The concentration of Mn and Fe metals in water and sediment of the Sanga-Sanga River, East Kalimantan Province

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ABSTRACT

This study aimed to analyze the concentrations of manganese (Mn) and iron (Fe) in both water and sediment samples from the Sanga-Sanga River, Kutai Kartanegara Regency, East Kalimantan Province. The research was conducted from October to December 2024 at three stations representing the upstream, midstream, and downstream sections of the river. Sampling was performed using a purposive method based on site characteristics, and analyses were carried out both in situ and at the Water Quality Laboratory, Faculty of Fisheries and Marine Science, Mulawarman University. The concentrations of Mn and Fe were compared with the Indonesian river water quality standard (Government Regulation No. 22 of 2021) and sediment quality guidelines established by the Australian and New Zealand Environment and Conservation Council (ANZECC, 2000). The results showed that Mn concentrations in river water ranged from 0.325 to 1.181 mg/L, exceeding the permissible limit of 0.1 mg/L, while Fe concentrations ranged from 0.3475 to 0.468 mg/L, surpassing the standard of 0.3 mg/L. In sediments, Mn concentrations ranged from 42.38 to 964.47 mg/kg and Fe concentrations from 11,341.23 to 50,344.72 mg/kg, with several stations exceeding the ANZECC guideline limits. Higher concentrations were generally found at midstream and downstream stations, particularly in areas influenced by coal mining, barge transport, and ship repair activities. These findings indicate that the Sanga-Sanga River has experienced notable contamination by Mn and Fe, primarily due to anthropogenic activities related to coal industry operations. Continuous monitoring, stricter waste management, and the implementation of pollution control measures are recommended to prevent further environmental degradation and protect aquatic ecosystems.

INTRODUCTION

Waste is the residual output of daily human activities and natural processes, typically in solid form. Indonesia is estimated to be the second-largest contributor to plastic pollution in the world among 129 countries (Jambeck et al., 2015). According to the Ministry of Environment and Forestry, the average amount of waste generated in Indonesia reaches approximately 175,000 tons per day, equivalent to 64 million tons per year, with an individual daily waste output of around 0.7 kg (Ministry of Environment and Forestry, 2019).

A river is defined as a natural and/or artificial watercourse or channel consisting of a drainage network and the water flowing within it, extending from the upstream to the downstream area, and bounded on both sides by riparian zones (Government Regulation of the Republic of Indonesia No. 38 of 2011 concerning Rivers). As one of the key components of the environment, rivers play a crucial role in supporting life and serve as potential areas for water catchment, storage, and distribution (Halim, 2014). The majority of Indonesia's population relies on river water for their daily needs, including bathing, washing, and cooking (Retnowati and Istiana, 2019).

One of the tributaries of the Mahakam River, located in the Mahakam Delta region specifically in Sanga-Sanga District, Kutai Kartanegara Regency is known as the Sanga-Sanga River. The Sanga-Sanga River has an average depth of approximately 20 meters and a width of about 150 meters (Maghiszha, 2019). The river is surrounded by dense residential areas, traditional markets, coal mining operations, river transportation, sand washing sites, and loading–unloading activities for coal and petroleum vessels. Consequently, various human and industrial activities depend heavily on the river. However, water quality degradation and pollution have occurred as a result of increasing human population and waste accumulation from domestic and industrial sources, which accelerate the decline in water quality (Akhirul et al., 2020).

A water body can be considered polluted when the concentration of heavy metals in wastewater exceeds the established quality standards (Suryani et al., 2022). Heavy metals refer to toxic metallic elements characterized by high density or atomic mass (Pasaribu et al., 2017). These pollutants are persistent and not easily degraded in the environment. Once heavy metals enter a water body, they tend to accumulate in aquatic organisms and may subsequently be ingested by humans (Fadhilah et al., 2018). Heavy metals can inhibit enzymatic active sites, disrupting normal enzyme function and metabolism, and may lead to allergic reactions, mutagenic, teratogenic, or carcinogenic effects in humans and other organisms (Permana et al., 2022). Consumption of aquatic organisms contaminated with heavy metals can cause adverse health effects, including throat inflammation, headaches, dermatitis, skin cancer, allergies, anemia, kidney failure, pneumonia, lung cancer, autoimmune diseases, endometriosis, and reproductive disorders (Mitra et al., 2022).

