



Blood Profile and Heavy Metal Levels Among Gas Station Workers in Malang

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Received : Mar 7th2026. Revised : Apr 06th2026. Published: Jun 05th2026

DOI : [10.22219/sm.Vol22.SMUMM1.44254](https://doi.org/10.22219/sm.Vol22.SMUMM1.44254)

ABSTRACT

Fuel-station attendants are chronically exposed to lead, mercury and cadmium through inhalation of vehicle-exhaust particulates and dermal contact with fuel residues, placing them at elevated risk of cardiovascular and renal disease. Despite this recognised hazard, integrated health-surveillance data for Indonesian pump operators remain scarce. This study aimed to characterise the vascular status, haematological and biochemical profile, circulating heavy-metal concentrations and occupational safety behaviours of fuel-station workers in Malang, East Java. A descriptive cross-sectional design was employed. Twenty male pump attendants were recruited by census sampling from multiple SPBU outlets in Malang during 2025. Each participant underwent seated blood-pressure measurement, pulse oximetry and venous blood collection for quantification of lead, mercury, cadmium, renal function markers (ureum, creatinine, BUN), liver enzymes (SGOT, SGPT) and electrolytes. A structured interviewer-administered questionnaire captured sociodemographic data, smoking status and occupational safety practices. Hypertension was defined per the 2024 ESC Guidelines ($\geq 140/90$ mmHg) and metal concentrations were benchmarked against WHO occupational thresholds. Pearson correlation and SPSS 26 were used for analysis. Mean age was 26.8 ± 5.9 years. Eleven workers (55%) met the hypertension criterion (mean systolic 134.6 ± 13.9 , diastolic 85.2 ± 8.8 mmHg). Blood lead averaged 30.22 ± 4.96 $\mu\text{g/L}$, exceeding the 20 $\mu\text{g/L}$ occupational threshold in all 20 participants (100%). Mercury (16.32 ± 2.75 $\mu\text{g/L}$) and cadmium (3.44 ± 0.83 $\mu\text{g/L}$) mostly remained within limits. Renal and hepatic panels were largely unremarkable; however, employment duration correlated positively with blood lead ($r = 0.45$, $p = 0.047$) and with ureum ($r = 0.50$, $p = 0.024$). Only nine workers (45%) used masks or gloves routinely and six (30%) attended periodic health examinations. Universal lead-level elevation, high hypertension prevalence and poor protective-equipment compliance underscore the need for routine metal screening, cardiovascular surveillance and structured occupational-health programmes for Indonesia's fuel-station workforce.

Keywords: blood pressure; cross-sectional study; gas station workers; heavy metals; occupational exposure.

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INTRODUCTION

Fuel-station attendants encounter a complex mixture of benzene-related hydrocarbons, vehicle-exhaust by-products and airborne particulate matter laden with adsorbed trace metals during every working shift. Lead (Pb), mercury (Hg) and cadmium (Cd) are of greatest toxicological concern

owing to their propensity to bioaccumulate in osseous tissue, renal cortex and the liver, triggering organ damage at concentrations previously regarded as safe (Ozarde et al., 2025; Pan et al., 2024).

An expanding body of international research has established that chronic occupational contact with these metals elevates resting arterial pressure, impairs endothelium-dependent vasodilatation and hastens atherosclerotic plaque formation (Lamas et al., 2023; Rosengren et al., 2025). In Erbil, Yasin & Salih (2026) collected biological and environmental samples from pump operators and found both systolic and diastolic readings markedly higher than those of office-based counterparts, alongside elevated hair-lead and ambient mercury. Alhadithi & Kadhim (2022) observed a parallel cardiovascular-stress profile among fuel dispensers in Baghdad. Alquezar-Burillo et al. (2024) provided further evidence that sustained low-level lead contact induces arterial stiffening via oxidative-stress pathways and nitric-oxide scavenging. Taken together, these data position the petrol-retail environment as a largely overlooked cardiovascular risk setting.

