Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 12 ~ Issue 1 (January 2026) pp: 59-65
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Plastic pollution as a multidimensional urban challenge : environmental, health and socio-economic impacts in Madagascar (case of Toliara)

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Abstract
In coastal cities of the Global South, plastic pollution generates impacts that go far beyond environmental degradation alone. This article examines the environmental, health and socio-economic impacts of plastic pollution in the urban municipality of Toliara, within a context characterized by insufficient infrastructures and high coastal vulnerability. The methodological approach combines field data collection, interviews and questionnaires with local stakeholders, ecological assessments of soils, waters and coastal ecosystems, as well as socio-economic indicators. The results highlight the degradation of marine and coastal ecosystems, public health risks, and negative effects on artisanal fisheries, tourism and the quality of life of local communities. The study underscores the need for integrated and sustainable plastic waste management based on a systemic approach and circular economy principles in order to strengthen urban resilience and reduce socio-environmental vulnerabilities.

*Received 06 Jan., 2026; **R**evised 14 Jan., 2026; **A**ccepted 16 Jan., 2026 © The author(s) 2026.*
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I. INTRODUCTION

Plastic pollution has emerged as a major global environmental challenge, with particularly severe consequences in coastal cities of the Global South, where rapid urbanization, weak waste management infrastructures and strong exposure to marine and climatic dynamics exacerbate environmental, health and socio-economic vulnerabilities (UNEP, 2021; World Bank, 2020). Beyond visible environmental degradation, plastic waste increasingly affects public health, livelihoods and urban quality of life, transforming waste accumulation into a structural urban challenge rather than a purely environmental issue (Dewar & Yoder, 2016; Davis, 2022).

In Madagascar, this problem is intensified by rapid demographic growth, insufficient waste collection services, increased consumption of single-use plastics and limited environmental awareness, resulting in the uncontrolled dispersion of plastic waste into both urban and coastal environments (Raharinirina, 2018). In the coastal and port city of Toliara, located in southwestern Madagascar, plastic pollution originates from multiple sources including households, markets, commercial activities, artisanal fisheries and marine inputs. These combined pressures place sensitive coastal ecosystems such as mangroves and coral reefs at high risk, while increasing human exposure to polluted environments (INSTAT Madagascar, 2025; Dewar & Yoder, 2016).

The plastic waste observed in Toliara consists predominantly of single-use items such as bags, packaging and bottles, alongside more durable plastics and an increasing presence of microplastics. The fragmentation, dispersion and ingestion of these materials by wildlife and human populations pose significant environmental and health risks, particularly in densely populated urban areas and coastal zones (Law, 2017; UNEP, 2021). The uncontrolled accumulation of plastic waste contributes to the degradation of soils, drainage systems and coastal ecosystems, promotes the proliferation of disease vectors through stagnant water, and disrupts key socio-economic activities including artisanal fisheries, trade and tourism.

These impacts unfold within a context characterized by insufficient infrastructure, financial constraints, persistent informal waste flows and limited institutional capacity, which collectively amplify urban vulnerability and constrain effective waste management responses (World Bank, 2020; Raharinirina, 2018). In this regard, plastic pollution in Toliara cannot be understood solely as a waste management issue, but rather as a multidimensional urban phenomenon at the intersection of environmental degradation, public health risks and socio-economic fragility.

In response to this complexity, the circular economy has emerged as a central theoretical framework for rethinking plastic management, promoting a shift away from the linear "produce–consume–dispose" model toward strategies of reduction, reuse, recycling and valorization, while generating local economic opportunities and strengthening urban resilience (Geissdoerfer et al., 2017; Kirchherr et al., 2017). Although international experiences demonstrate the relevance of such approaches, their applicability in vulnerable coastal cities of the Global South requires a robust understanding of the specific impacts and constraints shaping local contexts.

