



Analysis of the skills required for green economy: The local government sector perspective.



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Final Report

To

The Local Government Sector Education and Training (LGSETA)

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Executive summary

Introduction: National development that is anchored on the principles of green economy is that which is driven by ecological economics and resource utilization strategies for sustainable human well-being. Currently, there are global concerted efforts towards adopting and improving green economy to mitigate against global warming resulting from carbon emissions. The adoption of green economy is imperative in order to respond to the ever increasing environmental degradation caused by carbon emissions from locomotives and industries.

South Africa is one of the major world's producers of green-house gases from coal processing industries. Mitigation against air and water pollution is crucial for the implementation of green economy. Like in all water stressed countries, South African food industry is very sensitive to water provision, without which farming industry, which primarily rely on irrigation, cannot survive. Water is thus, a very important resource for a green economy. The aim of this project is to assess the capacity and challenges of the local government to adopt green economic practices, and to propose responsible strategies in this regard.

The project was carried out within the context of the role of local government in the adoption of green economy strategy. The role of the local government in promoting green economy should be both reactive and proactive. The reactive aspect of the role relates to the activities that have taken place at any point in time and need policy based corrective measures. As far as the proactive strategies are concerned, the local government sector can employ and facilitate the adoption of approaches such as waste beneficiation and renewable energy. The current study assessed the capability of local governments to effectively play the dual roles. Both qualitative and quantitative approaches were implemented, and both national and regional data were used. Studies showed that many technical staff working in local governments have very little or no knowledge of green economy. It is expected that the findings will guide policy decisions on capacity or skill development priorities of the local government sector.

Compliance indicators: Green economy is invariably driven by green technology, for which the main objective is to improve the quality of life in a sustainable way for the present and future generation. In this work, the indicators for green technology compliance have been chosen as:

- Green house gas emissions
- Compliance of the effluence quality with set regulations
- Potential environmental impact of the sludge and liquid effluent
- Possibility of using liquid affluent for irrigation
- Possibility of using solid liquid affluent for irrigation

Key findings: The performance of the wastewater treatment plants needs to be improved to produce treated water that meets quality requirements. None on the sampled plants meets the required standards for Green Drop Certification. Both the operators and process controllers have formal tertiary education and are all rated by the Department of Water Affairs (DWA). In a number of cases, wastewater treatment (WWT) facilities were operating above their design capacity with throughput going as high as 140% of design capacity. Intervention has to be undertaken that in order to achieve design quality specifications, design capacity limits need to be honoured. Most municipalities either do not use anaerobic digesters or do not use them appropriately. Both staffed and under-staffed facilities are faced with the challenge of underqualified employees in terms of NQF ratings and required skills. Some of the employees are yet to be registered/rated by DWA. There is poor communication of training opportunities to staff at wastewater treatment plants. Most municipalities do not have on job trainers or assistance that would ensure seamless transfer and application of skills learnt from the classroom to the plant

Proposed interventions: LGSETA will need to work with its higher education institution (HEI) partners to plan addressing the skills shortage in the waste water treatment sector with incorporation of green economy concepts and priorities, LGSETA should in the future engage its Higher Education Institution partners for waste water treatment ensure that this sector is included in plans for establishment RPL centres. Specific interventions include:

LGSETA Intervention strategies

- Sector skills planning for waste water treatment
- Development of learning programmes using existing SAQA qualifications
- Development and implementation of RPL programmes through existing partnerships with HEI's.
- LGSETA to facilitate collaboration between HEIs and local governments

Local Government Intervention strategies

- Increase skilled human resources capacity in the WWT sector
- Implement functional and continuous maintenance programme for WWT facilities
- Increase throughput capacities of the current WWT facilities to handle increased influent streams
- Employ technologies that involve process integration that include anaerobic digestion
- Develop and implement mentorship and succession plans

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Abbreviations

AFRICEGE – Africa Centre for a Green Economy
AOPs – Advanced Oxidation Processes
BNR – Biological Nutrients Removal
BOD – Biological Oxygen Demand
BRICS - Brazil, Russia, India, China and South Africa
BRT – Bus Rapid Transport
BTech – Bachelor of Technology
BTF – Biological Trickling Filters
CCKD - Centre for Climate Knowledge for Development
COD – Chemical Oxygen Demand
DEA - Department of Environmental Affairs
DWA – Department of Water Affairs
EDD - Economic Development Department
ENR = Enhanced Nutrient Removal
EU – European Union
FiT - Feed-in Tariff
FY – Financial Year
FYP- Five-Year Plans
GDC – Gross Dealer Concession
GDP – Gross Domestic Product
GDS – Global Distribution System
GE – Green Economy
GETS - Green Economy Target Scenario
HEI – Higher Education Institution
IAS - Invasive Alien Species
ICRAF - World Agroforestry Centre
ICT – Information Communication Technology
IWRM - Integrated Water Resource Management
LEGDP - Limpopo Employment Growth and Development Plan
LGSETA – Local Government Sector Education and Training Authority
LPG – Liquefied Petroleum Gas

NCCASP - National Climate Change Adaptation Strategy and Plan
NGOs - Non-Governmental Organisations
NGP –New Growth Path
NQF – National Qualification Framework
NREGA - National Rural Employment Guarantee Act
NRM – Natural Resource Management
NWP – North West Plan
PAT – Process Analytical Technology
REFIT - Renewable Energy Feed in Tariffs
RMS - Rwanda Meteorological Service
RO – Reverse Osmosis
RPL – Recognition of Prior Learning
SAGEM – South African Green Economy Modelling
SAQA – South African Qualification Authority
SWH – Solar Water Heaters
TIEP - Tshwane Integrated Environmental Policy
TOC - Total Chemical Oxygen
UN – United Nations
UNDP – United Nations Development Programme
UNEP -United Nations Environmental Programme
UNFCCC – United Nations Framework Convention on Climate Change
USA –United States of America
VUT – Vaal University of Technology
WRI – Water Recourses Institute
WfW – Working for Water
WWT – Waste Water Treatment

CHAPTER 1

1. Introduction

1.1. Green economy concept

The United Nations Environmental Programme (UNEP) working definition of green economy “as one that results in improved human wellbeing and social equity, while significantly reducing environmental risk and ecological scarcities”. Green economy is invariably driven by green technology, for which the main objective is to improve the quality of life in a sustainable way for the present and future generation. The need for green technology is coming in the backdrop of technological advancement which results in the depletion of the natural resources and in turn produces wastes that have negative impact on the environment. Green economy is a relatively new concept in the sense that most of the practicing engineers and scientists did not encounter such concepts during their training. It is for this reason that it is pertinent to link the successful implementation of green technology to skills development. This fits the narrative of technology transformation agenda. The significance of green economy is that it is built on the foundation of sustainable use of resources such as water, energy and food. All these issues are currently of national priority. The current water problem in South Africa has almost reached crisis level. This is coming immediately after the winter load shedding which proved to be very disruptive to the economy. Some of the biological methods of wastewater treatment used by the local government result in air pollution, which cause health problems.

The green economy consists of several concepts:

- The low or reduced carbon economy - The low carbon development describes economic development plans or strategies that are made up of climate-resilient economic growth (Netzer and Eds, 2012). This concept is based on evaluating the amount of carbon emissions caused by economic activities.
- The green growth concept - This concept consists of steps in the evolution of sustainable development strategies focusing on green sectors as growth mechanisms.
- Green jobs - this concept describes jobs in green sectors that play a key role in the conservation of the environment. The green jobs can be found in sectors such as service

delivery, administration, manufacturing, agriculture, and research and development (Netzer and Eds, 2012).

- Circular economy – this is an economy in which waste is recycled and used as an input in the same or a different process.
- Ecological economy - an economy dependent on ecological principles and using ecological functions to contribute to both the economy and ecosystems.

Based on these concepts, green economy (GE) can therefore be well-defined as the most environmental friendly and beneficial way in which a process is carried out to produce a product, and the whole process has a positive impact on human nature, natural resources and the economic capital investments (UNEP, 2013). A ‘green’ economy is achieved when there is less consumption of resources and less greenhouse gas emissions. The whole initiative’s concept is to focus on protecting by saving human basic needs like waste, food and clean air. GE encourages technologies which consume less of the input resources whilst producing more of the products, in a process resulting to less carbon emissions to the atmosphere, and reduced water and land pollution. These technologies must be applied in such a manner that energy is produced from resources which are renewable and contain low carbon (UNEP, 2013).

1.2. Green economy from the context of the local government sector

Green economy within the local government context centre around service deliveries such as water and wastewater management, urban transport, sanitation and road maintenance. Efficient delivery of these services require appropriate skills and competencies. The provision of these skills involves the participation of various stake holders including academic institutions and other government organs. A partnership between the local government sector education and training authority (LGSETA) and an academic institution is one of the ideal vehicles to drive this agenda. In this regard, some of the imperatives include resource driven technologies such energy generation from fossil fuel which may cause as much concern as the production of renewable energy from food materials. It is a well-known fact that the production of biofuels from food materials could be regarded as green technology. However, the consequences such as the high demand for water and as its threat to food security, especially in developing countries negate the possible benefits. It therefore follows that the whole value chain needs to be evaluated to identify the interdependencies and synergies that exist among different sectors. In particular, the local

government sector can play a pivotal role in the green economy strategy. The key question is, what constitutes green economy from a local government perspective? Firstly, local governments have a key role to play in delivering efficient service to the public. Secondly, they have a dual role of player and referee in the game of green economy. The main challenge therefore is to effectively integrate these two roles. As players, municipalities must employ green technologies in their operations including wastewater, water and energy management. As referees, municipalities must ensure that what industries discharge into the atmosphere and water bodies do not have negative impacts on the environment. For municipalities to play this dual role the next key question to be asked is whether it has the will, capacity and skills to do this. The aim of this project is therefore to assess the capacity and challenges of the local government to adopt green economic practices, and to propose responsible strategies in this regard.

1.3. The Green Economy Accord

In order to achieve the goal of New Growth Path to promote green economy, the government of South Africa together with constituencies of the stakeholders signed Green Economy Accord on the 17th November 2011. The four constituencies that signed the accord are:

- The Government;
- Business;
- Organized Labour and
- Community.

The aim of the Accord, as stated by the Minister of Economic Development (Minister Ebrahim Patel) is to create large numbers of jobs, provide a spur for industrialization and help to create a sustainable future for this and the next generations. He went ahead to emphasize that the Accord is one of a series of agreements in which social partners commit to work together to achieve the goals of the New Growth Path (NGP). The key messages of the Accord are: opportunity, innovation, responsibility and partnership. The government is to create enabling environment in which partnerships can be developed to conduct business through the application of innovative and sustainable technologies to make the world better for the present and future generations. From the national and international perspectives, green economy rests on five imperatives (Naidoo et al., 2013):

- Renewable energy;
- Water and wastewater management;
- Green buildings;
- Clean transportation and
- Land management.

Establishment of green economy, from the local government sector perspective; must be such that the service delivery integrates the key messages of the Accord in the context of the NGP and in line with the five imperatives of green economic development.

Water and air are two major ingredients of life, the management of the two determines the quality of service delivery (DWA, 1986). The food we eat is more than 80% water, and for the food to be converted into energy that our body needs, air is required. Unfortunately, most of the health problems originate from water or air that our body needs. Advancement in technology has negative effects on both water and air quality and consequently affect the food we eat. A green economy is influenced by the quality of air and water, which finally influence the quality of life.

1.4. National and local government context

In the South African context, one of the key areas of concern with regard to green technology is the energy production from coal which results in high carbon emission. This can be looked at from two perspectives. The first one relates to the production of fuel from coal. The second one is the production of electricity from coal. These two different processes, with high carbon footprint, cause major water and air pollution, which make them fall under the category of black technologies. The major industries that can be associated with these technologies in the South Africa are Eskom and Sasol. The kind of wastes discharged by these industries, like many other industries such as abattoirs, have impact on the water and wastewater treatment plants managed by local governments. There is therefore a need for the technicians/engineers operating these facilities to have an in depth understanding of the emerging challenges and changing global standards. From the local government perspective, the major challenge is that green economy is linked to some activities that are outside the domain of the local governments. However, in this content the role of municipalities could be in form of policies that regulate the activities of such industries. The policies may include pollution deterrence on the one side and the conversion of wastes into products on the other side. This approach will promote the adoption of policy driven

green technology by industries with the local government sector being the custodian and not an observer as is the present case. Such technologies include process integration (Apollo et al., 2013).

Attaining a green economy does not depend only on treating the waste that has been deposited at the door step of the municipalities. Instead, it requires proactive steps that prevent the production of the waste in the first place. To do this effectively, the municipalities need to be equipped with scientific data to help formulate policies to enhance green technology. Such kind of data can come from research units with expertise in renewable energy and water management. This is where the partnership among the LGSETA and research institutions become very important.

1.5. Objectives

The specific objectives of the green economy studies were to:

- a. Analyse the available and required skills in the local government sector, particularly in the municipalities;
- b. Identify skill gaps and recommend possible interventions;
- c. Provide information on the emerging jobs in green sectors;
- d. Conduct the skills audit on green economy in the municipalities and
- e. Develop a strategy that will be responsive to the green economy interventions in the municipalities.

CHAPTER 2

2. Analysis of green economy concept application

2.1. Green economy

A major climate deal (Paris 2015) has been agreed on and given approval by the world in December 2015. The agreement has been ratified by 195 countries after two weeks of discussions by diplomats from around the world in Paris, France. The deal is intended to increase capacity for further growth through addition of structure and momentum to efforts that are currently in progress aimed at tackling climate change. These efforts are geared towards decreasing the quantity of greenhouse gas emissions responsible for global warming. A radically different approach was taken by the Paris talks by allowing every country to decide for itself how it plans to take on the initiative of reducing greenhouse gas emissions taking into consideration the country's unique domestic situation. For credibility purposes, there is a need to back up international commitments by domestic action plans. There is a change in global climate policy with a 'bottom up' building of international agreements from domestic plans rather than a binding worldwide treaty built from the top and passed down to countries (Fankhauser et al., 2015). A number of pledges had been submitted to the United Nations (UN) by almost every single emitter prior to the Paris agreement. Some of the pledges submitted include (UNFCCC 2014);

- The United States is planning to reduce its greenhouse gas emissions by at least 26% below the emission level reported in 2005. The 26% reduction is expected to be achieved by the year 2025. To achieve this, the USA has put in place policies such as the Clean Power Plan which is intended at introducing power plants that do not release carbon dioxide into the atmosphere.
- The European Union (EU) as a whole intends to reduce its emissions by 40% below emission levels experienced in 1990 by the year 2030.
- China's emissions will peak around 2030 with 20% of its electricity generated from carbon free sources by then.
- India intends to carry on reducing its carbon dioxide emissions per unit of economic activity using its past emission levels for guidance.
- Kenya seeks to abate its greenhouse gas emissions by 30% by 2030 in line with its development agenda of becoming an industrialized middle income country by then.

- A National Climate Change Adaptation Strategy and Plan (NCCASP) is being developed by South Africa. The NCCASP which is informed by an assessment of sectoral, cross-sectoral and geographical vulnerability to the effects of climate change which are contrary to the country's welfare, will quantify and present pathways for adaptation towards a climate resilient economy.

Based on each country's analysis of what is politically and technologically feasible, all the pledges made are plausible. However, these pledges if uncoordinated and unsupported, are insufficient in abating the serious climatic challenges arising from global warming. Assuming that every country implemented its pledge as presented to the UN, global emissions are still expected to keep rising resulting to approximately 3°C of global warming by the end of the 21st century. A 3°C rise in global temperature is way past the 2°C mark that is already considered bad news. Due to the inability of the countries to tackle climate change on their own, the Paris agreement had to come into play to provide a supportive structure aimed at strengthening the national pledges making them stronger overtime. The key features in the final Paris climate deal include but not limited to (Vox Energy and Environment 2015);

- Overall temperature goal – countries are aiming at less than 2°C total global warming and if possible keep it down to 1.5°C.
- Overall emissions goal – countries agreed to realise peak emissions of greenhouse gases as soon as possible and possibly achieve a net zero emission by the second half of the century.
- Pledges to be reviewed every five years – starting from the year 2020, countries are expected to submit new and stronger pledges that are in line with the changing technological and climatic conditions.
- Financing for poor countries – developed countries are required to provide aid to help poorer countries in adopting clean energy technologies and practices, and adapting to adverse climatic impacts such as flooding, storms and rising sea level.

2.2. Green economy basics

Domestic wastes, greenhouse gas emissions and shortages in energy supply are major threats faced by several countries all over the world. These issues have a major impact on the environment as they cause pollution leading to environmental degradation and climate change. This has created an urgent need for alternative resources and processes to control, reduce or if possible to completely eliminate these effects on the environment (De Vrieze et al., 2014). Many communities

are promoting the culture of recycling, re-using, reduction of waste and energy conservation. These alternatives fall under the initiative called ‘Green Economy’.

The current imperative global energy, food and financial crises and the danger of the transgression of ecological limits, has shifted world-wide attention towards this alternative vision for growth and development known as the ‘Green Economy’. The green economy, defined as an environmentally clean economy, consists of the following sectors; renewable energy, green building and energy efficient technology, energy efficient infrastructure and transportation, and recycling and waste-to-energy (Development, 2012). The Green Economy initiative is made of a holistic character which holds the key aspects of development that is; social, environmental and economic developments (Dittrich et al., 2012).

2.3. Green economy opportunities and challenges

The basics of green economy include the inherent assumptions, clusters and priority issues. From a business perspective, GE is based on two main assumptions; decoupling of economic growth achieved through clean technologies from environmental degradation and it applies to any country whether rich or poor. The GE is composed of three main clusters; natural capital (agriculture, forestry, fishing and water), built capital, and enabling conditions such as policy reform and capacity building (Rueff et al., 2015). Among these clusters the local government has a significant role to play, more particularly due to the fact that local governments typically serve high population density areas. Efficient service delivery to such social construct requires collaboration among various stake holders including the LGSETA and other government organs.

The LGSETA is mandated by the Skills Development Act of 1998 to conduct research on human resources planning and this responsibility is further underpinned by a White Paper on Post-School Education and Training which emphasises a need to conduct sectorial research. Like in many emerging economies, currently, national priority issues include sustainable resources utilization, and these include water, energy and food. The provision of these resources in a sustainable way requires skilled labour that has the capacity to adapt existing technologies to suit region specific challenges. This is the context in which the goal of New Growth Path can be achieved.

2.4. Global perspective of green economy

This whole concept of ‘green economy’ brought attention to the political leaders across the world more than 20 years ago. Many discussions were based on issues including poverty reduction at the

Rio+20 United Nations Conference in 2012 (Schlör et al., 2014), and the conclusion was aimed to set the course for achieving sustainable development across the world in the concept of green economy (Dittrich et al., 2012). United Nations Environmental program (UNEP) is the current program that not only focuses on the sustainable development but also strongly enforces the reduction of environmental risks. The Global aim of the Green Economy Initiative is to revive the world economy, create jobs, alleviate poverty, reduce carbon dependency, and reduce ecosystem degradation.

