PHYSICOCHEMICAL CHARACTERIZATION OF DAIRY FARM WASTEWATER FROM SMALLHOLDER FARMER

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ABSTRACT. The dairy industry generates a large volume of wastewater containing high levels of organic matter, including fats, proteins, and lactose. If not properly treated, this organic matter can lead to elevated levels of biochemical oxygen demand and chemical oxygen demand. Therefore, a study was conducted on a small dairy farm in Semenyih, Selangor to analyse undiluted wastewater samples collected twice weekly for 18 weeks, assessing various quality parameters. A total of 35 samples were tested and, the results revealed high mean values for biochemical oxygen demand (286 mg/L), chemical oxygen demand (1,674 mg/L), total suspended solids (3,186 mg/L), and ammonia nitrogen (157 mg/L), while pH and temperature remained within acceptable limits. These findings indicate that the dairy farm's wastewater in the study substantially exceeds Malaysian effluent standards, necessitating further treatment to address environmental and health concerns. Implementing effective wastewater treatment strategies is crucial to mitigate risks, ensure regulatory compliance, and enable sustainable water reuse on the farm. This approach promotes responsible agricultural practices and environmental stewardship in Malaysia's growing dairy sector.

Keywords: wastewater quality, discharge standards, pollutant level, dairy farm

INTRODUCTION

The dairy industry generates a large volume of wastewater containing high levels of organic matter, including oil and fat, nitrogen and phosphorous, dissolved sugars, and other nutrients (Purnima *et al*., 2012). If not properly treated, this organic matter can lead to elevated levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

Dairy farms produce significant amounts of solid waste and effluent, which can pollute surface and groundwater, and contribute to soil degradation. According to the Environmental Protection Agency (EPA), dairy farm wastewater has an average COD of 4,997 mg/L and BOD of 1,003 mg/L, with COD ranging from 2,000 to 7,000 mg/L depending on management practices (Osama *et al*., 2015).

The environmental impact of untreated dairy wastewater is significant. When released into water bodies without proper treatment, it can lead to surface and groundwater pollution, soil degradation, and serve as a medium for disease transmission (Jesse *et al*., 2022). This poses particular risks to rural populations that rely heavily on groundwater from private wells for domestic use and drinking water (Sasakova *et al.,* 2018). Contaminants from dairy farming activities can alter the natural composition of both groundwater and surface water, potentially leading to long-term environmental and health consequences.

Given these concerns, this study aims to characterise dairy farm wastewater in Semenyih, Selangor by analysing key parameters including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids

(TSS), Total Dissolved Solids (TDS), Total Solids (TS), Volatile Solids (VS), temperature, pH, and Ammonia-Nitrogen (NH_3-N). The results will provide crucial preliminary data for monitoring wastewater quality in the Malaysian dairy industry.

MATERIALS AND METHODS

Study Site and Sample Collection

The dairy farm wastewater used in this study was obtained from a local dairy farm located in Semenyih, Selangor, housing approximately 90 adult dairy cattle and 25 young cattle. Daily manure production was estimated at 8 -16 kg per adult cattle, with each animal requiring 35 -45 L of water daily for cleaning.

Undiluted dairy farm wastewater samples were collected over 18 weeks, with sampling events conducted twice weekly from August to December 2019. To ensure a representative distribution, sampling occurred on alternating days, covering all days of the week at varying times. Samples were collected from the main discharge point after the wastewater had undergone treatment in a small-scale underground ceramic anaerobic digester with a capacity of 50 m^3.

Sample Preservation and Storage

Immediately after collection, samples were transferred into sterile containers and stored refrigerated at 4 °C. Appropriate preservation techniques were employed to maintain sample integrity prior to analysis, following standard protocols for handling wastewater samples.

Analytical Methods

The key physicochemical characteristics, including pH, BOD, COD, TSS, TS, TDS, VS, and NH_3-N were determined. All analyses were conducted according to the APHA Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Quality control measures, including the use of blanks and standards, were implemented throughout the analytical process to ensure accuracy.