A previous study by Nurisa (2023) reported that Fe concentrations at all sampling stations exceeded the water quality standard of 0.3 mg/L. The elevated Fe levels were attributed to waste generated from ship repair activities involving hazardous materials. The study concluded that Fe contamination in the Sanga-Sanga River estuary has reached a polluted level. Given the potential for pollution in the Sanga-Sanga River, which serves as a clean water source, lack of proper analysis and responsible management may lead to significant environmental and health consequences. Therefore, this study aims to determine the concentration of metals in the water and sediment of the Sanga-Sanga River, East Kalimantan Province.

METHODOLOGY

This research was conducted from October to December 2024 in the Sanga-Sanga River, located in Sanga-Sanga District, Kutai Kartanegara Regency, East Kalimantan Province. Sample analyses were carried out both *in situ* (directly in the field) and at the Water Quality Laboratory, Faculty of Fisheries and Marine Science, Mulawarman University. The study consisted of several stages, including preparation (literature review), determination of sampling stations, laboratory analysis (acid digestion), data processing, and final report preparation.

Sampling locations were selected using a *purposive sampling* method based on the distinct characteristics of each station. Station 1, located in Sanga-Sanga Dalam near the 27 Januari Bridge, represents the upstream area; Station 2, located in Sarijaya, represents the midstream section; and Station 3, situated near the river mouth, represents the downstream section. Water samples were collected using a water sampler, while sediment samples were obtained using a sediment grab. Samples from each of the three stations were taken from three points and subsequently composited.

The concentrations of metals were analyzed descriptively by comparing the observed values with the river water quality standards specified in Government Regulation No. 22 of 2021 and the sediment quality guidelines established by the Australian and New Zealand Environment and Conservation Council (ANZECC, 2000).