Current technologies, educational standards and other forms of activities of all the countries in the world are characterized by modernization whereby whatever is introduced, produced or studied has to conform to certain requirements. The requirements depend on each of the country's level of economic development and thus differ from country to country (Maria et al., 2015). In developed countries, the uptake of green economy is seen as an enhancement of workplaces and marketability development. On the other hand, developing countries view transition to green economy as a focus on sustainable development and poverty alleviation. BRICS group (Brazil, Russia, India, China and South Africa) agreed on implementation of effective use of natural resources as a strategy for green growth. Despite the different approaches to green economy, the utilization of cleaner technologies to achieve environmentally friendly production remains a common goal for all the countries intending to transition to a greener economy (Golub, 2003).

Most countries have failed to drive structural changes by focusing on environmental stability on its own. Economic development and environmental protection have largely remained separate for a long period of time (Gibbs and O'Neill, 2015). It is therefore imperative to link environmental protection to conventional aims of industrial policy such as job creation, competitiveness and innovation (Pegels and Lütkenhorst, 2014). The 2008-2009 global financial meltdown, which triggered various fiscal stimulus plans in several countries around the world, provided an important opportunity for transition towards a GE within the context of energy and climate policies by routing for investment towards low carbon technologies (Sonnenschein and Mundaca, 2015). A 'Global Green New Deal' intended for economic revival while simultaneously playing a catalytic role in the fight against climate change, poverty and environmental deterioration, was requested by UNEP (2009). UNEP recommended investment packages that would stimulate the economy in five critical areas:

- i. Buildings that are energy efficient;

- ii. Renewable energy sources such as geothermal, wind and solar;
- iii. Transport technologies that are sustainable such as hybrid vehicles and high speed rail;
- iv. The planet's ecological infrastructure, including freshwaters, forest, soils and coral reefs, and
- v. Sustainable agricultural practices including organic farming.

In some countries like USA, China, South Korea, South Africa and the European Union, economic packages and policies that promote green economies were implemented (Mundaca and Markandya, 2015). By 2010, South Korea had allocated nearly 95% of her US\$ 38 billion fiscal stimulus to green investments such as construction of energy efficient buildings, energy production from renewable sources and low-carbon utilising vehicles. Other successful stories achieved from the transition to GE include; Renewable Energy in China, Organic Agriculture in Uganda, Solar Energy in Tunisia, Forest Management in Nepal, Sustainable Urban Planning in Brazil, Rural Ecological Infrastructure in India and Feed-in tariffs in Kenya (UNEP 2010).

2.4.1. GE in the United States of America

United States of America (US) is one of the countries that strongly participate in and champion the concept of green economy. President Obama, after his election in 2008, prioritized investments that would enable transition to a green economy. To achieve his goal, the president promoted clean energy technologies with the aim of transitioning to a low carbon economy. The US president spent \$787 billion stimulus package focusing on the 'green' concept. About a quarter of the money was spent on projects intended to green the nation's energy, transportation and environmental conservation sectors (Collina, 2009). The rate at which green jobs are created to US workers which were affected by the economic downfall is of key interest. Most of these workers possess skills and occupations which can aid in reducing global warming and progression into a clean energy economy in the USA. The implementation of green projects intended to aid in the transition to green economy has resulted in the creation of green jobs thus making green investments favourable.

2.4.2. Green Economy in Germany

Germany is aiming to achieve a 40% decrease in greenhouse gas emissions by 2020. The country had created 300 000 green jobs in the renewable energy sector by 2009, representing 87% rise in green jobs creation since 2004. The transition to green economy success in Germany is attributable

to implementation of policies such as the feed-in tariff which plays an important role in the enhancing renewable energy technologies. The feed-in tariff law is long-term and stable thus providing a high level of investor certainty. Due the nature of the tariff, investment in renewable energy is viewed as relatively safe especially with the difficult economic times experienced globally.

Table 1: CO₂ mitigated and jobs created by solar and wind energy in Germany, 2011-2012.

Sector	Investment jobs	Operation and maintenance jobs	CO₂ emission avoided (in 1000 t)
Wind (onshore)	81,300	18,600	} 70,728
Wind (offshore)	17,300	700	
Solar PV	182,200	16,500	33,846

Source; *Pegels and Lütkenhorst, 2014*

The green transition in Germany targets many sectors such as waste management, biofuels production and efficient environmental technologies. The most prominent green project in Germany is the energy transition known as *Energiewende*. The transition is aimed at phasing out nuclear energy while replacing the same with renewable energy sources such as solar and wind. The renewable energy promotion is based on the concept of feed-in tariff (FiT) which constitutes a well-made legal and policy framework, funding for diverse research institutions and emphasized price-based rather than quota-based investments incentives. To date, FiT has been replicated in over 50 countries where it has been used as a benchmark for renewable energy policy design. Germany's *Energiewende* has propelled the country towards achieving its green industrial aims at reasonable costs with uptake of wind energy performing better as compared to solar leading to creation of jobs and mitigated CO₂ emissions as summarised in Table 1. The energy transition in Germany is expected to contribute to (Pegels and Lütkenhorst, 2014);

- Strengthened leading global market for climate-friendly technologies originating from Germany;
- Maintained competitiveness from affordable and reliable energy supply;
- Boosting of industrial innovative capabilities;
- Renewable energy development leading to creation of job opportunities;
- Climate change mitigation, and
- Reduced import dependence on fossil fuel and saving of scarce resources.

2.4.3. GE in China

China is the leading emitter of greenhouse gases in the world with per capita CO₂ emission approaching 6 t per year surpassing the European per capita average (Lorek and Spangenberg, 2014). Over the past few years, China has made green development a priority in most of its leading economic sectors due to its potential to increase employment and reduce the country's negative environmental impact (Weng et al, 2015). China's transformation to a green economy is currently playing a big role in the worldwide perception of economic development. China is responsible for aiding in the global promotion of sustainable development, fighting against climate change and helping developing countries by means of research and identification of new technologies. Transition to a GE has been recognized in China as a strategy for sustainable economic growth and environmental conservation. This is evidenced by China's adoption of energy and economic policies such as investment in the conservation of energy, reducing greenhouse gas emissions, and environmental engineering projects (Yi and Liu, 2015).

The justifications behind the transition to GE are driven by environmental, economic and social considerations. Rapid development in China has resulted in a heavy environmental toll such as; deteriorating air quality due to coal burning, surging greenhouse gas emissions, degrading water quality and resources, and worsening rural environments and land-based ecosystems (Pan et al., 2011). China has a set of Five-Year Plans (FYP) that guide its economic development in the concept of green economy. The current Five-Year-Plan (12th Five-Year Plan), Table 2, has a chapter intact on green development which deals with issues such as energy from renewable sources, climate change, efficient use of resources, circular economy, control of environmental pollution, ecological conservation, and prevention of natural disasters (Weng et al, 2015).

According to (UNEP, 2010), combining investments and the motivation of policy formulations has promoted improvements in renewable energy technologies such as solar and wind power. China has the highest added wind power capacity in the world. An annual growth rate in wind power generation of more than 100% since 2005 has seen 13.8 GW new installations coming online in China by 2009. The Chinese government targets an increased installed capacity of 100 GW of wind power by 2020. China is currently the highest manufacturer of Solar PV's globally; it produced 45% of the solar PV's in the world in 2009. China is targeting a 1.8 – 20 GW installed capacity of solar PV by 2020. The massive investment in green energy sources has created an estimated 650 000 jobs in solar industry, 266 00 in biomass generation and 22 000 in wind power

at the end of 2009. China's experience provides an example of renewable energy that can lead to job creation, high revenue for the country and increased household income, and ultimately improve the living conditions of the citizens.

Table 2: Major Policy targets in China's 12th Five-Year-Plan (Weng et al., 2015).

Areas	Targets	Feature of target
Economic Growth and Structure	<ul style="list-style-type: none"> ▪ Average annual GDP growth of 7%; service industry contributing 47% to GDP; urbanisation rate reaching 51.5% 	Anticipatory
Energy, Climate and Environment	<ul style="list-style-type: none"> ▪ A drop in Energy consumption per unit GDP to 0.869 tonnes of coal, representing a decrease of 16% and 32% as compared to 2010 and 2005 levels respectively ▪ Energy savings of 670 million tonnes of standard coal ▪ Reduction in carbon emissions per unit GDP of 17% as compared to the target set in 11th FYP ▪ 11.4% rise in consumption of non-fossil fuel as primary energy ▪ 30% lowering of water consumption per unit of industrial added value ▪ National total chemical oxygen (TOC) demand and sulphur dioxide (SO₂) emissions decrease of 8% as compared to 2010 ▪ 10% reduction of national total ammonia (NH₃) and nitrogen oxides (NO_x) emissions compared to 2010 levels ▪ Rising rate of forest coverage to 21.66 % of the total land area ▪ Stable cultivated land area at 18.18 million hectares 	Binding
Economic Development	<ul style="list-style-type: none"> ▪ Research and development expenditure increasing to 2.2 % of GDP ▪ Strategic emerging industry accounting for ~8% of GDP 	Anticipatory
Social Development	<ul style="list-style-type: none"> ▪ An average annual increase in the number of jobs newly created in urban areas topping 45 million ▪ Urban unemployment rate staying below 5% 	Anticipatory

2.4.4. GE in India

India is one of the largest emerging economies in the world. According to Chatterjee (2011), there is enterprise and investment potential in India. When looking at green economy in the context of money and the ecosystem, the disadvantage of the two elements is that money is not produced for enhancing and accounting for ecosystem services but rather as a social responsibility. This could

be majorly due to the fact that in most cases the environment is government led and managed with all the framework limitations associated with the attendant. India's entire environmental sector is government led and the private sector does not play any role in environmental development, it only acts as a service provider. The suggestions made by Chatterjee (2011), are that the private sectors should lead a green-economy movement, an important milestone in India's officially declared decade of Bio-Diversity. Let there be utilization of affordable technologies and success stories to mainstream products and services of bio-diversity; develop waste recycling and value-addition industry; make profit in waste to oils to energy and by-products like glycerine, carbon black and organic fertilizer. Off-grid, distributed generation and supply of power using waste-based fuels are all happening small enterprises in India. Large companies on the other hand are expected to get into the green economy markets and enlarge them.

India's national Rural Employment Guarantee act 2005 (NREGA) is a program guaranteed to create green jobs and improve the standard of those living in rural areas. This act also aims at promoting efficient use of natural resources by providing environmental conservation skills in rural areas. Water conservation is one of the projects heavily funded by NREGA, it funded 850 000 water conservation projects which were conducted and completed within two years that is from 2006 to 2008. NREGA provided jobs and training intended to reduce water shortages in India's villages through development of solutions to the heavily silted water harvesting infrastructure. NREGA has promoted inclusive growth and restoration of ecological infrastructure, empowered India's lower class citizens and contributed to the wage increment of labourers in the agricultural sector (UNEP, 2010).

2.5. GE in Africa.

African countries are naturally endowed and rely on natural resources for economic growth (Collier and Venables, 2012). Increased economic growth in most African countries is as a result of the immense utilization of these natural resources. Despite the reported economic performance, African countries still remain poverty stricken with high unemployment rates. Due to its environmental degradation, changes in climatic conditions and desertification, Africa's economic growth is currently at risk. Transition towards an inclusive green economy in Africa will provide an opportunity to address poverty, create employment and improve the overall population well-being (UNEP, 2015). There has been a remarkable drive and commitment to creating sustainable economic growth in Africa as demonstrated by countries such as Ghana, Kenya, Rwanda, South

Africa, and Morocco among others. Green public procurement, sound fiscal reforms, capacity building programs and sound institutions have led to the development of sustainably produced food, renewable energy and energy efficiency (UNEP, 2015).

Uptake of renewable energy is one of the major changes taking place in Africa. Very large power generating plants that use renewable energy such as hydropower and geothermal are coming up in countries as diverse as Kenya, Ghana, Nigeria and Ethiopia. Solar lighting in households in Sub-Saharan Africa has risen to 5% from 1% in 2009. Renewable energy potential is enough to power the continent, with 93% of natural and renewable energy sources untapped. Renewable energy can reduce Africa's dependence on foreign energy sources, increase employment and reduce the use of wood fuel (UNEP, 2015).

2.5.1. GE in Rwanda

The Republic of Rwanda has experienced substantial development in its economy in the recent past. Its sustainable green policies such as long-term vision, favourable economic growth and good governance have attracted foreign investments and its ecotourism has recently gained a lot of attention. Rwanda's agricultural production has rapidly increased doubling since 2007, thereby improving the country's food security. The mining sector has been privatized increasing export earnings, while industries and services are expanding creating jobs off farms for Rwanda's growing population. The climate change crisis however, is affecting Rwanda's future socio-economic development, by putting pressure on the country's natural resources such as food, land, water and energy sources (Megan 2011).

Despite the climate change crisis, Rwanda lies amongst the countries that emit the least amount of carbon dioxide in the world. Rwanda green growth strategy in what is called vision 2020, aims to transform the country into a better economic society. The strategic project 'vision 2020' envisions Rwanda as a developed country having high employment, high levels of poverty alleviation and decreased negative impacts on the environment by the agricultural and industrial sectors. The strategic planned actions that will make this possible are divided into two categories; low carbon development and climate resilience (Megan, 2011), which are further divided into several aspects;

i. Low carbon development;

- Geothermal power generation - Geothermal which is a clean, renewable, reliable and large-scale energy resource, together with other renewable energy sources such as wind, solar and hydro, will provide energy security by reducing the energy costs and vulnerability to external economic shocks arising from practices such as electricity importation. The use of renewable and readily available energy sources will ultimately promote economic development in Rwanda.
- Integrated soil fertility management – This can be achieved by reducing demand for inorganic fertilizers through the application of integrated approach to soil fertility and nutrient management. The approach employs agro ecology, resource recovery and reuse, and fertilizer enriched composts. An integrated approach will significantly lower inorganic fertilizer demand thereby reducing dependence on oil since most inorganic fertilizers are made from oil products. A reduced dependence on oil will significantly result into reduced GHG emissions. An increase in farm profitability is expected due to reduced input costs for farmers. The integrated approaches will also improve the soil structure and water retention capacity leading to climate resilient agricultural ecosystems and sustainable food security.
- High density walkable cities – Rwanda has a growing population and as the case with other African countries, this increase has led to urbanization as a result of rural to urban migration in search for better jobs and living conditions. Designing high density cities with corridors for pedestrians and cyclists, and green public spaces is expected to reduce the need for energy intensive transport, improve quality of life and reduce the risk of flooding. Reduced demand for energy intensive transport will significantly reduce greenhouse gas emissions.

ii. Climate adaptation;

- Irrigation infrastructure - An improved infrastructure is aimed at giving farmers more control of the water resource and thereby reduce the susceptibility to changing rainfall patterns. It also allows for diversification of crops under production such as rice, contributes to efficient water and land utilisation as well as providing water to dry areas. This forms a crucial part of Integrated Water Resource Management (IWRM) as improved

watershed management allows for increased water supply and efficiency in other sectors as well.

- Robust road network – the building and maintenance of roads in a manner that is suitable for the value of the route and also resilient to more extreme weather conditions, will reduce the country's vulnerability and promote economic development, especially in rural areas.
- Centre for Climate Knowledge for Development - a Centre for Climate Knowledge for Development (CCKD), working with the Rwanda Meteorological Service (RMS) and research institutions, is expected to significantly improve climatic data and projections which are then translated into policies for decision makers to guide the country onto a development path that is climate resilient.
- Agroforestry – improved agroforestry will result into multiple additional benefits such as reduced soil erosion, increased resilience to heavy rains through improved slope stability, water management and nutrient recycling which will in turn improve agricultural production and carbon sequestration. Agroforestry is to be guided by latest best practices and research, such as those developed by the World Agroforestry Centre (ICRAF).

2.5.2. Green Economy in Nigeria

Nigeria's human and economic development is under threat due to climate change which has resulted in diseases, reduced food production, energy shortages, desertification and overall environmental degradation (Paper et al., 2013). Despite the negative climatic effects, Nigeria still has potential markets for promotion of green economy in sectors such as energy, tourism, construction and energy. Nigeria is endowed with clean and renewable energy from solar, wind, biomass and hydropower (Maji, 2015). Green economy in Nigeria however, is disadvantaged by a lack of environmental awareness, greening incentives, government support and lack of human and institutional capacity (Dittrich et al., 2012). Policy principles were suggested to conduct the explanation of integrated strategies and actions for the transition to a GE based on the study of the current and foreseeable climate change challenges in Nigeria. This was conducted to create collaborative environment between all relevant stakeholders involved in policy formulation (Montmasson-clair, 2012). The development of clean energy to drive the transition to green economy has been very slow despite the promotion of renewable sources.

Rather than a singular Green Economy strategy, Nigeria has a basket of policies aimed at climate change, adaptation, and renewable energy. To date, what has emerged from Nigeria with respect to Green Economy initiatives is an announcement about the country's first wind farm in Katsina province (Dittrich et al., 2012). Additionally, the government promotes initiatives that aid the country's transition to a greener economy such as the creation of Natural Resource Accounts, which will help in identifying the contribution of the environment to the nation's wealth. This will be achieved by developing satellite accounts for natural resources such as forests, water, minerals, wildlife and fish. The accounts will then be used to feed additional data into conventional national economic account thus making the calculation of the GDP to incorporate all the elements reflecting the country's natural capital, a crucial component of the green economy concept (Paper et al., 2012). The government is intending to launch a national policy on renewable energy which is expected to include strategies such as introduction of legal framework for renewable energy, license provision to private sector to invest in green energy, attractive tariff for foreign investment in renewable energy among others (Maji, 2015).

2.6. GE in South Africa

South Africa has abundant coal fuel and meets 77% of its energy need through coal. This high consumption of coal makes South Africa one of the leading greenhouse gas emitters in the world. South Africa's political decision making continuously impedes the attempts to change the situation as the transformation to renewable energy requires large financial investments, the cost of which will be passed on to consumers (Chidiebere, 2014). With South Africa's unemployment rate being so high, the decision to switch to renewable energy remains politically unpopular. South Africa's economic development and well-being of the citizens is heavily dependent on the ecosystem's services such as air, food, water, energy, and medicines. However, from measurements of environmental sustainability, it has been discovered that South Africa has surpassed its ecological carrying capacity (Kaggwa et al., 2013). South Africa has the potential to benefit greatly from its transition to green economy as it contains large amounts of renewable resources that can be easily exploited (Montmasson-clair, 2012).

Unsustainable past economic growth patterns, a potential climatic crisis in future, and need for transformation of behaviour as well as industrial technologies and structures, are some of the

factors driving South Africa's transit to a greener economy. According to UNEP (2013), "Green Economy Scoping Study", South Africa's perspective of green economy is as follows: South Africa views green economy as a sustainable development route that is based on addressing the interdependence between economic growth, social protection and natural ecosystems". Five strategic priorities including; efficient and sustainable use of natural resources, effective response to climate change, building sustainable communities and enhanced systems for integrated planning and implementation, were identified by the National Strategy and Action Plan for Sustainable Development (Africa, 2014).

