Solid Waste Management in Rural Areas of the Global South: Multidimensional Analysis Framework Creation

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AD MAIORA

ABSTRACT

Solid Waste Management represents a challenge for human livelihood in the future. Particularly, uncontrolled waste and its threat to public health and the environment, due to the pollutants released from dumping sites and open-air burning, creates roaring concern in a growing human population with a forecasted increase in waste production. Although uncontrolled waste is potentially found anywhere globally, countries in the Global South are more affected, with rural areas within being more vulnerable and exposed to their presence. Different studies conducted in rural communities of the Global South point to a combination of factors and elements that affect waste management in these contexts. However, these studies are few in number and different in terms of objectives, format, and methodologies, hardly comparable to each other. This thesis aims to fill this gap by proposing a standardised and uniform analysis framework constructed in a multidimensional research model comprising dimensions such as: legal, socio-political-economic, infrastructural, and knowledge-behavioural. This framework is built through the combination of the findings from previous studies and the input of researchers and practitioners who have been researching and working in solid waste management in rural communities of the Global South. The framework is later applied to the case study of Gandiol, a rural community in Senegal affected by uncontrolled waste, focusing on household waste within the community. The framework application provides a detailed overview of the main aspects of the whole waste process, from the legal framework to national initiatives, from household waste practices to municipal and regional activities for disposal. Therefore, this research provides a new investigation tool to collect data in contexts where data are scarce, to enhance data collection and comparability among different communities, with the aim to provide researchers, practitioners, and institutions, support in designing sustainable solutions for these communities.

 Keywords:

Solid Waste Management; Rural Areas; Global South; Gandiol; Senegal; Sustainability; Household Waste; Multidimensional Analysis Framework;

ABBREVIATIONS

3R Reduce, Reuse, Recycle

CFA *Communauté Financière Africaine*

EPR Extended producer Responsibility

EU European Union

GIE *Group d'Intérêt Économique*

GIZ *Deutsche Gesellschaft für Internationale Zusammenarbeit*

HDPE High-Density Polyethylene

HICs High-Income Countries

IW Industrial waste

LMICs Low-middle Income Countries

MSEs Micro and Small Enterprises

MSW Municipal Solid Waste

MW Medical waste

NGOs Non-Governmental Organisations

PET Polyethylene Terephthalate

PGDSU *Projet de Gestion Durable des Déchets Solides Urbains*

PNGD *Programme National de Gestion des Déchets*

PP Polypropylene

PPP Polluter-Pays Principle

PROMOGED *Projet de Promotion de la Gestion Intégrée et de l'Économie des Déchets Solides au Sénégal*

SDGs Sustainable Development Goals

SOMETA *Société Métallurgique d'Afrique*

SONAGED *Société Nationale de Gestion Intégré des Déchets*

SWM Solid Waste Management

TA Thematic Analysis

TEOM *Taxe d'Enlèvement des Ordures Ménagères*

UCG *Unité de Coordination de la Gestion des déchets*

UN United Nations

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

WB World Bank

WEEE Waste electrical and electronic equipment

WFD Waste Framework Directive

WHP Waste Hierarchy Principle

WTE Waste-to-Energy

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Chapter 1. Introduction

1.1 Solid Waste, Health-Related and Environmental Risks

The term waste derives from the Latin concept *res derelicta*, i.e. abandoned object (Mustofa, 2020); essentially, it is the unintended by-product of consumption and production (United Nations Environment Programme, 2024). Its most general classification follows the state of matter: solid, liquid, gas. As such, waste is divided into solid waste, liquid and gas waste. Solid waste comprises different subcategories based on its origin: municipal, agricultural, construction and demolition, industrial and commercial, and healthcare waste (UNEP, 2024). With an increasing world population of over 8 billion as of 2024, projected by the United Nations (UN) to reach 9.8 billion in 2050 and 11.2 billion in 2100, the amount of solid waste produced on the planet will grow simultaneously. Solid waste is expected to grow twice as fast as the population growth in the next few decades (Jardosh & Kathuria, 2022). Human activities have always generated waste, but with urbanisation and the creation of large conurbations it has become a serious problem. With the evolution of science and technology, the increasing amount of waste generated has been processed through an organised, specialised and complex activity (Giusti, 2009), known as waste management.

Whereas solid waste is adequately managed, it is defined as 'controlled', if it is collected to be recycled or disposed of in a controlled facility. If it is not collected, and therefore 'not-controlled', it is either dumped and burned in the open by the waste generator (UNEP, 2024). These are dangerous practices that link waste management in a very close tie with the so-called three planetary crises: climate change, biodiversity loss, and pollution. On one hand, it is necessary to consider that transporting, processing and disposing of waste generates CO_2, thus having by any means an environmental footprint (UNEP, 2024). On the other hand, this feature is further exacerbated by the open burning of waste which releases black carbon (soot) that settles on the surface of sea ice that contributes to the acceleration of sea ice melting, hence, having a strong contribution to current global warming (UNEP, 2024). Estimates suggest that solid waste contributes approximately 5% of the overall emissions (Gautam & Agrawal, 2020). Indiscriminate waste disposal practices affect soil, water bodies and the air, by introducing hazardous substances and threatening the livelihood of flora and fauna, participating in biodiversity loss. Open burning of waste releases Unintentional Persistent Organic Pollutants, 'forever chemicals' that persist in the environment and have significant negative effects on human health and the environment (UNEP, 2024). Humans are exposed through direct dermal contact with waste, inhalation of contaminants via air pollution, and direct or indirect ingestion of contaminants via pollution of water, soil, or plants, and accumulation of pollutants in the food chain (Vinti et al., 2023). Products deliberately

dumped in the environment, such as chemical fertilisers and pesticides, pose a risk to humans and the environment if not managed or disposed of properly (Senekane et al., 2020). Chemicals leached from some plastics used in food beverage storage are harmful to human health, increasing the chances of developing cancer, cardiovascular system damage, adult-onset diabetes, obesity, early puberty and resistance to chemotherapy (Nxumalo et al., 2020).

Figure 1 by Ferronato & Torretta (2019) summarises waste types by sources and the effects arising from uncontrolled practices, such as open dumping and open burning.
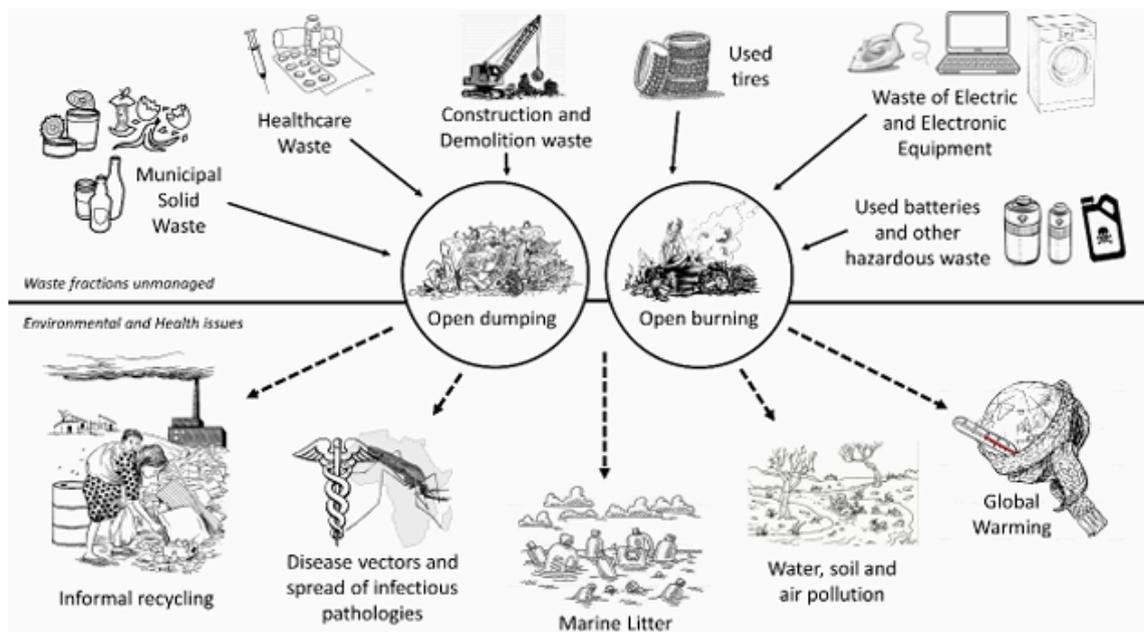
Figure 1.   Waste Sources and Contamination. Source: Ferronato & Torretta, 2019

Solid waste is thus directly impacting public life, due to the threat that its mismanagement poses to public health and the environment. Together with its impact on climate change and global warming, SWM has always been closely associated with the notion of sustainability and several studies linked it to some of the Sustainable Development Goals (SDGs). UNEP (2024) showed how SWM is actually related to all of the 17 (Fig. 2).

SUSTAINABLE DEVELOPMENT GOALS

Goal 1. No poverty: Waste workers in informal economies who have no health or social protections are vulnerable to exploitation and are paid only the material value of the materials they collect. Inclusive municipal waste management policies are most effective for addressing both poverty and pollution.

Goal 2. Zero hunger: While global hunger is increasing, one-third of all the food grown in the world is wasted. Hunger can be reduced by preventing food waste and redistributing excess food. Converting unavoidable food waste into compost can replenish depleted agricultural soils.

Goal 3. Good health and well-being: Communities without adequate municipal waste management services resort to dumping and open burning, both of which have significant negative health consequences, particularly for women and children.

Goal 4. Quality education: Waste management courses in tertiary and higher education are uncommon, resulting in a lack of professional technical capacity and a shortage of workers with appropriate skills and knowledge.

Goal 5. Gender equality: People's experience with waste and its management is gender-differentiated: e.g. household purchasing and domestic waste-generating activities, and levels of influence over community decision-making regarding waste collection services.

Goal 6. Clean water and sanitation: Pollutants leaching from dumpsites can contaminate freshwater sources and associated food chains. Meanwhile, combining municipal solid waste and container-based sanitation services can achieve economies of scale that make both services more attractive to investors.

Goal 7. Affordable and clean energy: Unavoidable food waste can be used to make biogas, a clean-burning renewable fuel that could be used to tackle energy poverty, including in off-grid communities.

Goal 8. Decent work and economic growth: The waste management and recycling sector is uniquely positioned to improve global resource efficiency, decouple economic growth from environmental degradation, and provide safe and decent work opportunities for all.

Goal 9. Industry, innovation and infrastructure: Decentralised waste management systems can attract private sector investment, encouraging innovation, entrepreneurship, domestic technology development, greater resource efficiency and increased employment opportunities, and reduce financial risks for governments and municipalities.

Goal 10. Reduced inequalities: Intragenerational and intergenerational inequalities must be addressed through developing waste and resource management systems; attention is required from all stakeholders because the transition to a more circular economy will not occur by default.

Goal 11. Sustainable cities and communities: Solid waste management is a basic utility service without which air quality and living conditions become degraded, leading to poor health and social discontent. To make cities and communities inclusive, safe, resilient and sustainable, universal access to municipal waste management services is essential.

Goal 12. Responsible consumption and production: Production and consumption patterns directly impact municipal waste generation. To reduce waste and prevent pollution, efforts are needed by companies, governments and citizens.

Goal 13. Climate action: Poorly managed waste generates a wide range of emissions that contribute to climate change, most significantly methane from landfills and dumpsites, and black carbon and a range of other emissions from the widespread practice of the open burning of waste.

Goal 14. Life below water: Understanding why and how land-based waste reaches the sea, and introducing mitigation measures, is essential. Urgent action is particularly required in the case of Small Island Developing States, which face a complex set of waste management challenges.

Goal 15. Life on land: The terrestrial environment continues to be the primary sink for waste, while rural communities face complex waste management challenges that if left unmanaged can significantly impact ecosystems and dependent livelihoods.

Goal 16. Peace, justice and strong institutions: The increasingly global nature of waste management calls for heightened international cooperation to build national capacity for the safe management of hazardous waste and to prevent its illegal trafficking.

Goal 17. Partnerships for the Sustainable Development Goals: Current investments in waste management are insufficient. Far higher investments will be needed in the future to cope with increasing waste generation and the accumulation of legacy waste. The return on investment for waste management needs to be realised to catalyse increased finance.

Figure 2.   Waste Management and Its Value for Each of the 17 SDGs. Source: UNEP, 2024

1.2 Locating the Criticality: Global South and Rural Areas

Uncontrolled waste is a feature encountered around the world, whose effects, even though generated locally, have an impact elsewhere, carried by waterways, deposited on terrestrial surfaces, and accumulated in the atmosphere; uncontrolled waste has "*no borders*" (UNEP, 2024). However, its distribution is not equal. Waste management varies significantly around the world: while Europe and North America typically manage waste in a controlled manner, Africa and Central Asia are distinguished by a widespread uncontrolled handling system (UNEP, 2024). In general, low-middle-income countries (LMICs) account for a third of the total amount of waste generated: in the case of Africa for instance, waste is expected to triple by 2050 (Salvia et al., 2020). Unlike high-income countries (HICs), whose recycled share of the total waste amount is around 51%, LMICs recycle approximately 16% of the total. The indicator that better shows the gap between the two blocks is the percentage of waste disposed of in open dumps: HICs only dispose of 2 % of their waste in open dumps, while in LMICs the level is at 93% (Shovon et al., 2024), outlining the higher presence of uncontrolled waste in these countries. Not only uncontrolled waste is unequally distributed between the Global North and the Global South, but there is a further division within its internal allocation: between urban and rural areas. As of 2018, an estimated 45% of the world's population was living in rural areas, which is about two-thirds of people living in LMICs (Vinti & Vaccari, 2022). The regions with the lowest collection rates (Oceania, Central and South Asia, and Sub-Saharan Africa) are those with the lowest urbanisation rates as well. According to the analysis conducted by UNEP (2024) at least 2.7 billion people do not have their waste collected, with 2 billion living in rural areas and 700 million in urban areas. Although on one side the waste generations in rural areas of LMICs tend to be lower, as a matter of poverty, lifestyle and resource consumption (Vinti & Vaccari, 2022), and on the other, the urbanisation trend predicts a growing number of people living in urban areas (World Economic Forum, 2019), understanding the challenges of rural areas' inhabitants and waste management is nonetheless relevant. This is because these are the areas where most of the uncontrolled waste is produced and disposed of, causing environmental threats locally and globally. Also, the challenges experienced in rural communities in the Global South concerning solid waste management often represent "*a critical and underrated topic*" (Vinti & Vaccari, 2022).

1.3 Senegal, Gandiol and Household Waste Management

In Senegal, a country in the Global South, rapid population growth, the adoption of modern consumption patterns and the increasing complexity and diversification of waste composition, resulted in the massive dispersion of pollutant waste products in its environment. Waste is one of Senegal's leading sectors in terms of CO2 emissions (Sabatier, 2023). Currently, national plans for an integrated waste management approach are being implemented and projects for waste treatment and valorisation are being conducted to build necessary infrastructure. However, there are persisting disparities and inequalities as the waste situation is extremely diverse across the country, between Dakar and other cities, between poor and rich neighbourhoods within the same city, between urban and rural areas (Sabatier, 2023).

Gandiol is a rural community located over the Northern Atlantic coast of Senegal. This community has been affected by human-driven natural disasters in the early 2000s, with effects that are persisting nowadays on a social and economic level. In addition to the impact of coastal erosion and its effects, Gandiol is experiencing issues with uncontrolled waste and the related hazard that it poses to public health and the environment.

Particularly, there is the presence of dispersed household waste within the community. Household waste, resulting from household activities and consumption, is either brought from other urban areas by the flow of the Senegal river, or dumped by inhabitants, and burned in the worst case scenario.

1.4 Research Model: The Four Dimensions

Solid Waste Management is a multidimensional issue. Several elements are associated with it, for instance, sanitation, public health, climate change, poverty as well as the peculiarities of the local contexts, such as socio-cultural and political dynamics (Chammas et al., 2020). Different stages constitute a sequence of events that determines the whole process (generation; collection, transfer, and transport practices; treatment; disposal; recycling) and several aspects are intertwined (technical; environmental; financial; socio-cultural; institutional; legal) (Chammas et al., 2020).

To explore this complexity, this research proposes a model to conceptualise the different factors and challenges into four dimensions that encompasses all of them: legal, socio-political-economic, infrastructural, and knowledge-behavioural (Fig. 3).
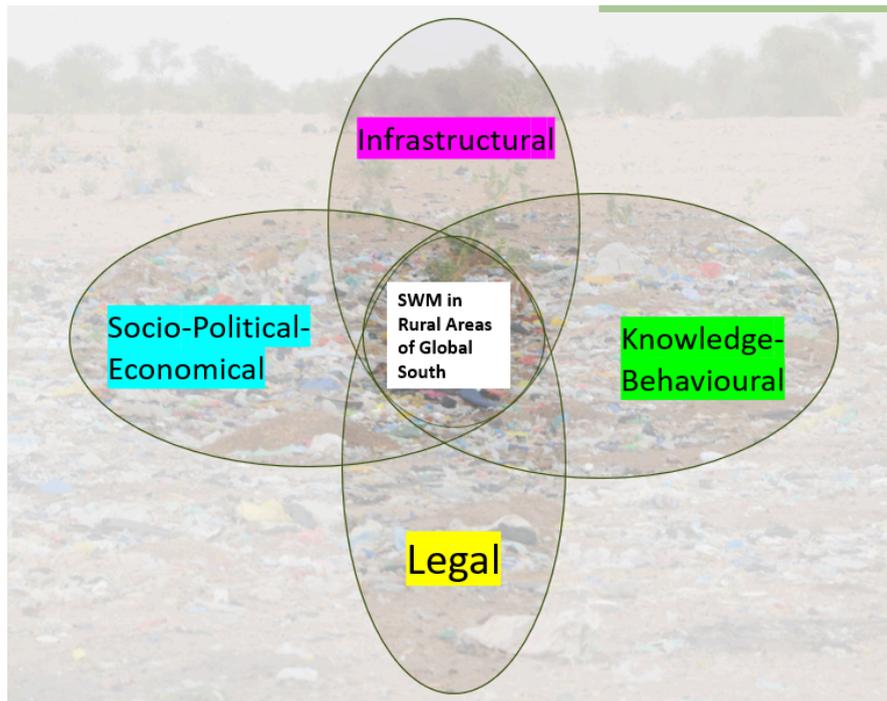
Figure 3.　　　Research Model: The Four Dimensions

1.5 Research Objectives

Since solid waste management in rural areas of the Global South is critical and underrated, but also potentially perilous for the communities exposed to uncontrolled waste, the main objective is to understand the factors and challenges that interplay in the complexity of waste management in rural areas of the Global South to address any research gap in order to contribute to the efforts in designing alternative sustainable solution to uncontrolled waste. In addition to this, additional objectives are:

- Research on the topic within a multidimensional perspective as an attempt to combine elements from different disciplines to understand how aspects of social, political, economic, infrastructural, legal, and behavioural nature, are interrelated and intersected in these communities;

- Outline the main features of solid waste management in Senegal, waste production, framework, and current waste initiatives and strategies; contextualise the research within the rural community of Gandiol, presenting local practices, infrastructures and stakeholders

and report data from the inquiry on their household waste management in a detailed and structured form;

● Contribute to the efforts to create sustainable waste management systems against waste pollution, providing analysis methods and structures to compare and evaluate waste management overviews to enhance the formulation of possible context-based solutions.

1.6 Research Structure

The research is articulated in the following 6 chapters.

Chapter 2 first describes what is waste management and how it is regulated; then, it contextualises the research under two layers, rural areas and Global South, introducing the state of the art over research on solid waste management in rural areas of the Global South. Once the literature has been reviewed, research gaps are identified and research questions are formulated.

Chapter 3 presents the research methods adopted to conduct the study to meet the research objectives.

Chapter 4 provides an overview of waste management in Senegal, displaying information on data on national waste production, legal framework, and waste initiatives undertaken by the country in recent years to tackle uncontrolled waste. Following, the case of Gandiol is presented in further detail.

In Chapter 5, the analytical tool called Multidimensional Solid Waste Management Analysis Framework is created through the methods described in Chapter 3.

In Chapter 6, the analysis framework is applied to the rural community of Gandiol, where data on waste management practices and public perception has been collected. Results are shown and analysed to grasp an insight over the waste management situation in Gandiol.

Chapter 7 concludes the research highlighting the relevance of the study and the benefits of its replicability, including its limitations and bringing forward further development and future directions.

Chapter 2. State of the Art: Solid Waste Management in Rural Areas of Developing Countries

This chapter serves to have a comprehensive knowledge of the issue at hand and to identify the challenges experienced on a local level within rural communities of developing countries. Firstly, this chapter outlines the basics of solid waste management. Secondly, it discusses peculiarities of SWM in Global North vs. Global South; thirdly, it narrows the focus on rural vs. urban areas in the Global South, and lastly it examines fieldworks conducted within these contexts in the last years by dividing their findings into four dimensions: infrastructural, socio-political-economic, legal, and knowledge-behavioural.

2.1 Understanding Solid Waste Management

2.1.1 Waste Categories

Waste management can be defined as all the activities dedicated to the handling of waste (van Velden, 2023). Waste is a result of any production and consumption process, and it needs accompaniment to be managed, and reduced, and to decrease its pollutant hazard. According to the subject or the institution of reference, waste is classified differently. The structure outlined here mostly reflects the work of Chang and Pires (2015) in their book *Sustainable Solid Waste Management: A Systems Engineering Approach,* where they state that *"waste characterization is fundamental".* Solid waste, defined by its inherent state of matter and divided so from liquid and gas waste, can be defined by its source, nature, physical and mechanical properties, chemical and elemental properties, biological/biodegradable properties, and combustible properties. The main sources generally identified are municipal solid waste (MSW), industrial waste (IW), medical waste (MW) and other types of waste that do not belong to the former categories. MSW, for instance, encompasses household waste, commercial waste, and institutional waste. Industrial waste is an umbrella term that refers to waste generated within productive activities, such as manufacturing, construction and demolition activities, refineries, chemical, automotive, energy, mining, and agriculture. Medical waste refers to waste obtained from medical facilities. These categories serve to identify the owner and producer of waste as well as their different components. SWM nature can be differentiated as hazardous waste, when there is at least one element that is hazardous for public health or environment, inert waste when it does not experience any physical, chemical or biological transformation, non-hazardous when there is no hazardous feature prior to physical, biological or chemical transformations. The physical properties related to waste include its density, moisture content, heat of waste and calorific value. Biological and biodegradable characteristics

are concerned with microorganism cultures existing in waste and how they use waste materials to survive.

Taking household waste as an example, typical components and fractions are plastics, paper and cardboard, organic waste, textiles, aluminium, ferrous materials, glass and wood. Its composition depends on some factors, such as economic development level, educational level and managerial-related factors. In addition, climate factors such as weather conditions or seasonal events, like public holidays, influence its composition (Chang & Pires, 2015).

