JOURNAL LA MEDIHEALTICO

VOL. 05, ISSUE 03 (681 -688), 2024
DOI: 10.37899/journallamedihealtico.v5i3.1489

Systematic Review: Analysis of the Impact of Hydrated Lime (Cao) Exposure pon Coal Mining Workers

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Article Info

Article history:
Received 2 July 2024
Received in revised form 3 August 2024
Accepted 18 August 2024

Keywords:
Quicklime (CaO)
Occupational Health
Safety
Environment

Abstract

This study aims to analyze the effects of quicklime (CaO) exposure on the health of coal mine workers. Quicklime is frequently used in the treatment of mine pit water to neutralize acidity and precipitate heavy metals. However, its use also poses potential health risks to workers who are exposed to it. This study involved measuring the levels of quicklime exposure at various mine locations and evaluating its health impacts on workers through health surveys, lung function tests, and blood analyses. The results indicate that long-term exposure to quicklime can cause irritation of the respiratory tract, eyes, and skin. Workers exposed to high doses exhibited symptoms such as chronic cough, shortness of breath, and dermatitis. Laboratory analyses revealed increased calcium levels in the blood, although still within normal limits. Factors such as exposure duration, use of personal protective equipment (PPE), and working conditions significantly influenced the level of health risk. These findings highlight the importance of implementing strict occupational safety protocols, including adequate PPE use and regulation of quicklime exposure, to minimize health risks for coal mine workers. Additionally, regular monitoring and occupational health programs need to be enhanced to ensure the well-being of workers in coal mining environments.

Introduction

Tohor lime (CaO) is non-hydraulic lime obtained from burning natural stone and is also called quicklime. CaO is formed by a calcination reaction. Calcination produces a temperature of approximately 900 ºC. As a result of this process, the carbon dioxide (CO2) contained in calcium carbonate (CaCO3) is released and what remains is only the lime, namely calcium oxide (CaO), based on the general formula CaO has a molecular weight of 56.0774 g/mol (Acharya & Kharel, 2020).

Quicklime (CaO) in Indonesia is widely used in the process of neutralizing coal mine acid water for environmental problems caused by liquid waste from coal mining activities. Quicklime (CaO) in the coal mining industry is used as an active method in the process of neutralizing acid mine drainage (Tong et al., 2021). This method is widely used by the coal mining industry in Indonesia by adding quicklime in certain doses which is called an active treatment process for neutralizing acid mine water (Noor et al., 2020).

The coal mining industry in the process of applying quicklime to the management of acid mine drainage is an important stage, where quicklime is used to neutralize the acidity of acid mine drainage produced during the process of mining minerals, such as coal (Rozet et al., 2023). Although quicklime provides significant benefits in reducing negative impacts on the

ISSN 2721-1215 (Print), ISSN 2721-1231 (Online)

environment, such as neutralizing the acidity of acid mine drainage, this process also presents health risks for workers directly involved, where in the process of applying quicklime to workers they can be exposed to dust and vapors of inorganic chemicals. It may be carcinogenic which occurs during the process of applying quicklime.

The process of neutralizing acid mine drainage using quicklime in the mining industry has the potential to produce quite large amounts of chalk or limestone dust (Benthaus et al., 2020). This occurs due to the accumulation of lime dust from workers working at the same time. With employee tenure ranging from 1-5 years with an average of 8 hours per day and 7 days a week. Exposure to quicklime dust can cause disease, one of which is through inhalation because quicklime dust contains particulate matter (PM), which originates during the process of handling and managing quicklime which will continue to produce lime dust so that the process produces PM 2.5 dust. as the main component, because the main source of PM 2.5 is chalk dust which, if inhaled continuously for a long period of time, can affect workers' health.