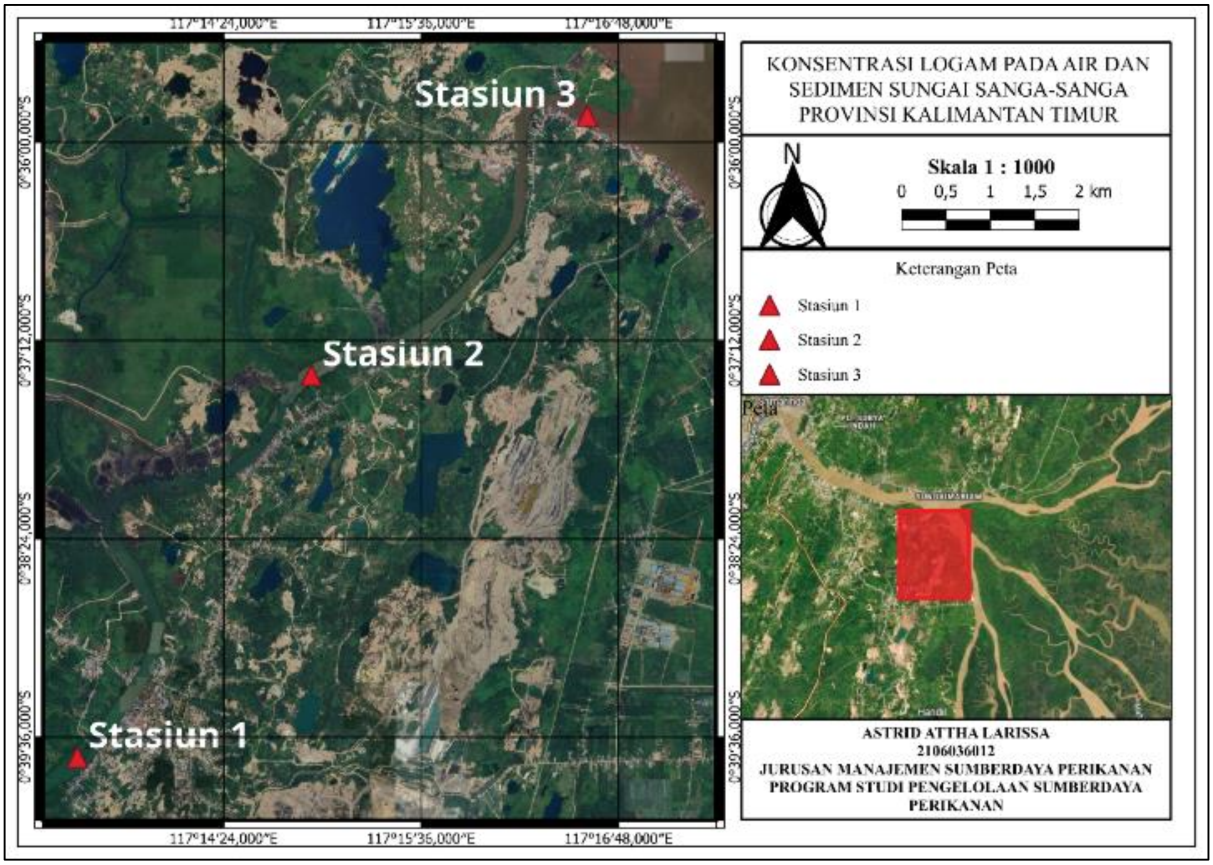

Figure 1. Study location

RESULT AND DISCUSSION

Manganese (Mn) concentration in the water of the Sanga-Sanga River

The concentration of Mn in the water from all three stations was compared with the river water quality standard specified in Government Regulation No. 22 of 2021 for Class I rivers, which sets the threshold for Mn at 0.1 mg/L. The detected Mn concentrations across the three stations ranged from 0.325 mg/L to 1.181 mg/L, exceeding the permissible limit. The Mn concentrations observed at Stations 1 and 2, representing the upstream and midstream sections of the Sanga-Sanga River, were higher than those at Station 3, located in the downstream section. This is presumably due to the wider river flow in the downstream area, which allows greater dilution of Mn concentrations.

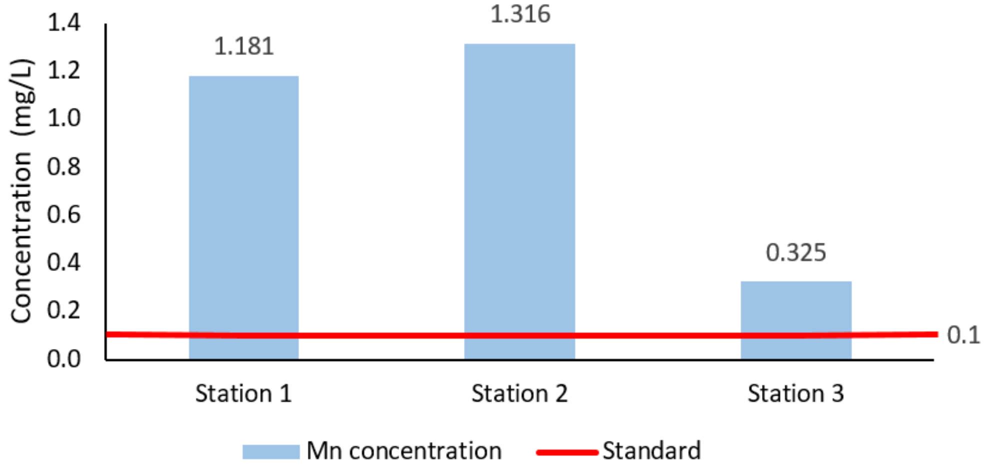

Figure 2. Manganese (Mn) Concentration in the Water at the Sanga-Sanga River Study Site

A similar observation was reported by Herbila et al. (2022), who stated that lower concentrations of heavy metals in water can result from dilution processes, as heavy metals adsorbed onto suspended particles tend to settle at the bottom of the water body. The source of Mn contamination in the Sanga-Sanga River is likely associated with coal mining activities in the surrounding area. Supporting this, Firman (2020) reported that coal ash, both fly ash and bottom ash, as analyzed using ICP-MS, contained high levels of heavy metals, particularly manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), lead (Pb), nickel (Ni), and arsenic (As).