Data Analysis

Descriptive statistics, including mean and standard deviation were calculated for each parameter using Microsoft Excel software. The results were compared with Malaysian environmental regulations for agricultural wastewater discharge to assess compliance and potential environmental impacts.

RESULTS AND DISCUSSION

Dairy farm wastewater was characterised by several key parameters that define its quality and composition. These parameters, covering physical, chemical, and biological properties, are crucial for understanding the effectiveness of the anaerobic digester used by the farmer and determining whether further treatment processes are necessary. This ensures that the discharged wastewater meets environmental standards and does not negatively impact the surrounding ecosystem. A total of 35 samples were tested for the selected parameters, and results of the analysis are presented in Table 1. The results were compared to Standard B of the Environmental Quality (Industrial Effluent) Regulations, 2009.

Table 1. Physicochemical parameters of the dairy farm wastewater and the limit thresholds for industrial liquid effluent discharges.

Parameter	Physicochemical analysis results in the final discharge		Mean ± SD	[1]Regulation 2009
	Minimum value	Maximum value		Standard B
Temperature, °C	27.2	29.9	28.6 ± 0.64	40
pH	6.4	7.7	6.8 ± 0.28	5.5 – 9.0
BOD (mg/L)	117	660	286 ± 106	50
COD (mg/L)	512	3,544	1,674 ± 638	200
COD: BOD	2.43	20.92	6.33 ± 3.16	4.00:1
TSS (mg/L)	1,154	9,140	3,186 ± 1,675	100
TS (mg/L)	2,886	22,850	7,966 ± 4,188	-
TDS (mg/L)	1,732	13,710	4,780 ± 2,513	-
VS (mg/L)	333	3,600	1,123 ± 791	-
NH_3-N (mg/L)	14	346	157 ± 98	20

[1]Malaysia Sewage and Industrial Effluent Discharge Standard (2009) for the requirement of Standard B

Temperature is an important physical factor in wastewater characterisation. The observed temperature of the samples, ranged from 27.2 °C to 29.9 °C, which falls within the acceptable range of less than 40 °C for effluent discharge standards (DOE, 2009). Maintaining appropriate temperature conditions during and after the treatment process ensures the stability of other properties and facilitates the chemical reactions mediated by microbial activities responsible for stabilising organic content in wastewater. Elevated temperatures can harm bacteria involved in secondary treatment processes, while subnormal temperatures reduce the efficiency of the water treatment process (Tchobanoglous & Eddy, 2014).

In the dairy industry, the use of acidic and alkaline cleaners, as well as sanitizers, affects wastewater characteristics and typically results in a highly variable pH, impacting the wastewater treatment (Luo & Ding, 2011). The pH values obtained, ranging from 6.4 to 7.7 after anaerobic digestion, are crucial indicators of effluent quality. The observed moderate alkaline pH values fall within the acceptable range for stable anaerobic digestion and effluent discharge standards. The optimal pH range for anaerobic digestion is generally between 6.5 and 7.2, with a neutral pH around 7.0 being ideal for most anaerobic processes (Latif *et al*., 2017). This pH range supports microbial growth in the small-scale digester, facilitating effective biological treatment without harming the surrounding aquatic ecosystem (Calabrò *et al*., 2021).

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are widely used parameters for assessing organic pollution in wastewater. BOD measures the amount of oxygen required for the biochemical degradation of organic matter by microorganisms, while COD represents the amount of oxygen needed for the chemical decomposition of organic waste (Aguilar-Torrejón *et al.,* 2023). High concentrations of BOD and COD indicate significant microbial loading and oxidizable organic material in the wastewater, respectively. Elevated levels of these parameters can lead to reduced dissolved oxygen (DO) levels, potentially creating anaerobic conditions and harming aquatic life in receiving waters (Tlili *et al*., 2023).

