2017

NATIONAL INVENTORY ON OPEN BURNING PRACTICES AND UNINTENTIONAL PERSISTENT ORGANIC POLLUTANTS (UPOPS) RELEASES

WISDOM M. DLAMINI
MDUDUZI M. MATHUNJWA
SIMISO K. MKHONTA
GCINA A. MAVIMBELA
SIZWE D. MABASO
IAN B. VAN ZUYDAM

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

APCS	Air Pollution Control System
BAT	Best Available Techniques
BEP	Best Environmental Practices
EGB	Expert Group (EGB) on Best Available Techniques (BAT) and Best Environment Practices (BEP)
EU	European Union
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gases
GoS	Government of Swaziland
HDI	Human Development Index
HFO	Heavy Fuel Oil
IPCC	Intergovernmental Panel on Climate Change
MTEA	Ministry of Tourism and Environmental Affairs
MEPD	Ministry of Economic Planning and Development
MNRE	Ministry of Natural Resources and Energy
MHUD	Ministry of Housing and Urban Development
MCIT	Ministry of Commerce, Industry and Trade
MoA	Ministry of Agriculture
MoE	Ministry of Education
MoH	Ministry of Health
MTAD	Ministry of Tinkhundla Administration and Development
MoJ	Ministry of Justice
NA	Not Applicable
ND	Not determined
PCB	Polychlorinated Biphenyls
PCDD	Polychlorinated dibenzo-p-dioxin
PCDD/PCDF	Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furan
PCDF	Polychlorinated dibenzo-p-furan
POPs	Persistent Organic Pollutants
RSSC	Royal Swaziland Sugar Corporation
SACU	Southern African Customs Union

SC	Stockholm Convention
SEA	Swaziland Environment Authority
SHIES	Swaziland Household Income and Expenditure Survey
SNL	Swazi Nation Land
PRSAP	Poverty Reduction Strategy and Action Plan
TEQ	Toxic Equivalent
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
uPOPs	Unintentionally produced POPs

DEFINITION OF TERMS

Buntfu: a characteristic of the human being which encapsulates human virtues; humanity and compassion.

Data: refers to information on waste generation.

Dumpsite: a piece of land (normally excavated) that is used as a disposal site for waste without any treatment nor leachate control.

Emerging town: is a town that has not yet been declared or gazetted as an urban area, with similar attributes as an upcoming development area.

Landfill: an actively managed piece of excavated and/or engineered land that is used to dispose of waste as regulated by a local government or relevant legislation.

Upcoming development community: this is an area that is not yet gazetted as a town, yet already possessing the attributes of a town. Examples include areas such as Buhleni, Siphofaneni and Lomahasha.

Urban area: this is an area demarcated as urban by the Central Statistical Office during the 2007 National Census exercise. This may or may not conform to the actual cadastral boundaries.

Waste: substances or objects that are not prime products (that is products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she intends to dispose of or are required to be disposed of by the provisions of the law.

Waste generated per capita: is waste generated per person per day.

Waste picker: is a person who salvages reusable or recyclable materials thrown away by others to sell or for personal consumption.

UNITS

g	gram
GJ	gigajoule
ha	hectare
kg	kilogram
kg/l	kilogram per litre
kg/m3	kilogram per cubic metre
kt	kilotonne
l	litre
kl	kilo litres
m3	cubic metre
MJ/kg	megajoule per kilogram
ppm	parts per million
t	tonne
TEQ/a	toxic equivalent per annum

EXECUTIVE SUMMARY

This report presents the results of the project **National Inventories on Open Burning Practices and Unintentional Persistent Organic Pollutants (uPOPs) Releases** under the auspices of the United Nations Industrial Development Organization (UNIDO) and the European Union. The beneficiary is the Swaziland Government, through the Swaziland Environment Authority (SEA) which is also the contracting authority. The consultancy team comprised a team of experts from the Department of Physics and that of Geography, Environmental Science and Planning at the University of Swaziland, Kwaluseni Campus. The overall objective of the project is to contribute to the project titled "Promotion of BAT/BEP to reduce uPOPs releases from waste open burning in participating African countries" through carrying out national inventories, conducting stakeholder consultations and workshops for private and public stakeholders and to develop a national waste database information on open burning of waste.

Through the innovative use of GIS-based census and affluence data coupled with field/actual waste disposal data, robust estimates were made of waste generation and uPOP emissions from open waste burning with a specific focus on key hotspots in the country. The total emissions from open burning were estimated at 1.17 g TEQ/a which is a decrease compared to the 2012 inventory (2.40 g TEQ/a). Similarly, backyard burning contributed 4.10 g TEQ/a in 2017. This is largely due to the notable reductions on the incidents of burning in waste disposal facilities in areas such as Nhlangano, Manzini and Matsapha over the last few years. Furthermore, the techniques used in this study were more robust through the inclusion of population and affluence variables, which are the key determinants of activity levels.

This will provide essential level of information to enable policy and strategic decisions to be made and identify priority activities that Swaziland should undertake in order to meet the requirements of the Stockholm Convention. This study has produced an updated inventory of uPOPs generated from open waste burning, quantified together with an accompanying spatially-enabled database. Short- and long-term action plans, based on best available techniques and best environmental practices, are provided as a pointer towards reduction of uPOPs emissions from open burning of waste in rural, peri-urban and urban areas. These plans shall also require continuous evaluation and monitoring. It is also necessary that other sources and waste streams be covered in-depth in future initiatives.

The recommended BAT/BEP actions for uPOPs reduction and elimination, where feasible, are given in below:

Proposed activities for reduction of backyard open burning of waste in peri-urban and rural areas

	Action	Responsibility
1	Domesticate the Stockholm Convention to make it a local law compatible with local regulatory framework	MTEA, SEA, MoJ, MTAD
2	Raise awareness on waste issues and the Stockholm Convention to peri-urban people and people in the rural areas	SEA, MTAD
3	Conduct education on and training: • Recycling • Composting • Upcycling • Open waste burning following BAT	SEA, Research institutions
4	Develop recyclable waste accumulation facilities in remote and rural areas where recyclable materials shall be collected at scheduled periods	SEA, Traditional authorities
5	Provide skip bins in hot spots particularly in peri-urban areas for collection by the closest municipality.	SEA, MHUD
6	Organise local casual labour to monitor the waste disposal at the skip bins (to ensure proper disposal of waste).	SEA
7	Set up a national solid waste management unit for monitoring evaluation of implemented interventions.	MTEA, MHUD, MTAD, MoA

Proposed activities for short-term reduction of uPOPs emissions from open burning of waste

	Action	Responsibility
1	Domesticate the Stockholm Convention on POPS to provide support for the enforcement of municipal bylaws or any waste regulations that may be put in place	MTEA, SEA, MoJ
2	Conduct national awareness raising, education and training on proper waste management practices opportunities, and health effects of uPOPs generated from open burning of waste through print media, electronic media, pamphlets, community gatherings, website and other available opportunities	SEA, MoT Municipalities, Companies, Institutions
3	Conduct stakeholder consultations with municipalities, company towns and upcoming development communities to find their limitations in waste management and strengthen their capacities	MHUD, SEA
4	Conduct stakeholder consultations with existing and potential recyclers to determine their capacities and constraints for waste recycling.	SEA
5	Develop strategies and set targets for waste reduction at source, increasing recycling of waste nationally, and reduce open burning.	SEA
6	Train relevant officers in municipalities, company towns and upcoming development areas on the BAT on open burning of waste described in Section 5.7.	SEA

7	Set up a national solid waste management unit for monitoring evaluation of implemented strategies.	MTEA, MHUD, MTAD, MoA
8	Develop a demonstration site on acceptable waste disposal techniques with open burning at a municipality or upcoming development area.	SEA

Proposed activities for long-term reduction of uPOPs emissions from open burning of waste

	Action	**Responsibility**
1	Domesticate the Stockholm Convention on POPS to provide support for the enforcement of municipal bylaws or any waste regulations that may be put in place	MTEA, SEA, MoJ
2	Conduct awareness raising, education and training on waste challenges, opportunities, and health effects of uPOPs generated from open burning of waste	SEA
3	Provide information on BAT technologies for waste management	SEA, MNRE, MoA, MTEA, MHUD, Research institutions
	a) Waste sorting facility	
	b) Incineration of waste to produce heat and electrical energy	
	c) Gasification of waste to produce heat, electricity and chemicals	
	d) Pyrolysis of waste to produce heat, electricity and chemicals	
	e) Biogas production from biodegradable organic waste	
	f) Composting of biodegradable organic waste	
4	Conduct detailed waste studies to quantify the different streams of waste suitable for the technologies listed in 3	SEA, Research institutions
5	Develop businesses models based on the technologies listed in 3 and make them available to some stakeholders	SEA, SIPA, SEDCO, Research institutions
6	Conduct stakeholder consultations with municipalities, company towns and upcoming development communities to develop a new national waste management strategy in view of existing technologies	SEA, Research institutions
7	Conduct stakeholder consultations with existing and potential recyclers, and waste management investors and entrepreneurs to determine how they fit into the new national strategy on waste management	SEA
8	Develop strategies and set targets for waste management following BAT and BEP	SEA
9	Set up a national solid waste management unit for monitoring evaluation of implemented strategies.	MTEA, MHUD, MTAD, MoA

1. BACKGROUND

The Swaziland Environment Authority (SEA), under the auspices of the Ministry of the Tourism and Environmental Affairs, is the nodal agency for planning, promoting and coordinating environmental programmes in Swaziland. The SEA is empowered to promulgate rules under the Environment Management Act 2002 and is responsible for ensuring effective implementation of legislation, monitoring and control of pollution, environmental clearances for development projects, promotion of environmental education, training and awareness, and coordination with concerned agencies at the national and international level. As such, the SEA is also the national focal point for the Stockholm Convention.

The Stockholm Convention (SC) is a global treaty to protect human health and the environment from persistent organic pollutants (POPs). POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms and are toxic to humans and wildlife. POPs also have the ability to circulate globally and cause damage wherever they are transported. In implementing the Convention, governments take measures to eliminate or reduce the release of POPs into the environment. Over 150 countries signed the Convention on 22nd May 2001 in the city of Stockholm, Sweden and it entered into force, on 17th May 2004, 90 days after the ratification by the 50th country. The Kingdom of Swaziland acceded to the convention on 13th January 2006, and hence, the entry into force for the country came on 13th April 2006. In May 2009, the Stockholm Convention was amended by the Conference of the Parties (COP) to the Convention to include several polybrominated diphenyl ethers (PBDEs) in its Annex A.

The 6th Session of the Intergovernmental Negotiating Committee of the Stockholm Convention on Persistent Organic Pollutants established the Expert Group (EGB) on Best Available Techniques (BAT) and Best Environment Practices (BEP) to develop guidelines on BAT and provisional guidance on BEP relevant to the provisions of Article 5 and Annex C of the Convention. The 1st Session of the EGB considered sources of Unintentional Persistent Organic Pollutants (uPOPs) and identified open burning as a priority source of emissions for which guidelines on BAT and guidance on BEP would be useful. The EGB noted the desirability of intercessional work on open burning source among other thematic areas and nominated volunteers to coordinate assembly and synthesis of information relating to this source category. Uncontrolled and minimally controlled combustion processes such as through wild fires, open

burning of agricultural residues and domestic waste and fires at landfills and open dumps are known to occur in all countries with varying extents.

For Parties to the Stockholm Convention, one of the first steps toward meeting the Convention's goal of continuously minimizing and, where feasible, eliminating releases of unintentionally produced organic pollutants (uPOPs) is the preparation of an inventory of uPOPs sources and the estimation of releases from those sources. This inventory is a critical component in the action plan that is specified under Article 5 of the Convention, which obligates each Party to develop an action or national implementation plan that is "designed to identify, characterize and address the release" of uPOPs listed in Annex C: 2:

- polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF), commonly referred to collectively as "dioxins";
- polychlorinated biphenyls (PCB),
- hexachlorobenzene (HCB), and
- pentachlorobenzene (PeCBz).

Primary sources of uPOPs, most significantly dioxins and furans, are industrial processes and incomplete burning resulting from low temperature burning and smoldering. As a result, the air, water, soil and ashes produced may contain these uPOPs thereby increasing the human and animal risk of exposure. Polychlorinated dibenzo-para-dioxins (dioxins) and polychlorinated dibenzofurans (furans) are two groups of planar tricyclic compounds that have very similar chemical structures and properties. Of the 210 dioxins and furans, 17 contribute most significantly to the toxicity of mixtures. Their properties vary with the number of chlorine atoms present and are neither produced commercially nor do they have known use. These two are byproducts resulting from the production of other chemicals. Dioxins may be released into the environment through the production of pesticides and other chlorinated substances while furans are a major contaminant of PCBs. Both dioxins and furans are related to a variety of incineration reactions, and the synthesis and use of a variety of chemical products. Dioxins and furans have been detected in emissions from the incineration of hospital waste, municipal waste, hazardous waste, cars, and the incineration of coal, peat and wood.

At present, the only persistent effect associated with dioxin exposure in humans is chloracne. Other health effects that have been reported include peripheral neuropathies, fatigue, depression, personality changes, hepatitis, enlarged liver, abnormal enzyme levels and porphyria cutanea tarda, though causal relationships were not established in every case. Some

studies also indicate increases in cancer risk such as thyroid cancer and myeloid leukaemia after exposure to these uPOPs. Since dioxins and furans are considered to be very stable and persistent, combined with high partition coefficients provides the necessary conditions for these compounds to bioconcentrate in organisms. The chemical properties of dioxins and furans (low water solubility, high stability and semi-volatility) favour their long-range transport. As with most other organochlorines, food is a major source of dioxins and furans in the general population, with food of animal origin contributing the most to human body burdens.

In addition, the processes that produce POPs result in the emission of greenhouse gases and particulate matter. There is therefore synergy between the SC and the UNFCCC, amongst other multilateral environmental agreements. Agricultural burning and waste disposal activities are particularly important sources of uPOPs. Heat and power generation and chemical and consumer goods production also result in significant but smaller quantities of dioxins and furans. In Swaziland, there are no intentionally produced dioxins and furans, but there may be produced unintentionally by the different sectors of the economy in activities such as combustion processes and some industrial manufacturing processes.

Swaziland has conducted two prior inventories of uPOPs, the first in 2010, and the second in 2014. These two inventories were conducted for Polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF). The 2012 inventory estimated the total emissions to be 74.44 g TEQ/a, which was an increase compared to the 2010 findings of 51.16 g TEQ/a. The major source of the emissions was found to be the waste from the disposal source group, which together contributed 44.6 g TEQ/a (60%). This was followed by heat and power generation, at 13.2 g TEQ/a (18%), open burning processes at 12.1 g TEQ/a (16%), and waste incineration at 4.5 g TEQ/a (6%). The highest emitter was sewage treatment whilst open burning processes were also significant contributors largely due to fires at dump-sites, sugarcane burning, forest fires, and open burning of domestic waste. The heat and power generation source was found to contribute through bagasse boilers while waste incineration originated mainly from medical waste incineration.

The previous inventories observed that in the country's large municipal waste was not deliberately burnt, but was dumped in landfills where it was compacted and covered with soil. However, this waste was not being segregated and therefore a mixture of everything thrown away by the urban population and businesses. In addition, waste pickers sometimes set the dumpsites on fire albeit without records of the frequency of occurrence the quantity of waste

burnt each time this happens. In smaller municipalities open waste burning was observed to be a method of choice for waste disposal due to lack of facilities. Pollution of the aquatic ecosystem by persistent pollutants continues to be a major threat to the aquatic biodiversity (SEA, 2012). The previous surveys seem to indicate that the general lack of reliable data and low level of awareness on POPs results in the non-existence of proper monitoring programmes.

Nevertheless, the country has been in the process of implementing the action plans developed through each inventory and has received support from different international bodies or treaties such as the Global Environment Facility (GEF) and United Nations Industrial Development Organization (UNIDO). In addition, the country developed a national implementation plan (NIP) in 2010, which was later updated in 2014. As a follow up and with support from UNIDO, the SEA is currently implementing a project on "Promotion of Best Available Techniques (BAT) and Best Environmental Practices (BEP) to reduce unintentional persistent organic pollutants (uPOPs) releases from waste open burning in the Kingdom of Swaziland". One of the goals of this assignment is to have an updated national information on current open burning practices and the establishment of uPOPs baseline inventories, i.e. hexachlorobenzene (HCB) and polychlorinated Biphenyls (PCB) included in Annex C Part I of the Convention.

2. COUNTRY PROFILE

2.1 Location

The Kingdom of Swaziland, with an area of 17365 km^2, is landlocked and bounded by South Africa in the north, west and south, and by Mozambique on the east. Located between 25.72° and 27.32°S and 30.79° and 32.13°E, the country's diverse geology influences the topographic and climatic characteristics of the landscape, resulting in the various land capabilities and agro-ecological zones. Such landscapes support varying land uses such as human settlement, grazing, wildlife, irrigation agriculture, livestock ranching, and subsistence agriculture, amongst several others (Remmelzwaal and Dlamini, 1994). These land uses are practiced under communal Swazi National Land (approximately 52% of total land area held in trust by the King and Title Deed Land, which constitutes about 47% of total land area (Remmelzwaal and Vilakati, 1994). Crown land (government land) and concession land are two other minor categories, which cover less than a percent of the country's surface area.

