International Journal of Social Science and Education Research Studies

ISSN(print): 2770-2782, ISSN(online): 2770-2790

Volume 05 Issue 03 March 2025

DOI: https://doi.org/10.55677/ijssers/V05I03Y2025-01, Impact Factor: 7.573

Page No : 235-244

Tanjaro River Pollution and its Impact on the Aquatic Food Chain

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ABSTRACT

The Tanjaro Waterway, found in the Sulaymaniyah governor north of Iraq, has been confronting noteworthy contamination issues in later decades. The stream, which streams through the city of Sulaymaniyah, is an energetic water source for mechanical, horticulture, drinking water, sewage water and biological systems in the locale. In any case, fast urbanization, mechanical activities, and insufficient squander administration have driven to extreme contamination, influencing the environment, open wellbeing, and the nearby ecosystem. In this ponder a diagram of the causes, impacts, and potential arrangements to Tanjaro Waterway contamination related to impacts of contamination in oceanic Nourishment Chains are talked about. In Sulaymaniyah, squander administration is not however modernized. Concurring to the Ministry of Municipalities (Sulaimaniyah Master Plan), Tanjaro has been chosen as the location for squander administration, based on discuss heading contemplations. The squander administration arrangement in our city is centered around the Tanjaro station, which involves a 200-acre range. This assigned location incorporates a huge square measuring 100 meters in length, 100 meters in width, and 10 meters in profundity. Every day, soil is included to the ground, beneath supervision, to make a solid environment that minimizes human affect, without turning to the burning of squander. As well as the primary routes by which MNPs enter the human food chain are addressed and the consequences they have on sources of food and feed while highlighting significant research gaps that impede the development of reliable risk assessments of MNP pollution.

Published Online: March 01, 2025

KEYWORDS:

Food chain, Water pollution, Toxicity, Aquatic ecosystem, Organic matter.

1. INTRODUCTION

Human activities significantly impact stream water quality and hydrological cycles, leading to a decline in water quality and adverse environmental effects. This degradation affects the structure of stream food webs, causing critical changes (Zou et al., 2018; Coll et al., 2011; Garay-Narváez et al., 2013; Guo et al., 2018). Freshwater ecosystems' environmental values are rapidly deteriorating due to the degradation of stream environments. habitat can be arranged by their structure and function. Structure refers to the community composition, while function refers to trophic levels or food chains and webs, which are crucial for energy transfer (Baird and Ulanowicz 1989; Zhao et al., 2019). Food webs, networks of dietary relationships among organisms, depict complex interactions within ecological communities.

In aquatic systems, the production of food is a source of several pollutants. For instance, diseases from raising cattle and nutrients from fertilized fields are lost. Most harmful toxins sink to the seafloor, where they are largely absorbed by creatures living in the bottom sediments of various aquatic environments. For survival, a wide range of microorganisms and biotic components like fish, plants, and mammals rely on the water surrounding them. The main pollutants that are

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****Cite this Article: Ivan Kamal Hamasalih, Ali Mohammed Salih, Solin Jawhar Mohammed Sdiq, Kamaran Qader Yaqub, Sumaia Muhammad Raheem, Akam Dler Latif (2025). Tanjaro River Pollution and its Impact on the Aquatic Food Chain. International Journal of Social Science and Education Research Studies, 5(3), 235-244***

harmful to aquatic ecosystems are toxic metals, eutrophication, micro plastics, etc. Here, we address the primary routes by which MNPs enter the human food chain and the consequences they have on sources of food and feed while highlighting significant research gaps that impede the development of reliable risk assessments of MNP pollution. Additionally, they demonstrate that hydrological factors are less likely to affect the stability of the food web than spatial variations in water quality. After total hardness, we discovered that the most significant variables influencing the spatial variation of the food-web structure in the study area are water and air temperature.

The least crucial element is transparency. Significant differences and diverse variations in the spatial distribution of driving forces of water quality and hydrological factors occur as a result of differences in geographic setting, salinity (salt vs fresh water), and environmental conditions (e.g., water pollution). However, across the globe, the reasons for the high success rate of aquatic ecosystem restoration projects in our study area and other cities have been discussed thoroughly and scientifically.

