Water Quality Parameters of Tofu Wastewater: A Review

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Abstract. The tofu industry's existence is quite potential in recruiting labors, which can improve the economy of the surrounding community. On the other hand, it can also have a negative impact due to the wastewater produced from the tofu making process, which can damage the environment. Water is widely used as material for washing and boiling soybeans; due to the large use of water in making tofu and tempeh, fermented soybeans. The resulting waste is also quite large. This research presents a literature review with primary data on articles, magazines, reports, and theories. The purpose of this research is to provide an overview of the water quality parameters of tofu waste. The liquid waste produced by the tofu-making industry is a thick liquid that is separated from the clumps of tofu, which is called whey. This liquid contains high levels of protein and can quickly break down. This waste is often disposed of directly without prior treatment, resulting in a bad smell and polluting the environment. There are several parameters used to measure water quality, including physical, chemical, and biological properties.

1. Introduction
Tofu is one of the most popular foods among Indonesians. This food is favored by almost all levels of society, lower, middle, and upper classes. It can be seen from the sale of tofu in all conditions, vegetable peddlers, markets, supermarkets, restaurants, and star hotels. One of the factors why it is liked by the public is because it is affordable and delicious. Tofu also has good nutritional contents such as protein and carbohydrates. In general, one is used as a side dish and snack.

The problem that arises in SME is the abundance of solid and liquid waste generated during production. Those wastes are still not properly managed, such as solid waste that can be reprocessed into soft tempeh or gembus, flour, and cakes. The water disposal system should be separated between liquid waste generated by the production installation and household liquid waste. This separation aims to classify waste management methods according to the source of the pollution. The liquid waste will react with the air and decompose by microorganisms, causing problems in the form of an unpleasant odor that pollutes the surrounding environment and water.

According to [1], if every quintal of soybeans used for making tofu produces 1.5 - 3 m³ of wastewater. For example, the amount of soybeans with a value of 116,290 kg = 1162.9 quintals produces wastewater ranging from 1162.9 quintals x 2 m³ = 2325.8 m³ / day = 69,774 m³ / month = 837,288 m³ / year of wastewater produced. Therefore, it becomes a serious problem if the large volume of waste produced exceeds the carrying capacity of the environment. The definition of the carrying capacity of the environment according to [2] is the amount of the ability of the environment to support the life of organisms expressed in space units.

In this paper, the researcher discusses how the impacts of tofu waste on the environment and the parameters for measuring the water quality of tofu waste. The purpose of this article is to provide a broader view of the water quality parameters of tofu waste.
2. Method
This research is a review, descriptive, and based on the non-empirical design [3], [4]. The collected information of scope was conducted in secondary sources of books, articles, journals, electronic sources, and theories. A review paper provides a summary and synthesis of research findings on a topic selected and completed by other authors [5]. The research review aims to find out the current state of relevant publications regarding the findings related to the chosen topic. This research is a descriptive study, an analysis that describes a phenomenon and its characteristics systematically, factually, and accurately [6]. One uses non-empirical design or also called theoretical research [7][8], which is not based on empirical evidence such as quantitative data or qualitative data but is still based on facts [9]. In this research, the researchers chose the topic of tofu wastewater and water quality, so the researchers looked for various articles that corresponded to the issue of water quality parameters of tofu wastewater from publications that have been published by other authors.

3. Discussion
3.1 Tofu Waste
Tofu waste comes from waste or residual processing of soybeans which is wasted because it is not properly solid so it cannot be consumed. It consists of two types, namely liquid and solid waste. This waste occurs because of the remaining tofu water that does not clot, pieces of tofu that are destroyed due to the imperfect clumping process, and yellowish liquid which can cause an unpleasant odor [10].

The solid waste of the tofu processing plant is in the form of dirt from cleaning soybeans (stones, soil, soybean skin, and other solid objects that stick to the soybeans) and the residue from the soybean pulps filter called tofu pulp. The solid waste in the form of manure comes from the initial process (washing) of soybean raw materials and generally, there is not so much solid waste (0.3% of the raw material for soybeans). Meanwhile, solid waste in the form of tofu dregs occurs in the soybean pulp filtering process. The number of tofu dregs that is formed ranges from 25-35% of the tofu produced [11]. This liquid contains high levels of protein and can break down quickly. This waste is often disposed of directly without prior treatment, resulting in a bad smell and polluting the environment [11].