2.2 Demographics and the Economy

The 2012 intercensal survey estimated a total population of 1,080,337 with an annual growth rate of 1.2%. The same survey indicated that the urban population accounted for 22% of the total population and projected to be 23.7% by 2017 largely concentrated within the Manzini and Mbabane corridor (Central Statistics Office, 2012). The major urban areas of Mbabane and Manzini and their hinterlands form dual growth points in the core region centered around the Matsapha industrial estate and connected by the Ezulwini valley (Figure 1). The Manzini and Mbabane corridor of economic activity attracts a significant number of migrants from outlying areas and other smaller towns and villages. Manzini, in particular, is the largest and fastest growing city in the country and is reported to have grown at an average rate of 5% during the period 1986-1997. Significantly Manzini is located close to Matsapha, the largest industrial site in the country that in large part is the main urbanization driver in Swaziland. The job opportunities in and around Matsapha makes the cities of Mbabane and Manzini target areas for rural migrants. This has placed enormous stress on existing land and available infrastructure, including waste disposal facilities, in the city of Manzini and surrounding areas. This has also created housing pressures and although some formal housing is provided, informal settling has become more commonplace, particularly on Swazi Nation Land (SNL) immediately outside the jurisdictions of the two cities.

The country continues to face major social challenges, such as high poverty and inequality; high unemployment, especially among youth; gender disparities; and a high rate of HIV/AIDS. Economically, the country is a lower-middle-income country and has a gross domestic product (GDP) per capita of US$ 3,911.4. Despite being a low middle-income country, around 63% of the population live below the poverty line whilst inequality is substantial (Gini coefficient of 0.51). This is also reflected in the Human Development Index (HDI) value remaining unchanged for four straight years of 0.531 from 2011 through 2015, placing the country at 150 out of 188 countries.

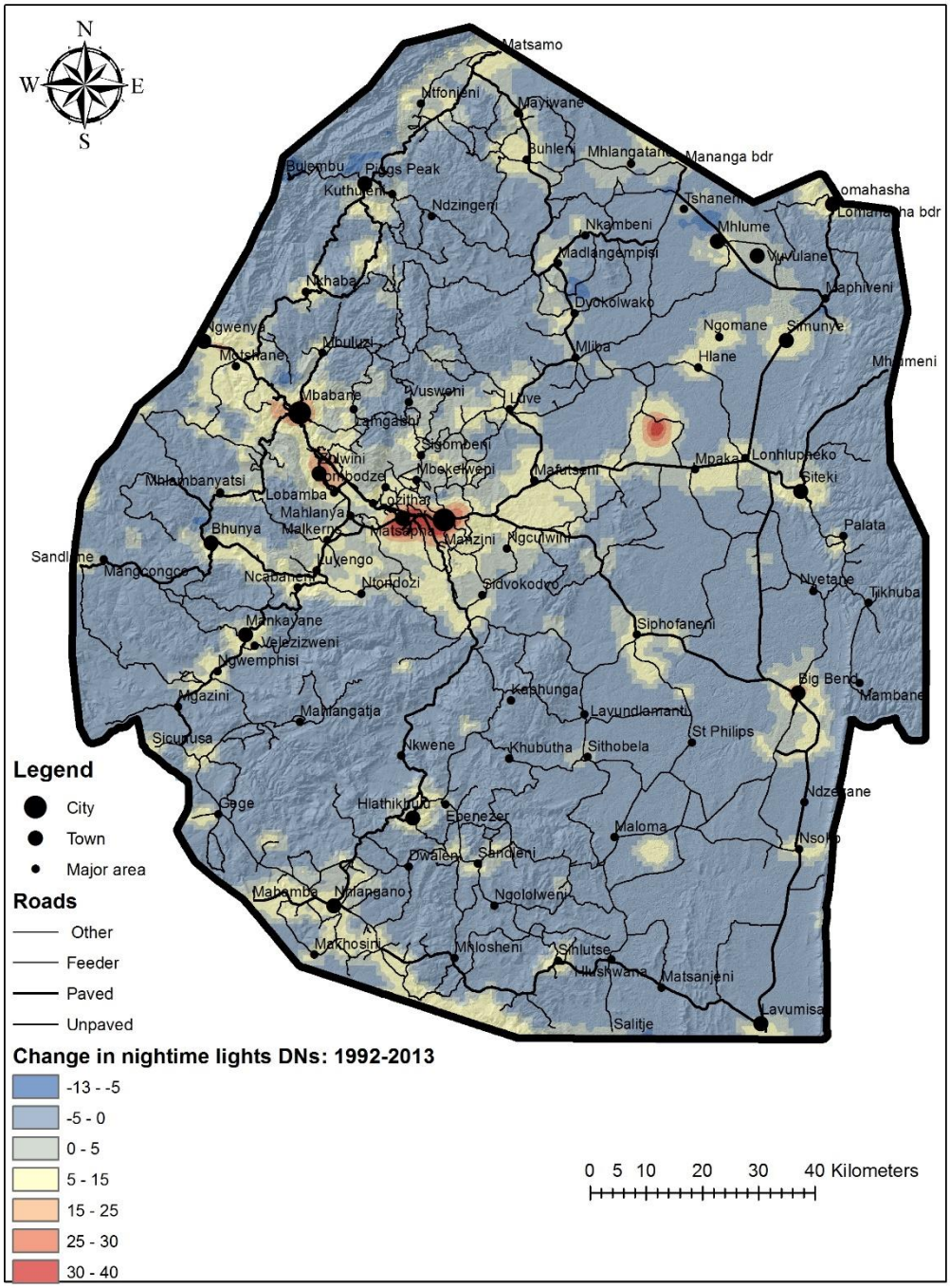

Figure 2-1: Location of major urban and population centres (Source: Dlamini et al., in prep)

The economy is largely derived from within the Southern African Customs Union (SACU) and very tightly linked to that of South Africa, which accounts for 94% of the country's imports. Agriculture and forestry contribute about 6% of GDP whilst the manufacturing (mainly textiles and sugar-related processing, metal works and light industry) sector represents 42% of GDP. Services, predominantly government services, constitute the remaining 51% of GDP. The economy is also export-oriented, the primary destinations being South Africa and the European

Union, which accounts for about 70% of the country's exports. Economic growth remains subdued and is estimated to have slowed down in 2016 to -0.6%, mainly due to two factors, severe drought and fiscal pressures; while prospects suggest it will be sluggish in 2017 and 2018 (African Economic Outlook, 2017). This is largely attributed to decline in agricultural production as a result of the El Niño-induced drought. Rain-fed crops, particularly maize and cotton, along with irrigated crops, mainly sugar cane, recorded significant declines. A large decline in revenues from the SACU also put considerable pressure on the fiscal account in addition to an expansionary fiscal stance that amplified the negative impact of these shocks.

2.3 Institutional, Policy and Regulatory Framework

2.3.1 Environment Policy Framework

The Constitution of the Kingdom of Swaziland 2005, which is the country's supreme law, commits the state and every citizen to the protection of the environment. Sections 60(11), 63(d), 210(2), 217(d) and 216 specifically and explicitly espouse the country's commitment to environmental protection and management. Every policy and legislation is, therefore, expected to derive or conform to its requirements and provisions.

The guiding principles underpinning environmental management in the country are stated in the National Environment Policy. The National Environmental Policy defines eleven core principles for environmental management:

- Environmental Responsibility;
- Buntfu;
- Environmental Rights;
- Sustainable Development;
- Public Awareness and Participation;
- Community Management;
- Preventive Action;
- Precautionary Approach;
- Polluter Pays Principle;
- Proximity Principle;
- Global and Regional Responsibilities.

The 1999 National Development Strategy (NDS) with its long-term development Vision 2022 provides the overall developmental policies in the country. All other subsequent policies and

strategies have been formulated to facilitate the achievement of the vision of the NDS. Within the NDS, environmental protection has been identified as one of the cornerstones for the national development process. Similarly, targets have been set for most sectors in line with the Sustainable Development Goals and the Vision 2022.

Prior to that, the now-outdated 1997 Swaziland Environment Action Plan (SEAP) provided guidance for environmental protection in the country. The Environmental Management Act of 2002 provides the legislative framework through, for instance, requiring a Strategic Environmental Assessment (SEA) of policies, programmes, strategies, action plans and legislative bills to ensure a holistic integration of environmental issues.

Swaziland has been actively pursuing environmental management goals since the establishment of the Swaziland Environment Authority in 1992. Some of the global environmental issues that the country continues to address include ozone layer depletion, land degradation and desertification, decline of biodiversity, climate change, food security, health and poverty. As such, environmental issues have been integrated in various sectoral and macro-economic policies notably the National Rural Resettlement Policy, the National Forest Policy, the Comprehensive Agricultural Sector Policy, the National Food Security Policy and the National Energy Policy, amongst others.

The Poverty Reduction Strategy and Action Plan (PRSAP) recognizes the importance of the environment in relation to the alleviation of poverty and has formulated a number of actions that relate to general environmental matters as well as to specific concerns in environmental management planning, safe water and sanitation, and ensuring sustainable energy.

With the assistance of the Danish Co-operation for Environment and Development (then DANCED, now DANIDA), the country developed its first National Solid Waste Management Strategy (NSWMS) which represented a long-term plan (up to 2010) for addressing key issues, needs and problems experienced with waste management in Swaziland. The strategy attempted to give effect to the National Environmental Policy National Environmental Management Act of 2002 and the Waste Regulations 2000. The focus of the strategy was to move towards a holistic approach in waste management, in line with internationally accepted principles but taking into account the specific context of Swaziland with regard to the institutional and legal framework. The strategic approach used was based on the international waste hierarchy approach, which included waste prevention, recycling, collection and transport, treatment and disposal. This was followed by reuse and recycling of waste (utilising waste as a resource) and

only after that treatment and disposal of the remaining waste. This, therefore, represented a move away from conventional waste management through impact management and remediation to a more proactive management system that focused on waste prevention and minimization. However, the focus of waste management in the country continues to be on collection and disposal of waste.

The Draft National Land Policy 1999 was formulated with a view to improving access to land and security of tenure on SNL including tenure on irrigation schemes, as well as clarifying roles and responsibilities for land administration. The draft policy considers the possibility of leasehold arrangements and transferable user rights for land owners on SNL. It also proposes changes to systems of land allocation to allow women to have equal access.

The National Rural Resettlement Policy 2003 is not limited to resettlement, but also sets out a wide ranging policy framework related to the improvement and planning of land use to establish a durable, practical and participatory framework for the planning and sustainable management of land, and the appropriate application of resettlement strategies in rural Swaziland, in order to increase agricultural production, promote the sustainable utilization of natural resources and improve livelihoods.

2.3.2 Environment Legislative Framework

There is a comprehensive range of environment related laws with the Environmental Management Act (2002) being the overarching piece of legislation. The Environment Management Act is intended to provide and promote the enhancement, protection and conservation of the environment and the sustainable management of natural resources. It establishes a more comprehensive legal framework for environmental protection and creates an appropriate legal basis for achieving the general specific objectives set out in the National Environmental Policy. As a method to ensure appropriate enforcement the Act allows both public and private prosecutions and further empowers the SEA to issue certain orders and automatic fines in cases of environmental damage and/or pollution.

This Act also transformed the Swaziland Environment Authority (SEA) into a body corporate while also establishing the National Environment Fund. In terms of this Act, the SEA has the power to halt any and all developments that have not been adequately assessed for their environmental impact. The same Act requires that any policy, bill, regulation, programme or plan be subjected to a Strategic Environmental Assessment. Additionally, the Act requires public participation, and sets out regulations for a register of environmental information,

requests for environmental information, public review and hearings, orders and prosecutions initiate by the public, civil actions and other regulations.

With regards to waste management, the Environment Management Act sets out the following guiding principles:

- Long-term integrated planning and co-ordination, integrated and cooperative efforts, which consider the whole environment must be used to prevent pollution;
- The Precautionary Principle and the Polluter Pays Principle: Generation of waste must be minimized wherever practicable and waste should, in order of priority be reused, recycled, recovered and disposed of safely;
- Non-renewable natural resources should be used prudently while renewable resources and ecosystems should be used in a manner that is sustainable.

Section 41 of the Environmental Management Act also gives effect to the principle of Duty of Care and provides the Minister responsible for the Environment with the mandate to regulate waste management.

Although the legislative framework can generally be considered adequate, waste management still requires more specific and stronger legislative support, e.g. biodiversity, waste and chemicals management.

2.3.3 The Environmental Audit, Assessment and Review Regulations, 2000

Made in terms of Section 18 of the Swaziland Environment Authority Act 1992, the objective of these Regulations is to avoid and mitigate adverse effects of proposed projects and existing undertakings. It provides a method of certifying project proponents who comply with both preliminary procedures for their activities. It also arms the SEA with sanctionary measures in times of non-compliance. Most of all, it is the only piece of legislation that provides for public participation in environmental matters, one of the most important components of the Rio 10 Principles.

2.3.4 The Waste Regulations, 2000

These Regulations are also made in terms of section 18 of the SEA Act. The objective of these regulations is to ensure appropriate waste management in the country. The Regulations came into force during April 2000 and provide the regulatory framework for waste management in the country. They also specify the duties and responsibilities of the SEA, waste generators and

waste service providers. In addition, new regulatory instruments, such as waste management licensing and waste management planning are encapsulated to enforce the following principles:

- The duty of care;
- The control of the import, export and trade in waste;
- Restrictions on the disposal of waste before a disposal facility is approved;
- Requirement for the provision of waste receptacles in all urban area premises;
- Requirement that generators of commercial or industrial waste arrange for waste to be collected and transported to an approved waste disposal facility.

The Waste Regulations also allows an area to be declared as a "Waste Control Area". This is particularly relevant to peri-urban and rural areas that are located on Swazi Nation Land, as well as Company Towns. The declaration of a Waste Control Area provides for a similar allocation of waste portfolios and responsibilities to that of Town Councils and/or Town Boards. They may, however, be implemented through different institutional arrangements.

2.3.5 The Ozone Depleting Substances Regulations, 2003

The purpose of these regulations is to control the licensing system on the import and export of ozone depleting substances as a means of regulating the transfer of such substances which can leave the country with adverse impacts. This will in turn help the SEA to improve its monitoring exercises to end users of such substances.

However, legislative enforcement remains a generally weak area coupled with inadequate technical and human capacity and institutional coherence.

2.4 Multilateral Environmental Agreements

Swaziland is party to international agreements and conventions pertaining to the environment, including the Montreal Protocol on Ozone Depleting Substances. Since signing this convention, Swaziland has actively implemented the requirements and, with the help of the United Nations, has addressed the requirements, which require that parties take measure to eliminate persistent organic pollutants.

Other relevant international conventions to which Swaziland is a signatory include, among others:

- The Basal Convention on Hazardous Wastes

- The Bamako Convention on the Ban of Import of Hazardous Wastes into Africa
- United Nations Framework Convention on Climate Change
- Convention on Biological Diversity
- The Convention to Combat Desertification
- The Convention on the International Trade on Endangered Species (CITES)
- Ramsar Convention
- Convention on Migratory Species

Swaziland has taken steps toward protecting its environment through, among other things, domesticating waste management programmes albeit with varying levels of success. The degree to which the country is actually active in treaties, implements treaty provisions, or enforces international law is unclear due to lack of adequate monitoring data.

2.5 Environmental Institutional Framework

2.5.1 Swaziland Environment Authority

The Swaziland Environment Authority is the institution with the overall responsibility for the environment. Since its establishment in 1992, the SEA has remained the key regulatory institution that coordinates many other supporting institutions. The SEA is also responsible for environmental policy making, legislation, planning, environmental protection, monitoring and enforcement using provisions of the Environment Management Act. With regards to waste management, the main function of SEA´s is that of a lead agency which includes enforcement of the regulations issued by the Authority, co-ordination of the activities of the other ministries with waste management functions, development of waste management policies and strategies, and setting of standards.

The institutional and the legal framework for duties and responsibilities of the SEA are fully defined in the Environment Management Act, 2002, the Environmental Impact Assessment Regulations, and the Waste Regulations 2000.

2.5.2 Ministry of Housing and Urban Development (MHUD)

The Ministry of Housing and Urban Development is responsible for the monitoring and control of household and commercial waste management, undertaken by the urban local government bodies, such as City Councils, Town Councils and Town Boards. A local authority means a City Council, a Town Council or a Town Board “declared” under the Urban Government Act of 1969 (currently under revision). The obligations of local authorities with regard to waste

management are defined in the Environment Management Act 2002 and the Waste Regulations 2000. However, these obligations have not been sufficiently integrated to the local authorities, in particular the Town Councils and the Town Boards. The current financial constraints experienced by many local authorities make it difficult for them to prioritise the entire suite of waste management services over and above a minimum of waste collection services.

There is no specific section or department within the MHUD that has responsibility over environmental management issues. However, the associated functional responsibilities are commonly understood to be vested with the Health Inspectors. Monitoring and support to local authorities on environmental management issues or policies is also limited.