Changes in biodiversity and species interactions can significantly affect food webs, with more complex webs showing greater stability against external shocks (Zhao et al., 2019 ; Yaqub, 2019). Research on food webs aids in understanding matter and energy flow, community composition, and species interactions (Baird and Ulanowicz, 1989; Mattsson et al., 2017). This knowledge underpins decisions about habitat preservation and restoration (Habib et al., 2022). There are three primary categories of food-web models. The first is the simple or random model proposed by (Angelini et al., 2005; Yaqub 2025). The second type, dynamic models, predict changes in food web structure over time. Ecopath model is the only energy flow model that gives nutritional balance as per food web structure of the system. (Zhao et al., 2019; Yaqub 2024). Analyzing ecosystems' structure and nutrient flow is essential. The eco- path model is widely used to study energy flow and food web structure and to predict the future development of aquatic ecosystems. It is recognized globally as a primary tool for the next generation of water ecosystem research (Zhao et al., 2019). All ecosystem services and functions are in turn affected by both water quality and hydrological habitat changes, which have consequences for the integrity of the food web and the hierarchy and structure of ecosystems Previous research often focused on identifying primary drivers rather than quantitatively analyzing regional differences in hydrology and water quality's impact on food web structure (Zhao et al., 2019; Salih et al, 2018).

A review of 78 ecological restoration projects in the US and Europe shows few successes, highlighting the need to understand human impact on ecosystems and food webs, reduce human activities' effects, study how changes in water flow impact the structure of food chains and the overall health of water bodies. (Zhao et al., 2019; Salih et al., 2020). In China, Ji'nan is a study city for water ecology. The Ministry of Water Resources' plan to create "healthy water ecosystems" for sustainable development designated Ji'nan as the first "pilot" city in 2013. Successful ecological restoration is expected to improve living standards and serve as a model for other cities globally (Zhao et al., 2019, Kay et al 2018).

Addressing issues in fragile aquatic ecosystems worldwide relies on this research. The United Nations' Sustainable Development Goals (SDGs), such as SDG #6, emphasize appropriate water quality as essential for sustainable water and sanitation. Water quality also underpins other SDGs, including health, food security, and biodiversity (Sun, S., Konar, M., et al., 2023). Humans depend on surface water for various ecosystem services like fisheries, recreation, biodiversity habitats, and drinking water (Sun, S., Konar, M., et al., 2023). However, surface water quality is globally harmed by pollution and wastewater discharges from homes, industries, and farms (Sun, S., Konar, M., et al., 2023).

Developing countries are especially at risk of water pollution because their environments are changing rapidly economic, and population changes. Even though China spends a lot of money to make water better, there are still many problems with dirty water (Zhang et al., 2016). Fixing the environment in China costs over 100 billion RMB every year, but bad water keeps hurting people, water safety, and water animals, making it hard to grow well.(Sun et al., 2023., Kedzierski et al 2020). Water in China's land changes a lot from place to place. This is because some areas have more natural water, while others have more pollution. Also, the rules for taking care of water can be different in different places. New studies help us know more about how water changes when there is pollution. (Sun et al., 2023; Napper et al 2016). China's water pollution issues result from rapid industrialization, economic growth, and lax environmental regulations. As a global manufacturing hub, China exports pollution through its supply chains, implicating consumers worldwide in China's declining water quality. Understanding consumption-driven pollution and supply chain impacts is crucial for addressing water quality issues (Sun et al., 2023; Zhao et al., 2019).

Research on "gray water footprints," or the water needed to dilute pollution to meet quality standards, connects water pollution to inter-regional and global trade. Recent studies aim to improve gray water footprint assessments and understand how consumption patterns affect water quality (Sun, S., Konar, M., et al., 2023., Ye, G.,et al 2011). The capacity of natural water bodies to dilute pollutants and the actual in-stream water quality are vital factors needing further study. (Coll, M., et al 2011).

2. PROBLEM FORMULATION

Causes of Tanjaro River Pollution

2.1 Industrial Waste:

Around 900 industries are found close the Tanjaro Waterway tanjaro station as shown in (Figure 1). Numerous businesses that are useful close the Tanjaro Stream do not have a substantial permit. The businesses made diverse sorts of development fabric, counting press, oil, plastic, Black-top, etc. All these manufacturing plants arrange of their fluid squander straightforwardly in the Tanjaro Waterway and arrange of their strong squander in cities' strong squander administration transfer. Tanjaro is an mechanical and agribusiness range with for the most part contaminated due to dumping assortment of squanders ether through point - source or non-point source contamination to the waterway. Production lines and mechanical offices close the stream release untreated or ineffectively treated wastewater containing overwhelming metals, chemicals, and other hurtful substances. Businesses such as materials, tanneries, and nourishment preparing contribute altogether to the contamination. These substances, particularly overwhelming metals and chemical contaminants, are commonly related with mechanical squander and can be discharged into waterways or other water bodies through diffuse (spread out) or prompt (particular) contamination sources. (Rahman et al., 2021; Yaqub 2019).

