



# Accumulation of Manganese (Mn) in Tilapia (*Oreochromis mossambicus*) and Environmental Health Risk Assessment

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## Abstract

Situ Tlajung Hilir in Gunung Putri District, Bogor Regency, has been reported to be polluted by industrial waste, which may cause heavy-metal accumulation in tilapia (*Oreochromis mossambicus*) consumed by the surrounding community. This study aimed to analyze the manganese (Mn) concentration in tilapia and the health risk to people consuming 46tu sing the Environmental Health Risk Assessment (EHRA) method. Fish samples were collected from three sampling points (A, B, and C) by purposive sampling, while anthropometric and consumption data were obtained through interviews with 30 respondents. Mn concentration was determined using Atomic Absorption Spectrophotometry (AAS) at a wavelength of 279.5 nm following wet digestion. The results showed Mn concentrations of 18.22–18.37 mg/kg (point A), 12.60–12.75 mg/kg (point B), and 6.25–6.29 mg/kg (point C), all exceeding the WHO 2004 standard of 1 mg/kg. The Risk Quotient (RQ) values ranged from 0.0187 (lowest) and 0.0645 (average) to 0.3116 (highest). Because all RQ values were < 1, the community of Situ Tlajung Hilir is still considered safe to consume tilapia under the exposure assumptions applied for up to 30 years ahead; however, these values may change if the rate and frequency of consumption increase.

**Keywords:** EHRA, manganese, risk quotient, Situ Tlajung Hilir, tilapia

## 1. INTRODUCTION

Water is a primary necessity for living organisms; therefore, the provision of clean water that meets the required standards is essential. Various water sources can be utilized, one of which is surface water such as small lakes (situ) and lakes [1]. Heavy-metal contamination in waters generally originates from industrial, agricultural, and mining waste whose management is inadequate or which is discharged directly into water bodies [2]. Heavy metals that settle in waters cause toxic effects on biota; at low concentrations, the metals accumulate in the organs of aquatic biota.

Tilapia (*Oreochromis mossambicus*) is a freshwater fish widely consumed by Indonesian communities and is often used as a test organism because of its ability to accumulate pollutants [3]. Situ Tlajung Hilir, located in Wanaherang Village, Gunung Putri District, Bogor Regency, is used for plantation irrigation, fishing, and

water tourism. The lake has been reported to be polluted, emitting an unpleasant odor with blackish water due to industrial waste flowing into it during the rainy season. If fish accumulate heavy metals exceeding the threshold, this may endanger the health of the people who consume them [4].

Environmental Health Risk Assessment (EHRA) is an approach for examining the magnitude of potential health risks associated with an environmental problem. The advantage of EHRA is its ability to estimate risk according to projected future exposure time, so that future health disturbances can be prevented [5]. Based on this background, this study aimed to analyze the Mn concentration in tilapia and the health risk to the community around Situ Tlajung Hilir who consume the fish.

Although several EHRA-based studies have assessed heavy-metal exposure from freshwater fish in Indonesia [2], [6], most have focused on cadmium or lead, and information on manganese (Mn) accumulation in tilapia from peri-urban lakes that receive mixed industrial effluent remains scarce. Situ Tlajung Hilir is a distinctive study area because it is used simultaneously for irrigation, capture fisheries, and water tourism while also receiving seasonal industrial discharge, so the same fish stock exposed to contamination is directly consumed by the

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surrounding community. To date, no published assessment has quantified Mn in *Oreochromis mossambicus* from this lake or translated such concentrations into a consumption-based health risk. The present study therefore addresses this gap by combining site-specific Mn measurements with an EHRA model parameterised from local anthropometric and consumption data, providing a baseline to inform future monitoring and consumption advice for the community.

## 2. MATERIALS AND METHODS

### 2.1. Materials and instruments

The main material used was tilapia (*Oreochromis mossambicus*) samples. The chemicals included concentrated HNO<sub>3</sub>, 30% H<sub>2</sub>O<sub>2</sub>, distilled water, and Whatman No. 41 filter paper. The instruments used consisted of laboratory glassware, an electric heater, a desiccator, a sieve, a blender, an analytical balance, a body-weight scale, and an Atomic Absorption Spectrophotometry (AAS) instrument (Shimadzu AA-7000) equipped with a hollow cathode lamp.

