



Title	Developing integrated and sustainable municipal solid waste management systems in low-income contexts : Lessons from Maputo City, Mozambique
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Citation	大阪大学, 2017, 博士論文
Version Type	VoR
URL	https://doi.org/10.18910/61733
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Note	

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Abstract of Thesis

Name (DOS MUCHANGOS, LETÍCIA SARMENTO)	
Title	Developing integrated and sustainable municipal solid waste management systems in low-income contexts: Lessons from Maputo City, Mozambique (低所得途上国における持続可能な一般廃棄物処理システムの開発：モザンビークマプト市を事例として)
<p>Municipal solid waste (MSW) has a significant degree of complexity and represents one of the major challenges of the 21st century in urban settings of all contexts. The challenge is particularly acute in the cities from the lowest-income countries, where poor waste management practices and related public health implications continue to be problematic, thus, municipal solid waste management (MSWM), being considered one of the most immediate and serious issues in these locations. Maputo City, the capital of Mozambique, represents an example on how low-income societies have been failing to create and maintain MSWM systems, despite the continuous efforts from the local authority. The challenges and problems within the MSWM system in Maputo City have been increasing, ranging from technical to non-technical problems, including weak institutional and management structure, lack or fragile relationships between stakeholders, low public awareness and participation, waste generation increase, limited waste collection coverage, financial unsustainability, inadequate infrastructure and equipment, and unsound waste treatment and final disposal schemes.</p> <p>The aim of this thesis is to evaluate a MSWM system to propose improvement measures and pathways, as a contribution to the decision-making process towards integrated and sustainable systems from low-income contexts, in a case study of Maputo City, Mozambique. The study was conducted based on the Integrated Sustainable Waste Management (ISWM), a comprehensive approach that considers the practical and technical elements of the waste management system, its stakeholders, and the enabling aspects. Thus, several analytical decision-making tools and system analysis methods were applied to respond to each of the topics addressed.</p> <p>Firstly, in Chapter Three, the policy and institutional aspects were accessed, through the identification and evaluation of the barriers to the current MSWM policy in Maputo City. The findings indicated the presence of 26 barriers distributed within six policy instruments - three for legislation and regulation; three for voluntary agreements; four for economic instruments; five for education and influence over behavioural change; four for monitoring, information and performance assessment; four for choice of technology; and three for community linkages. From the identified barriers, nine, which are mainly related to institutional weakness and lack of cooperation among stakeholders, are classified as influential/cause barriers, that is, barriers that contribute the most to the poor waste policy performance.</p> <p>In Chapter Four, the main stakeholders in the MSWM system, their role, interest, power, and the overall access to information, knowledge and satisfaction with the structure and functioning of the system, were evaluated; and the interrelationships related to the partnerships and collaborations and the sharing of information were also clarified. That resulted in the identification of 35 stakeholders, categorised among six key groups – the government, civil society, academia, service users, donors and cooperation agencies, and the private sector. All government institutions, a donor and cooperation agency, an academic and a private sector institution, and two organisations from civil society, featured as the most powerful and interested stakeholders. The stakeholders with interest in the system, but with little power, included the remaining stakeholders from academia, a civil society organisation, and three stakeholders from private sector. The remaining stakeholders presented much reduced power or interest in the system. Moreover, on the analysis on partnerships and collaborations and the sharing of information, at least one stakeholder from each group exhibited a prominent set of connections with other stakeholders, however, in general, stakeholders showed a</p>	

significant lack of connectivity in both types of interrelationships.

The following Chapter Five dealt with the understanding of the physical elements of the waste management system in Maputo City and the estimation of MSW flows for the years 2007 and 2014. The findings demonstrated that after MSW generation, MSW follows five main routes, either reused and recycled at the source, sent to material recovery markets, sent to formal and informal sites, uncollected, or disposed of in illegal dumpsites. Between the studied periods, MSW generation increased from 397×10^3 tonnes to 437×10^3 tonnes, and material recovery increased from 3×10^3 tonnes and 7×10^3 tonnes, yet, far below the potential. Waste final disposal in open dumps and illegal dumpsites triplicated from 76×10^3 tonnes in 2007, to 253×10^3 tonnes in 2014, due to the significant increase of waste collection coverage. The study also demonstrated the existence of gaps in the data compilation and consistency, causing the results to vary in average, between 29% and 71%, in 2007, and between 41% and 96%, in 2014. In turn, the sensitivity analysis clarified the parameters that influence each flow of MSW the most, which include, the rate of waste reused and recycled at the source, waste processed for recycling, MSW in the inner city, MSW in the municipal districts 6 and 7, collection rate, and illegal dumping rate.