The Building and Housing Act 1969 also makes provision for the MHUD to declare an area a "Controlled Area" even when it is located on Swazi Nation Land. This provision only requires a "Structural Plan" to be put in place, but this could be expanded to include the provisions made for the declaration of "Waste Control Areas", described in Waste Regulations 2000 and the Environment Management Act 2002 particularly because the characteristics of a Controlled Area tend to be similar to those of a Waste Control Area.

Company Towns are typically urbanized areas that are not necessarily under the jurisdiction of the MHUD. These are normally established through economic development such as the sugar industry, mining industry and forestry where industrial, commercial, residential and medical facilities have been established. Currently, these are not under the jurisdiction (physical planning and/or waste management planning) of any ministry and waste management services are independent of the government.

2.5.3 Ministry of Health (MoH)

The Ministry of Health (MoH) is responsible for all issues relating to public health and most importantly for the monitoring and control of with respect to health care waste generated from hospitals, health centres, clinics and medical retailers as per the Waste Regulations, 2000. Furthermore, the Ministry is responsible for regulating, enforcing and monitoring health standards, including solid waste management issues, related to food supplies intended for human consumption.

However, health officers, both at national government and local government level, do not have a specific legal mandate to enforce medical waste management *per se*. This limits the possibility of formulating interventions aimed at improving medical waste management.

2.5.4 Ministry of Tinkhundla Administration and Development

The Ministry of Tinkhundla Administration and Development (MTAD) is legally responsible for Tinkhundla, Regional Administration and Community Development. As a consequence, the Ministry is responsible for the monitoring and control of the Waste Regulations with respect to domestic waste generated in the rural and peri-urban areas, although these responsibilities have no specific legal basis.

A number of geographical areas within the jurisdiction of the MTAD are densely populated settlements in the peri-urban areas, where waste management systems and services are often limited by inaccessibility and jurisdiction. In addition, these settlements are typically located on Swazi Nation Land, where residents do not pay rates or fees that could be used for financing waste management services. The current institutional framework is also such that there is limited technical capacity to operate waste management services.

Nevertheless, the Waste Regulations 2000 do provide for the declaration of "Waste Control Areas" for which a waste management plan and waste management system must be implemented.

2.5.5 Ministry of Commerce, Industry and Trade (MCIT)

The Ministry of Commerce, Industry and Trade (MCIT) is responsible for monitoring and control of the implementation of the Waste Regulations 2000 within industrial estates. It is generally understood, that this responsibility includes not only the Matsapha Industrial Estate and other industrial estates, but also in the Company Towns. However, capacity to enforce waste legislation or to advise and monitor environmental management issues or policies within the industrial and commercial sector is wanting.

The Ministry is also the mother ministry for the Swaziland Standards Authority (SWASA) which is responsible for formulating national standards such as environmental standards (e.g. the SZNS ISO 14000 series) which have a strong relevance to waste management.

2.5.6 Ministry of Agriculture (MoA)

Although not explicitly stated as such, the Ministry of Agriculture (MoA) is generally perceived to be responsible for the monitoring and control of waste generated as a result of agricultural practices and their control and compliance with the Waste Regulations 2000.

The responsibility is mainly confined to the management and disposal of agrochemicals. However, MoA officers do not have explicit responsibilities and mandates as it relates to the enforcement of agricultural waste management.

2.5.7 Ministry of Natural Resources and Energy (MNRE)

The Ministry of Natural Resources and Energy (MNRE) is responsible for overall administration and supervision of mining activity under the Mines and Minerals Act, 2011. This responsibility includes: - Mineral Exploration, Industrial Minerals, Mapping, Fossil Fuels, Groundwater Resources, Drilling and the Laboratory. The MNRE can be thought of as responsible for waste generated as a result of mining practices as enshrined in both the Waste Regulations and the Mines and Minerals Act. Mining waste may be addressed within the environmental provisions of the Mines and Minerals Act, 2011.

2.5.8 Ministry of Economic Planning and Development (MEPD)

The Ministry of Economic Planning and Development (MEPD) is the Ministry responsible for National Economic Planning, Physical Planning, National Population issues, Co- ordination of Technical Co-operation Programmes and the Coordination of co-operation with the Donor community. In the context of waste management, the MEPD is expected to ensure that physical development plans (both regional and national) take into account waste management issues. This might also include, but not limited to, coordinating plans (in particular physical investments plans, including treatment facilities and landfill establishment) submitted by individual Ministries in order to avoid duplication and irrational expenditures of public funds. The MEPD is also an important role player in ensuring that sufficient funding is provided to meet the objectives of the national waste management programmes, including providing assistance and coordinating requests for donor assistance to implement the same.

2.5.9 Other Key Role Players

It is important to mention that waste management is an issue for all in the country and as such various associations, bodies and organizations including NGOs and a range of civil society organizations, all constitute important stakeholders in the management of waste in the country. Their involvement is broad and covers all sectors of society and the economy as well as all the areas critical to improved waste management.

The following bodies are considered to be of particular importance:

- Swaziland Federation of Employers and Chamber of Commerce

- Small Enterprise Development Company (SEDCO)
- The Construction Industry Council
- Swaziland Association of Architects, Engineers and Surveyors
- Swaziland Commercial Amadoda
- Swaziland Local Government Association (SWALGA)
- Local Authority Managers Association of Swaziland (LAMAS)
- Public Enterprises and the Public Enterprise Unit.

Other relevant bodies include:

- Hotel and Tourism Association
- Medical and Dental Council
- Swaziland Sugar Association
- Swaziland Water Services Corporation
- Swaziland Investment Promotion Authority (SIPA)
- Swaziland Industrial Development Company (SIDC).

Whilst there may be numerous NGOs and CBOs in Swaziland, only a few of them (e.g. PELUM and Nguwe Likusasa Letfu) are environmentally focused. Since waste management is a cross-cutting issue, the access provided by NGOs and CBOs to many constituencies, communities and stakeholders, is seen as an asset to the implementation of waste management programmes.

3. APPROACH AND METHODOLOGY

3.1 Estimates of Furan and Dioxins Emissions

The project activities followed the step-wise process with a view to undertake two main activities:

- Conducting a national inventory of uPOPs releases in Swaziland.
- Publication of a report on the inventory with supplementary information on observed and proposed best available techniques and best environmental practices.

As an initial step, a directory of stakeholders, which formed the basis for consultative meetings, was prepared (see Annex 1).

The method used for the inventory followed the guidelines provided in ***the 2013 United Nations Environment Programme (UNEP) Standardized Toolkit for Identification and Quantification of Dioxins and Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention***. Other documents that were consulted include:

- Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles (March 2017)
- Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants (Draft - January 2017)
- Guidance for the inventory, of Hexabromocyclododecane (HBCD) (Draft - March 2017)
- Guidance for the inventory of perfluorooctane sulfonic acid (PFOS) and related chemicals listed under the Stockholm Convention on Persistent Organic Pollutants (Draft – January 2017)

To quantify the annual national emissions of PCDD/PCDF into the environment through open burning processes, data was collected to estimate the amount of general waste burnt in Swaziland over the past year. The amount of uPOPs released into the environment over the same period was estimated using the UNEP toolkit. The methodology for data collection is given in the sections below.

Several institutions were approached for data collection and some of these include those listed in Annex 1. The data was then collected through site visits using the questionnaires provided in Annex 2 and the data sought included the following:

- Geographic (GPS) position of waste disposal site
- Identification of potential sources for uPOPs, and their precursors
- The kind of materials burnt in the various combustion processes
- Amount of materials burnt
- The amount of waste burnt in the open

The data analysis was done using the Microsoft Excel™ spreadsheet which forms part of the electronic version of the Toolkit. To compare the releases for 2010 to those of 2012 and the current one, the activity rates of 2010 were used along with the emission factors in the 2013 Toolkit to calculate source strength (quantity of dioxins per year). The GPS position enabled the mapping of the sources and for geographic visualization on a map as well as for possible future use in exposure assessments. The GPS position also allowed for future inventories to locate the same spots as well as for monitoring purposes.

The focus of this inventory was open burning source group (Category 6b), specifically burning of waste (which comprise mainly of domestic or municipal solid waste - including e-waste - burned in official dumpsites, and municipal waste burnt in other waste dumps or private backyards).

During open waste burning, conditions are commonly poor due to heterogeneous composition, compacted and poorly mixed fuel materials. Furthermore, moisture and lack of oxygen may contribute to additional complexity. Typically, there is no intervention to select the fuels or to improve the combustion conditions. In many areas, some of these processes were not authorized and were therefore un-documented. Consequently, the releases from these processes tended to be underestimated because of difficulties in assessing the individual site activity, particularly for peri-urban, rural and informal settlements.

The areas visited are listed in Annex 2. Some of the areas were identified through an analysis of earth observation data on fire occurrence particularly persistent fires, which are indicative of periodic burning of the same area associated with open waste burning. Similarly, trends in satellite-detected nighttime light data were also used as ancillary data to determine the growth points and other emerging potential hotspots. Active fire data from the US Defence Meteorological Satellite Program's Operational Linescan System (DMSP-OLS), National Aeronautics and Space Administration (NASA)'s Visible Infrared Imaging Radiometer Suite (VIIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) sensors were used for this purpose.

Throughout the open burning source group, releases of uPOPs with solid residues such as combustion ashes are regarded as releases to land rather than release to residue, since due to the lack of containment, the ashes are disposed on land and are typically not collected for further disposal. The release of uPOPs into the air, water, and land depends on the chemical content of the burnt waste and also the combustion conditions such as oxygen levels, and moisture content. Therefore, an emission factor for land was used. Subsequently, to avoid double-counting, no emission factor for residue was provided, although the release vector is ash.

To achieve the objectives of the project, data was collected through field visits, meetings, and interviews with key representatives of target source group of uPOPs including all those that were identified in the 2014 study that was compiled by one of the co-leading expert in this study. Management of uPOPs in Swaziland is largely on releases of dioxins and furans from four priority source sectors.

According to the UNEP toolkit the amount the source strength of uPOPs per year is given as

Source Strength (uPOPs emission per year) = (Emission factor) x (Activity Rate),

with the emissions given in grams of toxic equivalent per annum (g TEQ/a) units.

The toolkit for the Identification and Quantification of Releases of Dioxins, Furans and other uPOPs is under Article 5 of the Stockholm Convention. uPOP releases from open burning processes are addressed mainly in Category 6, 9 and 10.

The scope of this work was focused on the release of uPOPs from open burning of waste under *class 1* and *class 3*.

Table 3-1: PCDD/PCDF emission factors for category 6b source - open burning of waste

6b	**Open Burning of Waste and Accidental Fires**	**Emission Factors (µg TEQ/t material burned) for the different release path**				
Classification		Air	Water	Land	Product	Residue

1	Fires at waste dumps (compacted, wet, high organic content)	300	ND	10	NA	NA
2	Accidental fires in houses, factories	400	ND	400	NA	NA
3	Open burning of domestic waste	40	ND	1	NA	NA
4	Accidental fires in vehicles (per vehicle)	100	ND	18	NA	NA
5	Open burning of wood (construction/demolition)	60	10	10	NA	NA

Legend: Emission factor not determined (ND), Not Applicable (NA).

3.2 Determination of Domestic Waste Generation per capita

To quantify the amount of waste that is disposed via open burning processes in Swaziland, a desktop study was first conducted to estimate the domestic waste generation per capita. The amount of generated waste is important for estimating the amount of domestic waste that is disposed through backyards fires (Class 3) and also for verifying collected data on the amount of waste in dumpsites.

3.2.1 Generators of Solid Waste

Waste generators are countrywide, and include households (residential), industry and commercial shops, vendors, and institutions (hospitals, schools, etc.) as illustrated in Table 3.1. Generally, households are major contributors of waste.

Table 3-2: Soil waste streams and their composition.

Solid Waste Stream	Contribution in weight (%)	Waste Characteristic

Domestic/Household waste	52-80	Mainly food waste, packaging: paper; cardboard; plastic; textile; glass & ceramics; ashes; e-waste;
Vendor/Markets	4-20	Vegetable waste; chicken feather; packaging material; ashes
Commercial e.g. shops, hotels, offices (excluding markets)	4-8	Packaging material; food waste; paper; e-waste; glass; wood; scrap metals
Institutions (schools, colleges, Government ministries)	5	Food waste; stationery; packaging material; paper; e-waste
Manufacturing Industry	3	Packaging and industry dependent waste
Health care centres	1	Domestic waste, hazardous waste
Other (Sport centres, constructions sites, public park)	11	Mainly domestic waste

The percentages are adapted from East African studies (Okot-Okumu, 2012)

3.2.2 Household Income-based Estimation of Domestic Waste

The 2007 Housing and Population Census data and the average annual growth rate of the country, which according to the World Bank (World Bank, 2017) currently stands at 1.8%, were used to estimate the national population for the year 2016. According to the World Bank (2017) estimate the population of Swaziland for 2016 was 1.323 million.

To estimate the total waste generated in the country, population data per enumeration area was used. Using the same approach used to calculate the population and income-based estimates for urban areas, the 2007 national census data and socio-economic data from the 2010 Swaziland Household Income and Expenditure Survey data (SHIES, 2011) were used to classify each enumeration area into a high, medium or low class, using poverty incidences as an indicator. For urban areas, Table 3.3 was used, as explained to classify enumeration areas within urban areas into one of the three classes.

However, for rural enumeration areas, slightly different averages were used, informed by literature. According to the Department of Environmental Affairs and Tourism (DEAT, 2006), the daily average waste generated by a person in a rural area in the region is 0.65 kg. Rather than using this generalized value, the study factored in the fact that there are areas classified as rural, particularly near urban areas that have very low incidences of poverty (e.g. Nhlambeni), and thus, cannot be generalized into the lower daily waste rate. Similarly, with areas of higher

incidences of poverty in urban areas assigned 0.41 kg per person per day, it was decided against assigning areas of high poverty incidences in rural areas a higher value of 0.64 kg. Therefore, enumeration areas in the rural areas were classified into three classes too using poverty incidence, and the adopted daily waste generation per person in that class shown in Table 3.3.

The generation of waste in Swaziland was assumed to be consistent to South Africa, a neighboring country where the average waste generated by a person in a day in income category is in Table 3.3

Table 3-3: The daily waste generated per capita adopted in this study for both rural and urban areas according to income class

Income Class	Daily Waste Generated (Kg per Person)	
	Urban	**Rural**
High	1.29	1.29
Medium	0.74	0.65
Low	0.41	0.41

Source: Adapted from DEAT (2006)

Using the SHIES data (CSO, 2010), the spatial distribution of annual waste generated nationally at enumeration level was computed. Thereafter, a population and income-based annual waste generated by each enumeration area per *Inkhundla* was also computed.

From the total annual waste generated in rural areas, the amount of waste recycled was also estimated. The estimate made use of values obtained from a study in the Republic of South Africa that concluded that, for the general waste category, paper waste recycling was found to be 57%, plastic waste at 18%, and glass waste 32% (DEA, 2012), which averages to about 35%.

Next was to quantify the amount waste that is burnt in dumpsites/landfills (class 1) in the country whereby visited 24 urban areas were identified, in line with the 2007 census data and Defence Meteorological Satellite Program's Operational Linescan System (DMSP-OLS) nighttime light changes. Of these, two are cities, ten are gazetted towns, three are emerging towns, five are company towns, and four are company villages. In collaboration with SEA, a questionnaire that included information on the amount of waste disposed on the site, level of recycling and GPS coordinates of the dumpsite/landfill was designed (see Annex 2). Field visits were undertaken to identify the sites and to make visual and technical assessments of the waste disposal. The team received maximum cooperation and lot of interest in the subject, with the

exception of one stakeholder. The institution visited and contacts of the key waste personnel are attached in this report as Annex 1. Figure 3.1 is a map of Swaziland showing the spatial coverage of each landfill/dumpsite.