Iron (Fe) Concentration in the Water of the Sanga-Sanga River

Iron (Fe) is a naturally abundant element in the environment. It is a dense metal with a relatively low melting point and exhibits resistance to corrosion (Nurhaini and Affandi, 2016). The concentrations of Fe detected in water samples from Stations 1, 2, and 3 were compared with the river water quality standard specified in Government Regulation No. 22 of 2021 for Class I rivers, which sets the Fe threshold at 0.3 mg/L. The Fe concentrations at the three stations ranged from 0.3475 mg/L to 0.468 mg/L, exceeding the permissible limit.

These findings are consistent with the results reported by Suyatna et al. (2017), who found that Fe concentrations in the waters of Muara Jawa also exceeded the water quality standard across all sampling stations. Similarly, a previous study conducted by Nurisa (2023) in the Sanga-Sanga estuary reported Fe concentrations at three sampling points exceeding the quality standard, reaching 5.399 mg/L.

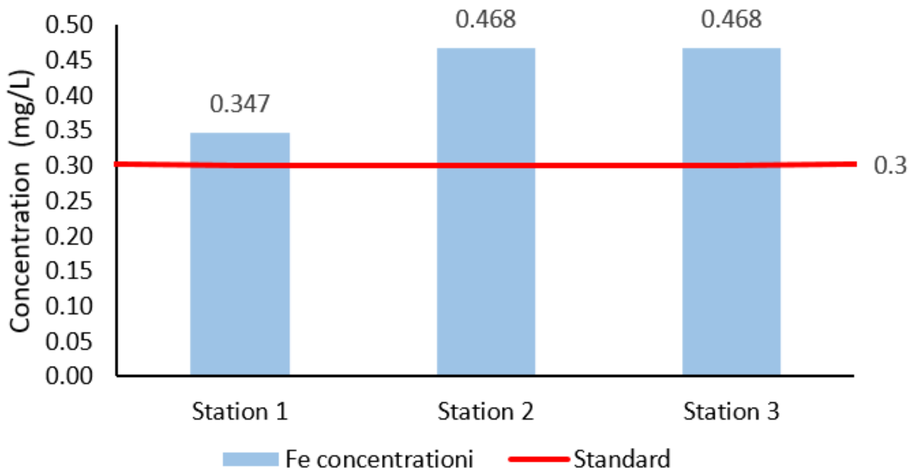

Figure 3. Iron (Fe) Concentration in the Water at the Sanga-Sanga River Study Site

The relatively lower Fe concentration at Station 1 compared to Stations 2 and 3 is likely due to its location in the upstream area of the Sanga-Sanga River, which experiences minimal human activity and is relatively distant from residential settlements. In contrast, Stations 2 and 3, representing the midstream and downstream areas, exhibited higher Fe concentrations, possibly due to intensive human activities, such as coal transport by barges, the presence of coal mining jetties and conveyors, shipwrecks, and ship repair workshops along the river. Ishak et al. (2023) also stated that variations in Fe concentrations among monitoring stations are generally influenced by differences in anthropogenic activities, such as industrial wastewater discharge into the river.

Manganese (Mn) Concentration in the Sediment of the Sanga-Sanga River

According to the Australian and New Zealand Environment and Conservation Council (ANZECC, 2000) sediment quality guidelines, the acceptable concentration range for Mn is 460–780 mg/kg (Figure 4). The Mn concentration at Station 1 was 42.38 mg/kg, which is below the minimum guideline value. At Station 2, the Mn concentration was 333.14 mg/kg, also below the minimum threshold. In contrast, Station 3 recorded an Mn concentration of 964.47 mg/kg, exceeding the maximum allowable limit.

The low Mn concentration observed at Station 1 is likely due to its location in the upstream section of the river, which experiences limited human activity. Conversely, Stations 2 and 3 showed a substantial increase in Mn concentration, presumably due to intensive anthropogenic activities in these areas, such as coal loading and unloading, coal conveyor operations, and heavy vessel traffic related to coal transportation. This assumption is supported by the findings of Warni et al. (2017), who reported that the presence of Mn in the sediment indicates significant accumulation in the waters of the Jetty Meulaboh Port, which was likely caused by coal-related pollution.

