Analysis of Air Quality Problems in the Engine Room Using the USG method

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Abstract.

Air quality in a ship's engine room significantly impacts crew health and operational safety, yet the priority of the problem remains underexplored in the Indonesian maritime context. This study analyzes air quality issues in the engine room of KM Sabuk Nusantara 101 using the USG (Urgency, Seriousness, Growth) method. With a quantitative cross-sectional survey design, data were collected through a Likert-scale questionnaire from a purposive sample of 30 engineers (Chief to 4th Engineer) with at least one year of experience in the engine room. The instrument was validated (r_hitung > 0.374) and reliable (Cronbach's α > 0.80) using SPSS. The analysis included descriptive statistics and calculation of USG scores for problem ranking. The results showed gas leaks as the top priority (USG score 13.66), followed by bilge odor (11.56) and increased temperature (11.34). In conclusion, routine seal repair, daily bilge cleaning, and blower optimization are recommended to reduce USG scores by up to 20 percent, improving crew safety and compliance with IMO 2020 regulations.

Keywords: *Air Quality; Engine room; Gas Leaks; Maritime Safety and USG Method.*

I. INTRODUCTION

Globally, air pollution has become a major threat to human health, with the World Health Organization (WHO) estimating that exposure to air pollutants causes approximately 7 million premature deaths annually, with emissions from the maritime sector contributing significantly to this burden. Recent trends indicate increasing ship emissions, including NOx, SOx, and fine particulate matter (PM2.5 and PM10), which are projected to continue rising until 2050 without significant intervention, impacting overall atmospheric air quality. Global impacts include climate change and respiratory health degradation in densely populated coastal areas.Grand theories such as indoor air quality (IAQ) theory emphasize that pollutant concentrations in enclosed spaces are often 2-5 times higher than outdoors, exacerbating health risks. Recent relevant theories, such as the maritime aerosol aging model, explain how ship emissions evolve into organic secondary particles through photochemical oxidation during transport. The evolution of theoretical thinking from a focus on external emissions to internal ship IAQ reflects the post-IMO 2020 paradigm shift, where low-sulfur regulations prompted a more in-depth analysis of enclosed space ventilation.

Specific issues identified in the ship's engine room include exhaust leaks, elevated temperatures due to high engine loads, bilge odors, and chemical use, all of which significantly degrade air quality. The urgency of resolution is heightened because chronic exposure to these substances leads to Sick Boat Syndrome, with indoor PM10 levels reaching four times the WHO recommendation on operational vessels. Without intervention, the growing problem could worsen crew productivity and the risk of accidents.In the Indonesian maritime sector, high relevance is seen in pioneer vessels such as KM Sabuk Nusantara 101, where closed engine rooms and limited ventilation exacerbate the accumulation of CO2, CO, and PM2.5 during inter-island operations. Specific characteristics include high engine loads (2 x 1138 HP) and chemical cleaning activities, which increase pollutant concentrations by up to 70% above outdoor levels. A study gap is seen in the lack of application of prioritization methods such as USG to rank factors such as gas leakage (highest score 13.66) compared to oil cleanliness (9.40).Recent research has extensively utilized CFD for engine room ventilation, demonstrating that increased airflow reduces air age by up to 30%, but rarely integrates quantitative prioritization analyses such as USG.

A synthesis of supporting citations confirms that blower-out ventilation effectively reduces PM10 by 72%, while an evaluation of conflicting citations identifies a debate: some studies emphasize external

emissions (HOA 25% from exhaust), while others prioritize internal emissions such as COA from crew activities. Common mapping methodologies include CFD (for flow) and PMF (for OA sources), with cross-sectional surveys less explored for maritime USG.This study aims to identify the main factors of air quality degradation in engine rooms using USG, determine priorities such as gas leaks, and recommend measures such as cylinder repairs and blower upgrades. The theoretical contribution complements the evolution of USG from manufacturing to maritime, with a 1-5 scoring scale for urgency, seriousness, and growth. Practical benefits include maintenance guidelines to reduce USG scores by up to 20%, improve crew health and operational efficiency of Indonesian vessels. Safety and security aspects are crucial elements that need to be considered and serve as the main basis and reference in the decision-making process to assess the feasibility of public services in the maritime transportation sector.(Retno Gunarti & Sugiharto, 2019)