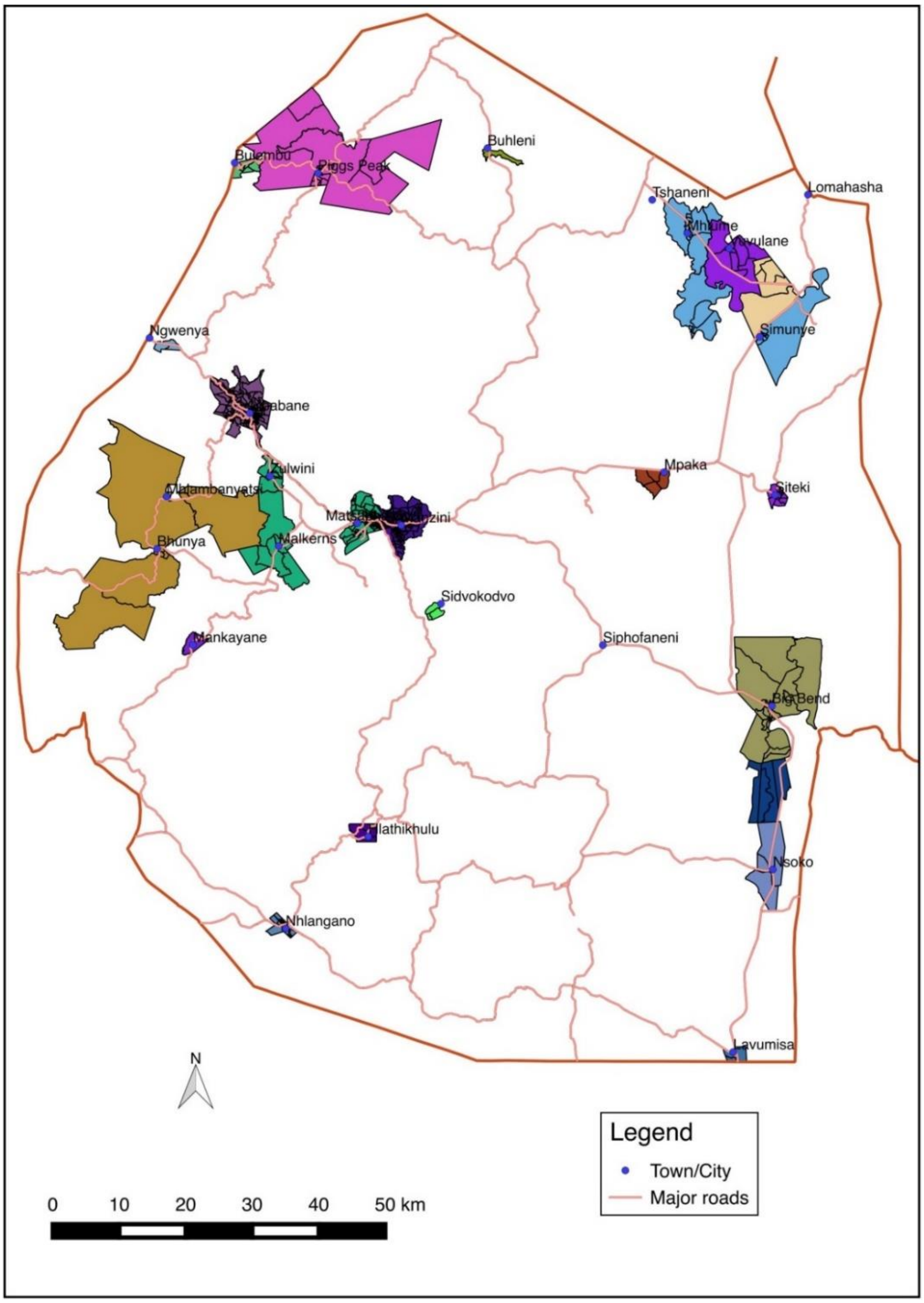

Figure 3-1: The geographical coverage of each landfill or dumpsite in the urban areas of Swaziland (NB: urban areas with the same colour share the same waste disposal facilities).

3.3 Waste Facilities With Data Capture

During the field visits, a number of waste sites that operate weighbridges and have appropriate records of the amount of waste disposed and the waste streams were observed. The following

municipal landfills/dumpsites and company towns had reliable data records: Mbabane, Matsapha, RSSC-Simunye, Big Bend and Bhunya-Montigny. The categories of received waste were available, and the amount of waste (in mass) collected during the 2016/2017 year was available.

3.4 Landfill Without Data Capture

In other municipalities landfill data is not recorded and waste quantities were estimated based on the volume of waste collection trucks utilized and the frequency the trucks collected waste to the dumpsite per week. Since waste quantity is usually measured by mass (kilograms or tonnes), the waste amount was calculated as follows:

Waste mass (kg) = vehicle volume (m^3) x loading factor x waste density (kg/ m^3)

Loading factor determine how full the truck is. The density of compacted and uncompacted waste were sourced from previous studies (Pichtels, 1997), and were assumed to be 400 kg/ m^3 and 150 kg/m^3, respectively.

3.5 Data Validation

The data from the field visits of municipal dumps was compared with the population-based waste estimates to check for consistency, as illustrated in Table 3.4. The total amount of collected waste by the municipalities was about 46% of the population-based estimates, which was found to be consistent with observations. Currently major urban areas like Manzini, Matsapha, and Mbabane consists of sprawling peri-urban areas where household waste is not collected by the municipalities.

Table 3-4: Population-based and actual annual waste collected in urban areas.

Town/City	Actual Annual Collected Waste (Tons/Year)	2016 Population-based Annual Total Waste (Tons/Year)
Mbabane	9902	33367

Manzini	6183	30242
Matsapha	11942	16733
Simunye	3071	4254
Piggs Peak	1530	3780
Nhlangano	3337	2740
Big Bend	243	2016
Siteki	2447	1750
Bhunya	5248	1511
Sidvokodvo	157	779
Mankayane	316	674
Hlatikhulu	352	644
Tabankulu	352	478
Matata	352	406
Mpaka	79	406
Lavumisa	392	351
Bulembu	No data	239
Buhleni	141	231
Ngwenya	526	175
Nsoko	39	159
Total	**46609**	**100933**

3.6 Combustible Waste

The amount of combustible waste was estimated to be 80% of the general waste excluding construction waste, ashes, and garden waste. Domestic waste typically consists of about 80% combustible materials such as plastic, food packaging, paper, and cardboard (Hoonweg, 2012). This assumption was generally found to be consistent with the field observations as illustrated in Fig. 4.2.

Figure 3-2: Typical domestic/general waste at different waste disposal sites.

The figure for Nhlangano dumpsite also illustrates the constraints faced by the town in that the waste accumulates to large levels because of poor access to compacting and covering equipment. This town experienced two unintended dumpsite fires in the past year alone. Animals can also be seen consuming some waste products.

4. RESULTS AND DISCUSSION

The primary aim of the research was to establish a national estimate of uPOPs released annually resulting from the open burning of waste. Populations of developing countries are characterized by relatively high levels of open waste burning as a means of waste disposal. Therefore, it was critical to estimate the amount of burnt waste from both urban and rural areas.

To estimate total waste generated in the country, as well as recycled waste and disposed waste that is burnt, the population of the country was classified as either urban or rural, using the 2007 national census data (CSO, 2007). The following sections present the results of such data, first waste collection in urban areas of Swaziland, then data on collected urban waste, followed by data on uncollected urban waste. Lastly, estimate waste data is presented for both urban and rural areas, as well as by each *inkhundla* (constituency) area in the country. As discussed in the Methodology, two classes under the open burning processes were factored given the scope of this study, namely class 1 – fires at the dumpsite and class (3) open burning of domestic waste.

4.1 Waste Collection in Urban Areas of Swaziland

A total of 24 urban areas (formal and informal) were identified in the country in line with the 2007 national census data. Of these, two are cities, ten are gazetted towns, three are emerging towns, five are company towns, and four are company villages (see Table 5.1). Of these, it was found that six (6) operate landfills, while thirteen (13) operate dumpsites. Of the six landfills, three (3) are engineered, while the other three are sanitary landfills. Of the thirteen (13) dumpsites, five (5) are controlled, one (1) is semi-controlled, and seven (7) are open.

Worth mentioning is that there are urban areas that receive and dispose waste from other urban areas in the country. As shown in Table 4.1, Malkerns and Ezulwini towns dispose their waste at Matsapha landfill. Similarly, waste from Vuvulane town is disposed at Siteki dumpsite, while waste from Mhlambanyatsi town is disposed at Bhunya landfill. It was also found that waste from Mhlume and Tshaneni urban areas is disposed at Simunye landfill. Figure 4.1 below shows the spatial coverage of each landfill/dumpsite.

Table 4-1: Urban areas in Swaziland and their waste disposal facilities.

City/Town	Designation	Landfill or Dumpsite Type	Comments
Mbabane	City	Sanitary landfill	
Manzini	City	Controlled dumpsite	
Matsapha	Town	Engineered landfill	Also serves Malkerns and Ezulwini towns
Siteki	Town	Open dumpsite	Also serves Vuvulane town
Nhlangano	Town	Controlled dumpsite	
Hlathikulu	Town	Open dumpsite	
Pigg's Peak	Town	Engineered landfill	
Lavumisa	Town	Open dumpsite	
Mankayane	Town	Open dumpsite	
Ezulwini	Town		Collected by Matsapha town
Vuvulane	Town		Collected by Siteki town
Ngwenya	Town	Controlled dumpsite	
Malkerns	Emerging town		Collected by Matsapha town
Nsoko	Emerging town	Open dumpsite	
Buhleni	Emerging town	Open dumpsite	
Matata	Company town	Controlled dumpsite	
Bhunya – Montigny	Company town	Engineered landfill	Also serves Mhlambanyatsi town
Simunye – RSSC	Company town	Sanitary landfill	Also serves Tshaneni and Mhlume towns
Mhlume – RSSC	Company town		Collected by Simunye town
Tshaneni – RSSC	Company village		Collected by Simunye town
Big Bend – Ubombo Sugar	Company town	Sanitary landfill	
Tabankulu – Hulle Sugars	Company village	Controlled dumpsite	
Mpaka – Swaziland Railways	Company village	Semi-controlled dumpsite	
Sidvokodvo – Swaziland Railways	Company village	Open dumpsite	

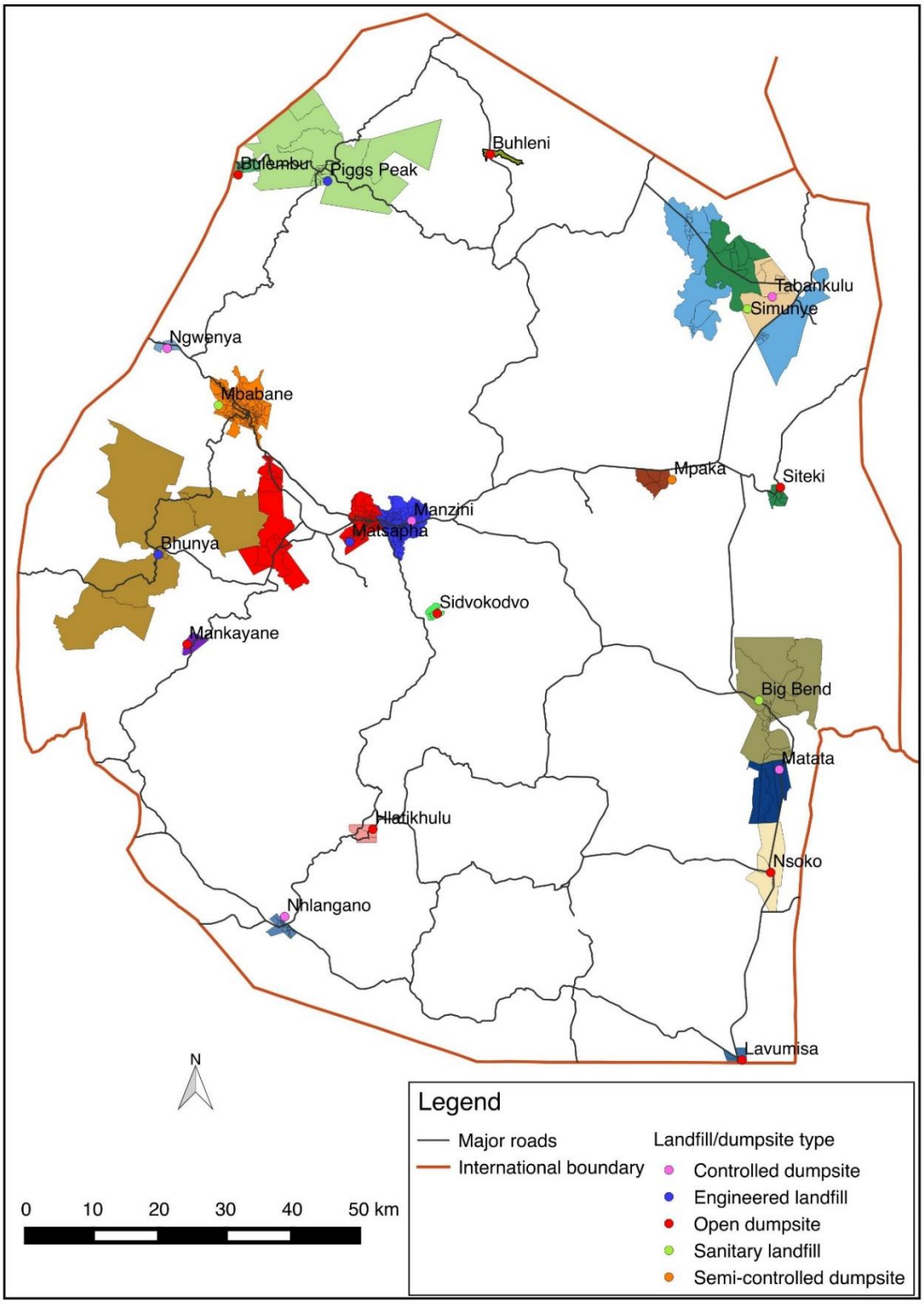

Figure 4-1: The geographical coverage of each landfill or dumpsite in the urban areas of Swaziland.

4.2 Waste Generated at National Level

The computation of waste generated per enumeration area using population census statistics and income-based waste generation is illustrated in Figure 4.2. The hotspot areas for waste generation are the cities or affluent towns, as well as peri-urban areas around these cities and towns. In summary, at a national level, the total amount of waste generated per annum is 238,341 tonnes of which 100,933 tonnes (42%) is generated in urban areas, whilst 137,409 tonnes (58%) is produced in rural areas (Table 4.2). Of this waste, 70,086 tonnes (29%) is recycled/reused per annum, with 21,993 tonnes recycled/reused in urban areas and 48,093 tonnes recycled/reused in rural areas.

Furthermore, a total of 106,413 tonnes (45%) of waste is burnt in Swaziland per annum; with about 34,961 tonnes burnt in urban areas and about 71,452 tonnes burnt in rural areas. Lastly, about 61,843 tonnes (26%) of waste is disposed in the country per annum. This comprises 43,980 tonnes disposed in urban areas, mainly the landfills and dumpsites, and 17,863 tonnes in rural areas (Table 4.2). Worth noting is that this disposed rural waste is predominantly incombustible.

Table 4-2: Recycled waste, burnt waste and net waste disposed in urban, rural, and nationally in Swaziland.

	Urban areas	**Rural areas**	**Total**
Recycled Waste (Tons/Year)	21,993	48,093	70,086
Burnt Waste (Tons/Year)	34,961	71,452	106,413
Net Waste Disposed (Tons/Year)	43,980	17,863	61,843
Total Waste Produced (Tons/Year)	**100,933**	**137,409**	**238,341**

This tallies well with the IPAT framework for the assessment of environmental impacts, where I = PAT is the mathematical notation of a formula put forward to describe the impact of human activity on the environment.

$I = P \times A \times T$

This mathematical expression equates human impact on the environment (I), in this case the ecological footprint of waste, to the product of three factors: Population (P), Affluence (A), and Technology (T).

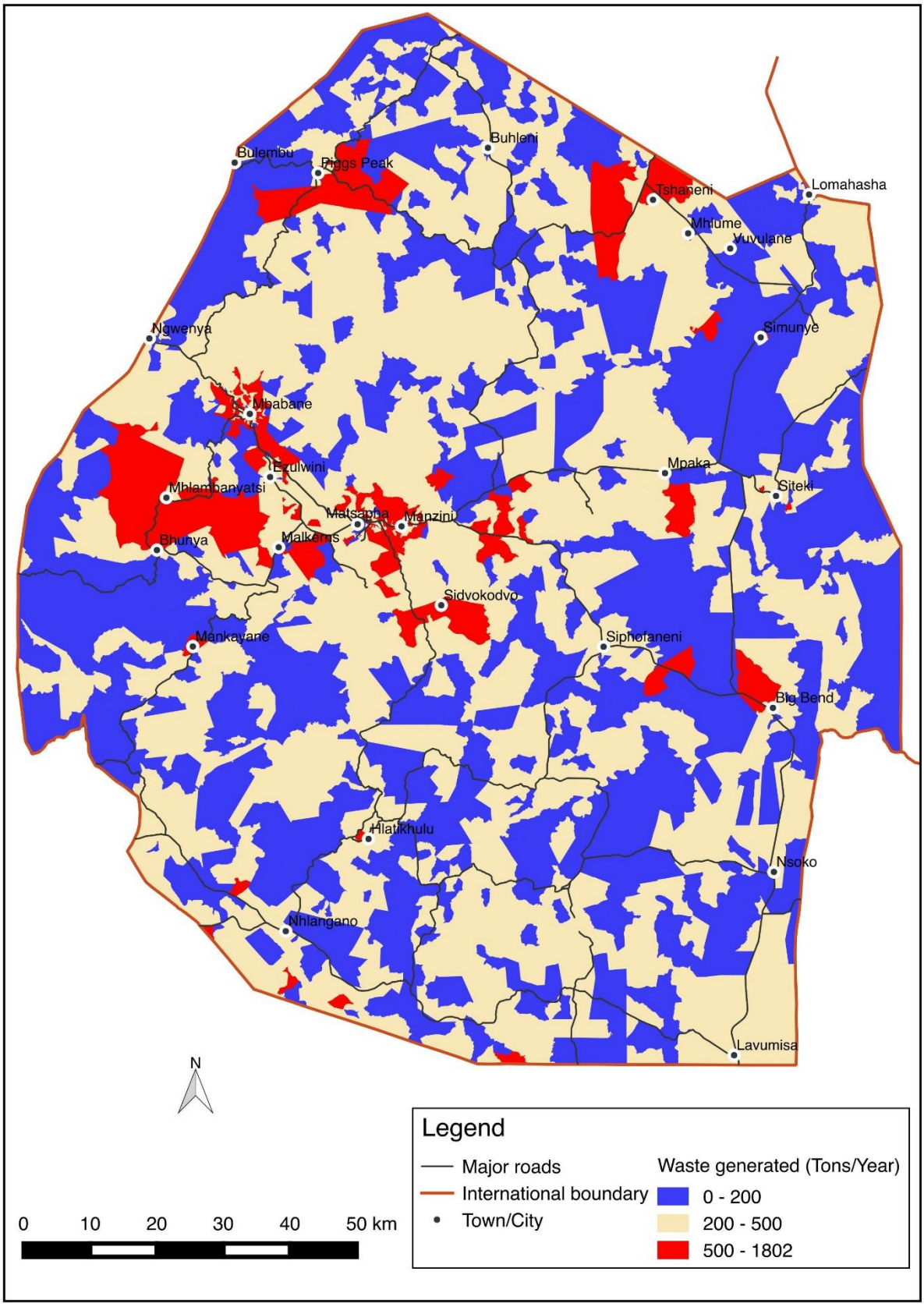

Figure 4-2: The spatial distribution of quantities of waste generated at enumeration area level.