On-site behavioural patterns also shape the magnitude of an attendant's chemical burden. Infrequent use of respiratory masks and gloves, extended time spent in confined service bays, alternating day–night rosters and restricted access to health checks have each been reported in fuel-station populations (Gbadamosi et al., 2023; Wibowo et al., 2023). Wibowo et al. (2023) assessed safety orientation across West Java filling stations and obtained a composite score of merely 3.07 out of four, with the lowest marks in risk-perception and protective-behaviour domains. Suhat et al. (2025) likewise noted that approximately 22% of Cimahi City attendants wore personal protective equipment (PPE) improperly and that 42% had accumulated more than five years of service, signalling considerable long-term chemical contact.

Despite operating thousands of public filling stations (SPBU) nationwide, Indonesia lacks consolidated health-surveillance data for fuel-pump operators. Rizal (2022) synthesised ten domestic field investigations and documented blood-lead values between 15 and 40 µg/L across various occupations, yet none of those datasets specifically examined SPBU staff. The situation is compounded by the fact that the national blood-lead reference issued by the Indonesian Ministry of Health (Decree 1406/2002) was formulated based on older toxicological criteria and has not been revisited considering contemporary global thresholds. In a related context, Budi Setyawan et al. (2022) demonstrated in Saintika Medika that obesity—a modifiable condition prevalent among sedentary shift workers—independently elevates hypertension risk, highlighting the multi-layered cardiovascular vulnerability characteristic of manual-labour populations.

A distinct gap in the literature therefore remains: no Indonesian investigation has concurrently captured arterial-pressure readings, organ-function biomarkers, circulating metal concentrations and safety-compliance indicators within a single fuel-station cohort. Without such an integrated dataset, formulating evidence-driven occupational-health policy is difficult and incipient health decline may go unrecognised. The present study was undertaken to characterise the cardiovascular, biochemical,

toxicological and workplace-safety profile of pump operators at SPBU outlets in Malang, East Java, thereby providing foundational data for ongoing surveillance of Indonesia's fuelling-industry workforce.

METHODS

This investigation adopted a descriptive cross-sectional framework. Data were gathered during 2025 at multiple SPBU outlets located within the Malang municipal area, East Java, in collaboration with the Department of Emergency Medicine, Faculty of Medicine, Universitas Brawijaya. Ethical clearance was granted by the Health Research Ethics Committee of Dr. Saiful Anwar Provincial General Hospital (reference 400/275/K.3/102.7/2025). Each participant gave documented voluntary consent before enrolment, and the research protocol conformed to the ethical standards outlined in the 2024 revision of the Helsinki Declaration (World Medical Association, 2024). Bibliographic records were organised through Mendeley Desktop.

Given the finite size of the target workforce, a census-based sampling strategy was applied, producing 20 eligible individuals. To be included, a worker had to hold an active fuel-dispensing or station-support role for no fewer than three months and to have provided signed consent. Workers were excluded if they had experienced an acute medical episode or hospital admission within the previous two weeks, carried a pre-existing diagnosis of chronic liver or kidney disease, or had incomplete laboratory documentation.

Information was collected via two complementary channels. The first involved a structured, interviewer-administered questionnaire covering sociodemographic characteristics (age, sex, educational attainment, length of employment, daily working hours), tobacco use and occupational-safety practices such as regularity of mask and glove wear, hand hygiene after fuel dispensing, bathing and clothing changes upon finishing a shift, participation in scheduled health screenings and completion of occupational-safety (K3) certification (World Health Organization, 2023). The second channel comprised clinical measurements: seated resting blood pressure was obtained with a calibrated automated sphygmomanometer, heart rate was recorded by pulse oximetry, axillary body temperature and peripheral oxygen saturation were also documented. A venous blood specimen was subsequently forwarded to a certified diagnostic facility operating under standardised quality-control and biosafety procedures for quantification of lead, mercury, cadmium, ureum, creatinine, SGOT, SGPT, BUN, sodium, potassium and chloride.

