

## ANALYSIS OF HEAVY METAL CONTAMINATION IN TEMPE INDUSTRY WASTEWATER

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| Article Info                                                                                                                                                                                                                                                                   | ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| <p><b>Article history:</b><br/>Received November 25<sup>th</sup>, 2025<br/>Revised December 28<sup>th</sup>, 2025<br/>Accepted February 11<sup>th</sup>, 2026</p> <p><b>*Corresponding Email:</b><br/><a href="mailto:yunitapp_12@yahoo.co.id">yunitapp_12@yahoo.co.id</a></p> | <p>Boiled soybean water produced during the tempeh production process is one of the major liquid wastes generated by both household-scale and large-scale industries. This wastewater is often discharged directly into the environment, such as drainage channels or water bodies (rivers). The potential contamination of heavy metals such as lead (Pb) and cadmium (Cd) may pose health risks if accumulated and entering the food chain or the environment. The aim of this study was to analyze the quality of tempeh wastewater in a home industry located in Bukit Baru Subdistrict, Ilir Barat I District, Palembang City, based on the examination of Pb and Cd heavy metal contents. The research employed a survey method, and samples were collected using purposive sampling. Testing of wastewater quality parameters was conducted at the UPTD Laboratory of the Environmental and Land Service of South Sumatra Province. Data were processed descriptively using quantitative analysis. The results of heavy metal testing in the boiled soybean water showed a total Cd concentration of &lt; 0.009 mg/L and a Pb concentration of &lt; 1.24 × 10<sup>-3</sup> mg/L. These findings indicate that the concentrations of Cd and Pb in tempeh wastewater remain below the quality standards set by the Ministry of Environment Regulation No. 03 of 2010.</p> <p><b>Keyword:</b> contamination, Pb, Cd, liquid waste, tempeh industry</p> |

### Introduction

Tempe is a very popular traditional Indonesian food that is rich in nutritional value. Both industrial-scale and household-scale tempe production generate significant amounts of liquid waste. Although tempe wastewater originates from organic matter, it often contains various pollutants, including heavy metals (Setyaningsih *et al.*, 2023). The environmental impact of liquid waste generated by the tempeh industry can be significant if not properly managed (Muliarta *et al.*, 2023). Some heavy metals commonly identified in tempeh wastewater include lead (Pb), cadmium (Cd), chromium (Cr), and copper (Cu) (Hidayati *et al.*, 2020).

Heavy metal contamination has become a critical issue due to its non degradable nature, its tendency to accumulate within the food chain, and its toxicity to living organisms, including humans even at low concentrations (Pratama *et al.*, 2022). Furthermore, the accumulation of heavy metals in fishery or agricultural products exposed to such wastewater may pose public health risks through consumption. The toxicological effects of heavy metals on humans may include neurological disorders, kidney and liver damage, and even long-term carcinogenic impacts (Wahyuningsih *et al.*, 2023). These health problems arise from the presence of heavy metals that are largely toxic and from their potential deposition in the kidneys (Manurung & Ginting, 2019).

The impacts of heavy metal contamination are extensive. Tempeh wastewater containing heavy metals that is discharged directly into aquatic environments can cause damage to aquatic ecosystems, disrupt the growth of aquatic plants, and threaten the sustainability of the organisms living within them (Nurjaman *et al.*, 2024). The tempeh production process involves soaking and boiling soybeans, followed by fermentation. These stages may release various compounds from the soybeans into the soaking and boiling water. In addition, sources of heavy metal contamination in tempeh wastewater may originate from the quality of the raw water used, contamination from production equipment, or even additives applied during the process (Astuti *et al.*, 2021).

Soybeans used as raw material for tempeh may become contaminated with heavy metals from the soil in which they grow (if the soil is polluted), irrigation water, or the use of pesticides and fertilizers containing heavy metals (Kumoro & Alhanif, 2022). Water used in the tempeh production process (washing, soaking, boiling) may also introduce heavy metals into the wastewater if it originates from contaminated sources, such as groundwater affected by industrial activities (Utami, 2025).

Tempeh wastewater is generated from various production stages, including soaking, boiling, and washing of soybeans. This wastewater contains high levels of organic substances such as carbohydrates, proteins, and fats (Rasmito *et al.*, 2019), which can increase the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of water. If discharged directly into water bodies without adequate treatment, this wastewater may lead to water pollution, negatively affecting environmental quality and public health in surrounding communities (Sari & Rahmawati, 2020).

According to the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014 on Wastewater Quality Standards for Soybean Processing Activities, organic pollutant indicators are represented by parameters such as BOD, COD, TSS, and pH (Sayow *et al.*, 2020). The pH value must fall within the range of 6 to 9, while the Biochemical Oxygen Demand (BOD) must not exceed 150 mg/L. Additionally, the Chemical Oxygen Demand (COD) is limited to a maximum of 300 mg/L, and Total Suspended Solids (TSS) must remain below 100 mg/L.