4.3 Waste Burning at Municipal Dumpsites

During the study, it was found that Siteki, Sidvokodvo, Mankayane, Hlatikhulu, Lavumisa, Buhleni, Ngwenya and Nsoko burn all the waste reaching their dump sites. However, in Nhlangano, waste is not deliberately burnt, but accidental fires occur about twice a year, and thus only about 3.8% of the combustible waste is likely burnt. All the other municipal waste was covered with top soil, ash or rubble periodically. The waste burning figures are reflected in Table 4.3.

Table 4-3: Annually generated combustible waste and actual burnt waste in urban areas.

Town/City	Net Waste Disposed[(a)] (Tons/Year)	Combustible Waste Estimates[(b)] (Tons/Year)	Burnt Waste (Tons/Year)	Burnt Waste (%)
Mbabane	9797	7838	0	0
Manzini	6096	4877	0	0
Matsapha	11818	9454	0	0
Simunye	2914	2331	0	0
Piggs Peak	1515	1212	0	0
Nhlangano	3304	2643	102	3.8
Big Bend	247	198	0	0
Siteki	2445	1956	1956	100
Bhunya	4723	3778	0	0
Sidvokodvo	157	126	127	100
Mankayane	313	250	250	100
Hlatikhulu	352	282	282	100
Tabankulu	333	267	0	0
Matata	348	279	279	100
Mpaka	79	63	24	37.5
Lavumisa	392	313	314	100
Bulembu	N/A	N/A	N/A	N/A
Buhleni	140	112	112	100
Ngwenya	521	417	417	100
Nsoko	39	31	31	100
Total	**45532**	**36425**	**3892**	**10.7**

NB: (a) Net disposed waste excludes recyclables that were reclaimed at the dumpsite. The net disposed waste also excluded "inert waste" such as building rubble, ash, and garden waste. (b) Combustible waste was assumed to be 80% of the Net Disposed Waste.

Nationally, the average burnt waste from collected waste in urban areas is 3,892 tonnes (10.7%) of the collected combustible waste. It is encouraging to note that the larger municipalities and most of the company towns/villages do not use open burning as a waste disposal mechanism. Moreover, a significant number of these run well constructed and maintained landfills. In contrast, the smaller towns use open waste burning as a waste disposal mechanism due to a number of constraints including technological, human and financial resource constraints (Figure 4.3).

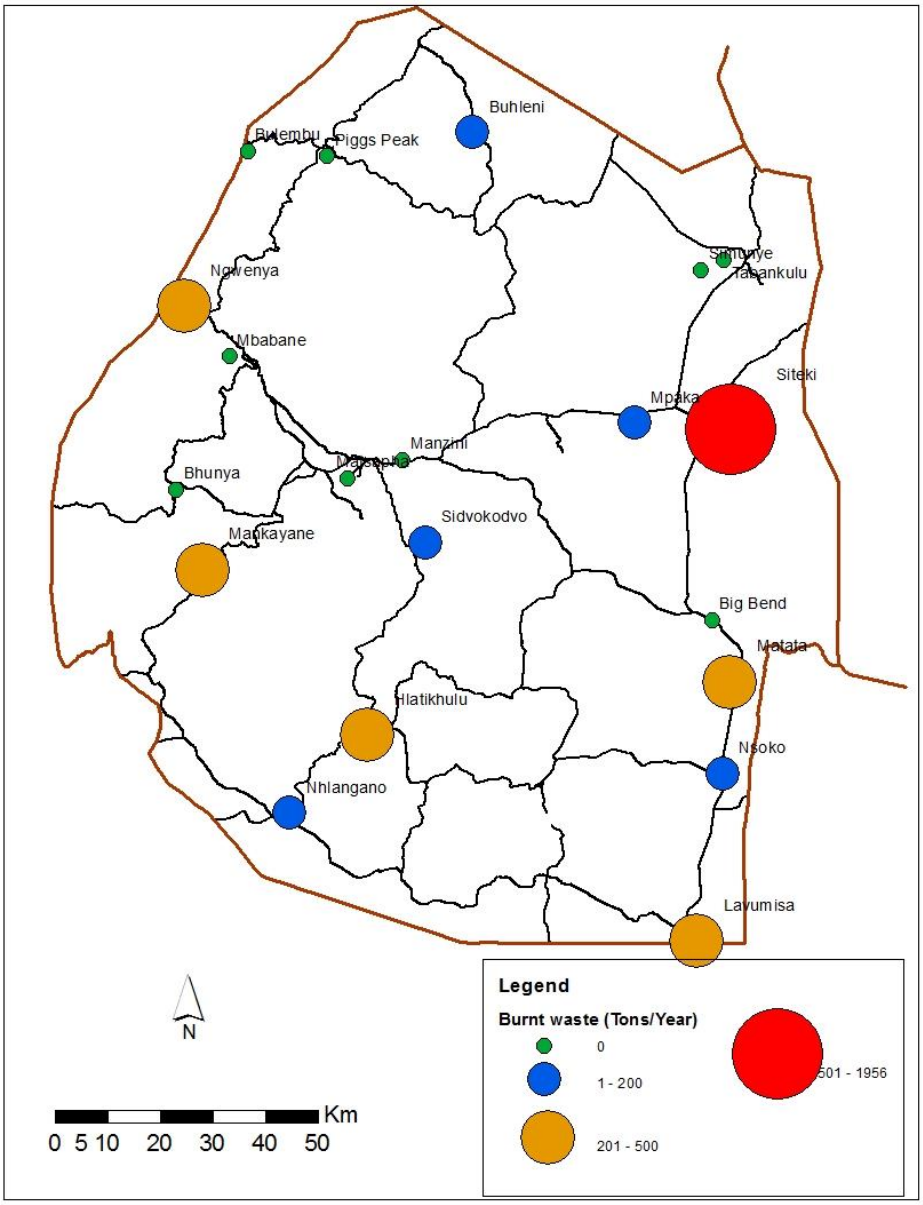

Figure 4-3: Collected waste that is burnt annually in urban areas of Swaziland.

4.4 Waste in Backyards of Urban Areas

Figure 4.3 compares the estimated waste generated by the population within each urban area, and the actual waste that is collected within that urban area. The comparison indicates that there is general under-collection in most urban areas as the actual collected waste is still relatively lower than the estimated generated waste (based on population and income). It is noted that in the three major urban areas in the country, namely Mbabane, Manzini and Matsapha, the difference between collected waste and estimated waste generated is significantly large. This can be attributed to the burgeoning suburban informal settlement populations within these areas where there are very few or no waste collection services or facilities. In contrast, it is found that in the other towns the two figures are comparable. However, Bhunya was found to be collecting far more waste than that expected from the population and income-based estimate.

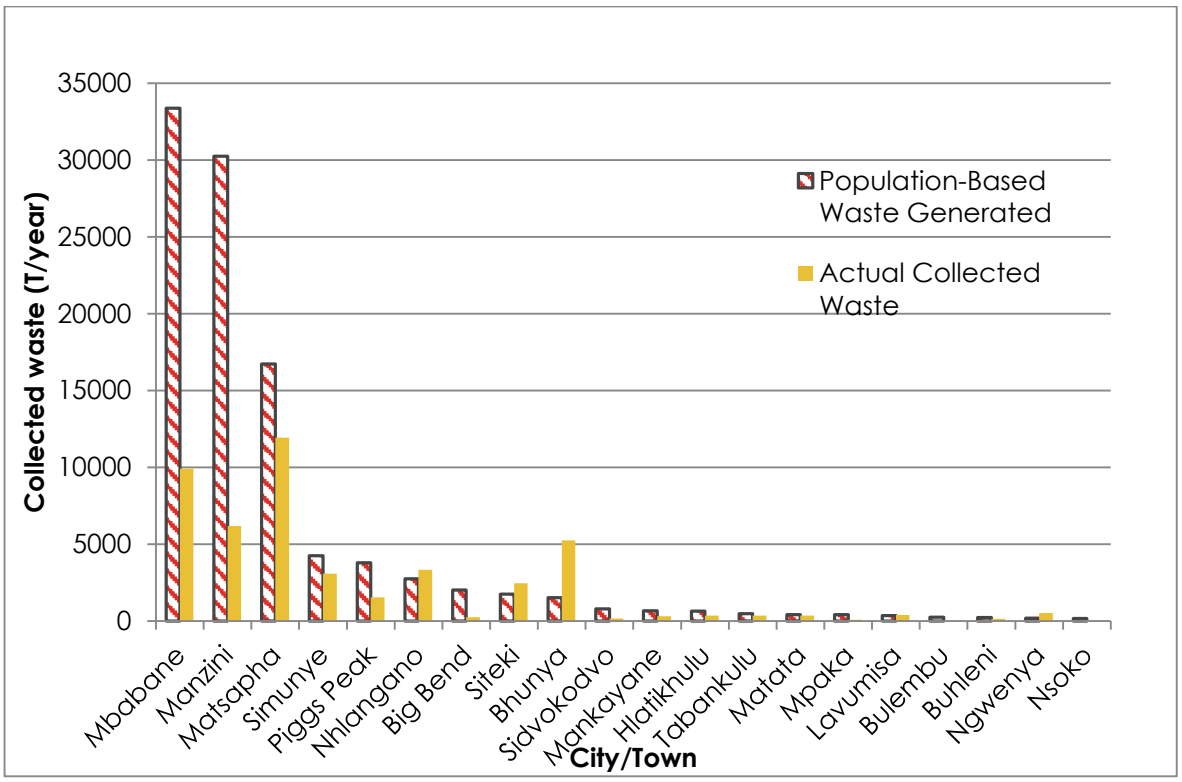

Figure 4-4: Comparison between population and income-based waste generation and actual waste collection estimates.

The difference between actual collected waste and the population based estimates a measure of the rate of waste collection in urban areas. The results are illustrated in Table 4.4 and

generally indicate that not all waste in urban is disposed in dumpsites. The exception was in the calculations for Nhlangano, Siteki, Bhunya, Lavumisa and Ngwenya where the waste collection was more than 100%. This anomaly may imply that these waste facilities collected waste outside their urban boundaries. Since Bhunya is an industrial town for the timber industry, this discrepancy may be explained since the methodology for waste generation estimates is based on household generated waste, it may underestimate general waste from industrial activities.

In total, the amount of uncollected urban household waste found to be 59,747.3 tonnes in these areas. It was assumed that on average, about 35% of this was recycled by the households, as it was observed by the Department of Environmental Affairs (2012) study in the Republic of South Africa. It was observed during the field visits that a majority of the uncollected urban wastes was disposed through open burning processes in backyards. Figure 4.5 illustrated some of the observation of backyard fires along the Mathangeni-Matsapha Town Council (Police College) road.

Figure 4-5: Backyard open burning of waste along the Mathangeni-Matsapha Town Council (Police College) road. *Unfortunately, this demonstrates the extent that open burning of waste is also practiced in peri-urban areas with excellent waste management facilities such as Matsapha closeby.*

Table 4.4 indicates that the total amount of burnt waste in all the urban areas of Swaziland, from both collected and uncollected waste, was 34,960.6 tonnes per annum. This equates to about 35% of all waste in urban areas. The amount of waste recycled in the urban areas was estimated to be 21,992.6 tonnes, which is 22% of all urban waste (both collected and uncollected). In total uncollected waste that is burnt in backyard in urban areas was 3,892 tonnes.

Table 4-4: Burnt and recycled waste from collected and uncollected waste in urban areas.

Town/City	2017 Population-based Waste (Tons/Year)	Uncollected Urban Burnt Waste (Tons/Year) **	Collected Urban Burnt Waste (Tons/ Year)	Uncollected Urban Recycled (Tons/Year)	Collected Urban Recycled Waste (Tons/Year)
Mbabane	33367	12202.0	0	8212.9	105
Manzini	30242	12510.8	0	8420.7	86
Matsapha	16733	2491.3	0	1676.8	124
Simunye	4254	615.0	0	413.9	157
Piggs Peak	3780	1169.8	0	787.4	15
Nhlangano	2740	0.0	102	0.0	33
Big Bend	2016	921.8	0	620.4	0
Siteki	1750	0.0	1956	0.0	2
Bhunya	1511	0.0	0	0.0	525
Sidvokodvo	779	323.7	127	217.9	0
Mankayane	674	186.0	250	125.2	3
Hlatikhulu	644	152.0	282	102.3	0
Tabankulu	478	65.4	0	44.0	19
Matata	406	28.0	279	18.9	4
Mpaka	406	170.1	24	114.5	0
Lavumisa	351	0.0	314	0.0	0
Bulembu	239	124.1	N/A	83.5	No data
Buhleni	231	46.6	112	31.4	1
Ngwenya	175	0.0	417	0.0	5
Nsoko	159	62.2	31	41.9	0
Total	**100933**	**31068.6**	**3892**	**20911.6**	**1081**
Grand Total		**34960.6**		**21992.6**	

** estimated using population based total combustible net waste

4.5 Waste Generation in Rural Areas and *Tinkhundla*

From the total annual waste generated in rural areas, the amount of waste recycled was also estimated from the national waste generation estimates. Again, the recycling rate of 35% was assumed. In rural areas of Swaziland, normally, all unrecyclable waste is disposed by open burning in waste pits, or disposed indiscriminately. Such waste is usually ultimately burnt by wild fires, which highlights that almost all combustible waste that is disposed is burnt, whether intentionally or unintentionally.

The annual estimated total recycled wastes is rural areas of Swaziland was found to be 48,093 tonnes. This meant that the annual waste disposed in rural areas of Swaziland was 89,316 tonnes annually. Therefore, assuming that about 80% of local disposable waste is combustible, the total combustible waste was estimated to be 71,452 tonnes per annum (Table 4.5). The residual waste that cannot be reduced by burning, per annum, for the country was estimated at 17,863 tonnes.

Table 4-5: Population and income-based waste generation estimates in rural areas.

Rural Population-based Waste (Tons/Year)	Rural Recycled Waste (Tons/Year)	Rural Disposed Waste (Tons/Year)	Rural Combustible Waste (Tons/Year)	Rural Burnt Waste (Tons/Year)
137409	48093	89316	71452	71452

The total annual estimate waste generated in Swaziland per *tinkhundla* areas, based on population and income, is 238,341.3 tonnes. From Table 4.6 and Figure 4.6, it is evident that *tinkhundla* areas with both high populations and a low poverty index produce more waste. As a matter of fact, the areas producing most waste are the cities or effluent towns, as well as peri-urban areas around these cities and towns. Accordingly, *tinkhundla* with the highest poverty incidences were found to generate the lowest amounts of annual waste. The integration of both the population and the poverty incidences indicator proved to be very useful. Section 4.4, and specifically Figure 4.5 shows the amount of combustible waste generated and burnt in the backyards in urban areas of the country. Similarly, estimates of combustible waste that is likely burnt in the backyards (of households and development centres) in rural areas were computed. Figure 4.7 is the spatial distribution of the estimate combustible waste generated in the rural areas of the country, where waste is not collected.

Table 4-6: Population and income-based waste produced per Inkhundla.