The BOD values ranged from 117 mg/L to 660 mg/L, and COD values ranged from 512 mg/L to 3,544 mg/L were recorded in the study. These values exceeded the acceptable discharge standards of 50 mg/L for BOD and 200 mg/L for COD. The BOD:COD ratio, which represents the biodegradability of the effluent, had a mean value of 0.2, indicating low biodegradability. The ratio of BOD to COD is an indicator of the biodegradability of wastewater, with a higher BOD:COD ratio indicating higher biodegradability. When the BOD:COD ratio is less than 0.1, it suggests the presence of highly concentrated organic matter that is difficult to biodegrade, hence the wastewater may be potentially toxic. The lowest recommended BOD:COD ratio for water to be considered easily biodegradable is 0.4, with the optimal ratio generally greater than 0.5, indicating that the organic matter can be effectively treated through biological processes (Bader *et al*., 2022).

Additionaly, the results of this study showed that the Total Suspended Solids (TSS) levels in the wastewater were extremely high, ranging from 1,154 to 9,140 mg/L with an average of 3,186 mg/L, far exceeding the acceptable discharge limit of 100 mg/L. These elevated TSS values can lead to the development of sludge deposits, anaerobic conditions, and reduced visibility in receiving water bodies, negatively impacting aquatic life (Bhat & Qayoom, 2019). The high TSS values are attributed to inadequate preliminary treatment processes, particularly ineffective sedimentation tanks, which should typically remove 50 - 70 % of suspended solids (Jasim, 2020). Proper design and operation of sedimentation tanks are crucial for improving wastewater quality and reducing TSS content before discharge.

Besides, the results indicated that other solids measurements, including Total Solids (TS), Total Dissolved Solids (TDS), and Volatile Solids (VS), were notably elevated. While specific regulatory standards for these parameters are not provided, the observed levels are considerably high compared to typical wastewater compositions. Such high solids content poses substantial challenges for treatment processes and, if left unaddressed, could have negative implications for the long-term sustainability of water resources (Adjovu *et al*., 2023).

This study revealed alarmingly high levels of ammonia nitrogen (NH_3-N) in dairy wastewater, ranging from 14 to 346 mg/L, with an average of 157 mg/L. These values significantly exceed Regulation 2009 Standard B, which sets a limit of 20 mg/L. Such elevated concentrations pose serious environmental risks, including potential toxicity to fish, excessive algal growth, and eutrophication when discharged untreated into waterways (Edwards *et al*., 2023). The findings align with global trends of increasing ammonia emissions, primarily from anthropogenic sources like livestock excreta. These high ammonia levels not only contribute to environmental degradation but also represent a substantial loss of potential nitrogen fertilizer (Liu *et al.,* 2022).

CONCLUSION

This study has shown that dairy farm wastewater is unfit for direct environmental discharge from the anaerobic digester without additional treatment. The majority of parameters tested exceeded Malaysia's effluent discharge standards, highlighting significant environmental concerns. Urgent measures are needed to address the associated environmental issues particularly odour generation, water contamination, and potential health risks. Implementing effective wastewater treatment processes is crucial for mitigating these risks and ensuring compliance with regulatory standards. This approach would not only protect local ecosystems and water resources but also safeguard public health and promote sustainable dairy farming practices. Furthermore, proper treatment could potentially allow for water reuse within the farm, contributing to resource conservation efforts.