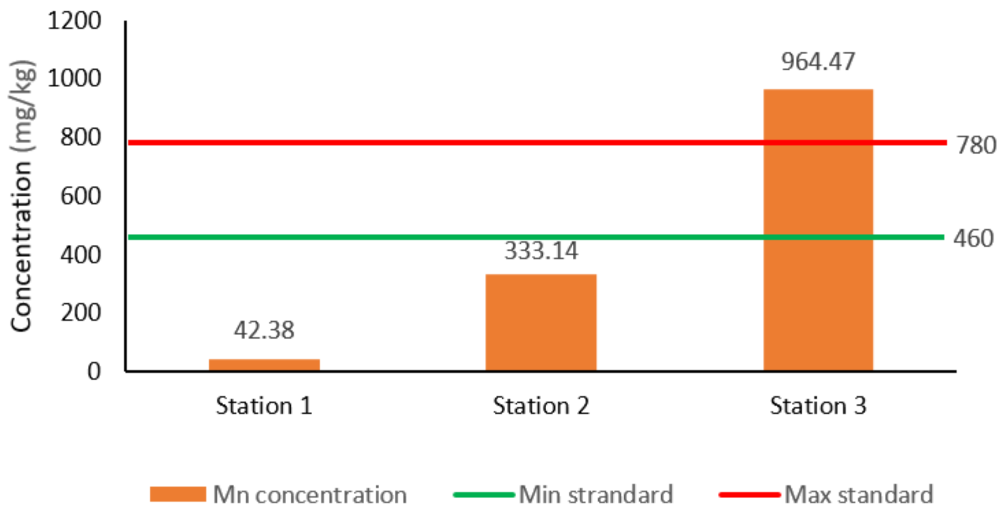

Figure 4. Manganese (Mn) Concentration in the Sediment at the Sanga-Sanga River Study Site

Iron (Fe) Concentration in the Sediment of the Sanga-Sanga River

Iron (Fe) is the second most abundant metal in the soil and is commonly found in the form of sediment (Didik et al., 2020). It constitutes approximately 5% of the Earth's crust and about 35% of the planet's total material composition (Safitri and Ramdani, 2018). Iron is widely used in construction materials, fences, and water pipes, among other applications (El Magfiroh, 2019). According to the sediment quality guidelines of the Australian and New Zealand Environment and Conservation Council (ANZECC, 2000), the acceptable Fe concentration range is 20,000–30,000 mg/kg (Figure 5).

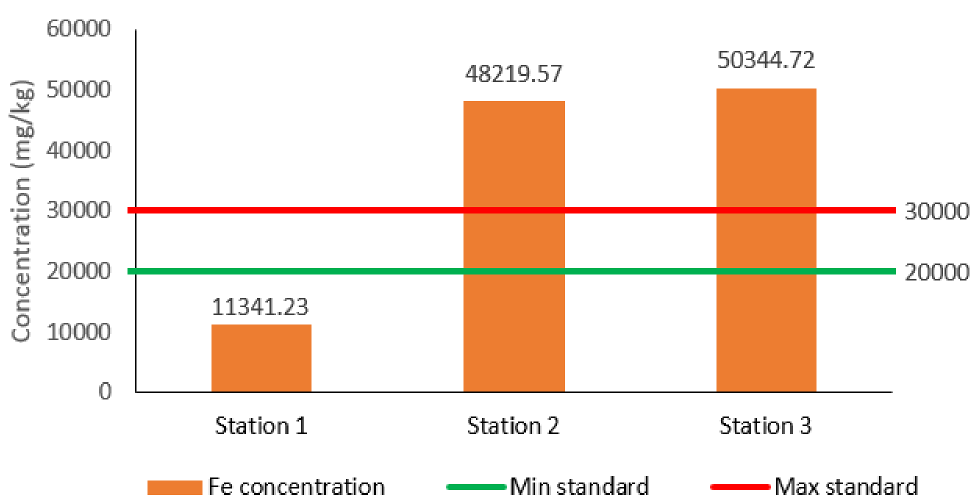

Figure 5. Iron (Fe) Concentration in the Sediment at the Sanga-Sanga River Study Site

At Station 1, the Fe concentration in sediment was 11,341.23 mg/kg, which is below the minimum guideline value. In contrast, Station 2 recorded an Fe concentration of 48,219.57 mg/kg, and Station 3 recorded 50,344.72 mg/kg—both exceeding the maximum permissible limit. The elevated Fe levels at these stations are presumably linked to various anthropogenic sources, including coal transport activities, domestic waste discharge, ship repair operations, mining activities, and abandoned vessels along the riverbanks.