Inkhundla Name	Total Annual Waste (Tons/Year)		*Inkhundla* Name	Total Annual Waste (Tons/Year)
Kwaluseni	19685.6		Mpolonjeni	3079.4
Manzini North	18625.0		Shiselweni	3044.3
Mbabane East	17335.4		Nhlambeni	2959.6
Mbabane West	11067.4		Maphalaleni	2913.3
Lobamba	8756.2		Ndzingeni	2862.5
Mhlume	8001.0		Mahlangatsha	2813.5
Motjane	7333.7		Kukhanyeni	2708.3
Manzini South	7264.1		Mthongwaneni	2591.0
Ludzeludze	6731.8		Mandlangempisi	2541.6
Maseyisini	6639.7		Matsanjeni South	2431.7
Mbangweni	6188.6		Nkhaba	2351.7
Sithobela	4542.3		Mayiwane	2264.3
Mtsambama	4487.1		Lubuli	2159.3
Mahlanya	4462.6		Mhlambanyatsi	2132.4
Gege	4320.0		Sandleni	1978.2
Dvokodvweni	4230.8		Matsanjeni North	1937.8
Pigg's Peak	4121.2		La-Mgabhi	1785.6
Ngwempisi	4078.1		Sigwe	1763.5
Hosea	4052.9		Hhukwini	1473.1
Zombodze Emuva	3814.5		Timphisini	1268.6
Nkilongo	3776.5		Ntondozi	1246.4
Mafutseni	3697.2		Ngudzeni	1206.4
Lugongolweni	3684.4		Nkwene	1073.3
Mkhiweni	3583.4		Hlane	1061.9
Siphofaneni	3517.4		Kubuta	1036.6
Mhlangatane	3357.6		Mangcongco	988.8
Lomahasha	3330.3		Lavumisa	817.2
Ntfonjeni	3166.1		**Total**	**238341.3**

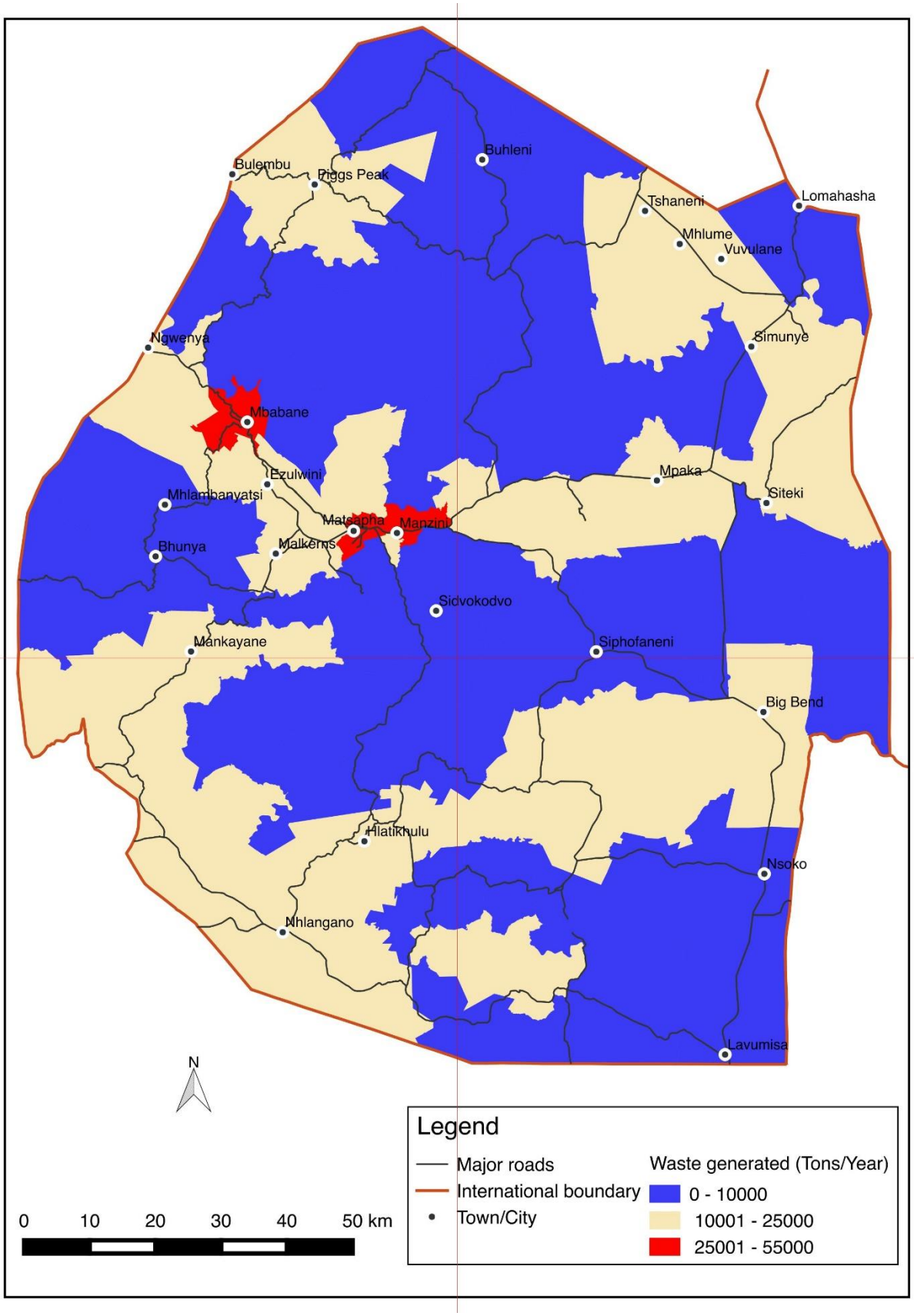

Figure 4-6: The spatial distribution of waste generated at Inkhundla level.

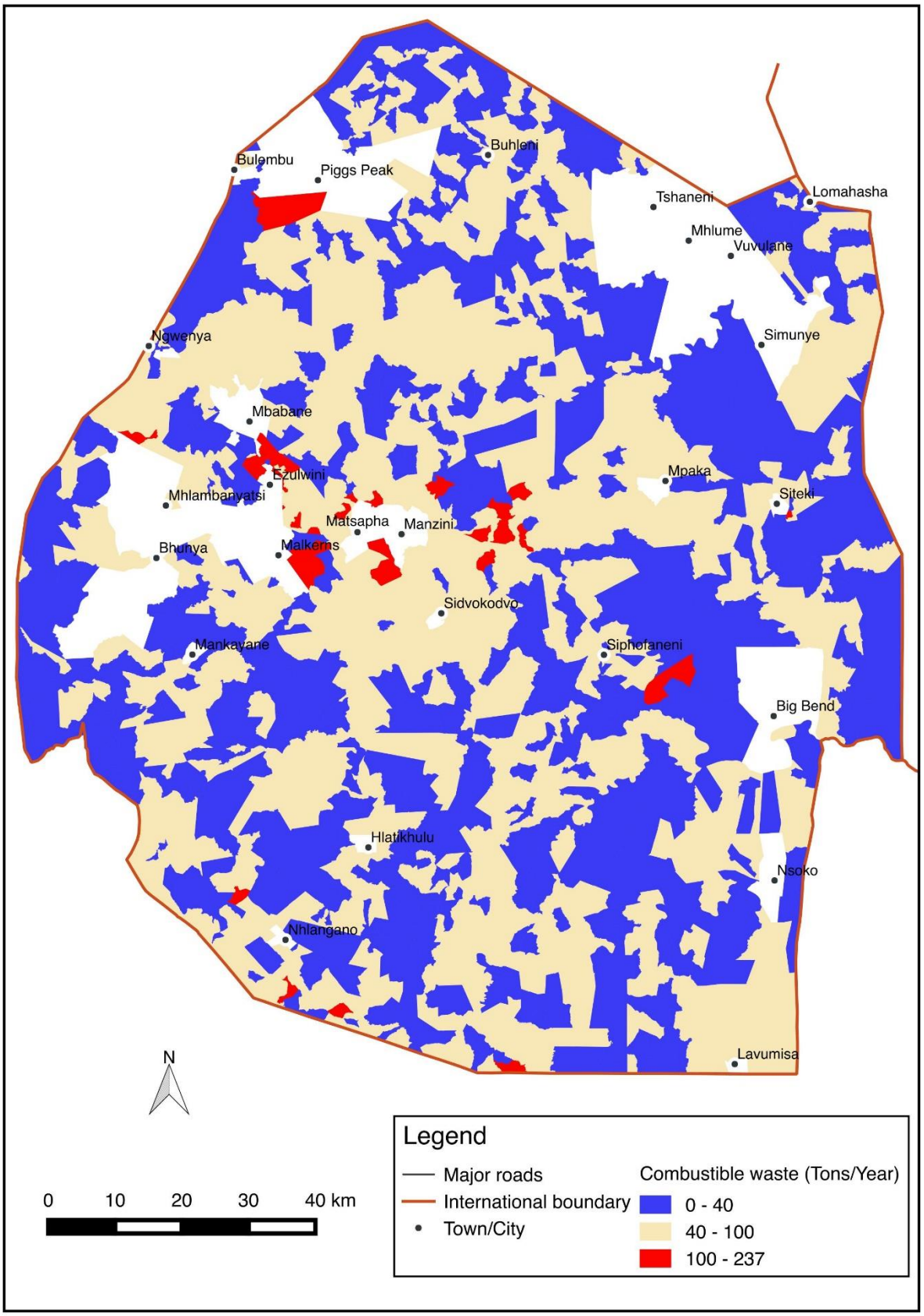

Figure 4-7: The spatial distribution of estimated combustible waste in rural areas.

4.6 Waste Generation at National Level

In summary, at a national level, the total amount of waste generated per annum is 238,341 tonnes of which 100,933 tonnes (42%) is generated in urban areas, whilst 137,409 tonnes (58%) is produced in rural areas (Table 4.7). The significance of the rural population is important to note because more than three quarters of the population resides in rural areas. Moreover, some of the key waste hotspots, including open burning hotspots, are in areas currently designated as rural.

Table 4-7: Recycled, burnt and net waste disposed in rural and urban areas.

	Urban Areas	**Rural Areas**	**National**
Recycled Waste (Tons/Year)	21,993	48,093	70,086
Burnt Waste (Tons/Year)	34,961	71,452	106,413
Net Waste Disposed (Tons/Year)	43,980	17,863	61,843
Total Waste Produced (Tons/Year)	**100,933**	**137,409**	**238,341**

4.7 Annual Estimate of Furans Emissions for Swaziland

In 2012 fires at waste dumps contributed 2.40 g TEQ/a while in 2017, the number has decreased to 1.17 g TEQ/a. Similarly, backyard burning contributions have notably decreased from 5.89 g TEQ/a in 2012 to 4.10 g TEQ/a in 2017. The decrease of waste in waste dumps could possibly be explained by the fact that places like Nhlangano that used to burn waste at the disposal site no longer do so. Similarly, the incidents of fires within landfills such as Manzini and Matsapha have drastically reduced over the last few years. Furthermore, the techniques used in this study were more robust through the inclusion of population and affluence variables, which are the key determinants of activity levels, which would also explain the decrease in the value of emissions for backyard burning.

Table 4-8: Activity data according to the emission sources.

6b	Open Burning of Waste and Accidental Fires	Activity Rate (Equivalent to the quantities of waste burnt per year)	Annual Release (g TEQ/annum)	
Classification			Air	Land
1	Fires at waste dumps (compacted, wet, high organic content)	3,892	1.17	0.0389
2	Accidental fires in houses, factories	NA		
3	Open burning of domestic waste (backyards)	102,519 *	4.10	0.103
4	Accidental fires in vehicles (per vehicle)	NA		
5	Open burning of wood (construction/demolition)	NA		
			5.27	0.142

NB: both urban and rural.

For comparison purposes, the estimates from the 2012 study (Mathunjwa, 2012) was considered. Table 4.9 below summarizes the annual releases from both air and land for disposal category 6b.

Table 4-9: Activity data for different emission sources from the 2012 study.

6b	Open Burning of Waste and Accidental Fires	Activity Rate (Equivalent to the quantities of waste burnt per year)	Annual Release (g TEQ/a)	
Classification			Air	Land
1	Fires at waste dumps (compacted, wet, high organic content)	7,998.063	2.40	0.0800
2	Accidental fires in houses, factories	NA		
3	Open burning of domestic waste (backyards)	147,193.8	5.89	0.147
4	Accidental fires in vehicles (per vehicle)	NA		
5	Open burning of wood (construction/demolition)	NA		

It is worth mentioning though that the estimates are largely based on parameters (emission factors and waste generation rates) from other countries. Although emissions estimation is not

expected to be an exact science, there are uncertainties associated with the use of such information, hence the need to conduct a comprehensive and detailed waste inventory at source level (i.e. household/industry/office/etc level)

4.8 Drivers of Waste Generation in Swaziland and Open Burning of Waste

Waste generation can be viewed as the inefficient use of resources and is a root cause of environmental pollution associated with open burning of waste. The main drivers of waste generation in Swaziland include socio-economic factors and institutional driver

4.8.1 Socio-economic Factors

- Population: The total population, more so the urban population, of Swaziland continues to increase. This fast growth has led to the mushrooming of peri-urban areas and other informal settlements that do not have access to waste collection services. Inadequate waste services leads to littering and the disposal of recyclable waste that could have otherwise been reclaimed at disposal site.
- Economy growth and affluence: As predicted by typical environmental Kuznets curves, an increase if affluence (income) is generally associated with increased volumes of waste generated. High income earners tend to consume more of prepared packaged foodstuffs, and thus contributing to food packaging wastes.
- Technology: The absence of a wide-spread recycling infrastructure and buy-back facilities that would promote diversion of waste streams contributes to the improper disposal of (even recyclable) waste. The country has a dire need for waste management technology including waste separation and reduction technologies.
- Roads also present a conduit for improper waste disposal throughout the country. Several parts of the country's roads are littered with waste and similarly the illegal dumpsites are very close to roads, which provide easy access to those sites.

4.8.2 Institutional Drivers

- Lack of socio-economic incentives for reduction of domestic solid waste residues such as deposit-refund schemes for beverage containers that are made of plastic or glass.
- Lack of a policy and regulatory framework which would actively promote an open-sharing of waste data within the waste management sector that could be exploited by the waste recycling industries.

- Insufficient of compliant landfill and hazardous waste management facilities, which hinders the safe disposal of all waste streams.
- Perception of the waste service sector as a business for "scavengers". The contribution of the waste management sector to the Swazi economy remains largely untapped and the waste reclamation industry remains under-appreciated yet it has huge potential to reduce waste outputs and also to provide thousands of job opportunities for unskilled and semi-skilled labour forces.

4.9 Limitations of the Study

Even though the objectives of the study were met, there are a number of limitations and cautions that need to be mentioned. These are:

1. ***The use of projected population data***
   Due to the unavailability of current population data, the study made use of projected population data from 2007 population census. The projections do not necessarily take into consideration immigration and emigration dynamics to and from each enumeration area. At the time of data collection and publication of the report, the 2017 census data was not yet available due to the rigorous analysis and approval processes it has to go through.

2. ***Waste estimates based on estimated per capita and not actual values***
   The study did not make use of actual values in the calculation of waste generated in the country but made use of estimates based on South Africa, which more or less shares similar household characteristics. This was then used together with population data and socio-economic indices to estimate the waste generation.

3. ***Un-matching urban boundaries***
   The study made use of the 2007 national census data that classifies areas as urban even though they fall outside urban areas as designated by the Ministry of Housing and Urban Development in their designation of urban areas. Boundaries are, by their nature, fluid on the ground particularly when considering human demographics and human settlements. Although not expected to have significant impacts on the findings of this study, the estimates of waste per urban area could be possibly under- or over-estimated.

5. ACTION PLAN FOR THE MANAGEMENT OF WASTE WITHOUT OPEN BURNING USING BEST ENVIRONMENTAL PRACTICES AND BEST AVAILABLE TECHNOLOGIES IN SWAZILAND

5.1 Best Available Techniques (BAT) and Best Environmental Practices (BEP)

Discussed in this section is and Action Plan to reduce or where possible eliminate the emission of uPOPS from open burning of waste by adopting best available techniques (BAT) and best environmental practices (BEP) to deal with municipal solid waste. According to UNIDO (UNIDO, 2013) "BAT means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for release limitations designed to prevent and, where that is not practicable, generally to reduce releases of chemicals listed in Part I of Annex C and their impact to the environment as a whole," and "BEP means the application of the most appropriate combination of environmental control measures and strategies." Examples of BAT include using modern engineered landfills and incineration with energy recovery, and those of BEP include reducing waste generation, and re-using.

The United Nations Environment Programme (UNEP) developed a document with guidelines to assist countries in adopting BAT and BEP. This document is titled Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. (SC, 2017) The guidance provides information on reducing the emissions of uPOPs from open burning of waste. It stresses that open burning of waste is a bad practice and that its improvement is not and endorsement of the practice, and that it should be "a last resort where there are no alternative disposal or recovery methods due to inadequate infrastructure; where sanitary disposal is required to control disease or pests; or in the case of disaster or other emergency." Entities in Swaziland that include small municipalities, some company towns and upcoming development communities were found to have inadequate infrastructure for waste management.