In Chapter Six, an assessment of the current and alternative waste treatment and final disposal schemes was completed, to estimate the greenhouse gas (GHG) emissions and the costs. The business-as-usual scenario, involves MSW being finally disposed of in open dumps, while in the alternative Scenario 2, MSW is disposed of in a sanitary landfill, and in the Scenario 3, MSW is recovered via recycling and biological treatment (3A - composting or 3B - anaerobic digestion), and the remaining MSW is disposed of in a sanitary landfill. The most environmentally impactful scenarios were Scenario 2, with GHG emissions values of 260,621 tonnes CO₂-eq per year, and the business-as-usual scenario with 201,112 tonnes CO₂-eq per year, while Scenario 3A and 3B showed negative net GHG emissions, -296,008 tonnes CO₂-eq per year and -211,603 tonnes CO₂-eq per year, respectively. In the cost perspective, Scenario 2 followed by Scenario 3A, presented the least costly alternatives, less than US\$ 1.0 million per year, and around US\$ 3.5 million per year, respectively. On the other hand, the business-as-usual scenario displayed the highest total cost, US\$ 27 million per year, due to the cost of inaction, and Scenario 3B the second highest, US\$ 14.5 million per year, due to the costs associated with large-scale and centralised facilities and equipment. Adding to that, with the potential increase in per capita income in the future, and subsequent changes in waste composition, the GHG emissions increased in both the business-as-usual scenario and Scenario 2, and the opposite was verified for Scenarios 3A and 3B, coupled with a significant increment of recyclable material.

The work completed in this thesis represents a contribution to the knowledge on ISWM, as a valid concept for cities in low-income contexts, to guide the development of environmentally friendly, socially just and economically viable MSWM systems, within a systematic and comprehensive framework.

論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

都市廃棄物の適正な処理処分は、地域の持続可能な開発において欠くべからざる機能である一方で、とりわけ低所得途上国においては、経済的な発展に伴い増加する廃棄物に計画的な対応が追いついていない現状にある。本論文は、アフリカ大陸南東部に位置するモザンビーク、首都マプトを対象として、統合的で持続可能な廃棄物管理の枠組みを問題解決に向けて適用し、将来戦略を検討するとともに、低所得発展途上国の都市問題解決にむけた移転可能な知見を得ることを目的に遂行されている。

本論文の第1章では、統合的廃棄物管理の概念を歴史的に整理するとともに、低所得途上国を対象とする場合の研究課題を抽出している。

第2章では、ケーススタディとして選んだマプト市の諸元を整理し、後述の解析に資する基礎データの整理を行うとともに、現状の未処理のままで搬入されるオープンダンピング型の最終処分場の公衆衛生上、環境上の問題点等を整理している。

第3章では、マプト市の廃棄物管理システムの問題点を、法制度面、廃棄物発生過程、収集と輸送過程、最終処分場、減量化・再使用・リサイクル方策の要素に分解したうえで、問題構造のモデルを作成し、廃棄物管理を計画的に進めるうえでの障壁要因ならびにその関連構造等を明らかにしている。さらに第4章では、廃棄物管理を担う利害関係者として、政府、専門家、市民、企業等の間の廃棄物管理に関するコミュニケーションの解析をおこない、情報の共有、相互協力といったことにおいて関係者間で分断していることを明らかにしている。

第5章では、2007年と2014年の2時点でマプト市の廃棄物のフローを解析し、この期間で資源回収量が2倍になったこと、最終処分される廃棄物量が3倍を超えていることを世界ではじめて明らかにしている。

第6章では、マプト市の廃棄物管理システムの将来シナリオとして、成り行きに任せる場合、衛生理め立てに転換する場合、コンポストによる資源回収を促進する場合、有機性廃棄物の嫌気性消化による資源回収を促進する場合、の4つのシナリオを比較評価し、温室効果ガスの発生量、コストの両面において、コンポストによる資源回収を促進する方法がもっともすぐれていることを明らかにしている。

第7章では、モザンビーク、マプト市で得られた知見を、廃棄物管理政策、関係者の役割、廃棄物の処理処分システムの構成、環境影響と費用負担という観点でまとめ、低所得途上国への知識の移転の可能性を論じている。

以上のように、本論文は、環境工学分野、特に低所得途上国の特徴を踏まえた、有効で持続可能な廃棄物管理戦略の計画論的研究に関し、大いに貢献する成果を提示している。

よって本論文は博士論文として価値あるものと認める。