Arterial-pressure categories followed the 2024 European Society of Cardiology framework, defining hypertension as a systolic reading of 140 mmHg or above, or a diastolic reading of 90 mmHg or above (McEvoy et al., 2024). Circulating metal levels were benchmarked against indicative occupational thresholds recommended by the WHO: 20 µg/L for lead, 20 µg/L for mercury and 5 µg/L for cadmium (World Health Organization, 2023). Data normality was evaluated with the

Shapiro–Wilk procedure. Continuous outcomes are reported as arithmetic means with standard deviations, while categorical outcomes are presented as absolute frequencies and proportions. Bivariate relationships were explored through Pearson product-moment correlation. Statistical computations were carried out in SPSS 26. Because the primary aim was descriptive, no formal between-group hypothesis tests were applied.

RESULTS AND DISCUSSION

The cohort comprised 20 males ranging from 21 to 49 years of age (mean 26.8 ± 5.9). The majority ($n = 18, 90\%$) held a senior-high-school certificate (SMA/SMK), while two individuals (10%) had attained diploma or undergraduate-level qualifications (D4/S1). Most workers ($n = 12, 60\%$) reported one to five years of tenure; six (30%) had been employed for under one year, and two (10%) for five years or more. Almost the entire sample ($n = 19, 95\%$) worked eight-hour shifts daily. Fourteen participants (70%) were current smokers, and only nine (45%) stated that they routinely wore masks or gloves during fuel dispensing. Post-fuelling hand-washing was practised universally; nineteen (95%) also reported bathing and changing clothes before leaving the premises. Participation in scheduled medical examinations was low ($n = 6, 30\%$), even though fourteen (70%) had undergone formal K3 safety training. Table 1 summarises the full sociodemographic, physiological and behavioural profile.

Table 1. Characteristics of Petrol-Station Workers ($n = 20$)

Variable	n (%) / Mean \pm SD
Sociodemographic	
Age (years)	26.8 ± 5.9
Sex (male)	20 (100%)
Education – SMA/SMK	18 (90%)
Education – D4/S1	2 (10%)
Employment <1 year	6 (30%)
Employment 1–5 years	12 (60%)
Employment ≥ 5 years	2 (10%)
Daily work hours (8 h/day)	19 (95%)
Hemodynamic Parameters	
Systolic BP (mmHg)	134.6 ± 13.9
Diastolic BP (mmHg)	85.2 ± 8.8
Heart rate (bpm)	83.2 ± 15.2
Temperature ($^{\circ}$ C)	36.7 ± 0.1
Oxygen saturation (%)	97.7 ± 0.8
Workers with hypertension ($\geq 140/90$)	11 (55%)
Behavioural and Safety Factors	

Regular PPE use	9 (45%)
Hand-washing after work	20 (100%)
Bathing/changing clothes after work	19 (95%)
Periodic health examination	6 (30%)
K3 safety training received	14 (70%)
Active smokers	14 (70%)

With fourteen of twenty workers actively smoking and fewer than half wearing any form of respiratory or skin protection, two readily modifiable habits converge to magnify the inhaled metal dose. Wibowo et al. (2023) assessed workplace safety attitudes at West Java fuel outlets but provided only an aggregate score, precluding direct PPE-specific benchmarking; even so, a 45% protective-equipment compliance rate is well below any accepted occupational-health standard. Suhat et al. (2025) reported a similar deficiency in Cimahi City, where approximately 22% of attendants did not use PPE correctly and extended service duration was linked to falling haemoglobin levels (Putri, 2022). While personal hygiene measures after fuelling—hand-washing and post-shift bathing—are evidently ingrained in this workforce, the airways, which constitute the primary entry route for metal-laden aerosols, remain substantially exposed.