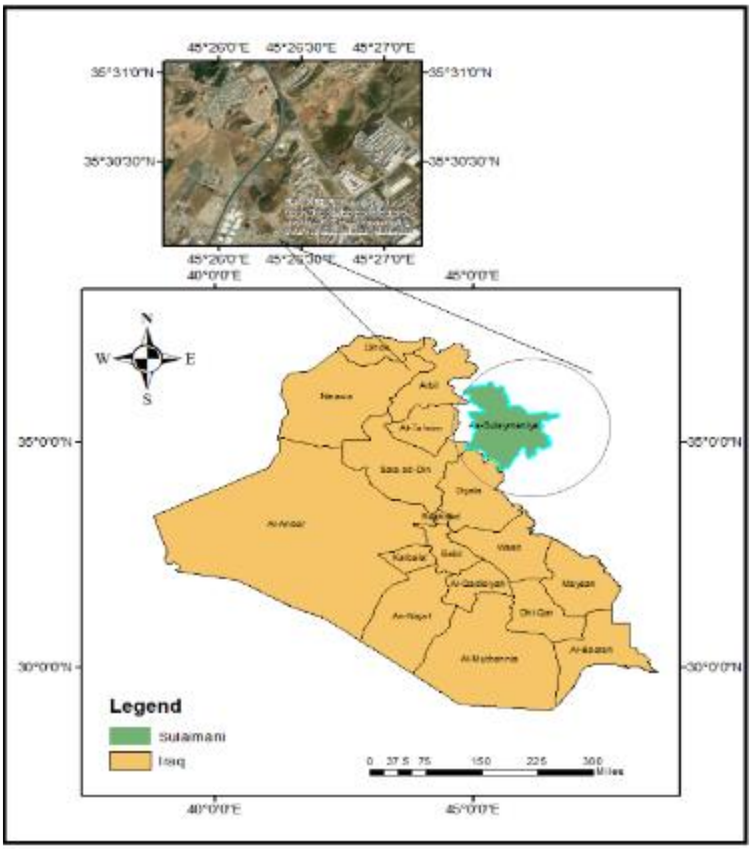

Figure 1: Tanjaro Station.

2.2 Sewage and Domestic Waste:
Untreated sewage from residential areas are often dumped directly into the river, introducing pathogens, organic waste, and nutrients that degrade and altering the nature of water quality. Lack of proper sewage treatment infrastructure worsens the problem and increase the risks on ecosystem and human health. (Rahman et al., 2021; Yaqub 2015)

2.3 Agricultural Runoff:
Agriculturists close the Tanjaro Waterway utilize fertilizers and pesticides without appropriate direction or oversight. The agribusiness division utilized to disseminate fertilizers to agriculturists but no longer controls the quality of these items in the showcase. As a non-point sources contamination counting Pesticides, herbicides, and fertilizers from adjacent, ranches or encompassed cowsheds are wash into the waterway amid precipitation, driving to eutrophication prepare and sully the stream. (Rahman et al., 2021; Salih et al., 2019)

2.4 Solid Waste Dumping:
Because of the Sulaymaniyah solid waste treatment station, all commercial and domestic wasteincluding plastics and organic and inorganic waste is frequently disposed of near the river or along its banks, endangering aquatic life and causing physical, biological, and chemical pollution. (Salih et al.,2020; Rahman et al., 2021)

2.5 Urbanization and Construction:
Due to overcrowding and increased demands on residential areas, Sulaimaniyah Governor is growing. Increased runoff of oil, construction debris, and other pollutants into the river is a result of rapid urban expansion. (Rahman et al., 2021)

3. EFFECTS OF TANJARO RIVER POLLUTION

3.1 Environmental Degradation:
Fish and other aquatic life are dying, biodiversity is declining, and the ecosystem of the river is heavily contaminated. The majority of aquatic life is killed by algal blooms brought on

by nutrient pollution because they lower oxygen levels, produce dead zones, and accelerate the process known as eutrophication. (Rahman et al., 2021; Salih et al., 2019)

