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Appraisal of Heavy Metals in the Fish *Sarotherodon galilaeus* and *Sarotherodon melanotheron* from Alaro Stream in Ibadan, Nigeria

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Abstract
An appraisal was carried out on the heavy metals in the fish *Sarotherodon melanotheron* and *Sarotherodon galilaeus* from Alaro Stream in Ibadan. The study was carried out because fish is a major source of affordable protein for the ever growing global human population. The concentration of heavy metals in the aquatic ecosystem as a result of human activities at any given time portend a health risk for consumers of fish and its products. A total of fifty fish comprising *S. melanotheron* (25) and *S. galileaus* (25) were collected from the study area. Dissected and pulverized fish organ samples were acid-digested in Teflon tubes for analyses using the Inductively Coupled Plasma Mass Spectrometer (ICP-MS). The mean Ni in the liver, gut and fins of both fish exceeded the World Health Organization (WHO) limit guideline (0.07ppm). All the mean Se concentration in the organs of the two fish were all above the WHO limit guideline of 0.04ppm. With the exception of the muscle (0.01ppm) in *S. galilaeus*, all the other mean V concentration in the organs of the two fish were higher than the limit guideline of 0.02ppm while there is no current value for Mn and Co. The study shows that organs of *S. galilaeus* and *S. melanotheron* had V, Ni and Se above the World Health Organization's limit guidelines thereby making the fish unfit for human consumption as long as the effluents discharged into the stream remain untreated. Continuous biomonitoring of the aquatic ecosystem for heavy metal pollution is recommended.

1. Introduction

Sarotherodon is a genus of tilapiine cichlids endemic to Africa and the Middle East, although a few species from this genus have been introduced far outside their native range due to their importance in aquaculture (Monro, 2011; Froese and Pauly, 2015). There are several clades in this genus based on mtDNA sequence analysis due to the fast speed of evolution from hybridization in the wild and captive breeding (Nagl *et al,* 2001). Fish as major source of affordable protein for the ever growing human population especially in the developing countries of Africa, Asia and South America and the major solution to dietary protein shortage due to increased production is increasingly faced with the challenge of heavy metal contamination (FAO, 2006; Gabriel *et al*, 2007; Nworie, 2011, Eroglu *et al*, 2015). Heavy metals get access to the aquatic environment naturally through weathering of the earth's crust and from human activities. Together with geological weathering, human activities have also given rise to large quantities of metals to local water bodies, thereby disturbing the natural composition in the aquatic ecosystem (Forstner and Wittmann, 1983; Kwon and Lee, 2001). Wastes from industrial effluents, agricultural runoffs, transport, burning of fossil fuels, animal and human excretions and geologic weathering and domestic waste elevate the heavy metals in the water bodies (Adnano, 1986; Raja *et al*, 2009; Adeosun *et al*, 2015). Heavy metals impact on human health due their rapid uptake into the food chain and bioaccumulation in living tissues and organs (Beijer and Jernelov, 1986). Bioaccumulation of heavy metals in living organisms and biomagnification describes the processes and pathways of these pollutants from one trophic level to another thereby exhibiting an elevated concentration in higher consumers (Nayaka *et al,* 2009; Bosch *et al*, 2016). Thus, the concentration of heavy metals in the aquatic ecosystem at any given time reflects the current pollution levels while that found in the organisms show a continuum of bioaccumulation from the time of birth (Ravera *et al*, 2003). Previous studies elsewhere and in Alaro Stream have shown that most likely sources of elevated levels of heavy metals in the aquatic ecosystem could be domestic, agricultural and industrial effluents as well as solid wastes (Ikem *et al*, 2003; Tyokumbur, 2014), thus highlighting the need for this study to assess the level of bioaccumulation. This study is intended to assess heavy metals Nickel (Ni), Selenium (Se), Vanadium (V), Manganese (Mn) and Cobalt (Co) in the organs and tissues of the fish *Sarotherodon galilaeus* and *Sarotherodon melanotheron* from Alaro Stream in Ibadan which is impacted by industrial effluents with the aim of comparing with set guidelines by the World Health Organization (WHO) and previous studies. This is intended to improve the quality of aquaculture resources from Nigeria that may be consumed locally and exported to other countries, as water from Alaro stream is being used in fish farming on a large scale.