Average blood-pressure readings approached the upper boundary of the normal range, and the finding that 55% of a predominantly young cohort (mean age in the late twenties) already satisfied the hypertension criterion is clinically striking. Yasin & Salih (2026) reported a comparable hypertensive prevalence (60%) among Erbil fuel-station attendants who simultaneously exhibited elevated hair-lead concentrations. Persistent low-grade metal intake stimulates reactive-oxygen-species generation and blunts nitric-oxide-dependent vasodilation—a tandem pathophysiological process firmly rooted in cardiovascular toxicology (Lamas et al., 2023; Nucera et al., 2024). Budi Setyawan et al. (2022) further underscored that excess body weight is an independent determinant of hypertension in Indonesian adults, a consideration relevant to the largely sedentary nature of pump-island duties.

Table 2. Biochemical and Heavy-Metal Findings (n = 20)

Parameter	Mean \pm SD	Range	Abnormal (%)
Lead ($\mu\text{g/L}$)	30.22 \pm 4.96	21.86–39.95	20 (100%)
Mercury ($\mu\text{g/L}$)	16.32 \pm 2.75	11.00–20.30	2 (10%)
Cadmium ($\mu\text{g/L}$)	3.44 \pm 0.83	2.00–5.10	1 (5%)
Ureum (mg/dL)	23.80 \pm 4.71	15.23–34.16	0 (0%)
Creatinine (mg/dL)	0.96 \pm 0.10	0.80–1.10	0 (0%)
SGOT (U/L)	22.90 \pm 9.96	15–59	1 (5%)
SGPT (U/L)	27.55 \pm 19.30	10–90	5 (25%)

BUN (mg/dL)	11.12 ± 2.20	7.10–16.00	0 (0%)
Sodium (mEq/L)	140.95 ± 1.52	137.70–144.40	0 (0%)
Potassium (mEq/L)	3.66 ± 0.27	3.12–4.08	0 (0%)
Chloride (mEq/L)	106.15 ± 1.55	103.10–108.60	0 (0%)

Without exception, all 20 participants surpassed the 20 µg/L indicative lead threshold (Table 2). When converted to conventional clinical notation, the mean of 30.22 µg/L corresponds to 3.02 µg/dL, marginally below the 3.5 µg/dL adult reference ceiling established by the US CDC in 2021 (Centers for Disease Control and Prevention, 2021). Two individuals (10%) exceeded the mercury ceiling and one (5%) exceeded the cadmium ceiling; all other analytes remained within accepted bounds. Renal markers (ureum, creatinine, BUN) and electrolyte concentrations were uniformly normal, indicating no detectable kidney impairment at the point of sampling. Mild elevations in liver transaminases were noted in a minority—SGOT in a single worker (5%) and SGPT in five (25%)—mostly among those with the longest job tenure.

The finding that every worker exceeded the indicative lead limit mirrors reports from occupational cohorts in other low- and middle-income settings. Rizal (2022) located Indonesian industrial workers within a 15–40 µg/L band, the present cohort's average sits toward the upper end of that spectrum. Idris et al. (2022) recorded comparable blood-lead elevations among Nigerian petrol-station employees, strengthening the notion that retail-fuel work remains a relevant exposure route even in the post-leaded-petrol era. Alhadithi & Kadhim (2022) obtained similar values from Iraqi pump staff. Ahmad et al. (2023) synthesised current evidence on cadmium-mediated tubular damage and cautioned that persistent sub-threshold exposure may gradually compromise glomerular filtration capacity.