3.2 Water Quality
According to [12], the parameters used to measure water quality include physical, chemical, and biological properties. These parameters are:

3.2.1 Physical Properties
The physical parameters of water that determine its quality are turbidity, temperature, color, smell, taste, amount of suspended solids, dissolved solids, and electrical conductivity (EC).

3.2.2 Chemical Properties
Chemical properties that can be used as indicators that determine water quality are pH, concentrations of potassium, magnesium, manganese, iron, sulfide, sulfate, ammonia, nitrite, nitrate, phosphate, dissolved oxygen, BOD, COD, oil, fat, and heavy metal.

3.2.3 Biological (Microbiological) Properties
Organisms in water can be used as indicators of pollution in an aquatic environment, for example bacteria, algae, plankton, and certain fish. The method of measurement taken for each parameter varies according to the circumstances [13]–[15].

1. Water Temperature, The temperature of the wastewater produced usually has a higher temperature than water in public drains[13]. DO in hot water is relatively small, so it also decreases in the common sewer where the tofu wastewater is disposed.
2. pH, is divided into acidic and alkaline properties [16]. Acidity is the ability to neutralize bases. Weak acidity can have high acidity. It means that it has the potential to release hydrogen. It is differentiated between free acidity and total acidity. Free acidity is caused by strong acids such as hydrochloric acid and sulfuric. Free acidity can lower pH. Total acidity consists of the free acidity and the acidity caused by weak acids. Meanwhile, the basicity of water is the capacity of water to neutralize acids. This is because there are bases or alkaline salts in the water. For example, NaOH, Ca(OH)₂, and so on. Basic salts that are often encountered are carbonates of the metals sodium, calcium, magnesium, and so on. While high acidity does not mean high pH. To fulfill the requirements of life, water must have a pH of about 6.5 - 7.5. It will be acidic or base depending on the big or small pH. If the pH <6.5 then the water is acidic, while water that has a pH > 7.5 is alkaline or base. Wastewater and industrial waste will change the pH of the water which will ultimately disrupt the life of aquatic biota which is sensitive to changes in pH [17].

3. TSS, Total solids suspended in water are inorganic, organic, and liquid particles that cannot mix in water. It includes soil, clay, and mud, while organic solid often encountered are plant fibers, algae cells, and bacteria. These solids are natural pollutants originating from water erosion while flowing [18]. Other suspended residue compounds come from the activities of the population using water. Residual waste and industrial waste usually contain a lot of suspended residues. The presence of suspended residues in water is undesirable for reasons of decreasing aesthetics of water, besides the suspended residues can be used as absorption sites for chemical or biological substances such as disease-causing microorganisms [19]. The maximum limit of suspended solids content in water for Class I water body designation is 50 mg/liter (PPRI-82, 2001).

4. BOD, BOD is the amount of oxygen needed by microorganisms to degrade the organic material in water [17]. According to [20], one is the amount of oxygen expressed in mg/l or parts per million (ppm) used by bacteria to oxidize in water. Organic material consisting of carbohydrates (cellulose, starch, sugar), protein, hydrocarbon oil, and other organic materials enters the water body from natural sources as well as from polluting sources. The natural sources of BOD in surface water come from plant rot and animal waste, while the source of BOD from human activities comes from feces, urine, detergents, oils, and fats [21]. In general, BOD is used to determine the level of wastewater pollution. Its measurement is a measurement of the amount of oxygen used by microorganisms in decomposing organic matter in water. The oxidation reaction during the BOD examination is the result of biological activity and the reaction that takes place is influenced by the number of populations and temperature. The temperature should be kept constant at 20°C which is the common temperature in nature. Theoretically, the time required for the complete oxidation process to break down organic material into CO₂ and H₂O is unlimited. In laboratory practice, it usually lasts for 5 days with the assumption that during that time the percentage of reactions is quite large from the total BOD [22]. If the high O₂ consumption is indicated by the smaller dissolved O₂, it means that the content of waste materials requires high O₂ [23].

5. COD, COD is defined as the amount of oxygen required for the waste materials present in water to be chemically oxidized. The organic waste material will be oxidized by Potassium Bichromate to CO₂ and H₂O gas to form Chrom ions. Potassium Bichromate is used as a source of oxygen (oxidizing agent) following the reaction: 22 CaHbOc + Cr₂O7²⁻ → 11CO₂ + H₂O + Cr₃⁺ (Source: [17]). The amount of oxygen required for the oxidation reaction against organic waste is the same as the amount of potassium bichromate used in the oxidation reaction [17]. Waters that have a high COD value are undesirable for fisheries and agriculture purposes. COD values in uncontaminated waters are usually less than 20 mg/l [15]. Its maximum levels are allowed to support aquatic organisms and for irrigation purposes range from 10 – 100 mg/l (PP No. 82 of 2001 concerning Water Quality Management and Water Pollution Control).