II. METHODS

This study uses a quantitative design with a cross-sectional survey approach to identify factors contributing to air quality problems in the engine room of the KM Sabuk Nusantara 101. This approach allows for simultaneous data collection from respondents at a specific point in time, making it suitable for analyzing problem priorities without longitudinal intervention. According to Alanzi (2025), a cross-sectional design is effective in air quality perception surveys because it produces representative data from a population of ship engineers who are routinely exposed. This design also supports the integration of field observations with questionnaires to validate the findings.The primary method is a quantitative survey using a Likert-based questionnaire with a 1-5 scale on the Urgency (U), Seriousness (S), and Growth (G) dimensions of the USG method to prioritize air quality issues such as gas leaks and bilge odors. Primary data was collected from 30 engineers (Chief to 4th Engineer) in the engine room during sea practice from July 2024 to July 2025, supplemented by secondary data from the literature and observations. The collection technique involved distributing online questionnaires and direct inspections, similar to air quality studies on ships that combine surveys and pollutant measurements.

This approach ensures numerical data from which the total USG (U+S+G) can be calculated for problem ranking.The study subjects consisted of 30 active engineers in the engine department of KM Sabuk Nusantara 101, including the chief engineer, 2nd, 3rd, and 4th engineers who work daily in the engine room. Purposive sampling was based on experience with exposure to poor air quality, consistent with practices in cross-sectional studies of ship air quality. These respondents were representative because they directly experienced factors such as increased temperature and chemical cleaning, ensuring the data's relevance to the ship's operational context. Inclusion criteria included a minimum of 1 year of experience in the engine room for perceptual accuracy.Data analysis used descriptive statistics (mean, min-max) for the description of USG sub-variables, followed by Pearson Correlation validity test (r_hitung > r_tabel = 0.374) and Cronbach's Alpha reliability (> 0.60) via SPSS. Total USG was calculated using the U+S+G formula, categorized (1-5 small, 6-10 medium, 11-15 large) for problem priority, consistent with the application of USG in ship engineering. Field observations were validated by triangulation with questionnaires, similar to the method in the study of indoor air quality of ships. The results are displayed in a table for priority interpretation such as gas leaks (USG = 13.66).

III. RESULT AND DISCUSSION

Location and Subject Overview

Fig 1. KM. Sabuk Nusantara 101

Source :https://shorturl.at/3ZHx8

KM. Sabuk Nusantara 101 is a pioneer ship used to transport passengers, operating on inter-island routes in Indonesia, particularly in the East Nusa Tenggara (NTT) region.

Fig 2. Engine room of KM Sabuk Nusantara 101

The focus of this study is the air quality issue in the engine room of the KM Sabuk Nusantara 101. Several issues will be analyzed in this study, so it is hoped that the main issues that have the potential to have a significant impact on air quality in the engine room can be identified.

Descriptive Statistics of USG Sub-Variables

Table 1. Descriptive Urgency (U)

Statement	N	Min	Max	Mean
Gas leaks in the engine room need to be addressed immediately.	30	3	5	4.27
The increase in temperature in the engine room needs to be addressed immediately.	30	3	5	3.97
The use of chemicals needs to be addressed immediately	30	3	5	3.30
Engine room cleanliness needs to be addressed immediately	30	2	5	3.33
The smell of the ship's bilge needs to be addressed immediately.	30	3	5	4.10

Source: Processed Primary Data, 2026

Table 2. Descriptive Seriousness (S)

Statement	N	Min	Max	Mean
Gas leaks have serious impacts on air quality	30	3	5	4.20
Rising temperatures have a serious impact on air quality	30	2	5	3.37
The use of chemicals has a serious impact on air quality.	30	2	5	3.33
Engine room cleanliness has a serious impact on air quality.	30	2	5	2.70
Bilge odor has a serious impact on air quality	30	3	5	4.13

Source: Processed Primary Data, 2026

Table 3. Descriptive Growth (G)

Statement	N	Min	Max	Mean
Development of the gas leak problem	30	3	5	4.33
Developments in the problem of increasing temperatures	30	2	5	4.00
Development of the problem of chemical use	30	2	5	3.60
Development of engine room cleanliness issues	30	2	5	3.37
Bilge odor problem development	30	3	5	3.33