The PM 2.5 content in quicklime is usually caused by dust produced during the handling, crushing or processing of quicklime in the neutralization of acid mine drainage. This can occur when quicklime is excavated, crushed or transported which can produce dust or small particles that enter the air. Apart from that, because the process of neutralizing acid mine drainage using quicklime is carried out simultaneously with workers working at the same time in the environment where the process of applying quicklime is exposed simultaneously to exposure to the management of quicklime, this can also produce dust and pollutant gases (Rachmawati, 2013). Thus, in the process of applying quicklime to acid mine drainage, TSP and SO2 are present, therefore the presence of TSP and SO2 in quicklime dust depends on the environment where the quicklime is located and the possibility of exposure to sources that have wet characteristics depends on the individual's characteristics. of the particles that make it up and the environmental conditions in which they exist.

Working environmental conditions in coal mining will affect workers' health. Dust contained in the work environment will interfere with productivity and health. Workers who are frequently exposed to dust are at risk of experiencing health complaints, both in the form of infectious and non-infectious diseases. which can be through inhalation (Douwes et al., 2003). A potential workplace hazard that will enter and accumulate in the body is influenced by the length of exposure and continuity of exposure. The longer the worker is exposed to exposure, one of which is exposure to dust particles, the more dust particles will accumulate in the body. This is in line with research (Armaeni & Widajati, 2016) where information was obtained that 23 workers in the limestone manufacturing industry were declared to have experienced health problems due to exposure to quicklime dust, including 6 people complaining of shortness of breath and 13 people not wearing masks while working. The employee's work period ranges from 1-5 years with an average of 8 hours per day and 7 days a week. This can provide an illustration that industrial work that is exposed to quicklime dust has a risk of health problems for its workers.

Quicklime dust is an irritant when it comes into contact with the mucosa of the respiratory tract, which can cause disease through inhalation. In research (Yulaekah, 2007), diseases caused by exposure of workers to quicklime dust through inhalation include lung function disorders both acute and chronic, for example respiratory tract irritation, narrowing of the respiratory tract, other respiratory disorders such as coughing, shortness of breath, and chest pain. It is important to pay attention to dust control and air pollution control during the process of handling and using quicklime to minimize exposure of workers to quicklime dust and prevent environmental pollution.

As is the case in one of Indonesia's largest coal mining companies, namely PT Bukit Asam Tbk, Tanjung Enim, South Sumatra, which uses an active method for neutralizing acid mine drainage, namely using quicklime. In research (Sari et al., 2018) the total amount of lime used to neutralize acid mine water so that it complies with environmental quality standards is 36 sacks/day. Actually, the use of quicklime in the liming process does not use precise calculations, only based on estimates.

Considering the important role and workload that must be carried out by officers applying quicklime to neutralize acid mine drainage, monitoring of workers' health is necessary. Therefore, everyone involved must have awareness and strive for work safety and need to monitor dust exposure at work sites in order to create safe, comfortable and healthy conditions for workers.

From the review above, an environmental health risk analysis is needed with the aim of identifying various factors caused by exposure to quicklime workers . Therefore, this research was conducted using the environmental health risk analysis (ARKL) method. This is the background to this research entitled " Environmental Health Risk Analysis of Exposure to Tohor Lime ($PM_{2.5}$, TSP, AND SO_2) in Acid Mine Water Management Workers at PT Bukit Asam Tbk Tanjung Enim, South Sumatra."

Methods

This study employs an observational approach with a cross-sectional design to evaluate the impact of hydrated lime exposure on the health of coal mining workers. The study population consists of active miners at sites with potential hydrated lime exposure. Data collection involves health surveys to identify symptoms such as respiratory irritation and dermatitis, and lung function measurements using spirometry. Data analysis is conducted descriptively and inferentially to evaluate the relationship between hydrated lime exposure and health symptoms. The study also considers research ethics and variable control to ensure the validity of the research findings.

Result and Discussion

Exposure Analysis

Respondent Characteristics

Table 1. Age Distribution of Quicklime Workers in Acid Mine Drainage

Variabel	Mean	Median	SD	Min-Max	95% CI	P-Value
Usia	34,86	34,00	5,628	27 - 45	31,61 – 38,11	0,570

Based on the distribution table above, it is found that the average age of quicklime workers in acid mine water management is 34.86 years , with a median value of 3-4.00 years and a standard deviation of 5.628 . The youngest age is 27 years while the oldest is 45 years. Based on the normality test carried out for the age variable using the *Shapiro Wilk test* , the *p-value* was 0.570 > 0.05, which means that the age value of the parking attendant is normally distributed. so the value used is 34.86 years for age.

