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CAPTURE – Climate Change Adaptation amid Plastic Waste Transport in the Umgeni River Environment

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ABSTRACT: Plastic pollution threatens wildlife and human health, food safety and quality as well as coastal tourism, and contributes to climate change. The world's rivers serve as conduits for waste and current models calculate up to 2.7 million tons of riverine micro- and macroplastics transported towards the oceans every year. The Durban area in South Africa is particularly impacted by such dynamics. There, five rivers, including the Umgeni River, carry an annual combined 1,340 tons of plastic waste towards the Indian Ocean leading to vast accumulations of particulate matter pollution on Durban's beaches. This paper presents the rationale, outline and preliminary results for a comprehensive multidisciplinary Umgeni River case study focusing on (1) input vectors, fluxes, retention and marine emission of plastic waste in riverine and estuarine habitats; (2) waste minimization, litter prevention and waste valorization strategies involving both the formal and informal waste sectors and (3) quantifying the effect of climate change on the municipal waste infrastructure and ultimately on the communities living near the river. The CAPTURE research program is a pioneering case study into capturing plastic waste "streams" to improve climate change resiliency on the African continent. In addition, this assessment shall serve as a blueprint to tackle similar challenges in other African as well as non-African contexts.

Keywords: Waste Management, Climate Change, Extreme Events, Plastic Waste Hotspots, Aquatic Plastic Waste Collection, Macroplastic, Microplastic, Ocean Emission, Mapping, Participatory Engagement, Modelling, Recycling, uMgeni River

1. INTRODUCTION

1.1 Global Plastic Pollution

With an estimated eight million tonnes of plastic waste entering the world's oceans annually, the accumulation of marine plastic has become a global crisis (Al-Zawaidah, Ravazzolo, & Friedrich, 2021; Jambeck et al., 2015). Plastic pollution threatens wildlife and human health, food safety and quality as well as coastal tourism, and contributes to climate change (Borrelle et al., 2020). The world's rivers are believed to be a substantial vector through which up to 2.7 million tons of riverine plastics are transported towards the oceans every year according to current models (Lebreton et al., 2017; Mai et al., 2020; Meijer, van Emmerik, van der Ent, Schmidt, & Lebreton, 2021; Schmidt, Krauth, & Wagner, 2017). It has been shown that estimates of mismanaged waste, which is potentially available to enter marine systems, are vastly higher than the observations of plastic debris and particles in marine systems can account for (Cózar et al., 2014; Eriksen et al., 2014). Gaps in research (Verster & Bouwman, 2020) suggest that either the amount of mismanaged waste has been over-estimated, or that debris is being retained in various marine and riverine habitats acting as sinks (Verster & Bouwman, 2020). Thus rivers may become a secondary source of plastic to the ocean even after the anthropogenic plastic release has diminished (van Emmerik et al., 2020). This prompts an essential research gap in regard to the amount of plastic in riverine habitats such as riverbanks and riverbed sediment and its retention time. Recent work, among other places, in the South African Orange and Vaal River catchments corroborate this hypothesis suggesting that most of the plastic that enters these rivers does not reach the sea and that dams are not the major areas of plastic retention (Duncan et al., 2020; Tramoy et al., 2020; van Emmerik & Schwarz, 2020; Weideman, Perold, & Ryan, 2019). However, the degree of retention varies depending on river geomorphology, hydrology and other characteristics, as well as the properties of the plastic debris such as types and material density (González-Fernández & Hanke, 2017). Many river systems are governed by vast seasonal precipitation and discharge variation and exposed to climate change-related weather events, which can exacerbate and complicate plastic waste management, while increasing livelihood risks to local communities (Douglas et al., 2008; Laner, Fellner, & Brunner, 2009).

1.2 The Case-Study of the uMgeni River in Durban, South Africa

Durban, a coastal city of South Africa's Kwazulu-Natal province with a population of over 3.5 million people (Figure 1), experiences most pollution challenges faced globally and within the Western Indian Ocean (WIO) region. Litter and dumping are commonplace, weak collection systems characterise impoverished areas, the city has an undeveloped recycling culture and a number of polluted rivers and waterways enter the ocean; five of which, including the Umgeni River, carry an annual combined 1,340 tons of plastic waste towards the Indian Ocean leading to vast accumulations of particulate matter pollution on Durban's beaches (Meijer et al., 2021). The uMgeni River and its urban tributaries, such as the Palmiet River, pass through several flood-prone informal settlements, like the Quarry Road and Johanna Road Informal settlements. Informal communities live side by side to formal middle/low and high-income communities, making the area a relevant case study for climate change adaptation investigations. The uMgeni River and Estuarine System is considered as one of the most polluted riverine habitats in South Africa and a major contributor of plastic waste entering and accumulating in the Indian Ocean (Carnie, 2013; Naidoo, Glassom, & Smit, 2015). The uMgeni, with a length of 230 kilometres and a catchment area of over 4,400 square kilometres, is also historically prone to flooding, a characteristic that has been heightened by climate change, leading to displacement within river-adjacent communities, and a sharp increase in the amount of plastic waste exiting the river mouth and accumulating on Durban's beaches (Chikodzi, Dube, & Ngcobo, 2021; van Marrewijk, Goeijenbier, Hoogerwaard, Hahury, & Gerritsen, 2019). At the uMgeni River, there is urgent need for a thorough and complete understanding of the mechanisms of micro- (<0.5 cm), meso- (>0.5 cm<5 cm) and macroplastic (>5 cm) pollution and the threats to livelihoods, to lead to sustainable solutions in the context of climate change.