Tempeh wastewater is characterized by a high organic load, acidic pH, and unpleasant odor, with COD, TSS, and pH values frequently exceeding the national wastewater quality standards for soybean-processing industries (Cundari, 2022). At the household scale, tempeh production commonly takes place in residential areas, and most producers do not have wastewater treatment facilities. As a result, wastewater is discharged directly into nearby water bodies, potentially degrading groundwater quality, producing foul odors, and increasing the risk of pathogenic microbial growth (Prabowo & Sunaryanto, 2023). In addition to high organic content, tempeh wastewater may also generate ammonia through protein decomposition, which can further disrupt aquatic ecosystems (Harahap, 2013).

Palembang is one of the regions with a high number of tempeh producers, including Bukit Baru Subdistrict, which has developed into a center of household-scale tempeh and tofu industries since the late 1990s. More than 90% of residents in RT 02/RW 05 are engaged in tempeh-tofu production or trade, and wastewater from processing activities is generally discharged into small drainage channels flowing into the Musi River without treatment (Ayuni & Putri, 2022). This condition increases the risk of eutrophication, reduces dissolved oxygen levels, and contributes to environmental pollution in the surrounding residential area. Given these potential environmental risks, it is necessary to analyze heavy metal contamination particularly cadmium in wastewater from tempeh industries in Bukit Baru Subdistrict, Ilir Barat I District, Palembang City, as a basis for pollution control and improved environmental management.

## Methods

This study employed a survey research method. Wastewater samples were collected using purposive sampling in November 2025. The tempeh wastewater sample was taken from a household-scale industry located in Bukit Baru Subdistrict, Ilir Barat I District, Palembang City. Laboratory analyses of wastewater quality parameters were conducted at the UPTD 0). Additional parameters assessed in this study included BOD, COD, TSS, and pH. The results were quantitatively compared with established wastewater quality standards.

## Tools and Materials

The equipment used in this study included sample bottles, a spectrophotometer, oven, digester, measuring pipettes, test tubes, beakers, magnetic stirrer, heating block, BOD bottles, water bath, incubator, Winkler bottles, volumetric flasks, DO meter, analytical balance, porcelain crucibles, filter paper, vacuum pump, desiccator, measuring cylinders, volumetric pipettes, and a pH meter. The materials used consisted of tempeh wastewater samples, potassium dichromate, ferrous sulfate,

ferroin indicator, COD standard solution (potassium hydrogen phthalate), nutrient buffer solution, BOD standard solution, distilled water, digestion solution, and sulfuric acid reagent solution.

## Procedure

### Collection of Tempeh Wastewater Samples

Tempeh wastewater samples were collected from soybean boiling water following the SNI 6989.59:2008 standards. Samples were taken from the surface, middle, and bottom layers and then composited. The samples were collected directly from the storage drum during the production process. A total volume of 1 liter was collected and stored in a sterile, labeled plastic container.

### Heavy Metal Analysis

Heavy metal analysis was performed using the Atomic Absorption Spectrophotometry (AAS) method. Cadmium (Cd) concentration was measured following SNI 6989.84:2019 on Water and Wastewater Analysis, Part 16: Test Method for Cadmium (Cd) Using Flame Atomic Absorption Spectrophotometry. Lead (Pb) concentration was determined based on SNI 6989.46:2009 on Water and Wastewater Analysis, Part 8: Test Method for Lead (Pb) Using Flame Atomic Absorption Spectrophotometry.

## Results and Discussion

Based on the analysis of tempeh wastewater quality from a household-scale industry in Bukit Baru Subdistrict, Ilir Barat I District, Palembang City, the examination included heavy metal contaminants cadmium (Cd) and lead (Pb). The tests were conducted at the Environmental and Land Agency Laboratory of South Sumatra Province. The results obtained are presented in the **Table 1**. It showed the measurement of heavy metal parameters in tempeh wastewater derived from soybean boiling water showed the following results: total Cd < 0.009 mg/L and Pb <  $1.24 \times 10^{-3}$  mg/L. These findings indicate that the levels of heavy metal contamination in the tempeh wastewater remain within safe limits according to the Indonesian National Standards (SNI 6989.84:2019 and SNI 6989.46:2009).