2. Materials and Methods

2.1. Study Area

Alaro Stream is the Oluyole Industrial Estate in Ibadan, Nigeria. It is impacted by receives effluents from diverse sources of heavy metals that includes agricultural, domestic and industrial wastes. It flows into Oluyole Estate in a west–south east direction from its source located at Agaloke within Apata in Ibadan. It joins River Ona at the south east end as a tributary where an animal husbandry farm is located. The stream is impacted by effluents discharged into it from industries in Oluyole Industrial Layout. Oluyole Industrial Layout is located between Latitude 7° 21’N -7 ° 22’N and Longitude 3 ° 50’-3 ° 52’E.

2.2. Sample Collection and Processing

The fish samples were collected along the Alaro stream downstream of the effluent discharge points. Cast nets with mesh sizes of 30-50mm with varying dimensions were used. The nets were cast and drawn with a string to bring the entangled fish to the surface. Gill nets with mesh sizes 30-50mm were tied to stakes with a lead weight in the stream and maintained vertically in water with the aid of floats overnight. Twenty five (25) *S. melanotheron* and 25 *S. galileaus* were collected from the study area.

The sampled fish were identified using Moses (1992). Dissections were carried out with dissecting set to remove the gills, fins, gut (intestine), liver, bones and muscle. The organs and tissues were oven dried separately at 105°C for 6 hours. The organs and tissues were pulverized separately into powdered form using a porcelain mortar and pestle. Pulverized samples were stored in sample bags and sealed for acid digestion.

Digestion of the pulverized samples was carried out by adding 2ml trace metal grade HNO_3 to 0.5g of each powdered sample in Teflon digestion tubes which was heated at 105°C for 1 hour in a heat block. The clear solution was then allowed to cool. This was followed by addition of 1ml H_2O_2. After simmering and boiling, it was left overnight. Digested samples were diluted to the 10ml mark using MilliQ water and then transferred into deionized water-rinsed test tubes heavy metal analyses using the inductively coupled plasma mass spectrometer

(ICP-MS). The Standard Reference Materials (SRMs) was bovine liver from the National Institute of Standards and Technology (NIST-1577) was used to ensure quality results. Agilent 7700 ICP-MS was used for the analyses of the samples. The ICP-MS was used because of its accuracy, sensitivity in detecting heavy metals, high precision and rapidity as a lab workhorse.

3. Results and Discussion

3.1. Heavy Metal Variation in Fish

Results of the heavy metal variation in *S. galilaeus* and *S. melanotheron* in comparison with World Health Organization guideline limits are shown in Figures 1 to 5 below.