Figure 1: Study perimeter of the uMgeni River Durban area. The study perimeter location on the African Continent is indicated by the white box in the left panel; the uMgeni River main stream in the Durban area is depicted by the blue meandering line in the right panel.

Understanding individual pollution sources and how much they potentially contribute to the marine environment provides knowledge and insight on which sources to target to maximise efficient pollution mitigation. Therefore, a coordination between public and private sectors responsible for management at different stages (e.g., land and water), supports the measures and practices required to tackle plastic pollution at relevant scales and locations within the waste stream. Durban Green Corridors, a non-governmental organisation associated within the eThekwini Municipality, has attempted to address this challenge through a series of litter booms within the uMgeni system, meant to trap and remove floating solid waste for proper disposal. However, the project remains in its infancy, and is challenged by several inefficiencies related to design, placement, and implementation of these trapping systems. Moreover, the project has yielded minimal benefit to stakeholders and affected citizens, as valorisation options for retrieved waste plastic have not been adequately explored. Moreover, the system remains extremely vulnerable to climate change-related weather events, and is often damaged by localised flooding, disasters that also threaten vulnerable local communities, which have been forced to adapt holistic but ad-hoc resiliency strategies. Nonetheless, if optimised, the litter boom systems hold great potential to significantly reduce the amount of plastic waste entering the Indian Ocean via the uMgeni and can create significant benefit to local communities through the valorisation of captured waste fractions and the coordination of risk management efforts.

The study is conducted in a collaboration between the SARCHI Chair in WaCC, The Ocean Cleanup research department (collaboration on Phase I of this project), the School of Life Science/Marine Biology at UKZN, the School of Development Studies at UKZN, Durban Green Corridors, the KwaMashu Waste Beneficiation Centre and the eThekwini Municipality. The primary target beneficiaries of the findings of this research are the citizens followed by Municipalities/Local Authorities Officials, Practitioners, SMMES, Scientists, Local/Provincial Government, Policy Makers, Waste Managers and Solid Waste Unit Personnel, Formal and Informal Recyclers, and University Students.

1.3 Research Gaps and Questions, Aims and Objectives

This paper presents the rationale and preliminary results of a comprehensive and multidisciplinary study 2021–2025 using the unique urban case study of the uMgeni River in the Durban region to address three major research gaps: (1) the major input vectors, fluxes, retention and marine emission of micro- and macroplastic waste in riverine and estuarine habitats (in conjunction with assessing and improving aquatic mechanical trapping systems such as the litter-booms); (2) the most promising waste minimization, litter prevention and waste valorisation strategies involving both the formal and informal waste sectors and (3) quantification of the effect of climate change on the waste management infrastructure, on the ability of the city to curb the plastic pollution and ultimately on the communities that live along the river that face constant mini-tsunamis of water and litter during extreme weather events. .

The statement of the three research gap clusters (1–3) above translate into the following research questions:

- Identifying river plastic pollution sources regarding (i) locations; (ii) manner of pollution and (iii) composition of plastic pollution reaching the river
- Investigating the role and quantitative pollution flux effect of riverine habitats acting as (temporary) sinks focusing on (i) riverbanks, (ii) riverbed and (iii) river mouth/tidal zone
- Quantifying cross sectional distribution within the water body: (i) horizontal water surface and (ii) vertical water column
- Assessing total fluxes of plastic pollution from the riverine to the marine domain with consideration to (i) extreme events and (ii) climate change
- How do seasonality and variation of precipitation, river discharge, winds, temperatures impact the mobilisation and transport of plastic debris in the river system?
- What is the potential impact of climate change on environmental waste concentrations, fluxes and river mouth emissions in the uMgeni system?
- What is the transport behaviour of plastic waste into and along the longitudinal axis of the uMgeni estuary system?
- How do abundance and composition of plastic waste compare between shoreline transects of the uMgeni River and the river mouth adjacent beaches on the Indian Ocean coastline?
- How can the litter boom system be optimised to maximise effectiveness?
- What valorisation options exist for captured waste?
- What adaptation and resilience strategies have local communities devised to cope with waste and climate change impacts?
- What tools can be applied towards adaptation and monitoring of waste and climate change in the uMgeni system?

The study is designed in two phases allowing to comprehensively scope (I) an empirical problem quali- and quantification as well as (II) the provision of evidence-based guidance for management decisions for mitigation and remediation. In this first African multi-year research programme, the cascade of actions comprises (i) Mapping, (ii) Testing, (iii) Trapping, (iv) Collecting, (v) Processing, (vi) Modelling and (vii) Community Engaging (Figure 2).

Collaterally, the study will develop innovative waste mapping and characterisation systems through the use of satellite and areal images in combination with artificial Intelligence. The ultimate aim is that of developing an integrated, replicable riverine/marine plastic waste source, transport, retention and final river mouth emission characterisation/mapping, trapping, collecting and valorising system that can be replicated across Southern Africa and the WIO region.