2.1.2 Waste Hierarchy and System Process

Japan has been described as the pioneer in defining principles of waste management by introducing a 3R (Reduce, Reuse, Recycle) initiative for the scientific disposal of waste (Chang & Pires 2015; Mustofa, 2020). Reducing reflects the attempt to limit the consumption of items that would be discarded after, reusing is the multiple use of substances or parts of substances already in use and recycling is described as the use of waste itself as wealth (Mustofa, 2020). These three principles point to the same goal: avoid waste generation. With this concept, waste is regarded as the only fraction of materials that cannot be reintroduced in human consumption and thus destined for landfills, as visible from the European, American, and International paradigms in Figure 4 (Chang & Pires, 2015).
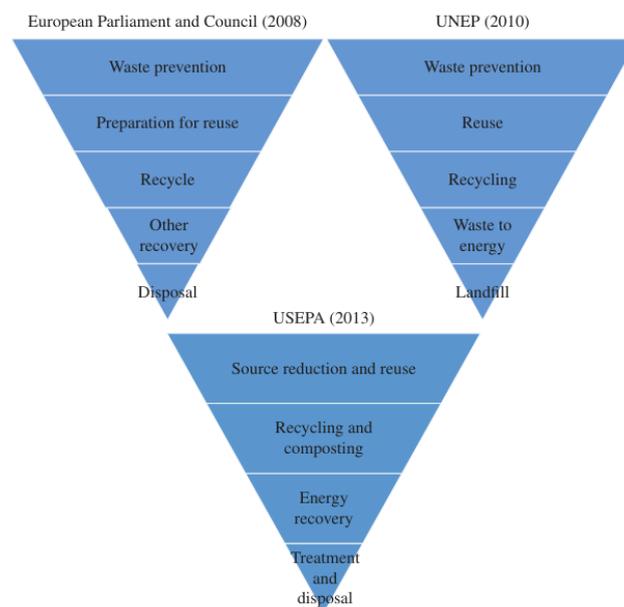

Figure 4.　　　Examples of Waste Hierarchy Principles of the European Union, United Nations and United States. Source: Chang & Pires, 2015

These hierarchy structures displayed above add to further layers at the bottom. Moving down from the 3R paradigm, reduce-reuse-recycle, two other practices become the end of the chain, such as recovery and disposal. Prior steps to recycling and disposal are segregation, collection, and transportation. Waste segregation consists in the identification, classification, division, and sorting of garbage and waste products (Bolt, 2024). Depending on the waste system, it can be done by the waste generator, different waste materials in different containers, or in alternative, it can be separated by materials recovery facilities in a later stage if the waste is unsorted. Collection is the removal of waste streams from its origin (i.e., household, commercial shop, construction sites, industries). Fundamental for collection is the container, the object that serves to collect solid waste, from paper to plastic bags to metal cans and garbage bins (Chang & Pires, 2015). Transport is the phase that serves to collect waste from the sources and move it to the transfer station. The vehicles adopted for such activity depend on the context and the type of waste. Where there is the presence of paved roads, common vehicle types are compactor trucks, roll-on-roll-off, and open trucks. If the waste final destination is not close to where it was created, at least one transfer station may be needed; later, waste is transported to a recycling or disposal plant (Aziz et al., 2021). According to the *Waste Framework Directive* (WFD) 2008/98/EC recycling of materials entails the recuperation process through which waste materials are waste materials are reprocessed into products, materials, or substances, whether for the original or other purposes (European Parliament and Council, 2008). Recycling economies, also known as circular economies, such as Japan and Europe, reintroduce waste into the human consumption system, activating a new economic flow (Chang & Pires, 2015). Biological recovery is another procedure contemplated as recycling. It either involves composting, the biological aerobic process converting the degradable organic waste into carbon dioxide and stabilised organic matter, or anaerobic digestion, where the rapid organic waste is decomposed to produce methane gas. Both processes produce compost that can be used as fertiliser. Other than biological recovery and recycling, the other final waste recovery technology is waste-to-energy (WTE), a waste treatment mechanism implemented to deliver cleaner energy (under the form of heat and electricity) than other energy production processes like coal-fired power plants (Chang & Pires, 2015). The last resort in the waste hierarchy principle is disposal, defined by the WFD as "*any operation that does not involve recovery*" (European Parliament and Council, 2008). Typical disposal operations are incineration without energy recovery and landfilling. A graphic representation of the SWM process is shown in Figure 5.
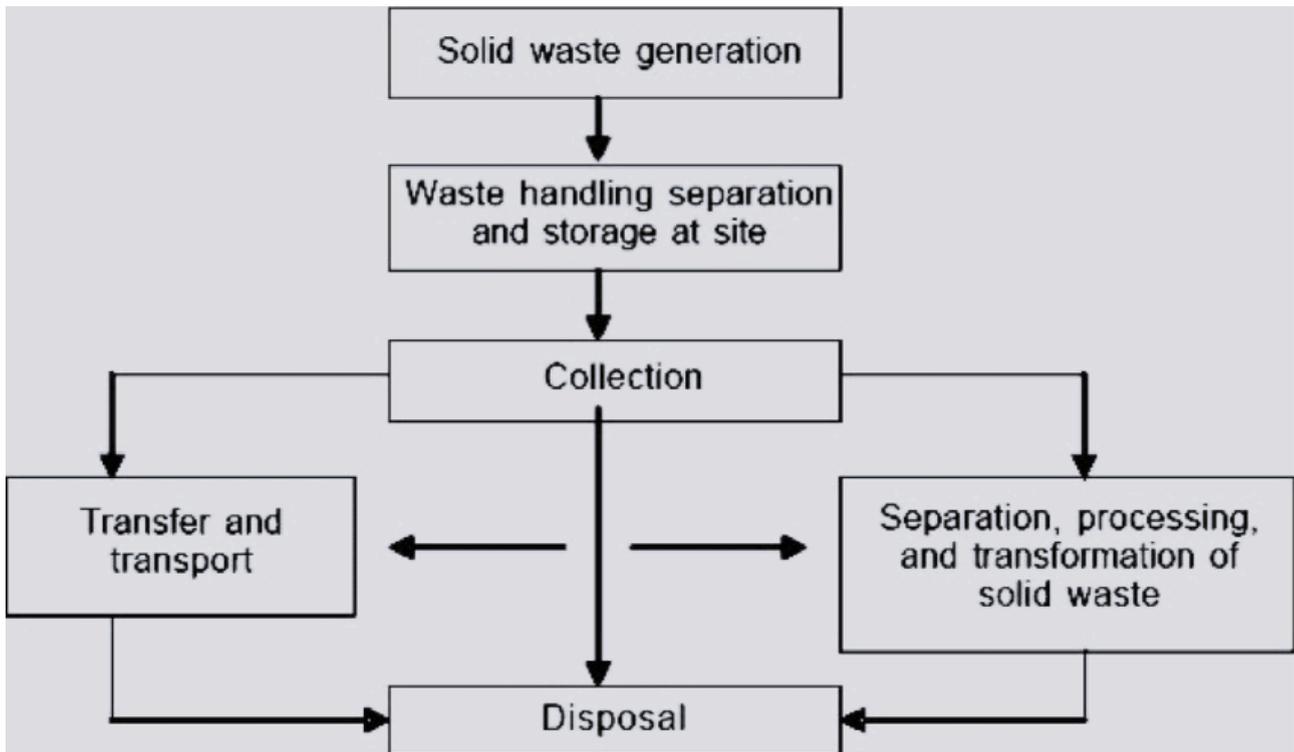
Figure 5.   Integrated Waste Management Diagram

2.1.3 Waste Legal Framework and Policy Tools

Chang & Pires (2015) see legislation as a fundamental part of SWM. First, its purpose is to protect the environment and public health from detrimental impacts due to waste management practices, by establishing how waste should be managed and disposed. Second, the legislation serves to define waste as raw, recycled, reused and recovered. Third, it assigns accountability between stakeholders and the operational units involved in the process. Fourth, from an economic perspective, it provides a reference framework to determine fees to be paid by users.

Even though waste management, likewise waste mismanagement and its perilous effects, is a transnational issue, there is an absence of a legal framework at the global level for SWM (Chang & Pires, 2015). Regional bodies often determine the common strategies to be applied by member states, for instance, the Bamako Convention on Hazardous Waste in Africa (2005), accessible to African countries only, aimed at forbidding the import of all hazardous wastes in Africa from all contracting parties. Another example is the Antarctic Treaty effective in 1961, prohibiting the disposal of nuclear waste and promoting the need to reduce waste production and disposal, outlining the practices of storage, disposal and removal in the Antarctic context. Several treaties and conventions were signed internationally, ultimately converging in the Basel Convention of

2011, signed by 180 countries, devoted to the movement of hazardous waste, focusing on its reduction, restriction of transboundary movement, and implementation of the legal framework for its circulation (Chang & Pires, 2015). The European Union (EU) uses policy instruments such as directives, regulations and decisions. The most notable are the *Waste Framework Directive* (2008/98/EC), the *Regulation on Shipment of Waste* (2024/1157/EC) as framework legislation and those for waste treatment operations such as *Incineration of Waste* (2006/76/EC) and *Landfill of Waste* (1999/31/EC). Directives are binding to the member states, although each can choose how to apply. Regulation is directly applicable to all countries and decisions are *"binding in its entirety upon those to whom it is addressed"* (Hedemann-Robinson, 2007). Strategies function as the main guidelines for future waste management practices.

According to Chang & Pires (2015), waste legislation is related to the economic development of a country. The approach of developing countries is to have a national framework to assign responsibilities and rights, and define stakeholders, while developed countries' legislation is rooted in an environmentally sound waste treatment approach to enforce a waste hierarchy principle. Waste legislation is entrenched within the underlying principles and the policies to comply accordingly and it is based on specific goals and how to achieve them. Examples of such principles are the previously mentioned Waste Hierarchy Principle (WHP), and Polluter-Pays Principle (PPP), Extended producer Responsibility (EPR), Precautionary Principle of Protection of Human Health and Environment Principles of Self-Sufficiency and Proximity, Zero Waste Principle and Integrated Product Policy. In PPP, the polluter, such as the entity generating waste or emitting from waste management, should bear the cost of preventing and controlling pollution. EPR shifted the responsibility to the producer instead of the users concerning the post-consumer stage of a product's life cycle. The Precautionary Principle of Protection of Human Health and the Environment is used to prevent the dissemination of waste management practices whose effects lack sufficient information in relation to their impacts on humans and the environment. Self-sufficiency and Proximity are paradigms to ensure that delimited geographic regions could be supported by an integrated solid waste management, to foster decentralisation and economies of scale. The Zero Waste principle aims at maximising recycling, minimising waste to approach zero, reducing consumption, and ensuring that products are planned to be reused, regenerated, repaired, and recycled internally or back into nature or the marketplace (Glavič and Lukman, 2007). Finally, the IPP is an approach to reduce the environmental impacts over the life cycle of products, from the mining of raw material to their waste management. Table 1 summarises the principle and their descriptions.

Table 1.   *Underlying Principles in Waste Legislation*

Principle	Description
Waste Hierarchy Principle (WHP)	Establishes an order of preference for waste management, emphasising prevention and minimising landfill use.
Polluter-Pays Principle (PPP)	Holds polluters responsible for the costs of pollution prevention and control.
Extended Producer Responsibility (EPR)	Shifts responsibility to producers for managing waste during a product's post-consumer stage.
Precautionary Principle of Protection	Aims to prevent practices with insufficient information about their impact on human health and the environment.
Self-Sufficiency and Proximity	Promotes integrated waste management within specific geographic regions, fostering decentralisation.
Zero Waste Principle	Maximises recycling, minimises waste, and designs products for reuse, regeneration, repair, and recycling.
Integrated Product Policy (IPP)	Focuses on reducing environmental impacts throughout a product's life cycle.

Note: elaboration of data based on Chang & Pires, 2015

Borrás & Edquist (2013) divided the policy instruments normally implemented by governments in regulatory, economic and financial, and soft instruments (Tab. 2). Regulatory instruments are the laws and regulations for which citizens and waste management services providers must legally comply with. Such tools are bans, standards and requirements.

The economic and financial instruments applied within the legal framework are fees, taxes, deposit-refund system and recycling credit schemes. It is a mechanism to change a polluter's behaviour based on economic motivation, using market-based instruments. The objectives are achieving acceptable levels of pollution control, developing a private sector's expertise and technologies in waste management, and arranging a source of revenue to pollution control programs.

Soft instruments are recommendations, normative appeals or voluntary and contractual agreements, instead of the aforementioned tools, legal and economic, that are more mandatory and monetary based (Borrás & Edquist, 2013). Soft instruments are divided into voluntary and informative instruments. The former focus on unilateral commitments, negotiated agreements and public voluntary programs, while the latter provide information to increase knowledge and trigger a change in behaviour (Huhtinen, 2009).

Table 2.   *Policy Instruments in Waste Management*

Instruments	Examples
Regulatory Instruments	● Landfill bans or restriction or diversion ● Substances bans or restriction ● Environmentally sound treatment standards ● Collection, reuse or refill, and recycling targets
Financial and Economic Instruments	● Fees or charges (includes variable charges like PAYT); ● Taxes ● Subsidies ● Deposit–refund ● Recycling credits
Soft Instruments	● Information campaign ● Information to treatment facilities ● Waste exchange program

Note: elaboration of data based on Borrás & Edquist (2013) and Chang & Pires (2015)

2.2 Differences in SWM between Rural and Urban areas, Global North and Global South

2.2.1 Developing Countries, Global South, Low-Middle Income Countries and Waste Management

Terms such as 'developing countries', 'low-middle-income countries', and 'Global South', are used interchangeably about solid waste management. There is no unanimity in defining what is a developing country in contrast to a developed country, although a developing country is generally understood as having a lower average standard of living in relation to others (Kulik, 2024). From 2021, the distinction introduced by the United Nations (UN) in 1996 to divide countries for statistical purposes between 'Developed Regions' and 'Developing Regions', was dismissed by the same institution (United Nations Statistics Division, n.d.). Low-Middle Income Countries (LMICs) is a term derived by the combination of the terms 'Low Income Countries' and 'Lower-Middle Income Countries', both grouped according to the GNI per capita as parameter by the World Bank (WB) (The World Bank, n.d.). Global South is a term that encompasses developing countries mostly located in the southern hemisphere, with generally low-income levels and facing different structural problems, in contrast to Global North, countries located in the northern hemisphere with high levels of income, technological advancement, and well-developed infrastructure (Kowalski, 2020). Since the division between developed and developing countries essentially divides the world into two blocks of countries, it is unclear whether further classifications of countries based on their development are considered. Most of the studies tend for example to treat least developed countries as part of developing countries implicitly. Others, like Bundhoo (2018), apply this classification and analyse the least developed countries separately. To avoid any confusion, the preferred term employed by this study is Global South as an umbrella term for countries located in Africa, South America, South and South-East Asia, following the imaginary line (Fig.6) drawn by Willy Brandt in 1980 (Kowalski, 2020). When referring to other sources, however, this study reports their findings with their terminology such as 'developing countries' or 'low-middle income countries'.
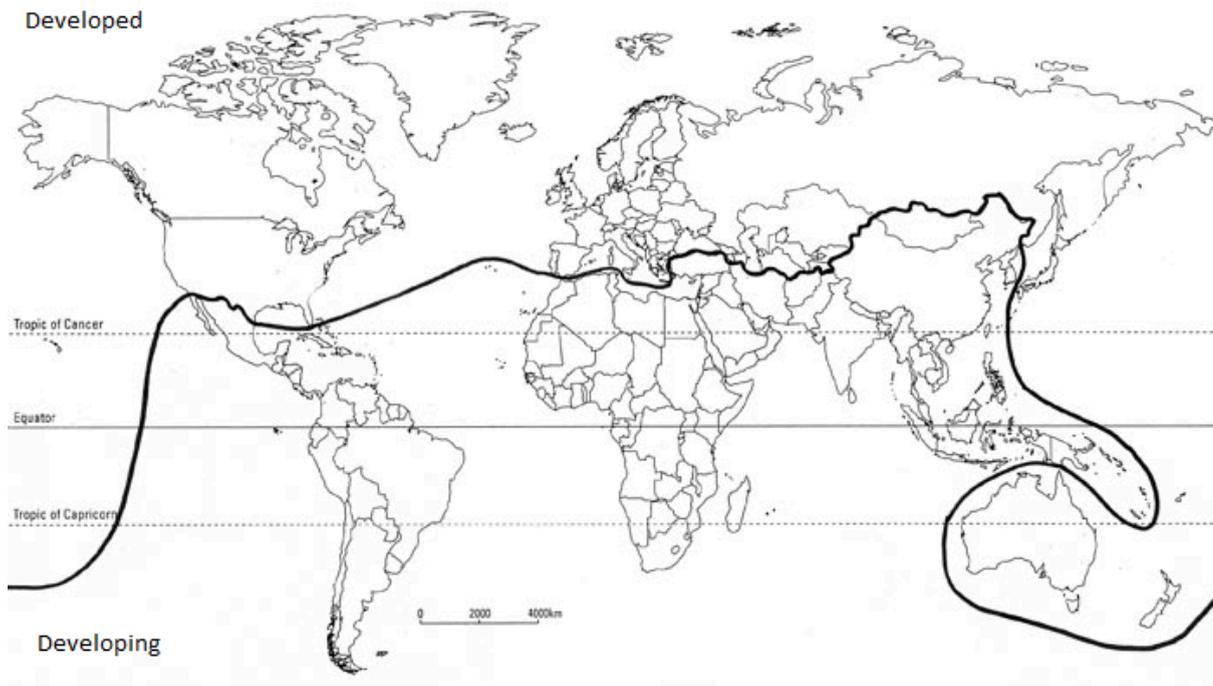
Figure 6.   World division between Global North and Global South According to the Brandt Report.

Source: (Wikipedia, n.d.)

Solid Waste Management performance has the tendency to rise from LMICs to HICs (Vinti & Vaccari, 2022) and the effects of waste mismanagement are more noticeable in the Global South (Chammas et al., 2020). Mixed and non-separated waste streams, low collection and recycling rates are recurrent features in these countries (El Bari & Trois, 2023). While developed countries typically rely on integrated systems that involve infrastructures such as landfills and incinerators, in developing countries dumping and subsequent open burning on waste constitute more perilous activities for inhabitants (Vinti et al., 2023). The amount of waste generated has been increasing due to a growing population, urbanisation trend and economic development, as well as the expansion of waste sectors, and the shift in household consumption habits (Salvia et al., 2021; El Bari & Trois, 2023). Even with an unequal distribution and speed, both urban and rural communities in developing countries have experienced an increase in population and thus an increase in waste generated. However, waste management in urban and rural areas may differ significantly, as discussed in the following section.

2.2.2 Rural Areas of Global South and Waste Management

Countries, both developed and developing, differently define rural areas in administrative terms based on population thresholds. In some cases, such as the one in Jamaica, also the

availability of certain amenities and facilities associated with 'modern living' determines urban areas, so that any non-urban areas automatically become rural (Dasgupta et al., 2014). This division enhances the perception of rural areas as a relative and residual category of urban areas (Lerner & Eakin, 2011). Urban and rural areas have thus been reduced to a dichotomy, although human settlements have always existed within a spectrum from rural to urban, such as large villages, small towns and small urban centres, though other analytical categories like peri-urban areas are applied within (Dasgupta et al., 2014). Therefore, geographically and demographically wise, rural areas are commonly identified as open country and small settlement zones, largely defined in contradistinction to urban areas. Instead, from a socio-economic perspective, rural areas in developing countries are characterised by a dependence on agriculture and natural resources, high prevalence of poverty, isolation, and marginality; features such as policymakers' neglect and lower human development often depict such regions (Dasgupta et al., 2014). Rural communities experience poorer health than the urban communities (Senekane et al., 2021)

Remote and rural areas are often distinguished by poorly managed domestic waste and inadequate treatment facilities (Viljoen et al., 2021). As a consequence of their geographic position, such as being distant from main urban areas, rural areas tend to be more isolated both in high and low-middle income countries, with the latter experiencing lower standards in terms of road infrastructure quality; the scarce availability of paved roads results in the difficulty for massive garbage trucks to collect waste within scattered communities (Vinti & Vaccari, 2022). The quality of road connections can be accounted as a factor affecting waste collection, since estimates indicate a waste collection rate between 48-71% in urban areas and 26-31% in rural areas of LMICs (Kaza et al., 2018). The willingness of households to participate in recyclables' separation in rural towns decreases from those living in urban towns (Viljoen et al., 2021).

2.3 Studies in SWM Conducted in Rural Areas of Developing Countries: Features and Challenges

Researchers have been conducting field studies to understand the challenges to implement solid waste management systems within rural communities in the Global South. The studies are different in nature and objectives, however, similar dynamics arise within rural communities around the world. The proposed analysis framework is divided into four clusters, representing the nature of the factors at hand. Some of the factors could be understood as belonging to one or more clusters, and, even though they are clustered for analytical purposes, they are interrelated in a complex system.

2.3.1 Legal Dimension

A frequently mentioned element in rural communities of the Global South is the inadequate legislation and the weak enforcement on the collection and disposal of waste. Examples of effects of this legislative vacuum include industries with inadequately disposing waste, such as using burning chambers as incinerators, or clinics dumping medical waste and human remains in unauthorised areas, in addition to waste collectors providing unauthorised services (Salvia et al., 2021). The same applies to households separating waste improperly or disposing of it in public places, if there is no legal framework that regulates these activities or any legal prosecution. For instance, in the communities at glance in rural South Africa, Viljoen et al. (2021) noticed that some dumping sites were located in the proximity of signs warning that dumping was illegal and that trespassers would have been prosecuted. This example clearly confirms that if penalties for illegal dumping are not enforced, illegal dumping and open waste burning would continue (Mihai & Taherzadeh, 2017). To mitigate the proliferation of plastic waste for example, by 2018 more than 60 countries had implemented legal bans on the production (United Nations Development Programme, 2018). Some LMIC also enforce bans in the last decades, such as the Rwandan ban in 2008 on manufacturing, use, and importation of plastic bags, replaced by paper and cotton ones. However, despite the introduction of the ban, recycling technologies were lacking so that people started smuggling from neighbouring countries (UNDP, 2018). In 2003 the South African government prohibited the production of small single use plastic bags and a nominal levy on retailers for larger reusable plastic bags. The problem lied on the the fact that it was circumscribed only to food items and not to other industries, such as clothing retailers, who were giving out free plastic bags; also, the nominal levy did not have the desired effect of reducing the demand for plastic bags, so that consumers became used and their single plastic use did not decrease (UNDP, 2018). Similarly, Kenya also promoted a ban in 2017. The government assessed citizens' compliance at 95% in 2021, even though as of 2023 the Nairobi county government warned about the continued use of banned bags by traders (Mutune, 2023). Therefore, countries have fought against the spreading of single use plastic bags, though bans seem an inefficient measure to limit plastic proliferation alone.

2.3.2 Social, Political, and Economic Dimension

Poverty seems to play a decisive role in waste management practices. Interviewed rural inhabitants confirmed that being poor precludes them from purchasing bins and refuse bags (Viljoen et al., 2021). Insufficient financial resources are indeed frequently mentioned as a cause of

poor waste management, since waste handling undoubtedly has a burden on municipal budgets (Chammas et al., 2020). Inadequate practices are seen as a responsibility of governmental stakeholders, with their role seen as highly relevant since they hold the legitimacy to intervene and the ability to lead issue resolution (Salvia et al., 2021). Internal dynamics in the political sphere also play a role, such as conflicts of interest and corruption when monetary and economic opportunities arise (Salvia et al., 2021), as well as scattered responsibilities among various ministries and agencies (Chammas et al., 2020). Therefore, partnership, networking and collaboration between stakeholders is often suggested as a key element to maximise the residual value of waste (Vinti & Vaccari, 2022).

2.3.3 Infrastructural Dimension

There is a widespread consensus on the fact that these communities lack proper waste management infrastructures, equipment, poor technologies and treatment centres (Nxumalo et al., 2020; Viljoen et al., 2021; Salvia et al., 2021). As mentioned earlier, unpaved roads are an obstacle to transport waste to recycling and treatment centres likely located in urban areas. Logistic issues are also to be found in the distance that households would have to travel to reach specific collection points, since they might often lack autonomous transport (Viljoen et al., 2021). Concurrently, another determining factor is the absence of curbside collection and separation systems. Communities experience the absence of commodities such as skips and bins for waste handling (Salvia et al., 2021). In addition, the very low access to electricity available to some communities should be a factor to be considered in the eventuality of establishing treatment centres (Vinti & Vaccari, 2022). All in all, this infrastructural precariousness is an important aspect in influencing people's low level of separation and waste collection, inducing behaviours such as littering and dumping as the alternative.

2.3.4 Knowledge - Behavioural Dimension

Poor public attitude, lack of participation and low awareness of waste management are factors affecting rural communities in the Global South (Chammas et al., 2020; Salvia et al., 2021). Residents are reported to be uninformed about appropriate ways of handling waste. In specific, they lack information about health risks (Salvia et al., 2021), about how to use their biodegradable waste for composting and how to reuse other recyclables, and they miss information about the location of the nearest collection facilities (Viljoen et al., 2021). The study of Chammas et al. (2020) also indicates that local inhabitants may have a waste production perception that differs from the real accounting of the generated waste. Local policies and initiatives are therefore put in place by institutions to educate citizens about waste management practices and risks. In some

communities, it is necessary to rely on oral and visual activities, given the high illiteracy rate in some developing countries (Senekane et al., 2021). These measures are intended to trigger behavioural change towards more sustainable waste practices. Despite these efforts, it is often reported that a lack of compliance and resistance to change (Salvia et al., 2021). For instance, In Viljoen et al.'s study (2021), respondents claimed that waste management is not a priority for them, since their immediate survival in a poor context is their primary concern. Others feel demotivated to participate in waste separation and disposal given the failure from the municipality to provide handling services and to enforce the law against illegal behaviours. In Senekane et al. 's research (2021), the traditional way of life understood by some rural communities of Lesotho, based on stories, myths, tradition and cultural practices, ensures environmental conservation, against modern waste management system practices.

2.4 Research Gap and Research Questions

In Section 2.2 , the main differences in waste management between countries in the Global North and in the Global South and between urban and rural communities within this geographical division have been described respectively. In Section 2.3, the features and challenges experienced by rural communities in the Global South have been divided into four dimensions of analysis to group factors by topic. Table 3 summarises the main findings for each dimension.

Table 3.   Factors and Challenges Affecting Rural Communities in the Global South Concerning Solid Waste Management

Infrastructural			
Unpaved roads	Scarce access to electricity	Lack of skips and bins	Lack of landfills and incinerators (treatment centres)
No curbside collection (i.e. trash cans, garbage bins)	Lack of transport (i.e. garbage trucks)	Absent separation of waste	Designated areas far away from people's residence
Socio-Political-Economic			
Lack of partnerships and collaboration between stakeholders	Scattered responsibilities among various ministries and agencies	Scarcity of financial resources	Poverty & Inequalities

Reported conflicts of interests and corruption	Cultural practices (traditional way of life)	Non-existence of traditional management systems of waste	
Legal			
Inadequate legislation and weak enforcement	Industries with inadequate waste treatment infrastructure	Waste collectors providing unauthorised services	Inappropriately mixing separated waste
Production ban on plastic items	Unauthorised areas for dumping	Law prosecution	
Knowledge-Behavioural			
Waste Management not perceived as a top one priority	Knowledge of designated areas for dumping	Knowledge about about composting and how to re-use other recyclables	Lack of incentives
Poor public attitude	Low awareness of waste management and of health risks	Lack of compliance and resistance to change	High illiteracy rates

The sources considered for this latter analysis are fieldwork conducted in recent years, except Vinti & Vaccari (2022), which is an overview study. Even though they belong to the same research field, the studies are different in terms of methods and objectives. Chammas et al. (2020) conducted research based on an ex-post assessment of the environmental and socio-behavioural contexts of solid waste management in Lebanese peri-urban communities. Nxumalo et al. (2020) investigated plastic waste management practices of rural households in Eswatini through the identification of the types of plastic generated and the estimated average amount produced per day. Senekane et al., (2021) conducted a study in the rural areas around Maseru (Kingdom of Lesotho) to obtain information about participants' feelings, perspectives, and opinions on solid waste management through direct observations and questionnaires. Viljoen et al., (2021) focused on communities in rural South Africa, by exploring challenges faced by households in municipal solid waste handling and their willingness to participate in separation-at-source. Salvia et al. (2021) conducted an attention-based research on stakeholders behaviours in Kisumu, Kenyan city. Even though the context seems more urban, their study has been included since the patterns observed in their research overlap with the ones from the other studies. All of these studies provide insight

into the challenges experienced by rural communities in LMIC in relation to waste management. Also, there is an overall consensus on considering waste management as a complex system of interrelated dynamics of different natures. The studies performed until now, with the exception of the common challenges and features they have identified, are different in methods, objectives and data collection, thus rarely comparable.

Enhancing comparability among different studies is crucial for robust research. Indeed, comparing results across multiple studies permits us to gain richer insights. With the harmonisation of data, patterns, trends, and associations that were not possible to establish when analysing individual studies in isolation, can be explored. Harmonisation helps to address methodological challenges arising from variations in data collection methods, instruments, and timeframes. More comparable data can improve the quality of research in the context of SWM in rural areas of the Global South. Furthermore, data on waste management in these contexts are lacking (Karouach & El Bari, 2023). Thus, proposing methods to collect data can support the expansion of the research in the field.

With this in mind, the idea is to propose a new way to investigate waste management in rural areas of the Global South by assessing different dimensions for the community at hand with a multidimensional framework as a tool. The case study is based on the community of Gandiol, in the Saint-Louis region, North Western Senegal, affected by persisting hazardous activities in waste management, particularly looking at how household waste is handled.

To address this lack of homogenous and standardised research practices within SWM in rural areas of the Global South, the aim of this study is to answer the following questions:

RQ1 How could a multidimensional analysis framework support research within Solid Waste Management in rural areas of the Global South?

RQ2 What are the main conclusions in applying the multidimensional analysis framework in the community of Gandiol about household waste management?

The research methods to address these questions are explained in Chapter 3.

Chapter 3. Research Methods

To fill up the gap in the literature, that is, the lack of coordinated and standardised research in the context of solid waste management in rural areas of the Global South, the aim is to develop a tool that would allow a screening of the waste situation in a given community through an assessment of different related dimensions.