South Africa's roadmap to a green economy is made up of the conceptualization of enabling and supporting policies to aid in the transition and the provision of funds to convey green projects (Kaggwa et al 2013). The South African government has developed various policies and strategies to promote the transition to a green economy (Montmasson-clair, 2012). The main green economy related policies and strategies in South Africa are; The Framework for Environmental fiscal Reform which deals with provision of guidelines and principles for effective and fair environmental taxes; The 10-Year Innovation Plan which deals with the country's supply of reliable, clean, safe and low cost energy, and climate change; The Medium-Term Strategic Framework which deals with the sustainable management of natural resources and livelihoods; The Industrial Policy Action Plan which deals with industrial green growth; The New Growth Path dealing with economical green growth; The Integrated Resource Plan 2010-2030 which deals with greenhouse gas emissions; The National Climate Change Response which quantifies and endorses greenhouse gases emission limits; The National Strategy for Sustainable Development consisting of indicators and goals cutting across environmental, social and economic issues; and The National Development Plan, a vision document for South Africa that sets a long term development trajectory for (AFRICEGE, 2013).

According to a green economy modelling report of South Africa (SA) presented by UNEP (2013), SA is considered as the topmost-middle income country in the Southern Africa. It is ranked as the 3rd biggest diversified country in the world in terms of natural resource supply. However, SA is faced with some major problems like poverty, youth unemployment, electricity cuts and water shortage. Limited agricultural land and inappropriate ways of utilizing the land are negatively affecting food security in the country. SA strongly depends on the supplies from the ecosystems,

and that has called for a transformation shift to green economy. South Africa is ranked 14th on the list of countries that emit large amounts of greenhouse gasses in the world as it is highly dependent on cheap coal as raw material for the production of electricity (Borel-Saladin and Turok, 2013). The green economy initiative is intended to move the economy of countries like South Africa out of crises.

In South Africa, the green economy concept has been envisioned as the route to sustainable development that will assist in solving economic, social and ecological interdependence, South Africa has already set short, medium and long-term goals that would contribute towards attaining an environmentally sustainable low carbon economy resilient to climatic change. A meeting between Department of Environmental Affairs (DEA) and UNEP was held in 2011 to formulate the green economy strategies for South Africa (SAGEM). In order for the SAGEM to go forward, there was an intervention needed from the government, stakeholders and research institutions by means of a workshop organized by DEA and UNEP. The four areas, chosen from nine green economy programmes that are nationally prioritised, and addressed by the participants include; natural resource management (NRM), agriculture, transport and energy (UNEP, 2013; Musango et al., 2014). South Africa currently has the following green economy plans in place

- i. Management and conservation of resources
- ii. Waste sustainable management practices
- iii. Water resource management
- iv. Environmental sustainability
- v. Green buildings
- vi. Sustainable transport
- vii. Efficient and clean energy
- viii. Agriculture and forestry
- ix. Sustainable production and consumption

The results obtained from the workshop stipulate that South African vision of green economy is mainly based on two inter-linked developments; growing economy due to the greening of the industrial sector through creation of jobs, competitiveness and cleaner industries, and the reducing of the negative effects of the industrial sector on the environment while promoting the socio-economic impact (UNEP, 2013). In South Africa, the transition to green economy is considered as

an opportunity to achieve an inclusive economy by tackling inequalities in human economic development such as poverty and social injustice (Smit and Musango, 2015).

2.6.1. Natural resource management

Natural resource management (NRM) consists of programs intended to protect all aspects of the environment. The Working for Water (WfW) program acquired the largest investments from the NRM. The goal of the program is to improve the services of the water ecosystem. Other NRM programs include Working for Wetlands, Working for Land, and working for Fire. WfW is expected to reduce the land area that has been invaded by invasive alien species (IAS), thereby maintaining the ecological integrity through restoration of water flows. The program also promotes value added activities from invasive alien biomass, offering opportunity to pursue Green Economy through the utilisation of waste materials (Maia et al., 2011).

The effects of global warming has led to drought in several countries like South Africa included. As a result, the country suffers from water shortage making it water stressed. South Africa is aware of the importance of water as part of the NRM factor, which has forced the country to consider water conservation implementations in its usages. Three different energy facilities situated in Mpumalanga and Western areas as reported by Groot et al. (2013) have implemented water conservation strategies so far. The results in the report reveals the overall water consumption of 1.73, 0.003 and 0.122 litre per kilowatt hour (l/kWh) by the Matla coal-fired power plant, Villiera wine farm (privately owned PV solar facility) and Kathu solar park, respectively. These results show the positive outcomes linked between the green renewable energy and the conservation of water (Groot et al, 2013).

The little effort put forward by the South African government to conserve the nature and its resources is indeed a life insurance policy that has multiple-benefits in the future. Many environmental issues such as climate change, erosion, shortage of water and poverty in this country will be resolved, as long as the value of the nature is appreciated. Hiware Bazzar village situated in China, has valued its natural resources by finding alternative ways in saving water losses. This village has built earth embankments around hills to help improve its agricultural productivity in saving rainwater and recharge groundwater (Brink et al, 2015).

2.6.2. Agriculture

Agricultural activities have the potential to contribute towards a green economy as they offer solutions to the social, economic and environmental challenges facing humans (Musvoto et al., 2014). South Africa has identified agriculture as one of the key sectors that will contribute towards the transition to a green economy. The agricultural model includes the food sector and is based on the Cob Douglas production function in which main production factors such as land, capital and labour, are influenced by the economic and environmental state of the country. The food sector which includes crop production, differentiates between utilization of organic and conventional inorganic fertilizers for production purposes.

Comparison of strategies such as increased yield and land area under agriculture, are utilized in implementing the roadmap to green economy. In the roadmap, equal allocation of investment to application of organic fertilizer is recommended. A specific area of land under organic fertilizer application is envisioned by the green economy target scenario (GETS). GETS also assumes that the production on agricultural land resulting from expansion under the National Development Plan, will utilize organic fertilizers (UNEP, 2013). Several steps have been suggested in order to achieve high food production and security such as;

- Making social grants available for households in need;
- Implementing initiatives that will create food safety, quality and dietary diversity awareness;
- Formulation and implementation of agricultural policies at provincial level and incorporation of food security into integrated development plans;
- Involving private sectors in food security initiatives through support and strengthening;
- Promoting markets for small producers in the food industry, and
- Commitments at provincial level to the regional procurement arrangements.

2.6.3. Transport

The reduction of carbon dioxide emissions and environmental conservation has become a priority in the transport sector. Due to growing demand for mobility, eco-innovation initiatives have focused on increasing energy efficiency while simultaneously improving safety (Department of Economic Development, 2010). Transportation offer services to the public in order for the

circulation of goods and people within particular cities. The productivity of major companies, organisations and even the public activities highly depend on the transport sector, which also contributes to the economy of the country. Green transport should reduce or if possible, completely eliminate the negative environmental impacts associated with conventional transportation systems which heavily rely on fossil fuels. Moreover, the sector should provide services which are easily accessible, safe and low cost (Oliveira et al, 2013).

The acquired demand of traveling in the South African cities, has made the need to improve and develop the transport infrastructure system an important issue. For the past years, the country has invested in public transportation by building the Gautrain system and introducing the bus-based rapid public transport system (BRT) in Gauteng, Western Cape and North West provinces. Even though there is notable progress towards the greening of the transport sector, there is quite a lot that still needs to be done. Similar BRT transport framework is also successfully used by the city of Curitiba and Toyama towards adopting its green transport system (Oliveira et al., 2013). South African cities, just like the city of Stockholm should promote walking or cycling to work places, which are said to be the greenest modes of transport. The city of Stockholm is mainly focusing on improving and innovating the environmental performance of the transport sector, amongst other driving forces towards greening its transport system (Stockholm Green Economy Leader Report).

2.6.4. Energy

South Africa's energy sector emits the highest amount of greenhouse gasses in the country, contributing to 80% of the country's greenhouse emission in 2009. The energy sector is highly dependent on fossil fuels with coal meeting 75% of the demand for fossil fuel translating to 90% of the electricity generated. The increasing energy consumption and demand, has called for other alternatives resources for energy in South Africa. Renewable energy resources such as, wind, solar and hydro energy have been identified for energy production and generation for the last decades. Interest in renewable energy has also increased due to the uncertain energy supply, depletion of fossil fuels and the negative effects they have on the environment. Renewable Energy Feed in Tariffs (REFIT) have been approved in South Africa and currently play a crucial role in developing and promoting renewable energy. South Africa targets 155 MW of electricity from renewable sources in 2020. This will result in 36 400 new direct jobs, 109 100 indirect jobs and approximately 70 000 people employed in biofuels (Department of Economic Development, 2010). For effective implementation of REFITs, South Africa should borrow heavily from the European countries

which had put in place the feed-in tariffs and policies for wind power as early as mid-1980s resulting in cost reductions in these countries (Lindman and Söderholm, 2015).

According to the Green Economy Accord, promoting energy solutions such as solar PV, wind power and bio-digesters can help with climate-change mitigation goals and green job creation. The government has created a partnership with the Solar Photovoltaic, Wind and CSP industry in order to; jointly develop the solar and wind industry localization and Industry Development Strategy, encourage technological development in South Africa through research and development, commercialization of local technologies and technology transfer arrangements, and to strengthen and contribute to the skills development initiatives in order to increase the number of skilled South Africans. Some industries already produce about 40% of their energy from a renewable resource. The biofuels and biogas sector is closely linked to building resilience in rural communities, as it will encourage smallholder agriculture and generating energy from biogas could contribute to cutting emissions from the agricultural sector in South Africa.

The South African production economy is highly dependent on electric energy which in turn is generated from fossil fuel with coal being the major one. South African products are thus high CO₂ emissions embodied. The production sector presents South Africa with a great opportunity to transit to green economy. Sweden has a climate road map of zero net greenhouse gas emissions by 2050, and fossil fuels independent vehicle motor fleet by 2030. South Africa can greatly reduce its greenhouse gas emissions by adopting Sweden's production based approach of low-carbon intensity electricity production (Mundaca et al., 2015). Due to the low electricity incentive production, Sweden has a negative Emissions Trading Balance with both the European Union (EU) and the rest of the world. The negative balance is due to higher CO₂ embodied emissions in imports than embodied emissions in exports.

2.7. Green employment in South Africa, current and potential

South Africa is faced with important environmental challenges which can only be addressed by improving energy efficiency, increasing renewable energies, providing sustainable transportation, improved housing as well as sustainable management of natural resources. The New Growth Path framework's goals include increasing green jobs in the different sectors by creating an additional amount of 30 000 direct jobs in green sectors by the year 2020. The construction and

manufacturing industries are expected to lead in green job creation and in turn lead to creation of jobs in operation and maintenance of the new environmental technologies developed (Sustainlabour and TIPS, 2013).

Table 3: South African green economy sectors, current and potential employment

Sector	Current employment	Potential new employment by 2025
Waste management	36,960-131,130 jobs (90% unskilled), including 40,000 in plastic recycling, 10,000 in scrap metal, 35,000 in beverage cans.	165,134-351,314 (90% unskilled) but only around 16 000 direct jobs
Natural resource management	23,000 full-time person-years employment to low-skilled workers in ecosystems restoration with the WfW	110,000 additional full-time equivalent person-years employed with the WfW program. 350,000 person-year in soil and land management through payment for ecosystem services.
Sustainable transport	Unknown	41,642 jobs in bus rapid transit in the long term and 148,000 with the Gautrain and bus system.
Wind energy	Insignificant	5,000 jobs in the long term.
Solar energy	Very low	At least 165,000 direct jobs with 13,500 in photovoltaic and 3,000 in concentrated solar power.
Waste-to-energy	Not yet determined	37,000 direct jobs in biomass industry, 10,000 in cogeneration and 7,000 in landfill gas.

Source: *Adapted from Montmasson-clair (2012).*

The Economic Development Department (EDD) estimated a potential creation of 400 000 green jobs by the year 2030. This rise in employment will be triggered by expanding the already existing employment in the environmental sector and biofuel production.

shows a summary of potential green employment in different sectors of the envisioned South African green economy by 2025. In Bangladesh, a country with similar solar irradiation to South Africa, solar photovoltaic has been widely applied for rural electrification (Sharif and Mithila, 2013). Germany experiences a much lower solar irradiation than both South Africa and

Bangladesh but has greatly advanced in both solar and wind energy technologies with 205,000 jobs created in both sectors by the year 2012 as compared to very low number of jobs created in South Africa (Table 3) in the same sector. South Africa can thus use the technologies in both Germany and Bangladesh as a benchmark in utilising its vast renewable solar and wind energies.

2.8. Conclusion

The current imperative global energy, food and financial crises and the danger of the transgression of ecological limits, has shifted world-wide attention towards green economy. Current technologies, educational standards and other forms of activities of all the countries in the world are characterized by modernization whereby whatever is introduced, produced or studied has to conform to certain requirements, in some cases international ones. The implementation of green projects intended to aid in the transition to green economy has resulted in the creation of green jobs thus making green investments favourable. China's experience provides an example of renewable energy that can lead to job creation, high revenue for the country and increased household income, and ultimately improve the living conditions of the citizens

CHAPTER 3

3. Strengths and challenges

3.1. Emerging contaminants

Heavy metals: Heavy metals that are commonly found in wastewater include Fe, Cu, Zn, Co, Cd and Pb. These metals are not only non-biodegradable but also accumulate in the plants and animals tissues. On the one hand, it has been reported that the toxic effect of heavy metals is attributed to the disruption of enzyme function and structure by binding the metals with thiol and other groups on protein molecules or by replacing naturally occurring metals in the enzyme prosthetic groups (Chen et al., 2007). On the other hand, it has been reported that these metals are essential part of the enzymes; for example Fe^{3+} favour photocatalytic degradation process (Mounir et al., 2007). It therefore, follows that there is an optimal amount of heavy metals that is necessary for the biological process, above which the metals impede biodegradation.

Chlorophenolics: Chlorophenols are among the most toxic forms of the phenolic compounds, which include monochlorophenols, dichlorophenols, trichlorophenols, tetrachlorophenols and pentachlorophenol. However, there is no consensus in the literature as to the correlation between the degree of toxicity and the number of chloro-substituents in the aromatic. Further, it has been reported that chlorophenols disrupt the proton gradient across membranes and interfere with energy transduction of cells (Chen et al., 2007).

3.2. Existing and required skills

At the international level there is a sterling output in water research in South African, as such, one would not hesitate to commend the key role of facilitation played by Water Research Commission, among others. In spite of the impressive research output by South African water researchers, availability of clean water to all South Africans is still an elusive dream. The situation is not good to the extent that some sectors have reported water crisis in the country. The fact that there is an impressive research output in water by South Africans is an indication that indeed there exists a good pool of water experts in South Africa. The next logical question therefore is how to harness this expertise to solve the water management problem in this country.

Crucial to water management, though, is the role of engineers. It was reported by John (2015) at the round table discussion held in Johannesburg that in South Africa for every 3,166 people, there is one engineer. It was further reported that in Namibia, for every 1639 people one is an engineer. One may tend to justify the numbers on the basis of population difference; approximately 2.5 million in Namibia compared to 54 million in South Africa currently. The other side of the story is a comparison between South Africa and a fellow BRICS country, like India, with a very huge population (approx. 1.27 billion). For every 136 people in India one is an engineer. This compels us to look elsewhere to explain the disparity. One may blame this on history, which is true to some extent. However, more importantly, the disparity could be more to do with our mind set than history. If history created the mind-set then it is not too late to develop a curriculum that will create a paradigm shift. This must be done collectively and now.

Studies in the field show that there are sets of problems that must be approached differently. Firstly, there is a problem of a lack of technical skills required to efficient water management in existing water and wastewater facilities. The second problem relates to the management of the available skills and facilities to optimize output and service delivery. Thirdly, owing to the emerging challenges, further training are required in certain fields in line with the concept of green economy, and such fields include;

- a) Sludge characterization and subsequent utilization in agricultural production
- b) Generation of biogas from solid and liquid wastewater
- c) Techniques to improve biodegradability of wastewater streams
- d) Wastewater treatment process integration where conventional method are integrated with modern advanced oxidation processes
- e) Application of the concept of water pinch to optimize rather than minimize water utilization

Information gathered through questionnaires and observation of the activities at various service delivery sites indicate that availability of resources (human capital and infrastructure) is just one part of the bigger problem of water and wastewater management. At the core of the problem is a lack of management structures to promote or integrate benefit sharing in service delivery. Benefit sharing is one of the pillars of green economy whereby what is perceived to be a waste by one sector is a raw material to the other. For this to work, the so called waste must be in a form that

can be feasibly used by the receiving sector. As a way of example, it was observed that large sludge volumes is a problem to many municipalities. However, for this sludge to be accepted by farmers, it must not contain high levels of toxic compounds and pathogens. The studies show that a high proportion of engineers who work in wastewater treatment plants have civil engineering background. The nature of training in civil engineering could be limiting with regard to the complex biochemical reaction taking place in the biological systems. The problem becomes more pronounced if the reactions involve biorecalcitrant emerging contaminants.

3.3. The role of local governments in green economy

The role of local government in green economy has become centre of focus in the recent years due increasing urban to rural migration in many developing countries. This kind of social dynamics coupled with the global concern about climate change leaves local governments with no option but to be a major player in this game of green economy. The topic of climate change may seem abstract for many local governments since the creation of low-carbon economies and green jobs relates to factors falling outside their direct control. However, in practice, cities and local governments are likely to have some comparative advantages as they are the closest to; local businesses, job seekers, and the disadvantaged communities in local labour markets. More than 3.5 billion people representing half of the world's total population live in urban areas. This number is expected to rise 70% by 2050 (UN Habitat, 2010). Cities are at the heart of transition to a global green economy as they contribute highly to global warming and are also considered as key engines to economic growth (Hammer et al., 2011). Local governments in developing and poor countries face threats that are more severe than in developed countries, and are closely related to the deterioration of human health and the environment. Local governments are becoming more prosperous with deeper and wider patterns of consumption and production leading to increased environmental impact, the effect of which can be felt globally (UNEP 2011b).

Local governments can take steps to promote changes in the pattern of local private investment, as well as green practices, through appropriate regulations, policies, public investments and partnerships (UNDP 2013). Local governments have an important role in identifying infrastructural and other deficits and providing the infrastructure needed to support enterprise and promote development. Local governments also efficiently and speedily deliver essential services to businesses and are geared to respond to the needs of local communities, employers and entrepreneurs. Fundamental changes in urban area development are crucial for the transition to a

greener economy. Due to rapid urbanization, there is an increasing pressure exerted on resources such as fresh water supply, sewage, environment and public health, affecting the urban most poor (UNEP, 2011a).

3.4. Green economy jobs sectors and drivers in local governments at international level

The renewable energy sector has become a potential business sector which will play a major role in the transition to green economy. Cities and local governments around the world are taking part in greening initiatives in support of the fight against climate change. The initiatives are depicted in many shapes which include; targets for CO₂ emission reduction, carbon-neutral towns, usage of renewable energy, energy efficient buildings and eco-cities.

