Affordable Metal Oxide Gas Sensor as Environmental Friendly Method for Ammonia Gas Measurement

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Abstract. This research report new method for ammonia gas concentration measurement using metal oxide sensor-based instrument. Ammonia gas prepared by diluting concentrated liquid ammonia in water collected in container. Ammonia gas then streamed into monitoring path made by acrylic cube. Ammonia gas concentration measured as voltage from MEMS MICS 5524 sensor, then with ESP 8266 based IoT module logged into google sheet. Correlation between voltage and ammonia gas concentration evaluated by linearity test, compare with SNI 19-7117.6-2005 standard method and resulted more than 0.9 linearity. This measurement totally nondestructive test, it carries no chemical agent could damage environment.

Keywords: ammonia, metal oxide sensor, MICS 5524, SNI 19-7117.6-2005

1. Introduction
Ammonia gas well known as air pollutant parameter that dangerously both for environment and health [1]. It has specific gas characteristic; sharp smell with transparent color. In Indonesia, KepMenLH No.50/1996 as odor quality standards [2], confined its concentration in environment, while for industry that emitted ammonia gas in its process, its emission quality standards for ammonia gas confined with KepMenLH No.13/1995 [3]. Strict regulation for ammonia gas caused by its severity for health, like lungs damage or bronchitis [4].

Ammonia gas emission in industry periodically inspected by accredited testing laboratory. Measured result reported to local environmental agency as industrial environment obedient. For this environmental monitoring, industry should comply its own sampling infrastructure [5]. Ammonia gas concentration commonly measured by standard method SNI 19-7117.6-2005 [6] in absorption-based technique using chemical reagent as absorption agent. Ammonia gas absorb with boric acid solution then analyze with old indophenol method using spectrophotometer in 630 nm wavelength [7]. This method unsafe for environment because it produces toxic and hazardous material. Other and also the oldest and traditional method it is organoleptic method, this is qualitative method [8]. Gas measurement technology continues in develop, some of them electrochemical base measurement like Metal Oxide Semiconductor (MOS) based sensor. MOS measure ammonia gas using output voltage reading and resistance value in every ammonia gas concentration diffused in [9]. Later this sensor utilization could be developed for industrial application as self monitoring for industrial emission.
2. Experimental Details
Main idea of this research focused on ammonia gas measurement flows through measuring path, equipped with inlet, outlet for gas and also ammonia gas sensor MICS 5524. This sensor typically multiple gas sensor for various gas detection with voltage reading as raw data measurement. It needs to be calibrated firmly then it can read ammonia gas concentration more accurate. This calibration process performed with standard method SNI 19-7117.6-2005 correlation with sensor voltage reading. For proper calibration process, gas sensor need to be calibrated with vary ammonia gas concentration, high and low concentration [10, 11].

Ammonia gas made by diluting 4 ml 25% concentrated liquid ammonia to 1000 ml for high concentration, 2.5 ml 25% concentrated liquid ammonia to 1000 ml for middle concentration and 1 ml 25% concentrated liquid ammonia to 1000 ml for low concentration, also we made blank concentration for noise concentration measurement. This ammonia solution then prepared in ammonia container, preserve in room temperature will create low and steady ammonia evaporation generated as ammonia gas. Generated gas flowed using an air pump with 1 litre per minute constant air flow. It will made voltage reading when ammonia gas hit MICS 5524 sensor. By using ESP 8266 based microcontroller, voltage reading transmitted and tabulated in google sheet for data analysis. For calibration purposes, boric acid solution as absorbing solution comply SNI 19-7117.6-2005 used for spectrophotometric indophenol method for two minutes. This exposure time slightly different with SNI 19-7117.6-2005 suggested sampling time for 20 minutes as trial result for ammonia gas generated from liquid ammonia much higher than common ammonia gas concentration for this standard method [12]. Instrument measurement setup for this research quite simple, shown in figure 1.