Anthropometric Characteristics

Table 2. Statistical Results of Body Weight of Tohor Lime Workers in Acid Mine Water

Variable	Mean	Median	elementary school	Min-Max	95%CI	P-Value
Body Weight (Kg)	69.71	69.00	9,008	55 - 85	64.51 – 74.92	0.727

Based on the distribution table above, it can be concluded that the average body weight of quicklime workers in acid mine water management weighs 69.71 kg with a median value of 69.00 with a standard deviation of 9.008. The worker who has the lightest body weight is 55 kg, while the quicklime worker has the highest weight, namely 8.5 kg . From the results of the data normality test for the weight variable, the *Shapiro Wilk test was used* which obtained a *p-*

value of 0.727 > 0.05 and the data was said to have a normal distribution, so the value used was 69.71 kg for body weight.

Respondents' Exposure Patterns

Table 3. Statistical Results of Exposure Patterns of Tohor Lime Workers to Acid Mine Water

Variable	Mean	Median	elementary school	Min-Max	95%CI	P-Value
Duration of Exposure (Hours/Days morning - afternoon)	3.00	3.00	1,038	1 - 5	2.40 – 3.60	0.346
Duration of Exposure (Hours/Days Afternoon-Afternoon)	2.79	2.00	1,251	1 - 5	2.06 – 3.51	0.018
Exposure Frequency (Days/week)	5.21	6.00	1,477	2 - 7	4.36 – 6.07	0.002
Exposure Frequency (week/Year)	319.86	305.00	61,047	215 - 431	284.61 – 355.10	0.006
Duration of Exposure (Years)	4.36	4.00	1,499	2 - 7	3.49 – 5.22	0.153

Based on the table of statistical results above, it can be seen that the average exposure time of quicklime workers to acid mine drainage management is 3.00 hours/day for those with a median value of 8.00 hours/day with a standard deviation of 2. 13. The longest exposure time is 14.5 hours/day, while the shortest exposure time for quicklime workers is 5 hours/day working. The average frequency of exposure was 5.21 days/week with a median value of 7 days/week . The average frequency of exposure to quicklime workers is 319.86 weeks/year with a median value of 305.00 weeks/year . The lowest exposure frequency was 215 weeks/year and the highest exposure frequency was 431 weeks/year. The average duration of exposure was 4.36 years with a median value of 4 years . The workers who had worked the longest were 2 years, while those who had worked the longest were 7 years.

After carrying out a normality test on all variables using the *Shapiro Wilk test* to produce a *p-value* has a value <0.05, which means the data for this variable is not normally distributed. so the value used is the median value for each variable.

Non-Carcinogenic Exposure Estimation

the estimated exposure value for concentrations of Nitrogen dioxide (NO_2) and Carbon monoxide (CO) are as follows:

Estimated value of real time exposure to Nitrogen dioxide (NO_2) concentration

$$EF=\frac{ET X EF X ED}{AT}$$

$$EF=\frac{8\frac{jam}{hari} X 7\frac{hari}{minggu} x 51,29\frac{minggu}{tahun} X 5 tahun}{24\frac{jam}{hari} X7\frac{hari}{minggu} x 52,14\frac{minggu}{tahun} x 5 tahun}$$

$$EF=\frac{8 X 7x 51,29}{24 X7x 52,14}$$

$$EF=\frac{2.872,24}{8.759,52}$$

EF= 0.32

Then, $C_{air\text{-}adj}$ = CX EF

$C_{air\text{-}adj}$ = 3.04 µg/Nm ^{3} X 0.32

ISSN 2721-1215 (Print), ISSN 2721-1231 (Online)