Table 4: Jobs in green sectors

Sector	Example of jobs
Energy	<ul style="list-style-type: none"> ▪ Energy engineers ▪ System installation electricians and plumbers ▪ Mechanics building the infrastructure ▪ Renewable energy plant operators ▪ Energy efficiency engineers and scientists
Transport	<ul style="list-style-type: none"> ▪ Employees of public transport ▪ Bus retrofitters ▪ Constructors of rail networks
Housing	<ul style="list-style-type: none"> ▪ Employees of firms producing green building materials ▪ Green building contractors and construction workers
Pollution management	<ul style="list-style-type: none"> ▪ Workers employed for water infrastructure renewal ▪ Workers removing hazardous materials ▪ Chemists developing environmentally friendly packaging, clean products and sprays
Green services	<ul style="list-style-type: none"> ▪ Energy contractors ▪ Specialized consultants ▪ Trainers ▪ Marketers ▪ Green-civil engineers ▪ NGOs

Source; Adapted from OECD Regional Development Working Papers 2011

The green economy offers many benefits to local governments as it creates green jobs and green business which in turn results into an increase in local government revenue. The transition to a greener infrastructure in cities involves a lot of activities such as drainage enhancement, creation of efficient recycling services, establishment of public transport networks and improving roads and buildings, hence creating greener jobs (UNEP, 2011) that will enable local governments to address the issue of poverty which is widespread in developing countries (UNEP, 2011b). There are examples of cities across the world such as San Diego in United States, Hamburg in Germany, Baoding in China and Casablanca in Morocco where local governments have taken concrete steps towards green economy by promoting renewable energy businesses (Mans and Meerow, 2012). Freiburg, a city in Germany inhabited by 200,000 people, has been known for its recycling investment initiatives and sustainable buildings. Its CO₂ emission was reduced by 12% between 1992 and 2003 (UNEP, 2011b).

The quality-of-life, problems like crime, unemployment and poverty, and climate change that urbanization poses, adds more pressure on the local and global environmental principle. According to Nicholson-lord (2002), cities take up to 2% of the total land area in the world . The consumption of resources by these cities is roughly around 75%, automatically resulting in the generation of waste, pollution and toxic effluent directly related to the resources consumed. The environmental significant as a result of these activities indicate that cities are major contributors of climate change and greenhouse gas emissions. Technologies and sustainable design strategies have been made available in order to improve natural resource management by improving urban transportation, housing, water, waste management and housing (UNEP 2011b).

3.4.1. Transport

According to Nicholson-lord (2002), for a transport system to be defined as sustainable it must cause minimal harm to the environment, it must not be costly and it must be easy to reach. However, even though in this present time as much as petroleum-based fuels dominate transport-sector energy consumptions, there is still hope for transformation to a green transport. The strategy for a green economic future transportation in green cities across the world includes;

- Environment friendly low carbon public transport systems;
- Promotion of non-motorized transport;
- Integrated urban transport planning, and
- Adequate management of traffic.

Alternative initiatives for greening the transport sector include introduction and development of new vehicle technologies and modes of transportation. What seems to be the world's promising key for transportation sector is the information technology in the design of transport systems that are sustainable. Initiatives aimed at greening the cities' transport systems prioritize reducing the use of motorized transport or slowing its growth. The congestion charge in central London was reduced by 65, 000 daily vehicle trips and CO₂ emissions by 19.5% following the introduction of Bus Rapid Transport (BRT) system. BRT system has also contributed to a 14% drop in emissions per passenger (UNEP 2011b).

In Copenhagen, the capital city of Denmark, 36% of journeys to work and education are by bicycle. The high rate of cycling has reduced the city's traffic management costs in reduced congestion, accidents and infrastructure, with an estimated US\$ 43 million saved annually. This has resulted from comprehensive policy packages which made the city's roads and buildings bicycle friendly through construction of ways for cycling, restricting car parking and effective regulation of land use to make work place accessible (Baker et al., 2013). Most local governments in the Copenhagen metropolitan employ these policies that make the city's roads and buildings bicycle friendly. Chinese municipalities improved urban rail systems, with a total of 37 lines in operation by 2010. Twenty-five cities in China are planning a combined total of 5,000 kilometres of urban rail systems which will increase green job creation (Pan et al., 2011).

3.4.2. Water and waste management

The management of water in most national cities in respective local governments comprises of; decentralization of wastewater system, rainwater harvesting and wastewater recycling. Local governments in Tokyo and Phnom Penh have used volumetric water charges and promoted adequate maintenance of water systems in order to reduce water losses. Water flushes consume most of the water in many households therefore initiatives such as waterless urinals and toilets can be used to reduce water usage in the cities (Nicholson-lord, 2002). Greenhouse gas emissions and generation of wastes, as well as the management thereof, are both directly and indirectly linked. Wastes greatly contribute to the levels of greenhouse gas emissions and the situation is exacerbated in the absence of efficient waste management.

Growing population in cities and urban centres, improved lifestyle, increase in income and changing consumption patterns are among the factors that have led to increased amount of waste generated across the world. Poor waste management practices in urban centres such as low capacity for waste management, waste disposal in informal dumpsites, waste disposal in water ways and uncontrolled burning of wastes, have led to problems such as urban flooding and increased greenhouse gas emissions. Countries like Denmark and Norway have taken the lead in coming up with efficient and effective waste management techniques that results in energy recovery from the wastes and also eliminate the severe negative problems associated with wastes (Abila, 2014).

3.4.3. Energy

Economic development is literally powered by energy, thus any industrial policy must have energy policy as its cornerstone regardless of the former's objectives, approach and execution method (Pegels and Lütkenhorst, 2014). In order to achieve a green economy which will be environmentally sustainable, promoting the use of renewable resources to fuel urban areas is crucial. Energy plays an important role in the development of urban socioeconomics within the local governments. The stability of energy consumption in the cities creates energy conservation opportunities which can be attained by employing technical initiatives such as (Nicholson-lord, 2002);

- Energy-saving light bulbs;
- Street lighting with automatic switching;
- Improved management and operation of buildings;
- Power savings from optimized pumping of water and sewerage systems, and
- Smart grids, distributed power, and efficient district heating and cooling.

The World Bank and the Global Environment Fund recently funded a project in the People's Republic of China which is aimed at building energy efficient homes that would result in low carbon cities. The project referred to will (Nicholson-lord, 2002);

- Improve application of energy-efficiency standards for buildings, as well as the design and use of insulation and other energy saving measures;
- Introduce heat metering, cost-based pricing, and consumption-based billing, and
- Improve heat supply systems so that residents can control the heat being turned on or off.

South Africa is amongst the few developing countries that are still struggling to manufacture products from renewable energy. Countries such as, the Republic of Korea and Malaysia have already taken the leading role in supplying renewable energy technologies to other developing countries (UNEP, 2013). Even so, the energy sector in the developing countries has recently grown especially in the production of electricity from renewable energy resources. The Democratic Republic of Congo (DRC) for example is expected to generate tremendous amounts of energy from its local dam, which will enable the country to among other things, export electricity its neighbouring countries. It is therefore very clear how much potential power can be generated from these environmentally-friendly sources of energy in order to drive sustainable economic growth (UNEP, 2013).

3.4.4. Housing

Use of fossil fuels for operational purposes such as heating, lighting and cooling, is responsible for the 30% of the global greenhouse gas emissions caused by buildings. The building sector is also responsible for 40% and 20% of global energy and water consumptions respectively (Baker et al., 2013). Buildings have the highest potential for reducing greenhouse gas emissions through introduction of efficient energy measures including insulation, heat energy to electricity conversion, sourced renewable heating and renewable micro regeneration. Most countries in the world are currently designing and implementing these energy efficiency measures.

A good example of a vehicle that can effectively encourage environmental-friendly building construction, is the USA Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System. This voluntary system encourages builders to use industry-wide standards for the design, construction, and operation of buildings in a manner consistent with long-term environmental sustainability. The operational costs of buildings constructed and operated based on this system, are lower than those of conventional buildings. The low cost is as a result of less consumption of water and energy, and generation of less waste. Moreover the less consumption of energy results in reduced greenhouse gas generation. Asset value of buildings built on this system is generally higher than those of common buildings thus motivating the switch to green housing (Nicholson-lord, 2002). This system can be used as a baseline by other local

governments in developing construction guidelines and rating systems that are in tandem with long-term environmental sustainability.

3.4.5. Legislations

There are laws put in place by major emitters of greenhouse gases for the purposes of controlling emissions, conserving energy, avoiding deforestation and promoting clean energy production. It is estimated that close to 500 climate related laws had been passed in 66 leading economies by the end of 2013 (Fankhauser et al., 2015). The international climate plans such as the Paris Climate Deal 2015, are moving towards a system recognizing every nation's intended determined contributions. It is through domestic legislations that will give credibility to these international climate agreements. Many organizations are at risk of being fined, having to pay user fees and clean-up costs due to government legislation, regulations and lawsuits which have resulted from the increasing need for environmental control. Governments monitor and consult companies in order to ensure that companies that comply to the regulations and take the lead in areas of future regulation are rewarded in return (Soediono, 1989). The municipality in the city of Sao Paulo in Brazil has approved a policy for climate change as part of its green economy strategic plans. The law stipulates a percentage reduction of 30% of 2005 levels of greenhouse gas emissions by the year 2012. The law was put into place to address several issues on the areas of; transportation, energy sustainable solutions, waste management, construction and land use (WRI, 2011).

3.5. Green Economy in African Cities and Local Governments

The rate of urbanization in Africa is increasing at a rate higher than any other continent in the world. The number of African urban residents currently account for 42% of the total population and is expected to rise to 50% by 2035. The expected expansion would be difficult to manage even with the best urban governance, yet African cities have often suffered from unplanned sprawl. The increasing rate of urbanization in Africa has strongly fuelled the need for alternative energy sources and sustainable resource management strategies as the existing energy, water and waste management infrastructure is already stretched to its limits (Economist Intelligence Unit, 2012).

African municipalities in their respective local governments can play a vital role in the transition towards a green economy. The municipalities are dependent on both the private and public sector for investments in order to implement innovative ideas and technologies. The decisions, rules and policies made up by the municipalities in the cities plays a significant role in the green economy

transformation as the policies have an impact on the climate change based on low carbon policies and enhanced settlement resilience by instituting climate adaptation policies. Municipalities in the local governments are responsible for the appropriate management in the energy and water sector that also form the movement towards sustainable development and green economy, which leads to poverty reduction, green jobs creation and finally environmentally-friendly economies (Mhamo et al, 2015).

3.6. Green economy in South African Local Governments

South African cities and local governments are among the leading cities on green policies with strong local structures and technologies in the African continent (Economist Intelligence Unit, 2012a). However, on quantifiable metrics such as electricity consumption, waste generation and water consumption, none of the leading South African cities (Cape Town, Durban and Johannesburg) perform any better as they have among the highest CO₂ emissions from electricity due to the high dependent on coal for electricity production. This drawback on consumption is however, mitigated by consistent strong environmental policies.

A good example is Cape Town which has established a comprehensive Energy and Climate Change Action Plan to improve green performance. Durban and Johannesburg also perform generally well when it comes to environmental policies (Economist Intelligence Unit, 2012b). Table 5 depicts some of South Africa's Local Governments Green Economy policies in the cities of Cape Town, Johannesburg and Tshwane. South Africa's local government Green Economy strategies includes the Free State green economy strategy (2014); North West Renewable Energy Strategy and Implementation Plan and the Industrialization Programme (2013); Limpopo green economy plan including provincial climate change response (2013); Green is Smart: Western Cape Green Economy Strategy (2013); Green economy strategy for KwaZulu-Natal province (2013); and a strategy for a developmental green economy for Gauteng (2010).

Table 5: Supportive landscapes for local governments in South Africa (AFRICEGE 2013).

Cape Town	Johannesburg	City of Tshwane
<ul style="list-style-type: none"> ▪ Information and Guideline Document on the Implementation of Green Procurement , 2012 ▪ Environmental Awareness, Education and Training for City Staff and Councillors, 2011 ▪ Report on Energy and Climate Change– What the City is doing, 2010 ▪ Energy and Climate Change Action Plan, 2010 ▪ Local biodiversity Strategy and Action Plan, 2009 ▪ City of Cape Town environmental Agenda (2009-2014) ▪ Framework for a Strategy and Action Plan for the Management of Invasive Alien Species, 2008 ▪ Energy and Climate Change Strategy, 2007 ▪ Coastal Zone Management Strategy, 2003 ▪ Integrated Metropolitan Environmental Policy, 2001 	<ul style="list-style-type: none"> ▪ City of Johannesburg Integrated Development Plan, 2013 ▪ City of Johannesburg Integrated Waste, 2011 Management Plan ▪ Johannesburg 2040 Growth and Development Strategy, 2011 ▪ City of Johannesburg Biodiversity Strategy and Action Plan, 2009 ▪ Climate Change Adaptation Plan, 2009 ▪ City of Johannesburg State of Energy Report, 2008 ▪ City of Johannesburg Economic Development Policy and Strategy, 2008 Framework ▪ Climate Change programme, 2006 ▪ State of the Environment Report, 2003 	<ul style="list-style-type: none"> ▪ City of Tshwane Green Economy Strategy, 2014 ▪ City of Tshwane Integrated Development Plan, 2013 ▪ Green Buildings By-Law, 2010 ▪ Green Buildings Development Policy, 2009 ▪ The Tshwane Integrated Environmental Policy (TIEP), 2007Implementation Plan ▪ City of Tshwane: State of Energy Report, 2006 ▪ State of the Environment Report for the City of Tshwane, 2006 ▪ Air Quality Management Plan for the City of Tshwane Metropolitan Municipality, 2005 ▪ Tshwane Environmental Education Awareness Strategy, 2005

3.6.1. North West Green Economy Strategy

The Northwest Renewable Energy Strategy and Implementation Plan consist of the following initiatives (North West Renewable Energy Strategy and Implementation Plan, 2013):

- i. *Bio-Mass (Clean Cook Stoves)*-By using clean cook stoves, greenhouse gas emissions are reduced and green jobs are created during the manufacturing of the stoves. In addition, use of the clean cook stove has saved lives, empowered women, improved livelihoods and has

helped in combating climate change. This is as a result of the reduced fuel consumption and exposure to harmful smokes associated with conventional cook stoves. It is estimated that greenhouse gas emission resulting from traditional heating and cooking could potentially reduce by 40-90% through the rolling out of clean cook stoves. To ensure reduced overall cost of clean cook stoves and increased job opportunity resulting from the roll out especially if local manufacturing is encouraged.

- ii. *Municipal Solid Waste* – Waste to energy technologies can be applied using municipal solid waste disposed in landfills through biogas recovery technologies. Waste generation is on the increase due to the growing number of people clustered in urban and semi-urban centres. Harnessing of these wastes can significantly contribute to the energy requirements of NWP and South Africa at large. Energy generated from the wastes can provide off-grid and micro-grid alternative energy for municipalities. Techniques such as landfill methane recovery, anaerobic digestion of activated sewage sludge and biodegradable wastes can be used by the municipalities in energy recovery. Despite having commercially viable oil and gas, Denmark and Norway are good examples of countries deriving multiple benefits from wastes through advanced and effective waste management techniques (Abila, 2014).
- iii. *Solar Photovoltaic Technologies and Solar Water Heaters* –The use of Solar PV in the northwest province will play a significant role in the reduction of greenhouse gas emissions. The use of solar energy, the most readily available renewable energy in South Africa, forms one of the key areas that NWP should focus on in its quest to transit to green economy. Northern Cape has been targeted by the majority of solar PV projects due to its favourable solar irradiation conditions. Since NWP has irradiation levels that is only 5-11% lower than Northern Cape, the solar PV project can be successfully implemented in NWP as well.
- iv. *Co-generation and Waste Heat Recovery* –This initiative will result in fossil fuel conservation, reduced energy costs, reduced greenhouse gas emissions, diversification of electricity supply base and low lead times to completion. NWP being a mining and processing province, has an opportunity for waste heat recovery and cogeneration. Ferrochrome smelting and processing, cement manufacturing, gold and uranium plants account for approximately 63% of NWP electricity consumption. The mining industries through their smelters and furnaces can be used for heat recovery and cogeneration.

3.6.2. Green economy strategy in Limpopo

Limpopo Employment Growth and Development Plan (LEGDP) is the driving force towards its transition to a green economy. The province's objectives are based on addressing issues that influence the standard of living in the society. Most importantly, the main aim stated in the LEGDP is focusing on achieving and transitioning people's quality of life. Letsoalo (2013), mentioned critical aspects areas that the national perspective together with provincial priorities will assist on in the green economy plan. Limpopo province has implementation plans as far as the key areas of green economy are concerned. The plans clearly indicate short, medium and long term goals in achieving the main objective of improving quality of living. Limpopo province is prioritising following key areas:

- i. **Sustainable Production and Consumption** - According to the National Sustainable Development Strategy and Action Plan, the province will make sustainable alignments with all the industrial sectors in the province, thereby putting the province on the map as a green tourism destination, and in the process developing a green tertiary sector. **Water Management** - Limpopo province is taking initiatives in water provision and security. The priorities for water management includes, ways to save, conserve and store water; monitoring mining water usage; improve water network system; recycle water from sewage farms; alternative ways for water harvesting; decrease water consumption in households, agriculture and commercial businesses; and influence the promotion of STP biogas production.
- ii. **Sustainable Waste and Energy Efficiency** - The province will prioritise sustainable waste and energy efficiency by; focusing on facilitating efficient waste management through creation of awareness around issues regarding waste, and also simultaneously license and monitor waste disposal sites in the province. It will base its focus in prioritising waste beneficiation, which consists of waste collection forces, recycling and reuse, establish facilities for waste recovery and utilize waste disposal and sewage waste to recovery methane for energy use.
- iii. **Clean Energy and Energy Efficiency** - The LEGDP clearly emphasises the importance of securing energy. In its energy plans, the province is looking at renewable energy complex in electricity production through concentrated solar plant given its potential geographic location, and establishing solar panels manufactures since they are the biggest producers of silicon smelters in the country. Energy efficiency will be achieved through promoting

public awareness in collaboration with Eskom and Non-Governmental Organisations (NGOs). The development of human resources will be achieved through introduction of renewable energy and energy efficiency modules in all educational levels inclusive of high learning level, and by developing alternative renewable resources for electricity generation like biofuel and biogas production.

- iv. Resource Conservation and Management - The natural ecosystem is strongly influenced by the activities of humankind. Limpopo perspective in biodiversity and conservation of natural resources involves planning and valuation. Establishing and up-scaling “working for-programmes” which will help in maintaining the different plant species. Tree planting of different kinds of species in specific areas of interest is also emphasized as the priority in the resources conservation and management.
- v. Agriculture, Food Production and Forestry - The Limpopo province is prioritising in promoting sustainability in the agricultural sector by supporting organic and local production, and urban agriculture. To monitor the use of resources the province will be focusing on water efficiency, seed and food banks and also biofuel resources.
- vi. Green Buildings and the built environment - The severe impact that buildings have on the environment and the energy sector is a concern for country and the local governments. Both parties play part in promoting green practices in all government and private buildings in Limpopo. This also includes green principles in proper infrastructure and town planning.
- vii. Sustainable Transport and Infrastructure - Limpopo province targets alternative energy saving vehicles in public transportation, regulations that will reintroduce rail transport that is accessible and flexible to use, and establishing solar traffic and street lights including road maintenance. From these priorities and targeted tasks by the province, there is a clear link between the energy and transportation sectors.
- viii. Green Municipalities - The high profile people and stakeholders in both the national and local municipalities have a great influential platform to address the public about the benefits associated with green living in our lifetime. Therefore, the Limpopo provinces challenges every local municipality for the to compete for green municipality, by promoting sustainable practices such as waste, water and energy management; governance and capacity building; and also public participation. The LEGDP will also base its priorities in promoting green municipalities by reviewing all municipal by-laws and the calculation of ecological footprint of the municipalities.