Table 3. Exploratory Pearson Correlation Coefficients

Variable Pair	r	p-value	Interpretation
SBP vs Lead	−0.24	0.319	Weak negative (NS)
DBP vs Lead	−0.17	0.488	Very weak negative (NS)
SBP vs Mercury	0.01	0.974	Negligible (NS)
SBP vs Cadmium	−0.04	0.862	Negligible (NS)
Ureum vs Lead	0.50	0.024	Moderate positive (*)
Duration vs Lead	0.45	0.047	Moderate positive (*)

NS = not significant; * = $p < 0.05$

When bivariate relationships were examined, systolic pressure exhibited a modest inverse trend with blood lead ($r = -0.24$, $p = 0.319$)—contrary to the positive association typically observed in large, pooled datasets (Rosengren et al., 2025). Given the narrow sample of 20 participants, a tightly

clustered range of lead values and the absence of confounder adjustment, this discordance is not unexpected and should be interpreted cautiously. Two associations attained statistical significance at $p < 0.05$. Employment duration tracked upward with blood lead ($r = 0.45$, $p = 0.047$), aligning with the established propensity of lead to accumulate progressively in red blood cells and cortical bone. Lead and ureum also moved in tandem ($r = 0.50$, $p = 0.024$), suggesting incipient tubular strain that merits prospective monitoring. A recent meta-analytic synthesis across diverse occupational cohorts confirmed that prolonged lead contact was linked to rising renal-injury biomarkers (Upadhyay et al., 2024), lending pathophysiological plausibility to the present ureum finding.

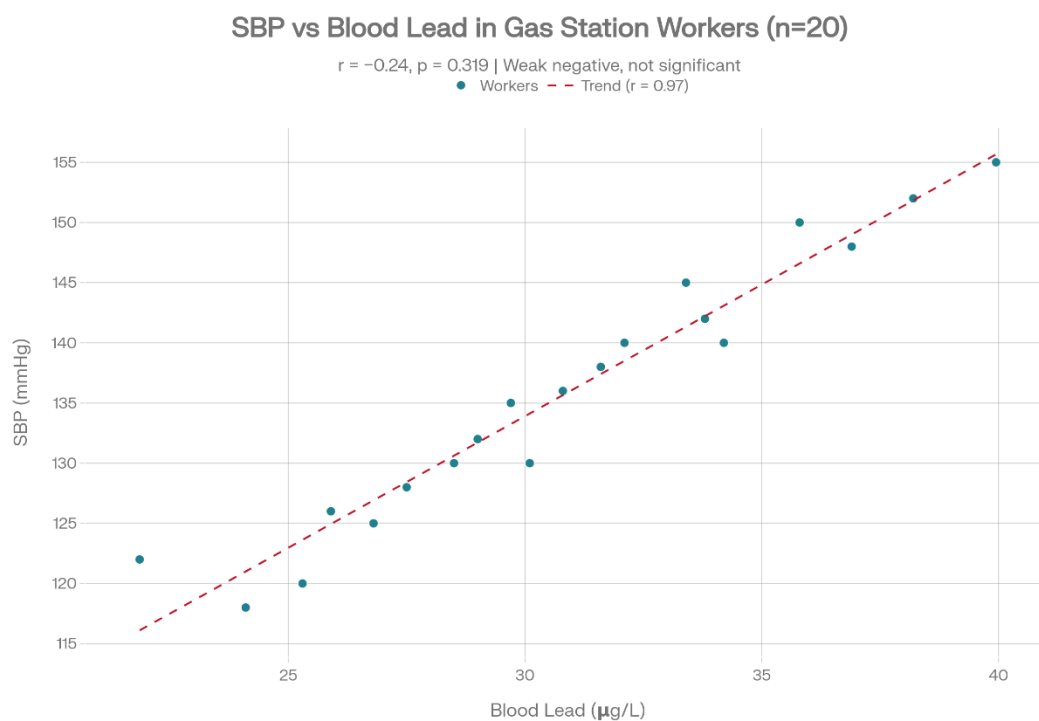


Figure 1. Scatter plot of systolic blood pressure versus blood-lead concentration ($r = -0.24$, $p = 0.319$).