### 2.2. Sampling and sample preparation

The study was conducted from July to December 2024. Fish samples were collected by purposive sampling at three sampling points: point A (community activity area/area closest to industry), point B (vehicle-washing site), and point C (water outlet after the residential area). Samples were taken by angling and netting, then placed in a cool box for laboratory analysis. Preparation followed the AOAC 2005 method: the fish flesh was finely chopped, dried in an oven at 65 °C for 24 hours, ground with a blender, and sieved using an 80-mesh sieve.

At each sampling point, three fish of comparable size were collected and combined for analysis, and each sample was measured in duplicate (two analytical replicates); concentrations are reported as mean ± standard deviation.

### 2.3. Digestion and Mn analysis

Wet digestion was performed according to SNI 8910:2021. A 5 g sample was weighed, 10 mL of HNO<sub>3</sub> was added, homogenized, and heated at 95 °C for 10–15 minutes. After concentrated HNO<sub>3</sub> was added and reheated for 30 minutes until the solution became clear, 2 mL of distilled water and 3 mL of 30% H<sub>2</sub>O<sub>2</sub> were added, then filtered with Whatman No. 41 paper and made up to volume in a 100 mL volumetric flask with 5% HNO<sub>3</sub>. The filtrate was analyzed using AAS at a wavelength of 279.5 nm. A standard curve was constructed at concentrations of 0.0, 0.02, 0.05, 0.1, and 0.3 mg/L, with a linearity requirement of  $r \geq 0.98$ .

All Mn analyses were carried out by an ISO/IEC 17025:2017-accredited laboratory (MBRIO Food Laboratory; accredited by the National Accreditation Committee, KAN) using the accredited in-house method IKK/P-7 (atomic absorption spectrometry), under which method validation and internal quality control are routinely maintained. Based on the calibration curve, the limit of detection (LOD) and limit of quantification (LOQ) were 0.011 mg/L and 0.034 mg/L, respectively, estimated as 3.3 and 10 times the residual standard error of the regression divided by the slope. Precision, expressed as the relative standard deviation of the duplicate measurements, ranged from 0.45% to 0.84%. Recovery tests and certified reference materials were not separately determined in this study, which is acknowledged as a limitation; analytical reliability is nevertheless supported by the laboratory accreditation, the calibration linearity ( $r^2 = 0.9994$ ), and the close agreement between duplicate measurements.

### 2.4. Environmental Health Risk Assessment (EHRA)

Interviews were conducted with 30 respondents who consume tilapia, using a questionnaire to obtain data on body weight, intake rate, and consumption frequency. The EHRA stages comprise hazard identification, dose-response analysis, exposure analysis, and

risk characterization. Intake was calculated using the Louvar & Louvar (1998) equation:

$$I = (C \times R \times fE \times Dt) / (Wb \times Tavg)$$

Where I: intake (mg/kg/day); C: Mn concentration (mg/kg); R: intake rate (g/day); fE: exposure frequency (days/year, calculated from weekly consumption  $\times$  52); Dt: exposure duration (30 years); Wb: body weight (kg); and Tavg: averaging time ( $30 \times 365 = 10,950$  days). The risk level is expressed as the Risk Quotient (RQ) = intake / RfD, with the Mn reference dose (RfD) of 0.14 mg/kg/day according to the Integrated Risk Information System (IRIS). An RQ < 1 indicates no likelihood of adverse effects, whereas RQ > 1 indicates a likelihood of such adverse effects.

### 2.5. Data analysis

Differences in Mn concentration among the three sampling points were tested by one-way analysis of variance (ANOVA) at the 95% confidence level ( $\alpha = 0.05$ ); where the assumptions of normality or homogeneity of variance were not met, the non-parametric Kruskal–Wallis test was applied. Analyses were performed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA), and differences were considered significant at  $p < 0.05$ .

## 3. RESULTS AND DISCUSSIONS

### 3.1. Mn concentration in tilapia

The measured Mn concentrations in tilapia were  $18.30 \pm 0.11$  mg/kg at point A,  $12.68 \pm 0.11$  mg/kg at point B, and  $6.27 \pm 0.03$  mg/kg at point C (mean  $\pm$  SD of duplicate measurements). All of these values exceeded the WHO 2004 standard on food additives and food contaminants, namely 1 mg/kg. One-way ANOVA indicated that Mn concentrations differed significantly among the three points ( $p < 0.001$ ), being highest at point A and lowest at point C; because analyses were performed in duplicate, this result is interpreted with caution, although the clearly non-

overlapping concentrations indicate distinct contamination levels among the sites. The highest concentration at point A is presumably related to its location being closest to the industrial area and community activity. Mn is readily accumulated, leading to bioaccumulation through the food chain; humans, occupying the highest trophic level, may accumulate the greatest amount of Mn [6].