3. Result and Discussion
Ammonia gas reading in this research use MICS 5524 sensor, specifically this sensor using voltage reading 0 – 5 volts as ammonia gas concentration correlation [13, 14]. In cleaner air condition, this have voltage reading approximately 0.4 volt, this figured on figure 2. It shown when concentrated ammonia spread through measuring path, voltage reading begins rise significantly from 0.4 volt to higher voltage.
Figure 2. Typical voltage reading for MICS 5524

This small MICS 5524 sensor shown on figure 3, commonly sold in marketplace with price around IDR 200,000. It sensor datasheet claimed that this sensor has ammonia gas concentration range from 1 – 500 ppm, seeing this is cheap gas sensor it needs calibrated firmly using calibration gas standard or compared with standard method measurement like SNI 19-7117.6-2005. In this research we use this standard method for this calibration, as we want made this method as cheap also affordable for ammonia gas concentration reading.

Figure 3. MICS 5524 sensor

This research begins with ammonia gas making for several concentration by adding liquid ammonia into certain volume of aquadest, we made variable of 0 mL, 1 mL, 2.5 mL, and 4 mL liquid ammonia with 25% ammonia concentration. This variable will give various ammonia gas concentration by its ammonia evaporation on room temperature. This ammonia gas generates by ammonia vapor in gas concentration then flowed into measuring path with 1 liter / minute flow using diaphragm pump. In this measuring path, ammonia gas concentration read as voltage reading. This voltage data tabulated using ESP 8266 based microcontroller into google sheet, typical data saved, shown in figure 4.
After pass the measuring path, this ammonia gas absorbed with ammonia gas absorber, boric acid solution, the analyze with indophenol-based method, SNI 19-7117.6-2005. This ammonia then read as μg/mL by spectrophotometry analysis, then calculate with volumetric air sampled and multiplied by dilution factor to obtain mg/Nm³ unit, by this formula (1), where $A$ is ammonia concentration in sample, $B$ is blank concentration, $df$ is dilution factor, $V_s$ is volumetric air sampled, $17$ is ammonia molecular weight and $24,45$ is gas volume in standard condition $25^\circ$C, 760 mmHg.

$$C = \frac{(A-B) \times df}{V_s} \times \frac{17}{24,45} \quad (1)$$

With previous ammonia variable, we could made ammonia gas correlation to voltage reading, represent low concentration and high concentration as shown in figure 5 and have liner correlation more than 0,9 indicated this correlation fairly significant [15 in 16].

![Figure 5](image-url)

**Figure 5.** Ammonia gas concentration and voltage reading, (a) high concentration, (b) low concentration, (c) relatively blank concentration
There is identical respond between voltage and ammonia gas concentration, for relatively blank concentration, low concentration and high concentration also have linearity more than 0.9 that indicated positive correlation for these two parameters, this condition sufficiently needs as voltage correlation into ammonia gas concentration. We could measure ammonia concentration simply by put voltage reading into linear equation $y = 1368.5x - 438.12$, where $x$ indicates voltage reading. From this curve, we could also specify measurement range for this gas sensor, as we could see for lowest concentration measured on 0.31 volt converted to ammonia gas concentration we get 27.03 mg/Nm$^3$. For the highest concentration we made in this research we get 0.94 voltage reading for 867 mg/Nm$^3$. In this research it almost impossible to compare higher concentration with standard method used in this research, because it will make saturated color that impossible to analyze using spectrophotometer. But we could extrapolate it using linear equation and get 6404 mg/Nm$^3$ ammonia gas concentration when this sensor hit 5-volt reading using extrapolated measurement. By this result, this research suggested measurement range for this sensor from 27.03 mg/Nm$^3$ - 6404 mg/Nm$^3$ ammonia gas concentration.

4. Conclusion
In conclusion we have developed a new instrument setup for ammonia gas measurement using MICS 5524 correlated with SNI 19-7117.6-2005 standard method. The measurement can be done with ammonia gas prepared from ammonia liquid evaporation in gas container on room temperature flowed into measuring path equipped with MICS 5524 gas sensor. Entire measurement completed in real time, data tabulated on google sheet using ESP 8266 based microcontroller, which this method faster than SNI 19-7117.6-2005 standard method and totally nondestructive test, it carries no chemical agent could damage environment. We are in the process of developing this method and measurement for ammonia gas in industrial emission.

5. References
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