In this perspective, this article aims to assess the environmental, health and socio-economic impacts of plastic pollution in the urban municipality of Toliara by analyzing its effects on soils, drainage systems, coastal ecosystems, public health, local economic activities and the quality of life of urban populations. Rather than focusing on waste quantification or spatial distribution, this study adopts an impact-oriented and systemic perspective, examining how plastic pollution affects urban functioning and amplifies existing vulnerabilities in a coastal city of the Global South.

By combining field observations, stakeholder surveys and indicator-based analysis, this research contributes to a better understanding of plastic pollution as a multidimensional urban challenge and provides context-adapted insights relevant for informing sustainable and integrated management approaches. While previous work quantified and mapped plastic waste distribution in Toliara, this study focuses specifically on the multidimensional impacts of plastic pollution and their implications for urban vulnerability, public health and socio-economic resilience.

II. Materials and Methods

2.1. Overall methodological approach

This study adopts a **qualitative, analytical, and spatially integrated approach** to assess plastic pollution as a multidimensional urban challenge in the city of Toliara, Madagascar. The methodology combines **field surveys**, **semi-structured interviews**, **questionnaires**, **ecological observations**, and **spatial analysis**, in order to capture the environmental, health, and socio-economic dimensions of plastic pollution within an urban coastal context.
The methodological framework is grounded in a **territorial description of the study area** and in **standardized data collection protocols**, while impact assessment and interpretation are developed in the Results and Discussion sections. This integrative approach allows for a systemic understanding of plastic pollution dynamics in cities of the Global South (Raharinirina, 2018; Dewar & Yoder, 2016; Geissdoerfer et al., 2017).

2.2. Data collection methods

2.2.1. Social surveys and stakeholder interviews

Primary social data were collected through **semi-structured interviews** and **questionnaires** administered to **households, traders, fishermen, and local authorities**. These tools were designed to document:

- plastic consumption patterns and waste management practices,
- perceptions of environmental and health risks,
- socio-economic impacts associated with plastic pollution,
- institutional and community responses to waste management challenges.

This qualitative approach enabled the integration of local knowledge and stakeholder perspectives into the analysis of plastic pollution dynamics.

2.2.2. Field observations and ecological assessment

Systematic **field observations** were conducted across urban, peri-urban, and coastal areas of Toliara. Ecological assessments focused on key environmental compartments, including:

- soils and urban public spaces,
- drainage channels and surface water bodies,
- coastal areas, beaches, mangroves, and coral reef zones.

These observations provided direct evidence of plastic accumulation, dispersion pathways, and interactions with sensitive ecosystems, supporting the environmental impact assessment.

2.3. Indicators for impact assessment

The evaluation of plastic pollution impacts is based on a set of **environmental, social, and economic indicators**, defined using field observations, survey data, stakeholder interviews, and documentary analysis.

- **Environmental indicators** address soil degradation, contamination of water bodies and coastal environments, and damage to sensitive ecosystems such as mangroves and coral reefs.
- **Social indicators** focus on quality of life, exposure to environmental nuisances, and health risks linked to plastic waste accumulation.
- **Economic indicators** assess impacts on artisanal fisheries, commerce, and tourism, as well as waste management costs borne by local authorities.

This indicator-based framework allows qualitative observations to be translated into **structured and comparable impacts**, adapted to the realities of urban environments in the Global South (Geyer et al., 2017; World Bank, 2020).

2.4. Spatial analysis and waste flow modelling

Data derived from waste quantification and indicator analysis were integrated into a **spatial and functional modelling framework** aimed at analyzing plastic waste flows from generation to accumulation or potential recovery.

Geographic Information Systems (**GIS**) and digital tools were used to:

- map spatial distribution and hotspots of plastic pollution,
- analyze dispersion pathways influenced by urban structure and natural factors,
- identify dysfunctions and breakpoints within the existing waste management system.

This modelling approach supports the evaluation of alternative waste management scenarios and contributes to the development of **locally adapted circular economy strategies**, incorporating collection, source separation, recycling, and valorization processes, as well as stakeholder involvement (Geissdoerfer et al., 2017).