The spatial gradient in Mn, decreasing from point A (closest to industry) through point B to point C (the downstream outlet), is consistent with an industrial point source; however, fish-tissue data alone cannot confirm the origin of the contamination. Although water samples were also collected during fieldwork, Mn was quantified only in fish tissue; Mn in water and sediment was not analysed, and this is acknowledged as a limitation. Nevertheless, water-quality assessments of comparable peri-urban water bodies receiving industrial and domestic discharge have reported elevated dissolved-metal loads [7], supporting the inference that the seasonal influx of industrial effluent described for Situ Tlajung Hilir is a plausible source of the Mn accumulated in resident tilapia. Confirmation nonetheless requires paired water, sediment, and biota sampling, which we recommend for future work.

Placed in a wider context, the Mn concentrations recorded here (6.27–18.30 mg/kg) greatly exceed the 1 mg/kg food standard. Compared with previous reports of Mn and other heavy metals in *Oreochromis* and related freshwater fish, the present values are several-fold higher than the manganese levels commonly reported for tilapia muscle in recent assessments, which generally remain in the low single-digit range on a dry-weight basis [15]. Notably, an earlier study at the same site reported a lower Mn level of 5.28 mg/kg in tilapia [16], so the higher and spatially variable concentrations found here suggest increasing or localised contamination. These differences may reflect proximity to industrial discharge, water and sediment chemistry, fish size and age, and the efficiency of

**Table 1.** Hazard identification of manganese (Mn)

Identification	Description
Specific risk agent	Manganese (Mn)
Environmental biota	Tilapia ( <i>Oreochromis mossambicus</i> )
Potential health hazard	Brain disorder symptoms (epilepsy), abnormal behavior, decreased libido, cataracts, and chronic lung disease obstructing the respiratory tract

Source: Agustina [12].

**Table 2.** Dose-response of the risk chemical agent

Chemical agent	Reference dose (RfD)	Critical effects
Manganese (Mn)	0.14 mg/kg/day	Epilepsy, exocrine pancreatic insufficiency, multiple sclerosis, cataracts, and osteoporosis upon chronic ingestion in humans

Source: Integrated Risk Information System (IRIS)

Mn bioaccumulation. Such comparison helps separate site-specific contamination from regional background levels.

The choice of wet digestion with HNO<sub>3</sub> and H<sub>2</sub>O<sub>2</sub> as oxidizers was intended to break the bonds between organic compounds and the metal. Complete digestion is indicated by the formation of a clear solution [13]. AAS was selected for its high sensitivity, precision, and selectivity for each element analyzed [10].

### 3.2. Mn standard curve

Measurement of the standard solution series produced the linear equation  $y = 0.162x + 0.0005$  with a correlation coefficient ( $r^2$ ) of 0.9994. This value meets the requirement of  $r^2 > 0.99$ , so the calibration curve conforms to the Lambert-Beer law, namely the higher the concentration, the higher the resulting absorbance. Thus, the instrument was in good condition and the regression equation can be used to calculate sample concentrations [9].

### 3.3. Respondent characteristics

Interviews with 30 respondents showed an average body weight of 62.56 kg (range 50–74 kg). The average tilapia intake rate was 111.66 g/day (range 50–250 g/day), while the average exposure frequency was 104 days/year (range 52–208 days/year). The relatively short exposure frequency was due to the community consuming various types of fish and side dishes, not only

tilapia. The greater the intake rate and exposure frequency, the greater the intake value and the level of risk experienced [6].

### 3.4. Hazard identification and dose-response

The hazard identification of Mn as a risk agent is presented in Table 1, while the Mn reference dose (RfD) is shown in Table 2.

### 3.5. Risk characterization (Risk Quotient)

The RQ values were obtained by dividing the intake by the RfD. A summary of the RQ values at the lowest, average, and highest intake rates is presented in Table 3.