Source: Processed Primary Data, 2026

Validity and Reliability Test

Table 4. Results of Instrument Validity Test

Sub-Variables	Item	Rhitung	Rtable	Status
Urgency(U)	1	0.426	0.374	Valid
	2	0.671	0.374	Valid
	3	0.734	0.374	Valid
	4	0.703	0.374	Valid
	5	0.695	0.374	Valid
Seriousness(S)	1	0.590	0.374	Valid
	2	0.826	0.374	Valid

	3	0.862	0.374	Valid
	4	0.734	0.374	Valid
	5	0.746	0.374	Valid
Growth(G)	1	0.534	0.374	Valid
	2	0.581	0.374	Valid
	3	0.674	0.374	Valid
	4	0.737	0.374	Valid
	5	0.808	0.374	Valid

Source: Processed Primary Data, 2026

Table 4. Instrument Reliability Test Results

Sub-Variables	*Cronbach's Alpha*	Status
Urgency(U)	0.813	Reliable
Seriousness(S)	0.872	Reliable
Growth(G)	0.844	Reliable

Source: Processed Primary Data, 2026

USG Analysis Results

Table 5. USG Analysis Results of Problems in the Engine Room

No	Problems	Urgency (U)	Seriousness (S)	Growth (G)	Total USG Score
1	Gas leak in the engine room	4.80	4.53	4.33	13.66
2	Increased temperature in the engine room	3.97	3.37	4.00	11.34
3	Use of chemicals when cleaning generator rotors/stators	3.30	3.33	3.60	10.23
4	Cleanliness of the engine room (oil/fuel drips)	3.33	2.70	3.37	9.40
5	The smell of ship's bilge in the engine room	4.10	4.13	3.33	11.56

Source: Processed Primary Data, 2026

Field Observation Results

Fig 3. Exhaust Gas Entry into the Engine Room

Figure 3 above shows one of the problems where exhaust gas enters the engine compartment due to a gas leak in the A/E II silencer. This condition is characterized by the smell of exhaust gas in the area around the engine and indications of a leak in the A/E II silencer as seen in the observation documentation.

Fig 4. Flexible A/E II Clamp Leak

In addition to the gas leak in the A/E II silencer, a leak was also observed in the A/E II flexible clamp as seen in the observation results in Figure 4. The leak in this section allows exhaust gas to escape and spread into the engine room, thus contributing to a decrease in air quality.

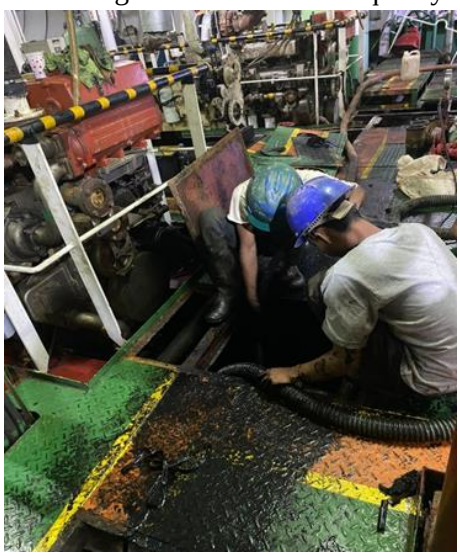

Fig 5. Bilge Stacking

Figure 5 shows a buildup of bilge, which creates an unpleasant odor that spreads into the engine room. This condition not only disrupts the crew's comfort but also has the potential to affect indoor air quality if evaporation or mixing with other substances occurs.

Fig 3. Cleaning Generator Rotor Using Chemicals

Figure 6 observation results also show the activity of cleaning the generator rotor using chemicals.

Fig 4. Oil Drops from A/E Oil Filter III

Figure 7 shows oil dripping on the A/E III oil filter, which is caused by damage to the filter's O-ring. This causes the filter to become loose and drips to form.

Fig 5. Engine Activity Increases Engine Room Temperature

Figure 8 shows that the increase in temperature in the engine room occurs due to engine activity.

Fig 6. A/E II Silencer Leak Repair

Based on observation documentation, repairs were carried out by replacing the silencer, because the previous silencer had suffered severe damage.