The research is divided into two phases. The first one is dedicated to the creation of the tool, named 'Multidimensional Solid Waste Management Analysis Framework', shortened as Multidimensional Analysis Framework. This framework is created by combining the findings from the literature review, divided into the four dimensions following the proposed research model, with the perspectives from scholars and practitioners over aspects to take into consideration while assessing the different dimensions related to solid waste management in a community. At a later stage, the framework is applied to the case study of Gandiol, where data is collected through methods such as surveys, questionnaires and document review to fill in the newly designed framework.

In this chapter, the methods explained are interviews, surveys, questionnaires and document reviews. The interviews serve to support the construction of the Multidimensional Analysis Framework in Chapter 5. Surveys, questionnaires, and document review, serve to collect data to fill in the framework, a process shown in Chapter 6.

The next sections outline the selected research methods and the purpose of implementing them in this research. The methodological structure of this research is displayed in Figure 7.
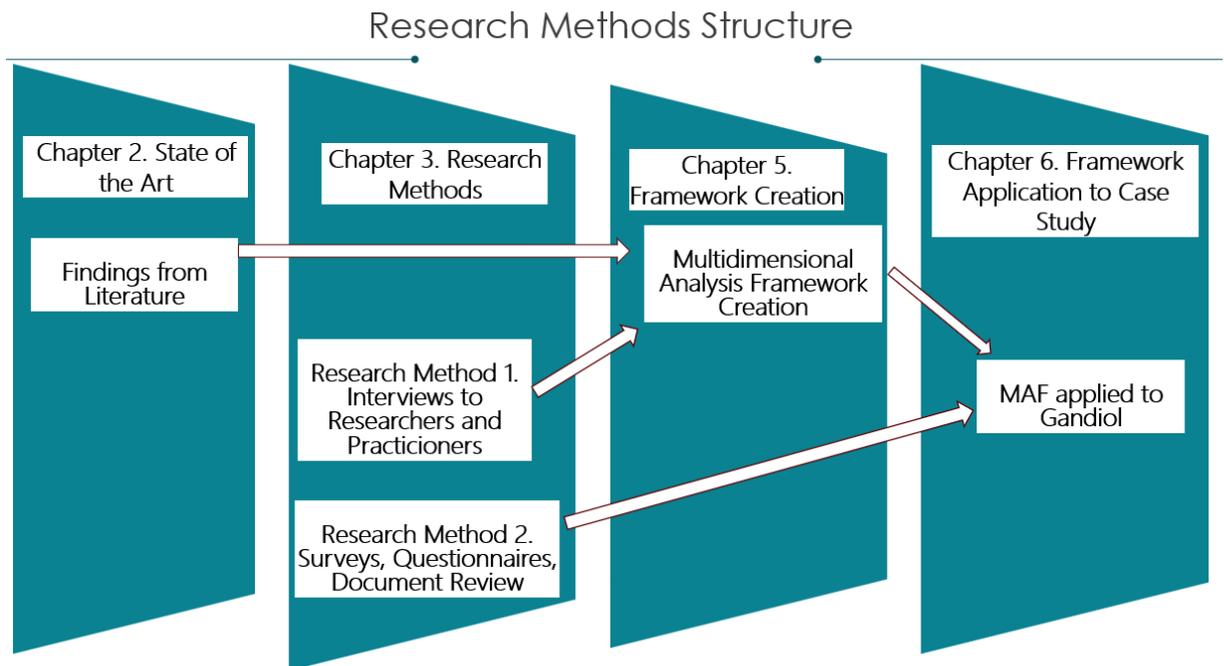
Figure 7.   Research Methods Structure

3.1 Interviews with Experts and Practitioners

In order to have a higher comprehension of the features and challenges experienced worldwide by rural communities in the Global South concerning their waste management practices and dynamics, the proposed method is to collect this information through interviews with scholars and practitioners in the field of solid waste management, particularly in rural communities of the Global South. Scientists have research experience in the field, while practitioners are people who have actively engaged with initiatives related to waste management in the community where they worked and/or lived, such as project managers, environmental technicians, and local authorities. This is to achieve a multi-perspective view of the issue.

Interviews are aimed at gathering the personal experience of people who have been involved in researching or working in these contexts in an effort to consider additional aspects that have not been mentioned in the studies they have conducted and to understand levels that should be measured and taken into account while conducting this type of study. The idea is to involve participants in a conversation that allows them to reflect on a larger picture and thus identify common patterns across communities around the world, also giving the opportunity to share features of specific cases that might also apply to other communities. The format selected for this process is online semi-structured interviews. They

are flexible and versatile tools to collect qualitative data (Kallio et al., 2016). This type of interview starts with a set of predetermined questions to be addressed to participants but also allows the interview to take other directions and adjust meanwhile accordingly (Magaldi & Berler, 2020). Generally, they are considered to be a tool to allow participants to share their experiences and to allow them to explore more in-depth issues that are more concerning or of interest for the participants.

The next section explains how the interviews are prepared, the participants selected and the research ethics arrangements established.

3.1.1 Participants' Choice and Profiles, Questions Preparation, Research Ethics

The structure, although not rigid as semi-structured interviews do not require one, is divided into three parts. The first set of questions explore topics on a more general level, asking participants to map the common challenges experienced by communities and the main factors that restrain communities from designing sustainable SWM systems. After, the focus moves on the aspects related to the four dimensions. To conclude, the questions contemplate underrated yet worthy to be investigated topics in relation to SWM in rural areas of the Global South, and strategies to implement on an international level to mitigate the effects of waste mismanagement. This last part is inserted to give the chance to participants to provide additional topics they feel should be addressed in the future and how, on an international level, efforts shall be made to provide solutions for waste management in these contexts.

The selection criteria for researchers is to have at least contributed to one study published on the topic, while for practitioners is to have a proven experience in the field of waste management and to be a local or have worked extensively in a rural community. Among several identified candidates contacted to take part in the interview process, four of them agreed to participate: three scientists Dr. Najat A. Saliba, Prof. Catherina Schenck, Dr. Giovanni Vinti and one practitioner, Mr. Babacar Diallo (Tab. 4)

Table 4.   *Summary and Description of Interviews' Participants*

Researchers		
Name	**Profile**	**Publication**
Dr. Najat Saliba	Full Professor at the Chemistry Department, Faculty of Arts and Science at the American University of Beirut (AUB). Director of the AUB-Nature Conservation Center (AUB-NCC).	Co-author of "Transdisciplinary Interventions for Environmental Sustainability" (Chammas et al., 2020), an ex-post assessment of the environmental and socio-behavioural contexts of solid waste management in the peri-urban Lebanese community surrounding the Naafeh landfilling.
Prof. Catherina Schenck	Chair of the Waste and Society Department at the University of the Western Cape. More than 30 years of experience in research related to waste management.	Co-author of "Household Waste Management Practices and Challenges in a Rural Remote Town in the Hantam Municipality in the Northern Cape, South Africa" (Viljoen et al., 2021).
Dr. Giovanni Vinti	Research Fellow at the University of Palermo. Environmental engineer with a PhD in Environmental Engineering, International Cooperation and Mathematics.	Co-author of "Solid Waste Management in Rural Communities of Developing Countries: An Overview of Challenges and Opportunities" (Vinti & Vaccari, 2022) and "Health risks of solid waste management practices in rural Ghana: A semi-quantitative approach toward a solid waste safety plan" (Vinti et al., 2023).
Practitioners		
Mr. Babacar Diallo	*Hahatay* Environmental Responsible and Project Manager for *Defaratt* Recycling Centre.	

The interviews' structure, although not rigid as semi-structured interviews do not require one, is divided in three parts. The first set of questions explore topics on a more general level, asking participants to map the common challenges experienced by communities and the main factors that restrain communities to design sustainable SWM systems. After, the focus moves on the aspects related to the four dimensions. To conclude with, the questions contemplate underrated yet worthy to be investigated topics in relation to SWM in rural areas of the Global South, and strategies to implement on an international level to mitigate the effects of waste mismanagement. This last part is inserted to give the chance to participants to provide additional topics they feel they should be addressed in the future and how, on an international level, efforts shall be made to provide solutions for waste management in these contexts.

While Dr. Saliba and Prof. Schenck participated in an online meeting on *Zoom*, Dr. Vinti and Mr. Diallo were available to fill in an offline questionnaire. Before their engagement, all the participants were informed about the identity of the interviewer, the institutions under which the research is conducted, its purpose and methodology, and the data management. Prior to the online interviews, a formal request for recording was asked, providing the date by which the recordings would have been deleted. Participants were given the opportunity at any point to ask for additional information if needed.

The questionnaires were shared in May 2024 and the two interviews were conducted in the same period, with a length of approximately 30 minutes for Dr. Saliba and 50 minutes for Prof. Schenck.

3.2 Surveys, Questionnaire and Document Review

The second research methods are implemented with the purpose of collecting data on waste management practices from a specific community. Three types of data are collected: quantitative data obtained through surveys, qualitative data from questionnaires and document consultation. The survey is shared among a sample of residents in Gandiol to grasp an insight of people's waste practices within the community and to understand the public cognition on waste and environment. The questionnaire is filled by a waste management expert in the community to obtain an overview of the community waste situation and context at the national level. A review of the waste legal framework and national initiatives completes the data collection. Since the objective is the creation of a new analysis tool, this constitutes a mixed methods exploratory study conducted to gather information to compile the Multidimensional Analysis Framework.

3.2.1 Narrowing the Scope: Household Waste Management in Gandiol

As discussed in Chapter 1 and 2, solid waste is a broad category encompassing different subcategories based on the waste source. This study narrows the scope to household waste, which represents a major fraction in developing countries (Lozano Lazo et al., 2023). In addition, it is the predominant fraction in the case study based in Gandiol. However, it is likely that their fraction of uncontrolled waste is also composed by other waste sources other than household waste, as it could also be the case in other communities. Therefore, focusing exclusively on these waste streams only partially covers the waste situation; an aspect that is considered discussed in the last chapter among the limitations of this study. Nevertheless, although this framework is based on household waste management, the same structure can be applied to other waste streams, diagnosing the current waste management system of that specific stream through the four dimensions.

3.2.2 Surveys and Data Management, Questionnaire and Document Consultation

Surveys are designed considering previous research conducted in the community at hand, Gandiol, and studies carried out in communities in rural areas of the Global South, such as those of Chammas et al. (2020) in Lebanon and Viljoen et al. (2021) in South Africa. Previous research in the community offers insight into the type of information acquired in relation to people's practices and perceptions around waste management. As part of the activities of *Defaratt*, a survey was conducted in 2022 in Gandiol, interviewing 221 residents, mostly in person. This data, unpublished, is treated only in relation to the type of questions that were addressed at the time. No data referring to the results or to the participants involved is mentioned in this study. *Defaratt* has given prior approval for handling this data for this purpose only and under confidentiality. The reason to imitate previous research in the same context is that it was structured particularly around it, so that it shows some features and patterns peculiar to the community. For instance, the multiple choice answers concerning the type of waste collection in the community already give an indication of the type of collection in place. Replicating methods implemented in previous studies offers the possibility to compare results among different cases.

Surveys consist of two types of questions: multiple choice questions, where participants can select one of the options available, and Likert-scale (also known as rating scale) questions, where people select an option based on a provided scale. Survey results are processed through statistical analysis, such as frequency distribution and regression

analysis, following the methods implemented by previous studies to achieve uniformity between this and the other studies.

The sample consists of local residents in Gandiol, distributed in the seven of the villages that compose the community. The selection criteria is age, which must be over 18, and only one participant per household can be represented. Participants are informed about the purposes of the research and the methodology. Compliance with data management regulations is communicated beforehand and the right to withdraw from participation is granted.

The questionnaire integrates aspects not covered by the survey, such as specific information about the waste management system of the community, the region as a whole, and orientation concerning the national waste legislation. The participant in this questionnaire is Mr. Babacar Diallo, the environmental technician representative of *Defaratt*. Together with his contribution, document review of the national waste framework supports the analysis.

Chapter 4. Case Study: Senegal and Gandiol

4.1 Overview

Similarly to other countries in the Global South, Senegal is experiencing high population growth and rapid urbanisation: these trends brought a change in consumption patterns and an increase in levels and types of waste in turn (*Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH*, henceforth GIZ, 2021). The World Bank described Senegal as suffering "*from a chronic deficit of access to solid waste management services*" (2017), particularly in relation to the uncollected fraction of solid waste accounting for 45% of the total generated per year. Considering the absence of operational landfills, the common alternative to dispose of waste is large unregulated dumpsites (The World Bank, 2017). With the rapid growth of Senegalese urban areas, large dumpsites are widening around the country, for instance, the country's largest one Mbeubeuss on Dakar's seaside, is spread across 114 hectares and receiving approximately 1,300 tons of waste every day (Ehui, 2020; Maclean, 2022). In particular, Senegal is dealing with the overwhelming amount of plastic waste produced, due to the growing demand for packaged mass-produced products (Maclean, 2022). The Senegalese government has tried twice to tackle this issue with two plastic bans in 2015 and 2020 specifically targeting single-use plastic bags, although their use is still significantly widespread in the country (Ollivier, 2021). The collection of municipal solid waste is uneven across regions, with the Dakar area benefiting from an 84% collection rate, while in the regional capitals of about 33% and only 22% in secondary municipalities (Global Recycling, 2022), with the latest data presumably referring to communities in the rural areas. Most of the data and the focus of articles and reports are based on cities and urban areas, with rural areas frequently left outside of the spotlight. Therefore, this study contributes to discussing waste management practices in Senegalese rural areas, presenting the case of the community of Gandiol. Before introducing the community at a glance, this chapter presents a summary of the Senegalese waste composition, management and legal framework.

4.1.1 Waste Production, Composition and Waste Destination

Waste production in Senegal has been rising steadily for some thirty years, mainly as a result of urbanisation and the development of main cities as Dakar (the capital) Touba, Saint

Louis and Thies[1] (Sabatier, 2023). Urban waste production in Senegalese cities rose by almost 50% between 1990 and 2002, from 540,000 to 810,000 tonnes. Municipal solid waste per capita in Senegal is around 0.5kg a day (GIZ, 2021), apparently lower than the estimated average in Sub-Saharan African countries, between 0.7 and 0.8kg/person/day (UNEP, 2024). Senegal's total population was 18.3 million in 2023, meaning that over 3 million tonnes of waste are currently produced each year in Senegal (Sabatier, 2023)

Tables 5, 6, and 7 show the waste municipal composition In Senegal and the plastic waste categories in detail.

Table 5.   *Municipal Waste Composition in Senegal*

Type of Waste	% of Waste Production	Total Volume (in tonnes)
Fine Elements	61.8	1,852,500
Plastic	10.3	307,500
Organic Waste	9.0	249,300
Textile	4.0	120,000
Non-combustible	4.0	120,000
Other Waste	11.0	330,000

Note: elaboration of data from Sabatier, 2023

Table 6.   *Municipal Waste Composition in Senegal Without Fine Elements*

Type of Waste	% of Waste Production
Plastic	24.5
Organic Waste	22.8
Textile	15.0
Non-combustible	15.0
Other Waste	27.8

Note: elaboration of data from Sabatier, 2023

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[1] 2024 Population Estimate: Dakar (2,476,400), Thies (572,320), Touba (529,176), Saint-Louis (176,000). Source: World Population Review, 2024

Table 7.   *Plastic Waste Type Composition in Senegal*

Type of Plastic Waste	% of Waste Production	Total Volume (in tonnes)
Polyolefin	55.4	170,417
PET	23.0	70,817
PVC and Polystyrenes	8.8	26,999
Other Plastic	12.8	39,237

Note: elaboration of data from Sabatier, 2023

The majority of waste produced in Senegal consists of fine elements such as sand. This is due to the fact that most of the Senegalese soil is desertic. Fine elements make up 61.75% of total waste. Plastic is the second largest component of waste, Nearly 10.25% of the waste produced is plastic of all kinds, representing almost 300,000 tonnes of plastic a year (Sabatier, 2023). In specific, the majority of this waste is polyolefin film, mostly used as packaging for many food and non-food products. In second place, PET (Polyethylene Terephthalate) bottles and flasks, which account for almost one in four items of plastic waste. In a country like Senegal, where access to good-quality drinking water remains an essential issue for many people, the use of single-use plastic water bottles is, therefore, a standard practice (Sabatier, 2023).

Generally, there is no precise regulation on the processing of household waste streams: indeed, the primary collection is an informal activity in the country (GIZ, 2021). Some of the waste materials that are collected from households or recovered from dumps are sold to tradespeople to be used in manufacturing processes such as aluminium foundries, street blacksmiths and tailors, or to intermediaries for stocking to resale. Some others are sold to merchants for reuse, such as jars and bottles, or used as animal feed, like food scraps, paper and cardboard (GIZ, 2021). In some places, mainly the capital and the suburban area, the Solid Waste Management Coordinating Unit (*Unité de Coordination de la Gestion des déchets*, henceforth UCG) has been in charge of transportation and collection services. From 2022, it has been replaced by the *Société Nationale de Gestion Intégré des Déchets* (National Integrated Waste Management Company) known as SONAGED. However, most of the waste ends up in uncontrolled dump sites (GIZ, 2021). The rate for organic recovery from putrescible waste is 12%, while resource recovery accounts for 20% from iron and other metals, plastics, paper and cardboard and energy recovery from textiles, wood and fuel is assessed at 10%; the remaining 58% of solid waste is considered non-reusable (GIZ, 2021). Some local industries recycle different types of waste materials. The *Société Métallurgique*

d'Afrique (SOMETA) recycles around 50.000 tonnes of metal, small-scale industrial plants turn plastics into flakes and granules to be reinserted into new production cycles, while Waste electrical and electronic equipment (WEEE) is partially recovered through disassembling, although there is not a formalised industry behind, despite emerging market opportunities. *PRONAT* uses 2 tonnes of waste paper and cardboard to create egg trays, while organic waste is used for cattle feed and farmers' compost. In general, the recovery rate for organic waste and paper and cardboard in Senegal remains very low (GIZ, 2021).

4.1.2 Legal Framework and Taxation

The legal framework governing waste management in Senegal in the last two decades has been based on the Environmental Code, whose law was promulgated in January 2001 and its implementing decree n° 282 signed in April 2001, referred to as *Law n°2001-01* on the Environmental Code (ACED, 2006). The code stipulated that waste should have been disposed of and recycled in a rational and environmentally safe way. Under this code, any waste generator was supposed to either eliminate or recycle their waste in principle, or as an alternative, deliver the waste to local authorities or companies authorised by the State. At the same time, local authorities and associations were liable for the disposal of household and non-household wastes in liaison with regional and national services of the state (ACED, 2006). The code expressly prohibited wild dumpsites, immersion, incineration in any body of water on the Senegalese soil. Landfills were allowed to be constructed only after the approval of the Ministry of the Environment. Other regulations concerning waste management regulation are for instance the Standards on emissions, the Hygiene Code, the Labour Code, the Code of Local authorities, and the Decree regulating the discharge of household wastes (ACED, 2006).

On August 2nd, 2023, more than twenty years after the promulgation of the first Environmental Code (*Law n°2001-01)*, the Senegalese government, after the parliamentary approval, promulgated an update replacing the previous legislation, with *Law n°2023-15,* known as Environmental Code (*Code de l'Environnement)*. According to the new code, this update was needed because to address gaps and insufficiencies from the code of 2001, such as:

- the inadequacy of legal provisions relating to noxious and hazardous waste;

- the failure to take account of these substances and wastes in the regulatory part;

- the weakness of the environmental assessment procedure;

- the unsuitability of the nomenclature of classified installations for the protection of the environment in relation to international standards and norms;

- the absence of a complete and up-to-date legal framework to facilitate the drawing up of plans.

Among the waste-related purposes of the new Environmental Code, there are the strengthening of the definitional framework (Tab. 8) and of the framework for the management of hazardous and noxious substances and waste, and enshrining the principle of the liability of legal entities (Gouvernement du Sénégal, 2023). The code is divided into seven titles, with dispositions concerning provisions, environmental protection instruments, environmental assessments, prevention and control of pollution, risks and nuisances; the protection and enhancement of receiving environments, administrative sanctions, and final provisions (Gouvernement du Sénégal, 2023). Relevant sections for the analysis are discussed in Chapter 6.

Table 8.   Waste Terms Definition in the Senegalese Environmental Code

Waste	The residue of a production, transformation or use process, any substance, material, product or, more generally, any object or movable asset which the holder discards, intends to discard or is obliged to discard or dispose of, in accordance with the laws and regulations in force;
Household and Similar Waste	Ordinary waste from households or human or industrial establishments, which its holder, at a given time and in a given place, intends to abandon or to manage in an organised manner;
Waste Management	Pre-collection, collection, sorting, packaging and repackaging, storage, transport, treatment, recycling, energy recovery or any other form of recovery and final disposal of waste;
Recycling	The direct reintroduction of waste into a production cycle as a total or partial replacement for a virgin raw material;
Waste Disposal	Operations aimed at the final elimination of waste, such as incineration, burial and storage in reserved areas or deposit in landfill sites, in accordance with conditions ensuring the prevention of risks to human health and without using methods and means likely to cause damage to the environment;

Landfill	Storage of waste in the ground and/or subsoil;

Source: *Law n°2023-15* (2023)

The main source of funding for waste collection and treatment in municipalities is the household waste collection tax (*Taxe d'Enlèvement des Ordures Ménagères*, henceforth TEOM), introduced by law no. 72-52 of 12 June 1972. According to Sabatier (2023), the TEOM system has two major shortcomings: the tax base and collection. The tax base, based on the rental value of landed property, is insufficient to finance waste management, even if tax collection is perfect. The collection of TEOM is also problematic, with a national collection rate of only 33% (Sabatier, 2023). The direct charge from households to those responsible for waste collection is a cornerstone of the system in Senegal, with each household typically paying 1,000 CFA francs per month. This system is more effective and widespread than the household waste collection tax (TEOM). However, the direct charge faces issues, particularly with the collection, with an average collection rate of 62% (Sabatier, 2023). This aspect is later investigated in the case study of Gandiol.

4.1.3 Decentralisation and Stakeholders Involved

The role of the Senegalese state in waste collection has varied since independence (1960), with a decline from the 1980s to the end of the 2000s due to the introduction of the liberal New Economic Model and increasing privatisation of the waste sector (Sabatier, 2023). However, the state returned to the forefront of waste management from the end of the 2000s, initiating two large-scale programmes: the National Waste Management Programme (*Programme National de Gestion des Déchets*, also known as PNGD) in 2013 and the Project to Promote the Integrated Management and Economy of Solid Waste in Senegal (*Projet de Promotion de la Gestion Intégrée et de l'Économie des Déchets Solides au Sénégal*, also known as PROMOGED) in 2021. In 2022 UCG was reorganised into SONAGED, and it is nowadays the state's main entity for waste management. It coordinates collection, transport, landfill, and treatment/recovery, as well as street cleaning. Despite its broad remit, its operations are mainly in towns and cities. (Sabatier, 2023). Several ministries and decentralised agencies also have some responsibilities related to waste collection and management. Since the decentralisation laws of 1996 and 2013, municipalities are officially responsible for waste management in Senegal. However, many lack the financial and technical resources to effectively manage waste; the financial aspect is explained in the upcoming sections. In this context, The informal economy plays a key role in the collection of waste in Senegal. Carters use animal-drawn carts to collect waste, covering almost 15% of

Senegal's secondary communes. In some areas, such as the tourist destinations like the Petite Côte, large private companies, such as SAPCO and SetTIC, are in charge of collections to prevent negative effects of the impact of rubbish on tourism (Sabatier, 2023). Since the 1990s, NGOs have taken on significant roles in waste management in Senegal due to the state's disengagement and the push for private enterprise. Smaller NGOs have become particularly active in this area, supporting numerous waste collection projects across the country. They provide support to Micro and Small Enterprises (MSEs) responsible for pre-collection in towns or rural areas, often through funding for equipment and help with organisational management (Sabatier, 2023).

4.1.4 Historic of Waste Initiatives

In 2013, the Senegalese Government launched the National Waste Management Programme (Programme National de Gestion des Déchets, PNGD) as a mechanism to provide support and assistance at the municipal level with a scheme to provide municipal development investment and another to strengthen local governments' institutional, technical, organisational and financial capacities (GIZ, 2021).

In January 2014, with the support of the Islamic Development Bank, which provided funding amounting to XOF 17.5 billion (EUR 26.67 million), the Senegalese Government also launched the Sustainable Solid Urban Waste Management Project (*Projet de Gestion Durable des Déchets Solides Urbains*, PGDSU), which aimed to improve the way solid waste management systems were run by local authorities in the Dakar region and in the communities of Tivaouane, Kaolack and Touba Mosquée, thus being mostly urban focused. The project commissioned the construction of three solid waste treatment and disposal facilities and 32 standardised waste collection points, and light, heavy and mobile equipment was procured for road sweeping and to collect and transport the solid waste (GIZ, 2021).

In March 2020, as part of the second phase of PNGD, the government launched PROMOGED (*Projet de Promotion de la Gestion Intégrée et de l'Économie des Déchets Solides au Sénégal*, a six-year project to promote solid waste management with support from the World Bank and other international partners (GIZ, 2021). The project aims to improve solid household waste management in beneficiary communes by promoting integrated approaches. Key objectives include waste valorization, proposing reforms for better governance, and creating sustainable management systems. The project will enhance sorting and recovery processes, focusing on material valorization (recycling) and organic valorization (compost production). Additionally, it will strengthen the waste management

sector through the establishment of municipal technical services and improved local-level coordination (PROMOGED, n.d.).

The National Assembly voted on the bill 06/2022 creating SONAGED. The objectives of SONAGED are, among other things, to create a structure that favours inter-community and partnerships and other PPP contracts for the construction and management of modern waste-to-energy infrastructures as part of the development of the circular economy. Also, to professionalise the sector to fight youth unemployment by promoting job creation, to allow communities to establish another form of public partnership (Sabatier, 2023)

4.2 Rural Community of Gandiol, Saint-Louis Region

Ndiébène Gandiol (commonly referred to as Gandiol, the ancient name of the historical province) is a municipality within the Rao county and Saint-Louis region, located 20 km south from Saint-Louis (Figure 8), the regional capital. It is composed of 30 villages (Figure 9) and has a population of approximately 20.000 inhabitants (Brüning, 2021).