- ix. Cross-cutting Issues - Every individual has the responsibility and a role to play in transitioning towards green economy. The importance of regulations, policies and laws will be clearly stated to ensure proper monitoring and implementation regarding the transition to the green economy. Therefore, the province of Limpopo will prioritise in cross cutting issues by monitoring and evaluating green economy in the province, it also plans to initiate and establish a research hub on green economy and a national Green Economy Indaba and make it an annual event. The province is also ambitious in targeting to mainstream all documents concerning the Limpopo province green economy plans.

3.6.3. Gauteng green economy strategy

Gauteng, the economic heartbeat of South Africa, has experienced a growth path that has historically experienced an exploitative and resource intensive industrial and mining activities that has resulted to mounting sustainability challenges. The challenges are evidenced by insecure water supply, high energy intensity, sprawling of informal settlements in urban areas, increased air and water pollution, and the unique phenomenon of acid mine drainage (Gotz and Schaffler, 2015).

Table 6 presents agriculture as potentially crucial to the economic growth of Gauteng, but still under exploited. Green agriculture will require green practises and sustainable production leading to green jobs created as envisioned, and at the same time address food insecurity brought about by climate change leading to environmental degradation. In Italy, the greening of the agricultural sector has led to growth of green jobs among young people mostly interested in green innovation. Gauteng can create more green jobs from agriculture alone by investing in eco-innovation, packaging to waste management, biomass reuse, renewable energies, tourism and recreation in the agricultural landscape (Viola et al., 2016). For effective realisation of proposed agricultural initiatives, Gauteng will need human resources that can work on green innovations, design and planning, technology transfer, and on land management systems.

Table 6: Proposed Initiatives - summary of findings

Recommendation	Job Creation Potential	Costs	Benefits
(1) Urban Agriculture			
1,030,872 households to cultivate 100 m ² for vegetable plantation per household, thereby reducing expenditure on fresh food.	None direct (Food production for poorest households)	Investment into basic infrastructure, capacity building and support.	Food security, job creation, economic growth, building social and environmental capital, provision of free ecosystem services.
387,022 households cultivate 300 m ² for vegetable plantation per household, thereby reducing expenditure on fresh food	387,022 households receive supplementary income.	Investment into basic infrastructure, capacity building and support.	Food security, job creation, economic growth, building social and environmental capital, provision of free ecosystem services
To meet the basic fresh produce requirements of the population of Gauteng, 26,672 hectares need to be cultivated which can be done by 444,538 people on 600 m ² plots.	444,538 direct jobs created	Investment into basic infrastructure, capacity building and support.	Food security, job creation, economic growth, building social and environmental capital, provision of free ecosystem services
(2) Land reform			
Land reform: to increase regional production in rural and peri-urban areas would also serve to secure food for regional consumption whilst creating employment and stimulating the regional economy further.	28,718 direct jobs created	Investment into basic infrastructure, capacity building and support.	Land reform, food security, job creation, economic growth.
(3) Regionalising the value chain			
Increasing agricultural production is key to achieving food security but must be coupled with “broader, more systemic interventions in the value chains linking the production, manufacturing and retail of food.	High needs further research work.	Facilitated industry dialogue to identify opportunities for regionalisation and increasing efficiencies.	Multiplier effect on regional economy, job creation, increased efficiencies, economic growth, sustainable best practice

Source; *Adopted from Spencer et al, (2010).*

Gauteng’s developmental green economy strategy consists of the following initiatives (Spencer et al 2010):

- i. Food security - The overall aim of food security is to foster job creation through local food production by minimizing the amount of food being imported into the country whilst simultaneously creating jobs and building a stronger regional food economy. Table 6 gives proposed initiatives for improved food production and job creation in Gauteng.
- ii. Energy security - The aim of energy security is to reduce the province’s dependence on non-renewable fossil fuels such as oil and coal, by promoting alternative renewable energy

sources like solar. Solar Water Heaters (SWH) can be used to replace conventional water heating methods in providing hot water for personal hygiene and household cleaning in low and high income homes. Table 7 gives the approximate energy savings when solar heating is employed. According to the developmental green economy for Gauteng Final Report, local production of solar water heaters can create about 6700 green jobs (Spencer et al 2010).

- iii. *Energy Efficiency* - The aim of the energy efficiency initiative is to reduce the Gauteng's greenhouse gas emission by reducing the province's energy consumption. Table 8 gives the Proposed Energy efficiency initiatives for different sectors of the Gauteng economy (Spencer et al 2010):

Table 7: Energy Saved through utilization of Solar Water Heaters in Gauteng

	High income households	Low income households
Conservative estimate of average electricity consumption per year	2722 kWh	1164 kWh
Typical savings with SWH	70%	90%
Projected annual electricity savings	1905.4 kWh	814.8 kWh
Projected annual electricity bill savings	R 1143.24	R 651.84
Total annual electricity savings in Gauteng	2413 GWh	543.08 GWh

Source; Adopted from Spencer et al, (2010).

- iv. *Water Security* - South Africa is a water-stressed country and the implementation of water conservation and demand management measures are a critical requirement. At present a significant amount of water is lost as a result of poor water infrastructure. The push for water demand management by local authorities may also stipulate the installation of water saving devices, which could potentially stimulate a potential manufacturing of such devices. The aim of the water security initiative is to promote water conservation and efficient water use in order to reduce water loss and to avoid water shortages. Several recommendations such as water demand management through leak control programmes and adequate water system maintenance in low income households were presented. Also recommended is pollution reduction through; improvement of storm water infrastructure and management, improvement of sanitation in low income communities, household plumbing maintenance in low income communities to reduce flows into wastewater works.
- v. *Waste management* - The aim of waste management is to change community perspectives by promoting waste to product initiatives; Development of Composting Initiatives whereby

products such as fertilizers are created from organic waste, Waste Minimization Clubs in which the services of waste contractors are improved, Waste to Energy in which waste is promoted as a renewable energy source for clean energy, and Green Procurement which focuses on promoting the recycle of products that can be easily recycled. Recycling is one of the ways to promote green living around communities. South Africa has many waste management programmes and companies that encourages people in the communities to recycle and re-use in order to keep the environments clean and thus, save the ecosystem. Other programmes also rewards the society by buying the recycled items (UNDP, 2012).

Table 8: Proposed energy efficiency initiatives for Gauteng

Sector	Energy Efficiency Initiatives
Industrial	<ul style="list-style-type: none"> ▪ Variable speed drives to reduce unnecessary power consumption in electrical motors with varying loads ▪ Efficient motors ▪ Compressed air management ▪ Efficient lighting ▪ Heating, ventilation and cooling through better maintenance and the installation of appropriate equipment.
Commercial	<ul style="list-style-type: none"> ▪ Energy efficient windows ▪ Insulation ▪ Green IT
Housing	<ul style="list-style-type: none"> ▪ Supply & install energy efficient lights ▪ Installing ceilings and other no-cost measures to improve the thermal efficiency of the buildings ▪ Promote more efficient appliances ▪ Switch from electricity and/or paraffin to LPG for cooking; ▪ Supply & install energy efficient lights
Transport	<ul style="list-style-type: none"> ▪ Switch from cars to mass transport systems

- vi. *Sustainable Mobility* - The aim of sustainable mobility is to decrease the high use of non-renewable resources and to promote low carbon transport systems by; employing sustainable transport systems and promoting non-motorized transport.

3.7. Technology for green economy in wastewater treatment

Wastewater treatment methods have evolved over the years with new technologies emerging in response to new generation pollutants. Among the most commonly used technologies, biological treatment method is the oldest due to the fact that it is low cost and simple. There are two fundamental biological wastewater treatment methods; these are aerobic and anaerobic digestion. The aerobic digestion is considered to be more costly than the anaerobic one because of the cost

of aeration. In anaerobic digestion, there is pollution control and energy recovery in form of biogas. It is a well-established technology for methane production from wastewater, mainly originating from food processing industries, domestic and agricultural wastes.

The anaerobic technology has been applied using almost similar design and operating parameters despite variations in environmental and raw conditions. This results in a mismatch between the operating conditions and the characteristics of raw materials. Temperature has been identified as one of the key parameters that influence the yield and rate of biogas production. For this reason, Africa, especially South Africa is geographically favoured to use this technology with little or no addition of external energy due to many months of sunshine per year. Further, with increasing cost of electricity in South Africa, in particular, there is an additional incentive for exploring alternative energy sources. These two most widely employed technique for biological wastewater treatment, aerobic and anaerobic digestion, are compared in Table 9.

Gauteng has a large population that has created a huge demand for food processing industries, which generate large volumes of nutrient-rich effluents with high energy generation potential. In this regard, there are several wastewater treatment facilities generating biogas. In Ekurhuleni Metro, the reported capacities of wastewater treatment facilities that generate biogas as shown in Table 9, range from 0.32 ML/day to 108 ML/day (PDG 2004). It is interesting to note that one of the facilities in the region (Ester Park) with a relatively small capacity of 0.32 ML/day and processing waste with a mean COD value of 450 ppm is reported to produce 18,570 m³/day of biogas. The largest facility reported in Ekurhuleni Metro at Waterwal with a capacity of 108 ML/day, processing wastewater of COD strength of 1002 ppm is reported to produce methane at a rate of 37 740 m³ per day. At Ester park facility, the rate of methane production is two times smaller than the Waterwal one, however, it is 338 times smaller than the Waterwal one. The huge differences in biogas yield could be due to an error in data capture. Further, it can be seen in Table 9 that the yield given for the Ester plant is completely different from the rest.

Table 9: Comparison of aerobic and anaerobic treatments*

Comparison	Anaerobic	Aerobic
Mineralization model of substrate	$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$	$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$
Carbon balance	($\Delta G_o = -393 \text{ kJ/mole glucose}$) 95% converted to biogas; 5% incorporated into microbial biomass	($\Delta G_o = -393 \text{ kJ/mole glucose}$) 50-60% converted into CO_2 incorporated into microbial biomass
Energy balance	95% retained as CH_4 , 3-5% wasted as heat, 5-7% is stored in new biomass	60% of energy is stored in new biomass, 40% lost as process heat
Energy	Low external energy input	High external energy input
Nutrients	Low nutrients requirements	May be required
Start-up period	Long	Short
State of development	Under development	Established
Pathogen removal	Low	Low
Nutrients removal	Via post treatment	Can be incorporated
Capital investment	Low	High
Operating cost	Low	High
Process stability	Unstable	Stable

*Adopted from Enongene, 2003

The performance of wastewater treatment plants can be evaluated on the basis of biogas yield, which is determined from the COD load and biogas production. The yield was calculated by taking the biogas temperature as 25°C and the biogas composition as 60% methane and 40% CO_2 and density of 1.184 kg/m^3 . It can be seen in Table 6 that Rooiwal water works produces the highest volume ($12,280 \text{ m}^3/\text{d}$) of methane. However, this plant has the lowest ($0.125 \text{ kgCH}_4/\text{kg COD}$) biogas yield. Table 7 shows that the number of aerobic system is comparable to the anaerobic ones in the same region.

Table 10; Wastewater treatment facility characteristics, Ekurhuleni Metro-Gauteng

Name and location of facility	Mean flow ML/day	Mean COD mg/L	Biogas production m³/day	Yield, kgBiogas/kgCOD
Ester Park	0.32	450	18,570	
Olifantsfontein	69.95	759	10,530	0.2349
Hartbeesfontein	35.70	845	10,530	0.4134
Ancor	26.49	856	7,920	0.4137
Benoni	8.31	646	1,875	0.4137
Daveyton	6.91	925	2,230	0.4132
Carl Grunding	2.22	895	Na	
Herbet Bickley	13.21	755	3,480	0.4133
Jans Smuts	6.55	450	1,030	0.4139
JP Marais	13.18	695	Na	
Rynfield	5.81	460	930	0.4121
Tsakane	14.01	387	Na	
Welgedacht	42.02	579	Na	
Rondebult	14.59	1230	6,270	0.4138
Dekema	26.23	822	7,530	0.4136
Vlakplaats	80.39	695	19,515	0.4137
Waterval	107.83	1002	37,740	0.4137

(Ochieng and Onyango 2011)

3.8. Conclusion

The adoption of green economy is imperative in order to respond to the ever increasing environmental degradation caused by carbon emissions from locomotives and industries. South Africa is one of the major world's producers of green-house gases from coal processing industries. Mitigation against air and water pollution is crucial for the implementation of green economy. From GE perspective the performance of a biological wastewater treatment plants can be evaluated on the basis of biogas yield, which is determined from the COD load and biogas production. In many wastewater treatment facilities, there is a mismatch between the operating conditions and the characteristics of raw materials. This has led to underutilization of the facilities or their total

collapse. Part of this problem can be attributed to a lack of required competencies and skills. Studies showed that many technical staff working in local governments have very little or no knowledge of green economy. South African cities and local governments are among the leading cities on green policies with strong local structures and technologies in the African continent. Efficient delivery of service requires appropriate skills and competencies. The provision of these skills involves the participation of various stakeholders including academic institutions and other government organs. It is expected that the findings will guide policy decisions on capacity or skill development priorities of the local government sector.

CHAPTER 4

4. Wastewater Treatment and Management of Infrastructure

4.1. Introduction

A total number of eleven (11) wastewater treatment plants that were studied from seven (7) municipalities in three (3) provinces of Gauteng, Mpumalanga and North West are shown on Table 11. The WWT plant study involved investigating underutilisation and overutilization of the plant, sources of waste water, pollutant loads in waste water, quality of the treated water, waste water treatment technology used, and management and maintenance of the plants. Each treatment plant was investigated individually to look at its design capacity in comparison to the current operational throughput. Waste water sources and pollutants loads in the effluent were also reviewed and the quality of the treated water was compared to the standards given for Green Drop compliance. The latest available Green Drop scores for each plant were checked and the risk ratings of the treated water to the environment is used to see if the plant is green technology compliant or not.

Table 11: Waste Water Treatment Plants studied

Province	Municipality District	WWT Plant
Gauteng	Emfuleni	Sebokeng
		Leeuwkuil
		Rietspruit
	Midvaal	Meyerton
	Westonaria	Westonaria
North West	Madibeng	Brits
	Matlosana	Hartebeesfontein
		Stilfontein
		Klerksdorp
Mpumalanga	Albert Luthuli	Carolina
	Lekwa	Standerton

4.2. Sources of feed to municipal plants

The main sources of influent in the majority of the wastewater treatment plants that were studied is comprised of domestic sewage water, industrial effluents, abattoirs effluents, and mines. Agricultural runoffs pollutants are often limited by agricultural activities in the vicinity and that is why most of the plants are not affected by such pollutants. Table 12 shows the sources of influent to eleven (11) plants that were studied.

Table 12: Sources of pollutants in wastewater treatment plants

Municipality	Matlosana			Emfuleni			Albert Luthuli	Lekwa	Westonaria	Midvaal	Madibeng
Sources	Hartebeesfontein	Stilfontein	Klersdoorp	Sebokeng	Leeuwkuil	Rietspruit	Carolina	Standerton	Westonaria	Meyerton	Brits
Domestic	X	X	X	X	X	X	X	X	X	X	X
Abattoirs					X			X			X
Industries		X	X		X	X		X		X	X
Agricultural activities											X
Petroleum industries											
Breweries											
Storm water		X								X	
Other (mines)							X		X		X

Pollution loads (qualitative analysis)

Table 13 summarises a sample of the pollution loads of some of the studied WWT plants. Not all studied WWT plants had the information about the loads of pollutants in the incoming influent streams.

Table 13: Pollution loads in wastewater influents

Municipality	Matlosana				Madibeng	
Raw Influent						
Determinand	Hartebeesfontein	Orkney	Stilfontein	Klersdoorp	Letlhabile	Brits
BOD (mg/L)						
COD (mg/L)	2480	1213	290	564	200	197
SS at 105 °C	939	308	101	244	390	28
TDS at 180 °C	1136	777	592	708		
TOC						
pH	7.27	7.91	7.74	7.6	7.14	7.42
Ammonia (NH4) (mg/L N)	112	55	17	38	70.4	2.18
Conductivity (mS/m)	238	138	108	136	143.7	201.5
TP (mg/L P)						12
Orthophosphate (mg/L P)	14	3.1	1	2		
TN (mg/L N)						
Nitrates & Nitrites (mg/L N)	<0.5	<0.5	<0.5	<0.5	<0.4	<0.5
E.coli (count/1mL)					80000000	65000000
Total Coliform (count/1mL)					1200000000	119000000
Bacteria, coliform, faecal (cfu/100 ml)						

4.3. Effluent characteristics

Table 14 some of the quality final effluent after it has been treated as it is being released to rivers and catchment ponds.

Table 14: Characteristics of the water quality after treatment

Municipality	Matlosana				Emfuleni	Madibeng	
Final Effluent							
BOD							
COD	58	361	55	186	20	51	55
SS at 105 °C	11	90	12	60	25	28	92
TDS	768	727	673	750			
TOC							
pH	7.64	7.61	7.62	7.55	1.3	7.37	7.42
Ammonia (NH4)	0.3	40	2.3	36	1.2	18.99	22.79
Conductivity (S/m)	130	138	109	143	3	116.4	201.5
TP (mg/L)					3.64		
TN (mg/L N)							
Nitrates & Nitrites (mg/L N)	<0.5	<0.5	2.7	<0.5	3.1	<0.5	0.8
E.coli (count/1mL)				4900	2676	100000	700
Total Coliform (count/1mL)					4296	169000	1700
Bacteria, coliform, faecal (cfu/100 ml)	>8000	>8000	>8000	4900			

4.4. Treatment method (aerobic, biofilters, anaerobic digesters)

As most of these plants were built during different time periods and also the fact that the plants are used to treat different types of waste water, the technology used in the plants were found to differ in general. Even though the treatment processes may be fundamentally similar, the process layout and unit operations or equipment used were found to be generally different. Table 15 shows the treatment technologies as used in studied treatment plants.

Table 15: Technology used for water treatment

Description	Hartebeesfontein	Stilfontein	Klersdoorp	Carolina	Standerton	Westonaria	Sebokeng	Leeukiel	Rietspruit	Meyerton	Brits
Screening	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Grit chamber	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Primary settling tank	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Trickling filter			N	N	N	N	N	Y	Y	N	N
Anaerobic	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Aerobic /activate sludge	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dissolved air flotation	N	N	N	N	N	N	Y	N	Y	N	N
Secondary settling tank	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Anaerobic digester	Y	N	N	N	N	N	Y	N	N	N	Y
Chlorination	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Sludge dewatering	Y	Y	N	N	N	Y	Y	Y	Y	N	Y
Lagoons/Ponds	Y	N	Y	N	N	N		Y		Y	N
Drying beds	Y	Y	Y	N	Y	Y	Y		Y	Y	Y

4.5. Influent flow rates and plant capacity

Table 16 shows the capacity and the operating throughputs of the studied plants.