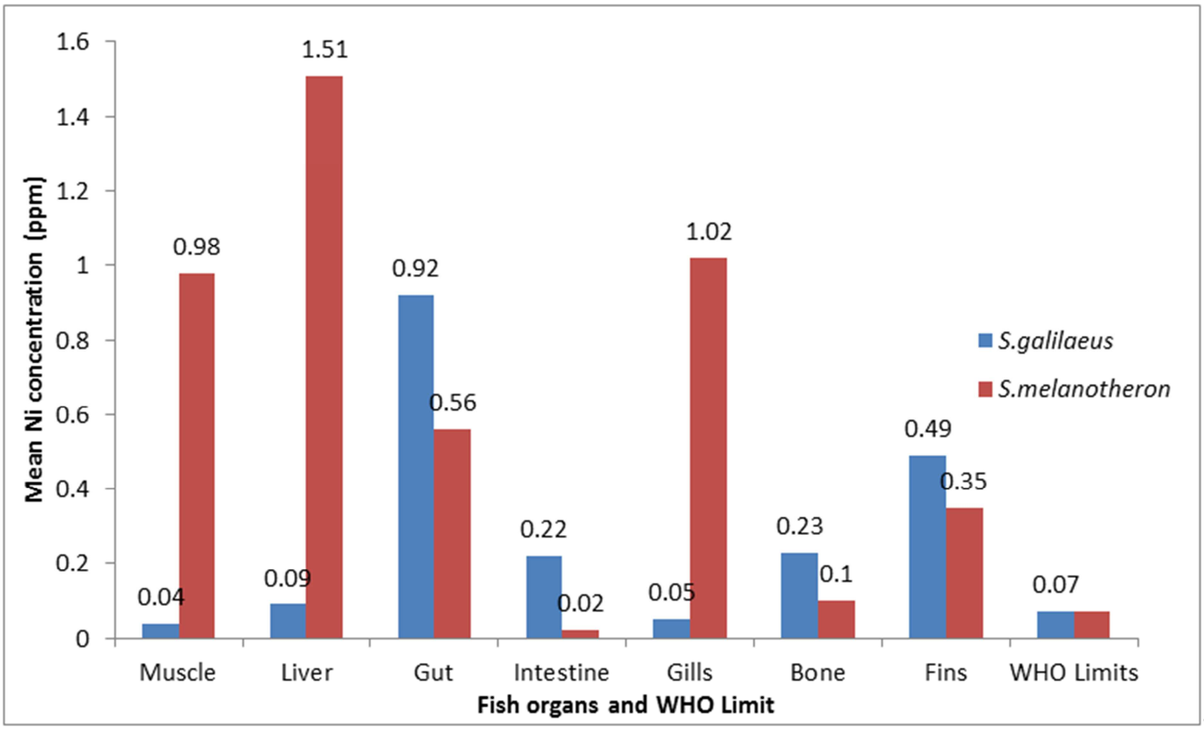

Figure 1. *Mean nickel (Ni) concentration in S. galilaeus and S. melanotheron.*

Comparatively, the highest mean Ni concentration was found in the liver of *S. melanotheron* (1.51ppm), while the least was in the intestine (0.02ppm). The mean Ni in the liver, gut and fins of both fish exceeded the World Health Organization (WHO) limit guideline (0.07ppm) (ASTDR, 2015; EFSA, 2015). The mean Ni concentration in the muscle (0.04ppm) and gills (0.05ppm) of *S. galilaeus*, intestine (0.02ppm) of *S. melanotheron* were below the WHO limit guideline.

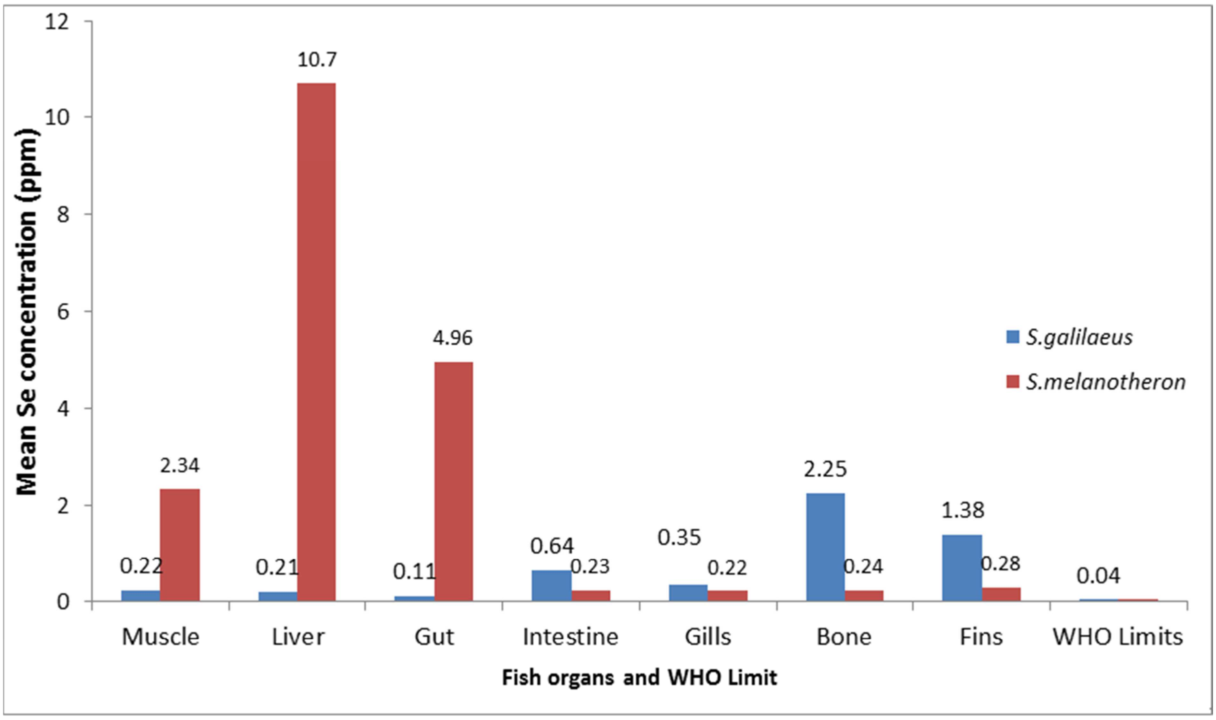

Figure 2. *Mean Selenium (Se) concentration in S. galilaeus and S. melanotheron.*