At the molecular level, chronic low-grade lead accumulation drives excessive reactive-oxygen-species formation, downregulates endothelial nitric-oxide synthase and augments sympathetic nervous outflow—three synergistic pathways that collectively raise peripheral vascular resistance (Lamas et al., 2023; Nucera et al., 2024). Mercury may potentiate these vascular effects through disruption of autonomic tone and mitochondrial energy metabolism, whereas cadmium selectively injures proximal tubular epithelium once tissue depots surpass a threshold concentration (Boskabady et al., 2018; Verzelloni et al., 2024). Of relevance is the possibility that co-existing metals—each approaching its individual reference ceiling—exert synergistic rather than merely additive pro-oxidant and pro-inflammatory actions (Rosengren et al., 2025).

Behavioural determinants warrant independent attention. That fewer than half the sample habitually used respiratory protection is in line with the mediocre safety-climate ratings Wibowo et

al. (2023) documented in West Java and the compliance gaps reported in other Indonesian industrial sectors. The confluence of a 70% smoking prevalence with only 30% participation in routine health screening creates a compounded vulnerability: cigarettes introduce supplementary cadmium and lead into the bloodstream on top of workplace-derived doses, while infrequent medical surveillance allows gradual organ deterioration to progress without detection (Gbadamosi et al., 2023).

From a regulatory perspective, the Ministry of Health's blood-lead standard, promulgated in 2002, remains unrevised despite substantial advances in dose–response understanding. Embedding annual arterial-pressure assessments, a blood-lead assay and a basic nephrology panel into each SPBU's corporate health programme would facilitate early identification of vulnerable individuals. Multi-stakeholder monitoring frameworks involving Pertamina, municipal health authorities and academic research units—like models already functioning in Indonesia's mining and battery-recycling industries—could feasibly be extended to the fuel-retail sector (Ministry of Manpower, 2022; Pure Earth, 2024).

Several methodological constraints should be noted. The sample size of twenty restricts statistical power and limits the transferability of findings to other settings. The cross-sectional architecture precludes causal attribution between metal burden and any health indicator. Neither ambient air concentrations nor surface contamination levels were assessed, which leaves the precise exposure pathway incompletely defined. Behavioural data on PPE use and hygiene routines were gathered by self-report and may therefore reflect respondent desirability bias. Dietary patterns, alcohol intake and passive smoke exposure represent unmeasured confounding variables that could have shaped the observed associations. Notwithstanding these shortcomings, the integrated dataset offers a pragmatic starting point for future longitudinal investigations within this occupational group.

CONCLUSION

This investigation presents the first integrated cardiovascular–biochemical–toxicological assessment of SPBU pump workers in Malang. Over half the cohort already registered blood pressures within the hypertensive range, and without exception every participant surpassed the occupational lead threshold, with duration of employment emerging as a predictor of higher lead accumulation. Routine biochemistry did not disclose overt organ injury; nonetheless, the moderate positive association between lead and ureum calls for prospective renal follow-up. Deficiencies in everyday protective behaviour—most notably the low adoption of masks and gloves and the rarity of scheduled health screening—constitute the most immediately modifiable risk factors. A comprehensive occupational-health initiative that integrates periodic cardiovascular evaluation, serial blood-lead measurement and tobacco-cessation counselling should be given priority for Indonesia's fuel-station workforce.

Follow-up studies should enrol substantially larger, geographically diverse samples under a longitudinal cohort framework so that the time course linking cumulative metal loading to cardiovascular and renal

deterioration can be mapped. Coupling personal air-quality monitors with biological specimen collection at each workstation would refine exposure estimation well beyond what venous sampling provides in isolation. Pragmatic trials are also needed to determine whether structured respiratory-protection training, improved forecourt airflow engineering and scheduled biomonitoring effectively curb blood-metal concentrations in this workforce. Lastly, the prospect that concurrent uptake of several trace metals alongside the volatile hydrocarbons endemic to petrol retailing may trigger supra-additive toxic effects warrants dedicated mechanistic inquiry, ideally employing emerging biomarker technologies and formal dose–response modelling.