Table 16: Design capacities and operating capacities of studied WWT plants

Municipality	WWTP	Year Commisioned	Design capacity (Mℓ/d)	Current Throughput (Mℓ/d)	Average influent rate (Mℓ/d)	Upgrading approved/ in progress
Matlosana	Hartebeesfontein		8	6.5	6	Not available
	Stilfontein		8	13	11	Not available
	Klersdoorp		36	26	26	Y
Emfuleni	Sebokeng	1955	100	145	139	Y
	Leeuwkuil	1954	36	48	44	N
	Rietspruit	1952	36	30	28	N
Albert Luthuli	Carolina		2.5	1.6	1.4	Y
Gert Sibande	Lekwa		12			Y
Westonaria	Westonaria		37	25	14	N
Madibeng	Brits		14	7	7	N
Midvaal	Meyerton	1970	10	14	14	Y

4.6. Management of the infrastructure (settling tanks, impellers, wetlands)

A study using a rubric was also performed to assess effectiveness of infrastructure management and maintenance.

Table 17 shows the results of the rubric study on state of the infrastructure.

Table 17: Management and maintenance of the treatment facilities

Municipality	Matlosana			Emfuleni			Albert Luthuli	Lekwa	Westonaria	Madibeng	Midvaal
Description	Hartebeesfontein	Stilfontein	Klersdoorp	Sebokeng	Leeuwkuil	Rietspruit	Carolina	Standerton	Westonaria	Brits	Meyerton
Structurally sound, protected from corrosion	N	N	N	N	Y	Y	N	Y	Y	Y	N
Pipes/valves/disconnects in good working condition	Y	N	N	N		Y	N	Y	Y	Y	Y
Fenced	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y
Grounds well maintained in safe sanitary condition	N	Y	N	Y	Y	Y	N	N	Y	Y	Y
Control panel enclosures in good condition	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y
Monitoring data collected as required	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Sludge holding tanks in good condition	N	Y	N	Y	N	Y	N	Y	Y	Y	Y
Screening bars and secondary filters in good condition	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y
Aeration system operating properly	N	Y	N	Y	N	Y	N	Y	Y	Y	Y
Clarifiers in good condition	N	N	N	Y	N	Y	N	N	Y	Y	Y
Flow monitoring devices and chlorinator in good condition	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y

Key: N= No; Y=Yes

Furthermore, the maintenance rubric was further translated into a chart shown on Figure 1. This shows that 36% of the studied plants are not well maintained, while 64% shows good to excellent maintenance standings of more than 56% score in the rubric.

□ Poor (0-27%) ▨ Fair (28-55%) ▩ Good (56-82%) ■ Excellent (83-100%)

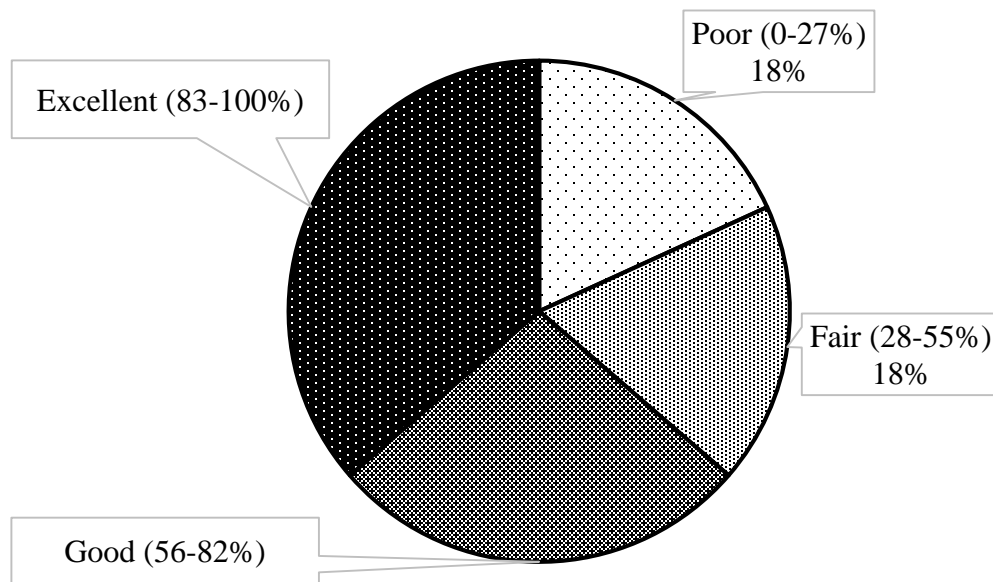


Figure 1: A chart showing maintenance state of the WWT facilities

Most of the structures displayed signs of corrosion, however it should be well noted that the only thing that is contributing to this condition is paint. Generally, any structure is susceptible to corrosion, and this can be prevented by repainting some of the structures after a certain period. Some of the pipelines, pumps, motors, and valves disconnected during maintenance were still in good condition. It is highly commended that most of the wastewater treatment plants are fenced to minimize unauthorized trespassing and minimize possibility of equipment from being vandalised. Although some of the treatments plants are maintaining the grounds/gardens (sanitation), it is always a challenge because some treatment works yards are huge and don't have enough employees (especially general workers) and equipment such as grass mowers, grass trimmers, etc. In general, wastewater treatment control panels are well enclosed and are in good conditions, except for those treatment works shown in table. It has already been emphasized that some of the treatment works equipment such as clarifiers and aeration systems are not in good conditions either due to maintenances issues or an act of negligence and these issues should be given attention by the responsible personnel in any plant. Although all of the treatments plants concede that they are monitoring data (e.g., sampling, flow calculations, analysis, etc.) as per required, it should be highly scrutinized because one of the concerns raised in green drop report is that majority of the plants do not collect data as per required and this is regarded as a green drop deficiency. Some of

the plants do not have flow measuring devices or the measuring devices are not working accurate (e.g., influent flow meters, aeration flow meter, etc.) such as in Stilfontein, Standerton, and Carolina WWTPs as shown in Table 17.

Currently most of the wastewater treatment plants utilize screening auto and manual operated screens, grit chambers, primary settling tanks (PSTs), aerobic, anaerobic, secondary settling tanks (SSTs), chlorination, and drying beds as primary methods to treat wastewater. Biological trickling filters, dissolved air floatation, anaerobic digesters, and lagoons/ponds wastewater treatment methods are used by few treatment works. It was observed that all of the treatment work uses BNR systems (aerobic, anoxic and anaerobic methods) to remove nutrients from the wastewater. None of the treatment works is producing biogas from the anaerobic digesters. Either the biogas is released to the atmosphere such as in Sebokeng WWTP or the digesters are completely decommissioned in most of the plants. Therefore, one of the opportunities in wastewater treatment plants is to thoroughly investigate feasibility of using anaerobic digesters for biogas production.

4.6.1. Emfuleni municipality

Emfuleni municipality has three wastewater treatment plants (WWTP), namely: Sebokeng (Figure 2), Rietspruit (Figure 3) and Leeukuil (Figure 4). Sebokeng is the largest WWTP in Emfuleni with a 100 Mℓ/d plant design capacity, while the design capacity of both Leeukuil and Rietspruit is 36 Mℓ/d each. Domestic sewage is the main waste water supply to the Sebokeng WWTP. Sebokeng WWTP is divided into three activated sludge processes or modules of 30 Mℓ/d, 35 Mℓ/d and 35 Mℓ/d. Currently, Sebokeng WWTP has an average influent rate of ± 140 Mℓ/d. The plant is currently overloaded with ± 40 Mℓ/d (40%) excess of domestic sewage water and this overload creates a major challenge for the plant to produce product water quality in compliance with green economy as outlined in Department of Water Affairs legislature. Unfortunately, this overload on the system has a high influence on final water quality and can impact on the green drop scores (GDS) and the green drop certificate (GDC), which are used as measures of quality compliance (Department of Water Affairs, 2011). GDC certificate is only given to plants or municipalities with >90% green drop scores, while on the other hand wastewater risk rating should always be kept at least below 50% (low risk) and not more than that. Sebokeng plant achieved 66% green drop score in 2011 according to green drop report (Department of Water Affairs 2011). However, it is acknowledged that the municipality has realised the importance of compliance and green economy by proposing that the current plant capacity should be increased. The current

infrastructure is well maintained, the municipality has implemented a plan to expand and upgrade the 100 Mℓ/d plant to 150 Mℓ/d. A 50 Mℓ/d plant is currently being constructed according the municipality plan. Therefore, the current construction and expansion of the plant is expected to alleviate some of the current effluent quality deficits which are a result of capacity overload. The 100 Mℓ/d plant use biological nutrients removal (BNR) system to remove nitrates, ammonia, and phosphates in the wastewater. The plant facilities are well maintained and the overall condition of the plant is neat. The plant has several anaerobic digesters. However the digesters are only used for raw sludge treatment and the gas produced in the digesters is released to the atmosphere. This can provide a good opportunity to produce green gas biofuel. It is noted that green drop wastewater risk rating of the plant has increased from 56% (moderate risk) in 2013 to 75% (high risk) in 2014 (Water Institute of South Africa 2014). Main factors which highly contributed to a current risk rating are poor effluent discharge quality compliance, over capacitated plant, and partial availability of technical skilled personnel.



Figure 2: Sections of Sebokeng WWT plant

Designed capacity of Rietspruit WWTP is 36 Mℓ/d with an average influent rate of ± 28 Mℓ/d. Rietspruit WWTP has two modules, one module uses BNR, and the other use biological trickling filters (BTF). Rietspruit WWTP treat domestic sewage, and industrial effluent. BNR system is well maintain and more attention should be given to sedimentation tanks of BTF system. Rietspruit

green drop wastewater risk rating has increased from 48% (low risk) in 2013 to 55% (moderate risk) in 2014 (Water Institute of South Africa 2014). The risk are associated with low water quality compliance and inadequate technical skills. It was observed that the chlorination system does not allow adequate residence time with final effluent because the dosing of chlorine is done in a pipeline with the final effluent, and there is no chlorination chamber. The plant obtained 61% green drop scores in 2011 which is well below the GDC requirement of above 90% (Department of Water Affairs 2011).



Figure 3: Section of Rietspruit WWT plant

Leeukuil WWTP has a capacity of 36 Mℓ/d, and the average influent rate of ± 44 Mℓ/d. This plant has two modules that utilize biological trickling filters (16 Mℓ/d), and biological nutrients removal (20 Mℓ/d). Leeukuil WWTP treat domestic sewage, abattoir effluent, and industrial effluent. Unfortunately the current BNR system is overloaded because biological trickling filters are not working. Some of BTFs equipment are decommissioned due to a previous financial dispute between municipality and the contractor who was responsible to service the filters. However, it is highly acknowledged that municipality and water affairs department have approved financial proposal to buy new trickling filter equipment and recommission the BTF module and this will improve green drop ratings. It will be challenging however at this stage to obtain a good green drop score on an overloaded aeration BNR module, and a nonworking BTF module as the final

effluent will not fully comply with the water quality standards. The plant has anaerobic digesters but they are not working at this stage. The plant achieved 72% green drop score according to green drop report of 2011 (Department of Water Affairs 2011). Leeukuil green drop wastewater risk rating has increased from 48% (low risk) in 2013 to 55% (moderate risk) in 2014 (Water Institute of South Africa 2014). Main factors which contributed to a current risk rating are poor microbial discharge quality compliance, over capacitated plant, and partial availability of technical skilled personnel.



Figure 4: Section of Leeukuil WWT plant

Recommendations

- Adopt and implement green drop PAT document.
- Increase technical skilled personnel on the plants.
- Prioritize discharge effluent deficits.
- Over capacitated treatment works are addressed.

4.6.2. Matlosana Municipality

Matlosana municipality has several waste water treatment plants which include: Klerksdorp, Haartbeesfontein, and Stilfontein. Klerksdorp WWTP (

Figure 5) has a design capacity of 36 Mℓ/d, and the average influent rate of ± 26 Mℓ/d. Domestic sewage and industrial effluent are the main sources of pollutants in this treatment works. The overall condition of this plant is poor and needs attention. Sludge holding tanks, screening, aeration system, and clarifiers are all in a poor condition. The treatment works has three automated mechanical screen, but currently only one screen is working. Grit removal pump is not working properly. The plant use BNR system, however it was observed that several mechanical aerators of the system and clarifiers are neither working at all nor not working properly. It should be well noted that some of these technical problems have been there for more than seven months. According to a green drop report of 2014 risk ratings of Klerksdorp treatment works increased from 56% (moderate risk) in 2013 to 78% (high risk) in 2014 (Water Institute of South Africa 2014). Overall, the high wastewater risk rating is attributed to shortage of technical skills at the plant, poor monitoring/measuring of the influent and effluent, and poor annual average effluent compliance quality (according to microbial and chemical compliances). It is however acknowledged that according to the report assessment criteria, physical compliance of the treatment is excellent (100% compliance).



Figure 5: Section of Klerksdorp WWT plant

Hartbeesfontein WWTP has a design capacity of 8 Mℓ/d, and the average influent rate of ± 6 Mℓ/d. The main source of pollutant to this treatment works is domestic sewage waste. The plant has similar technical problems as those encountered at Klerksdorp treatment plant, however some of these problems have existed for more than a year. Flow meters need to be calibrated. According to 2014 green drop progress report it shows that risk ratings of Hartbeesfontein treatment works increased from 70% (high risk) in 2013 to 100% (critical risk) (Water Institute of South Africa 2014).

Stilfontein WWTP has a plant capacity of 8 Mℓ/d, with an average flow of ± 11 Mℓ/d. Flow meters need calibration, and clarifiers are not in a good condition. Risk ratings of Stilfontein WWTP increased from 54% (moderate risk) in 2013 to 100% (critical risk) in 2014 (Water Institute of South Africa 2014). Overall, the high wastewater risk rating is attributed to shortage of technical skills at the plant, poor monitoring/measuring of the influent and effluent, and poor annual average effluent compliance quality (according to microbial and chemical compliances).

Recommendations

- Have technical skilled and maintenance team onsite.
- Schedule maintenance on weekly basis.
- Implement preventative maintenance schedules.
- Increase maintenance plan turnaround time.
- Repair or replace equipment and parts.
- Ensure that all flow measuring devices are working.
- Outline wastewater quality monitoring program (sampling sites, frequency of sampling, etc.).

4.6.3. Albert Luthuli municipality

The municipality has portable and wastewater treatment plant situated in Carolina (

Figure 6). Carolina WWTP has a design capacity of 2.5 Mℓ/d, and the average influent rate is estimated to be ± 1.6 Mℓ/d although the influent flow meter is not working properly. It is said that the meter was fixed several times but it is still not working properly. The plant has two mechanical aerators, but one of the aerators is not working. Sludge from clarifiers is not discharged to any lagoons, drying beds or ponds because it does not have such treatment facilities. It is foreseen that the two final clarifiers will be overloaded with the activated sludge, consequently causing the plant

to be bypassed several times in order to clean the clarifiers or the high concentration of the activated sludge will increase torque loads on the clarifier rake blades causing the blades to break. This will have devastating impact on the overall performance of the plant. The plant treats domestic sewage and trivial amount of mining pollutants. The plant does not have any bio filters or anaerobic digesters. The municipality is prioritising on portable water but it is still vital to maintain the WWTP.

Most of the surrounding areas (communities) are still using old sanitation systems such as pit toilets and they are not connected to the current sewer system. However the municipality has approved a plan to incorporate the communities into the current sewage system, but this will increase the WWTP influent rate. However, it is highly acknowledged that the municipality has realised the importance of compliance and green economy by proposing that the current plant capacity should be increased. The current infrastructure is poorly maintained, the municipality has proposed to expand and upgrade the 2.5 Mℓ/d plant to 4 Mℓ/d. Therefore, the expansion and upgrading of the plant is expected to alleviate the existing effluent quality deficits and address green economy. The plant achieved 18% green drop score in 2011 according to green drop report (Department of Water Affairs 2011), and this shows how serious is the problem in the treatment works. Green drop risk ratings of Carolina treatment works has not changed for the year 2013-2014 and it is still 76% (high risk) (Water Institute of South Africa 2014). The high risk rating of this plant according to the green drop report is due to lack of plant supervision, shortage of maintenance skills, poor flows monitoring, and poor effluent quality compliance.



Figure 6: Section of Carolina WWT plant

Recommendations

- Have a plant supervisor and skilled maintenance team onsite.
- Implement preventative maintenance schedules.
- Ensure that all flow measuring devices are working accurate.
- Maintain infrastructure regularly.
- Outline wastewater quality monitoring program (sampling sites, frequency of sampling, etc.).
- Monitor sludge and final effluent.

4.6.4. Madibeng municipality

Brits WWTP (Figure 7) in Madibeng municipality has a plant designed capacity of 14 Mℓ/d , and the current average influent rate is ± 7 Mℓ/d. Sources of pollutants into this WWTP are domestic sewage, abattoirs effluents, mining effluents, and agricultural runoffs. The plant use BNR system, and the infrastructure is well maintained. The plant has its own onsite analytical laboratory to do

all the water quality analysis. Green drop wastewater risk rating of this plant has increased from 45% (low risk) in 2013 to 50% (moderate risk) in 2014 (Water Institute of South Africa 2014). Effluent compliance and low technical skilled personnel contributed towards an increase in the rating risk.

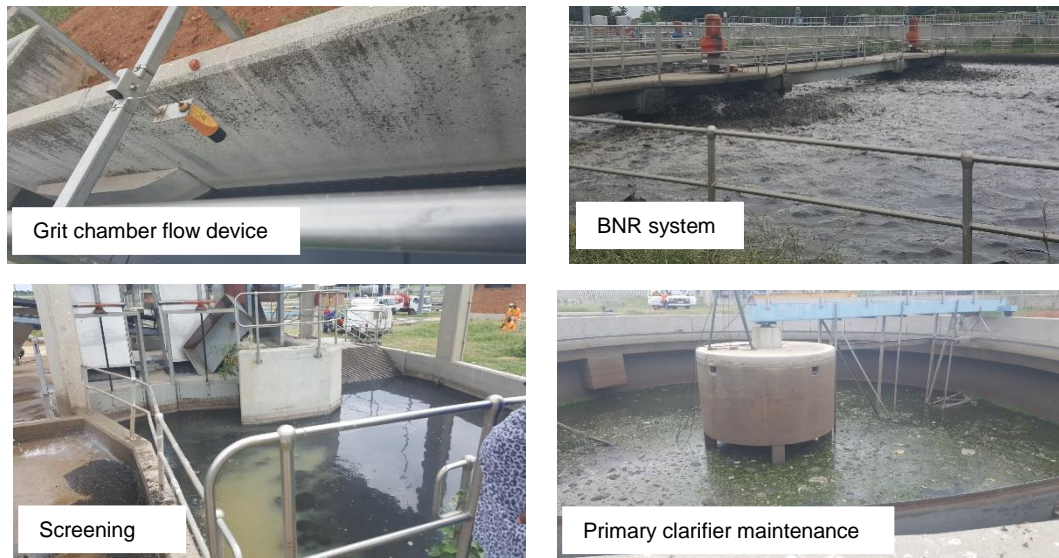


Figure 7: Section of Brits WWT plant

4.6.5. Midvaal municipality

Meyerton WWTP in Midvaal municipality has a designed plant capacity of 10 Mℓ/d, and the current average influent rate is ± 14 Mℓ/d. The plant is currently over capacitated with ± 4 Mℓ/d ($\pm 40\%$) and it can be challenging to address green economy specifically looking at the effluent quality compliance according to water affairs legislation. However, it is highly acknowledged that the municipality has realised the importance of compliance and green economy by proposing that the current plant capacity should be increased. The current infrastructure is well maintained, the municipality has implemented a plan to expand and upgrade the 10 Mℓ/d plant to 25 Mℓ/d. Additional works with a treatment plant capacity of 15 Mℓ/d is being constructed. Therefore, the current construction and expansion of the plant is expected to alleviate existing effluent quality analysis deficits. Domestic sewage, storm water, and industrial effluent are the main sources of pollutants to this treatment works. Green drop wastewater risk rating of this plant has increased from 68% (high risk) in 2013 to 72% (high risk) in 2014 (Water Institute of South Africa 2014).