2.5. SWOT analysis of the plastic waste management system

A **SWOT analysis** (Strengths, Weaknesses, Opportunities, Threats) was conducted to assess the plastic waste management system of the urban municipality of Toliara.

The analysis is based on:

- field survey results,
- interviews with institutional and community stakeholders,
- secondary data from technical reports and policy documents.

The SWOT framework enables the identification of structural constraints, existing leverage points, opportunities linked to circular economy development, and future environmental and socio-economic risks. It provides a strategic basis for formulating policy-oriented recommendations and sustainable waste management pathways.

2.6. Methodological positioning of impact analysis

While this section details the **data collection tools, indicators, and analytical frameworks**, the **assessment of environmental, health, and socio-economic impacts** is presented in the Results and Discussion sections. This distinction ensures methodological clarity and reinforces the analytical consistency of the study.

III. RESULTS

3.1. Environmental impacts of plastic pollution

The results highlight **significant environmental impacts** of plastic pollution on soils, water systems, and biodiversity within the urban municipality of Toliara.

In **urban and peri-urban soils**, plastic waste density ranges between **3 and 5 kg per 100 m²**, particularly in central districts and around major markets. This accumulation reduces soil permeability, limits water infiltration, and alters soil water retention capacity. As a result, air–water exchanges within the soil matrix are disrupted, leading to a decline in soil fertility, notably in peripheral market gardening areas. Progressive fragmentation of plastics further contributes to the **diffuse presence of microplastics**, causing persistent soil contamination.

Aquatic environments are also severely affected. Plastic waste accumulates in drainage channels, ditches, and urban gutters, leading to partial or complete obstruction. This situation promotes water stagnation, disrupts drainage system functionality, and facilitates the transport of plastic fragments and microplastics toward coastal zones.

Regarding **biodiversity**, the results reveal pronounced impacts on coastal and marine ecosystems. Plastic ingestion and entanglement in abandoned fishing nets and ropes are frequently observed in artisanal fishing areas. Accumulation of plastic debris in **mangroves and coral reefs** degrades these critical habitats, directly affecting species reproduction and survival and, consequently, local fishery resources.

Table 1. Main environmental impacts of plastic pollution in Toliara

Environmental compartment	**Observed impacts**	**Consequences**
Urban and peri-urban soils	Plastic accumulation (3–5 kg/100 m²), microplastics	Reduced permeability, soil fertility decline
Drainage systems and water bodies	Obstructed channels, stagnant water	Altered drainage, pollutant dispersion
Mangroves and coral reefs	Plastic accumulation, entanglement	Habitat degradation, biodiversity loss

3.2. Health impacts associated with plastic pollution

Plastic pollution represents a major public health concern in Toliara. Urban populations are exposed to polluted environments through multiple pathways, including contact with waste accumulation sites, stagnant water and degraded drainage infrastructure.

Field observations indicate that obstructed drainage channels create favorable conditions for the proliferation of disease vectors such as mosquitoes and rodents. In addition, plastic fragmentation contributes to the presence of fine particles in the urban environment, increasing potential inhalation exposure.

Health risks are particularly pronounced in densely populated neighborhoods with limited access to waste collection and sanitation services. Vulnerable groups, including children and low-income households, appear disproportionately exposed to these conditions.

Table 1. Health risks associated with plastic pollution exposure pathways in Toliara

Exposure pathway	**Observed conditions**	**Potential health risks**
Water and food	Contaminated water and seafood	Digestive and metabolic disorders
Air	Plastic fragmentation and dust	Respiratory irritation
Stagnant water	Vector proliferation	Waterborne and parasitic diseases

Figure 2. Obstructed drainage channels and stagnant water creating health risk hotspots

3.3. Socio-economic impacts of plastic pollution

The results demonstrate that plastic pollution directly affects several **key sectors of the local economy**. **Artisanal fisheries**, a major livelihood source in Toliara, experience significant impacts due to plastic ingestion by marine species, habitat degradation, and entanglement of fishing gear. These factors result in reduced catches, damaged equipment, and increased food insecurity for fishing communities.