Figure 8.   Localisation of Senegal and Gandiol

Figure 9.   Village division in the Ndiebene-Gandiol municipality. Source: Brüning, 2022

In 2003, the city of Saint Louis experienced severe flooding, a fact that led authorities to open a drainage canal on the Langue de Barbarie, a 30 kilometres sandbank separating the Senegal river from the Atlantic Ocean (Brüning, 2021). The idea was to open a 4 m canal (the so-called *Brèche,* from French 'breach') for the river water to flow in the Ocean, but it rapidly and unexpectedly grew southward, reaching a width of 5,200 metres in 2015, bringing severe coastal erosion (Brüning, 2021). The environmental and social impacts are still

relevant nowadays, since the *Brèche* destroyed habitats and cultivations, market gardening and livestock production because of the advancing sea and the salinisation of the soil. This environmental catastrophe resulted inevitably in precarious conditions for many workers in agriculture, fishery and farming, for which migration is seen as an alternative (Brüning, 2021).

As a result, and unavoidably, waste management has been largely neglected. In addition, not only Gandiol has to face the overwhelming pressure of locally produced waste and its increasing diversification due to the modern consumption patterns becoming a habit, but also the arrival of waste transported by the stream of the Senegal river; many people living along the river, especially from urban areas like Saint-Louis, discharge their waste directly on river, and the water transports it downstream and accumulates debris on the coast of Gandiol.

4.2.1 Hahatay Son Risas de Gandiol and Defaratt

In this context, the local association *Hahatay Son Risas de Gandiol* was born to promote communal self-realisation in the rural area of Gandiol. Their activities range from the creation of entrepreneurial hubs, cultural events and activities, professional formation, women workforce development (Hahatay, n.d.).

In order to fight the massive proliferation of plastic in the community, *Hahatay* sponsored the creation of the social enterprise and start up called *Defaratt* ("To re do, to transform" in the local language Wolof) from 2019. *Defaratt*'s aims are the fight against plastic pollution and the creation of a circular economy around plastic waste. The areas of intervention are environmental education and awareness, municipal waste management, plastic waste separation, recycling and valorisation. In the long term, their idea is to actively take part in the waste management capacity building on a communal and regional level, while in the short term, their main activity is the plastic collection and recycling. In 2022, *Defaratt* collected 11 tonnes of plastic waste scattered throughout the community. Their recycling process consists first of collection and separation, based on their types such as Polypropylene (PP), High-Density Polyethylene (HDPE), Polyethylene Terephthalate (PET), and their colours. Later, with a shrink wrap machine, the plastic waste is transformed into granules that are either implemented to form new objects, like tiles, or sold to companies in the plastic market, where plastic is then used for new production cycles.

4.2.2 Waste Situation in Gandiol

According to the latest recon performed by the environmental engineer Mr. B.D. in 2021 in six of the most populous villages in Gandiol (Mouit, Tassinere, Ndiebene, Pilote, Ndiol et Gopp), 15 dumping sites have been identified with an estimates of the different components

(light and heavy plastic, paper and cardboard, metal and glass, other) and their extensions with the aid of GPS images (Fig. 10, 11). Of these fifteen dumpsites, two of them were considered abandoned, meaning that people were not dumping there anymore. Ndiebene had 8 dump sites within its territory, 3 were found in Tassinere, and Ndiol, Mouit, Pilote and Gopp had one each. They are divided in the three categories, small (0.019-0.38 ha), medium (0.38-0.75 ha) and large (0.75-1.12 ha). The highest waste amount was found in Ndiebene (53% of the total measured) and Tassinere (20%). All together, they cover a surface area of 4.0773 Ha. All of them are considered hazardous given their proximity to people's residence and to the river's bank, especially since waste burning is still a common occurrence within the community, as reported by Mr. B.D.. In some of the dumpsites, there is less waste found than the amount discharged, since burning reduces the volume. In Figure 12 some of these dump sites have been documented.
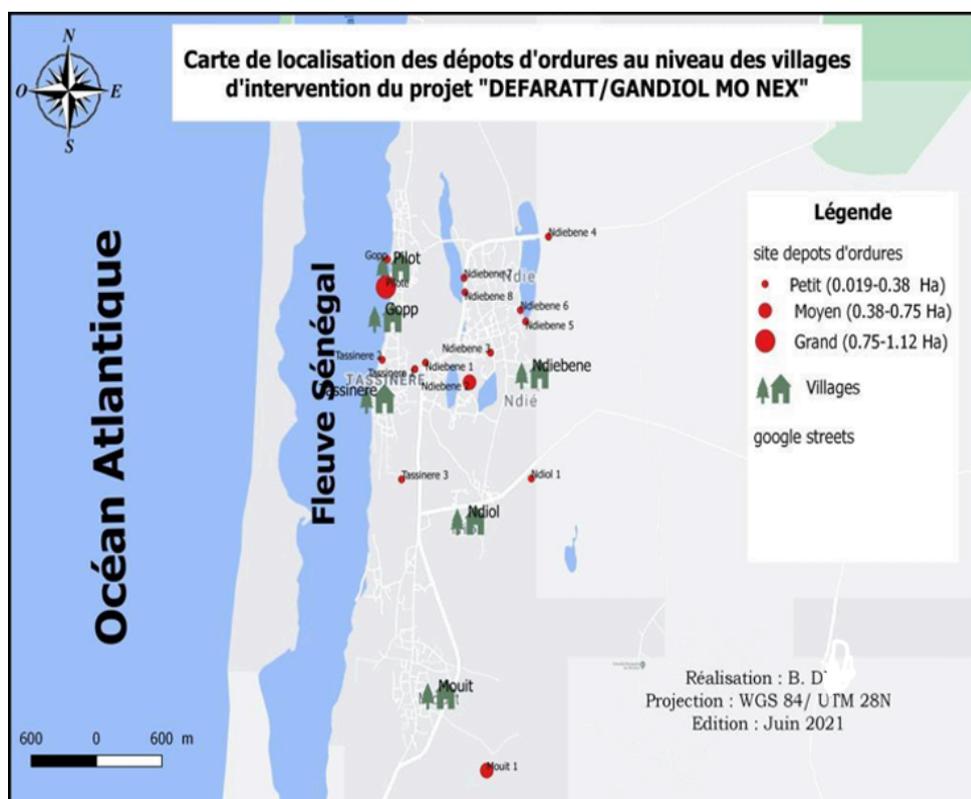
Figure 10.   Localisation of dumping sites within some of the villages in the Gandiol community divided by area extension in three categories: small, medium and large. Source: Study conducted by Mr. B. D. in 2021, shared by Defaratt.
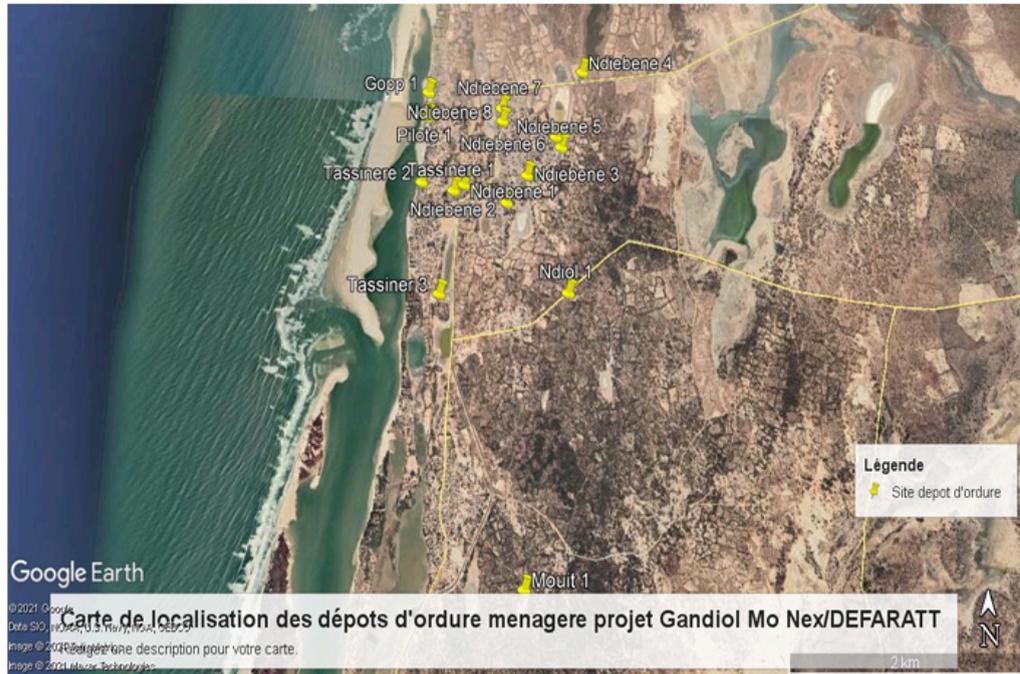
Figure 11.   GPS map of dumping sites in the Gandiol area identified in the study of Mr. B.D.

Source: Study conducted by Mr. B.D. in 2021, shared by Defaratt.

Figure 12.   Images of dumpsites in the community of Gandiol

Note: The two pictures on top were taken in proximity of the dumpsite 'Tassinere 1' and the two on the bottom next to dumpsite 'Tassinere 2', as named by Mr. Diop. All pictures were taken in August 2023.

Chapter 5. Framework Creation

In the first part of this chapter, the results of the interviews to researchers and practitioners, introduced in Chapter 3 and analysed through Thematic Analysis, are presented. Their insight serves to co-create, together with the findings from the state of the art in Chapter 2, the Multidimensional Solid Waste Management Analysis Framework, outlined in Section 5.2. In the last section, the data collection design implemented to fill in the newly created framework is explained in detail.

5.1 Results of Interviews and Questionnaires through Thematic Analysis

The type of analysis implemented for the interviews is Thematic Analysis (TA). It is a highly popular technique to analyse qualitative data through the identification and interpretation of patterns or themes in a data set (Naeem et al., 2023). At first, the intention was to conduct solely semi-structured interviews and use TA as the analysis tool; considering that some interviews were converted in questionnaires, TA was applied nonetheless, because it allows to analyse data from multiple data sets of different nature, such as interviews, conversations, open-ended survey responses, and social media posts (Crosley, 2021). Braun & Clarke (2006) have identified the conduction of thematic analysis in 6 phases: familiarisation with data, generation of initial codes, searching for themes, definition and naming of themes, production of the report. Each of them is defined and followed accordingly. The software used to familiarise with the data and to facilitate the analysis is *NVivo 12 Plus.*

- **Familiarisation with Data**

To begin with, the researcher should become familiar with the data with careful and repeated readings. Initial ideas are taken down at this point (Braun & Clarke, 2006).

As such, the transcripts were read several times, especially the interviews data that were rich in material and with questions that were spread during the process. An initial approach has been to assign each answer to the specific questions related to the four dimensions, to follow a similar structure that resembled the one of questionnaires, which is more rigid, given the fact that there is no interaction in that process.

- **Generating Initial Codes**

The second step consists in creating codes and connecting them to extracts from the transcriptions. Codes represent issues of interest for the analyst that are found across data (Braun & Clarke, 2006)

The strategy implemented here is to read through the first transcript, and generate the first set of codes and connect them to specific quotes from the first interview. The same process applies for the second interview. Codes generated analysing the first interview are found in the second interview, although new codes are found as well. Same goes for the third and fourth transcripts. The result is a list of codes found in the four interviews. Since new codes are generated in each transcript, transcripts are read again and all the codes generated are assigned to the four transcripts.

- **Searching for Themes**
- **Reviewing Themes**

Once data has been coded, the phases of searching and review for potential themes begins (Braun & Clarke, 2006).

For practical reasons, these phases have been merged. Generally, TA is adopted with extensive datasets in which a large variety of codes are identified. Given the reduced amount of transcripts, codes were easier to identify and distribute in groups.

To facilitate the searching of themes, codes are divided into groups if they are similar or if they belong to the same macro-topic.

- **Defining and Naming Themes**

At this point, themes are defined and named. Braun & Clarke (2006) use the term '*define and refine*' as the identification of the essence of what each theme is about.

In this case, groups of codes converged to create two themes with names that explain the main findings from the TA.

In this case, the two main themes are: 'Local Accountability Stakeholders' and 'National Strategies and intervention for a Waste Integrated Framework'

- **Producing the Report**

The final step in TA is to describe and explain the themes identified during the analysis (Braun & Clarke, 2006)

The interviews and questionnaires constituted an occasion to gather insight from professionals, both academic and practitioners, about their perspectives on a complex issue such as SWM in rural communities of the Global South. All of them have had experience in these contexts, so that many of the examples that were given to describe patterns happening around the world related to the communities they have studied, in the case of the academics, and those where they have worked in the case of the practitioner, Mr. Diallo. Also, in the case

of Prof. Schenck and Dr. Saliba, many references were related to the countries where they are based, South Africa and Lebanon respectively, providing a contextual understanding of the waste management in these countries.

To begin with, the first group of codes identified is 'Scarce Factors'. These codes refer to the scarcity of these factors that according to the interviewees are directly impacting on the absence or the inefficiency of waste management in the communities. For example, financial, resources, infrastructures, transport, legal system and collaboration between municipalities; all these elements are mentioned in the literature.

To explain why rural communities in the Global South experience a mismanagement of waste, interviewees mentioned a number of causes, constituting the group of code named accordingly. Modern consumption patterns experienced nowadays, existing inequalities and specific political situations were among those remarked.

The third group of codes has been named 'Community Dynamics'. The contextual understanding of communities is a pivotal factor to comprehend the complex internal dynamics within the waste management. This group of codes reflects a number of elements mentioned within the data pointing at specific issues happening within communities. Internal figures in communities such as traditional leaders and the role of organised crime in waste management were mentioned within the interviews. However, a decisive role identified in the interviews and questionnaires is the one of the municipalities and the expectation upon them to carry out waste related services, which are frequently undelivered.

Last, frequently remarked aspects were the tools implemented on the national level to contribute in fighting against waste mismanagement, such as introducing producer's accountability, products ban, awareness campaigns and innovation opportunities.

Bringing together the group of codes, the identified themes within the data are named: 'Local context, accountability and stakeholders' and 'National strategies and intervention for a waste integrated framework'.

The first one emphasises the consideration of peculiarities of the local context of intervention, especially concerning the accountability in waste management and the stakeholders involved within. The second is concerned with the national waste framework and the initiatives and strategies taken country-wise to tackle down challenges in implementing waste management integrated systems.

What is evident from the interviews, therefore, rather than new elements of factor that should be measured in the context of SWM in rural communities of the Global South, is a

recommendation that comes waste management scholars and experts: being aware of the local context, the stakeholders involved, and how accountability is spread among them, and understanding what are the waste management initiatives on a the national level.

These aspects are taken into account while designing the multidimensional analysis framework in the next section. Figure 13 graphically illustrates the TA process.
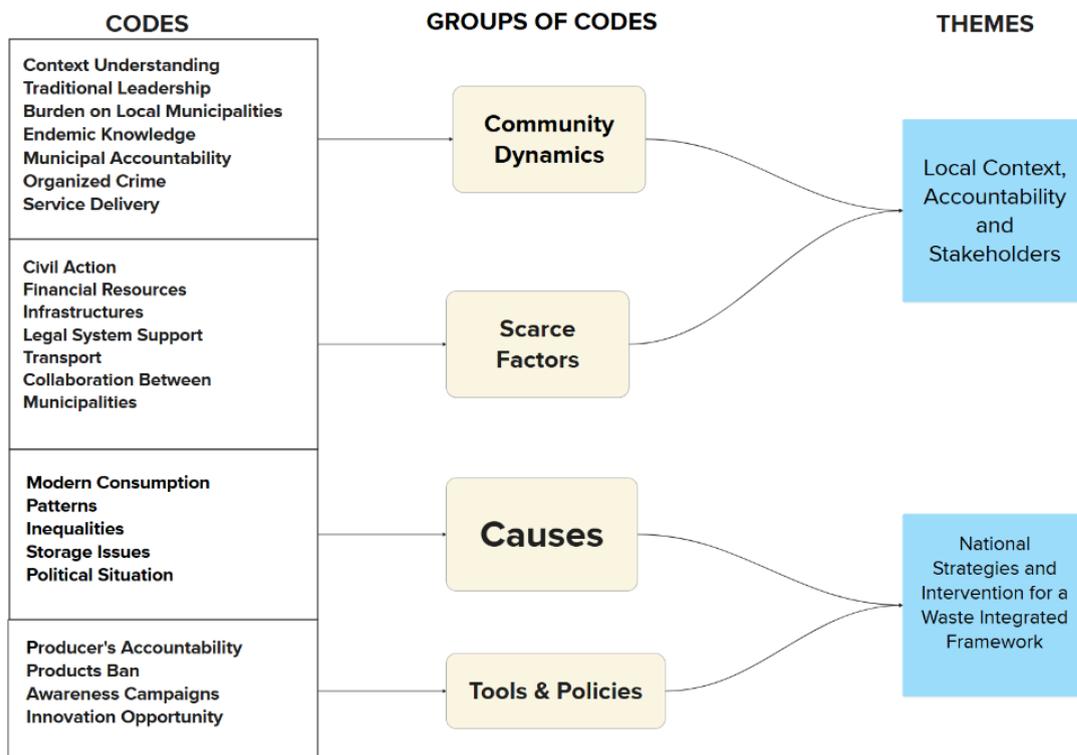
Figure 13.   Thematic Analysis results divided into codes, group of codes, and themes

5.2 Multidimensional Analysis Framework Construction

The term 'Multidimensional Solid Waste Management Analysis Framework' is the name given to this new and innovative tool conceived in this study to gather information about SWM in communities in rural areas of the Global South. The objective of creating this framework is to facilitate the collection and display of information about solid waste management from a determined community at a specific moment in time. This serves to map

the main aspects, divided into four dimensions, needed to develop a general understanding of the current situation. With this information available, researchers, practitioners and project managers can deepen their understanding, create and co-design sustainable waste management systems. Framing the system in macro-areas, reflecting the analytical dimensions proposed in this study, serves to outline the main components of SWM as a system and derive related information.

The purposes of implementing this tool are:

- Acquiring information over the process of SWM in a specific community, from the beginning to end of the whole process, that is, from separation to disposal;

- Understanding how accountability is spread within different entities both on a national, regional and local level. In this scenario, is relevant to consider who are the stakeholders involved and what are the roles and responsibilities assigned to each;

- Contemplating the legal framework in place in the country where the community lives, how waste management is centralised or decentralised, and the economic tools implemented with such as taxes, fines, environmental fees;

- Collecting information about the knowledge, perception, and behaviour related to SWM from those who are part of and affected by the waste management.

The chosen structure type is the framework matrix, because it enables summarising and analysing qualitative data in a table of rows and columns (Macfarlan, n.d.). However, the collected data are both qualitative and quantitative, although the quantitative data will be reported in a descriptive qualitative manner to keep the structure coherent.

The framework is constructed by considering elements highlighted in Chapter 2, such as waste management process basics and elements and factors constituting challenges in rural areas of the Global South as reported by previous studies. In addition, the insight from the interviews and questionnaires, with a particular emphasis on accountability and waste management national initiatives, is considered while selecting the variables composing the matrices.

5.2.1 Framework Dimensions

The framework matrix is structured in four parts, following the division presented at the beginning of the study. Their features are essentially the same highlighted in each of the dimensions, and they maintain the same label identified at the beginning of the study to maintain internal coherence. In addition, each dimension includes specific elements to be investigated. Table 9 shows how the matrix is structured. Tables 10, 11, 12, 13 display the composition of each matrix dimension.

Table 9.   Framework Structure

Matrix Dimension	Dimension Name	Dimension Focus
Matrix Dimension 1 **(MD1)**	Legal	Waste Legal Framework and Waste Initiatives
Matrix Dimension 2 **(MD2)**	Infrastructural	Waste Management Process
Matrix Dimension 3 **(MD3)**	Socio-Political-Economic	Accountability and Resources
Matrix Dimension 4 **(MD4)**	Knowledge-Behavioral	Knowledge - Perception - Attitude - Concern

MATRIX DIMENSION 1. Legal: Waste Legal Framework And Waste Initiatives

This section of the matrix (MD1) takes into consideration the legal framework under which waste is managed. The national legislation (of the country where the community is located) on waste is taken as the reference to look at, although eventual regional or sub-regional directives are also considered. The focal points of these sections are the waste hierarchy principle and policies, possible production and consumption bans, the law prosecution for waste related infringements, and waste initiatives for an integrated national waste management system.

Table 10.   *Matrix Dimension 1*

Matrix Dimension 1: Legal Dimension	
Waste Legal Framework and Waste Initiatives	
LEVEL	**QUESTIONS**
National Framework	• What is the national legal framework? • Are there any regional or sub-regional directives?
Waste Hierarchy Principles	• What are the hierarchy principles followed to manage waste? • What are the policy tools implemented within the framework • Are there any subnational regulations?
Productions & Consumption Ban	• According to the waste framework, is there any production or consumption ban on specific products?
Law Prosecution	• What kind of waste related activity constitutes a criminal offence?
Waste Initiatives	• What are the national strategies for waste management? • What are initiatives undertaken for waste management?

MATRIX DIMENSION 2. Socio-Political-Economic: Accountability And Resources

This part of the matrix (MD2) is concerned with accountability and economic resources. The upper part aims at understanding who is responsible for waste management in the communities and what are the roles and responsibilities of stakeholders. Instead, the lower is concerned with the economic measures in place in the community such as a waste tax. In the case of the absence of such a measure, the question would be whether inhabitants would be willing to participate economically for a waste management service.

Table 11.   Matrix Dimension 2

Matrix Dimension 2: Socio-Political-Economic Dimension	
Accountability and Resources	
LEVEL	**QUESTIONS**
Accountability	● Who is accountable for waste management within the community? ● Who is directly participating in this process?
Resources	● Are inhabitants of these communities subject to any form of waste tax? ● Would people be willing to devote a monetary contribution for a waste service?

MATRIX DIMENSION 3. Infrastructural Dimension: Waste Management Process

In MD3, the first part of the matrix is related to the waste management process. The objective here is to understand what is the community practice in terms of handling household waste, from household activities to final disposal. The matrix is divided into five sections, reflecting the five phases of the process: separation, collection, transport, recovery and disposal. Specific questions are addressed for each phase.

Table 12.   *Matrix Dimension 3*

Matrix Dimension 3: Infrastructural Dimension	
Waste Management Process	
LEVEL	**QUESTIONS**
Separation	● Do people separate different types of waste? ● How do people separate different types of household waste?
Collection	● How is household waste collected? ● What kind of facilities or infrastructures are in place for people to evacuate their waste? ● What kind of collection activities are in place on a community level?
Transport	● How is waste transferred to other locations from household residence or collection points after being collected?
Recovery	● Is household waste recovered somehow? ● Are there any decentralised composting facilities? ● Is there any facility dedicated to plastic recycling? ● Is household waste transferred to any energy recovery site nearby?
Disposal	● Are there any facilities nearby where household waste is transferred for disposal, such as sanitary landfills, or incinerators not used for energy recovery?

MATRIX DIMENSION 4. Knowledge-Behavioural Dimension: Knowledge - Perception - Attitude - Concern

The last section of the matrix (MD4) addresses four aspects about the relationship between people in the community and waste: their knowledge about waste, their perception and attitude on waste and sustainability, and their concern on environmental risks related to waste mismanagement. The matrix is divided into three layers.

Table 13.   *Matrix Dimension 4*

Matrix Dimension 4: Knowledge-Behavioural Dimension	
Knowledge - Perception - Attitude - Concern	
LEVEL	**QUESTIONS**
Knowledge	● What is people's knowledge level about waste types and waste management?
Perception & Attitude	● How do people assess their environmental attitude? ● How do people perceive their contribution in reducing their waste generation? ● How do people behave in terms of recycling? ● Are people satisfied with the way waste is handled in their community?
Concern	● How much are people aware of the health related risks of waste management? ● How much are people concerned with the health related risks of waste management?

5.3 Data Collection Design

In this section, the methods for data collection are explained. To facilitate the consultation, the matrix research composition is displayed in the Appendix. The surveys and the questionnaires have been translated in French, the official language of Senegal.

Social and Demographic Information

Participants are asked for information such as age, gender, income level, education level and the village where they live. The age ranges are 18-24, 25-34, 35-44,45-54,55-59, 60+ , like those used by Viljoen et al., (2021). Likewise, from the same study, income levels are converted from the South African currency, rand (ZAF), to the one used in Senegal, the West African Franc, XOF, commonly referred as CFA (from French *Communauté Financière Africaine)*. Choices available are: No Income, 1-13,000 CFA, 13,001-26,000 CFA, 26,001-52,000 CFA, 52,001- 104,000 CFA, 104,001- 208,000 CFA, 208,001 - 414, 000 CFA, + 414,001 CFA. The education level options are: No Formal Education, Primary School Degree, Middle School Degree, High School Degree, University Level Degree, Other. The gender options are Male, Female, Other and the residence options are the villages comprising the community of Gandiol, such as; Ndiebene, Tassinere, Mouit, Mboumbaye, Ndiol, Pilote, Keur Barka, Other. See Table A0.

MD1 Legal Dimension

Data for MD1 are collected through the questionnaire in addition to the related document consultation, such as national waste directives and environmental codes. The questions addressed in the questionnaire are those stated in Table 10, divided into five levels: National Framework, Waste Hierarchy Principles, Production and Consumption Ban, Law Prosecution, Waste Initiatives. See Table A1.

MD2 Socio-Political-Economic Dimension

Reflecting the outcome of the interviews, this matrix dimension focuses on the importance given to accountability for waste management. Here, the questionnaire asks the waste management expert about the accountability at the community level and the stakeholders involved, while the survey participants are asked who in their opinion should primarily be in charge of the process. The choices available for them are: 'National Government', 'Municipality', 'Private Company', 'NGO and GIE' (from French *Groupement d'Intérêt Economique*, discussed in the following chapter), 'I do not know', 'Other'.

The second level of this matrix is Resources. The purpose of this section is to understand if there are financial measures that supposedly inhabitants are subject to contribute to for waste management (question to the waste expert), if they are effectively paying any tax or fee, and, if they are not, if they would be willingly contribute with a monetary amount for a waste service collection and transport (asked to the survey participants). The available choices for the former question are 'Yes', 'No', 'I do not know', and for the latter: 'Yes, up to 1000 CFA', 'Yes, up to 500 CFA', 'No', 'Prefer not to say'. This last question is replicated from *Defaratt*'s 2022 survey. See Table A2.