6. DO. Dissolved oxygen is important to use to decompose or oxidize organic and inorganic materials in aerobic processes in water. The main source of oxygen in waters comes from the air through the diffusion process and the photosynthesis of organisms in these waters [22]. In freshwater, dissolved oxygen levels at 25°C are around 8 mg/l [15]. According to [16], in flowing waters, usually oxygen is not a limiting factor. In a river that is clear and swift, the oxygen
concentration reaches saturation. Dissolved oxygen determinations must be carried out multiple times, at various locations, at different depth levels at different times. If the water is running slowly or there are pollutants then the dissolved oxygen may be undersaturated, so the oxygen again becomes the limiting factor. It depends on (1) temperature; (2) the presence of photosynthetic plants; (3) The level of light penetration depends on the depth and turbidity of the water; (4) Water hardness level; (5) The amount of organic material that has been broken down in water such as garbage, dead algae, or industrial waste.

7. \( \text{NH}_3 \) In the waters, nitrogen is in the form of inorganic and organic. Inorganic nitrogen consists of ammonia (\( \text{NH}_3 \)), ammonium (\( \text{NH}_4 \)), nitrite (NO\(_2\)), nitrate (NO\(_3\)), and nitrogen molecules (N\(_2\)) in gaseous form. Organic nitrogen is in the form of protein, amino acids, and urea. The main source of anthropogenic nitrogen in waters comes from agricultural areas that use fertilizers intensively and from domestic activities. Ammonia and its salts are soluble in water. The source of ammonia in the waters is the breakdown of organic nitrogen (protein and urea) and inorganic nitrogen found in soil and water, which comes from the decomposition of dead plant and aquatic biota by microbes and fungi [15]. The free ammonia content for drinking water purposes should not be more than 0.5 mg/l, while for fisheries, the free ammonia content for sensitive fish is \( \leq 0.02 \text{ mg/l} \) as NH\(_3\) (Government Regulation No. 82 of 2001 concerning Water Quality Management and Water Pollution Control).1) \( 2\text{NH}_4^+ + 3\text{O}_2 + \text{Nitrosomonas} \to 2\text{NO}_2^- + 2\text{H}_2\text{O} + 4\text{H}^+ + \text{Energy} \) 2) \( 2\text{NO}_2^- + \text{O}_2 + \text{Nitrobacter} \to 2\text{NO}_3^- + \text{Energy} \) (Source: [15]).

The presence of nitrite content in the waste shows that little of the organic nitrogen compounds are oxidized. It is only a little in new waste, but in stale waste, a large amount of nitrite is found. The presence of nitrates indicates that change is taking place, thereby indicating imperfect waste management. Nitrate (NO\(_3\)) and ammonium (NH\(_4\)) are the main sources of nitrogen in the water, but NH\(_4\) is preferred by plants. One represents the end product of the degradation of organic material (nitrogen). Nitrate-nitrogen levels in natural waters are almost never more than 0.1 mg/l. NO\(_3\) levels of more than 5 mg/l represent the occurrence of anthropogenic contamination originating from human activities and animal feces. Nitrate-nitrogen levels of more than 0.2 mg/l can result in eutrophication (enrichment) of water, which in turn stimulates the rapid growth of algae and aquatic plants (blooming). In waters that receive runoff from agricultural areas that contain lots of fertilizers, nitrate levels can reach 1000 mg/l. Nitrate levels for drinking water should not exceed 10 mg/l (PP 82 of 2001 concerning Water Quality Management and Water Pollution Control). Adults have a high tolerance for nitrate ions, but for babies and animals, these ions are toxic. In the digestive systems of babies and animals, nitrates are reduced by nitrates. Nitrite can bind to hemoglobin in the blood [24]. The N content in water as total nitrogen (N), dissolved nitrogen (DIN), nitrate (NO\(_3^-\)N), and ammonium (NH\(_4^-\)N) increases along with the rainy season. Rainfall and water runoff are the main drivers that cause N from non-point sources to be released from their catchment areas, while fertilizers cause the input of large amounts of N into the environment and agricultural activities accelerate the transformation of N into water bodies [25].