$C_{air\text{-}adj}$ = 0.9728 µg/Nm ^{3}

Estimated value of real time exposure to Carbon monoxide (CO) concentration

$$EF = \frac{ET \ X \ EF \ X \ ED}{AT}$$

$$EF = \frac{8\frac{jam}{hari} \ X \ 7\frac{hari}{minggu} \ x \ 51{,}29\frac{minggu}{tahun} X \ 5 \ tahun}{24\frac{jam}{hari} \ X7\frac{hari}{minggu} \ x \ 52{,}14\frac{minggu}{tahun} \ x \ 5 \ tahun}$$

$$EF = \frac{8 \ X \ 7x \ 51{,}29}{24 \ X7x \ 52{,}14}$$

$$EF = \frac{2.872{,}24}{8.759{,}52}$$

EF= 0.32

Then, $C_{air\text{-}adj}$ = CX EF

$C_{air\text{-}adj}$ = 8,405 µg/Nm ^{3} X 0.32

$C_{air\text{-}adj}$ = 2,689.6 µg/Nm ^{3}

Based on the results of these calculations, the estimated value for all respondents of quicklime workers' exposure to PM 2.5 is 0.9728 µg/Nm ^{3} while TSP exposure was 2,689.6 µg/Nm ^{3} .

Risk Characteristics (RQ)

step of ARKL is risk characteristics, where this stage is a comparison between the estimated exposure (exposure estimate) with the appropriate guide value (dose response). In this risk characteristics stage, RQ calculations are carried out for the non-carcinogenic effects category and ECR for the carcinogenic effects category, which has a different formula. Exposure to Nitrogen dioxide (NO2) and Carbon monoxide (CO) does not have a carcinogenic effect, so using RQ and exposure occurs through inhalation, the calculation formula is obtained as follows:

$$RQ = \frac{estimasi \ pajanan}{RFC} \text{or } HQ = \frac{Cadj-air}{RFC}$$

The risk level calculation (RQ) for concentrations of Nitrogen dioxide (NO_2) and Carbon monoxide (CO) is as follows:

Real time RQ value Nitrogen dioxide (NO_2)

$$RQ = \frac{Cair-adj}{RFC}$$

$$RQ = \frac{0{,}9728 \ \mu g/Nm^3}{188{,}15 \ \ \mu g/Nm^3}$$

RQ = 0.00 5

Real time RQ value of Carbon monoxide (CO)

$$RQ = \frac{Cair-adj}{RFC}$$

$$RQ = \frac{2.689{,}6 \ \mu g/Nm^3}{40.014{,}2 \ \ \mu g/Nm^3}$$

RQ = 0.0 67 = 0.07

From the calculation results of the non-carcinogenic RQ value for all respondents, exposure to NO_2 and CO is not risky or in the safe category because both exposures have an RQ value <1.

ISSN 2721-1215 (Print), ISSN 2721-1231 (Online)

Concentration

This research was carried out at PT Bukit Asam Tbk Tanjung Enim, South Sumatra with 3 air sampling points, namely 1 (Timbunana PIT 3 West area), point 2 (Timbunana PIT 3 area near KPL), and point 3 (PIT BB area). Measuring PM $_{2.5}$ refers to SNI 7119.14:2016 using a High Volume Air Sampler (HVAS) tool. Before taking measurements, the tool must be calibrated first where the tool used by air sampling officers from the Provincial Environmental Service has been calibrated externally every 1 year The aim is to obtain results can be consistent and valid. The results of research on the PM $_{2.5}$ concentration variable in this study were carried out in the morning and afternoon and produced an average concentration of 0.0350 at the 3 measurement points. If you look at the measurement results, the highest concentration of PM $_{2.5}$ is at point III 00370 and the lowest concentration is at point II at 0.0320. However, these 3 measurement points are still within safe limits because they do not exceed the quality standard, which is stipulated by PP RI No. 22 of 2021. However, monitoring of PM $_{2.5}$ must still be carried out because monitoring PM $_{2.5}$ in measuring quicklime dust is very important because PM $_{2.5}$ is a fine particle with a diameter of 2.5 micrometers or smaller. which can be easily inhaled into the human respiratory system. Quicklime dust used in the management of acid mine drainage, can contain dangerous chemical compounds which, when present as PM $_{2.5}$, can worsen these health impacts. Monitoring PM 2.5 is crucial for protecting the health of workers in mining work environments. Furthermore, this monitoring is also important to ensure that the air quality in the workplace meets the health standards set by environmental regulations. By monitoring PM $_{2.5}$ regularly, you can identification of potential hazards that may not be visible in larger particles, thereby enabling appropriate preventive or corrective action to be taken to reduce the health risks faced by workers.