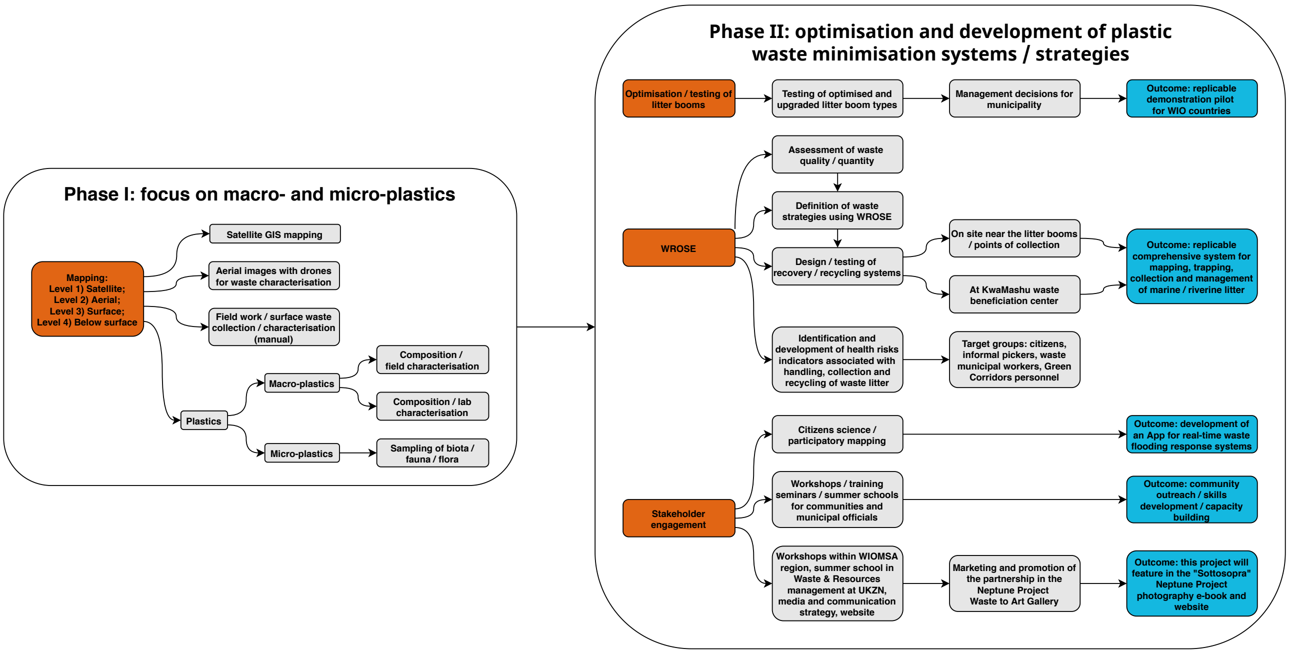


Figure 2: Structure of the two-phased, multi-year CAPTURE research project addressing the environmental dynamics of micro- and macroplastics (I) in the uMgeni River catchment as well as the optimisation and development of plastic waste minimisation systems / strategies (II).

2. MATERIAL AND METHODS

The following section lays out the various systematic and technical approaches taken to derive the data required for exploring the stated research gaps and answering the stated research questions. A core element of the study is to combine a variety of mapping methodologies, including experimental drone technology, Geographic Information Systems (GIS), artificial intelligence (AI), Field sampling and Laboratory analysis of plastics and biota; and participatory mapping with affected communities to map the uMgeni system, with a focus on identifying major waste entry points, dumping hotspots, and spaces vulnerable to climate change-related events such as flooding. These mapping exercises will allow for the optimal spatial arrangement of the litter boom systems, while providing data to support on-going waste mitigation and anti-dumping enforcement activities. The combination of deductive (GIS+AI) mapping with inductive, participatory mapping exercises will allow for the creation of 'smarter' systems that incorporate more responsive inputs. In addition to these mapping exercises.