3.2 Public Health Risks:
Tanjero is traveling a considerable distance—roughly 2000 km2—to reach Kalar City and Darbandikan. Without adequate treatment, local residents continue to use the contaminated river. Communities that depend on the river for irrigation, drinking water, and recreation are at major risk for health problems due to contaminated water. People who are exposed to contaminated water are frequently affected by waterborne illnesses like cholera, dysentery, and skin infections. (Rahman et al., 2021; Salih et al.,2020)

3.3 Agricultural Impact:
Farmers are increasing the risks and contaminating crops by using polluted water for irrigation. Once more, this may result in problems with food safety and decreased agricultural output. (Rahman et al., 2021)

3.4 Economic Consequences:
Local residents, workers, fishermen, tourists, and farmers—all of whom are vital to the local economy—are impacted by pollution. Wastewater must be treated for both environmental and health reasons. Significant financial resources and additional costs are needed for cleanup and restoration projects. (Rahman et al., 2021)

3.5 Social Issues:
Vulnerable communities, such as low-income families and farmers, who mainly depend on the river for their livelihoods, are disproportionately impacted by pollution. The locals departed without making the decision to relocate to neighboring cities. (Rahman et al., 2021)

4. THE THREATS THAT MNP POLLUTION POSES TO FOOD SECURITY AND SAFETY

In Sulaimaniyah, squander administration is not however modernized. Concurring to the Ministry of Municipalities (Sulaimaniyah Master Plan), Tanjaro has been chosen as the location for squander administration, based on discuss heading contemplations. The squander administration arrangement in our city is centered around the Tanjaro station, which involves a 200-acre range. This assigned location incorporates a huge square measuring 100 meters in length, 100 meters in width, and 10 meters in profundity. Every day, soil is included to the ground, beneath supervision, to make a solid environment that minimizes human affect, without turning to the burning of squander. Because they move around a lot in nature, small metal particles can get into our food in many ways. They can move from one animal to another, come out of food wrappers, get breathed in, or travel from sewage to our food. (Nelis, J.L., Schacht, V.J., and et al 2023., Dessì, C. Okoffo, E.D., and et al., 2021., Fadare, O.O. and et al 2020., Kedzierski, M. and et al., 2020., Danopoulos, E., Twiddy, M. and et al., 2020., Farrell, P. and Nelson, K., 2013., Mattsson, K. Johnson, E.V and et., al., 2017).

Food containing MNPs originating from is consumed by humans, however the predominant routes of MNP intake are still unknown. Recent research has identified food processing and packaging as a major intake pathway (Baird, D., et al., 2004., Habib, R.Z., Nelis, J.L., Schacht, V.J., and et al., 2023; Dessð, C., Okoffo, E.D., and et al., 2021). Aquatic organisms have evidence of MNP trophic transfer, especially for smaller particles (Habib, R.Z., Poulose, V., and et al., 2022; Farrell, P. and Nelson, K., 2013; Mattsson, K. Johnson, E.V. and et al., 2017., Campanale, C., Massarelli, C., and et al., 2020., Zhao, C.S., et al 2018). However, the majority of MNPs probably pass through the digestive tract without further interaction. When MNP hotspots—local areas with exceptionally high MNP concentrations—occur alongside nutrient- and biodiversity-rich regions, they have the potential to seriously harm marine ecosystems and consequently fish stocks (Woodward, J., Li, J., and et al.,2021.,Kane, I.A., Clare, M.A., and et al.,2020., Nelis, J.L., Schacht, V.J., and et al 2023).

Toxic substances, including plastic additives, can be transferred through ingestion of MNP (Kane, I.A., Clare, M.A., and et al., 2020., Zou et al 2018; Yaqub, 2018). This could lead to the bioaccumulation of these chemicals in organisms that humans subsequently eat, thus posing a risk to food safety. Additionally, eating MNP can cause an organism to consume less nutrients, experience cellular stress, inflammation, symbiosis, and be less able to reproduce (Kane, I.A., Clare, M.A., and et al., 2020., Marana, M.H., Poulsen, et al., 2022; Ye, G., Zhang and et al., 2021., Nelsonis et al., 2023; Yaqub). This might change Due to their environmental movement, small bits have many chances to get into people's food (Fig. 1). moving through food, slowly coming out of food bags, breathing them in, and bits going from waste to food are some examples. harder to figure out how dangerous it is. However, it has been shown that microbial communities known as plastisphere communities—those affixed to plastic particles—have the capacity to contaminate agricultural soil with genes that resist antibiotics. (Nelis, J.L., Schacht, V.J., and et al., 2023; Rüthi, J., Bölsterli, DB., and et al., 2020; Zhu, D., Ma, J., and et al., 2022). The main research gaps are noted and these subjects are covered in more detail below.

