



Wet Scrubber Performance Optimization Application Assisted with Electrochemical-Based Ammonia Sensors

Ikha Rasti Julia Sari¹, Januar Arif Fatkhurahman¹, Bekti Marlana¹, Nani Harihastuti¹, Farida Crisnaningtyas¹, Yose Andriani¹, Nasuka¹

¹ Center of Industrial Pollution Prevention Technology, Jl. Ki Mangunsarkoro No. 6 Semarang 50136, Central Java, Indonesia

ARTICLE INFO

Article history:

Received 23 August 2019

Received in revised form 5 December 2019

Accepted 12 December 2019

Available online 16 December 2019

Keywords :

Crumb rubber

Ammonia

Wet scrubber

Sensor electrochemical

ABSTRACT

Crumb rubber is one of Indonesia's agroindustry export commodities. This industry faces environmental problems due to their wastes, both liquid and air. The source of air pollution is commonly from drying process that emitted odor from its evaporation and heating phenomena. Industry uses wet scrubber technology as air pollution control from emitted odor from drying process. Preliminary identification in noncontrolled wet scrubber shown that wet scrubber efficiency around 47%. Low efficiency wet scrubbing process causes rain drop of water vapor around drying process. This research used electrochemical based sensor MICS 5524 as ammonia monitoring instrument, assisted with arduino as microcontroller to regulate water discharge through valve controlling scrubbing process. This electrochemical based sensor reads ammonia based on voltage reads by Arduino microcontroller. Ammonia reading then control scrubbing process by adjusting valve opening for spray water distribution. Wet scrubber efficiency increases to 66,96% due to water scrubbing control, also can save water utilization as high as 61,90%, followed by absence of rain drop contains ammonia around drying process area.

1. INTRODUCTION

Rubber as an agroindustry export commodity has great contribution for Indonesian trade income. Natural rubber also take important role for industry, especially manufacturing industry (Barlow, 1983). Mostly, natural rubber exports from Indonesia are semi-finished materials in crumb rubber with Standard Indonesian Rubber (SIR) quality (Anon, n.d.). SIR is the technical specification of rubber which is judged on the level of impurities, ash content and volatile substances. Energy requirement in line with amount of product, high quality SIR need the more energy (Utomo et al., 2010), and generally use the greater water in production process (Maulina et al., 2015).

Crumb rubber factory in general is a process of natural rubber from brown crepe or lump to crumb rubber with certain specifications in the form of *bandella* which will be a raw material for mixing rubber products such as tires. Crumb rubber processing in physical process could be describe as treatment of raw material, starting from washing, chopping, grinding, drying, crumbing and drying (Setyamidjaja, 1993).

Crumb rubber processing provides potential pollution of the water and air for environment. They used water in washing process until brown crepe grinding, this process generates wastewater of washing from the impurities

*Correspondence author.

E-mail : ikharasti@kemenperin.go.id

doi: <https://10.21771/jrtpi.2019.v10.no.2.p36-42>

2503-5010/2087-0965© 2018 Jurnal Riset Teknologi Pencegahan Pencemaran Industri-BBTPPI (JRTPPPI-BBTPPI).

This is an open access article under the CC BY-NC-SA license (<https://creativecommons.org/licenses/by-nc-sa/4.0/>).

Accreditation number : (LIPI) 756/Akred/P2MI-LIPI/08/2016

that stick to the raw material of rubber. Due to its high needs of water, this process generate high quantity of wastewater that must pass through a Waste Water Treatment Plant before being Include the numbers, literature or data from the rubber processing industry flowed into the river. The main pollutant parameters in crumb rubber waste water are BOD (Biological Oxigen Demand), COD (Chemical Oxigen Demand), and TSS (Total Suspended Solid). The highest levels of BOD and COD were 313 mg/l and 928.1 mg/l from an acid bath, TSS came from shreeder at 190 mg/l, while ammonia at 38.45 mg/l from the effluent scrubber (Andriani et al., 2019).

The main air pollutant produced by the crumb rubber industry is odor from the drying process. Ammonia (NH_3) sourced from the decomposition of proteins contained in raw materials from fungal/bacterial activity (Atagana* et al., 1999). Control of odor in crumb rubber industry has been carried out by a wet scrubber. Wet scrubber is an effective device to control gas and particle contamination from exhaust gas (US EPA, n.d.)(Byeon et al., 2012). The type of wet scrubber that is commonly used in industry is spray tower(Bhargava, 2017).