MD3 Infrastructural Dimension

The third dimension of the matrix is concerned with the whole waste process, from separation to disposal, targeting household waste in specific. Survey participants are asked if they separate any material among organic waste, plastic, metal, paper and cardboard, ceramic and glass, or if they separate any other material not mentioned above. Concerning waste collection, the first question is about how they collect waste in their households, if with bins, plastic or rice bags, basins or buckets, or other methods. In the second question, they are asked about waste evacuation, if it happens with a horse drawn collection, a vehicle

transport, or if it is instead dumped in an undesignated area, either burned, or buried, in line with a question from *Defaratt's* 2022 survey. The third question is related to the collection facilities available in their villages, such as bins and garbage cans for instance, if there are any, if people use it, if they are not available for use (i.e. they are damaged). The fourth question is about collection services on a village level, if there any, if they are private (informal) collectors, if the GIE is in charge, or any other form of collection. The following levels such as Transport, Recovery and Disposal are addressed in the questionnaire to the waste management experts, with the exact same questions reported in Table 12. See also Tables A3.1 and A3.2.

MD4 Knowledge-Behavioural Dimension

The last dimension of the matrix is divided into 3 parts, namely Knowledge, Perception and Attitude, and Concern. In the Knowledge part, participants are asked their level of familiarity (from 1 to 5: '1 = very unfamiliar', '2 = unfamiliar', '3 = somewhat familiar', '4 = familiar', '5 = very familiar') with the following concepts: separation, organic waste, composting, pollution, trash can and garbage bin, littering, dumping, waste destination after collection, environmental law, waste framework, environmental tax, and environmental tax. Participants are then asked if they ever heard or seen a communication campaign (both on information or awareness) about waste management and through which media was it promoted, if through a community representative, TV, radio, social media, or other.

The perception and attitude part is constructed based on the studies of Chammas et al., 2020, adapting to the matrix 6 of their 9 variables, namely 'Reduction Behaviour', 'Recycling Knowledge', 'Recycling Moral Obligation', 'Environmental Identity', 'Environmental Concern'. For each of the variables, a statement is associated and participants can rate their level of agreement with them from 1 to 5 ('1 = strongly disagree', '2 = disagree', '3 = neither agree nor disagree', '4 = agree', '5 = strongly agree'). An additional question investigates their perception about the factors that mostly influence the mismanagement of waste in their villages and communities. The answer options are obtained by the most common answers from the *Defaratt's* 2022 survey, such as: 'Absence or inefficiency of collection service', 'Absence of designated dump areas', 'Insufficient civil commitment','Defecting collection material', 'Lack of agreement within the community', 'Refusal of people to pay a collection fee', 'Other'.

The last part of MD4, Concern, is based on Viljoen et al.'s study (2021). Here, two variables are measured: littering and dumping. Participants have the opportunity to rate their

level of concern from 1 to 5 ('1 = not concerned', '2 = barely concerned', '3 = somewhat concerned', ' 4 = concerned', ' 5 = very concerned'). See Tables A4.1, A4.2, A4.3.

Chapter 6. Results and Discussion: Framework Application to the Case Study

This chapter focuses on the data gathered through the survey, questionnaire and document review on the Senegalese waste framework and household waste practices in Gandiol. The findings are discussed for each matrix dimension and elaborated to fill the Multidimensional Analysis Framework applied to the community of Gandiol. Later they are discussed as a whole and compared with previous studies.

6.1 Participants Demographics

The demographic characteristics of the survey respondents from the community of Gandiol are summarised in Table 14.

Considering that the survey has been conducted online in a rural context, where electronic device use is not widespread, chances to include representatives from each level for each variable were extremely limited. As such, the survey has been able to reach out to a sample of people from three villages (Ndiebene, Tassinere and Pilote), mostly between the ages of 18 and 34 (most likely due to their higher practicality in using smartphones rather than older age groups). The education level of the sample is significantly higher than the national average, with two-thirds of the respondents holding a high school degree, with the national average estimated at around 35% (Unesco, 2024). There are no statistics available regarding income distribution in Gandiol, while the sample proves to be an accurate representation of the female/male ratio, in line with the 2013 census; women account for more than 60% of the total resident population for each age group, due to male migration being predominant in this context (Brüning, 2021).

Table 14.   *Survey Participants' Demographics*

Personal Background of the Respondents	Percentage
Gender (n=73)	
Male	38.3
Female	61.7
Age Category (n=73)	
18-24	36.9
25-34	38.4
35-44	21.9
45-54	2.7
Education Level (n=73)	
Middle School Degree	24.7
High School Degree	65.8
University Degree	9.6
Income (n=73)	
No Income	4.1
1-13,000 CFA	9.6
13,001 CFA - 26,000 CFA	19.2
26,001 CFA - 52,000 CFA	26.0
52,001 CFA - 104,000 CFA	20.6
104,001 CFA - 208,000 CFA	12.3
208,001 CFA - 414,000 CFA	5.5
+ 414,001 CFA	2.7
Residence (n=73)	
Ndiebene	35.6
Tassinere	46.6
Pilote	17.8

6.2 Matrix Dimension 1: Legal Dimension

The Matrix Dimension 1 of the Multidimensional Solid Waste Management Analysis Framework focuses on the legal aspect of waste management in the country where the community at hand is based. The levels of this dimension are: National Framework, Waste Hierarchy Principles, Production and Consumption Bans, Law Prosecution and Waste Initiatives. The data collection for this part of the matrix has been supported by Mr. Babacar Diallo, who provided information through a questionnaire regarding legal documentation within the Senegalese Civil Code and laws.

National Framework

Within the national jurisdiction, the Constitution represents the legislative document of the highest degree. Concerning aspects related to waste management, Article 8 of the Senegalese Constitution guarantees the rights of health and a healthy environment. For two decades, the main reference for solid waste management has been the *Law n°2001-01* (2021) of January 15th, 2001, defining the country's first Environmental Code, which defined the conditions under which collection, sorting, storage, transport, recovery, reuse, recycling

and any other treatment operation must be carried out. The Environmental Code has been updated and formally replaced with the New Environmental Code with *Law n°2023-15* of August 2nd, 2023. Specifically concerning household waste, an important reference regarding financial resources is *Law n°72-52* of June 12th, 1972, setting the rates and collection procedures for the *Taxe d'Enlèvement des Ordures Ménagères* (TEOM) (household waste collection tax), which applies to all properties subject to the property tax on built-up or temporarily built-up properties. In 1974, Decree *n°74-883* of April 10th was issued to regulate the disposal and deposit of household waste, defining the characteristics of a statutory rubbish bin, establishing criteria for controlled landfills and the characteristics and process of incineration.

Waste Hierarchy Principles

The Waste Hierarchy Principles are enshrined in Title IV "Prevention And Control Of Pollution, Risks And Nuisances", Chapter III "Waste Prevention and Management ", Article 69 of *Law n°2023-15* (2023)*:*

" An environmentally sound waste management is based on following principles

- *the principle of priority to prevention and reduction;*

- *the principle of the hierarchy of waste treatment methods consisting of prioritise in order: reuse, recycling, energy recovery and disposal;*

- *the principle of proximity;*

- *the principle of extended producer responsibility. "*

Production and Consumption Ban

The *Law n°2020-04* (2020) "*on prevention and reduction of the incidence of plastic on the environment*" represents Senegal's attempt to fight against plastic waste pollution. According to Chapter II, Article 4 "*Production, importation, detention in view of the sale, offering for sale, and sale under any form of single-use plastic products or disposable plastic products are prohibited*". Examples of prohibited plastic items of these kinds are cups, glasses, cutleries, straws, water or non-alcoholic drinks bags.

Law Prosecution

Law n°2023-15 (2023)*,* Title IV "Prevention And Control Of Pollution, Risks And Nuisances", Chapter III "Waste Prevention and Management ", defines waste illegal practices:

- **Article 70** states that "*a person whose activity produces waste or who holds waste itself, manages it, respecting the priority of treatment*", however "*the provisions of this Article shall not apply to household waste*".

- **Article 72**:" *the immersion, incineration or disposal of waste in water continental, maritime, or fluvial water, under Senegalese jurisdiction are forbidden*". Article 73 "*Open burning of waste, with the exception of 'slash-and-burn', is prohibited. Open burning of used tires is prohibited.*".

- **Article 74**: "*The landfill of waste can only be carried out after authorization from the Minister responsible for the Environment who sets technical requirements and special rules to be observed.*" .

- **Article 91**: "*Dumping on the public domain is prohibited*".

Title VI "Administrative and Criminal Penalties", Chapter II "Criminal Provisions", lists the administrative and criminal sanctions:

- **Article 216***. - Is punishable by imprisonment of two (02) years to five (05) years and a fine of one million (1,000,000) to five (5) million (5,000,000) CFA francs or either of these two penalties, any person who has accidentally polluted, degrades soil and subsoil in violation of the provisions of this Act. The person in charge shall proceed without delay to the restoration of the site.*"

- **Article 217**: "*A fine of one million (1,000,000) to five (5) million (5,000,000) CFA francs and a prison sentence of one (01) month to one (01) year or one of those two sentences only, any person who has buried or burned waste or used tires, in violation of the provisions of this Act.*

Essentially, dumping and open burning of waste are not allowed, and they constitute a criminal offence that can lead to from a monetary sanction to a prison sentence.

Waste Initiatives

As explained in the previous chapter, the Senegalese government has promoted initiatives to address municipal waste management in the country. Currently, the main ongoing initiatives are PROMOGED (taking over part of the PNGD activities), and SONAGED. PROMOGED aims at the construction of standardised collection points, sorting and transfer centres, integrated, waste recovery centres and the rehabilitation of landfills in three agglomerations other than Dakar, Thiès area (Thiès, Mbour and Tivaouane), Northern area (Saint-Louis and Matam), Southern area (Ziguinchor, Kolda and Sédhiou) (PROMOGED, n.d.). SONAGED, launched in 2021, is the public funded company in charge of waste

collection on a national level. Among their activities are unauthorised dumping areas eradication, periodical community cleanings, capacity building for permanent collection points (SONAGED, n.d.). The Matrix Dimension 1 is thus composed in Table 15.

Table 15.   Case Study MD1

MATRIX DIMENSION 1: LEGAL DIMENSION (Senegal)	
LEVEL	**Results**
NATIONAL FRAMEWORK	*Law n°2023-15* of August 2nd, 2023 (Environmental Code) General disposition on waste management *Law n°72-52* of June 12th, 1972 Taxe *d'Enlèvement des Ordures Ménagères* (TEOM) Household Waste Tax

WASTE HIERARCHY PRINCIPLES	- Prevention and Reduction
	   - Reuse
	   - Recycling
	   - Energy Recovery
	
	Other Principles: Proximity and Extended Producer Responsibility

PRODUCTIONS & CONSUMPTION BAN	*Law n°2020-04 on prevention and reduction of the incidence of plastic on the environment* Production, importation, detention in view of the sale, offering for sale, and sale under any form of single-use plastic products or disposable plastic products are prohibited
LAW PROSECUTION	*Law n°2023-15* of August 2nd, 2023, Title IV, Chapter III and Title IV, Chapter II Dumping on soil, terrestrial and territorial water and open burning of waste are forbidden; they constitute a criminal offence
WASTE INITIATIVES	- PROMOGED (from 2021) Infrastructure building: collection points, sorting and transfer centres, integrated, waste recovery centres and the rehabilitation of landfills - SONAGED (from 2022) Waste collection services: unauthorised dumping areas eradication, periodical community cleanings, capacity building for permanent collection points

6.3 Matrix Dimension 2: Socio-Political-Economic Dimension

The Matrix Dimension 2 of the Multidimensional Solid Waste Management Analysis Framework is concerned with the accountability in the waste management process in the community of Gandiol and the resources, in the form of monetary contribution, that citizens are subjected to pay or that they would be willing to pay for a waste management service in their community.

Accountability

As a result of the decentralisation of activities from the state to the sub-regional bodies, the accountability in terms of waste management lies in the hands of the municipality. As also confirmed by the questionnaire, municipalities are responsible for defining organisational and operational management policies and strategies, as it was defined by the Environmental Code of 2001, confirmed in the Article 305 *Code Générale des Collectivités Locales* (General Code of Local Authorities) from 2013 (Sabatier, 2023), and reiterated in the New Environmental Code of 2023.

However, in Gandiol, the local authority cannot solely manage waste on its own, stated Mr. Diallo. Indeed, it is supported by technical partners, such as GIEs and local associations (Hahatay with Defaratt as an example), and financial partners to assist in waste related activities.

What is visible from the survey results is that the majority of the population (60.3%) believes that it is the municipality that should be primarily responsible for waste management, while others believe should be a private company (12.3%), the national government (9.6%), NGOs and GIEs (6.9%) and some participants that are unsure about.

Resources

Households in Senegal from 1972 are subjected to the payment of the *Taxe d'Enlèvement des Ordures Ménagères* (TEOM) (household waste collection tax) calculated on the net income of landowners and tenants, with a national maximum of 3% (3.6% in Dakar) (Sabatier, 2023). However, according to Sabatier (2023), the TEOM proves to be an insufficient revenue source (even if collected at 100%) to cover all the expenses for waste services, and it is frequently uncollected some areas, where in many cases inhabitants refuse to pay for the dissatisfaction of the waste handling. Especially in rural areas, municipalities struggle to collect the TEOM (Sabatier, 2023).

The results in Table 16 show that more than half of the respondents (57.5%) declared that they are not aware whether they are paying any tax, fee or contribution service for waste collection, while the 34.3% denied to be paying any amount and only 8.2% of the respondents affirmed to economically contribute to it.

Whether they would be willing to monthly contribute to a waste service, almost four respondents out of five answered positively. Most would participate with 1000 CFA, a smaller

fraction with 500 CFA; about 16.5% of the respondents would not participate. Matrix Dimension 2 is filled in Table 17.

Table 16.   *Accountability and Resources Survey Results*

Accountability	
Question: Who do you think should be primarily in charge of waste management? (n=73)	
Answer Choices	**Percentage**
National Government	9.6
Municipality	60.3
Private Company	12.3
NGO and GIE	6.9
I do not know	11.0
Resources	
Question: Do you currently pay any tax, fee or contribution for a waste service? (n=73)	
Answer Choices	**Percentage**
Yes	8.2
No	34.3
I do not know	57.5
Question: Would you participate with a monthly monetary contribution for a waste service? (n=73)	
Answer Choices	**Percentage**
Yes, up to 1000 CFA	58.9
Yes, up to 500 CFA	19.2
No	16.4
Prefer not to say	5.5

Table 17.   Case Study MD2

MATRIX DIMENSION 2: SOCIO-POLITICAL-ECONOMIC DIMENSION (Gandiol)	
LEVEL	**Results**
ACCOUNTABILITY	● Municipalities are the entities responsible for municipal waste management in Senegal. ● The Municipality of Ndiebene Gandiol is responsible for the community of Gandiol. ● GIE and Local Association support the activity of the municipality. ● The majority of respondents believe the municipality should be primarily in charge.
RESOURCES	● House owners and tenants in Senegal are subjected to contribute with TEOM (max. 3% of net income). ● Most of the respondents are not paying or are not aware if their households are paying any contribution. ● The majority of respondents is willing to contribute monthly for an amount of 1000 CFA, a smaller fraction of them for 500 CFA.

6.4 Matrix Dimension 3: Infrastructural Dimension

The Matrix Dimension 3 of the Multidimensional Solid Waste Management Analysis Framework gives an overview of the waste management process in the community of Gandiol, from waste separation to disposal. The respondents were asked about the material they separate at home, how the household collects and evacuates waste, the collection facilities and the collection services available in their villages (Tab. 18). Metal and plastic waste are the most separated items in two thirds of the respondents' households (65.8% and 64.4 %). Almost half of the sample separates organic waste (48%), with a slightly lower percentage for paper and cardboard waste (42.5%) and a low percentage of respondents separating glass and ceramic (8.2%). Almost a fourth (23.3%) of the respondents do not separate waste in their household

Table 18.   Separation Survey Results

Separation	
Question: Which materials do you separate at home? (n=73)	
Answer Choices	**Percentage**
None	23.3
Organic Waste	48.0
Plastic	65.8
Metal	64.4
Paper and Cardboard	42.5
Ceramic and Glass	8.2

Table 19 displays participants' responses related to household collection and evacuation, communal waste facilities and collection services. Collection-wise, bins are the most used item (37%), followed by basin and buckets (35.6%) plastic bags and rice bags (20.6%). Almost 7% of respondents declared that there is no waste collection in their household. About the evacuation and transport methods, the same amount of respondents declared horse drawn collection and dump in undesignated areas (41.1% each), followed in a much lower percentage by open burning (8.2%), burial (4.1%), vehicles transport (1.4%). Those who chose 'Other', answered 'by cart', 'walking', and 'we take it to Defaratt'.

Regarding the waste collection facilities available in the community, over more than a third of respondents affirmed that there are not present where they live (37 %), while almost a third said that there are bins in their communities, while the rest affirm that there are bins, the large amount of them make use of it (30.1%), others say that they are unused (16.4%), and there rest noticed that they are not available for waste use (12.3%).

About any collection service in the villages where they live, a third of respondents (32.9%) is not aware of any, while almost the same amount declare that there are not (31.5%), while the other third affirmed that there are private collectors (35.6%).

Table 19.   *Household Collection and Evacuation, Communal Services and Facilities*
Survey Results

Collection and Evacuation	
Question: How is waste collected in your household? (n=73)	
Answer Choices	**Percentage**
Bins	37.0
Plastic Bags / Rice Bags	20.6
Basins / Buckets	35.6
There is no collection	6.9
Question: How is waste evacuated? (n=73)	
Answer Choices	**Percentage**
Horse drawn collection	41.1
Vehicles transport	1.4
Dump in undesignated area	41.1
Open burning of waste	8.2
Burial	4.1
Other	4.1
Question: Are there any collection facilities (i.e. bins, garbage cans, etc. etc.) in your village? (n=73)	
Answer Choices	**Percentage**
Yes, there are and people make use of them	30.1
Yes, there are bins but they are not used	16.4
Yes, there are bins but they are not available for use (i.e. they are damaged)	12.3
No, there are not	37.0
I do not know	4.1
Question: Is there any collection service in your village? (n=73)	
Answer Choices	**Percentage**
Yes, private collector	35.6
No, there are not	31.5
I do not know	32.9

The transport of waste within the community of Gandiol and outside happens in two phases, as explained by Mr. Diallo:

"***Level 1 Pre-Collection****: this is carried out at village level by a management committee or an association responsible for packaging and evacuating household waste to a designated transit site. Pre-collection is carried out with the help of an animal-drawn cart (horse) which passes daily through each household to collect the waste and evacuate it to a designated depot." . "**Level 2 Collection**: this is carried out by the municipality with the support of its partners, such as SONAGED, which has the equipment and heavy machinery to transfer solid waste to the Gandon landfill site for final treatment."*

Examples of household waste recovery activities are Defaratt, established in 2019, with a production capacity of 2 to 3 tonnes of plastic granules per month. Other recovery activities are scrap metal and aluminium collected and sold by local people to private operators who regularly come to the community and purchase the material.

In Gandiol, there are no centralised or decentralised composting facilities, nor there are landfills, treatment centres, energy recovery infrastructures. Gandon (10km from Gandiol) is the nearest landfill site (under rehabilitation). Matrix Dimension 3 is filled accordingly in Table 20.

Table 20.   Case Study MD3

MATRIX DIMENSION 3: INFRASTRUCTURAL DIMENSION (Gandiol)		
LEVEL	**Results**	
SEPARATION	**Waste Types**	- Metal and Plastics are the most separated waste items in Gandiol by two thirds of the respondents - Almost half of the sample separates organic waste and paper and cardboard - Glass and ceramic are sporadically separated - Out household out of four does not separated waste
COLLECTION and EVACUATION	**Household Waste Collection**	Bins, basins and buckets are the predominant collection items for households in Gandiol. Others use plastic and rice bags. A small percentage of the sample does not collect waste.
	Household Waste Evacuation	- A significant portion from the sample receive a horse drawn collection of their waste evacuation. Another large part dumps waste in undesignated areas. - Direct burn of waste and burial are practised by some households. - Few participants evacuate with vehicles transport, walking, or deliver to the recycling centre (Defaratt)
	Community Collection Facilities	- Many respondents claim that there are community collection facilities, such as bins. In some cases the population makes use of them, in some others they do not, and in other these facilities are unusable. - More than a third of the survey participants declare that there are no community collection facilities in their villages. Almost the same amount states that there bins and the
	Community Collection Services	A third of the participants are not aware of any waste collection service in their villages. Another third believes that there are not, while the rest claim that there are private collectors performing this duty.

MATRIX DIMENSION 3: INFRASTRUCTURAL DIMENSION (Gandiol)	
TRANSPORT	*Level 1 Pre-Collection*: animal-drawn cart (horse) transports household waste to designated dumping areas *Level 2 Collection*: SONAGED, with equipment and heavy machinery, transfers periodically part of the waste to the Gandon landfill site
RECOVERY	- Plastic: Defaratt recycling centre - Metal and Aluminium: sold to buyers
DISPOSAL	- No centralised or decentralised composting facilities, nor there are landfills, - Treatment centres, energy recovery infrastructures. - Nearest landfill Gandon , distant 10km(under rehabilitation).

6.5 Matrix Dimension 4: Knowledge-Behavioural Dimension

The Matrix Dimension 4 of the Multidimensional Solid Waste Management Analysis Framework gives insight on the knowledge about waste management practices and activities, the attitude and behaviour towards it, and the concern about environmental health related risks by the inhabitants of the community.

Knowledge

When asked if they have ever heard or seen a communication campaign about waste management, 63% of the participants responded positively and 37% negatively. The former were also asked what was the source of information. The most selected options are community representatives and social media (70.8% and 43.8% respectively), followed by TV (18.8%) and radio (4.2%); others responded *Defaratt* (Tab. 21).

Table 21.   *Communication Campaign Survey Results*

Question: Have you ever heard or seen a communication campaign about waste management? (n=73)	
Answer Choices	**Percentage**
Yes	63.0
No	37.0
Question: If you answered yes in the previous question, can you tell where did you hear or see one? (n=48)	
Answer Choices	**Percentage**
Community Representatives	70.8
TV	18.8
Radio	4.2
Social media	43.8
Other	4.2

The results of the knowledge about waste related concepts measured with the familiarity level are illustrated in Figure 14. Participants were asked to rank on a scale from 1 (low) to 5 (high), same for perception, attitude and concern, discussed later. The highest scores have been assigned to pollution (4.26 average), and organic waste (3.99), while the lowest have been environmental tax (3.26) and environmental fine (3.21). Grouping the concepts by similarity, and labelled as 'Waste Basics' (Separation, Organic Waste, Composting, Pollution, Trash Cans and Garbage Bins), 'Waste Management Process', (Littering, Dumping, Waste Destination, Waste Treatment), 'Waste Legal Tools' (Environmental Law, Waste Framework, Environmental Tax, Environmental Fine), it is observable a decreasing trend in Figure 15.
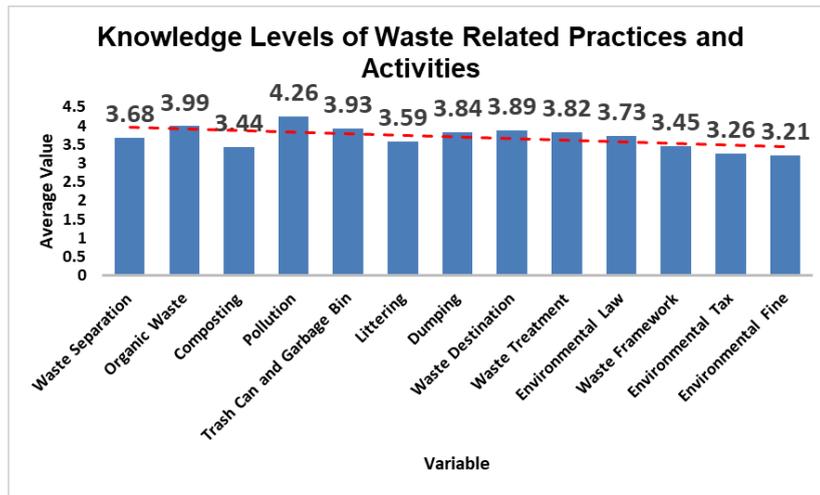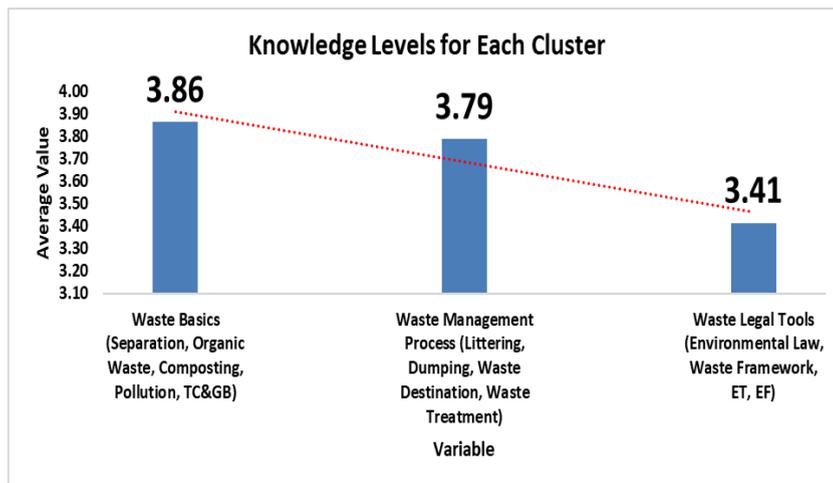
Figure 14.   Knowledge levels in Gandiol

Figure 15.   Knowledge levels divided per clusters

Perception and Attitude

Participants have been asked to identify what in their opinion were the factors mostly affecting waste management in Gandiol among those proposed (Tab. 22). The most selected one is 'Insufficient civil commitment' (57.5%), followed by 'Absence or inefficiency of collection services' (53.4%), 'Absence of designated dump areas' (47.9%), 'Lack of agreement within the community' (42.5%), 'Defecting collection material' (32.9%), 'Refusal of people to pay a collection fee' (11%),

Table 22.   *Factors Affecting Waste Management Survey Results*

Question What factors do you think mostly influence the waste management in your village/ community? (n=73)	
Answer Choices	**Percentage**
Absence or inefficiency of collection service	53.4
Absence of designated dump areas	47.9
Insufficient civil commitment	57.5
Defecting collection material	32.9
Lack of agreement within the community	42.5
Refusal of people to pay a collection fee	11.0

Following the research of Chammas et al., (2020), respondents have been asked the level of agreement with statements related to six variables among those identified in the study, to see their level of attitude towards and perception of waste and environmental issues (Fig. 16). The results show higher levels if compared to the knowledge question presented before. In Particular, respondents seem confident in their knowledge of recycling (4.29 average) and concerned about the environment (4.15).
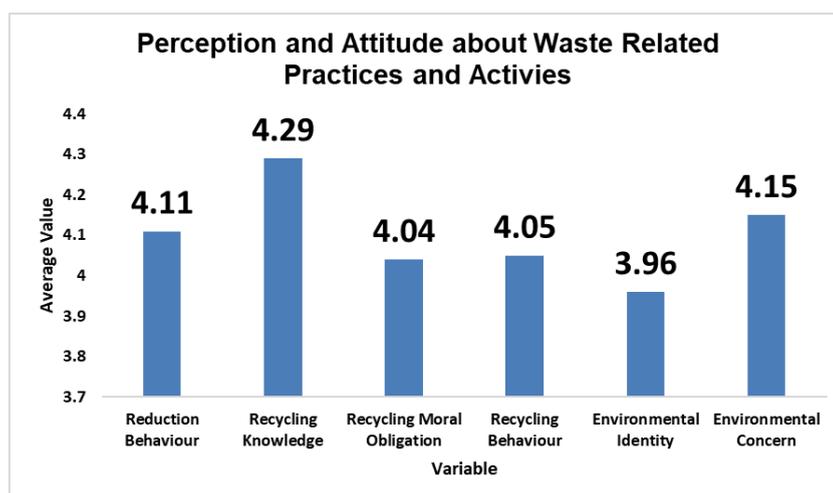

Figure 16.   Perception and Attitude Levels in Gandiol

Concern

The level of concern about health-related risks from littering and dumping has been measured as in Viljoen's et al.'s study (2021). The level of concern is high for both, with participants more concerned about dumping rather than littering (Figure 17).
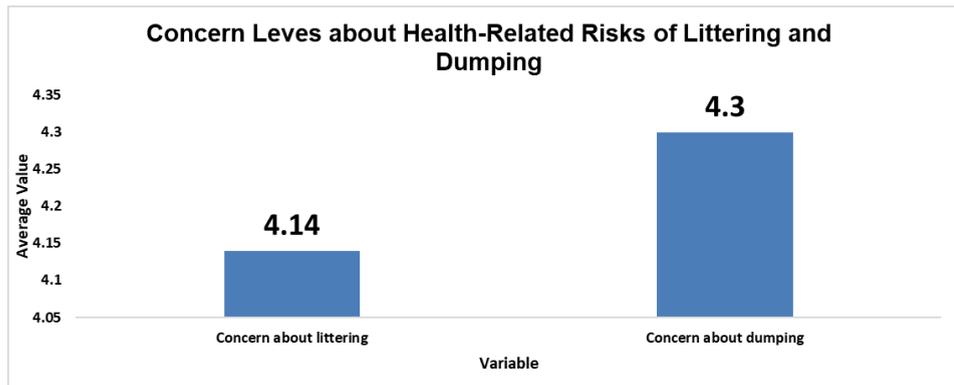

Figure 17.   Concern Levels in Gandiol

The results for Matrix 4 are elaborated in Table 23.