REFERENCES

- Ahmad, S., Mahmood, R., & Iqbal, M. (2023). Cadmium-induced oxidative damage in renal tubular cells: mechanisms and protective strategies. *Toxicology Letters*, *383*, 38–49. <https://doi.org/10.1016/j.toxlet.2023.05.008>
- Alhadithi, A. Q., & Kadhim, F. (2022). Detecting the Concentration of Some Trace Elements in Blood Samples of Fuel Station Workers. *INTERNATIONAL JOURNAL OF DRUG DELIVERY TECHNOLOGY*, *13*(02), 584–590. <https://doi.org/10.25258/ijddt.13.2.19>
- Alquezar-Burillo, A., Pena-Baquedano, E., & Lopez-Anton, R. (2024). Chronic lead exposure and cardiovascular risk: mechanisms and clinical implications. *Journal of Clinical Medicine*, *13*(10), 2901. <https://doi.org/10.3390/jcm13102901>
- Boskabady, M., Marefati, N., Farkhondeh, T., Shakeri, F., Farshbaf, A., & Boskabady, M. H. (2018). The effect of environmental lead exposure on human health and the mechanism of oxidative stress. *Environment International*, *120*, 404–420. <https://doi.org/10.1016/j.envint.2018.08.013>
- Budi Setyawan, F. E., Riana Widyastuti, Shandi Andara Putra, Ashifarachma Ekasari, Novianita Anugrah Islami, Nur Hafidhah Fitriani, & Lingga Caraka Putri. (2022). Obesity As A Risk Factor For Hypertension. *Saintika Medika*, *18*(2), 100–112. <https://doi.org/10.22219/sm.Vol18.SMUMM2.24113>
- Centers for Disease Control and Prevention. (2021). *CDC Updates Blood Lead Reference Value*. <https://www.cdc.gov/lead-prevention/php/news-features/updates-blood-lead-reference-value.html>
- Gbadamosi, M. R., Afolabi, T. A., Ogunneye, A. L., & Oladunjoye, M. A. (2023). Heavy metals in stormwater runoff from fuel stations and their environmental implications. *Chemosphere*, *338*, 139533. <https://doi.org/10.1016/j.chemosphere.2023.139533>
- Idris, S. H., Abdulrahman, A. A., & Musa, B. M. (2022). Blood lead level among petrol station attendants in Kaduna, Nigeria. *Annals of African Medical Research*, *5*(1), 1–8. <https://africa.pagepress.net/aamr/article/download/403/261/2434>
- Indonesian Ministry of Health. (2002). *Keputusan Menteri Kesehatan Republik Indonesia Nomor 1406/Menkes/SK/XI/2002 tentang Standar Pemeriksaan Kadar Timah Hitam dalam Darah*.