Wet scrubber as a controller of air pollution in the rubber crumb industry is some times still far from optimal in operation. Ammonia gas released by the wet scrubber does not meet quality standards of KepmenLH No. 50 of 1996 (> 2 ppm) (Andriani et al., 2019). The effect of this ammonia is the emergence of a pungent odor and the tendency of the wet scrubber's inefficiency.

The development of environmental technology, monitoring of emissions can be done using sensors(Dong Dong et al., n.d.)(Jeong et al., 2012). Low cost sensor types are widely used for monitoring ambient air(Popoola et al., 2018)(Munir et al., 2019), because is lower and simpler sensor. Now spreading rapidly for non regulatory application.

This research as approach in applied research as a problem solving in industry, aiming to apply the ammonia sensor to assist the wet scrubber in the crumb rubber industry. Electrochemical-based ammonia sensor assisted

not only for monitoring tool but also developed as a control instrument integrated with arduino based microcontroller. This control device is used to adjust the amount of water spray on the wet scrubber, and is expected to improve the performance of the wet scrubber by increasing the binding efficiency of ammonia.

2. METHODS

Wet scrubber used in experiment (Golsta model GS-AS2) has specification as follows : capacity 3 T/H, body material stainless steel, 2 scrubbing stage, chimney height 600 cm and 76 cm diameter with tellerettes packing equipped with water circulating pump 10 HP as shown in Figure 1.

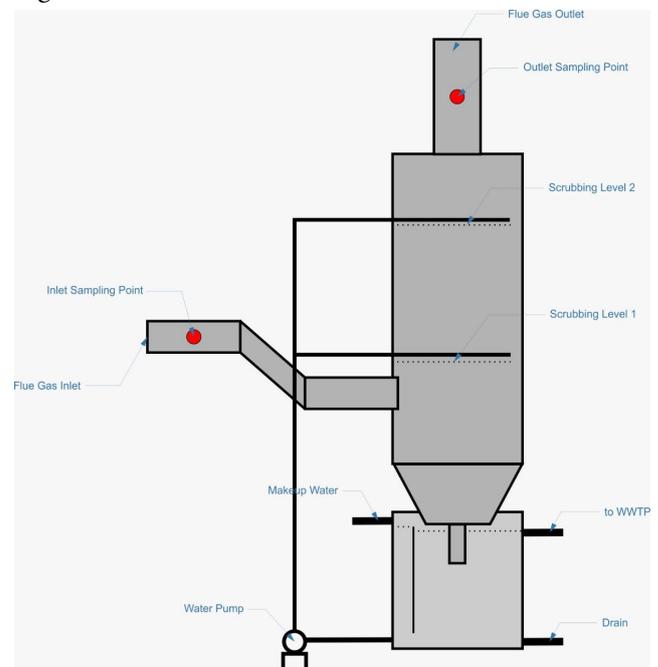


Figure 1. Wet scrubber existing

Micro-electro-mechanical System (MEMS) sensor for ammonia (MICS 5524, China). Microcontroller (Mega 2560, Arduino UNO, China) and raspberry pi, motorized ball valve (CWX 15Q, China)

Procedure

This research was conducted in two stages, the first was observation and the second was application of a sensor-based control system