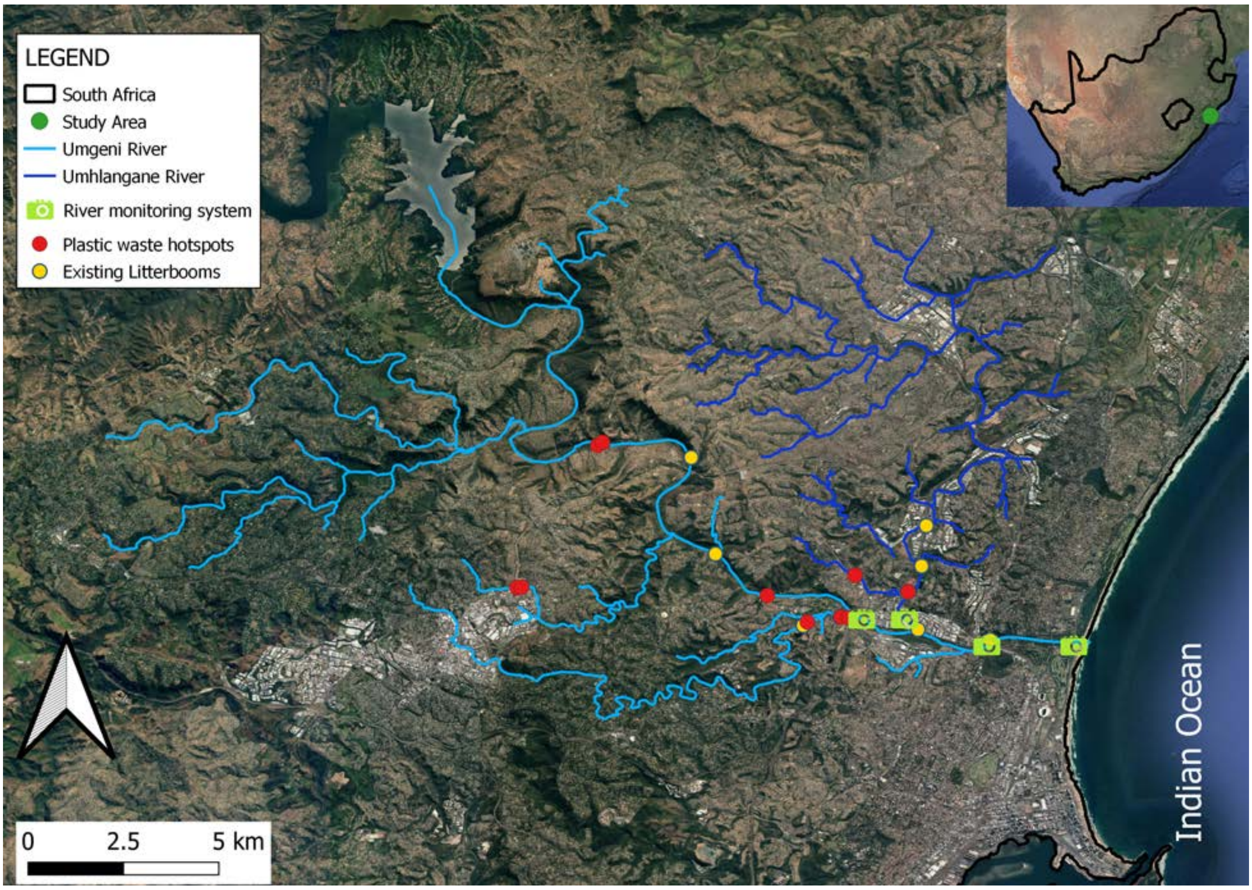


Figure 3: Principal locations of plastic waste transport and hotspot evolution monitoring as well as existing litterbooms deployed by Durban Green Corridors in the uMgeni River and its tributaries.

2.1 Phase I, Mapping and Monitoring Micro- and Macroplastics

Phase I of the study is dedicated to the investigation of the physical layers of the pedosphere and hydrosphere within the relevant study perimeter (Figure 1). This phase involves the (i) Mapping, (ii) Testing and (v) Modelling of the mechanisms of macro- and microplastics pollution sources, waste accumulation hotspots, pathways, fluxes and ocean emissions through interpolation of data acquired through satellite images and GIS sources; airplane and drone-derived footage; river surface camera monitoring and suspended solids sampling; deployment of active GPS and passive waste trackers and sampling on the riverine and marine shoreline as well as in the riverine water column and bed sediments.

In the relevant scopes, consideration is also given to sampled biota and eco-tox levels. Recorded images are processed using machine learning algorithms to recognize and classify plastic debris. Characterization and quantification of litter in the riverine environment will facilitate the design and calibration of a model which will be used to estimate river plastic inputs and their migration. Phase I offers empirical insight into the mechanics of (a) sources, (b) pathways, (c) fluxes and concentrations, (d) deposition and stocks as well as (e) ocean emissions of plastic waste of the uMgeni River within seasonal weather and discharge variation as well as climate change.

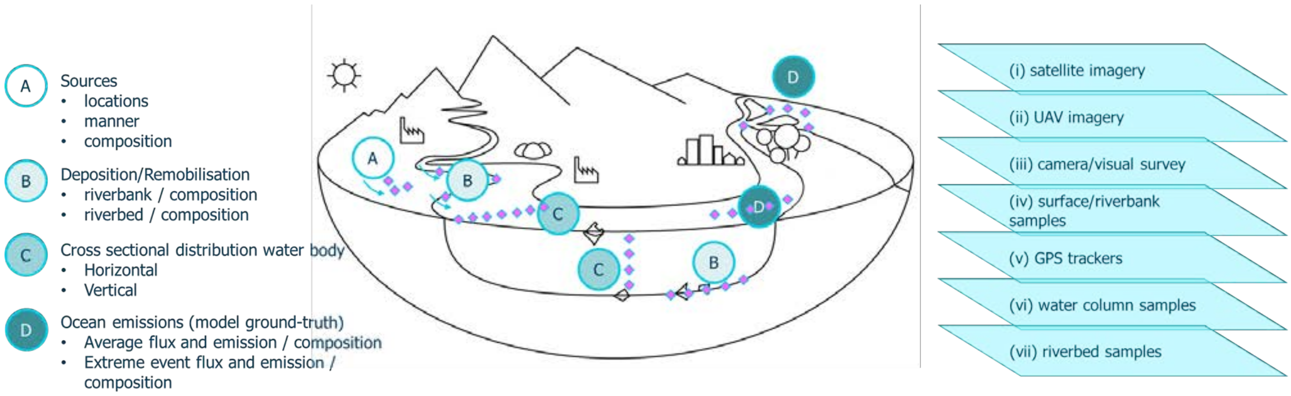


Figure 4: The four focal dynamics for the environmental scientific study of plastic waste in the uMgeni River during Phase I (circles A–D on the left). The focal dynamics are studied through a multi-layer investigation, depicted on the right (I–vii).

2.1.1 Waste Stream Analysis Mapping and Characterisation

Accurately quantifying the sources, distribution, transport and sinks of plastics in the riverine and marine environment requires an understanding of their location in time and space. This study attempts to identify sources of litter contributing most to the uMgeni River and to quantify their different fractions after being dispersed. A mapping exercise of the Umgeni system which combines data acquired by satellites, drones and Geographic Information Systems (GIS) will be carried out with the aim to identify plastic waste entry points, major accumulation zones and the effect on these through weather- and season-induced dynamics. Characterization and quantification of litter in the riverine environment will facilitate the design and calibration of a model which will be used to estimate river plastic inputs and their migration. Generated data will be interpolated with waste composition data collected (manually) on the water surface and with waste characterisation data of macro- plastics.

