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Overview of Cadmium Levels in the Blood of Smoking Gas Station Workers in Comal District, Pemalang Regency

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ABSTRACT

Background & objectives: Cigarettes are addictive substances that contain harmful chemicals, such as nicotine, tar, carbon monoxide, acetone, benzene, lead, and cadmium. Cadmium is a heavy metal contained in cigarettes that has a fairly high toxicity. Cadmium that enters the body will accumulate for a long time in the liver and kidneys. In the body, cadmium is absorbed into the bloodstream and then distributed to tissues, where it can bind to various types of molecules, such as proteins, phospholipids, purines, enzymes, and porphyrins. Gas station workers are frequently exposed to vehicle exhaust, which also contains cadmium, originating from vehicle activities such as fuel combustion and the erosion of vehicle components. This study aims to determine the cadmium levels in the blood of respondents who are smokers and work at gas stations in Comal District, Pemalang Regency. **Methods:** This study is a descriptive study. Samples were taken using purposive sampling from a population of 17 people, with 9 respondents meeting the inclusion and exclusion criteria. **Results:** Blood sample testing using an Atomic Absorption Spectrophotometer (AAS) showed that two respondents had cadmium levels of 0.2 µg/dL or below the normal value according to the CDC (Centers for Disease Control and Prevention), while the other seven respondents had cadmium levels below the LOD (Limit of Detection) on the AAS device. **Conclusion:** The cadmium levels were 100% within the normal range. The highest cadmium levels were found in samples S6 and S8, at 0.2 µg/dL.

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Introduction

Air pollution is a continuous problem. Pollution has always been an issue for Indonesians, and pollution levels are increasing every year. The air is polluted by various types of substances or particles that can harm human health, animals, and the environment. These substances or particles come from vehicle emissions, industry, cigarette smoke, and so on. According to the World Health Organization (WHO) in 2019, approximately 4.2 million premature deaths in urban and rural areas were caused by exposure to fine particles, which cause cardiovascular and respiratory diseases, as well as cancer (Organization, 2024). Vehicle exhaust is a major contributor to air pollution in Indonesia. Other factors include waste burning and cigarette smoke, which can cause disease and health problems (Candrasari et al., 2023). Indonesia has the largest number of smokers in the world after China and India. Although many people are aware of the dangers of smoking, it remains an activity that is difficult to give up.

Based on data from the 2023 Indonesian Health Survey (SKI) conducted by the Ministry of Health (Kemenkes), the total number of active smokers is estimated to reach 70 million people, 7.4% of whom are aged 10 to 18 years (Kemenkes, 2024). Cigarettes produce smoke that is very dangerous to the health of smokers themselves, namely active smokers. Active smokers are at risk of liver and lung cancer, respiratory disorders, stroke, and oral cancer. The dangers posed by cigarette smoke are not only experienced by active smokers, but can also be harmful to people who are frequently exposed to or inhale cigarette smoke as passive smokers (Rosita & Andriyati, 2019). Natural sources of cadmium are found in the earth's crust and volcanic eruptions. In addition, cadmium is produced by anthropogenic (human activity), such as the use of fuel, forest fires, industrial waste, the use of fertilizers and sludge from agricultural land, which can cause soil pollution. This has an impact on increasing cadmium absorption from crops and vegetables as a source of human food (Yuniar, 2020).

Cadmium is a heavy metal contained in cigarettes that has a fairly high toxicity. Cadmium that enters the body will accumulate for a long time in the liver and kidneys (Nova Florentina Ambarwati, 2020). Cadmium can enter the human body through the gastrointestinal tract, inhalation, and dermal contact (Qadriyah et al., 2019). Cadmium is then absorbed into the bloodstream and distributed to tissues, where it can bind to various types of molecules, such as proteins (metallothionein), phospholipids, purines, enzymes (metalloenzymes), and porphyrins. The amount of cadmium absorbed through the gastrointestinal tract is around 3 to 8%, while cadmium absorption through inhalation is higher than absorption through the gastrointestinal tract, which is around 25 to 50% (Sidebang, 2018).

Blood is a fluid found in all living things (except plants). Blood has very important functions for the body, namely carrying oxygen from the lungs to body tissues, maintaining water balance in the body so that water levels in the body are maintained, and as a defense against viruses and bacteria (Yuhanita, 2022). Cadmium levels can be tested using blood samples. Cadmium that enters through inhalation or

the digestive system will be absorbed into the bloodstream, found in red blood cells (erythrocytes) and white blood cells (leukocytes) 90%, while found in blood plasma around 10%. Cadmium accumulated in the blood can increase systolic and diastolic blood pressure, which triggers hypertension (Dewi, 2020).