Ishak et al. (2023) reported that Fe contamination may originate from untreated industrial and domestic waste discharged into rivers through corroded iron pipelines, as well as from effluents released by nearby ship repair workshops. Although Fe is an essential element required in small quantities by the human body, excessive concentrations can pose serious health risks, such as cardiovascular disorders, vascular damage, and liver cancer (Mashadi et al., 2018).

CONCLUSION

This study revealed that both manganese (Mn) and iron (Fe) concentrations in the Sanga-Sanga River exceeded the established water and sediment quality standards, indicating significant metal contamination across the study area. Mn concentrations in river water ranged from 0.325 to 1.181 mg/L, surpassing the permissible limit of 0.1 mg/L, while Fe concentrations ranged from 0.3475 to 0.468 mg/L, exceeding the standard value of 0.3 mg/L as stated in Government Regulation No. 22 of 2021. The elevated metal concentrations were more pronounced in the upstream and midstream sections for Mn and in the midstream and downstream sections for Fe, reflecting spatial variations influenced by local environmental conditions and anthropogenic inputs.

In sediments, Mn concentrations ranged from 42.38 to 964.47 mg/kg, with the highest value at the downstream station exceeding the ANZECC (2000) guideline of 780 mg/kg. Similarly, Fe concentrations ranged from 11,341.23 to 50,344.72 mg/kg, with values at the midstream and downstream stations exceeding the upper limit of 30,000 mg/kg. These findings indicate substantial metal accumulation in sediments, particularly in areas with intense human activities such as coal loading, transport operations, ship maintenance, and domestic waste discharge.

Overall, the results demonstrate that the Sanga-Sanga River is experiencing considerable Mn and Fe pollution, largely driven by coal mining and associated industrial activities along its course. Continuous monitoring and stricter management of waste discharge are necessary to mitigate further contamination and protect the aquatic ecosystem and community health. Future research should focus on seasonal monitoring, bioaccumulation studies in aquatic organisms, and the assessment of potential ecological and human health risks.

REFERENCES

Akhirul, Witra, Y., Umar, I., dan Erianjoni. (2020). Dampak Negatif Pertumbuhan Penduduk Terhadap Lingkungan dan Upaya Mengatasinya. Jurnal Kependudukan dan Pembangunan Lingkungan, 1(3): 76-84.

Didik, L. A., dan Wahyudi, M. (2020). Analisa kandungan Fe dan karakteristik sifat listrik pasir besi Pantai Telindung yang disintesis dengan beberapa metode. *Indonesian Physical Review*, *3*(2), 64-71.

El Maghfiroh, R. (2019). Efek Temperatur Terhadap Laju Korosi. *Jurnal Flywheel*, *10*(1), 26-32.

Fadhilah, R., Oginawati, K., dan Romantis, N. A. Y. (2018). The Pollution Profile of Citarik, Cimande, And Cikijing Rivers In Rancaekek District, West Java, Indonesia. Indonesian Journal of Urban and Environmental Technology, 2(1), 14-26.

Firman, F. (2020). Analisis Kandungan Logam Berat Abu Batubara PLTU Bangko Barat Kab. Muara Enim Sumatera Selatan. *Journal Of Science and Engineering*, *3*(1).

Halim, F. (2014). Pengaruh hubungan tata guna lahan dengan debit banjir pada Daerah Aliran Sungai Malalayang. Jurnal Ilmiah Media Engineering, 4(1)

Herbila, S., Syam, N., dan Batara, A. S. (2022). Analisis Konsentrasi Logam Berat Seng (Zn) Pada Air, Sedimen, Dan Ikan Nila (Oreochromis Niloticus) Di Kanal Kota Makassar. *Window of Public Health Journal*, *3*(6), 1044-1053.