All the mean Se concentration in the organs of the two fish were all above the WHO limit guideline of 0.04ppm (WHO, 2011). In *S. galilaeus*, the highest mean Se was 2.25ppm in the bone, while the least was in the 0.11ppm (gut). In *S. melanotheron*, mean Se concentration in the organs was highest in the liver (10.7ppm) and the least was 0.22ppm (gills).

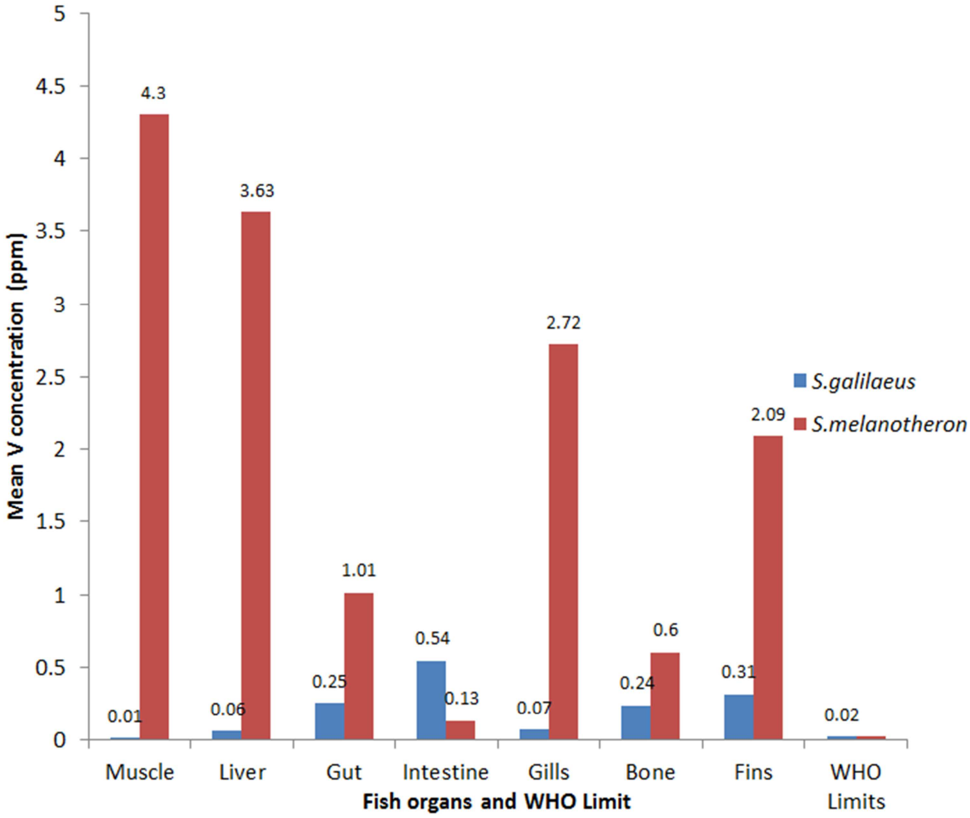

Figure 3. *Mean Vanadium (V) concentration in S. galilaeus and S. melanotheron.*

With the exception of the muscle (0.01ppm) in *S. galilaeus*, all the other mean V concentration in the organs of the two fish was higher than the WHO limit guideline. In *S. melanotheron*, the least mean V concentration in the organs was in the intestine (0.13ppm) while the highest was in the muscle (4.3ppm). In *S. galilaeus*, the highest mean V concentration was in the intestine (0.54ppm) while the least was 0.01ppm (muscle).