Atomic Absorption Spectrophotometry (AAS) is an analytical method used to determine the concentration of a metal element sample or a substance with a low concentration. The AAS method is based on the absorption of light from atoms that absorb light at wavelengths corresponding to the AAS instrument, to determine the concentration of cadmium metal in a sample, namely at a wavelength of 228.8 nm.

Objective

This study aims to determine the cadmium levels in the blood and the highest and lowest cadmium levels in the blood of smokers (active and passive smokers) who work at gas stations in Comal District, Pemalang Regency.

Method

This study employed a descriptive research method with a population consisting of 17 smoking workers (both active and passive smokers) from fuel station operators in Comal Subdistrict, Pemalang Regency. Using purposive sampling, nine respondents were selected based on inclusion and exclusion criteria, such as being an SPBU operator, working ≥ 5 years, active or passive smoking history, smoking duration ≥ 3 years, and willingness to fill out questionnaires. Respondents with hypertension or anemia, or those unwilling to participate, were excluded. The research was conducted from September 2024 to February 2025, with venous blood samples collected at SPBU Comal.

The laboratory analysis was carried out at the Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, using Atomic Absorption Spectrophotometry (AAS) at a wavelength of 228.8 nm. Primary data were obtained through observation, interviews, questionnaires, and specimen examination, while secondary data were gathered from WHO official websites, reference books, and scientific journals. The results were converted from mg/L to µg/dL, tabulated, and analyzed descriptively, then compared to the CDC standard for normal cadmium levels in blood (< 5 µg/L) (Bakr et al., 2023).

Result

Based on the results of research on cadmium levels in 9 respondents who underwent blood sample testing (active and passive smokers) who were gas station workers in Comal District, Pemalang Regency, the following results were obtained:

TABLE 1. Respondent Characteristics

Sample code	Age	Duration of smoking	Smoker (active/passive)	Number of cigarettes/sticks	Use of PPE (mask)
S1	60 years	28 years	Active	6 sticks	Yes
S2	35 years	17 years	Active	8 sticks	No
S3	25 years	-	Passive	-	Yes
S4	21 years	4 years	Active	12 sticks	No
S5	36 years	-	Passive	-	No
S6	51 years	33 years	Active	12 sticks	No
S7	48 years	-	Passive	-	No
S8	32 years	-	Passive	-	No
S9	35 years	-	Passive	-	No

Table 1 shows the profile of respondents, all of whom are male, aged 21–60 years, and have worked for 6–30 years. The data was obtained from a questionnaire distributed to all gas station workers in Comal Subdistrict, Pemalang Regency.

TABEL 2. Results of Cadmium Levels in Blood Tests

Sample code	Smoker (active/passive)	Cd Level (µg/dl)	Description
S1	active	- 0,2 µg/dL	Not Deteced
S2	active	- 0,6 µg/dL	Not Deteced
S3	passive	- 0,3 µg/dL	Not Deteced
S4	active	- 0,7 µg/dL	Not Deteced
S5	passive	-1,3 µg/dL	Not Deteced
S6	active	0,2 µg/dL	Normal
S7	passive	- 0,8 µg/dL	Not Deteced
S8	passive	0,2 µg/dL	Normal
S9	passive	- 0,8 µg/dL	Not Deteced

Table 2. Shows the results of cadmium level tests conducted at the Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences (MIPA) at Semarang State University (Unnes) using the Atomic Absorption Spectrophotometer (AAS) method. Seven of the nine samples were found to be Not Detected, meaning that the cadmium levels were below the detection limit set by the instrument. Two samples, S6 and S8, showed cadmium levels of 0.2 µg/dL. The highest cadmium levels in this study were found in samples S6 and S8, namely 0.2 µg/dL, but these levels were still within the normal cadmium range according to the CDC (Centers for Disease Control and Prevention), which is < 5 µg/dL. Meanwhile, one of the lowest cadmium levels was found in sample S5, namely -1.3 µg/dL, which is below the LOD (Limit of Detection) on the SSA device.

Discussion

Based on the laboratory test results, the cadmium levels in the blood of active smoker gas station workers presented in Table 4.2 showed that cadmium was detected in sample S6 (active smoker) at 0.2 µg/dL and in sample S8 (passive smoker) at 0.2 µg/dL. Both values were within the normal category. Respondent S6 did not use personal protective equipment (mask) during work and was an active smoker with a smoking history of 33 years, consuming around 12 cigarettes or more per day. This

respondent was in the older age group, 51 years old. As a person ages, cadmium levels in the body may be affected due to decreased activity of biotransformase enzymes and impaired organ functions. Thus, older individuals have higher sensitivity to cadmium exposure compared to younger ones (Nova Florentina Ambarwati, 2020). According to the World Health Organization (2021), one cigarette is estimated to contain around 1–2 µg of the heavy metal cadmium, of which approximately 10% to 50% can enter the body through inhalation during smoking. However, in this study, the detected cadmium level was only 0.2 µg/dL. This result was not consistent with WHO's theoretical estimation, given that respondent S6 consumed 1–12 cigarettes daily, yet the cadmium level was only 0.2 µg/dL. This may be influenced by the type of cigarette consumed, namely conventional cigarettes with filters. Conventional cigarettes generally use cellulose acetate filters, which function to trap harmful substances from cigarette smoke, including cadmium (Dinh et al., 2021).