Mapping and monitoring near river shore waste hotspots – potential drivers of riverine pollution

Through the aid of satellite images and field investigations, the accumulation of terrestrial plastic waste hotspots will be mapped along the uMgeni River section between the Inanda Dam and the Indian Ocean in Durban. Such hotspots may emerge through dumping of mismanaged waste or form as a temporary sink through environmental transport agents such as wind, rain, gravity and terrestrial surface matrix. Rising water levels and the forces of other environmental agents may release proportions of their debris to the water body. A subset of the identified hotspots (n = 10) will be monitored monthly using 3rd generation drones flying systematic and repeated grid flights over the designated areas at 0.5 cm ground sampling distance (Geraeds, van Emmerik, de Vries, & bin Ab Razak, 2019; Papakonstantinou, Batsaris, Spondylidis, & Topouzelis, 2021). Through monitoring over two years, the evolution of the spatial and volumetric extent of these hotspots can be assessed in correlation to the environmental forces governing their transport and potential spillage to the waterbody.

Water surface macroplastics visual and optical surveys

To study flux quantities and horizontal distribution patterns of macroplastics on the river water surface, bridge fastened cameras will be continuously deployed at two bridge locations, near the river mouth and further upstream (van Lieshout, van Oeveren, van Emmerik, & Postma, 2020).The solar-powered cameras featuring a telemetry module for real time image transfer will cover the majority of the river cross sections in their field of view and will be set to capture images at sub-hour intervals (see example image capture Figure 5). To cross-validate the camera data and to deepen the data quality, human surveyors will be deployed at the camera sites regularly to record number and type of debris floating past the cross section (van Calcar & van Emmerik, 2019; van Lieshout et al., 2020).

Table 1. uMgeni River Monitoring System (RMS) current early phase sensor deployment setup

RMS site	Number of RMS	Transect width(m)	Percentage coverage	Bridge Height (m)
RMS_location_1 (M4)	7	150	40%	10-15
RMS_location_2 (R102-railway)	6	62	100%	10-15
RMS_location_3 (M21-Inanda_Rd)	1	30	30%	1-10
RMS_location_4 (N2_bridge)	1	40	25%	10-20

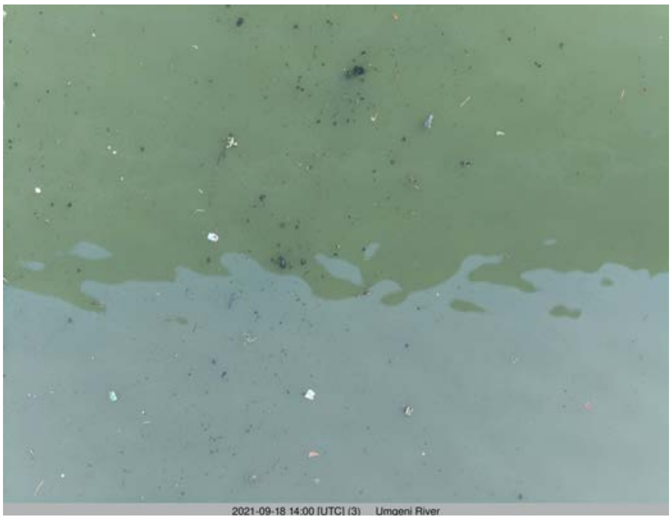


Figure 5: uMgeni River water surface captured from a stationary bridge fastened camera upstream of the Blue Lagoon in Durban, South Africa. Visible debris consisting of biogenic (e.g. leaves) and anthropogenic (e.g. plastic waste) matter.

Riverbank and Marine Beach Micro – and Macroplastics Surveying

To study stocks, accumulation, deposition and remobilization of macroplastics, each four riverbank and marine beach transects of 50 m will be surveyed monthly by cleanup (Ryan, Moore, Van Franeker, & Moloney, 2009). By comparing abundance and composition of riverine and marine beach transects, the question of riverine contribution to beach pollution may be addressed.

Assessment of longitudinal debris transport dynamics using GPS-trackers

To assess lateral and longitudinal debris transport behaviour 20 disguised GPS trackers (Duncan et al., 2020) will be periodically re-deployed and collected at several month intervals. Trackers will be simultaneously deployed and recovered from the river system after >12 months for each campaign (Tramoy et al., 2020). This experiment is intended to inform about the connectedness of various river sections to each other with regard to macro debris transport by using the trackers as proxies for macroplastic waste. Furthermore, the erratic impact of high discharge and flooding events on the transport dynamics of suspended anthropogenic debris shall be investigated this way.

Micro- and Macroplastic Debris Sampling and field characterisation

The floating, suspended and deposited Micro- and Macroplastics fractions will be enumerated at ten locations along the river on the water surface, in the water column and in the riverbed sediments and of the uMgeni River, upstream and downstream of litter booms, in concert with sampling for biota. Samples will be taken using pumps, nets and sediment corers; surveys will be conducted monthly, including an immediate before and after boom installation phase. The investigations will cover periods of both high and low flow as well as varying weather events (rain and wind) and seasons. Additional surveys may be conducted opportunistically in the event of extreme weather events. Retained Plastics will be counted and characterised by size and shape under a microscope after being stained with Nile Red. Characterisation of plastic polymers, if deemed necessary will be conducted using FTIR spectroscopy.

A preliminary field-based waste characterisation was conducted during 2020 at two operational litter-booms, namely, the Johanna Road and SPCA litter-booms, data was also correlated with historical data collected by DGC at other litterbooms.