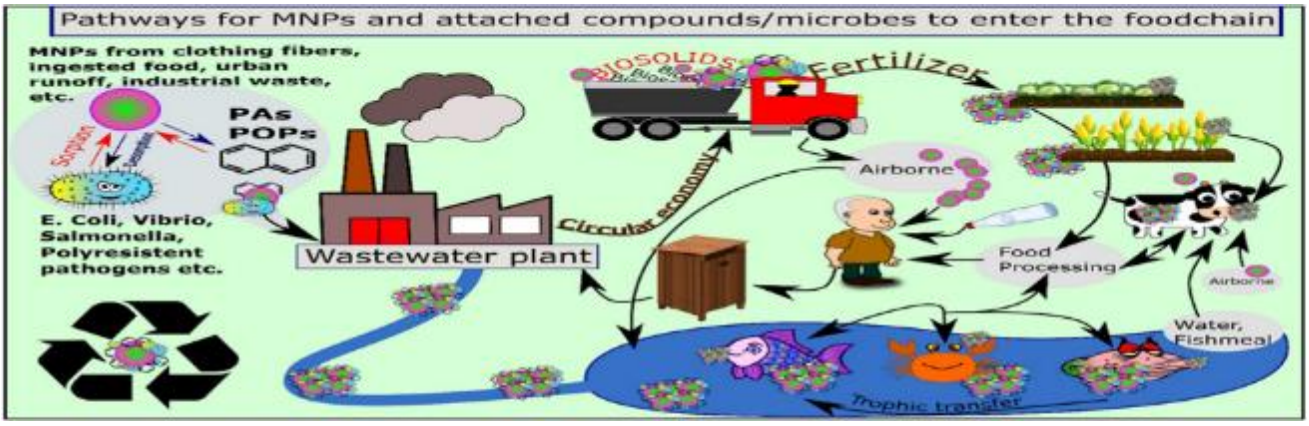

Figure 2: A picture of MNP moving through nature shows how it affects food safety worldwide. This does not cover all possibilities but gives an idea of how MNPs get into and move through the food system.(Zhu, D., Ma, J., and et al., 2022)

4.1. An example of how MNPs get into the human food chain

520 sweeper working daily in this city to collecting and cleaning waste, 1500 type of waste garbage work for collect and transport waste to Tanjaro, at normal day municipality team working to collect 1200 ton of waste at Sulaimaniyah, so the rate of waster shown in (Figure 4) at celebrate day the waste increase to 1250-1300 ton. These amount of waste change seasonally, waste at summer and spring increase on 2014-2015 waste at Sulaimaniyah increase than last years because of homeless from west and middle of Iraq. (Ministry of Sulaimaniyah municipal). Urban wastewater contains significant amounts of micro plastic particles (MNP), especially microfibers, primarily from synthetic clothing. A typical 6 kg washing machine cycle can release over 700,000 microfibers. Wastewater treatment plants (WWTPs) are tasked with removing these microfibers. Research by Sun et al. shows that tertiary-treated WWTPs can remove over 97% of micro plastics from wastewater, with most MNPs retained in bio solids, the organic byproducts of sewage treatment. Identifying and removing micro plastics in these facilities is crucial for addressing urban wastewater pollution (Okoffo et al., 2019; Nelis et al., 2023; Napper and Thompson, 2016). Water research, 152, 21–37 pages. According to (Nelis et al., 2023; Kay et al., 2018, MP concentrations have nevertheless increased five to twenty times downstream of WWTPs. As shown in (Figure 3) the organic matter transfer to the environment. The sources of MPs in river systems are diverse and include untreated wastewater discharge, urban runoff, and WWTP effluent (Nelis et al., 2023; Woodward et al., 2021). Water flow has been shown to carry MNPs to the ocean and create hotspots for the accumulation of microplastics in low-flow riverine ecosystems, where there is not enough water flow to carry particles into the ocean.