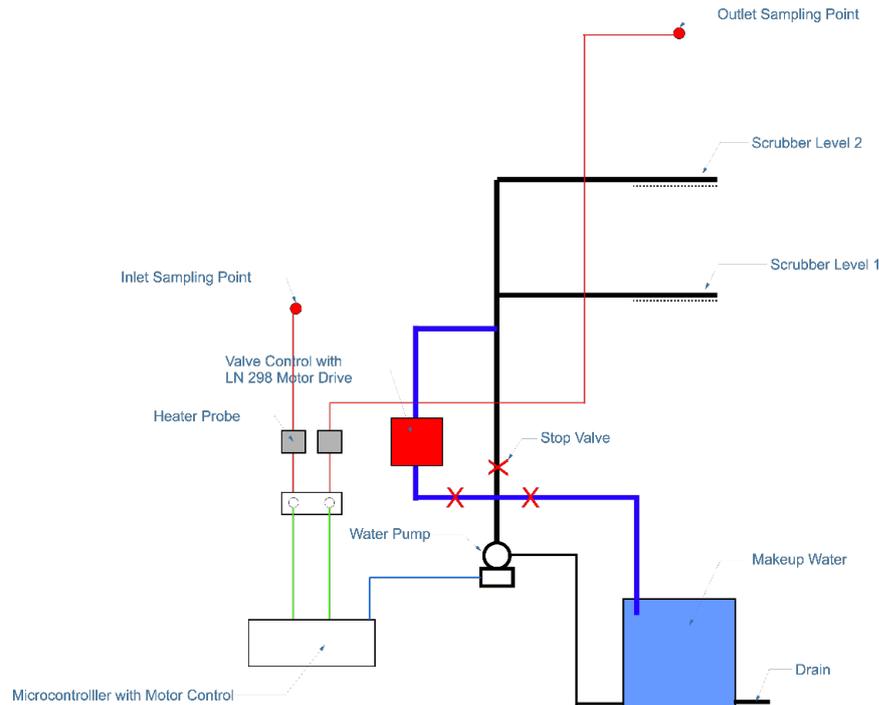


Figure 2. Experimental Setup

Observation of existing wet scrubber was carried out by visual observation and exhaust gas quality measurement during wet scrubber operation. Ammonia concentration of exhaust gas from dryer is measured as well as exhaust gas passed through the scrubber. This is done to determine the concentration of ammonia in and out of the scrubber as well as to determine the initial performance of the scrubber

Application step consists of designing a control system, installation in a wet scrubber, and evaluation. The design of the control system is carried out in the Center of Industrial Pollution Prevention Technology's laboratory. Sensor-based control system, consisting of a sensor, microcontroller, raspberry as LCD screen display, motorized ball valve.

The control system is installed on the existing wet scrubber by making some adjustments. Installation of control devices as shown in Figure 2.

After installed the control system, measurements were made of the concentration of ammonia released by the scrubber and the use of water used to absorb ammonia.

Ammonia outlet concentration data is used as a reference to drive the motorized solenoid valve. Controlled discharge is measured using valve open and close conditions

Quality of ammonia inlet and outlet scrubber were sampled by using air monitoring sampling standard method SNI 19-7119-1-2005 (Anon, n.d.) .

The efficiency calculation is done by analyzing the readings of the scrubber inlet and outlet using an ammonia sensor and data on water use savings are calculated from the control valve. And also we can calculate the using of spray water.

3. RESULT AND DISCUSSION

Visual observations of an existing wet scrubber in the industry showed that there was visible vogs and water droplets came out of chimney lead to local rain drop occurs around the plant. Spray water is manually pumped from the reservoir with a discharge of 0.675 liters/second.

Measurement results on ammonia inlet and outlet scrubber were shown in Figure 3.



Figure 3. Ammonia Emission Measurement Data Before Control

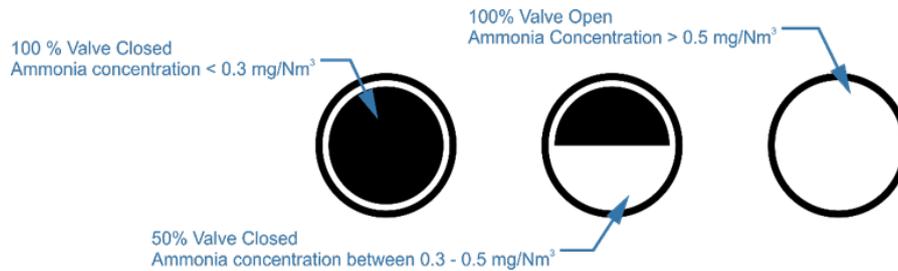


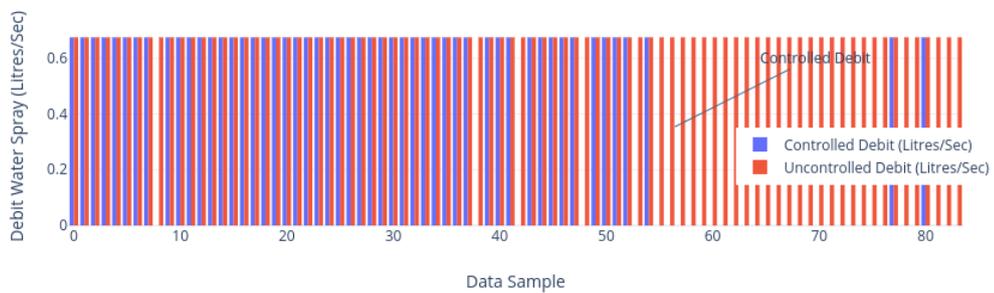
Figure 4. Trial Valve of Unit Control

Typical Inlet and Outlet Reading



(a)