Main factors which highly contributed to a current risk rating are poor effluent discharge quality compliance, over capacitated plant, and partial availability of technical skilled personnel.

Recommendations

- Over capacitated plant is being addressed accordingly.
- Prioritize on water quality compliance.
- Increase technical skilled personnel.
- Outline wastewater quality monitoring program (sampling sites, frequency of sampling, etc.).

4.6.6. Westonaria municipality

Westonaria WWTP has a designed capacity of 37 Mℓ/d (18 Mℓ/d old blower plant, and a new 15 Mℓ/d BNR plant) and the current average influent rate is ± 14 Mℓ/d. It should be well noted and acknowledged that the municipality commissioned a new 15 Mℓ/d BNR plant in 2014. This should translate to a significant green drop improvement in the future. According to the design of Westonaria WWTP a planned operating capacity should be ± 25 Mℓ/d, however the plant is currently under capacitated. Main sources of pollutants in Westonaria WWTP are domestic pollutants and mining effluents. Westonaria is described as a dolomitic area, and it is suspected that some of the influent from the surrounding areas or from pumping stations is lost through the dolomitic sinkholes. This happens because often time's dolomitic areas develop several sinking holes over the period of time, as this happens resistance of the installed influent pipelines underground is reduced and the pipelines are prone to bending or bursting causing the influent to be lost through the ground. The plant consist of a new automated BNR (with aerators) module, and an old manual operating module (with compressed air). The old module plant had anaerobic digesters, however the digesters are no longer working. The plant facilities are well maintained and the overall condition of the plant is neat. Green drop report shows not significant changes in the risk ratings of 2013-2014. The rating for 2013-2014 is 51.9% (moderate risk). The risk can be addressed by improving water quality compliance and by having more technical skilled personnel. However it is possible that the old plant effluent quality has an effect on the average effluent quality of the whole plant even after the commissioning of the new BNR system.



Figure 8: Section of Westonaria WWT plant

Recommendations

- Increase technical skilled personnel.
- Ensure that onsite daily plant results are well recorded.
- Prioritize on the effluent quality of the old plant.
- Identify the effect of mining sinkholes on the overall plant performance.

4.6.7. Lekwa municipality

Standerton WWTP in Lekwa municipality has a plant designed capacity of 12 Mℓ/d. The influent to this treatment works is from industries, domestic sewage, and abattoirs. This plant has BNR and BTF systems, however some of the biofilters has structural and mechanical breakdown, some of which is being attended to. No measuring device (flow meter at influent) and the drying beds are not well maintained. The current BNR system infrastructure is well maintained and more should be done on the old BTF system. It was observed that the municipality has implemented a plan to expand the plant (screening and grit chamber sections) and the work is already in progress. The plant has achieved 19% green drop score in 2011 according to green drop report (Department of Water Affairs 2011). The plant risk rating is high and this is attributed to inadequate skilled

personnel, irregular influent and effluent quality monitoring, poor water quality compliances, and inadequate maintenance team.



Figure 9: Section of Standerton WWT plant

Recommendations

- Increase technical skilled person.
- Escalate maintenance plan turnaround time.
- Install/repair flow measuring devices.
- Outline wastewater quality monitoring program (sampling sites, frequency of sampling, etc.).

4.7. Compliance with green technology

All the studied WWT plant have been given the risk rating above the minimum requirement limit (<50%) as shown in Table 18.

Table 18: Green Drop Risk rating of studied WWT plants

Municipality	WWTP	Green Drop Risk Rating	Risk Factor	Green Technology Compliance
Matlosana	Hartebeesfontein	100%	Critical Risk	NO
	Stilfontein	100%	Critical Risk	NO
	Klerksdorp	78%	High Risk	NO
Emfuleni	Sebokeng	75%	High Risk	NO
	Leeuwkuil	55%	Moderate Risk	NO
	Rietspruit	55%	Moderate Risk	NO
Albert Luthuli	Carolina	76%	High Risk	NO
Gert Sibande	Lekwa			
Westonaria	Westonaria	52%	Moderate Risk	NO
Madibeng	Brits	50%	Moderate Risk	NO
Midvaal	Meyerton	72%	High Risk	NO

Source; *Adapted from Water Institute of South Africa 2014.*

It can be seen that, based on risk factor rating alone, none of the plants are not green drop compliant, and therefore cannot be considered to green economy requirements.

4.1. Conclusions

The plant facilities are well maintained and neat. However, the overall condition of most plants visited is poor and needs attention. Sludge holding tanks, screening, aeration system, and clarifiers are all in a poor condition. In some plants, treated effluent was hardly distinguishable from the influent even in terms of colour. In some plants, old plant effluent quality has an effect on the average effluent quality of the whole plant even after the commissioning of the new systems. There was a lack of proper maintenance in most plants with some equipment being out of commission for up to about a year. A number of plants are used above their design limit, with some going as much as 140% of the design capacity. The water quality produced by all the plants studied does not meet the green drop risk rating with some plants showing critical risk of 100%.

CHAPTER 5

5. Conventional and advanced wastewater treatment methods

The main objective for treating wastewater is to allow the safe disposal of effluents from human and industrial activities without causing damage to human health or the environment. Wastewater can be effectively disposed of by utilizing it for irrigation or other industrial purposes such as cooling. The quality of the treated effluent on these activities however, has an effect on the plant or aquaculture system. For example in the case of agriculture, the effluent quality will depend on the crops to be irrigated, soil condition and the system for distribution of effluent. While restriction of crops and irrigation system selection could minimize health risk and thus reducing the degree of wastewater pre-application treatment, similar approach to aquaculture is not achievable hence more reliance must be placed on control through effective treatment of wastewater. Moreover most WWT plants especially in South Africa discharge their treated effluent into natural water bodies where the aquatic flora and fauna must be preserved. The treatment methods adopted despite targeting the recommended effluent standards, should also take into consideration cost and also acknowledge the difficulty in reliable operation of complex systems especially in developing countries.

Conventional wastewater treatment involves physical, chemical or biological processes or combinations of these processes, and operations to remove organic matter, solids and nutrients in some cases. Conventional treatment processes have been long established in removing contaminants that are of concern to the environment and public health (Singh et al., 2011). Treatment of wastewater takes into consideration the aspects related to contamination and has to ensure that the treated effluent is free from any substance that might have an adverse effect on humans and the environment. The different degrees for conventional treatment are preliminary, primary, secondary, and tertiary and/or advanced treatment, in increasing order. Figure 10 gives a summary of this processes. The conventional methods do not remove some organic pollutants, thus necessitating the need for further treatment (advanced methods) to convert the pollutants into harmless products such as CO₂ and H₂O (Abdullah et al., 2013). The elimination of toxic industrial pollutants from wastewater is presently an important subject in pollution control. A number of the emerging industrial pollutants are resistant to conventional chemical and biological treatment

methods (Kositzi et al., 2004). With the rapid industrialization, the development of an efficient wastewater treatment method is therefore necessary.

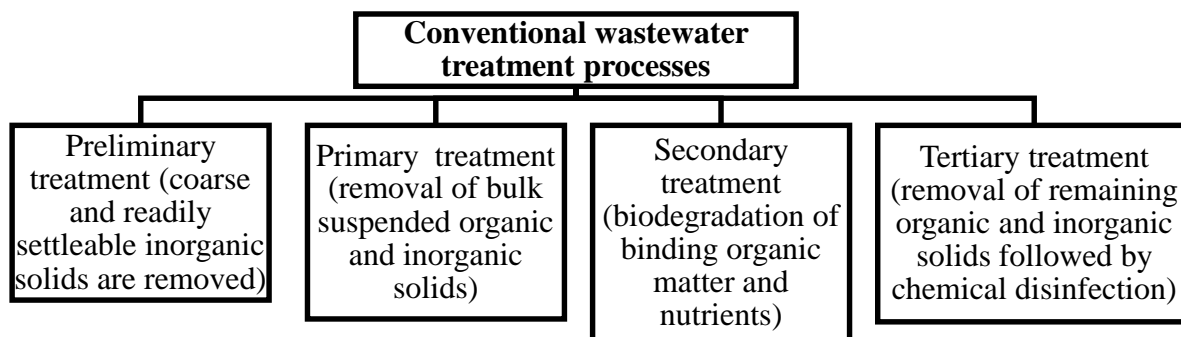


Figure 10: Schematic diagram of conventional waste water treatment processes.

New techniques for wastewater treatment have emerged with improved performance and are also environmental friendly. Various physicochemical methods such as adsorption, coagulation-flocculation, and advanced oxidation processes (AOPs) such as heterogeneous photocatalysis, Fenton, photo-Fenton and ozonation have been tested for the treatment of wastewater. These techniques have received attention due to their ‘green’ nature in that they eliminate or reduce the use or generation of hazardous substances (Navgire et al., 2012). The main challenge with the use of AOPs is the production of intermediate compounds, which affect the performance of the photo reactors. Most of the technical difficulties associated with AOPs arise from the fact that oxidation processes are non-selective with the potential for significant interference (Stocking et al., 2011).

5.1. Biological treatment methods

Secondary treatment is aimed at further treatment of effluent from primary treatment in order to remove residual organics and reduce total suspended solids. Secondary treatment in most cases follow primary treatment and involves removal of colloidal and dissolved organic matter that are biodegradable using biological treatment methods. Biodegradation of complex, toxic and recalcitrant compounds can be achieved by using microorganisms such as bacteria, fungi, an actinomycetes. These microorganisms have an inherent capacity to metabolize a variety of substrates. Biodegradation and decolorization of colour pigment present in industrial wastewater especially from distillery and fermentation industry has been exploited (Pillai *et al.*, 2012) The

biological treatment of wastewater undergoes two processes which include anaerobic and aerobic treatments.

Apart from aerobic and anaerobic systems, some of the plants also employ natural low-rate biological treatment systems, which tend to be lower in cost and easily maintained and operated. These processes are however land intensive, but, are more effective and reliable in pathogen removal if properly designed and not overloaded. Among the natural systems available, stabilization and lagoon ponds have been widely used by the WWT plants. The ponds in most cases are overloaded and not well maintained (Figure 11) thus defeating their primary purpose.



Figure 11; Unmaintained lagoon pond

Anaerobic treatment is an accepted practice with a high rate reactor designs being tried at pilot and full scales (Santal and Singh, 2013). Aerobic treatment of anaerobically treated wastewater has also been explored. This method of treatment however is not common in most South African wastewater treatment plants due to both high installation and maintenance costs. The anaerobic digesters in the visited WWT plants are either used for sludge storage or not utilized at all. Figure 12 gives some of the unutilized anaerobic digesters. In anaerobic treatment, energy is extracted from the waste components without introducing air or oxygen. It involves biological processes in which organic materials are degraded to produce biogas. The energy extracted can be used to run the treatment process thereby cutting on the treatment cost. Even after anaerobic treatment, some organic compounds causing color still remain. These compounds can be removed to a minimal extent by aerobic digestion (Rajagopal *et al.*, 2014).



Figure 12; Unutilized anaerobic digesters

Aerobic treatment is performed in the presence of oxygen by anaerobic bacteria that metabolize the organic matter resulting thus producing more microorganisms and inorganic end products such as H_2O , CO_2 and NH_3 . All the WWT plants visited employ several aerobic biological processes for secondary treatment with the main difference on the manner of oxygen supply to the microorganisms and in the metabolism rate of organic matter. High rate processes are characterised by high concentration of microorganisms. Common high rate processes employed by the WWT plants visited include activated sludge, biofilters and biological nutrient removal (BNR). In BNR systems, biological processes are incorporated to reduce effluent loads of total nitrogen and total phosphorus. This method is more effective than the trickling filters (biofilters) as evidenced by the discharged effluents in Figure 13 and 14 for both BNR and biofilter systems respectively.



Figure 13; A BNR system with clear effluent discharged in secondary settling tank.



Figure 14; Biofilter system with turbid effluent discharged from secondary settling tank.

Whereas the BNR seems to be very effective in nutrient removal resulting in almost clear effluent, BNR limits are still not enough for the protection of water quality. The nutrient levels of effluents from BNR systems of more than 10 mg/L and 5 mg/L for total nitrogen and total phosphorus, as observed in most plants, can cause unbalanced ecosystems given the large amount of effluent discharged by the WWT plants. A new acronym ENR for enhanced nutrient removal has been introduced in other parts of the world. BNR is further refined by ENR leading to the removal of total nitrogen and total phosphorus to levels as low as 3 mg/L and 0.3 mg/L respectively. Given that most plants are already utilising BNR systems, introduction of ENR will be relatively simple as it only involves addition of tertiary filtration such as denitrification filters (deep-bed or continuous backwash filters). Other tertiary or advanced treatment processes that could be employed for effective treatment of wastewater to remove recalcitrant contaminants include adsorption, coagulation and flocculation, membrane and advanced oxidation processes.

5.2. Adsorption

Adsorption occurs when a substances (adsorbate) in gas or liquid is physically or chemically bonded to a surface of a solid (adsorbent). Adsorption process has been used to recover polyphenols from wastewater using common solvents and adsorbents. Adsorption is considered as an effective, efficient and economic method for the removal of water contaminants. Effective adsorbents include: activated carbon, clay minerals and silica, zeolites, metal oxides and modified composites. Adsorption operation exploits the ability of certain solid to preferentially concentrate specific substance from solution to their surface. This method is effective in the removal of organic pollutants from industrial effluents (Kulkarni *et al.*, 2011).

5.3. Coagulation and flocculation processes

Coagulation is the destabilization of colloids by neutralizing the forces keeping them apart. Cationic coagulants provide positive electric charges to reduce the negative charge of the colloids. This results in the particles colliding to form larger particles known as flocs. Flocculation is the action of polymers to form bridges between the flocs, and bind the particles into larger clumps. Coagulation and flocculation are commonly used methods for the removal of particulates and organic matter from wastewater. These methods are conducted by adding chemicals such as aluminium sulphate which leads to the formation of the flocs (Tripathi *et al.*, 2012). These chemicals possess harmful effects and the sludge that remains after treatment contains high concentrations of coagulants and flocculants making it unsuitable for use as addition to fertilizer or feed.

5.4. Advanced oxidation processes (ozone, Fenton and photo Fenton)

Advanced oxidation processes (AOPs) are widely used for the removal of organic constituents from industrial wastewater. AOP type procedures are promising technologies for treating wastewater containing non-biodegradable toxic organic compounds. The procedures are based on generation of highly oxidative hydroxyl radicals (HO^\bullet) in the reaction medium. Fenton oxidation is one of the AOPs where hydrogen peroxide (H_2O_2) is reacted with ferrous ion (Fe^{2+}) to generate hydroxyl radicals (HO^\bullet) (Equation 1) with high oxidation potential leading to decolorization of wastewater. Fenton oxidation is effective in wastewater treatment but suffer from high sensitivity to condition of operation and the pollutants present in the wastewater. The reaction can be enhanced by UV/Vis light (Equation 2), producing additional HO^\bullet radicals and leading to the regeneration of the catalyst a process known as photo Fenton reaction (Kositzki, *et al.*, 2004).



Ozonation has been used for degradation of recalcitrant organic compounds of both natural and anthropogenic origin. Ozone (O_3) has desirable properties such as solubility in water, powerful oxidative capability for degradation of many organic compounds and also results in biodegradable oxidation products. Ozone is very reactive towards compounds incorporating conjugated double bonds, often associated with color, and functional group with high electron densities. O_3 is used in

main areas such as disinfection, removal of taste, odour, color and particles. The addition of hydrogen peroxide (H_2O_2) to aqueous solution of ozone enhances the decomposition of O_3 with the formation of more hydroxyl radicals. The combination of UV light and ozone/hydrogen peroxide or both significantly enhances the rate of generating free radicals. Homogeneous and heterogeneous catalysts have been shown to improve the efficiency for removal of organic compounds in aqueous solution. Homogeneous catalysts such as zinc and copper sulfates, silver nitrate, chromium trioxide and also heterogeneous catalysts, Ru/CeO_2 , MnO_2 , $\text{TiO}_2/\text{Al}_2\text{O}_3$ and $\text{Pt/Al}_2\text{O}_3$ have been applied in catalytic ozonation (Heponiemi and Lassi, 2012).

Duff et al. (2002) reported that ozone treatment of wastewater reduced COD by 22% but increased the overall BOD. This was as a result of the conversion of high molecular weight COD to lower molecular weight compounds capable of exerting a BOD influence. Ozonation alone is therefore not effective in treatment of distillery wastewater COD. Ozonation seems effective when coupled with biodegradation as it is suitable for increasing the biodegradability of distillery wastewater. Ozone being an electrophilic agent can attack aromatic polyphenols which are toxic to microorganisms. Ozonation pre-treatment followed by aerobic biological oxidation has been found to be the preferable ozone combined with biodegradation treatment method for distillery wastewater.

Since emerging contaminants are recalcitrant to biodegradation, their elimination is mainly based on physical or chemical procedures such as adsorption, coagulation and flocculation, and oxidation. Some of these methods are effective but suffer shortcomings such as high reagent dosage, high cost, formation of hazardous by-products, and high energy consumption in addition to generating large amount of sludge (Pillai et al., 2012). Photocatalysis, which forms part of advanced oxidation processes (AOPs), is an emerging technique valuable for water purification and wastewater treatment. Photocatalysis offer the advantage of destroying pollutants in contrast to other methods that transfer the contaminants from one form to another. In this way, organic and inorganic substances are transformed or degraded into less harmful products.

5.5. Photocatalysis

Photocatalysis is a photoinduced reaction accelerated by the presence of a catalyst (Mills & Hunte, 2000). Photocatalytic reactions are activated by absorption of a photon which has sufficient energy that is equal to or higher than the bandgap energy of the absorbing catalyst. This absorption causes charge separation resulting from the promotion of an electron (e^-) from the valence band of the semiconductor catalyst to the conduction band leading to the generation of a hole (h^+) in the valence band (Akpan & Hameed, 2009). The promoted electrons in the conduction band reduce oxygen to $O_2^{\bullet-}$. Positive holes oxidize OH^- or H_2O resulting in the formation of hydroxyl radicals (HO^\bullet) which further oxidize most of the organic substrate in addition to the minimal direct oxidation of the substrate by h^+ . According to Litter (1999) the oxidative pathway performed by direct hole attack or mediated by HO^\bullet radicals in their free or adsorbed forms, in many cases lead to complete mineralization of organic substrate to CO_2 and H_2O . The excited electrons can also react with oxygen molecules to form superoxide radicals ($O_2^{\bullet-}$), which can react with H^+ to provide hydroxyl radicals.