Table 23.   Case Study MD4

Matrix Dimension 4: KNOWLEDGE BEHAVIOURAL	
Knowledge	
Level	**Results**
Waste Basics	Overall high knowledge of the terms. Composting is less known, while pollution is well known within the sample
Waste Management Process	The sample has an understanding of the terms littering (to a lower extent) and dumping (to a higher extent). Participant seem to be aware of what happens to waste after collection and evacuation
Waste Legal Tools	There is a lower level of knowledge than the previous categories. The sample is more unfamiliar with terms such as environmental law, tax, fine and waste framework
Waste Management Awareness Campaigns	Almost two thirds of the sample has been exposed to a waste management awareness campaign
Information Sources	Community Representatives and Social Media are the information sources most selected by those who have been exposed to a waste management awareness campaign
Perception and Attitude	
Level	**Results**
Reduction Behaviour	Most of the participants in the sample claim to embrace a reduction behaviour in the amount of waste they produce
Recycling Knowledge, Behaviour, Moral Obligation	Recycling seems to be a term well known by participants. Behaviour and Moral Obligation levels are high but to a lower extent.
Environmental Identity and Concern	Participants are concerned about the environment, more than they identify environmental sustainability as a value they promote
Factors Affecting Waste Management	According to the survey results, people have identified the factors affecting waste management in their community in this order: - Insufficient civil commitment - Absence or inefficiency of collection service - Absence of designated dump areas - Lack of agreement within the community - Defecting collection material - Refusal of people to pay a collection fee
Concern	
Level	**Results**
Littering	Most of the participants are concerned with health-related risks of littering
Dumping	Most of the participants are concerned with health-related risks of dumping, onto a higher extent than littering

6.6 Results Discussion

The results from the survey, questionnaire, and document review have been used to compose the Multidimensional Analysis Framework for household waste management in the community of Gandiol. The framework helps to visualise the main features over the waste management process divided into four dimensions, legal, socio-political-economical, infrastructural and knowledge-behavioural, and to support the discussion of the results.

The discussion of the results is divided into two parts. The first examines household practices in Gandiol in the context of the Senegalese waste management framework and initiatives, particularly on the first three dimensions of the Multidimensional Analysis Framework: legal, socio-political-economic and infrastructural.

The second part is concerned with the fourth dimension of the framework, comparing findings on knowledge, perception, attitude, and concern with previous studies from Chammas et al. (2020) and Viljoen et al. (2021).

The main aspect at the core of this study is the presence of uncontrolled waste, particularly in rural areas in the Global South, posing a serious threat to public health and the environment in these communities. The community of Gandiol in North Western Senegal is an example of a community affected by the presence of uncontrolled waste. According to the findings from the survey, actions such as dumping, burial and open burning of waste are practised by members of the community.

To better understand the context within and around the community, the Multidimensional Analysis Framework facilitates the comprehension of the situation in Gandiol by contemplating four dimensions. The first, legal, provides an overview of the national waste framework and current initiatives. The second, socio-political-economic, concerns the accountability on the local level and the monetary resources that households give to contribute to waste services. The third, infrastructural, analyses the full waste management process, from household separation to disposal, while the fourth, knowledge-behavioural, considers knowledge, perception, attitude and concern over waste management and related risks.

6.6.1 National Level, Municipal Accountability and Resources

Senegal, is making steps towards better regulating waste management by revising the outdated environmental code with the approval of the new one in 2023. The Waste-Hierarchy-Principles are clearly stated and they offer an orientation for waste practices. In addition, the document establishes dumping and open burning as criminal

offences, thus taking a stance against polluting perilous activities for the environment, by discouraging people to perform these actions. These recently added elements in the legal code contribute to reinforce the fight against waste pollution, along with *Law n°2020-04* enacted to fight against single use plastic products. The major initiatives on a national level undertaken in the last years to manage uncontrolled waste are PROMOGED and SONAGED. According to Sabatier (2023), they represent the move by the State to take back control over the process of waste management that has been decentralised in the previous decades. Essentially, PROMOGED is a project aimed at infrastructure building for waste collection, transport, recovery and disposal, while SONAGED is the state-backed company in charge of providing waste related services. Together, they represent the attempt to coordinate the efforts on a national level to create an integrated waste management system. In the context of these acts and initiatives, however, two important aspects, identified in the second matrix dimension, play an important role, especially at the local level: accountability and resources. The accountability at the local level for waste management is ultimately in the hands of the municipality. This is a legacy of the decentralisation laws of 1996 and 2013, mentioned in Chapter 5. According to the sample results, the majority of respondents hold the belief that the municipality should be indeed the entity primarily in charge of the waste management. However, the municipality alone cannot provide all the waste related services and phases. This is why local stakeholders are also important in the process, especially on a small-scale level. As mentioned in Section 5.1.3, in the Senegalese context, local non-governmental entities play a role in the process. For instance, *Defaratt* supports plastic collection and recycling in this context.

For an efficient waste management system, resources are indispensable. However, most of the respondents in Gandiol are not contributing monetary to any service or they are not aware, although they are subjected to the TEOM. It seems to be an outdated revenue source, an inefficient and insufficient funding method, a perception shared by many interviewed by Sabatier (2023). Indeed, one of the objectives of PROMOGED is indeed to reform TEOM with new financial instruments. A promising outcome from the survey, in this sense, is the willingness of many respondents to contribute monthly to a waste service. Features from MD1 and MD2 are visible in Figure 18.

Legal Framework

Law n°2023-15 of August 2nd, 2023 (Environmental Code)

Financial Resources

Law n°72-52 of June 12th, 1972 (TEOM) Household Waste Tax

Accountability

Municipality

Other Stakeholders

- Defaratt
- Private Collectors

Figure 18.   Visual representation of main elements from MD1 and MD2

6.6.2 Gandiol Household Waste System

Similar separation practices happen at the village level in Gandiol, according to the results from the findings from the three villages where respondents are from, Ndiebene, Tassinere et Pilote. The highest value for households not collecting their waste is in Tassinere, for organic waste is in Pilote, for plastic, metal, paper and cardboard, ceramic and glass is in Ndiebene (Fig. 19).
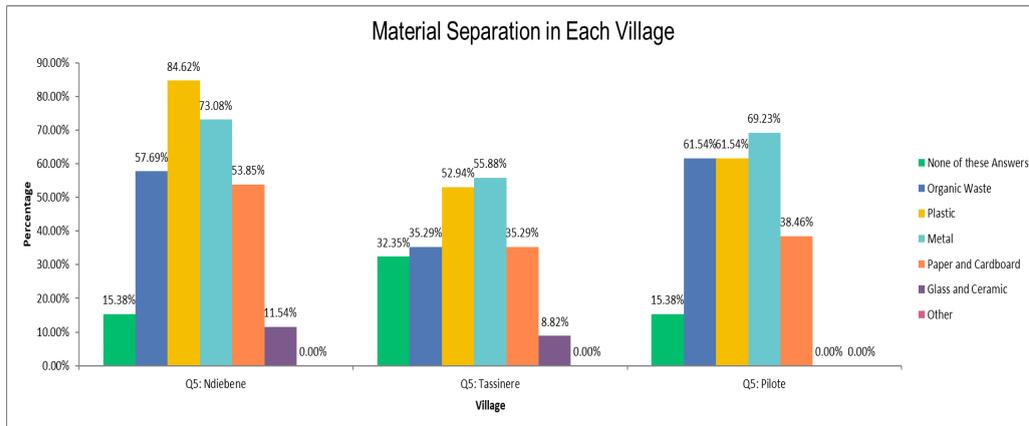
Figure 19.   Material Separation in Each Village

Household collection is mostly performed with bins in Ndiebene, and with basins and buckets in Pilote. Also in Pilote, there is the highest value for the absence of household collection (Fig. 20).
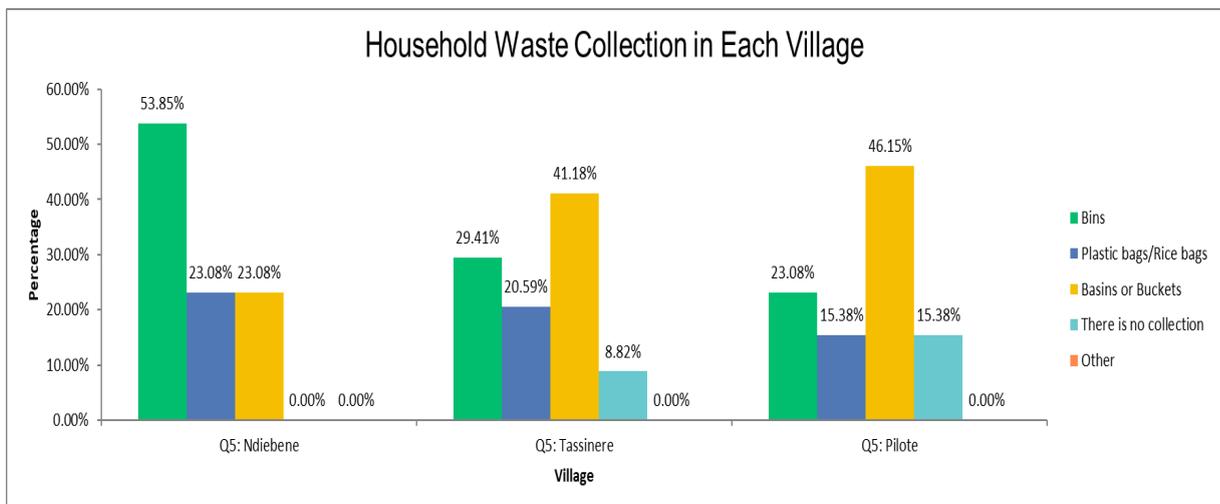

Figure 20.   Household Waste Collection in Each Village

The presence of collection facilities such as bins and garbage cans on a village level is found in the three villages. However, in Ndiebene, half of the households claim that people in the village make use of them, while in Tassinere and Pilote almost the same amount claim that there are not any in their villages (Fig. 21)
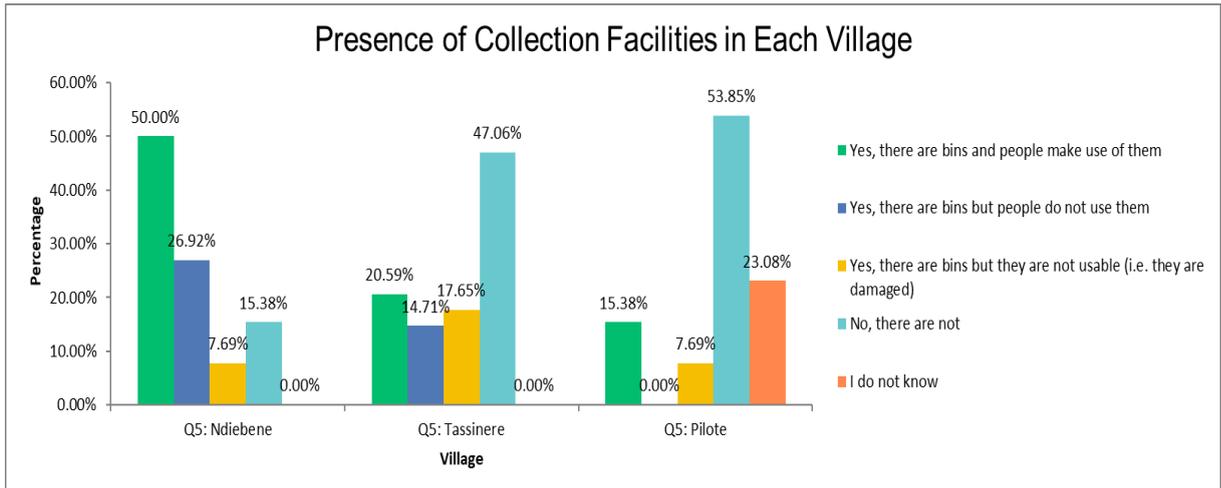
Figure 21.   Presence of Collection Facilities in Each Village

Household waste evacuation is mainly horse drawn in Ndiebene, and by dumping in Tassinere and Pilote. Tassinere has the highest value in terms of open burning, while Pilote has the highest in burial (Fig. 22).
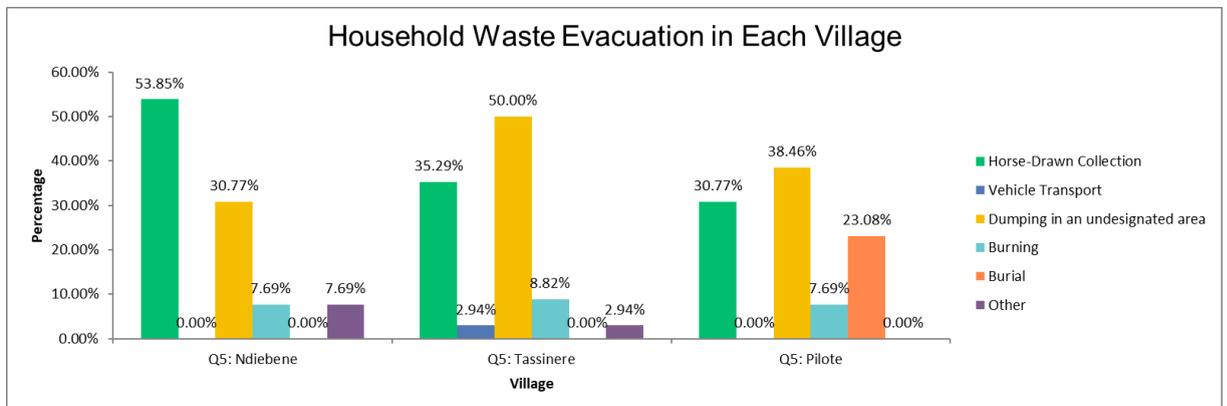

Figure 22.   Household Waste Evacuation in Each Village

These data are in line with the answers related to collection service within the village. In Ndiebene the half of the respondents claimed that there are private collectors performing the task, while in Tassinere and Pilote the majority of respondents combined affirmed that there are not or that they are not aware (Fig. 23).
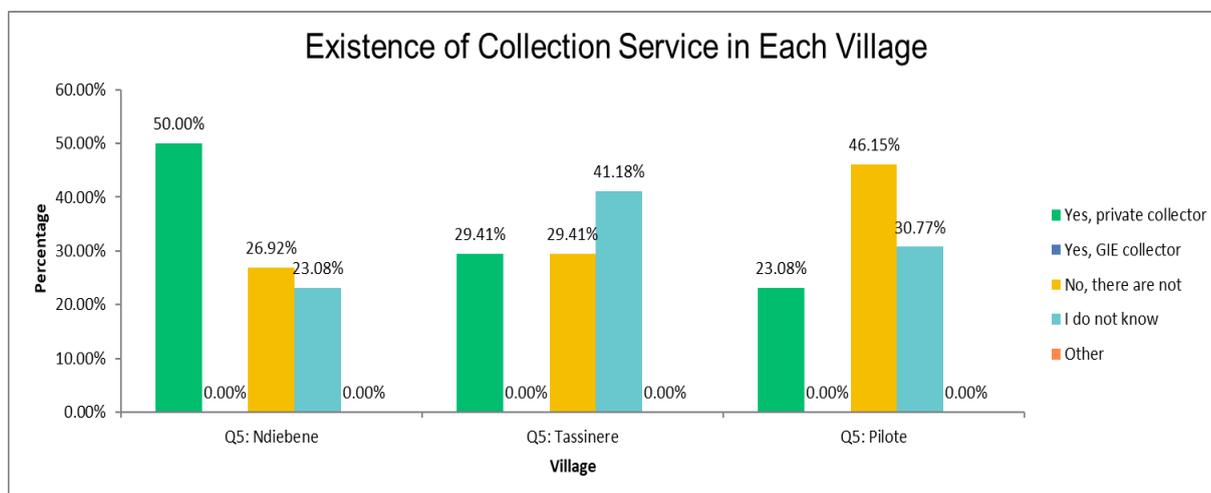
Figure 23.   Existence of Collection Service in Each Village

This data, combined with the results from the questionnaire, give an indication to the overall waste management in Gandiol. Indeed, Mr. Diallo has certified the presence of a pre-collection phase such as horse-drawn collection and transport of household waste to a designated dump area. From there, periodically, SONAGED collects waste with trucks to be transported to the Gandon landfill (currently under rehabilitation). This can be visualised by the infrastructure map from PROMOGED in Figure 24.

Figure 24.   GPS View of Gandiol Collection Point and Gandon Landfill Area. Source:

PROMOGED, n.d.[2]

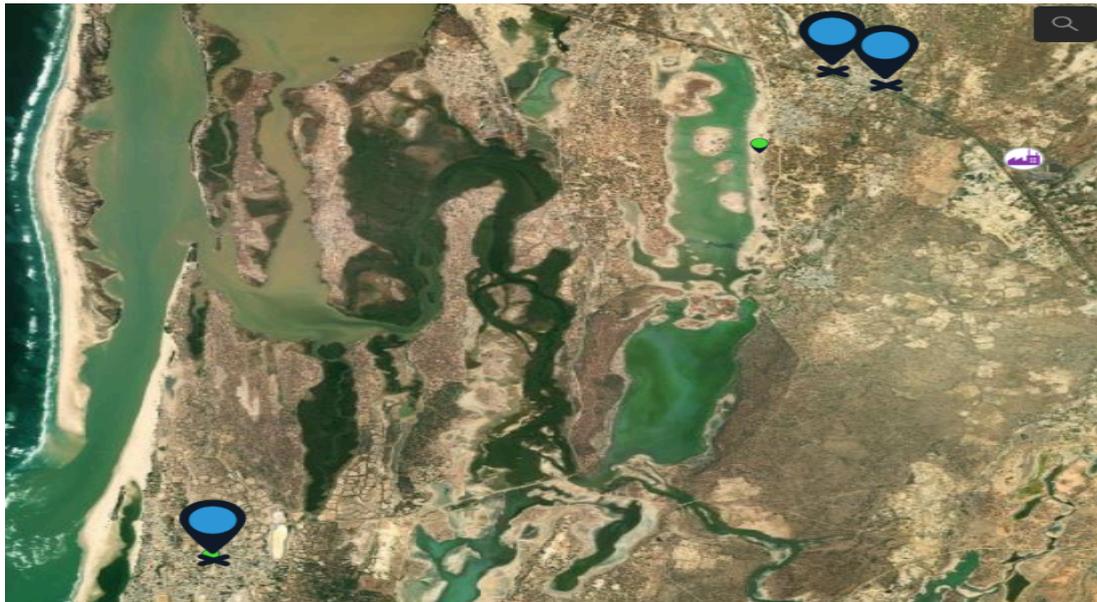In the right bottom corner, the pin designs a collection point established in Ndiebene. In the left top corner, there are other collection points and, where Gandon is located, an industry icon, meaning that a construction site for a treatment centre is ongoing.

To sum up, the household waste management process in Gandiol takes this sequence. First, it is separated into waste types by households. Then it is collected, with bins, buckets, bags and basins. Then it is evacuated by households, either with horse drawn collection (which presumably also collects trash in the bins and garbage cans scattered in the village), or either directly dumped in undesignated areas, burned or buried. The collected waste from this informal animal drawn collection service is then brought to the designated collection area for a pick-up by SONAGED.

The rest of the waste that is not gathered by SONAGED, is either collected by *Defaratt* (plastic recycling) or bought by private collectors (metal and aluminium). Otherwise, the waste is uncontrolled and dispersed in the environment. Last Google Earth available images (March 2024) show how some of the undesignated dumping areas are still in use within the community (Fig. 25).

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[2] Interactive map available at: https://promoged.sn/fr/territorialisation-du-promoged

Figure 25. Screenshots of Dumping Areas GPS Images in Gandiol. Source: Google Earth, images updated to March 2024.

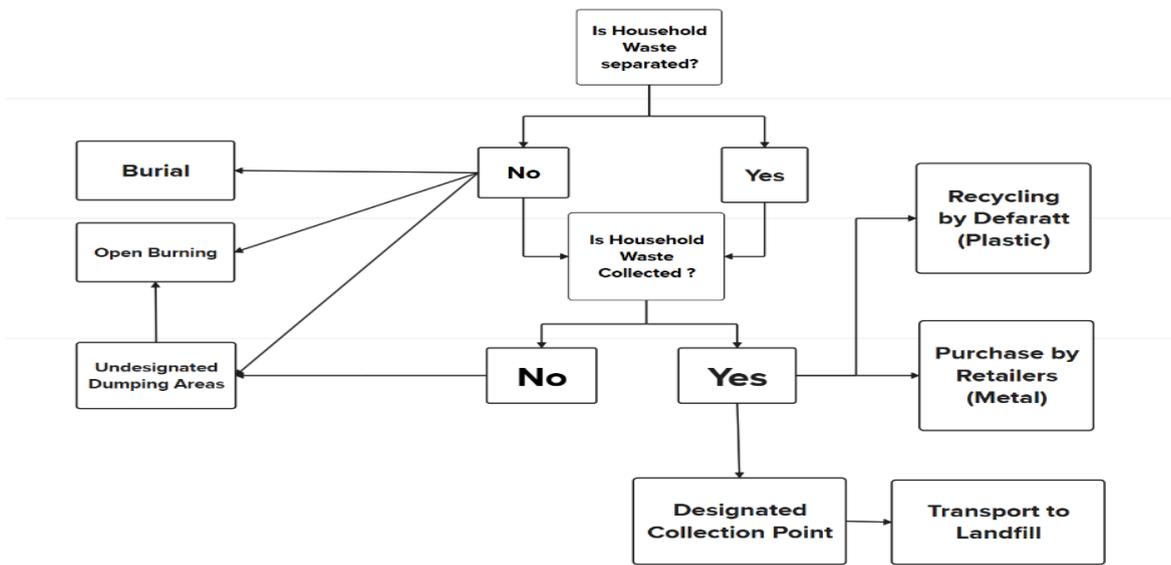The model for household waste management process in Gandiol is summarised in Figure 26.

Figure 26. Flowchart Displaying Household Waste Management Process in Gandiol

6.6.3 Knowledge, Perception, Attitude, Concern on Waste and Environment

As highlighted in Section 6.1, the sample interviewed in Gandiol is not representative of the population. This is because some groups are disproportionately represented for variables like age and education level, or their distribution is unknown like residence and income. Nevertheless, the data available allow the comparison among different groups as identified through the socio-demographic information of the participants, to understand how knowledge levels are distributed among the sample.

To accomplish that, the proposed discussion is based on the calculation of a total score for the three dimensions: knowledge, perception and attitude and concern. Their calculation are based on the following formulas:

Knowledge Total Score: Waste Basics Score + Waste Management Process Score + Waste Legal Tools

- Waste Basics Score = Sum of the Average of Separation, Organic Waste, Composting, Pollution, Trash Cans and Garbage Bins / 5

- Waste Management Process Score = Sum of the Average of Littering, Dumping, Waste Destination, Waste Treatment / 4

- Waste Legal Tools Score = Sum of the Average of Environmental Law, Waste Framework, Environmental Tax, Environmental Fine / 4

Perception & Attitude Total Score: Reduction Score + Recycling Score + Environment Score

- Reduction Score = Average of Reduction Behaviour

- Recycling Score = Sum of the Average of Recycling Knowledge + Recycling Moral Obligation + Recycling Behaviour / 3

- Environment Score = Sum of the Average of Environmental Identity + Environmental Concern / 2

Concern Total Score: Littering Score + Dumping Score / 2

- Littering Score: Average of Concern about Littering

- Dumping Score: Average of Concern about Dumping

Scores are calculated for each group for the variables age, gender, income, education, village. In addition, they are calculated for exposure to waste communication campaigns and evacuation practice.