The river as intended must always be in its condition, namely by being protected and preserved; enhanced functions and benefits; and the destructive power of the environment is controlled [25]. This condition will cause all dissolved pollutants in the form of liquid and solid waste to enter the river flow. The number of pollutants that enter the river will affect the quality of river water. At a certain point, there will be pollution [14].

3.3 Community Behavior
Behaviors are the result of all human experiences and interactions with the environment which are manifested in the form of knowledge, attitudes, and actions [27]. One is formed through a process and takes place in human and environmental interactions. It is formed through internal and external factors. Internal factors include knowledge, intelligence, emotion, and innovation. Meanwhile, external factors include the surrounding environment, both physical and non-physical, such as climate, socio-economy, and culture. The behavior is a person's response or reaction to external stimulus [28]. Therefore it occurs through the process of a stimulus to the organism, then the organism responds, so the SKINNER theory is called an S-O-R theory or Stimulus Organism Response. Community behavior
is the process of evaluating a person towards an object, event, or stimulus by involving experiences related to that object through processes of cognition and affection to form an object. Besides, behavior is influenced by three factors, namely predisposing, predisposing, enabling, and reinforcing factors[29]. Predisposing factors are positive factors that facilitate the practice. These factors include knowledge, attitudes, beliefs, traditions, social norms, experience, education level, beliefs, and other forms that exist in individuals/communities.

4. Conclusion
Tofu industrial waste is generally divided into two forms of waste, namely solid and liquid waste. There are three parameters that can be used to measure water quality, namely physical, chemical, and biological properties. Physical properties include turbidity, temperature, color, smell, taste, amount of suspended solids, dissolved solids, and electrical conductivity (EC). Chemical properties focus on the pH of potassium, magnesium, manganese, iron, sulfide, sulfate, ammonia, nitrite, nitrate, phosphate, dissolved oxygen, BOD, COD, oil, fat, and heavy metal. Meanwhile, the biological properties (microbiology) include water temperature, pH, TSS, BOD, COD, DO, and NH₃. Finally, the community behavior pattern in the tofu production process also needs attention. One is formed through internal and external factors. The internal factors include knowledge, intelligence, emotions, and innovation. Meanwhile, the external factors include the surrounding environment, both physical and non-physical, such as climate, socio-economy, and culture.

5. References
[1] P. B. Aji and J. Kimia, “PENURUNAN NILAI COD AIR LIMBAH PABRIK TAHU Info Artikel,” Indones. J. Chem. Sci., vol. 5, no. 2, pp. 2–5, 2016.
[2] O. Soemarwoto, Ekologi, Lingkungan Hidup Dan Pembangunan. Jakarta: Djambatan, 2004.
[3] S. Apriyanto, Dalman, and D. Santoso, “The urgency of forensic linguistics in a police interrogation process,” Int. J. Psychosoc. Rehabil., vol. 24, no. 6, pp. 4766–4772, 2020, doi: 10.37200/IJPR/V24I6/PR260467.
[4] O. Hidayat, S. Apriyanto, P. Program, A. Science, U. Tun, and H. Onn, “Drama Excerpt : Tool in Enhancing Speaking Ability for Junior High School,” vol. 2, no. 3, pp. 1–9, 2019.
[5] R. W. Palmatier, M. B. Houston, and J. Hulland, “Review articles: purpose, process, and structure,” J. Acad. Mark. Sci., vol. 46, no. 1, pp. 1–5, 2018, doi: 10.1007/s11747-017-0563-4.
[6] H. Nassaji, “Qualitative and descriptive research: Data type versus data analysis,” Lang. Teach. Res., vol. 19, no. 2, pp. 129–132, 2015, doi: 10.1177/1362168815572747.
[7] R. C. GARDNER and P. F. TREMBLAY, “On Motivation, Research Agendas, and Theoretical Frameworks,” Mod. Lang. J., vol. 78, no. 3, pp. 359–368, 1994, doi: 10.1111/j.1540-4781.1994.tb02050.x.
[8] K. Moen and A. L. Middelthon, “Qualitative Research Methods,” in Research in Medical and Biological Sciences: From Planning and Preparation to Grant Application and Publication, Australia: Elsevier Ltd, 2015, pp. 321–378.
[9] O. O. Fidelis, “Writing non-empirical articles for publication,” Int. J. Adv. Acad. Res., vol. 3, no. 3, pp. 25–31, 2017.
[10] Nohong, “Pemanfaatan Limbah Tahu sebagai Bahan Penyerap Logam Krom, Kadmiun dan Besi Dalam Air Lindi TPA,” J. Pembelajaran Sains, vol. 6, no. 2, pp. 257–269, 2010.
[11] F. Kaswinarni, “Kajian Teknis Pengolahan Limbah Padat Dan Cair Industri Tahu (Studi Kasus Industri Tahu Tandang Semarang, Sederhana Kendal, dan Gagak Sipat Boyolali),” Univ. Diponegoro, 2007.
[12] R. Slamet, Pencemaran Air Seri Lingkungan. Surabaya: Karya Anda, 1984.
[13] W. S. Nursandi S. Mumu; Hartati, Etih, “Perbaikan Kualitas Air Limbah Industri Farmasi Menggunakan Koagulan Biji Kelor (Moringa Oleifera Lam) Dan Pac (Poly Alunnum Chloride),” J. Teknol. Lingkung. Univ. Trisakti, vol. 4, no. Vol 4, No 3 (2008): JUNI 2008, pp. 68–73, 2008.
[14] T. T. Pairunan, “Perangkat Lunak Pendukung Keputusan Analisis Pengelolaan Kualitas Dan
Pengendalian Pencemaran Air Sungai,” *J. Ilm. Sains*, vol. 12, no. 2, p. 105, 2012, doi: 10.35799/jis.12.2.2012.610.