5.2 Conditions for the Formation of PCDD and PCDF

If open burning is the only option available at the time it is important to be aware of the conditions suitable for the formation of PCDD and PCDF uPOPs. Open burning is not an ideal

combustion process as it leads to the formation of carbon monoxide, methane, volatile organic pollutants (VOP) such as benzene, semi-volatile organic pollutants (SVOP) such as polycyclic aromatic hydrocarbons (PAH) in addition to pollutants such as soot and particulate matter (PM). Open burning also produces other pollutants part of which are polychlorinated dibenzo-*p*-dioxins and dibenzofurans, also called dioxins and furans. (Zhang, Buekens, & Li, 2017) They are formed in all combustion processes where carbon and chlorine are present. In industrial processes the dioxins and furans are emitted high up in chimneys into the atmosphere. In open waste burning these are produced close to the ground and therefore are likely to have more local impact. Dioxins and furans are highly toxic pollutants that bioaccumulate in the body. Exposure to dioxins and furans can cause ill effects in humans such as cancer, severe reproductive and developmental problems, damage to the immune system and hormonal systems, and skin disorders, among others. (EPA, 2017)

Conditions that lead to the formation of dioxins and furans: (SC, 2017)

- Low temperature of combustion
- Insufficient oxygen content
- Poor gas phase mixing (due to dense waste)
- Presence of particulate matter bound to metal (copper, iron, aluminium and chromium) species
- Presence of hydrochloric acid or molecular chlorine

There are two temperature windows for the formation of dioxins and furans (Zhang, Buekens, & Li, 2017; Altarawneh, Dlugogorski, Kennedy, & Mackie, 2009). The first is between 500 and 800^{o}C where the precursor molecules such as chlorophenols, chlorinated benzenes or chlorinated biphenylenes are formed together with the dioxins and furans through high heat conditions. Dioxins and furans are also formed in the second temperature window of between 200 and 450^{o}C, facilitated by the catalytic process of metal oxides. In open burning of waste the temperature ranges from 120 to below 650^{o}C which is envisaged by the production of a lot of smoke (ADEC, 2005). Open waste burning at these temperatures, in the presence of metals (iron, copper, aluminium and chromium) and chlorine provides ideal conditions for the production of dioxins and furans (SC, 2017). Full combustion of combustible matter occurs for fires that burn with a low amount of smoke producing mainly carbon dioxide, water and ash.

5.3 Open Burning of Waste in Swaziland

This study and previous studies have shown that open waste burning is widely practiced in Swaziland as a means of waste disposal. Swaziland is not alone in this as numerous studies reveal that open burning of waste is the most important source of uPOPS in the form of polychlorinated dioxins and furans amongst most countries that are signatory to the Stockholm Convention on POPs, more especially the developing countries (UNIDO, Vitalstrat.net, 2016). The practice of open burning of waste is carried out in (i) dumpsites of some formal structures such as municipalities, company towns, and upcoming development areas and (iii) waste pits in the domestic sector, particularly in the peri-urban and rural areas. It is used as means to reduce the volume of waste produced and to dispose of combustible waste materials. In the process dangerous pollutants some of which are uPOPs are emitted directly into the air and some left in residues which eventually get washed by rainwater ending up in river and dam sediments. This study revealed that the formal structures disposing waste by open burning were well aware that it was a bad practice but were faced with financial constraints such that they did not have any other options. Upcoming development areas were found to have inadequate knowledge that open waste burning was bad for the environment and human health. Some of them do not even have formal administrative structures to address their waste issues, and so burning waste in a pit behind their structures is the simplest solution. The SEA and MHUD has made some interventions jointly and separately at Buhleni, Lobamba, Lomahasha and Malkerns to assist them in waste disposal challenges. Households in the peri-urban and rural areas see it as a method of choice to dispose of waste by open burning as they do not have any other alternative method. These observations indicate that there is need for interventions to tackle the issue of open waste burning through best available techniques (BAT) and best environmental practices (BEP) for waste disposal. BAT and BEP aims to reduce the emission of uPOPs or completely eliminate their release where possible.

5.4 Observations of BAT and BEP in Swaziland Related to Open Burning

In carrying out this study it was observed that in Swaziland there is already some evidence of BAT and BEP. Examples of BAT include the use of engineered landfills by three municipalities in the country and two company towns, and composting of organic waste in one municipality. The BEP observed in Swaziland include the diversion of combustible waste to useful applications such as upcycling of old car tyres into flower planters and garden decorations; grocery plastic bags being turned into house decorations, removal of plastics; paper and

cardboard from the waste for recycling; composting of organic waste; and the collection of planks and poles for reuse. Figure 5-1 (a) shows a case of the upcycling of car tyres while (b) shows the upcycling of grocery plastic bags into office decorations.

(a)

(b)

Figure 5-1: Tyres used for landscaping at a municipal nursery (left) and office decorations made from grocery plastic bags (b). NB: the composting area behind the nursery is a composting area.

5.5 State of Recycling and Reusing in Swaziland

A lot of the recycling happens in the areas with high population densities where the recyclers tend to locate. The reason is that recyclers cannot justify the collection of small amounts of waste from far to reach areas. It was also observed that not all the waste ended up being upcycled, recycled or reused, even in areas where there is access to recycling facilities.

The most recycled materials seem to be (i) ferrous metals and nonferrous metals, (ii) very clear glass bottles, (iii) aluminium cans, (iv) clear plastic, and (v) cardboard. There is one case in Matsapha where they recycle almost every type of plastic including plastic crates, 20 and 25 litres liquid containers and mixed colour grocery bag plastics to manufacture refuse bags. Milk, juice and other beverage cartons were collected for recycling in some areas and not in others, and the same applied to sour milk plastic containers. At the dumpsites or landfills there are a lot of plastics to be found despite the recycling that exists. There are therefore gaps in the removal of combustible waste from the waste destined for disposal either to a landfill or for open burning. Figure 5-2 (a) shows levelled waste that is about to be covered with soil and a lot of plastics are seen while there is an almost all plastic recycling facility within a kilometre

from the site. In (b) valuable clear plastic that sells for E1.50 per kg placed for open burning while in (c) the same type of plastic is scattered into the bushes.

(a) (b) (c)

Figure 5-2: Waste at an engineered landfill ready to be recovered and compacted (left) and waste at a dumpsite accumulated for burning (right).

Related to recycling is the issue of waste pickers who collect the different types of waste material for recycling or reuse. In almost all the cases these people are not directly linked to the establishment responsible for the dumpsite or landfill. They work independently of the establishment sometimes given access and sometimes trespassing. They do not have sanitary facilities or protective equipment. There is one engineered landfill where these people are provided protective clothing by the establishment but work independently from it.

The gaps in recycling are as follows:

- There are municipalities and communities where there is no recycling but only reuse of items like soft drink and beer glass bottles.
- Not all recyclable waste is recycled even where there are recycling facilities close by.
- Ferrous tin cans have a very low value of 20 cents per kilogram and therefore not attractive for collectors, while other ferrous metals and aluminium cans are E2.00 and E10.00 per kg, respectively. These tins contain iron whose oxides make catalysts for the formation of dioxins and furans.
- Metal recyclers have no cushion against international metal price fluctuations
- Some open burning sites do not reject fluorescent lights and tyres
- The location of some open burning sites are in gullies

- There are no publicised strategies and targets for recycling in order to reduce open burning of waste
- Some communities are very far from waste recycling areas and therefore do not bother to try to recycle
- In some areas there is no restriction of the waste that goes to the dumpsite with the exception of medical waste.

Figure 5-3 (a) shows abundance of rusted tin cans at an open burning dumpsite, which (b) shown open burning of waste in a gully. Figure 5-4 (a) shows a container of some unknown chemical labelled in Mandarin at the open waste burning site, while (b) shows a smouldering fire at another part of the same dumpsite.

(a) (b)

Figure 5-3: (a) Open burning site showing lots of rusted uncollected tin cans. (b) Open burning at a gulley.

Figure 5-4: (a) Chemical container at an open burning dumpsite and (b) a smouldering fire at another part of the same site.

(a) (b)

5.6 BEP to Address Open Burning of Waste

If open burning is not avoidable as a waste disposal method the best environmental practice is to reduce the amount of waste destined for open burning. This can be achieved in two ways as BEPs. The first would be to study the combustible waste streams and identify means of reducing the source. The other is waste sorting to divert most of the combustible waste from reaching the dumb site for open burning.

5.6.1 Waste Reduction at Source

Waste reduction at source could depend on a number of parameters. The type and source of the organic waste must be identified. Manufactures and retailers must be involved in the development of reduction of the source of the combustible waste streams. Swaziland imports a lot of her consumed products mainly from South Africa. Reducing packaging at source would therefore be a challenge, as it would require a regional intervention.

5.6.2 Waste Sorting

Waste sorting can preferably be done at the waste generating source or at a centralised location, where all the waste is destined to. Municipal solid waste mainly constitutes of the following: (Edugreen, Types of solid waste)

Biodegradable waste: This is waste that can be decomposed by bacteria, fungi and or any other biological means. Such waste contains nutrients that are needed by the microorganisms responsible for the biodegradation. Examples of biodegradable waste include food, paper, cardboard, plant material, etc. Such waste can be recycled, composted, diverted to a biogas digester to produce biogas energy, or burnt in an incinerator to produce energy in a waste-to-energy project.

Recyclable materials: These are waste materials that can be converted to other useful materials and products. These include mainly metals, glass, plastics, paper and cardboard.

Reusable waste: Reusable waste can be reused without necessarily being transformed to another form. Such waste would include clothes, shoes, furniture, planks, containers, etc.

Unpcyclable Waste: This is the type of waste that can be made into a better product of higher value than when considered a waste product.

Inert waste: Inert waste constitutes of materials that are hardly react both biologically and chemically. Such waste takes a very long time to decompose and is not a threat to the environment except for taking up landfill space without giving up any as a result of decomposition. Examples of such waste include demolition materials from manmade structures, dugout dirt and rocks etc.

Waste Electrical and Electronic Equipment: This is waste electrical and electronic equipment that has reached the end of its functional life or has become obsolete and has to be disposed of. It includes household items like fridges, stoves, televisions, kettles, hair dryers etc., electrical tools like grinders, drills, etc., IT equipment like computers, cell phones, tablets etc., and many other types.

The waste that eventually goes to the dumpsite for burning can be drastically reduced if the recyclable, reusable and upcyclable materials are removed. In addition, the sorting can ensure that metals, glass, wet waste and inert materials are separated from the waste that is eventually burnt. That way the catalytic metals and materials that promote smouldering can be removed improving the combustion process, resulting in a high temperature fire with less pollution.

Some of the non-recyclable waste can be converted to useful forms such as heat, electricity or fuels using different means such as combustion, gasification, pyrolysis, anaerobic digestion and landfill gas recovery. Any of these processes are waste to energy conversions which can be used to reduce the country's energy demands.

5.7 BAT to Address Open Burning of Waste

The open burning of waste can continue as a short-term measure while alternative means to complete elimination are under development. Emissions of uPOPs from open burning can be reduced by adopting the following measures (SC, 2017):

1. ***Prevent smouldering fires (smouldering fires burn at low temperature and produce the highest amounts of pollutants)***
    - Combusted waste must be free
        - free of non-combustible material such as glass
        - free of wet waste material – material to be burnt must be dry
        - free of materials of low combustibility

- Non-compacted and well blended for efficient combustion (compacting limits oxygen causing smouldering)
- Extinguish fire after burning
- Keep fires well ventilated or provide forced air if possible

2. ***Prevent the presence of catalysts***
   - Waste must be free of metals like iron, copper, aluminium and chromium even in small quantities
3. ***Prevent the presence of chlorine***
   - Remove waste loads high in chlorine and/ or bromine including inorganic salts or halogenated organic materials such as polyvinyl chloride (PVC)
4. ***Potentially explosive items and hazardous materials should be removed***
5. **Ash from mixed waste burning**
   - Should be kept from forage areas, and landfilled rather than land-spread.
6. **Limit exposure to open waste burning sites**
   - Open waste burning sites should be away from the population
   - Open waste burning sites should be downwind from residential areas.

5.8 Action Plan for BAT and BEP

Open burning of waste shall still be practiced in Swaziland up to the near future because of inadequate resources for alternate waste disposal in some municipalities, company towns and upcoming development communities, and peri-urban and rural households. The country needs to set up strategies and targets to minimize the emission of uPOPs from open burning of waste through the adoption of best available technologies (BAT) or best environmental practices (BEP) nationwide.

Three action plans are suggested for BAT and BEP addressing open burning in Swaziland. The first is for the peri-urban and rural areas, and the other two are short and long-term plans for municipalities, company towns and upcoming development areas. These are outlined below in the next sections.

5.8.1 BAT and BEP Action Plan for Peri-urban and Rural areas

This action plan for peri-urban and rural areas does not allow open burning in peri-urban areas but allow open burning in rural areas following BAT and BEP.

Table 5-1: Action plan for peri-urban and rural areas on backyard open burning of waste

	Action	Responsibility
1	Fully domesticate the Stockholm Convention to make it a local law compatible with local regulatory framework	MTEA, SEA, MoJ, MTAD
2	Raise awareness on waste issues and the Stockholm Convention to peri-urban people and people in the rural areas	SEA, MHUD MoTAD, MoH
3	Conduct education on and training: • Recycling • Composting • Upcycling • Open waste burning following BAT	SEA, Academic and research institutions
4	Develop recyclable waste accumulation facilities in remote and rural areas where recyclable materials shall be collected at scheduled periods	SEA, Traditional authorities
5	Provide skip bins in hot spots particularly in peri-urban areas for collection by the closest municipality.	SEA, MHUD
6	Organize local casual labour (e.g. the proposed litter wardens) to monitor the waste disposal at the skip bins (to ensure proper disposal of waste) and waste hotspots.	SEA, MHUD, MTAD
7	Set up a national solid waste management unit for monitoring evaluation of implemented interventions.	MTEA, MHUD, MTAD, MoA

5.8.2 Shot-term Action Plan for Reduction of uPOPs Emissions from Open Burning of Waste

The short-term action plan for the reduction of emissions from open burning shall allow open burning following the BAT approach. Only dry combustible waste shall be burnt. Non-combustibles shall not be made part of the waste to be burnt, and shall be deposited at the landfill and routinely covered with soil. For municipalities and upcoming development areas far from recycling facilities, waste storage sites shall be developed for the accumulation of waste to quantities suitable for collection over the long distances.

Table 5-2: Short-term action plan for reduction of uPOPs emissions from open burning of waste

	Action	Responsibility
1	Domesticate the Stockholm Convention on POPS to provide support for the enforcement of municipal bylaws or any waste regulations that may be put in place	MTEA, SEA, MoJ
2	Conduct national awareness raising, education and training on proper waste management practices opportunities, and health effects of uPOPs generated from open burning of waste through print media, electronic media, pamphlets, community gatherings, website and other available opportunities	SEA, MTAD, MoH, MoE Municipalities, Companies, Institutions
3	Conduct stakeholder consultations with municipalities, company towns and upcoming development communities to find their limitations in waste management and strengthen their capacities	MHUD, SEA
4	Conduct stakeholder consultations with existing and potential recyclers to determine their capacities and constraints for waste recycling.	SEA
5	Develop strategies and set targets for waste reduction at source, increasing recycling of waste nationally, and reduce open burning.	SEA, MHUD
6	Train relevant officers in municipalities, company towns and upcoming development areas on the BAT on open burning of waste described in section 5.7.	SEA, MHUD
7	Set up a national solid waste management unit for monitoring evaluation of implemented strategies.	MTEA, MHUD, MTAD, MoA
8	Develop a demonstration site on acceptable waste disposal techniques with open burning at a municipality or upcoming development area.	SEA
9	Encourage the inclusion of waste management into the existing school and university curricular.	MoE, Academic institutions, NCC

5.8.3 Long-term plan for Reduction of uPOPs Emissions from Open Burning of Waste

The long-term plan shall aim at completely eliminating open burning everywhere, where there is a waste management administrative structure. This includes all municipalities, company towns and upcoming community development areas. The action plan is given in Table 5.3.

Table 5-3: Long-term plan for reduction of uPOPs emissions from open burning of waste

	Action	By who?
1	Domesticate the Stockholm Convention on POPS to provide support for the enforcement of municipal bylaws or any waste regulations that may be put in place	MTEA, SEA, MoJ
2	Conduct awareness raising, education and training on waste challenges, opportunities, and health effects of uPOPs generated from open burning of waste	SEA
3	Provide information on BAT technologies for waste management	SEA, MNRE, MoA, MTEA, MHUD, Research institutions
	g) Waste sorting facility	
	h) Incineration of waste to produce heat and electrical energy	
	i) Gasification of waste to produce heat, electricity and chemicals	
	j) Pyrolysis of waste to produce heat, electricity and chemicals	
	k) Biogas production from biodegradable organic waste	
	l) Composting of biodegradable organic waste	
4	Conduct detailed waste studies to quantify the different streams of waste suitable for the technologies listed in 3	SEA, Research institutions
5	Develop businesses models and mentorship programmes based on the technologies listed in 3 and make them available to some stakeholders	SEA, SIPA, MoCIT SEDCO, Research institutions

6	Conduct stakeholder consultations with municipalities, company towns and upcoming development communities to develop a new national waste management strategy in view of existing technologies	SEA, Research institutions
7	Conduct stakeholder consultations with existing and potential recyclers, and waste management investors and entrepreneurs to determine how they fit into the new national strategy on waste management	SEA
8	Develop strategies and set targets for waste management following BAT and BEP	SEA
9	Set up a national solid waste management unit for monitoring evaluation of implemented strategies.	SEA, MTEA, MHUD, MTAD, MoA

It is in order to briefly explain the technologies listed in action 3. It is also important to note that these technologies are also suitable for climate change mitigation as they can limit the amount of methane produced in a landfill. These technologies are briefly discussed below.

Waste sorting: This is the process by which waste is separated into different categories such as ferrous metals, glass, inert material organic biodegradable, organic recyclable, etc. Waste sorting can be done manually at the source, manually or automatically at materials recovery facilities. This result in the removal of recyclable waste and reusable products to reduce landfill space requirements for the waste generated.