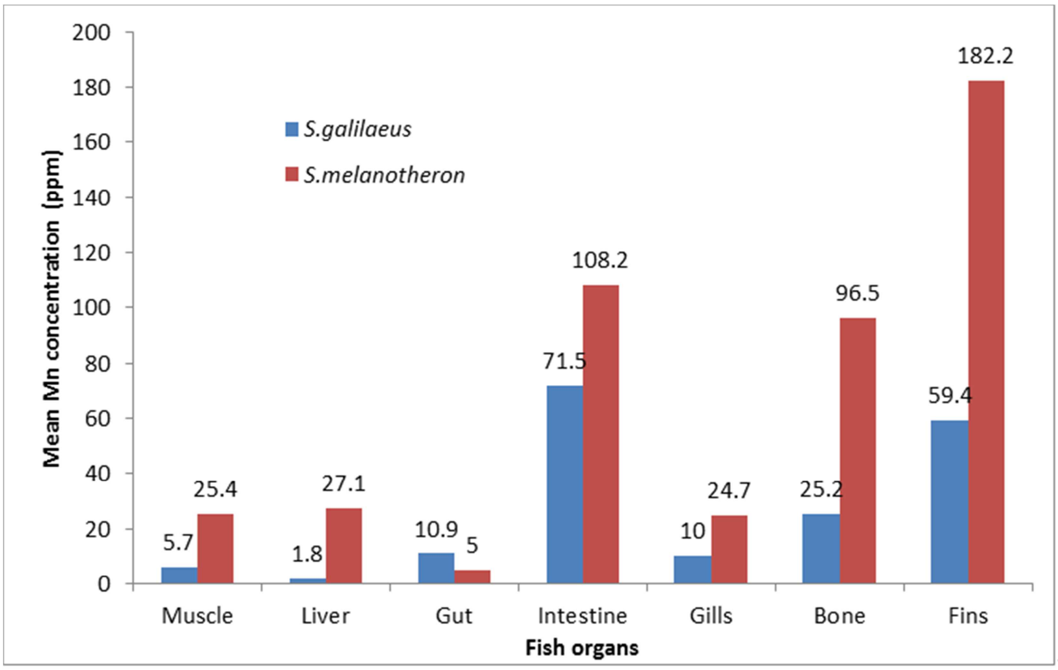

Figure 4. *Mean Manganese (Mn) concentration in S. galilaeus and S. melanotheron.*

Among the two fish, the highest mean Mn concentration in the organs was in the fins (182.2ppm) of *S. melanotheron* while the least was in the liver (1.8ppm) in *S. galilaeus*.