Exposure to PM $_{2.5}$ in quicklime can have an impact on workers, such as causing various respiratory problems in quicklime workers. These small particles can penetrate deep into the respiratory tract and reach the alveoli in the lungs. As a result, workers may experience symptoms such as coughing, shortness of breath, bronchitis, and an increased risk of respiratory infections. In the long term, continued exposure can cause chronic obstructive pulmonary disease (COPD) and decreased lung function. Apart from that, PM 2.5 can also cause irritation to the eyes and skin. Workers who are exposed to this fine dust often experience red, itchy and watery eyes. In addition, skin exposure to PM 2.5 can cause contact dermatitis, which is characterized by dry, itchy, and red skin.

Total Suspended Particulate (TSP) Concentration

Based on the results of research regarding the analysis of TSP concentrations in quicklime workers with 3 air sampling points. Measurements using a hight volume water sampler, the results of TSP concentration research produce concentrations that are mg/m ^{3} at 3 measurement points. Apart from the average value, the unit value for each area is also quite varied, namely ... mg/m ^{3} is the highest measurement result which is the measurement result at point 1, namely at .... Meanwhile, the lowest figure obtained was at point 3, namely 0.0813 mg/m ^{3} . However, none of the TSP concentration results exceeded the quality standards set by PP RI No. 22 of 2021.

SO2 Concentration

Based on the results of research regarding the analysis of the concentration of Sulfur Dioxide (SO_2) in limestone workers managing acid mine water with 3 air sampling points. Measurements using a high volume water sampler, the results of research on the concentration of Sulfur Dioxide (SO_2) produce an average concentration of mg/m ^{3} at all 3 measurement points. is the highest measurement result which is the measurement result at point 1, namely at... Meanwhile, the lowest figure obtained was at point 3, namely 0.0813 mg/m ^{3}. However, none of the TSP concentration results exceeded the quality standards set by PP RI No. 22 of 2021

Based on research that has been carried out by filling out questionnaires through interviews with research respondents, namely quicklime workers in acid mine water management have an average age of 34.86 years with the youngest being 27 years and the oldest being 45 years. Age is one of the factors that influences a person's level of health, supported by research which shows that there is a significant relationship between age and the incidence of respiratory disorders due to a decrease in lung function capacity, lung ventilation and lung oxygen uptake capacity as age increases. This is why older people are more susceptible to ARI compared to young people. Long-term exposure to air pollutants and hazardous substances can cause accumulative damage to the lungs and respiratory tract. Meanwhile, in the elderly, the function of the immune system and the ability to regenerate tissue decreases, making them more susceptible to chronic diseases and respiratory infections.

Older age groups are at higher risk of disease compared to young people, and this is supported by various studies showing the relationship between age and health. The immune system tends to decline with age, making older people more susceptible to infectious and chronic diseases.

Research shows that the prevalence of chronic conditions increases with age. Data from the 2018 National Health Interview Survey indicates that people over 45 years of age have a higher prevalence of chronic conditions compared with younger age groups (CDC). This suggests that older people are more vulnerable to respiratory diseases and require more specific interventions to protect them (BioMed Central). In general, this research supports the view that older age groups, especially those over 40 years old, have a higher risk of experiencing health problems, such as decreased lung function and increased blood pressure, compared with younger age groups (CDC) (BioMed Central).

Conclusion

Lime dust exposure has significant negative impacts on the health of coal mining workers, particularly on the respiratory system, skin, and eyes. The implementation of mitigation measures such as the use of PPE, dust control, occupational health education and training, and regular health check-ups is crucial to reduce health risks and improve workplace safety in coal mines. Further research and the enforcement of strict occupational health regulations are necessary to ensure a safer working environment for miners.

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ISSN 2721-1215 (Print), ISSN 2721-1231 (Online)