Typical Controlled and Uncontrolled Debit



(b)

Figure 5. Typical Inlet and Outlet Reading After Control (a), Use of Water After Control(b)

Average concentration of ammonia inlet were 1.175 ppm, while concentration outlet was 0.627 ppm. Fig. 3 showed that more than 50% measurements of ammonia emissions were exceeded quality standard. An average efficiency of wet scrubber was around 47%. The existing wet scrubber average efficiency data shows the low efficiency of the wet scrubber, compared to the theoretical specification of the wet scrubber by 99% (Chien et al., 2015), besides that in the existing wet scrubber, the ammonia tendency to be discharged through the chimney is still above the quality standard.

Before designing the control system, ammonia sensors were verified using ammonia gas containers from liquid ammonia vapor, the verification results showed a linearity correlation > 0.9 . The ammonia sensor verification results show the possibility of using electrochemical sensors as a monitoring and control tool (Fatkhurrahman and Sari, 2019).

The design of the control system uses the following mechanism: the sensor reads the concentration of ammonia gas in the scrubber. The sensor is connected to the micro controller which is drive the motorized solenoid valve to regulate the amount of spray water.

There were three setting control on opening or close valve, if the ammonia cons $> 0.3 \text{ mg} / \text{nM}^3$, the valve will open 100%, if the cons was between $0.3 - 0.1 \text{ mg} / \text{Nm}^3$ the valve will open 50%, if the cons $< 0.1 \text{ mg} / \text{Nm}^3$ the valve will closed. Ammonia outlet concentration data is used as a reference to drive the motorized solenoid valve.

The design of the wet scrubber monitoring and control unit is based on an electrochemical sensor as shown in the figure 4.

Control system that has been made, installed in wet scrubber as Fig. 2. Trials of automatic valve control system was carried out to see the extent of improved NH_3 absorption efficiency and water use efficiency. Trials were carried out 3 hours, from 7 hours the regular production process. Controlled discharge is measured using valve open and close conditions, with typical data as shown in the figure below.

Using data from Figure 3, we calculate initial efficiency of this scrubber by comparing average outlet to average inlet concentration of ammonia, that is 47% efficiency. Application of water spray controlling using Arduino based microcontroller indicate different result specifically on outlet concentration of ammonia, as we see on Figure 5(a), no more ammonia reach national standard ammonia for emission. The average sorption efficiency of ammonia increased by 20% in the range of 66,96% by experimental data result as the rate of absorption is influenced by the contact area between the absorbing fluid and the gas (Maile et al., 2015), when water uncontrolled there is less time and area contact between ammonia as gas and water as absorbing liquid. We also can reduce the use of spray water until 62% during the period of experiment. This is in accordance with previous similar studies on the use of waterspray for particulate pollutants control which can save water use by an average of 59.8% (Fatkhurrahman et al., 2017).

4. CONCLUSION

Utilization of electrochemical-based ammonia sensors as ammonia emission monitor could be developed as assisted control device integrated with Arduino based microcontroller to control the use of water spray on wet scrubbers. This optimization process can increase the binding efficiency of ammonia by 20% from 47% to 66.96% and can save the use of spray water by 61.90%. Saving in water spray directly impact on reducing the burden of wastewater treatment.

ACKNOWLEDGMENT

This research had been supported by a research grant of Center for Industrial Pollution Prevention Technology (BBTPPI), under the Ministry of Industry, Indonesia. The authors express their gratitude to CV. Jadi Jaya Makmur as their supporting both location and emission sample and Mr. Yohan K aleb Setiadi as his support in analysis samples.