Waste stream analysis was carried at the booms for the selected intervals of 7 days to provide a "snapshot" characteristic analysis of the waste found in the river. The total waste removed from the booms per day were measured and recorded into the following categories: Glass, Cardboard/Paper, Organic/ Vegetative matter, Metal, Textile, Rubber. Plastics were categorised into: PETE, HDPE, PVC, LDPE, PP, PS, OTHERS, Residual.

The data was tested using the Kolmogorov–Smirnov test. A non-parametric Mann-Whitney U test was used to determine if a significant difference in the quantity of waste exists between the two litter-booms.

PET data from the onset of 2020 was then projected alongside precipitation data which was provided by the eThekwini municipality. The precipitation datasets were collected from the Kennedy Road weather station within a 2km range from the study site. The data was then subjected to SPSS testing to determine if a correlation between rainfall events and the quantity of PET waste exists. A non-parametric Kendall's tau b statistical test was used to indicate the correlation. Probability values $p < 0.05$ was considered to show any correlation. To further illustrate areas that can be affected by climate change events, a map indicating the 100-year flood plain was projected using ArcGIS v10.4.

2.1.2 Biological Sampling and Analysis

Biota/Fauna will be sampled at a number of distances upstream and downstream of the litter booms. Sampling will focus on riverine invertebrates following the methods of the SASS (South African Scoring System) version 5 (Dickens & Graham, 2002), with the exception that the fauna of marginal vegetation will not be sampled. Both benthic and planktonic invertebrates will be collected. The sampling design will allow for temporal and spatial variability in fauna. Sampling will be conducted before the installation of booms and additional samples will be collected one week, one month, three months and 6 months after their installation. Fauna will be sampled at a number of sections upstream and downstream of the booms on each occasion. Where possible, samples will be collected and compared between 'old' and newly designed, improved booms. 2) Since fish are often more sensitive to changes in flow than invertebrates, riverine fish will also be sampled by electro-fishing, seine netting or cast nets (Evans, 2017). The Fish Response Assessment Index (FRAI) (Kleynhans, 2007) will be used to assess the health of fish assemblages at each site. In addition to collection of fauna, several physical and chemical properties of the water, including oxygen level, turbidity and conductivity will be measured during each sampling.

2.2 Phase II Optimisation and Development of Plastic Waste Minimisation Systems / Strategies

Phase II is targeted at providing evidence-based guidance for pollution and climate change related risk mitigation and remediation through the optimisation of waste (iii) Trapping, (iv) Collecting, (v) Processing, (vi) Modelling and (vii) Community Engaging. Modelling in this context is directed at the development of strategies for the collection and management of the plastics using the WROSE model (Waste to Resource Optimisation and Scenario Evaluation Model) developed by the SARCHI Chair Waste and Climate Change at UKZN to assist municipalities in the waste management decision-making process. Additionally, the study interfaces artificial intelligence GIS-based systems with real-time waste-flooding response systems, to assist the community with early warning systems for flooding, but also, by enabling the community, through the system of participatory mapping, to create a feedback-driven response system for riverine/marine litter and plastics entering the river catchment. We believe that this feedback-driven system (smartphone application) will enable the community and the municipality to direct collection systems and/or trapping systems that will be more efficient in the handling and collection of the marine/riverine litter.

2.2.1 Waste Valorisation Options

This Phase includes a series of desktop studies and laboratory experiments, which will examine contextually appropriate waste valorisation strategies for the various waste fractions captured by the litter boom systems. Each strategy or technology will be evaluated based on a number of factors, including its ability to minimise climate change contributions, generate maximum return on investment, and provide benefit to local communities. The research team will also apply the Waste Resource Optimisation and Scenario Evaluation (WROSE) model (Trois and Jagath, 2011; Kissoon and Trois, 2019), in order to evaluate different adaptation and valorisation scenarios. This phase will culminate in the selection of an experimental technological solution that will be developed into a pilot-scale material recovery facility in order to demonstrate proof of concept and provide instruction for scaling up and application within the uMgeni system and nearby township.

2.2.2 Redesign and Pilot Deployment of Litter Boom Technology

This activity focuses on the re-engineering of the existing litter boom design in order increase resiliency, cost-effectiveness, and efficiency. This Phase will also see a pilot deployment of the new design, including testing, monitoring, and improving, before being rolled out throughout the uMgeni system (Figure 6).

Figure 6: Examples of litter-booms deployed in the uMgeni River.

3. PRELIMINARY RESULTS AND DISCUSSION

Preliminary results of the project refer to the piloting and mobilisation phase. By visually screening Sentinel and open source Google Earth satellite imagery of the study perimeter, and by following up in ground truthing missions using visual and drone base verification, a list of 26 relevant waste accumulation sites (hotspots) have been identified for evolution monitoring over the course of the project (see excerpt of unweighted decision factors in Table 2). After finalising the ground truthing missions, weighting the factors and calculating the relevance, the Hotspot list is shortened to n = 10 for the monitoring phase of this project.

Table 2. uMgeni River Hotspot (waste accumulation sites) identification. Spillage possibility is based on litter accumulation within 35-metre distance from a water body with high chances of entering the waterbody. Hotspots

with consistent litter accumulation (visible on satellite images 2019–2020) and high spillage possibility were chosen for monitoring, these are marked with *.