A study conducted by Dinh et al. (2021) investigated the distribution and absorption capacity of cigarette filters available on the international market in reducing cadmium. The study showed that cellulose acetate filters could absorb approximately 5.5% of the cadmium content in one cigarette. This indicates that filters can reduce cadmium exposure during smoking but cannot completely eliminate it. Small particles may still pass through the filter and enter the respiratory tract. Therefore, although conventional cigarettes with filters may pose a lower risk compared to cigarettes without filters, they are not safe to consume (Dinh et al., 2021). Meanwhile, respondent S8 was younger compared to respondent S1, who was an active smoker. In this study, however, cadmium levels in respondent S1's blood were not detected or were below the instrument's Limit of Detection (LOD). This may be due to respondent S1's use of personal protective equipment (mask) while working, which reduced cadmium exposure, as well as their lower daily cigarette consumption. Cadmium has a long biological half-life in the body, around 10 to 30 years, meaning that after 30 years, some cadmium can be excreted in urine. However, this process is influenced by several factors such as age and exposure levels (Satarug S, Garrett SH, Sens MA, 2017). Respondent S1, aged 60 with 30 years of work experience, had cadmium levels below the instrument's detection limit. This could be explained by cadmium accumulation over more than 30 years, with cadmium shifting from the bloodstream into organs. As a result, when analyzed by AAS, cadmium in respondent S1's blood was detected at very low levels or below the instrument's LOD.

Cadmium enters the body through inhalation, is absorbed into the bloodstream, and filtered by the kidneys. Gas station workers are frequently exposed to vehicle exhaust fumes, which are a major source of air pollution and cause long-term health problems. Cadmium can be released into the air through vehicle activities, such as fuel combustion and wear of brakes, tires, and clutches (Singh & Devi, 2023). Prolonged cadmium exposure may lead to hazardous health effects; when ingested, it can cause nausea, vomiting, salivation, diarrhea, and abdominal cramps. Toxic effects of cadmium include oxidative stress, carcinogenesis, increased blood pressure, kidney

damage, and red blood cell impairment (Yuniar, 2020). In this study, other factors influencing low cadmium levels may include residential environment, health history, and dietary patterns involving antioxidants and milk consumption (Anungsugihantono, 2021). Consistent with Rosita & Andriyati (2019), diets rich in antioxidants such as fruits and vegetables can mitigate cadmium exposure effects in the body. Therefore, the cadmium levels detected in samples S6 and S8 might have been influenced by insufficient antioxidant intake.

Although the detected level of 0.2 µg/dL in respondents S6 and S8 was considered safe and normal according to CDC standards, caution is still required. Long-term cadmium exposure, even in small amounts, can cause toxic effects, including hepatotoxicity, changes in blood pressure, kidney disorders, impaired lung function, and increased cancer risk (Ayuda, 2019). Cadmium toxicity involves multiple mechanisms, such as oxidative stress through increased levels of superoxide (O^{2-}), hydrogen peroxide (H_2O_2), and hydroxyl radicals (OH^-). These reactive species can damage lipids, proteins, and DNA, disrupt mitochondrial function, and activate stress signaling pathways, eventually leading to cell injury and death (Qu & Zheng, 2024).

Conclusion

Based on the results of research on cadmium levels in the blood of smokers (active and passive smokers) working at gas stations in Comal District, Pemalang Regency, it can be concluded that the highest cadmium levels were found in samples S6 and S8, namely 0.2 µg/dL. The rest of the samples had cadmium levels below the SSA device's LOD (Limit Of Detection). However, these levels were still below the normal limit, so this study did not find any blood cadmium levels in the samples that were above normal. Meanwhile, the lowest cadmium level was found in sample S5, which was -1.3 µg/dL. This study did not find cadmium levels above the normal limit. Therefore, the percentage of cadmium levels detected in all samples (100%) was still within the normal range according to the CDC (Centers for Disease Control and Prevention), which is < 5 µg/dL.

Future researchers are encouraged to conduct more comprehensive health examinations of respondents and to pay close attention to the detailed dietary patterns of respondents.

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