**Table 1.** Results of Heavy Metal Concentration Measurements in Tempeh Wastewater

| No. | Heavy metal      | Methods          | Results                      | *Quality Standard |
|-----|------------------|------------------|------------------------------|-------------------|
| 1   | Cadmium (Cd)     | SNI 6989.84:2019 | < 0.009 mg/L                 | 0.1 mg/L          |
| 2   | Timah Hitam (Pb) | SNI 6989.46:2009 | < $1.24 \times 10^{-3}$ mg/L | 1 mg/L            |

Note : \* Heavy Metal Quality Standards for Cadmium (Cd) and Lead (Pb) Based on the Indonesian Minister of Environment Regulation No. 03 of 2010

In addition to accumulating in soybean boiling water, heavy metals may also accumulate in soybean-based food products such as tempeh and soy beverages. A study on heavy metal content in tempeh produced by household industries in Kaloran Village, Nganjuk Regency, reported average concentrations of Cd at 0.0073 mg/kg and Pb at 0.0042 mg/kg, both of which fall within acceptable limits. According to the Indonesian National Standard (BSN, 2015), the permissible heavy metal levels in tempeh are: Cadmium (Cd)  $\leq 0.2$  mg/kg, Lead (Pb)  $\leq 0.25$  mg/kg, Tin (Sn)  $\leq 40$  mg/kg, and Mercury (Hg)  $\leq 0.03$  mg/kg (Widyastuti *et al.*, 2022).

Heavy metals may also accumulate in plant-based protein beverages made from soybeans (soy beverages), which are commonly consumed as substitutes for cow's milk. Soy beverages have been reported to contain Cd at concentrations of  $5.6 \pm 4.2$   $\mu$ g/L and Mn at  $117.4 \pm 30.3$   $\mu$ g/L, while Pb levels reach  $13.4 \pm 9.6$   $\mu$ g/L. Toxic metals such as lead (Pb), cadmium (Cd), and manganese (Mn) although Mn is essential are neurotoxic at elevated concentrations and may interfere with normal development in children. Considering the toxicity and bioaccumulation potential of these metals, and the fact that soy-

based foods and beverages are routinely consumed across all age groups, including infants, strict monitoring of metal levels in soy beverages is necessary (Andrade *et al.*, 2023).

The presence of heavy metals in soybean boiling wastewater may also be influenced by production equipment that does not meet sanitary or material standards. This is evidenced by the use of plastic containers for soaking soybeans, iron-based vessels for boiling, and iron tanks for wastewater storage. Wastewater generated from the soaking and boiling of soybeans contains high levels of organic matter, as indicated by the strong odor it produces. In this study, supporting wastewater quality parameters COD, BOD, TSS, and pH were also examined. The results of these measurements are presented in the Table 2.

**Table 2.** Tempeh Wastewater Quality Parameters

| No. | Parameter | Result      | *Quality Standard |
|-----|-----------|-------------|-------------------|
| 1   | BOD       | 10.675 mg/L | 150 mg/L          |
| 2   | COD       | 43.738 mg/L | 300 mg/L          |
| 3   | TSS       | 6.352 mg/L  | 100 mg/L          |
| 4   | pH        | 6.140       | 6–9               |

Note: \*Quality Standards are based on the Minister of Environment Regulation (Permen LH) No. 05 of 2014.

The measurement of wastewater quality parameters shows that the Biochemical Oxygen Demand (BOD), which represents the amount of oxygen required by microorganisms to biologically degrade organic matter in water (Sari & Rahmawati, 2020), reached 10,675 mg/L (Table 4.2). This value is far above the quality standard set by the Minister of Environment Regulation No. 05 of 2014, which is 150 mg/L. The extremely high BOD level indicates that tempeh wastewater contains a very high organic load (Pramaningsih *et al.*, 2022). Tempeh processing wastewater typically contains organic substances such as proteins (40–60%), carbohydrates (25–50%), and fats (up to 50%) (Lusitasari, 2019).

Such conditions can significantly reduce dissolved oxygen in receiving water bodies if the wastewater is discharged without proper treatment (Lusiana *et al.*, 2020). As a result, aquatic life such as fish and other oxygen-dependent organisms may be stressed or die. High BOD levels may also generate foul odors due to the decomposition of organic matter (Pangalanan *et al.*, 2022). Therefore, the very high BOD concentration is a critical indicator that tempeh industry wastewater requires proper management to prevent environmental pollution and protect aquatic ecosystems.

Based on the laboratory analysis, the Chemical Oxygen Demand (COD) value of the tempe wastewater was recorded at 43.738 mg/L. This value significantly exceeds the quality standard set by the Indonesian Minister of Environment Regulation No. 05 of 2014, which stipulates a maximum limit of 300 mg/L. This exceedance indicates that the organic content in tempe wastewater is very high, requiring a substantial amount of oxygen for chemical oxidation (Pakpahan *et al.*, 2021).

The high COD value reflects a considerable pollution load in the wastewater, primarily originating from organic compounds that are difficult to degrade biologically (Hidayatullah & Hendrasarie, 2025). If this wastewater is discharged into natural water bodies without adequate treatment, it may lead to a drastic reduction in dissolved oxygen levels (Pakpahan *et al.*, 2021). Such conditions have the potential to cause the death of aquatic organisms and disrupt ecosystem balance (Sugianti & Lismining, 2018).