[15] H. Effendi, *Telahah Kualitas Air: Bagi Pengelolaan Sumber Daya dan Lingkungan Perairan*. Yogyakarta: Kanisius, 2003.

[16] A. T. Sastrawijaya, *Pencemaran Lingkungan*. Jakarta: rineka cipta, 2000.

[17] W. Arya Wardhana, *Dampak Pencemaran Lingkungan*. Yogyakarta: Andi.

[18] A. L. Underwood and J. R. A Day, *Analisis Kimia Kuantitatif (terjemahan A. Hadyana Pudjaatmaka)*, 5th ed. Jakarta: Erlangga, 1999.

[19] P. Sunu, *Melindungi Lingkungan dengan Menerapkan ISO 14001*, Pertama. Jakarta: PT. Gramedia Indonesia, 2001.

[20] C. C. Hach, K. R. L. Jr, and C. R. Gibbs, “Introduction to Biochemical Oxygen Demand,” *Nephrology*, vol. 19, no. 7, pp. 1–1, 1997, doi: 10.1111/nep.12265.

[21] M. R. Penn, J. J. Pauer, and J. R. Mihelcic, “Biochemical oxygen demand. Environmental and Ecological Chemistry,” vol. II, pp. 278–297, 2009.

[22] Pariwono, “Oksigen Terlarut (DO) Dan Kebutuhan Oksigen Biologi (BOD) Sebagai Salah Satu Indikator Untuk Menentukan Kualitas Perairan,” *Oseana*, vol. 30, no. 3, pp. 21–26, 2005.

[23] S. Fardiaz, *Mikrobiologi Pangan 1*. Jakarta: Gramedia, 1992.

[24] R. Achmad, *Kimia Lingkungan*. Yogyakarta: Andi, 2004.

[25] Y. Xia, L. Huang, and L. Xu, “Characteristics of diffuse source N pollution in Lean River catchment,” *Procedia Environ. Sci.*, vol. 10, no. PART C, pp. 2437–2443, 2011, doi: 10.1016/j.proenv.2011.09.379.

[26] N. A. D. Putri, “Kebijakan Pemerintah Dalam Pengendalian Pencemaran Air Sungai SIAK,” *J. Ilmu Polit. dan Ilmu Pemerintah*, vol. 1, no. 1, pp. 68–79, 2011.

[27] L. W. Green and M. W. Kreuter, *Health promotion planning-An educational and environmental approach*, 2nd ed. California: Maytield Publishing, 2000.

[28] R. P. Fisher and R. E. Geiselman, “The Cognitive Interview method of conducting police interviews: Eliciting extensive information and promoting Therapeutic Jurisprudence,” *Int. J. Law Psychiatry*, vol. 33, no. 5–6, pp. 321–328, 2010, doi: 10.1016/j.ijlp.2010.09.004.

[29] S. Notoatmodjo, *Metodologi Penelitian Kesehatan*. Jakarta: Rineka cipta, 2005.

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