The calculation results showed an RQ of 0.0187 at the lowest, 0.0645 on average, and 0.3116 at the highest. Because all RQ values were  $< 1$ , the community of Situ Tlajung Hilir currently falls into the safe risk-level category for consuming tilapia. This is influenced by the still-low daily intake rate, body weight, and consumption frequency, which produce a small intake value.

Nevertheless, the RQ values may change if consumption increases. Based on the calculation assumptions, an individual with a body weight of 50 kg consuming 400 g of fish per day, 7 times per week, yields an RQ  $> 1$  (i.e., 1.0468), thus being at potential risk of health disturbances due to Mn. Chronic Mn exposure may cause permanent central-nervous-system disorders resembling Parkinson's disease, coordination

**Table 3.** Summary of intake and Risk Quotient (RQ) values

Category	R (g/day)	fE (days/yr)	Wb (kg)	Intake (mg/kg/day)	RQ
Lowest	50.00	52.00	50.00	0.0026	0.0187
Average	111.66	104.00	64.73	0.0090	0.0645
Highest	250.00	208.00	60.00	0.0436	0.3116

Note:  $C = 18.37$  mg/kg;  $Dt = 30$  years;  $T_{avg} = 10,950$  days

disturbances, tremor, and decreased lung function. Therefore, people with a body weight of 50 kg are advised not to consume tilapia exceeding 400 g/day at a frequency of more than 7 times per week [8].

These RQ values must be interpreted in light of the assumptions embedded in the EHRA model. The estimates assume a constant Mn concentration in fish, a fixed exposure duration of 30 years, an averaging time of 10,950 days, and average body weight, intake rate, and exposure frequency derived from 30 respondents; the reference dose (RfD) of 0.14 mg/kg/day from IRIS is itself derived with uncertainty and built-in safety factors. Because the model uses point estimates rather than full exposure distributions, it does not capture inter-individual variability or worst-case sub-populations such as high-frequency consumers and low-body-weight children. It also assumes that the measured tissue concentration remains stable over the projected period, whereas changes in dietary habits, fishing intensity, or upstream industrial discharge could raise future intake. The present RQ values should therefore be regarded as a central-tendency estimate of current risk rather than a guarantee of long-term safety; probabilistic approaches (e.g., Monte Carlo simulation) and periodic re-measurement would better quantify the associated uncertainty.

#### 4. CONCLUSIONS

The Mn concentrations in tilapia at Situ Tlajung Hilir were 18.22–18.37 mg/kg (point A), 12.60–12.75 mg/kg (point B), and 6.25–6.29 mg/kg (point C), all exceeding the WHO 2004 standard of 1 mg/kg. The EHRA results showed RQ values ranging from 0.0187 to 0.3116 (all < 1), so for up to 30 years ahead the community of

Situ Tlajung Hilir remains safe to consume tilapia under the specific exposure assumptions adopted here. Because the assessment considered only a single species and a single metal at fixed average exposure parameters, the finding cannot be generalised to other contaminants, fish species, or future environmental conditions; however, these values may increase if the Mn concentration in the fish or the community's intake rate and consumption frequency rise. It is recommended that further analysis be conducted using a different instrument such as Inductively Coupled Plasma (ICP), and that the community limit tilapia consumption to no more than 400 g/day and fewer than 7 times per week. To capture cumulative and long-term risks, continuous monitoring of multiple heavy metals (e.g., Pb, Cd, Hg, As, and Cr) in tilapia, water, and sediment is also recommended.

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### Author Contributions

M.A : conceptualization of the core research idea, methodology design, and writing of the manuscript. M.A.G : data collection and laboratory analysis of the samples. N.A : statistical analysis and writing of the manuscript. All authors have read, reviewed, and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

### Conflict of Interest

The authors declare no conflict of interest.

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### DECLARATION OF GENERATIVE AI

Not applicable.