According to Table 4.2, the Total Suspended Solids (TSS) concentration reached 6.352 mg/L, which also far exceeds the standard limit of 100 mg/L. This finding is consistent with research by Sari & Rahmawati (2020), which reported that tempe wastewater contains high levels of TSS, indicating the presence of numerous suspended particles that may contaminate the environment. These suspended solids can increase water turbidity (Sonalitha *et al.*, 2024), interfere with light penetration, and degrade aquatic ecosystem quality if the wastewater is discharged directly into the environment (Mousavi *et al.*, 2023).

TSS merupakan parameter penting dalam menilai kualitas air limbah, karena menunjukkan jumlah partikel padat yang tidak larut dan tersuspensi dalam air seperti sisa-sisa kedelai, mikroorganisme, serta material organik dan anorganik lainnya. Nilai TSS yang sangat tinggi pada limbah tempe ini mencerminkan tingginya beban pencemar fisik dalam air yang dapat mengganggu kualitas lingkungan perairan (Prabowo & Sunaryanto, 2023).

Wastewater with high TSS levels, if discharged directly into water bodies without treatment, can increase water turbidity, inhibit sunlight penetration, and disrupt the photosynthesis of aquatic organisms (Fajarwati & Putri, 2022). In addition, the accumulation of suspended particles can settle at the bottom of the water body and damage benthic habitats (Mardhia & Abdullah, 2018). Therefore, the high TSS concentration in tempe wastewater not only causes physical pollution but also brings serious ecological impacts. Proper wastewater treatment is essential before disposal to prevent environmental degradation of aquatic ecosystems.

Tempe wastewater produced by household-scale industries shows a significant potential for pollution. Although its pH value of 6.14 is still within the safe threshold, it can still affect aquatic ecosystems and human health. pH is an important parameter that indicates the acidity or alkalinity of water, serving as a key determinant of water quality and pollution levels. Water bodies with highly acidic conditions can disturb aquatic biota and ecosystems and reduce the usability of water resources (Rosmawati, 2013). The increase in pH observed in this study is consistent with findings reported by Sapta & Yanti (2016). Adverse effects of abnormal pH on human health include atopic dermatitis, contact dermatitis, ichthyosis, red bumps, acne, dry skin, and wrinkles. Meanwhile, excessively low pH levels can lead to damage to hair and skin (Sa'adah *et al.*, 2019).

The tempe wastewater generated from production activities in a household-scale industry located in Bukit Baru Subdistrict, Ilir Barat I District, Palembang City, demonstrates a significant potential for environmental pollution. Laboratory test results for key water quality parameters BOD, COD, and TSS indicate that most of the constituent levels in the wastewater exceed the threshold limits set by the Ministry of Environment Regulation (Permen LH) No. 05 of 2014.

The exceptionally high BOD and COD values indicate an excessive organic load, which can reduce dissolved oxygen levels, threaten aquatic life, and produce unpleasant odors. In addition, the TSS concentration, which far exceeds the quality standards, causes turbidity, inhibits light penetration, and disrupts photosynthesis processes, ultimately affecting the overall balance of aquatic ecosystems. Thus, untreated tempe wastewater discharged into the environment may lead to serious ecological impacts including chemical, biological, and physical pollution resulting in habitat degradation and disturbance of aquatic ecosystem stability. Therefore, appropriate and sustainable wastewater treatment measures are essential to ensure that household-scale tempe industries remain productive without compromising environmental sustainability.

## Conclusion

Based on the results of the heavy metal analysis of soybean boiling water from the tempe production process in a household-scale industry located in Bukit Baru Subdistrict, Ilir Barat I District, Palembang City, the concentrations of total Cd ( $< 0.009$  mg/L) and Pb ( $< 1.24 \times 10^{-3}$  mg/L) were found to be below the quality standards established in the Ministry of Environment Regulation (Permen LH) No. 03 of 2010.

The supporting parameters of wastewater quality indicate that the pH level of the tempe wastewater falls within the acceptable range, recorded at 6.14 (standard 6–9). However, the values of BOD, COD, and TSS were far above the permissible limits set by Permen LH No. 05 of 2014, with measurements of 10,675 mg/L for BOD (standard 150 mg/L), 43,738 mg/L for COD (standard 300 mg/L), and 6,352 mg/L for TSS (standard 100 mg/L).

These findings demonstrate that tempe wastewater contains a very high organic load and suspended solids concentration, which may cause environmental pollution if discharged without proper treatment. Therefore, effective wastewater management is required before disposal into water bodies to prevent adverse ecological impacts.

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