REFERENCES

1. Adjovu, G. E., Stephen, H., James, D., & Ahmad, S. (2023). Measurement of Total Dissolved Solids and Total Suspended Solids in Water Systems: A Review of the Issues, Conventional, and Remote Sensing Techniques. *Remote Sens*, *15*(14), 3534–3534. https://doi.org/10.3390/rs15143534
2. APHA, American Public Health Association. (2005). Standard Methods for the Examination of Water and Wastewater, APHA, Washington DC, USA, 46.
3. Aguilar-Torrejón, J. A., Balderas-Hernández, P., Roa-Morales, G., Barrera-Díaz, C. E., Rodríguez-Torres, I., & Torres-Blancas, T. (2023). Relationship, importance, and development of analytical techniques: COD, BOD, and TOC in water—An overview through time. *SN Appl. Sci*, *5*(4). https://doi.org/10.1007/s42452-023-05318-7
4. Bader, A.C., Hussein, H.J. & Jabar, M.T. (2022). BOD: COD Ratio as Indicator for Wastewater and Industrial Water Pollution. *Int J Spec Educ*, 37(2), 2164.
5. Bhat, S. U., & Qayoom, U. (2019). Implications of sewage discharge on freshwater ecosystems Sami Ullah Bhat, Umara Qayoom. s.n. In book: Sewage - Recent Advances, New Perspectives and Applications. Edited by Tao Zhang
6. Calabrò, P. S., Fazzino, F., Limonti, C., & Siciliano, A. (2021). Enhancement of Anaerobic Digestion of Waste-Activated Sludge by Conductive Materials under High Volatile Fatty Acids-to-Alkalinity Ratios. *Water*, *13*(4), 391. https://doi.org/10.3390/w13040391
7. DOE, 2009. Malaysia Sewage and Industrial Effluent Discharge Standard (2009).
8. Edwards, T. M., Puglis, H. J., Kent, D. B., Durán, J. L., Bradshaw, L. M., & Farag, A. M. (2023). Ammonia and aquatic ecosystems – A review of global sources, biogeochemical cycling, and effects on fish. *Sci. Total Environ*, *907*, 167911. https://doi.org/10.1016/j.scitotenv.2023.167911
9. Jasim, N. A. (2020). The design for wastewater treatment plant (WWTP) with GPS X modelling. *Cogent Eng*, *7*(1). https://doi.org/10.1080/23311916.2020.1723782
10. Jesse, A., Firdaus, F., Gopi, N.R., Wan Johari, W.L., Teik Chung, E.L., Thlama, B.P., Bura P., Mohd Lila, M.A., & Haron, A.W., (2022) Assessment of drinking water and wastewater quality in selected dairy cattle farms from Malaysia. *J. Adv. Vet. Res 12 (2*). pp.
11. Latif, M. A., Mehta, C. M., & Batstone, D. J. (2017). Influence of low pH on continuous anaerobic digestion of waste activated sludge. *Water Res*, *113*, 42–49. https://doi.org/10.1016/j.watres.2017.02.002
12. Liu, L., Xu, W., Lu, X., Zhong, B., Guo, Y., Lu, X., Zhao, Y., He, W., Wang, S., Zhang, X., Liu, X., & Vitousek, P. (2022). Exploring global changes in agricultural ammonia emissions and their contribution to nitrogen deposition since 1980. *Proc. Natl. Acad. Sci*, *119*(14). https://doi.org/10.1073/pnas.2121998119
13. Luo, J., & Ding, L. (2011). Influence of pH on treatment of dairy wastewater by nanofiltration using shear-enhanced filtration system. *Desalination*, *278*(1–3), 150–156. https://doi.org/10.1016/j.desal.2011.05.025
14. Osama, A.N., Patil, S.S. & Salve, K.S. (2015). Characterization Of Dairy Wastewater and Its Effects on Environment. *World J. Pharm. Res. 4(7).*
15. Purnima, D., Siddiqi, T.O., Altaf, A., Rita, K. and Ani, K. (2012). Restructuring BOD: COD Ratio of Dairy Milk Industrial Watewaters in BOD Analysis by Formulating a Specific Microbial Seed. Sci. World J. doi:10.1100/2012/105712
16. Sasakova, N., Gregova, G., Takacova, D., Mojzisova, J., Papajova, I., Venglovsky, J., Szaboova, T., & Kovacova, S. (2018). Pollution of Surface and Ground Water by Sources Related to Agricultural Activities. *Front. Sustain. Food Syst*, *2*(42). https://doi.org/10.3389/fsufs.2018.00042
17. Tchobanoglous, G., & Eddy, M. (2014). *Wastewater engineering: treatment and resource recovery. Volume 1.* Mcgraw-Hill.

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