Knowledge

The results below display the knowledge levels (Fig. 27). From the results, males score higher than females. Concerning age, the first two groups, 18-24 and 25-34 have an identical knowledge level, while there is an increase in the subsequent group, 35-44, and a downward trend for the group 45-54, although this last one is only represented by two respondents. Education level seems to play an important role in increasing knowledge levels in waste and waste management, with the positive trend visible from middle school level to university level. Although there is a substantial difference among the two extremes from income level, such as those with no income and those above 414,001 CFA, the former shows a similar level as the second wealthiest group (208,001 CFA - 414k CFA). Income is therefore not strictly determinant of knowledge level. Last, the highest level of knowledge was reached by participants from Ndiebene, with those from Pilote and Tassinere showing similar values. Respondents who have been exposed to a waste communication campaign have a higher knowledge level than those who were not. Regarding hazardous activities and waste knowledge, comparing people who have admitted to practising hazardous activities such as dumping, open burning and burial to those who do not, such as almost the other half who receive horse-drawn collection to evacuate their waste, they generally score lower (Fig. 28). Findings from knowledge levels among different groups are organised in Figure 29.
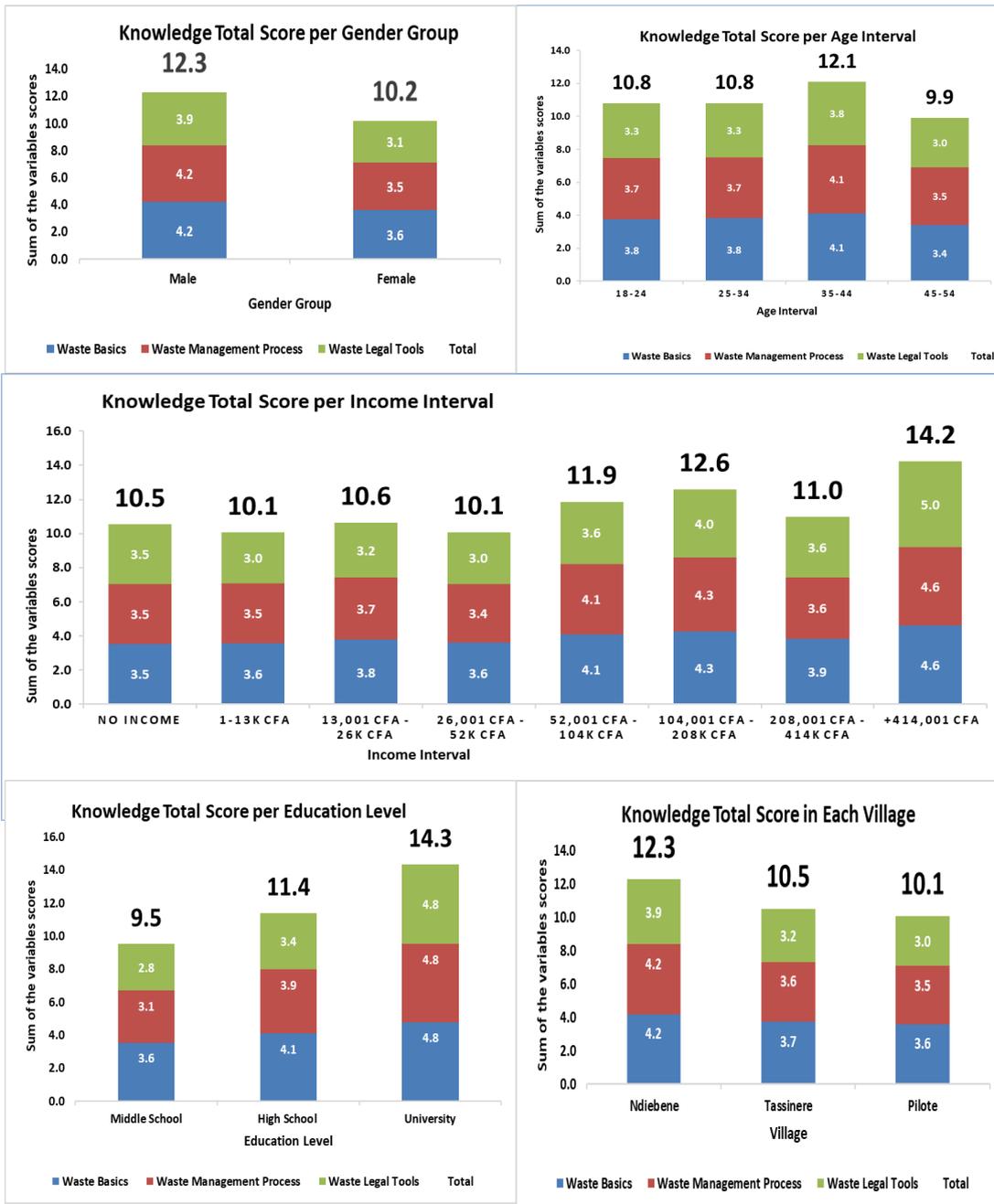
Figure 27.   Knowledge Total Score Across Gender, Age, Income, Education, Village
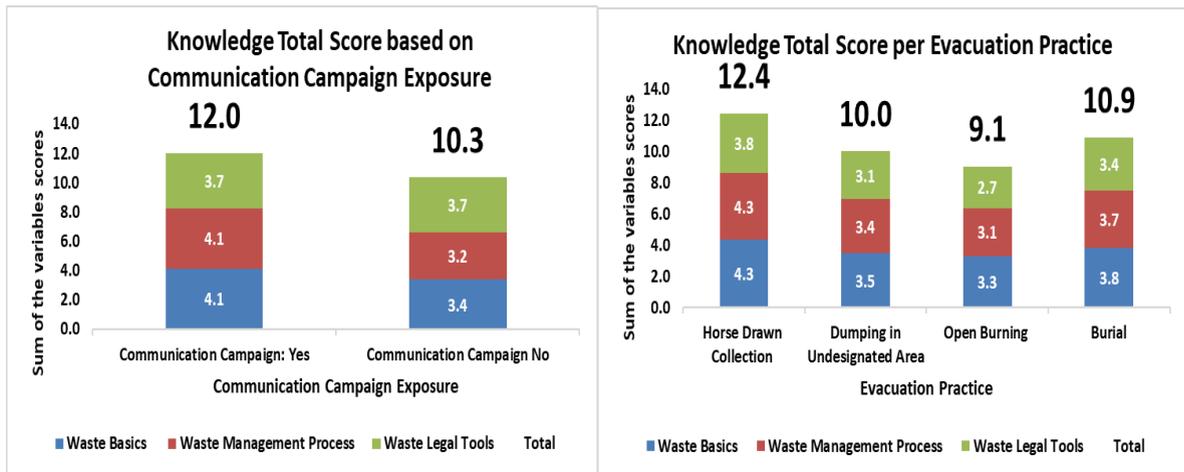
Figure 28.   Knowledge Total Score based on Exposure to Communication Campaign and
Evacuation Practice

WASTE KNOWLEDGE LEVELS IN GANDIOL							
GENDER							
MALES > FEMALES							
AGE							
18-24	25-34	35-44	45-56				
INCOME							
NO INCOME	1-13k CFA	13,001 CFA - 26k CFA	26,001 CFA - 52k CFA	52,001 CFA - 104k CFA	104,001 CFA - 208k CFA	208,001 CFA - 414k CFA	+414,001 CFA
EDUCATION							
MIDDLE SCHOOL LEVEL	HIGH SCHOOL LEVEL	UNIV. LEVEL					
VILLAGE							
NDIEBENE > TASSINERE > PILOTE							
EVACUATION PRACTICE							
DRAWN HORSE COLLECTION > DUMPING > BURIAL> BURNING							
EXPOSURE TO COMMUNICATION CAMPAIGN							
HAVE BEEN EXPOSED > NOT HAVE BEEN EXPOSED							

Figure 29.   Summary of Knowledge Findings in Gandiol

Perception and Attitude

The data collection for perception and attitude among participants takes the study from Chammas et al. (2020) as reference. The data from their study are displayed in Figure 30. In this case, the results can be compared 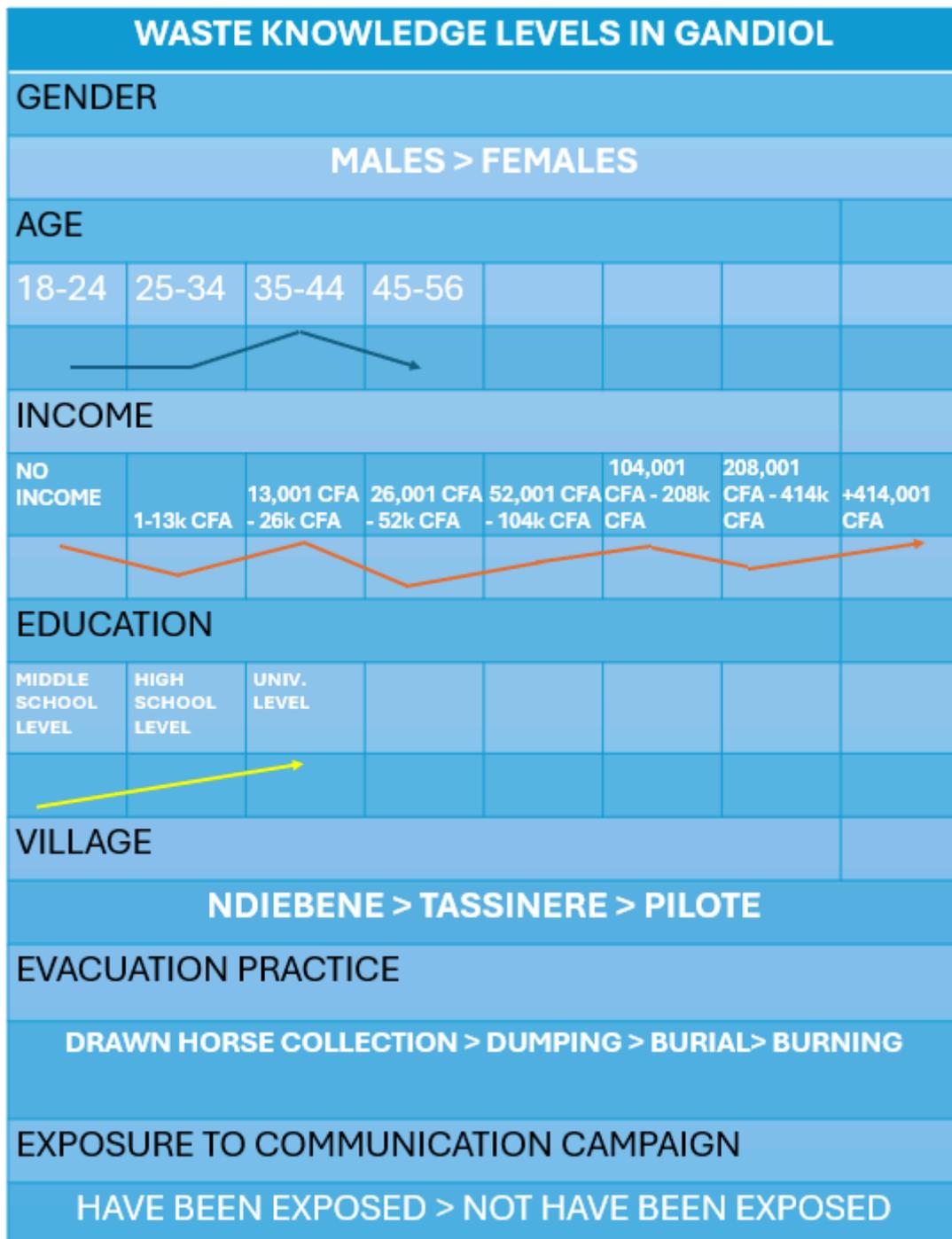by looking at the score results. However, they were collected in Lebanon with a different methodology, thus potentially leading to different results due to the methods applied.
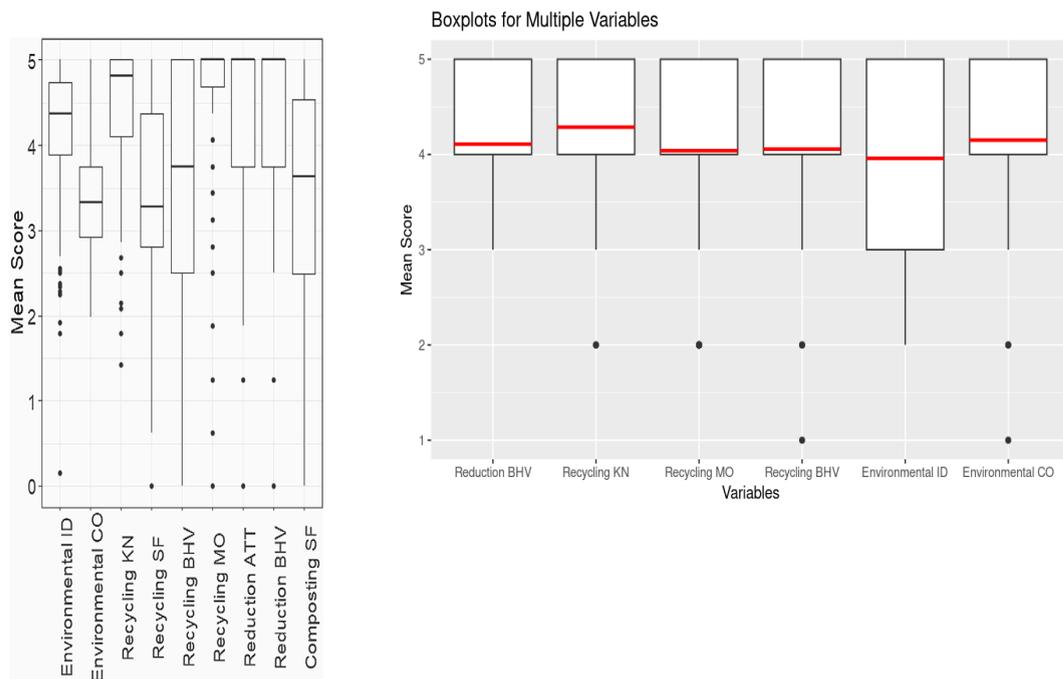

Figure 30.   Comparison of Box Plots displaying Perception and Attitude Variables in Naafeh (2020) and Gandiol (2024).

Note: On the left are shown the results from Chammas et al. (2020) from the study conducted in Lebanon, on the right those obtained from the inquiry in Gandiol

Based on the inquiry in Gandiol, participants generally have a high perception and attitude towards waste and environmental practices, considering that the median values for all the variables are placed with value 4.00, corresponding to "Agree" to statements based on the variables identified by the Lebanese study. In addition, all the mean scores are over 4.0, with the exception of Environmental Identity (3.96). This variable is the one where on average they were identifying less with.
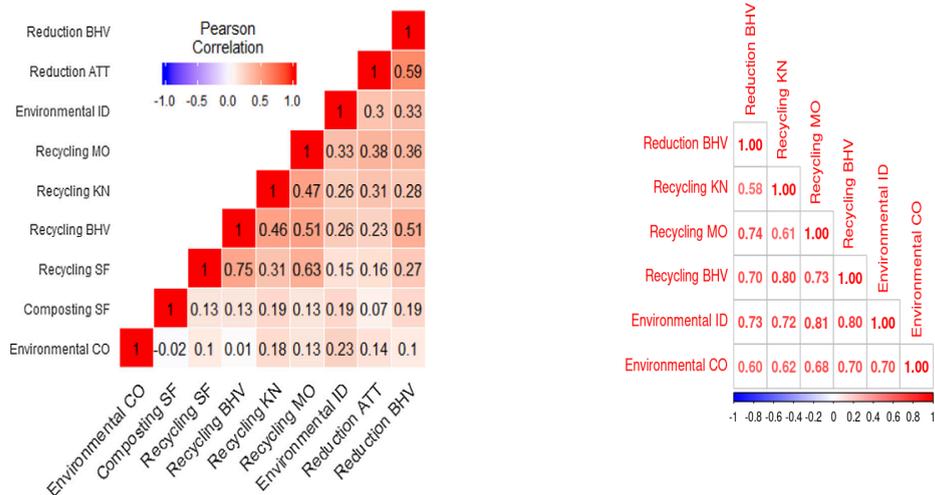
Figure 31.   Comparison of Correlation Matrices between Perception and Attitude Variables in

Naafeh (2020) and Gandiol (2024)

Note: On the left are shown the results from Chammas et al. (2020) from the study conducted in
Lebanon, on the right those obtained from the inquiry in gandiol

In terms of the correlation between the variables, the study conducted in Gandiol shows higher correlation coefficients than the ones from Chammas et al. (2020). The highest correlation values are the ones between Environmental Identity and Recycling Moral Obligation (Pearson Coefficient: 0.81) and Environmental Identity and Recycling Behaviour (Pearson Coefficient: 0.80). The lowest value, still highly correlated, is found between Recycling Knowledge and Reduction Behaviour (Pearson Coefficient: 0.58) (Fig. 31).

Perception and attitude scores are compared among different groups are displayed below. As for knowledge scores, also in terms of perception and attitude males tend to score higher than females, Ndiebene inhabitants score higher than the other villages, and the score increases with the increase in education level. Likewise knowledge levels, the perception and attitude scores fluctuate among income levels, although the two ends still represent the lowest and highest values. The difference from knowledge is noted in age groups, where the youngest (18-24) have the highest values of perception and attitude about waste and

environment among all the age groups. In relation to exposure to communication campaigns and evacuation practices, similar results to the previous sections are obtained by participants (Fig. 32, 33). Findings from perception and attitude levels among different groups are organised in Figure 34.
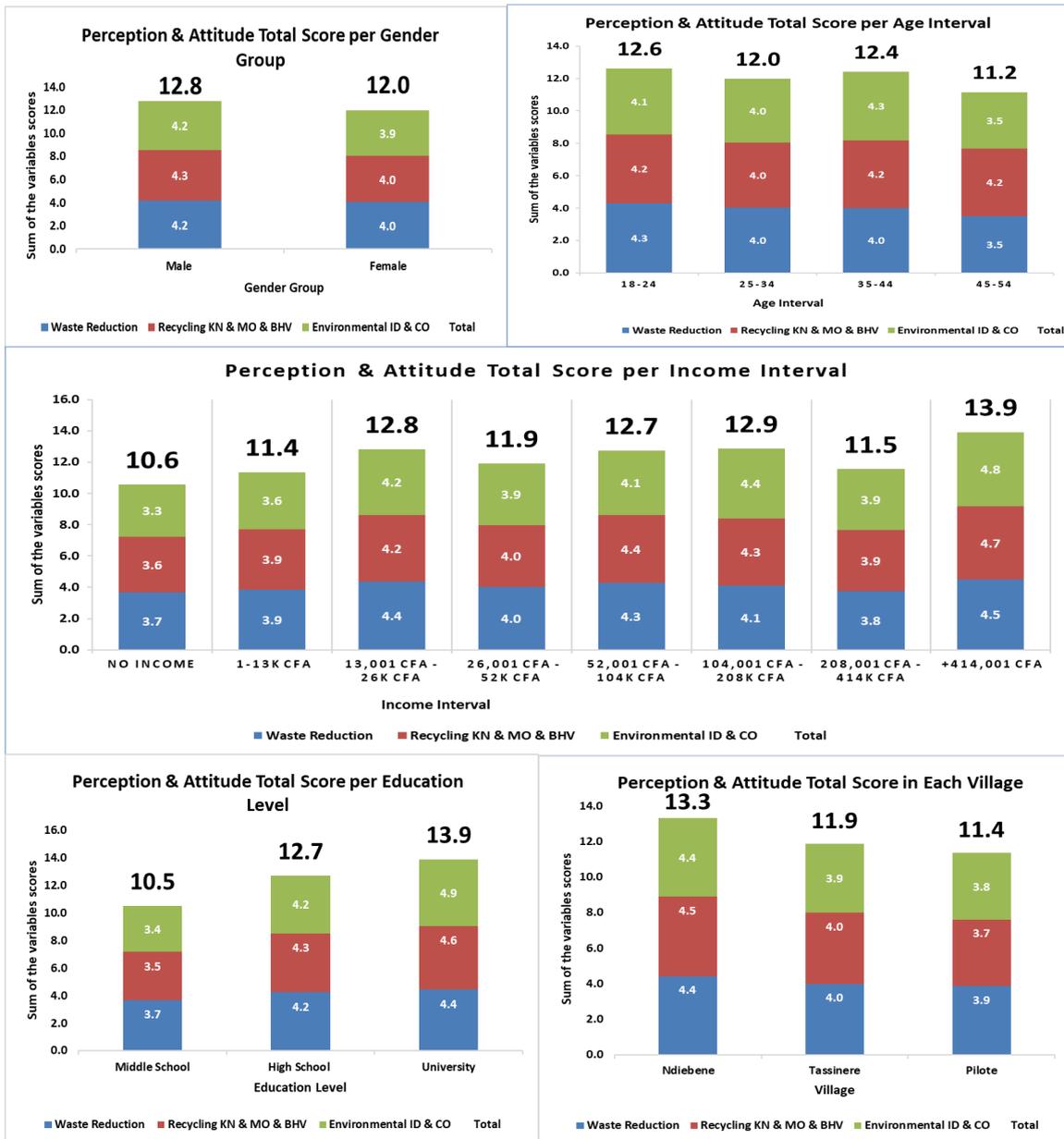
Figure 32. Perception and Attitude Total Score Across gender, Age, Income, Education, Village

Figure 33. Perception and Attitude Total Score based on Exposure to Communication Campaign and Evacuation Practice
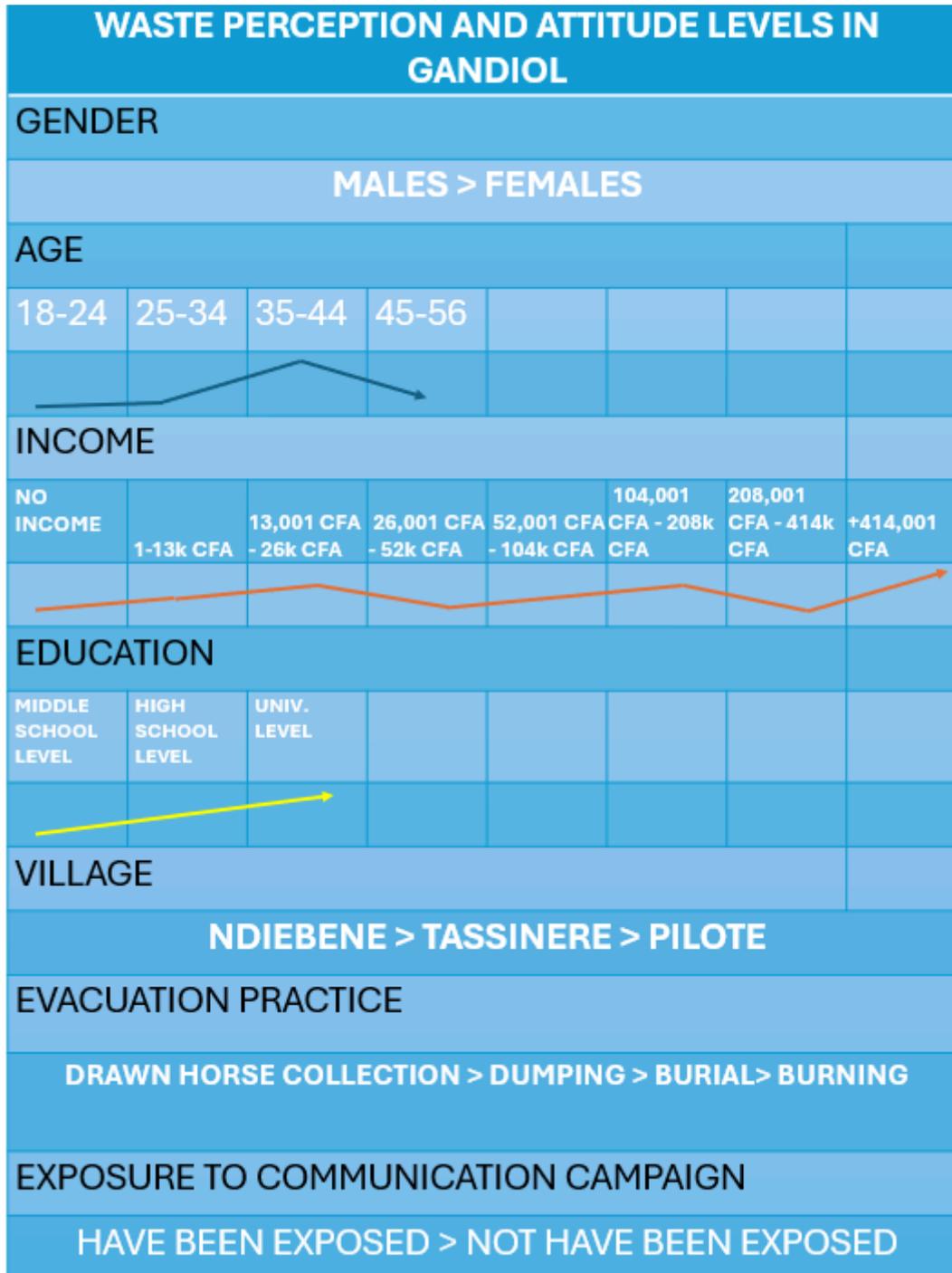
Figure 34.   Summary of Perception and Attitude Findings in Gandiol

Concern

The last variable to be discussed in concern, with Viljoen et al.'s study in the Hantam's municipality in South Africa (2020). Overall, Gandiol's inhabitants seem concerned about health-related risks from polluting practices such as littering (4.14 average score) and dumping (4.30), a data that is in line with the variable 'Environmental Concern' (4.15) from the previous section (Fig. 35). Unlike the study conducted in South Africa, in Gandiol there seems to be a transversal concern across income levels.
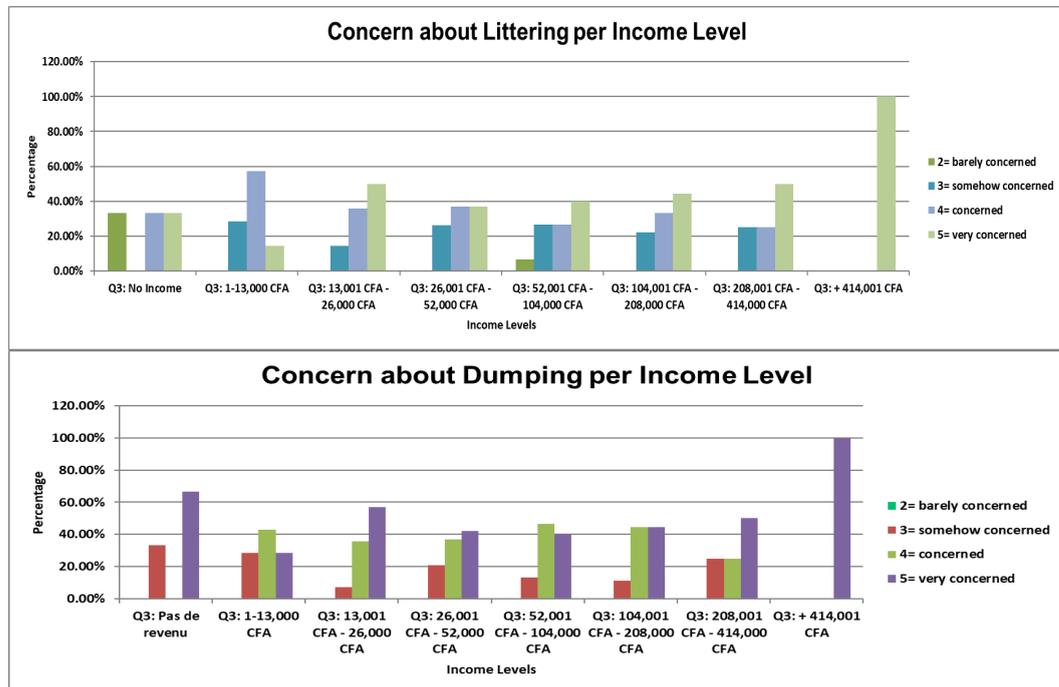
Figure 35.   Concern about Littering and Dumping Across Income Levels