REFERENCES

- Andriani, Y., Rasti, I., Sari, J., Fatkhurrahman, J.A. and Hariastuti, N., 2019. Potensi Cemar Lingkungan Di Industri Karet Alam Crumb Rubber. *Prosiding SNPBS (Seminar Nasional Pendidikan Biologi dan Saintek) Ke-4*, pp.445–451.
- Anon, Indonesia Rubber Industry | GBG.
- Anon, *Standar Nasional Indonesia Udara ambien-Bagian 1: Cara uji kadar amoniak (NH₃) dengan metoda indofenol menggunakan spektrofotometer Badan Standardisasi Nasional*.
- Atagana*, H.I., Ejechi, B.O. and Ayilumo, A.M., 1999. Fungi Associated with Degradation of Wastes from Rubber Processing Industry. *Environmental Monitoring and Assessment*, 55(3), pp.401–408.
- Barlow, C., 1983. The natural rubber industry. *Outlook on Agriculture*, 12(1), pp.2–11.
- Bhargava, A., 2017. Wet Scrubbers – Design of Spray Tower to Control Air Pollutants. *International Journal of Environmental Planning and Development*, 1(1), pp.36–41.
- Byeon, S.H., Lee, B.K. and Raj Mohan, B., 2012. Removal of ammonia and particulate matter using a modified turbulent wet scrubbing system. *Separation and Purification Technology*, 98, pp.221–229.
- Chien, C.-L., Tsai, C.-J., Sheu, S.-R., Cheng, Y.-H. and Starik, A.M., 2015. High-efficiency parallel-plate wet scrubber (PPWS) for soluble gas removal. *Separation and Purification Technology*, 142, pp.189–195.
- Dong Dong, McAvoy, T.J. and Chang, L.J., Emission monitoring using multivariate soft sensors. In *Proceedings of 1995 American Control Conference - ACC'95*. American Autom Control Council, pp. 761–765.
- Fatkhurrahman, J.A. and Sari, I.R.J., 2019. Affordable Metal Oxide Gas Sensor as Environmental Friendly Method for Ammonia Gas Measurement. *IOP Conference Series: Earth and Environmental Science*, 366, p.012027.
- Fatkhurrahman, J.A., Sari, I.R.J. and Zen, N., 2017. Low cost particulate sensor sebagai unit kontrol untuk meningkatkan efisiensi penggunaan air proses wet scrubber. *Jurnal Riset Teknologi Pencegahan Pencemaran Industri*, 8(1), p.35.
- Jeong, I.C., Li, G. and Lim, S.B., 2012. Sensor-based Emissions Monitoring System. In *6th International Conference on New Trends in Information Science, Service Science and Data Mining (NISS, ICMIA and NASNIT), 25 2012*. Taipei, Taiwan: IEEE.
- Maile, O.I., Tesfagiorgis, H.B. and Muzenda, E., 2015. Factors influencing chemical absorption of CO₂ and H₂S in biogas purification: A review. In *Proceedings of the World Congress on Engineering and Computer Science*. Newswood Limited, pp. 619–622.
- Maulina, S., Meriam Nik Sulaiman, N. and Zalina Mahmood, N., 2015. Enhancement of Eco-Efficiency Through Life Cycle Assessment in Crumb Rubber Processing. *Procedia-Social and Behavioral Sciences*, 195, pp.2475–2484.
- Munir, S., Mayfield, M., Coca, D., Jubb, S.A. and Osammor, O., 2019. Analysing the performance of low-cost air quality sensors, their drivers, relative benefits and calibration in cities-a case study in Sheffield. *Environmental monitoring and assessment*, 191(2), p.94.
- Popoola, O.A.M., Carruthers, D., Lad, C., Bright, V.B., Mead, M.I., Stettler, M.E.J., Saffell, J.R. and Jones, R.L., 2018. Use of networks of low cost air quality sensors to quantify air quality in urban settings. *Atmospheric Environment*, 194, pp.58–70.
- Setyamidjaja, D., 1993. *KARET*, Yogyakarta: Penerbit Kanisius (Anggota IKAPI).
- US EPA, Monitoring by Control Technique - Wet Scrubber For Particulate Matter.
- Utomo, T.P., Hasanudin, U. and Suroso, E., 2010. Comparative Study of Low and High-Grade Crumb

Rubber Processing Energy. In *Proceedings of World Congress on Engineering* . London.