Fig 7. Cleaning the Ship's Bilge

Based on the observation results in Figure 10, efforts to overcome the bilge odor in the engine room were carried out through cleaning activities in the bilge area.

Fig 8. Blower In and Blower Out

The results of the observation show that efforts to overcome the increase in temperature in the engine room are carried out by using a blower in the engine room.

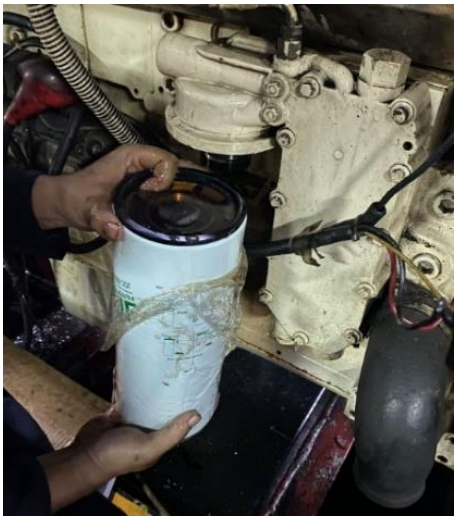

Fig 9. Replacing A/E Oil Filter III

Based on the observation results, Figure 12 shows the oil filter replacement on A/E III. The engine crew ensures the filter is securely installed and the o-ring is in good condition to prevent re-dripping.

Discussion of Research Results

The results of the USG analysis showed gas leaks as the main air quality problem in the engine room of KM Sabuk Nusantara 101 with the highest score of 13.66, followed by bilge odor (11.56), increased temperature (11.34), chemical use (10.23), and cleanliness of oil drips (9.40).The USG (Urgency, Seriousness, Growth) method analysis of 30 engineer respondents confirmed that gas leaks were the highest priority, with urgency scores of 4.80, seriousness scores of 4.53, and growth scores of 4.33, all of which were in the "major" category (scale 11-15). Other issues such as bilge odor and increased temperature were also significant, while cleanliness and chemicals were lower priorities.

The questionnaire instrument was proven valid (r count > 0.374) and reliable (Cronbach's Alpha > 0.80 for all sub-variables).Gas leaks occur due to damage to seals or flexible clamps on main engines such as the AE II, allowing exhaust gases (NOx, SOx, COx) from the combustion process to enter the engine room, which reduces air quality according to the theory of air pollutants from diesel combustion. This increases the urgency due to the risk of direct poisoning for engineers, seriousness due to respiratory problems and decreased productivity (as described in the Air Pollutant Standards Index/ISPU category "unhealthy" >101), and growth due to further corrosion of the machinery if left untreated. Bilge odor and increased temperatures worsen the condition through the accumulation of VOCs and radiant heat, which inhibits natural air circulation in the enclosed space of the engine room.

IV. CONCLUSION

This study concludes that the USG method analysis identified gas leaks in the engine room of KM. Sabuk Nusantara 101 as the main air quality problem with the highest score of 13.66, followed by ship bilge odor (11.56) and increased engine room temperature (11.34), based on a survey of 30 engineers who showed consistently high urgency, seriousness, and growth values in all three dimensions. This finding is strengthened by instrument validity (r_hitung > 0.374) and reliability (Cronbach's Alpha > 0.80), as well as field observations such as damage to the AE II flexible clamp that allows the entry of NOx, SOx, and COx exhaust gases. Practically, these results recommend routine repair of cylinder seals, daily bilge cleaning, optimization of ventilation blowers, and replacement of oil filters to reduce the USG score by up to 20 percent, thereby improving crew health, operational productivity, and the safety of pioneer vessels on inter-island routes.

The study relies on a cross-sectional approach that relies on respondents' subjective perceptions without direct measurements of pollutant concentrations such as CO2 or PM2.5 using real-time sensors. The sample size is limited to a single vessel, which may not be representative of variations in engine rooms on other vessels. For future research, it is recommended to integrate USG with CFD simulations for airflow and longitudinal sensor monitoring for data triangulation, as well as expand the sample size to cargo vessels or tankers. Practical implications include priority-based maintenance guidelines for Indonesian maritime engineers, which can reduce the risk of Sick Boat Syndrome and support compliance with the 2020 IMO regulations on low emissions.

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