It was suggested that the removal of pollutants in WSTS can be improved by increasing the wetting power of water used for scrubbing (The NALCO water handbook, 1988).

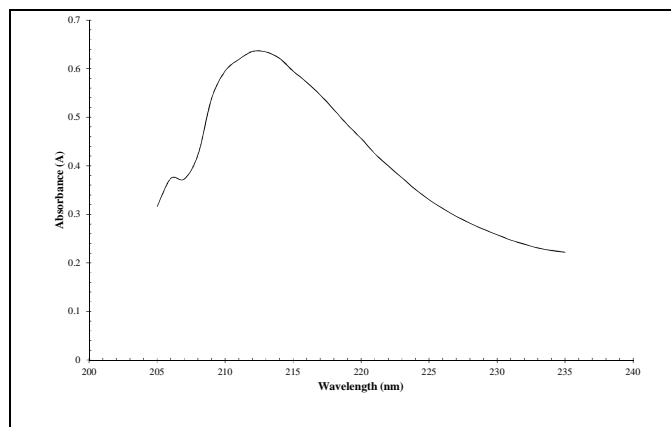


Figure 3: Typical UV spectrum for water scrubber samples (WSS)

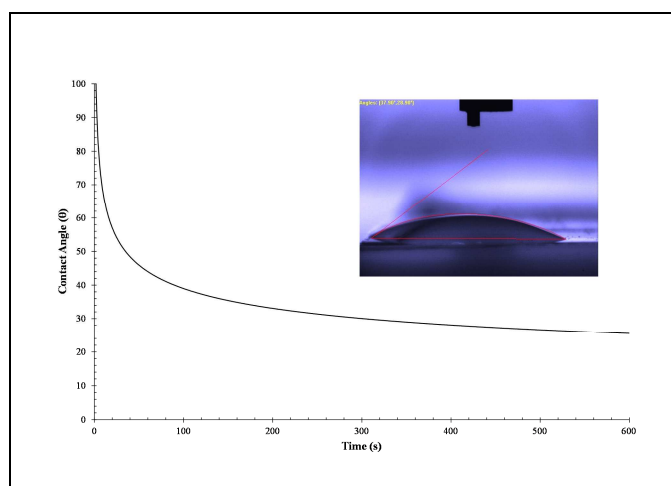


Figure 4: Typical graph and liquid drop shape from contact angle measurements

3.3 Relationship between UV measurable compounds, contact angle and odour concentration

Table 2 depicts the UV measurable compounds, contact angle and odour concentration of the WSS A1 and A2. From Table 2, a noticeable relationship can be observed between the UV measurable compounds absorbance at 210 nm, contact angle measurements and odour concentration of the WSS, before (-) and after (+) additions of the two different additives. It was found that the incorporation of additives was able to reduce the odour concentration level in both the WSS A1(+) and A2(+) when compared to WSS A1(-) and A2(-) with the reduction of 9.25% and 42.84%, respectively. Ironically, the findings were also accompanied with an increment of UV measurable compounds after additions of the additives in both WSS A1(+) and A2(+). This increase in the UV measurable compounds may perhaps be used as an indication towards a higher scrubbing efficiency that could have possibly occurred. Conversely, a lower contact angle was shown in both the WSS A1(+) and A2(+) after

incorporation of the additives, in comparison to WSS A1(-) and A2(+), respectively that of which are the WSS before additives were added. The reduction in the contact angle measurements is suggested to be related to an increase in the wetting power of the WSS and might promote to higher scrubbing efficiency.

Table 2: Results (mean \pm standard error) of UV measurable compounds ($N = 3$), contact angle, ($N = 1$) and odour concentration ($N = 1$)

Water scrubber samples (WSS)	UV measurable compounds (Abs 210 nm)	Contact angle (θ°) at equilibrium	Odour concentration (ou/m ³)
A1(-)	0.28 \pm 0.01	37.0	28585
A1(+)	0.33 \pm 0.02	31.7	25942
A2(-)	0.24 \pm 0.01	31.0	11771
A2(+)	0.64 \pm 0.01	26.0	6728

Symbols in parentheses represent (-) before - without additives and (+) after - with additives

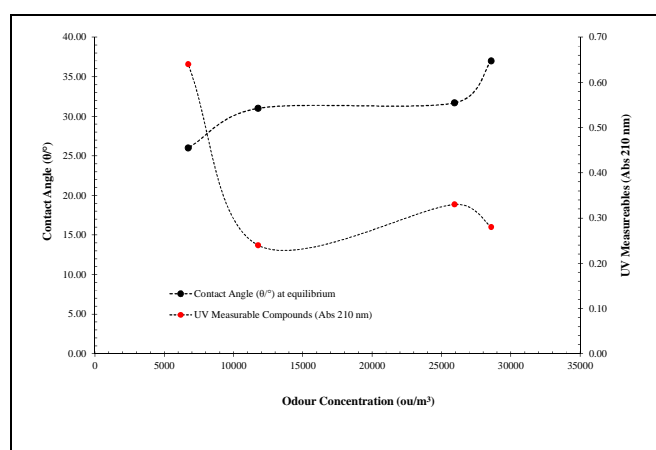


Figure 5: Trend of results obtained for UV measurable compounds and contact angle measurements plotted against odour concentration

To better simplify the associations perceived in Table 2, the measurements were plotted against each other and the trend attained was depicted in Figure 5. It was clearly indicated that upon adding the additives in both the WSS of A1 and A2, lower concentrations of odour were observed. This was also complemented with lower contact angel measurements, whereas the UV measurable compounds were shown to be vice versa in which it obtained higher values. On the whole, the incorporation of additives had shown the likely effects, either it be in the form of increment or decrement of the parameter measurements value. These parameter measurements might be of potential use to elucidate information related to the removal of

gaseous pollutants in the WSTS particularly in pertinent to the reduction of odour concentration.

4. CONCLUSION

The results highlighted were intriguing since each of the measurements comprising of total solid content, suspended solid, pH, UV measurable compounds and contact angel had exhibited some mode of effects that was interrelated with the odour concentration after two different additives were incorporated into the WSS of A1 and A2. The incorporation of the additives was shown to increase the total solid content, suspended solid, pH and UV measurable compounds of the WSS A1(+) and A2(+) in comparison to WSS A1(-) and A2(-), respectively which are the WSS before additives were added. On the other hand, lower contact angel measurements had been perceived in WSS A1(+) and A2(+) when compared to WSS A1(-) and A2(-), respectively which showed that wetting power of the WSS of A1 and A2 is increased. These measurement results obtained were under the notions that the additives could aid in the removal of gaseous pollutants, improve scrubbing efficiency and of utmost interest reduce the odour concentration, where a reduction of 9.25% and 42.84% in the odour concentration was shown in the WSS A1(+) and A2(+) as compared to WSS A1(-) and A2(-), respectively. The parameter measurements that had been used to show the effects of additives in reducing odour concentration is yet scarcely documented and can be used as a baseline in monitoring the operation and control of the WSTS in SMR processing factories. Further, the work should be extended at the field trials level to attain a more practical finding in efforts to aid in the mitigation of malodour issues encountered by SMR processing factory.

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