Hotspot location	Land_use	Settlement Area	Distance to River/ Tributary (m)	Spillage possibility
Clermont_1	Residential_housing	Formal	200	low
Clermont_2*	Residential_housing	Formal	10	high
Clermont_3*	Commercial_industrial	Formal	11	high
New_Germany_3	Commercial_industrial	Formal	70	low
New_Germany_4	Commercial_industrial	Formal	8	high
Westville_2	Residential_housing	Informal	37	low
Westville_4	Residential_housing	Informal	70	low
Westville_5	Residential_housing	Informal	55	low
Palmeit_1	Residential_housing	Formal	135	low
Palmeit_2	Residential_housing	Formal	52	low
Parlock_2*	Residential_housing	Formal	10	high
Quarry_road_settlement_1	Residential_housing	Formal	27	low
Quarry_road_settlement_2	Residential_housing	Formal	70	low
Quarry_road_settlement_3*	Commercial_industrial	Formal	35	high
Quarry_road_settlement_4	Commercial_industrial	Formal	70	low
Reservoirhills_1*	Commercial_industrial	Formal	24	high
Reservoirhills_2	Residential_housing	Informal	70	low
Kwadabeka_4*	Residential_housing	Informal	28	high
Kwadabeka_5*	Residential_housing	Informal	31	high
N2_Umgeni_interchange_1	Residential_housing	Formal	31	high
Reservoirhills_3*	Residential_housing	Informal	10	high
N2_Umgeni_interchange_2	Residential_urban	Formal	31	high

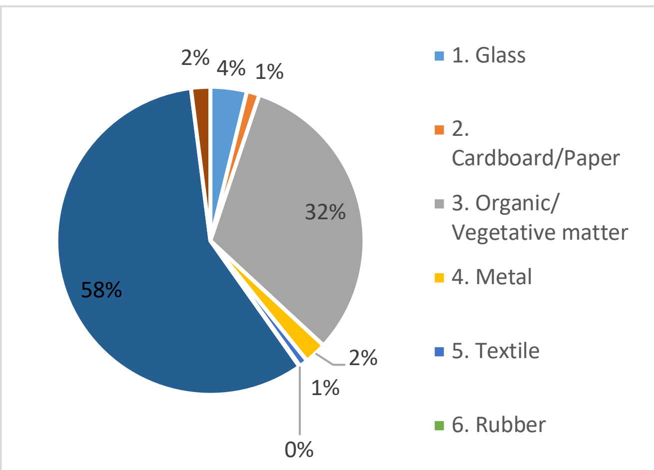
Clermont_4	Residential_housing	Formal	41	low
Reservoir_Hills_4*	Commercial_industrial	Formal	33	high
Reservoir_Hills_6	Residential_housing	Informal	2	high
Sea_cow_Lake*	Residential_housing	Informal	5	high

To approximate the movement patterns of plastic waste items in the Umgeni River, two GSM/GPS trackers were inserted into plastic containers the devices were deployed 14 km upstream of the uMgeni River mouth on 19/05/2021. The active tracking system has a potential offering towards understanding the movement patterns, accumulation zones and retention time of floating plastic debris in river systems. Device 1 travelled about 140m from the deployment site and was retained on a rocky patch for a month and a week before being removed from the river through suspected human activity. This indicates that rocky and vegetated areas have the potential to retain plastic debris as highlighted in previous studies (Al-Zawaidah et al., 2021, Martin et al., 2019). Device 2 travelled about 650m away from the deployment site before losing connection. Van Emmerik et al. (2019) report that distance travelled by plastic debris are influenced by the river discharge of which in this case, the month May falls under the dry season in Durban, hence low discharges are expected and as result there is minimal movement of debris. To get an improved understanding of the plastic debris movement patterns in the Umgeni River, future investigations will aim at deploying connection-refined trackers in both the dry and wet season.

Table 3: GSM/GPS tracker pilot experimental results

Device name	**Deployment date**	**Distance travelled (m)**	**Fate**
Device 1	19-May-2021	140	Found by Public
Device 2	19-May-2021	650	Unknown/No Connection

The results of the waste characterisation are reported in Figures 7 and 8. The Johanna Road and the SPCA litter-booms capture a weekly average of approximately 347kg and 41 kg of all waste streams, respectively. The percentages of waste trapped by these two litterbooms are presented in Figures 7 and 8.



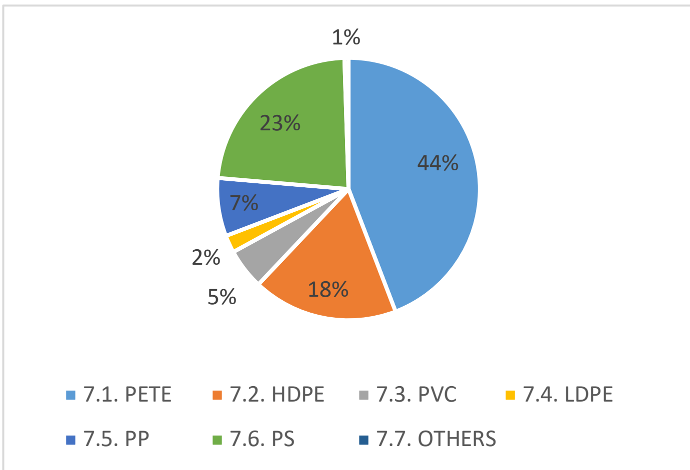


Figure 7: a) Waste composition and b) Plastics proportion at the Johanna Road Litter-boom