Incineration: This is the combustion of non-recyclable waste to produce heat and/or electricity. It is one of the non-hazardous waste management methods also used to offset carbon emissions from fossil fuels under the UNFCCC. It ranks below reduction, recycling and reusing, but better than disposal. The burning reduces the volume of waste going to the landfill while producing energy and is called an energy recovery technology. The operation temperature for the energy recovery incinerator is 850 to 1 000ºC, beyond the temperature ranges for the formation of dioxins and furans. (Climatetechwiki, 2009)

Pyrolysis: This is a process where volatile organic components of matter are thermally decomposed at temperatures of 350 to 800ºC in the absence of oxygen or air. The process needs a heat source and can be performed at a small scale to reduce transportation costs. The products are syngas, liquids, a solid residue (char) and ash. Syngas is a gaseous mixture of hydrogen and

carbon monoxide, and some carbon dioxide. Syngas can be used as a fuel to produce heat and/or electricity. The liquid can be treated and be used as a fuel like diesel. The char is rich in carbon and can be used as a solid fuel. The char is mainly produced at low temperatures below 450^{o}C while the syngas is mainly produced at the higher temperatures of 800^{o}C. The liquid is produced at intermediate temperatures. Pyrolysis of municipal wastes requires the mechanical preparation and separation of glass, metals and inert materials prior to processing the remaining waste in a pyrolysis reactor. (Zafar, 2015; GSTC, 2017)

Gasification: This is the next step after pyrolysis. After removal of volatile components of the waste by pyrolysis, the waste is heated at temperatures between 760 and 1650^{o}C with very little air or oxygen. The char that remained from pyrolysis is converted to additional syngas. (GSTC, 2017)

Biogas: Biogas is produced when microorganisms decompose biodegradable waste in the absence of oxygen producing a gas constituting mainly of methane (CH_4), carbon dioxide and hydrogen sulphide (H_2S). It requires a biogas digester where the organic waste mixed with the right amount of water at a higher level flows into. On the downside of the digester there is an opening to let out the slurry discharge after digestion. The digester is made to be airtight and no light is allowed in. The produced biogas can be used for heating or to produce electricity.

Composting: This is the decomposition of biodegradable waste in an oxygen rich environment. This is a natural process carried out by microorganisms such as bacteria and fungi that break down organic matter into simpler substances. Organic material like food waste, leaves, paper, cardboard, garden waste, manure are all compostable materials. The product of composting is a rich mixture fertiliser that can be applied to crop and pasture lands.

5.8.4 Other Issues of Relevance to the Action Plans

1. Improve enclosures and security around waste disposal sites
2. Develop fire breaks outside waste disposal sites
3. Formalise waste pickers and provide them with protective gear
4. Expand collection coverage area to discourage communities from backyard open burning of waste

5. Where there is no administered waste management system, establish community level waste recycling systems and the proceeds should go to community projects like water services roads, etc.
6. Disallow all fires at dumpsites except for those for the burning of combustible waste where the practice is still allowed
7. Develop measures to deal with accidental fires
8. Obtain and analyse samples on current open burning dumpsites leading to a streams or gullies. If concentration of dioxins and furans are high at current open burning sites, carryout rehabilitation of the site.

5.8.5 Recommended Possible Studies Addressing Solid Waste Management in Swaziland

It would be prudent that a study is conducted to ascertain the waste generation and emission factors from analysis of waste for Swaziland. This could be done through a robust study of sample households, industries and workplaces throughout the country. This would then form a very useful baseline for understanding the waste issue and in the formulation of appropriate waste management strategies.

It would also be useful to use more recent household income and expenditure survey data (scheduled for 2018) and data from the recent census, once available, in order to develop empirical models of waste generation in the country as a basis for future planning of waste disposal facilities throughout the country. The use of geospatial information technology coupled with earth observation (remote sensing) data can greatly enhance the estimation of emissions.

Specific studies being recommended in the country include:

1. A national study to establish actual local statistics for waste generated by individual households in rural, peri-urban (including informal settlements) and urban areas, and by sectors/industries and composition. This should also include the quantification of the different waste streams and ascertaining suitable waste management technologies.
2. A study or survey on municipalities, company towns and upcoming development communities to establish opportunities and limitations in waste management, and to strengthen their capacities, where necessary.
3. A study to determine waste management hierarchy in the country including, but not limited to reusing and recycling capacities, capabilities and constraints in the country.

5.9 Policy Recommendations

Governments at local, regional and national level can develop a range of policy options to encourage waste management practices that will reduce the waste that end-ups being disposed through open burning process. This can include:

- The Swaziland Government, through the SEA, needs to formulate/update regulations (for inclusion into existing regulations) to restrict the open burning of waste. More so the regulations need to set specific limits on the emissions in case there is burning of waste such as incineration.
- Controlling excessive packaging through appropriate regulations and through a set-up of packaging standards that will set the limit of packing space ratio for different products. Plastic and paper packaging form a large fraction of combustible waste.
- Promotion of deposit-refund-schemes to encourage the recycling of containers of various types of beverages.
- Promotion and facilitation of waste entrepreneurship in the country so as to stimulate an increase in the proper disposal and management of waste.

Hence, it is strongly recommended that the Government of Swaziland reviews the previous National Solid Waste Management Strategy and formulates a new Integrated National Waste Management Strategy taking into consideration emerging and contemporary issues on waste management, best practices and lessons learnt. Primarily, this strategy should focus on waste reduction, reuse and recycling whilst using BATs/BEPs for waste to energy conversion, incineration and landfilling.

BIBLIOGRAPHY

(n.d.). Retrieved September 20, 2017, from UNIDO: http://www.greenindustryplatform.org/wp-content/uploads/2013/12/POPs-Best-Available-Techniques-and-Best-Environmental-Practices_EN.pdf

ADEC. (2005, November). Alaska Department of Environmental Conservation. Retrieved September 13, 2017, from Burning Waste: http://itepsrv1.itep.nau.edu/itep_course_downloads/AQ-Alaska_Resources/Burning/BurningWaste.pdf

African Development Bank, Organisation for Economic Co-operation and Development, United Nations Development Programme (2017). African Economic Outlook 2017. African Development Bank, Organisation for Economic Co-operation and Development, United Nations Development Programme. Available from: http://dx.doi.org/10.1787/aeo-2017-en.

Altarawneh, M., Dlugogorski, B., Kennedy, E., & Mackie, J. (2009). Mechanisms for PCDF and PCB Formation from Fires: Pathways from Oxidation of Chlorobenzenes . International Association for Fire Safety Science.

Central Statistical Office (2007). Swaziland – Population and Housing Census 2007. Mbabane, Swaziland.

Climatetechwiki. (2009). Combustion of Municipal Solid Waste for District Heat or Electricity. Retrieved September 17, 2017, from Climatetechwiki: http://www.climatetechwiki.org/technology/msw-wte

DEA (Department of Environmental Affairs) (2012). National Waste Information Baseline Report. Department of Environmental Affairs. Pretoria, South Africa.

DEAT (Department of Environmental Affairs and Tourism) (2006). State of the Environment: Background Research Paper on Waste. Pretoria, South Africa.

Dlamini, W.M., Mabaso, S.D. and Zamberia, A.M. (in prep). A spatio-temporal analysis of urbanization dynamics in Swaziland using DMSP/OLS nighttime lights.

Edugreen. (n.d.). Types of solid waste. Retrieved September 13, 2017, from Edugreen: http://edugreen.teri.res.in/explore/solwaste/types.htm

Edugreen. (n.d.). Types of Solid Waste. Retrieved September 13, 2017, from Edugreen: http://edugreen.teri.res.in/explore/solwaste/types.htm

EPA. (2017, March 22). Learn about Dioxin. Retrieved September 22, 2017, from Environment Protection Agency: https://www.epa.gov/dioxin/learn-about-dioxin

GSTC. (2017). Gasification Vesus Pyrolysis. Retrieved September 21, 2017, from Gasification and Syngas Technology Council: http://www.gasification-syngas.org/applications/gasification-vs.-pyrolysis/

Hoornweg, D. and Bhada-Tata, P. (2012). What a Waste : A Global Review of Solid Waste Management. Urban development series; knowledge papers no. 15. World Bank, Washington, DC. Available from: https://openknowledge.worldbank.org/handle/10986/17388

Mathunjwa, M.M. & Dlamini, B.S. (2014). *PCDD/PCDF Inventory for Swaziland*. Report to the Swaziland Environment Authority, Mbabane.

Mathunjwa, M.M. (2009). *PCDD/PCDF Inventory for Swaziland*. Report to the Swaziland Environment Authority, Mbabane.

Ndlela, W. N. (2014). *Review and Update of the POPs Pesticides in the Kingdom of Swaziland. Report*. Report to the Swaziland Environment Authority, Mbabane.

Ndlovu, T. (2014). *Inventory report on POP-PBDEs , PFOS and PCBs (Industrial Chemicals) and contaminated sites in Swaziland - 2014*. . Report to the Swaziland Environment Authority, Mbabane.

Ndlovu, T. (2014). *The National Implementation Plan (NIP) for the Management of Persistent Organic Pollutants (POPs) in the Kingdom of Swaziland – 2014*. Swaziland Environment Authority, Mbabane.

Okot-Okumu J (2012). Solid Waste Management in African Cities – East Africa, Waste Management - An Integrated Vision, Rebellon LFM (Editor), InTech, DOI: 10.5772/50241. Available from: https://www.intechopen.com/books/waste-management-an-integrated-vision/solid-waste-management-in-african-cities-east-africa

Pichtel J (2014). Waste Management Practices: municipal, hazardous, and industrial (2nd edition). Taylor & Francis Group, New York, USA.

Remmelzwaal A & Dlamini WS 1994: *Present Land Use Map of Swaziland, Scale 1:250,000*. FAO/UNDP/GOS Land Use Planning for Rational Utilization of Land and Water Resources Prooject SWA/89/001. Field Doc. 9, Mbabane.

Remmelzwaal A & Vilakati JD 1994: *Land Tenure Map of Swaziland, Scale 1:250,000*. FAO/UNDP/GOS Land Use Planning for Rational Utilization of Land and Water Resources Project SWA/89/001. Field Doc. 10, Mbabane.

Sbrilli, A. (2017). *International experiences on open burning and in sampling and analysis of POPs for the update of UNEP Toolkit*. SADC Project on Demonstration of BAT and BEP in Open Burning activities in response to the Stockholm Convention on POPs Regional Workshop, 6-7 APRIL 2017, Maputo, Mozambique.

SC. (2017). Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. Geneva: UNEP.

SHIES (Swaziland Household Income and Expenditure Survey) (2011). Poverty in a decade of slow economic growth: Swaziland in the 2000's. Mbabane, Swaziland.

Swaziland Environment Authority (2010). *The National Implementation Plan (NIP) for the Management of Persistent Organic Pollutants (POPs) in the Kingdom of Swaziland*. Swaziland Environment Authority, Mbabane.

Swaziland Household Income and Expenditure Survey (2011). Poverty in a decade of slow economic growth: Swaziland in the 2000's. Mbabane, Swaziland.

Thwala, M. (2014). *Review and Update of Swaziland's Legal, Institutional and Policy Frameworks for the Stockholm Convention on Persistent Organic Pollutants (POPs).* Report to the Swaziland Environment Authority, Mbabane.

UNEP (2017). Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles - Relevant to substances listed in Annexes A, B and C of the Stockholm Convention on Persistent Organic Pollutants from 2009 to 2015 (March 2017 Draft).

UNIDO. (2013, December). Best Available Techniques and Best Environmental Practices (BAT/BEP) - For the elimination of unintentionally produced POPs releases. Retrieved

September 20, 2017, from Greenindustryplaform.org: http://www.greenindustryplatform.org/wp-content/uploads/2013/12/POPs-Best-Available-Techniques-and-Best-Environmental-Practices_EN.pdf

UNIDO. (2016). Vitalstrat.net. Retrieved September 15, 2017, from What is Open Burning?: http://vitalstrats.net/aecomregional/open-burning/

United Nations Environmental Programme (2013). *Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases 2013*. United Nations Environment Programme (UNEP), Nairobi, Kenya.

World Bank (2017). Indicators population growth - Swaziland. Available from http://www/worldbank.org/share/widget?indicators=SP.POP.GROW&locations=SZ

Zafar, S. (2015, April 29). Pyrolysis of Municipal Wastes. Retrieved September 20, 2017, from BioEnergy Consult: https://www.bioenergyconsult.com/pyrolysis-of-municipal-waste/

Zhang, M., Buekens, A., & Li, X. (2017, June 2017). Open Burning as a Source of Dioxins. Critical Reviews in Environmental Science and Technology, p. 17.

Zhang, M., Buekens, A., & Li, X. (2017, June 22). Open Burning as a Source of Dioxins. Critical Reviews in Environmental Science and Technology.

ANNEXES

ANNEX 1: LIST OF INSTITUTIONS AND PERSONS CONSULTED

ANNEX 1: LIST OF INSTITUTIONS AND PERSONS CONSULTED			
	Landfill/Dumpsite Operator	**Contact Person**	**Contact details**
Swaziland Municipals	**Mbabane City**		
	Piggs Peaks Town	Bongekile T. Mkhontfo (Environmental Public Health Officer)	
	Manzini City	Nomcebo Monareng (Public Health Officer)	76739308
	Matsapha Town/eZulwini/Malkerns	Mr Maphanga Waste Disposal Manager	
	Makanyane Town	Nkosingiphile Hlatshwayo (Inspector of Works)	25388001/76216452
	Siteki Town	Nosipho Mthupha (Community & Social Development Manager)	nosiphomthumpha@yahoo.com
	Hlathikhulu Town	Bongani Dlamini (Town CEO)	See Town board address
	Nhlangano Town	Jabulani Seyama (Environmental Public Health Officer)	Tel: 76112496 environ@ntc.co.sz
	Lavumisa Town	Joshua Dlamini (Environmental Public Health Officer)	jikdlamini@gmail.com
	Vuvulane Town	Mandla Mhlongo	
	Ngwenya Town	Brenda Dlamini (Environmental Public Health Officer)	ngwenyatown@realnet.co.sz 76150313
Undeclared Towns	**Buhleni**	Community members	
	Siphofaneni	N/A	
	Lomahasha	Mr Maziya (Chairman – Lomahasha Vendor's Association)	N/A

Company Towns/villages	**Bhunya/Mhlambanyatsi**	Wiseman Dlamini Montingy Villages Manager	wiseman.dlamini@montigny.co.sz
	Sidvokodvo/Mpaka	Sabelo Ndzimandze/Mavela Vilane/Sandile Dlamini Waste Disposal Managers for Swazi Railways	See Swazi railways
	Simunye/Mhlume/Tshaneni	Sipho Nxumalo Sanitation Foreman	23134707
	Big Bend	Hlelile Ginindza Environmental Manager	23638000 hginindza@illovo.co.za
	Matata	Sipho Matsenjwa (Sanitation Foreman)	76392274
	Nsoko	Community members	
	Tabankulu-Tongaat Village	Musa Hlatjwayo	See Thabankulu
Recyclers	**Ngwenya Glass. Contact : Chas Prettejohn (Managing Director), Tel : 2442 4053/ Cell: 7602 2730**		
	Matsapha plastic recycling plant, Matsapha scrap yard.		

a) Other people of interest interacted with during the study:

1) Nomkhosi Khoza, Eclipse Environmental Solutions site (contractor responsible for managing Manzini City Council Landfill)
Contacts: nomkhosikhoza06@gmail.com/cell 76362110

ANNEX 2: QUESTIONNAIRE USED IN THE INVENTORY

Name of Site and Location	
GPS Position	
Name of Operator	
Type of Owner • Private • Government • Unknown	
Rural/Urban/Sub-Urban/Industrial	
Description	*Describe type of facilities and activities close to the site*
Type of Disposal Site • Open • Controlled Dump • Sanitary Landfill	
Age of Dumping Site	
Designed Operational Life	
Total Surface and Depth (m^2 or Hectares)	*Indicate if residual space is available*
Types of Waste Received/Dumped • Domestic • Industrial • Bulky Waste • Mixed Waste • Construction Debris • Biomass • Other	
Volume of Waste Received Daily • Domestic • Industrial • Bulky Waste • Mixed Waste • Construction Debris • Biomass • Other	
Open Burning Observed • Voluntary • Accidental	
Visual Inspection (Scavenging, Burning, Odour, Leachate, Proximity to Homesteads, etc.)	

ANNEX 3: LIST OF AREAS THAT WERE VISITED DURING THE STUDY

CITIES	Mbabane	Manzini	
TOWNS	Matsapha	Hlathikhulu	Vuvulane*
	Lavumisa	Mankayane	Siteki*
	Lomahasha	Ngwenya	Luve*
	Buhleni	Gege	Malkerns
	Siphofaneni	Ezulwini	
	Piggs Peak	Lobamba	
COMPANY/EMERGING TOWNS		Big Bend	Tabankulu
	Simunye	Bhunya	Nsoko
	Mhlume	Mhlambanyatsi	Mpaka
	Tshaneni	Shiselweni Forest	Sidvokodvo
	RSSC-Simunye	Montigny	Swaziland Beverages
	RSSC-Mhlume	Shiselweni Forest	Textile
	Ubombo Sugar	Mondelez	Langa Bricks
	Peak Timbers	CONCO	Ngwenya Glass