This emphasizes that plastics-related wastewater release regulations need to be changed. MNP hotspots are also located in the bottom of ocean, where MNP accumulates due to bottom currents in nutrient- and oxygen-rich areas, creating a pathway for MNP to enter the food web through bottom-feeding organisms (Kane et al., 2020; Nelis, J.L., Schacht 2023). Reduced nutrient uptake from ingesting these particles may result in decreased fitness, which could have an impact on food security and ecosystem resilience. Risks to food safety may also be relevant since plastic additives, such as brominated flame retardants, can contaminate MNPs and have qualities that can cause toxicity and bioaccumulation (Nelis et al., 2023; Zhang et al., 2011).

Applying plastic mulch presents another possible route for MNPs to get into the food chain. This material can break down into smaller particles and affect the ecosystem and soil organisms in different ways (Nelis et al., 2023; Chae and An 2018). MNPs can also be introduced onto agricultural land by bio solids, which are frequently used as fertilizer. For example, it has been demonstrated in Australia that the MNP content of bio solids is rising exponentially. The end-use of bio solids was estimated to have released 4700 metric tons (Mt) of plastics into the environment in 2020. (Nelis et al., 2023; Okoffo et al., 2020). MNP concentrations in biosolids can reach 100 times higher values in some instances than those previously observed to have a major impact on the growth and metabolism of major food crops in laboratory settings. Without much thought given to the hazards, using bio solids as fertilizer is typically viewed as a good idea. However, a wealth of evidence indicates that this practice permits MNPs and plastic additives to build up in the soil, affecting aggregate stability and water holding capacity (Nelis et al., 2023; Okoffo et al 2020). It also permits NPs to be absorbed by plants and have an impact on plant growth (Nelis et al., 2023; Okoffo et al., 2019). Subsequently, soil degradation can impact food safety and security due to MNP leaching in groundwater reserves and decreased biomass production from food crops.

Processing of food has gained attention recently as a way that people consume plastic. Cutting boards made of polythene have been linked to MP contamination in meat. Although meat prepared by a butcher has been the subject of demonstrations to this effect thus far, meat prepared on similar chopping boards, including those in homes, is likely to experience this (Woodward et al., 2021; Kane et al., 2020). (Nelis et al., 2023; Mariana et al., 2022) packaged store-bought rice has also been found to contain plastic contamination. Food packaging trays were most likely the source of the extruded polystyrene micro particles found in packed poultry (Nelis et al., 2023; Ye, G., Zhang et al 2021). It has been discovered that MNPs are released during initial use of food containers and plastic cups that restaurants typically use for food delivery (Marana et al., 2022.; Nelis et al., 2023). According to estimates, this pathway consumes or releases more than 180 tonnes of MNPs into the environment each year (Marana et al., 2022; Nelis et al., 2023). A further route for human MNP consumption is drinking water, which includes both tap and bottled water (Rüthi et al., 2020; Nelis et al., 2023). At last, finding plastic bits in 13 out of 20 samples shows that breathing in tiny things may add to how much gets into the lung after death. (Zhu et al., 2022; Nelis et al., 2023; Salih at el., 2020). It is possible that livestock can also absorb MNP through freshwater and air contaminated with MNP, though no research on this subject has been found.

Figure 3: Diagrammatic representation of the primary origins, point of entry, and distribution of MNPs in the environment that extends to humans (Abomohra and Hanelt 2022)