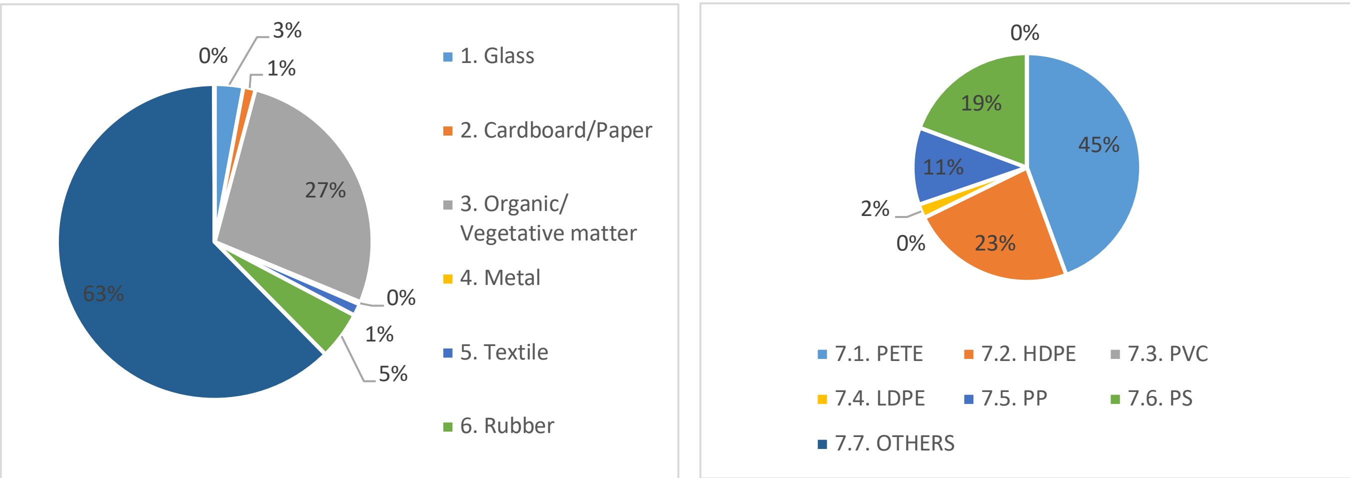


Figure 8: a) Waste composition and b) Plastics proportion at the SPCA Litter-boom

The large proportion of organic waste is due to large portions of the riparian zone being removed due to human activities along the river and the dumping of garden matter by neighbouring homes into the water body. These high amounts of organic waste can threaten the water body resulting in eutrophication and eventually hypoxic conditions.

An analysis of the 100-year floodplain shows that a large portion of industrial, residential areas and commercial zones fall within the range of the floodplain.

To establish if a correlation occurs between PET waste and rainfall events, data collected from the Johanna Road litterboom was graphed on the same axis as rainfall, as shown in Figure 9. This data does not indicate a clear correlation; however, the graph indicates that during spike events in rainfall, the mass of PET also rapidly increases.

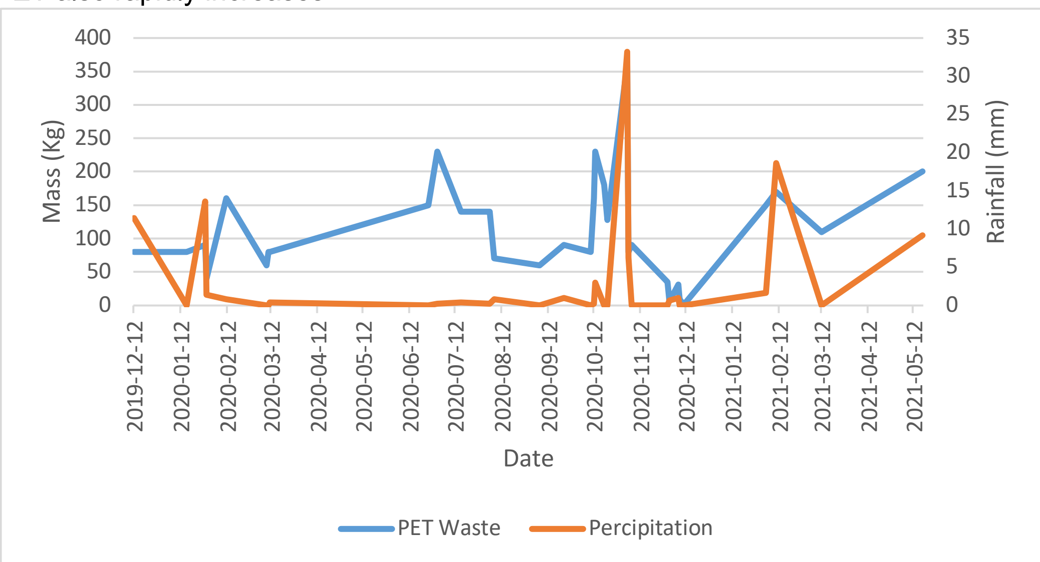


Figure 9: Correlation between rainfall and PET waste trapped at Johanna Rd Litter-boom.

4. CONCLUSIONS

The overall aim of the research is to use the uMgeni river system as a case study to quantify the stresses and effects of climate change on the waste management system in a large South African city. Moreover, the study aims at creating an optimised waste minimisation, litter prevention and waste valorisation system within the river catchment through community engagement and capacity building. The project will enable to develop an optimised litter-boom system and a replicable risk-management and climate change mitigation/adaptation strategy for extreme weather prone areas that takes in consideration the combined effect/impact of solid waste (plastic and marine litter) and water. This study features a strong environmental scientific focus covering the physical world aspects of pollution accumulation and environmental transport. Future scenarios of the research will focus on mapping the waste "hotspots" through remote sensing and drone imagery. These data will be correlated with a closer look at waste composition in relation to seasonality and insurgence of extreme weather events.

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