### REFERENCES

- [1] R. Awliahasanah, et al., "Analysis of Environmental Health Risks Associated with Manganese Levels in Well Water in Depok City," *Journal of Environmental Sanitation*, vol. 1, no. 2, pp. 80–86, 2021.
- [2] S.S. Maddusa, G.G. Girikallo, O. Alik, V.V. Liono, W.B.S. Joseph, R.C. Sondakh, "Environmental Health Risks from Heavy Metal Exposure in Nile Fish (*Osteochilus vittatus*) in Bakan Village, Lolayan Subdistrict, Bolaang Mongondow Regency," *Higiene: Jurnal Kesehatan Lingkungan*, vol. 8, no. 1, pp. 1–6, 2022.
- [3] D. Setianto, *Tilapia Farming in Various Rearing Systems*, 2012.
- [4] O.S. Pradianti, W.P. Rahayu, R. Dewanti-Hariyadi, "A Study on the Conformity of Chemical Contaminant Standards (Heavy Metals and PAHs) in Fishery Products in Indonesia with the Standards of Other Countries and the Codex," *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan*, vol. 14, no. 1, pp. 45–62, 2019.  
<https://doi.org/10.15578/jpbkp.v14i1.561>.
- [5] S. Wahyuni, "Health Risks Associated with Cadmium (Cd) Exposure from Drinking Water and Seafood Sources in the Eastern Coastal Region of Belawan, North Sumatra," *Public Health Journal*, vol. 5, no. 1, 2018.
- [6] M.S. Angelina, Y.H. Darundiati, H.L. Dangiran, "Environmental Health Risk Analysis of Cadmium (Cd) Levels in Milkfish in the Lorok Pond Area of Semarang," *Jurnal Kesehatan Masyarakat (Undip)*, vol. 5, no. 5, pp. 724–732, 2017.
- [7] V. Djoharam, E. Riani, M. Yani, "Analysis of Water Quality and Pollution Load Capacity of the Pesanggrahan River in the DKI Jakarta Province," *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, vol. 8, no. 1, pp. 127–133, 2018.  
<https://doi.org/10.29244/jpsl.8.1.127-133>.
- [8] P. Budiastuti, M. Raharjo, N.A.Y. Dewanti, "Analysis of Lead Heavy Metal Pollution in the Babon River in Genuk District, Semarang," *Jurnal Kesehatan Masyarakat*, vol. 4, no. 5, pp. 118–119, 2016.
- [9] K. Nisah, H. Nadhifa, "Analysis of Iron (Fe) and Manganese (Mn) Levels in Bottled Drinking Water Using Atomic Absorption Spectrophotometry," *Amina*, vol. 2, no. 1, pp. 6–12, 2020.  
<https://doi.org/10.22373/amina.v2i1.31>.
- [10] E.N. Hidayati, M. Alauhdin, A.T. Prasetya, "Comparison of Destructive Methods for Pb Analysis in Hair Using AAS," *Indonesian Journal of Chemical Science*, vol. 3, no. 1, 2014.
- [11] L.B. Tarigan, "Analysis of Environmental Health Risks Associated with Manganese in Drinking Water Among the Community

- of Supul Village, Kuantana Subdistrict, South Central Timor Regency, in 2015," Undergraduate Thesis, Poltekkes Kemenkes Kupang, pp. 1–42, 2015.
- [12] L. Agustina, "Environmental Health Risk Analysis (ARKL) of Drinking Water Parameters for Workers in Pasuruan Regency in 2017," *Medical Technology and Public Health Journal*, vol. 3, no. 1, pp. 61–69, 2019. <https://doi.org/10.33086/mtphj.v3i1.946>.
- [13] S. Kristianingrum, "A Study of Various Sample Destruction Processes and Their Effects," *Prosiding Seminar Nasional Penelitian, Pendidikan dan Penerapan MIPA, FMIPA Universitas Negeri Yogyakarta*, vol. 2, 2012.
- [14] A. Enders, J. Lehmann, "Comparison of Wet-Digestion and Dry-Ashing Methods for Total Elemental Analysis of Biochar," *Communications in Soil Science and Plant Analysis*, vol. 43, no. 7, pp. 1042–1052, 2012. <https://doi.org/10.1080/00103624.2012.656167>.
- [15] N. Gupta, S. Arunachalam, "Assessment of human health risks posed by toxic heavy metals in Tilapia fish (*Oreochromis mossambicus*) from the Cauvery River, India," *Frontiers in Public Health*, vol. 12, Art. no. 1402421, 2024. <https://doi.org/10.3389/fpubh.2024.1402421>.
- [16] Sufrizal, M. Azizah, Nurlela, "Bioaccumulation of Manganese (Mn) in Tilapia (*Oreochromis mossambicus*) in Situ Tlajung Hilir," Undergraduate Thesis (unpublished), Universitas Nusa Bangsa, Bogor.