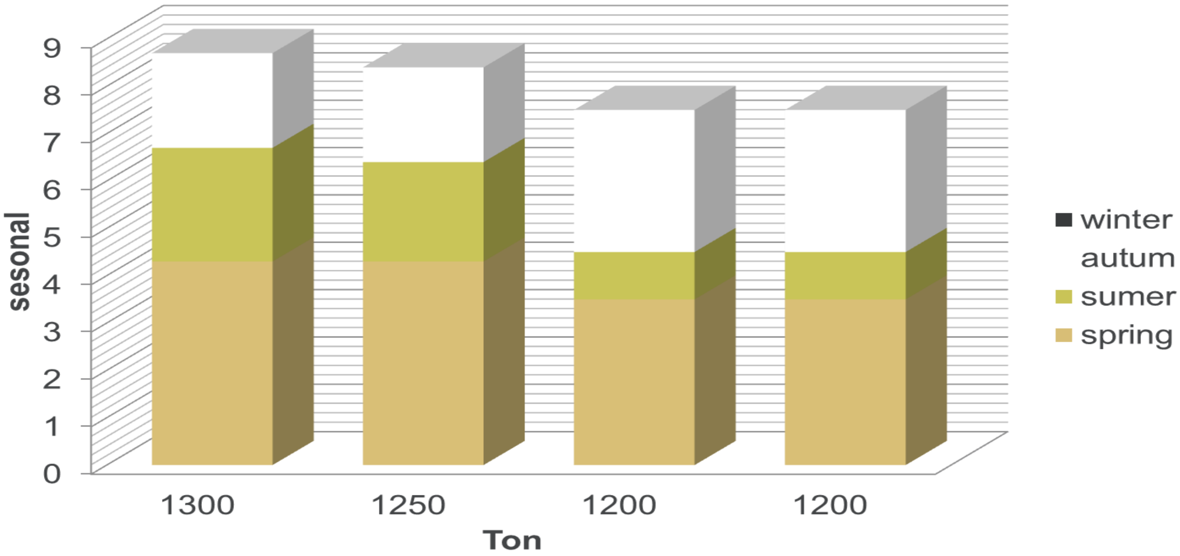

Figure 4: Solid waste management measurement (Ministry of Municipal, Iraq).

4.2. Proof of MNP toxicity in animal sources of food

More research has been done on aquatic species than on agricultural models. The limited scope of current studies uses poultry as a proxy for seabirds and raptors and pigs as a proxy for human exposure when examining the effects of MP exposure. According to (Nelis and colleagues 2023), studies on poultry have assessed the effects at the organism level. In these studies, animals were given oral exposure to MPs, either in the presence or absence of food. According to (Nelis et al., 2023), chicks exposed to MPs showed inhibited feed intake and delayed growth in comparison to control groups. Moreover, cardiotoxicity, including myocardial pyro ptosis, inflammation, and mitochondrial lesions, is demonstrated by a recent study in 1-day-old domestic chickens exposed to virgin polystyrene for 42 days. After Japanese birds were given MPs, the results in future groups were also checked. This is because animals given old plastic MPs had more masses in the baby making parts of grown-up males and slowed down the time to have babies for females. But, these changes did not lead to less living or less baby making. (Nelis et al., 2023), adult Additionally, exposure to naturally aged polystyrene fragments has been shown to have toxicological effects on Japanese quails that are not fatal. Among these effects are weight loss, oxidative stress, redox imbalance, and cholinesterase effects. However, because MPs occupied a portion of the stomach cavity, the control group did not receive non-plastic inert particles to account for variations in feed intake. Therefore, the noted consequences could just as easily be ascribed to a decrease in the amount of nutrients consumed as to the intrinsic toxicity of the particles. (Nelis and colleagues 2023), There have only been in vitro studies done on domestic pigs, and even then, the models used to mimic human exposure are frequently porcine tissue/cell lines. Numerous reactions, such as oxidative stress, reduced tissue and cell viability, elevated senescence and cell dysfunction, and disruption of steroidogenesis, have been observed in these studies. (Table 2). Nonetheless, these studies on MP toxicity in livestock also found a number of endpoint measures (a measure of the animals' health) that were unaffected by MNP exposure. For instance, 42 days of exposure to virgin polystyrene beads resulted in nothing happen in body weight, heart weight, or heart to body weight proportion in newly hatched chicks (Nelis et al., 2023). Research done on Japanese quails over several generations revealed that Between virgin and ocean-weathered polypropylene pellets, the study found no statistically significant differences in mortality, adult body weight, or reproductive output. These factors include the number of eggs laid, frequency of abnormal eggs, egg fertility, embryo weight, yolk weight, and eggshell strength. There were no histological alterations or exposure-induced lesions in the kidneys, thyroid, spleen, liver, cloacal glands, or female reproductive system. The concentrations of testosterone and estradiol remained unchanged following exposure (Nelis et al., 2023). The study's use of relatively large (3-4.5 mm) particles, which prevented potential translocation-related negative outcomes, may account for the absence of acute or severe toxicological effects that were observed (see table. 2). Also, check how the body works with MP. We can study how the body makes substances and how it may change with MP. This will help us see what MP does to the body, even if it is not clear.