Ishak, N. I., Ishak, E., Effendy, I. J., dan Fekri, L. (2023). Analisis Kandungan Logam Berat Pada Air Sungai Martapura, Provinsi Kalimantan Selatan Tahun 2022. *JSIPi (Jurnal Sains Dan Inovasi Perikanan) (Journal of Fishery Science and Innovation)*, *7*(1), 35-41.

Maghiszha. D. F. 2019. Sanga-Sanga, Kabupaten Kutai Kartanegara, Kalimantan Timur.https://www.tribunnewswiki.com/2019/08/30/sanga-sanga-kabupaten kutaikartanegarkalimantantimur text=Lebar%20sungai%20tersebut%20berkisar%20150%20meter%20dengan%20kedalaman%20hingga%2020%20meter (diakses pada 24 Maret 2023)

Mashadi, A., Surendro, B., Rakhmawati, A., dan Amin, M. (2018). Peningkatan Kualitas Ph, Fe Dan Kekeruhan Dari Air Sumur Gali Dengan Metode Filtrasi. *Jurnal Riset Rekayasa Sipil*, *1*(2), 105-113.

Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. B., Nainu, F., Khusro, A., ... dan Simal-Gandara, J. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University-Science*, *34*(3), 101865.

Nurhaini, R., dan Affandi, A. (2016). Analisa logam besi (fe) di sungai pasar daerah belangwetan klaten dengan metode spektrofotometri serapan atom. *Jurnal Ilmiah Manuntung: Sains Farmasi Dan Kesehatan*, *2*(1), 39-43.

Nurisa, T. P. (2023). Analisis Total Dissolved Solid (Tds), Chemical Oxygen Demand (Cod), Dan Besi (Fe) Pada Air Sungai Sanga-Sanga Kutai Kartanegara (Doctoral Dissertation, Politeknik Pertanian Negeri Samarinda).

Pasaribu, C., Sarifuddin dan Marbun, P. 2017. Kandungan Logam Berat Pb pada Kol dan Tomat di Beberapa Kecamatan Kabupaten Kare. Jurnal Agroekoteknologi. 5(2): 355-361

Pemerintah Republik Indonesia, 2011, *Peraturan Pemerintah No. 38 Tahun 2011 Tentang Sungai*, Lembaran Negara RI Tahun 2011, Sekretariat Negara, Jakarta.

Permana, R., dan Andhikawati, A. (2022). Metallotionein Pada Tanaman Akuatik Dan Peranannya Dalam Akumulasi Logam Berat. *Jurnal Akuatek*, *3*(1), 1-8.

Retnowati, R., dan Istiana, R. (2019). Membangkitkan Kepedulian Lingkungan Melalui Pemberdayaan Masyarakat Guna Menjamin Keberlanjutan Fungsi DAS Citarum. *Jurnal Difusi*, *2*(2), 1-10.

Safitri, B. R. A. (2019). Analisis kandungan mineral logam mangan (Mn) di kawasan pertambangan desa bangkang. *Jurnal Ilmiah IKIP Mataram*, *6*(1), 9-15.

Suryani, M. Y., Paramita, A., Susilo, H., dan Maharsih, I. K. (2022). Analisis penentuan kadar besi (Fe) dalam air limbah tambang batu bara menggunakan spektrofotometer UV-Vis. Indonesian Journal of Laboratory, 5(1), 7-15.

Suyatna, I., Adnan, A., Syahrir, M., Ghitarina, G., Abdunnur, A., dan Saleh, S. (2017). *Heavy metal levels in water and fish samples from coastal waters of* Mahakam Delta, Kutai Kartanegara District, East Kalimantan, Indonesia. *Aquaculture, Aquarium, Conservation dan Legislation*, *10*(5), 1319-1329.

Warni, D., Karina, S., dan Nurfadillah, N. (2017). Analisis Logam Pb, Mn, Cu dan Cd Pada Sedimen di Pelabuhan Jetty Meulaboh, Aceh Barat. *Jurnal Ilmiah Mahasiswa Kelautan Perikanan Unsyiah*, *2*(2).