- Lamas, G. A., Bhatnagar, A., Jones, M. R., Mann, K. K., Nasir, K., Tellez-Plaza, M., Ujueta, F., & Navas-Acien, A. (2023). Contaminant Metals as Cardiovascular Risk Factors: A Scientific Statement From the American Heart Association. *Journal of the American Heart Association*, 12(13). <https://doi.org/10.1161/JAHA.123.029852>
- McEvoy, J. W., McCarthy, C. P., Bruno, R. M., Brouwers, S., Canavan, M. D., Ceconi, C., Christodorescu, R. M., Daskalopoulou, S. S., Ferro, C. J., Gerds, E., Hanssen, H., Harris, J., Lauder, L., McManus, R. J., Molloy, G. J., Rahimi, K., Regitz-Zagrosek, V., Rossi, G. P., Sandset, E. C., ... Khamidullaeva, G. A. (2024). 2024 ESC Guidelines for the management of elevated blood pressure and hypertension. *European Heart Journal*, 45(38), 3912–4018. <https://doi.org/10.1093/eurheartj/ehae178>
- Ministry of Manpower, R. of I. (2022). *The Indonesian National OSH Profile 2022*.
- Nucera, S., Ruga, S., Cardamone, A., & others. (2024). Non-essential heavy metal effects in cardiovascular diseases: an overview of systematic reviews. *Environmental Research*, 251, 118667. <https://doi.org/10.1016/j.envres.2024.118667>
- Ozarde, Y., Purandare, D., Deshmukh, S., & Gadhave, R. (2025). Heavy metals and cardiovascular health: Uncovering links and health challenges. *Journal of Trace Elements in Medicine and Biology*, 89, 127648. <https://doi.org/10.1016/j.jtemb.2025.127648>
- Pan, Z., Gong, T., & Liang, P. (2024). Heavy Metal Exposure and Cardiovascular Disease. *Circulation Research*, 134(9), 1160–1178. <https://doi.org/10.1161/CIRCRESAHA.123.323617>
- Pure Earth. (2024). *The importance of highlighting occupational diseases from heavy metal exposure in Indonesia*. <https://www.pureearth.org>
- Putri, R. A. ; M. T. ; H. W. (2022). Use of personal protective equipment and health complaints in gas station workers. *Indonesian Journal of Occupational Safety and Health*, 11(1), 109–118. <https://doi.org/10.20473/ijosh.v11i1.2022.109-118>
- Rizal, F. (2022). Analysis of lead level in the blood of several professions in Indonesia: a review. *Asian Journal of Health and Applied Sciences*, 1(1), 15–22. <https://doi.org/DOI:10.55927/ajhas.v1i1.1858>
- Rosengren, E., Barregard, L., Sallsten, G., Fagerberg, B., Engström, G., Fagman, E., Forsgard, N., Lundh, T., Bergström, G., & Harari, F. (2025). Exposure to Lead and Coronary Artery Atherosclerosis: A Swedish Cross-Sectional Population-Based Study. *Journal of the American Heart Association*, 14(5). <https://doi.org/10.1161/JAHA.124.037633>
- Suhat, S., Yogisutanti, G., Natawaluya, H., & Hotmaida, L. (2025). Relationship Between Working Periode and Using PPE with Hb Levels of Gas station Officers with Benzene Exposure in Cimahi City. *Jurnal Ilmu Lingkungan*, 23(1), 201–207. <https://doi.org/10.14710/jil.23.1.201-207>
- Upadhyay, K., Viramgami, A., Bagepally, B. S., & Balachandar, R. (2024). Association between chronic lead exposure and markers of kidney injury: A systematic review and meta-analysis. *Toxicology Reports*, 13, 101837. <https://doi.org/10.1016/j.toxrep.2024.101837>

- Verzelloni, P., Giuliano, V., Wise, L. A., Urbano, T., Baraldi, C., Vinceti, M., & Filippini, T. (2024). Cadmium exposure and risk of hypertension: a systematic review and dose-response meta-analysis. *Environmental Research*, 263, 120014. <https://doi.org/10.1016/j.envres.2024.120014>
- Wibowo, A., Lestari, F., & Modjo, R. (2023). Safety Climate Assessment in Fuel Stations in the West Java Region. *Safety*, 9(1), 9. <https://doi.org/10.3390/safety9010009>
- World Health Organization. (2023). *Preventing disease through healthy environments: exposure to lead—a major public health concern*.
- World Medical Association. (2024). *Declaration of Helsinki: ethical principles for medical research involving human participants*. <https://www.wma.net/policies-post/wma-declaration-of-helsinki/>
- Yasin, S. A., & Salih, Z. R. (2026). Hematological Alterations Linked to Occupational Heavy Metal Exposure in Gasoline Station Workers: A Biomonitoring Study From Erbil City. *Journal of Applied Toxicology*, 46(2), 479–492. <https://doi.org/10.1002/jat.4899>