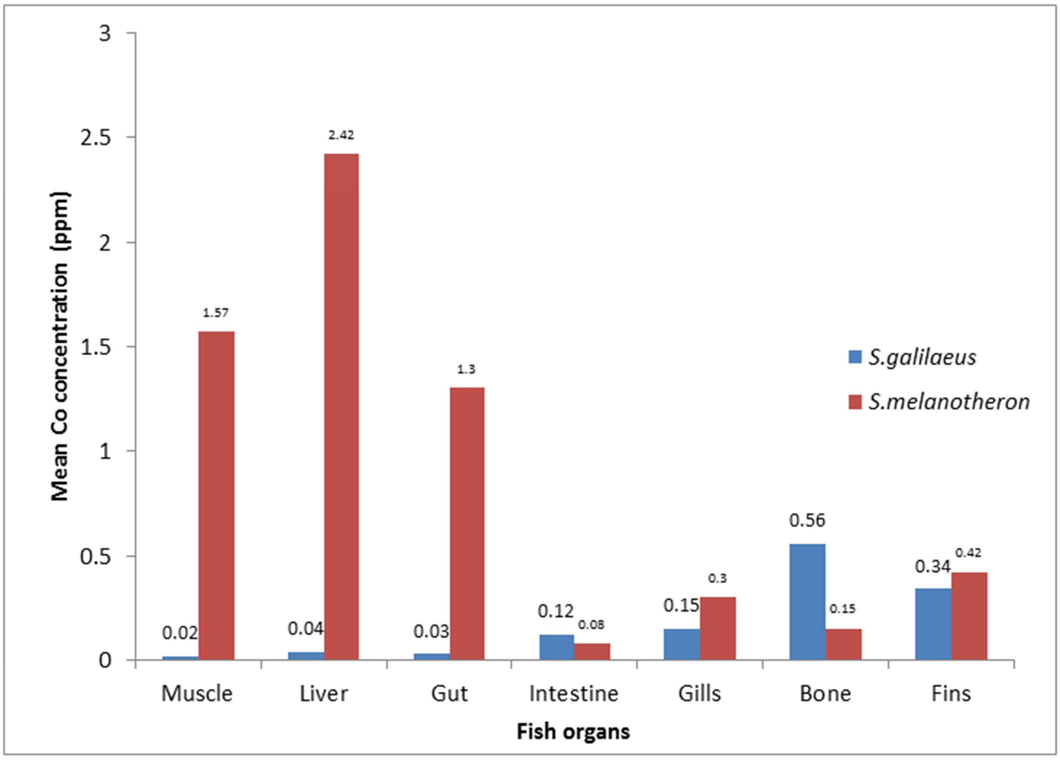

Figure 5. *Mean Cobalt (Co) concentration in S. galilaeus and S. melanotheron.*

The highest mean Co concentration was observed in the liver (2.42ppm) of *S. melanotheron* while the least value was in the muscle (0.02ppm) of *S. galilaeus* which also had its own peak value of 0.56ppm (bone). Since there is no set limit guideline for Co, it was not possible to compare it with the values from the study.

3.2. Heavy Metals in the Fish

The high mean Ni concentration found in the liver of *S. melanotheron* can be attributed o role of the organ in storage and detoxification (Forstner and Wittmann, 1983; Nagabhushanam *et al*, 1999). This study corroborates similar findings in previous studies by Ikem *et al* (2003) on trace elements in water, fish and sediment from Tuskegee Lake, Southeastern USA; Nayaka *et al* (2009) on impact of heavy metals on water, fish (*Cyprinus carpio*) in Tumkur, India; Raja et al (2009) on heavy metals concentration in four commercially valuable marine edible fish species from Parangipettai Coast, South East Coast of India; and Tyokumbur (2014) on heavy metal concentration in the fish *Channa obscura* from Alaro Stream in Ibadan. Similarly, the other heavy metals (Se, V, Co and Mn) showed elevated levels in the organs of *S. galilaeus* and *S. melanotheron* thereby substantiating the impacts of discharged wastes into the stream as shown in the listed previous studies.

3.3. World Health Organization WHO Limit Guidelines and Fish Contamination

The mean Ni in the liver, gut and fins of both fish exceeded the World Health Organization (WHO) limit guideline (0.07ppm) (ASTDR, 2015; Cui *et al*, 2015; EFSA, 2015) thereby indicating that these organs are unfit for human consumption nor for use in processing fish feeds. However, the muscle of *S. galilaeus* is within WHO limit guidelines even though continued consumption could lead to its bioaccumulation in the human consumers with dire health consequences. The study showed that there should be moderation in the consumption of fish from Alaro Stream since all the mean Se concentration in the organs of the two fish studied were above the WHO limit guideline of 0.04ppm (WHO, 2011). Like Ni, with the exception of the muscle of *S. galilaeus* which is within WHO limit guideline, there exists a potential health risk in excess consumption of the studied fish as far as Se and V may be the focus of study in the population. Since the WHO withdrew the limit guideline of 400ppm for Mn in 2011 (Friesbie *et al*, 2015) with the assertion that ‘‘this health-based value is well above concentrations of manganese normally found in drinking-water, it is not considered necessary to derive a formal guideline value”, no health implication cannot be ascertained in this study. Like Mn, there is no current listed limit for Co.

4. Conclusion and Recommendation

As shown in this study, most of the organs of *S. galilaeus* and *S. melanotheron* had V, Ni and Se that were well above the World Health Organization’s limit guidelines thereby making the fish unfit for human consumption as long as the effluents discharged into the stream remain untreated nor discharged elsewhere. There is the urgent need to re-evaluate the latest World Health Organization guidelines for toxic inorganic substances and to set for others like Mn and Co.

Continuous biomonitoring of the aquatic ecosystem for heavy metal pollution is therefore recommended. This will safeguard the consumers from the elevated levels of toxic heavy metals that would impact on environmental health and sustainable use of aquatic resources from Alaro Stream Ecosystem in Ibadan.

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