5. DISCUSSION

Food webs represented by mathematical models can be helpful in determining how best to manage multiple species (Angelini and Agostinho 2005), in analyzing the effects of the trophic cascade (Angelini and Agostinho2005), and in validating the correlation between stability and diversity (Mohammed et al., 2021; Angelini and Agostinho 2005.). In compartmental models, where it is common practice to group species, ecosystems or food webs are quantified. This kind of aggregation occurs often among species that share a diet, which reduces the complexity of the system and makes it easier to understand (Habib et al 2022). Sometimes aggregation is a useful tool for studying hierarchical complex systems (Auger et al.,2000).

On the other hand, aggregation suggests a number of issues: it may result in conclusions that are inaccurate and unclear about parameter values. The value of ascendency, a stability metric derived from information theory (Ulanowicz, 1996; Ulanowicz, 1997), can be strongly impacted by the manner of aggregation, as demonstrated by(Abomohra and Hanelt 2022).

The aims of this work are, firstly, to estimates ecotrophic community of the upper paraná river floodplain and secondly, to compare the effects of two species grouping techniques on system level data and other characteristics of the ecosystem because these ways increase and or aggravate the threats associated with habitat loss and fragmentation hydrological changes other Both nonnative invasive fish species identified intentionally or non-intentionally introduced by people are increasingly getting recognized as one of the major factors (Dudgeon et al., 2006). Although it is acknowledged that non-native species can also have beneficial effects, such as trophic subsidy, competitive release, and predatory release (Rodriguez, 2006; Schlaepfer et al., 2010), many others have detrimental ecological and evolutionary effects when they become invasive, causing anything from native species' behavioral changes in the presence of invaders to the total restructuring of food webs (Woodward et al 2021). Also in this article shows the Solid waste dumping, agricultural runoff, untreated sewage, and industrial waste are the main causes of the Tanjaro Waterway's pollution. These contaminants cause serious environmental harm, such as eutrophication, biodiversity loss, and fish kills. Because local communities depend on the river for drinking, irrigation, and recreation, there are serious health risks to the public. Farmers who use contaminated water for crops run the risk of lowering yields and compromising food safety. Local businesses, farmers, and fishermen are affected economically, and vulnerable communities are disproportionately affected by pollution, which leads to social inequality. To solve these problems and safeguard the environment and public health, immediate action is required.

6. CONCLUSION

The pollution of the Tanjaro Waterway presents a critical threat to the environment, public health, agriculture, and the local economy. Industrial, domestic, and agricultural waste, along with urban expansion, have severely contaminated the river. This contamination affects aquatic life, water quality, and the well-being of nearby communities. Addressing this issue requires urgent action to improve waste management, regulate industrial discharges, and ensure clean water access to safeguard both the ecosystem and public health for future generations. Research on the impact of water quality and hydrological variations on aquatic food webs shows that indicators such as Shannon's index, connectance index, system omnivory index, and the ratio of total primary production to total respiration are effective measures of food web complexity, connectivity, stability, and maturity. In Lake

Victoria, the food web remains simple and poorly connected, with unclear changes post-1980s recession despite some species recovery. The ecosystem primarily relies on phytoplankton and effectively uses primary productivity, with significant biomass flowing to detritus, indicating minimal fishery exploitation. However, pollution from micro- and nanoplastics (MNPs) is widespread, originating from various sources and affecting ecosystems involved in food, water, and biodiversity. MNP contamination is prevalent in agriculture, aquaculture, and food processing, but its impact on productivity, ecosystem resilience, and health is not well understood. Challenges in risk analysis include the diversity of MNPs (color, size, shape, weathering), uncharacterized plastic additives, dynamic leaching profiles, and the risk of pathogen transport via specialized communities on plastics. Additionally, the complex toxicological effects of low-dose MNP exposure complicate risk assessment. Addressing these issues requires interdisciplinary cooperation and advanced analytical techniques, such as Secondary Ion Mass Spectrometry (SIMS) for high-resolution MNP analysis, combined with omics approaches for characterizing plastic additive leaching and plastisphere communities. Omics analyses and dose-response studies can further elucidate MNP toxicity. High-throughput analyses of MNP content in soil and water are necessary to quantify MNP flux and presence. The ultimate goal is to establish safe MNP addition levels for agricultural and ecological systems to protect water supplies, ecosystems, and food safety. By filling research gaps and improving analytical methods, the authors aim to support the development of MNP regulations that ensure global food security and safety.

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