At the municipal level, plastic pollution generates **high management costs**, associated with cleaning operations and maintenance of obstructed infrastructure. These financial burdens reduce the capacity of local authorities to invest in sustainable waste management solutions. Additionally, plastic presence in agricultural and commercial areas lowers productivity and negatively affects household and business incomes.

The **tourism sector** is also impacted. Accumulation of plastic waste on beaches and coastal areas reduces site attractiveness, leading to declining tourist visits and associated revenue losses for local stakeholders.

Table 3. Socio-economic impacts of plastic pollution in Toliara

Sector	**Observed impacts (from field observations and surveys)**	**Documented socio-economic effects**
Artisanal fisheries	Entanglement of fishing nets, ingestion of plastics by marine species, degradation of coastal habitats	Reduced fishing efficiency, damage to fishing equipment, increased vulnerability of fishing households
Municipal waste management	Increased frequency of cleaning operations and maintenance of obstructed drainage infrastructure	Additional financial pressure on municipal services and limited capacity to invest in sustainable waste management
Tourism and coastal activities	Accumulation of plastic waste on beaches and coastal public spaces	Loss of attractiveness of tourist sites and reduced income for local tourism-related activities

3.4. Impacts on quality of life and urban well-being

The results indicate a **significant deterioration of quality of life** among residents of Toliara due to plastic pollution. Accumulation of plastic waste in streets, markets, and public spaces generates persistent **visual and olfactory nuisances**, degrading the urban living environment.

Continuous waste presence in drainage channels, sidewalks, and coastal areas restricts the use of public spaces, affects mobility, and reinforces a sense of **environmental vulnerability and insecurity**. In the absence of regular and effective collection services, residents often rely on informal cleaning practices, increasing social stress and household burdens.

Figure 3. Plastic waste accumulation in public spaces and impacts on daily life in Toliara.

IV. Discussion

The results confirm that plastic pollution in Toliara constitutes a **multidimensional urban challenge**, simultaneously affecting environmental compartments, public health, socio-economic activities and quality of life. The convergence between field observations, stakeholder perceptions and indicator-based analysis highlights the systemic nature of plastic pollution in coastal cities of the Global South.

4.1. Causal pathways and systemic impacts

Field observations reveal clear causal pathways through which plastic pollution generates cascading impacts. Waste accumulation leads to drainage obstruction and ecosystem degradation, which in turn increase human exposure, health risks and economic disruption. These interconnected processes transform plastic pollution from a localized environmental issue into a structural urban dysfunction.

Figure 4. Conceptual framework linking plastic pollution, exposure pathways and multidimensional impacts in Toliara.

4.2. Plastic pollution and urban vulnerability

Plastic pollution exacerbates existing urban vulnerabilities in Toliara by interacting with poverty, informal settlements, limited sanitation services and climate-related stressors. This interaction amplifies exposure of vulnerable populations and transforms environmental degradation into persistent public health and socio-economic risks.

4.3. Structural drivers amplifying impacts

The magnitude of observed impacts is strongly influenced by structural deficiencies in plastic waste management, including irregular collection services, lack of sorting and treatment infrastructure, limited institutional capacity and the persistence of informal waste flows.

Table 3. Structural and social drivers amplifying plastic pollution impacts in Toliara

Driver category	Observed limitations	Consequences
Waste collection	Irregular services	Accumulation in streets and drains
Infrastructure	Lack of sorting facilities	Environmental dispersion
Informal sector	Unregulated waste flows	Health and environmental risks
Social behavior	Low awareness	Persistent pollution
Institutional capacity	Limited funding	Weak control

V. Conclusion

Plastic pollution in Toliara emerges as a multidimensional urban challenge driven not only by environmental pressures, but also by structural, institutional and social vulnerabilities. Its impacts extend beyond environmental degradation to affect public health, livelihoods and urban quality of life. Understanding these interactions is essential for informing integrated and context-specific responses adapted to the realities of coastal cities in the Global South.

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