Other than income level, concern is very similar among other variables, as visible from Figure 36 and Figure 37. Findings from concern levels among different groups are organised in Figure 38.
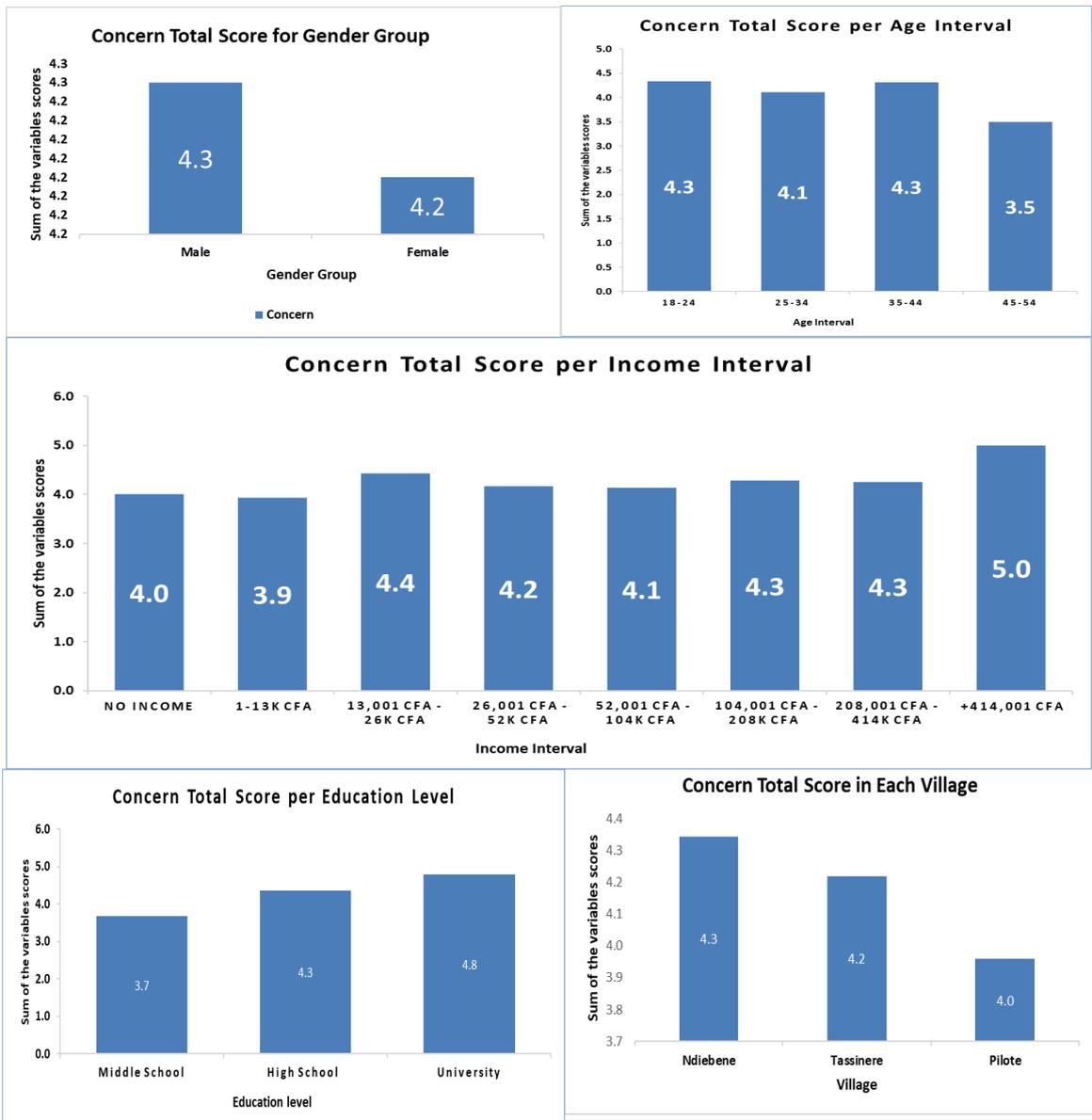
Figure 36.   Concern Total Score Across Gender, Age, Income, Education, Village
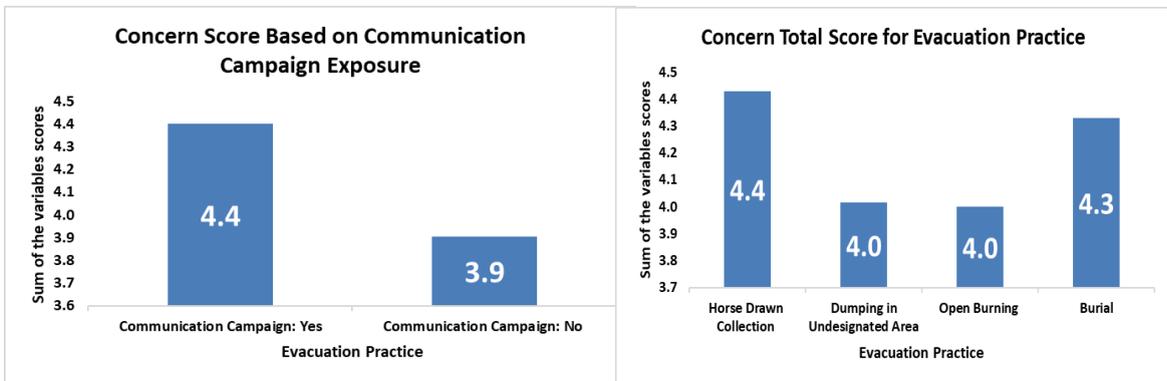
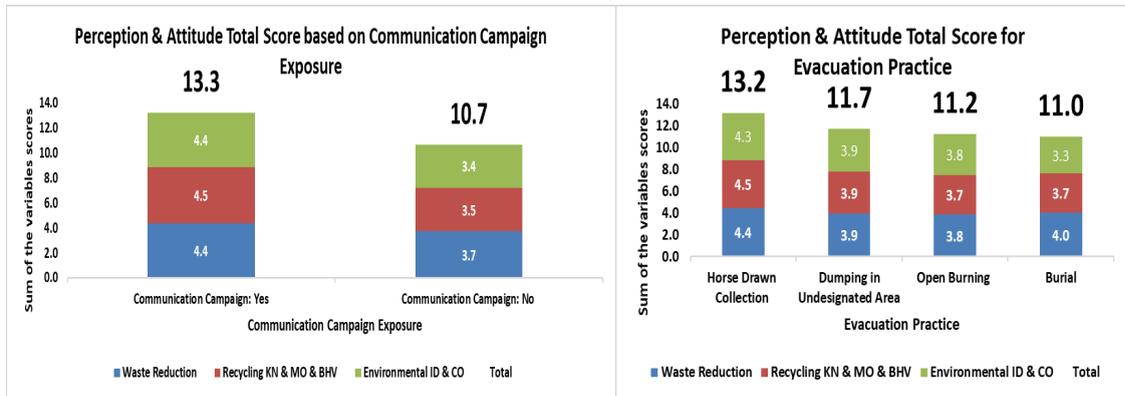*Figure 37.*   Concern Total Score based on Exposure to Communication Campaign and

Evacuation Practice

WASTE CONCERN LEVELS IN GANDIOL							
GENDER							
MALES > FEMALES							
AGE							
18-24	25-34	35-44	45-56				
INCOME							
NO INCOME	1-13k CFA	13,001 CFA - 26k CFA	26,001 CFA - 52k CFA	52,001 CFA - 104k CFA	104,001 CFA - 208k CFA	208,001 CFA - 414k CFA	+414,001 CFA
EDUCATION							
MIDDLE SCHOOL LEVEL	HIGH SCHOOL LEVEL	UNIV. LEVEL					
VILLAGE							
NDIEBENE > TASSINERE > PILOTE							
EVACUATION PRACTICE							
DRAWN HORSE COLLECTION > BURIAL > BURNING = DUMPING							
EXPOSURE TO COMMUNICATION CAMPAIGN							
HAVE BEEN EXPOSED > NOT HAVE BEEN EXPOSED							

Figure 38.   Summary of Concern Findings in Gandiol

Chapter 7. Conclusion

Uncontrolled waste is a threat to public health and the environment. Practices such as dumping and open burning of waste release pollutants and increase gas emissions. Particularly affected by these actions are rural communities in the Global South, lacking the waste management efficiency more common in the Global North, and often left out or barely involved in waste management processes and activities more common in urban areas. These communities are also facing socioeconomic dynamics that place them under more vulnerable conditions, with waste management that is not seen or treated as a priority.

The objective of this thesis, outlined at the beginning, was to understand the challenges experienced in waste management by these communities and to address any research gap while consulting previous studies conducted in the field by dividing findings in a multidimensional model (legal; socio-political-economic; infrastruct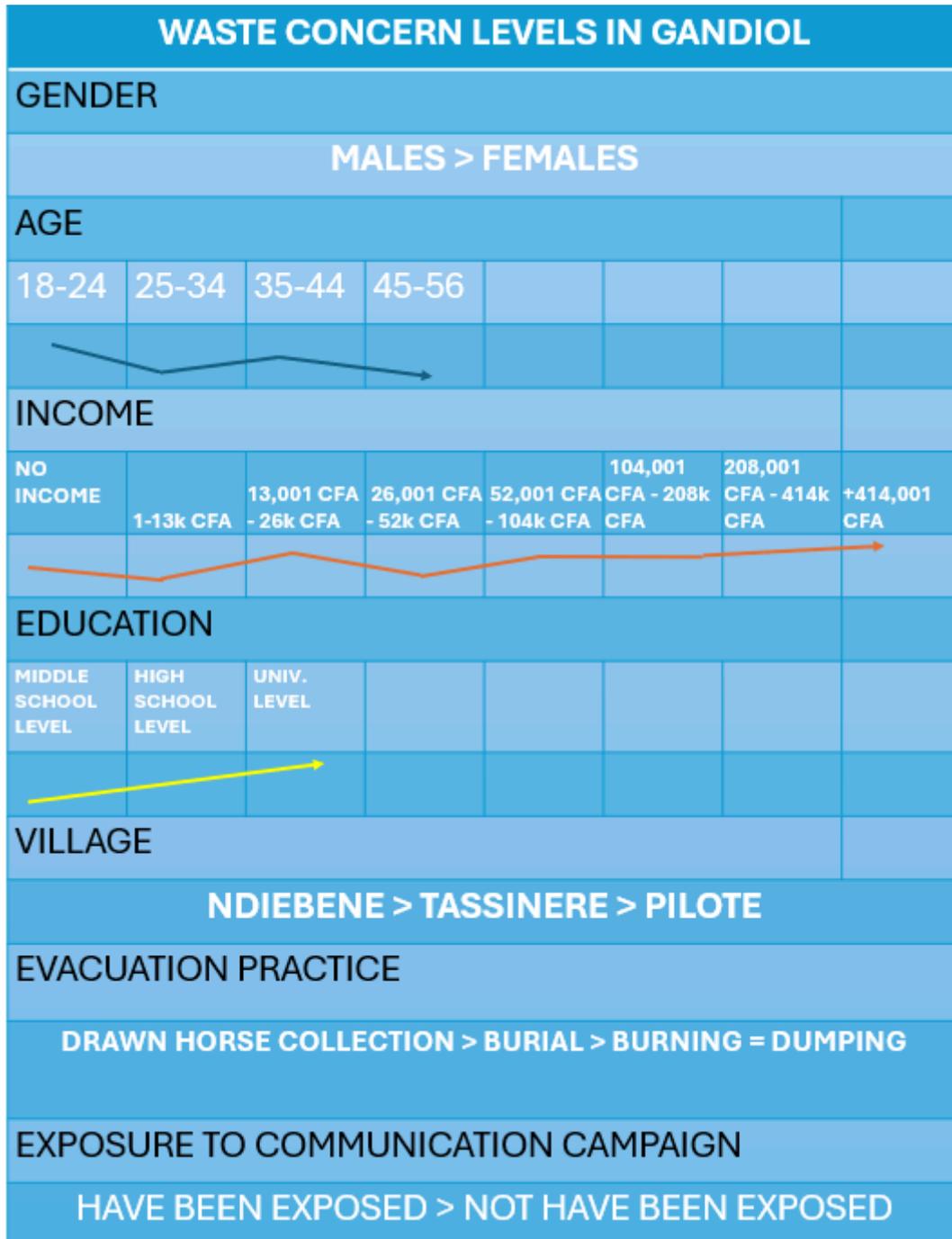ural; knowledge-behavioural). In addition, the case at hand, the rural community of Gandiol in Senegal, was aimed to be discussed by proposing a new analysis tool to investigate solid waste management in rural communities of the Global South. This is because previous studies have attempted to understand the factors that play a role in the mismanagement of solid waste, finding similarities across communities in the different parts of the Global South. These researches conducted on the fields, however, are very different among them, in terms of objectives, methodologies, focus and design. Therefore, their results and conclusions are hardly comparable.

This thesis has contributed to filling this gap, by proposing a standardised and uniform tool to investigate solid waste management in rural areas of the Global South, where waste data collection is generally lacking, by proposing a Multidimensional Analysis Framework. The framework serves to organise information on the different aspects related to solid waste management divided into four dimensions: legal, socio-political-economical, infrastructural, and knowledge-behavioural. The first dimension is concerned with the national level of the country where the community is located. It describes the legal national waste framework under which waste management is regulated, its hierarchy principles, any production or consumption ban for specific products, illegal waste activities and their prosecution, and current waste initiatives. The second dimension defines the accountability on waste management as well as the resources that inhabitants are subjected to pay for the process, and, if there are not, their possible willingness to contribute economically. The third

dimension provides a complete representation of the whole process, considering phases such as separation, evacuation, collection, transport, to final disposal, bringing together information about the available waste infrastructures and practices. The last dimension measures the knowledge, perception, attitude and concern level of inhabitants on waste and environmental practices.

The Multidimensional Analysis Framework, designed in the form of four combined matrices, enables reporting data in a structured and detailed manner. By combining the data collected for each dimension, an overview of the current state of a given community is produced, highlighting the main features of the waste management process and popular perception of it. If applied to multiple communities, it fosters comparison among them. Cross-study comparisons offer evidence for policy decisions. Ultimately, having more comparable data can enhance the quality of research in the context of solid waste management (SWM) in rural areas of the Global South.

This has been the case for the proposed case study, the rural community of Gandiol, in North-Western Senegal, dealing with the presence of uncontrolled waste within its territory. With the application of the Multidimensional Analysis Framework to this case, the main elements and factors related to waste management within the community are identified; the national context of the Senegalese legal framework under which waste management is regulated, the entities accountable, the stakeholders participating in the processing and the resources allocated. The waste practices in the community and the inhabitants' knowledge, perception, behaviour related to waste and the concern about polluting practices complete this investigation into household waste management in Gandiol.

The picture that emerges from the Multidimensional Analysis Framework is of a country, Senegal, that is making progress towards establishing a nationwide integrated solid waste management, both in legal terms and with essential infrastructure building. Gandiol is an example of a rural community that still lags behind the main development ongoing in urban areas. These kinds of communities are marginally involved in the process, with sporadic and limited waste collection by SONAGED, the newly created waste handling company. Therefore, people are still practising disposal methods, such as dumping and open burning, as the only available alternatives. Even though they admittedly do so, concern on the health and environmental associated risks is high, in a community like Gandiol that is still affected by the legacy of natural disasters that happened two decades ago. Particularly, those who have been participating in communication awareness campaigns, show higher levels. The presence of *Defaratt* and the efforts made to locally contribute in managing waste are visible. In conclusion, Gandiol is, like the whole country, in a transition process from uncontrolled to

controlled waste management. Future research in the country and the community will have the chance to assess the development level of this transition.

7.1 Limitations

Although the Multidimensional Solid Waste Management Analysis Framework proves to be an innovative investigation tool for a standardised and uniform research in SWM in rural areas of the Global South, there are limitations that must be acknowledged:

- The participation in interviews was limited and the expectation was to involve more participants, especially practitioners, particularly from different geographic areas of the Global South, in order to enrich the quality of a multi-perspective comprehension of local and global challenges experienced in rural communities within the Global South.

- The exploratory nature of the research means that it cannot be considered fully representative, as some data from the broader populations remain unknown in Gandiol. The survey respondents were few in number, potentially affecting the generalizability of findings.

- The survey respondents are residents of only three villages, limiting its scope. By gathering information exclusively on these three villages, the study may inadvertently emphasise local characteristics and practices specific to those areas. These findings might not apply universally across the other villages in Gandiol. Therefore, extrapolating conclusions from such a small subset to the entire population can lead to overgeneralization. The unique circumstances of these villages may not align with broader trends within the whole community.

- The study's concentration solely on household waste overlooks the broader waste ecosystem within the community. By excluding other waste streams (such as agricultural, industrial, or commercial waste), the study does not entirely capture the full extent of waste generation and disposal within Gandiol.

- Considering that this study has been conducted online, with interviews and surveys conducted remotely, the insight generated by these methods is poorer if compared with in-person data collection. Particularly, contextual clues, patterns, and local cultural dynamics are hardly considered with this approach.

7.2 Future Directions

The limitations addressed in the previous sections can be taken as the starting point to design future applications of the Multidimensional Solid Waste Management Analysis Framework. For the size and scope of this thesis, the focus has been limited to household waste management. As a matter of fact, the idea is to map and analyse all of the solid waste streams within a community. As such, the structure of the framework can be adapted to gather information on municipal waste, agricultural waste and industrial waste by looking at their specific legal framework, the accountable entities and the stakeholders involved, as well as the waste generators. By combining the results of all waste streams, the framework will indeed completely map the whole solid waste management in the community. While the framework has been designed through research methods applied remotely, it has the purpose of accompanying researchers in their field studies in rural communities in the Global South. The framework can be used in conjunction with other waste-related field measurements, such as waste composition, waste production, health risk assessment studies to enrich its significance and validity. Furthermore, field research can take into consideration cultural peculiarities within the community at hand, enriching the insight of data collected within the Multidimensional Analysis Framework.

To conclude, this thesis has attempted to contribute to the research in a field that, according to Dr. Vinti, is critical yet underrated, considering the negative impact that polluting activities related to waste management have on the health and the environment, locally and globally. Analysing the challenges experienced by rural communities in the Global South is, therefore, the first step to design sustainable solutions for the future.

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Appendix

Legend: S = Survey, Q= Questionnaire, DR= Document Review

Table A0

Survey: Social and Demographic Information of Participants

Factor	Answer Options	Factor	Answer Options	Factor	Answer Options
Age	18-24, 25-34, 35-44, 45-54, 55-59, 60+	Income Level	- No Income 1-13,000 CFA, 13,001-26,000 CFA, 26,001- 52,000 CFA, 52,001- 104,000 CFA, 104,001- 208,000 CFA, 208,001 - 414, 000 CFA, + 414,001 CFA	Village	- Ndiebene, - Tassinere, - Mouit, - Mboumbaye, - Ndiol, - Pilote, - Keur Barka, - Other.
Gender	- Male - Female - Other	Education Level	- No Formal Education, - Primary School Degree, - Middle School Degree, - High School Degree, - University Level Degree, - Other		

Table A1

MD1 Research Structure

MATRIX DIMENSION 1: LEGAL DIMENSION		
LEVEL	**Questions**	**Answer Options**
NATIONAL FRAMEWORK **(Q+DR)**	What is the national legal framework? Are there any regional or sub-regional directives?	**Open Answer**
WASTE HIERARCHY PRINCIPLES **(Q+DR)**	What are the national strategies for waste management? What are the hierarchy principles followed to manage waste? What are the policy tools implemented within the framework? Are there any subnational regulations?	**Open Answer**
PRODUCTIONS & CONSUMPTION BAN **(Q+DR)**	According to the waste framework, is there any production or consumption ban on specific products?	**Open Answer**
LAW PROSECUTION **(Q+DR)**	What kind of waste related activity constitutes a criminal offence?	**Open Answer**
WASTE INITIATIVES	What are the national strategies for waste management? What are initiatives undertaken for waste	**Open Answer**

	management?	

Table A2

MD2 Research Structure

MATRIX DIMENSION 2: SOCIO-POLITICAL-ECONOMIC DIMENSION		
LEVEL	**Questions**	**Answer Options**
ACCOUNTABILITY **(Q+S)**	Who is accountable for waste management within the community? Who is directly participating in this process?	**Open Question**

	Who do you think should be primarily in charge of waste management?	**Multiple Choice**
		    a) National Government, b) Municipality, c) Private Company,
		        d) NGO and GIE, e) I do not know, f) Other (please specify)

RESOURCES **(Q+S)**	Are inhabitants of these communities subject to any form of waste tax?	**Open Question**
	Do you currently pay any tax, fee or contribution for a waste service?	**Multiple Choice** a) Yes, b) No, c) I do not know
	Would you participate in a monthly monetary contribution for a waste service?	**Multiple Choice** a) Yes, up to 1000 CFA, b) Yes, up to 500 CFA, c) No, d) Prefer not to

		say	

Table A3.1

MD3 Research Structure

MATRIX DIMENSION 3: INFRASTRUCTURAL DIMENSION		
LEVEL	**Questions**	**Answer Options**
SEPARATION **(S)**	Which materials do you separate at home?	a) Organic waste, b) Plastic, c) Metal, d) Paper and Cardboard, e) Ceramic and Glass, f) None of the above, g) Other (please specify)
COLLECTION and EVACUATION **(S)**	1) How is waste collected in your household?	a) Bins, b) Plastic Bags / Rice Bags, c) Basins / Buckets, d) There is no collection e) Other (please specify)
	2) How is waste evacuated?	a) Horse drawn collection, b) Vehicles transport, c) Dump in undesignated area, d) Open burning of waste, e) Burial, f) Other (please specify)
	3) Are there any collection facilities (i.e. bins, garbage cans, etc. etc.) in your village?	a) Yes, there are and people make use of them b) Yes, there are bins but they are not used, c) Yes, there are bins but they are not available for use (i.e. they are damaged), d) No, there are not, e) I do not know
	4) Is there any collection service in your village?	a) Yes, private collector, b) Yes, GIE collector, c) No, there are not, d) I do not know, e) Other (please specify)

Table A3.2

MD3 Research Structure (part 2)

MATRIX DIMENSION 3: INFRASTRUCTURAL DIMENSION		
TRANSPORT (Q)	How is waste transferred to other locations from household residence or collection points after being collected?	**Open Question**
RECOVERY **(Q)**	- Is household waste recovered somehow? - Are there any decentralised composting facilities? - Is there any facility dedicated to plastic recycling? - Is household waste transferred to any energy recovery site nearby?	**Open Question**
DISPOSAL **(Q)**	Are there any facilities nearby where household waste is transferred for disposal, such as sanitary landfills, or incinerators not used for energy recovery?	**Open Question**

Table A4.1

MD4 Research Structure: Knowledge

MATRIX DIMENSION 4: KNOWLEDGE- BEHAVIOURAL	
Knowledge	
Rate from 1 to 5 the level of familiarity about the following statements (S)	
Statement	**Answer Options**
I know what waste separation is	1 = very unfamiliar 2 = unfamiliar 3 = somewhat familiar 4 = familiar 5 = very familiar
I know what organic waste is	
I know what composting is	
I know what pollution is	
I know what a trash can and garbage bin are	
I know what littering is	
I know what dumping is	
I know where waste is taken after collection	

I know what happens to waste after it is collected	
I know what environmental law is	
I know what is a waste framework	
I know what an environmental tax is	
I know what an environmental fine is	
Question	**Answer Options**
Have you ever heard or seen a communication campaign about waste management?	a) Yes b) No
If you answered yes in the previous question, can you tell where did you hear or see one?	a) Community Representative b) TV c) Radio d) Social Media e) Other (please specify)

Table A4.2

MD4 Research Structure: Perception and Attitude

MATRIX DIMENSION 4: KNOWLEDGE- BEHAVIOURAL		
Perception and Attitude		
Rate from 1 to 5 the level of agreement about the following statements (S)		
Variable	**Statement**	**Answer Options**
Reduction Behaviour	**I generally try to reduce the amount of waste I generate**	• 1 = strongly disagree • 2 = disagree • 3 = neither agree nor disagree • 4 = agree • 5 = strongly agree
Recycling Knowledge	**I know what is recycling**	
Recycling Moral Obligation	**I consider recycling as a moral obligation**	
Recycling Behaviour	**I practise recycling on a daily basis**	
Environmental Identity	**I consider environmental sustainability as a value I promote**	
Environmental Concern	**I am concerned about the environment**	
Question		**Answer Options**
What factors do you think mostly influence the waste management in your village/ community?		a) Absence or inefficiency of collection service, b) Absence of designated dump areas, c) Insufficient civil commitment, d) Defecting collection material, e) Lack of agreement within

the community, f) Refusal of people to pay a collection fee, e) Other (please specify)

Table A4.3

MD4 Research Structure: Concern

MATRIX DIMENSION 4: KNOWLEDGE- BEHAVIOURAL		
Concern		
Rate from 1 to 5 the level of concern about the following statements (S)		
Variable	**Statement**	**Answer Options**
Littering	**I am concerned about the health risks related to littering**	1 = not concerned 2 = barely concerned 3 = somewhat concerned 4 = concerned 5 = very concerned
Dumping	**I am concerned about the health risks related to dumping**	