Application of AOPs in treatment of industrial wastewater has been reported by many researchers. These processes can be combined in various ways to form hybrid systems that reduce the degradation time and while increasing the area of application. Apollo et al., (2014) used UV/ H_2O_2 /TiO₂/Zeolite hybrid system for the treatment of molasses wastewater for COD and color. Ozonation of distillery wastewater has also been tried to evaluate the process based on organic matter removal and decolorization efficiencies. Ozone generation was based on the reaction of oxygen with UV light (Navgire *et al.* 2012), successfully photodegraded molasses wastewater using a synthesized nanocrystalline composite of TiO₂ and MoO₃. The composite showed high activity for the photodegradation of molasses. While so many studies have looked into the application of AOPs in the treatment of industrial wastewater, few researches have been focused on distillery effluents especially molasses wastewater.

5.6. Membrane treatment

Membrane separation techniques including reverse osmosis, nanofiltration, ultrafiltration, micro-filtration, gas and vapour separation, and electro-dialysis have developed from laboratory to industrial scale application. A total ceramic membrane area of 0.2 m² was used to pre-treat molasses wastewater prior to anaerobic digestion. The pre-treatment reduced the COD by half from 36,000 to 18,000 mg/L, and also improved the efficiency of the anaerobic process as a result of the removal of inhibiting substances. Reverse osmosis (RO) has also been applied in the treatment of wastewater by holding up anaerobically digested effluent in a RO system maintained under aerobic conditions. The treated RO effluent can then be mixed with fresh water and reused in processes such as wastewater dilution, make-up cooling water and washing (Satyawali and Balakrishnan, 2008). Membrane technology integrated with anaerobic digestion can result in remarkable removal of COD.

5.1. Conclusion

All the WWT plants visited employ several aerobic biological processes for secondary treatment with the main difference on the manner of oxygen supply to the microorganisms and in the metabolism rate of organic matter. However, other tertiary or advanced treatment processes that could be employed for effective treatment of wastewater to remove recalcitrant contaminants include adsorption, coagulation and flocculation, reverse osmosis, membrane and advanced oxidation processes. These processes can be combined in various ways to form hybrid systems that reduce the degradation time and while increasing the area of application

CHAPTER 6

6. Skills Audit Findings.

One of the major requirements for ensuring regulatory compliance by the WWT plants is skills development. Several skills programs including plant operation, record keeping, safety management, process control, data reporting and maintenance operations are of importance when rating (NQF) employees. An audit on technical, managerial and soft skills was carried out on selected WWT plants in various municipalities across Gauteng, Mpumalanga and North West provinces. The findings of the audit contained herein are drawn from both questionnaires completed by various employees of the wastewater treatment plants surveyed, and oral interviews and observations carried out by the research team. The data obtained from the audit are summarised in pie charts followed by a general findings, and concludes with a breakdown of skills development and needs in each of the surveyed municipalities.

Given the current intended global switch to green economy, the audit also looked at the existence of formal or informal training that can capacitate the workers with new and emerging operating technologies and techniques, raise their skills performance and prepare them for green operations. General findings based on all the plants visited is presented followed by the plant to plant findings. All the plants visited had varying classifications of A, B or C as per DWA classification based on their capacities, and are required to comply by the schedule shown in (Table 19) for process compliance. In addition to the trained and NQF rated personnel, the WWT plants are also expected to have several general workers to assist with ground maintenance and other duties that would ensure effective running of the plants.

Table 19; Schedule for process compliance

WWT plant class	No. of Shifts	Class of PC per shift	Supervision	Operation and maintenance
A	3	Class III	Class V	Electrician, fitter and instrumentation technician
B	3	Class IV	Class V	
C	3	Class IV	Class V	

6.1. Summarized findings

This section presents a summarised findings from the respondents in all the municipalities visited. The audit assessed the training currently being offered, critical skills required by the employees, challenges to skill development, training needed, staff satisfaction with the training providers, age and gender of the employees.

6.1.1. *Qualifications in WWT plants*

The skills audit established that majority of the employees had matriculation as their highest level of formal education with 30% of the respondents, Figure 15, followed closely by 27.5% of the respondents who had no formal education (lower than matriculation). Despite the low level of formal qualifications, some of the employees with/without matriculation showed reasonable practical competency due to experience gained on work and by attending short training programmes on wastewater treatment. Some have also undergone on job training. Most of the employees with lower than matriculation, however, have difficulties in understanding the treatment process.

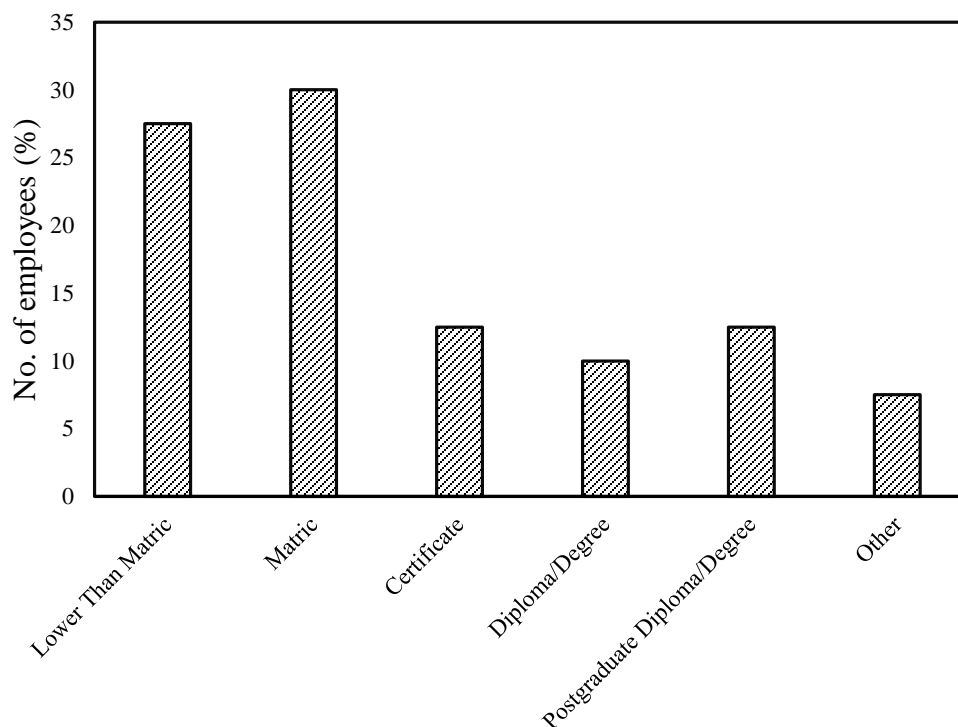


Figure 15; Highest formal qualification of the employees

6.1.2. Occupational distribution

The key occupations common across WWT plants are operators/process controllers, labourers and supervisors/superintendents. A substantial number of operators (55.4% of all employees) are employed by the WWT plants followed by 17% employed as labourers, Figure 16. A partly 3.1% are employed as technicians despite being highly required in the plants. The low number of technicians could be as a result of outsourcing of services such as laboratory analyses and maintenance operations in some plants. In some plants the operators also double up as technicians.

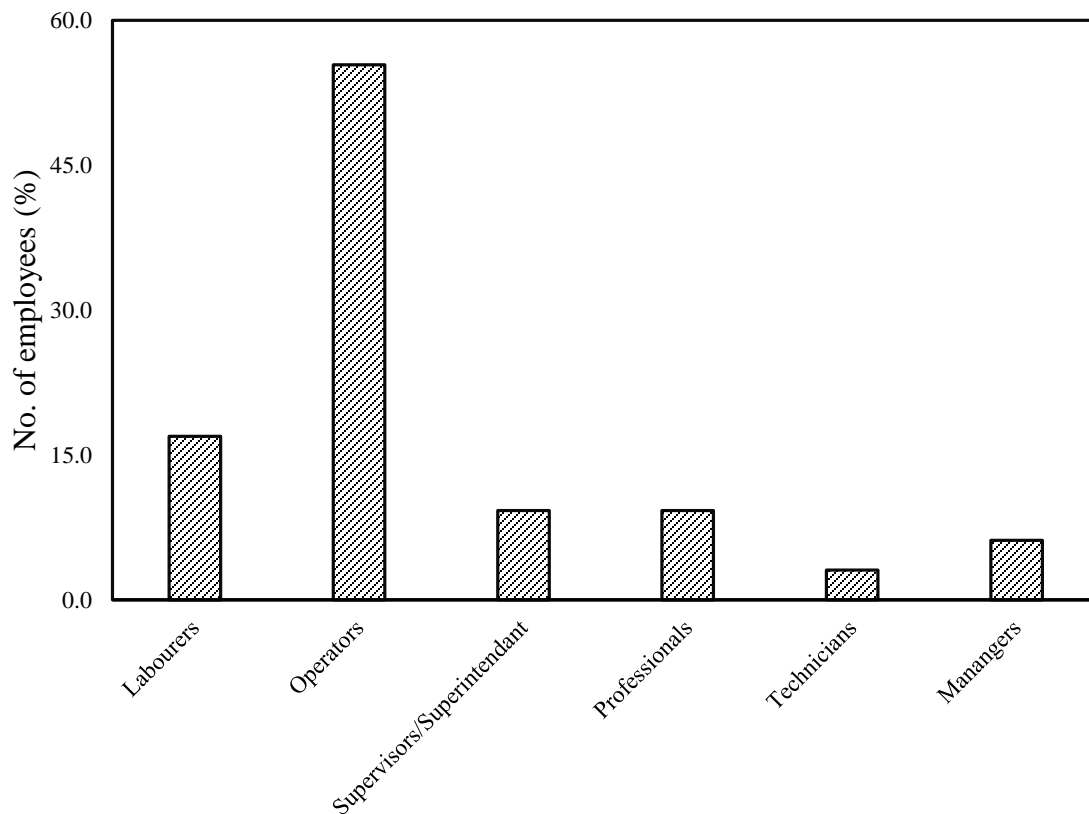


Figure 16; Occupational distribution of WWT employees

6.1.3. Trainings offered

The current trainings offered to the employees at the WWT plants, Figure 17, is majorly oriented at enhancing their technical skills with most respondents (46%) indicating to have attended technical based trainings. This is due to the NQF rating system which is based on the technical skills and experience an employee possesses, thus most municipalities, prefer technical training as

it enhances the NQF ratings, which in turn results to an improved green drop rating. Training on management skills (25%), which is interestingly higher than that on wastewater treatment operation skills (17%), is attributable to the non-target specific trainings offered to all employees across the municipality. The training on computer and other IT skills is rather low as most WWT plants lack basic IT infrastructure thus lack of motivation for staff training towards the same.

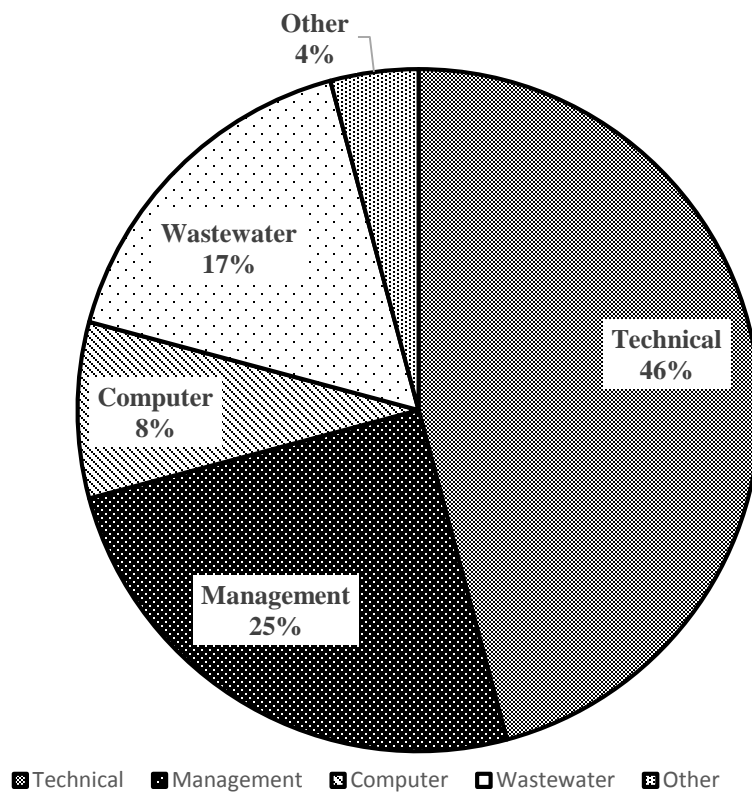


Figure 17; Training offered to employees at WWT plants.

6.1.4. Training needed and in house assistance

Despite being the most offered training from section 6.1.3, technical training is again still the most needed, Figure 18. This is majorly because the training is not offered in some municipalities while in the places where it is offered not all employees benefit, thus a good number of the respondents (44%) are still in need to technical training. On job training which is barely offered by the municipalities is the second most needed training by the respondents (19%), who also need to be trained on soft skills such as such as time management, financial management and other skills that would allow a holistic development. While some respondents need on job training others (17%) preferred coaching as it would ensure that one achieves her specific or professional goal.

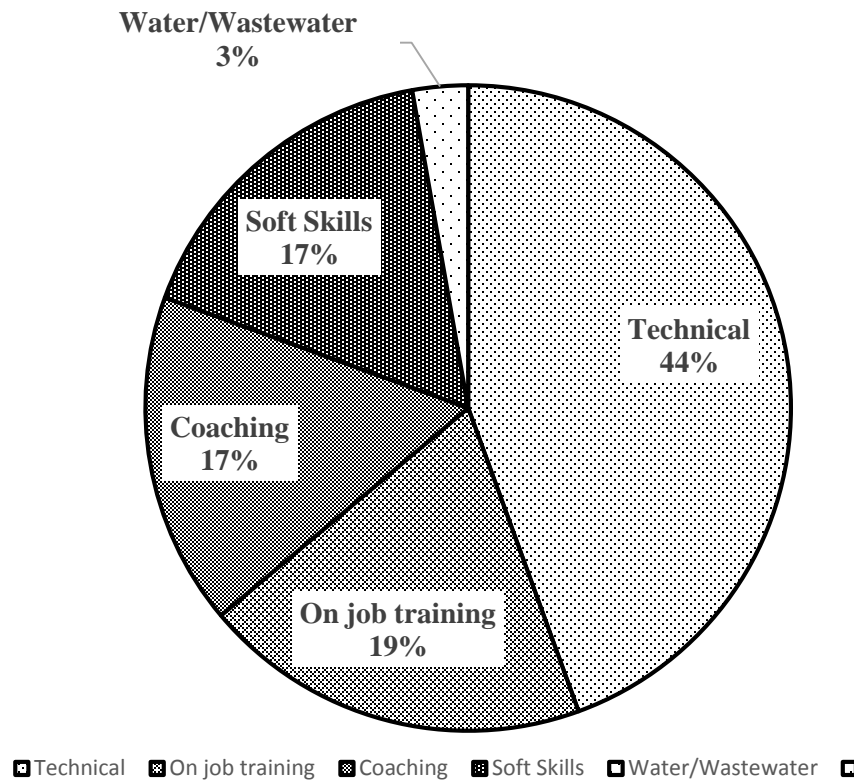


Figure 18; Training needed by employees at WWT plants.

6.1.5. Required skills

The two most required single skills at the WWT plants are process and electrical engineering followed by skills on plant maintenance operations, Figure 19. The low number of engineers especially process/chemical and electrical engineers employed at the plants is responsible for the joint high requirement observed. Moreover the training offered as already discussed in section 6.1.3 is majorly on technical aspects with no engineering or maintenance skills reported, thus aggravating the need for engineering skills. Maintenance operation skills being closely related to engineering is therefore not surprising to be the second most required skills. Also given from section 6.1.3 that training on computer skills is one of the least offered, the resulting 12% in Figure 17, making computer the fourth most required skill is therefore expected. Skills on microbiology is also required by the treatment plants as it plays an important role in ensuring effective role of biological analysis of treated effluent, which can result in discharge of pathogen free effluent. The microbiological quality of discharged effluent plays an important role in green drop rating.

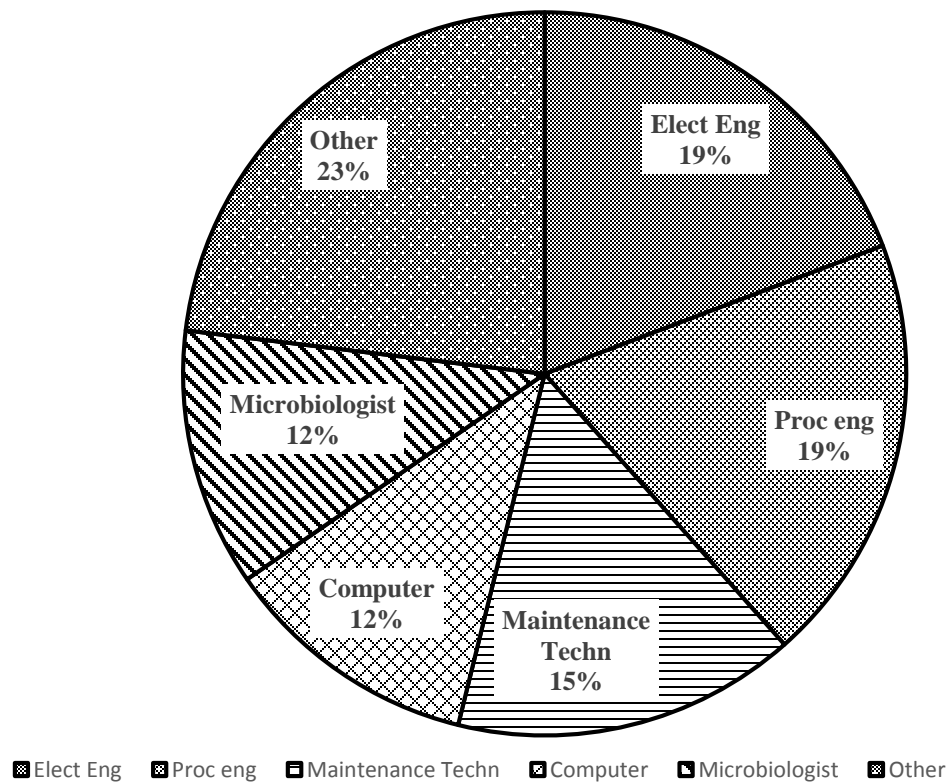


Figure 19; Required skills at the WWT plants.

6.1.6. Critical skills required

These are particular capabilities needed within the WWT plants that are critical to the effective running of the plant. Every employee in charge of plant operations should possess the basic understanding of these critical skills. Communication and problem solving are the single most needed critical skills with 19% of respondents mentioning each of the two, Figure 20. Problem identification, communication and solving of the same is of importance at WWT plants, where any problem that arises should be resolved before it can affect the quality of discharged effluent. Critical engineering skills, both mechanical and electrical, are also required each with 12% mention by the respondents. Since most WWT plants do not have engineers onsite, it is therefore important for the operators and process controllers to possess these skills for the purposes of solving minor breakdowns that would not require the presence of a professional engineer. Computer skills are also required for effective generation of reports and capturing of data.

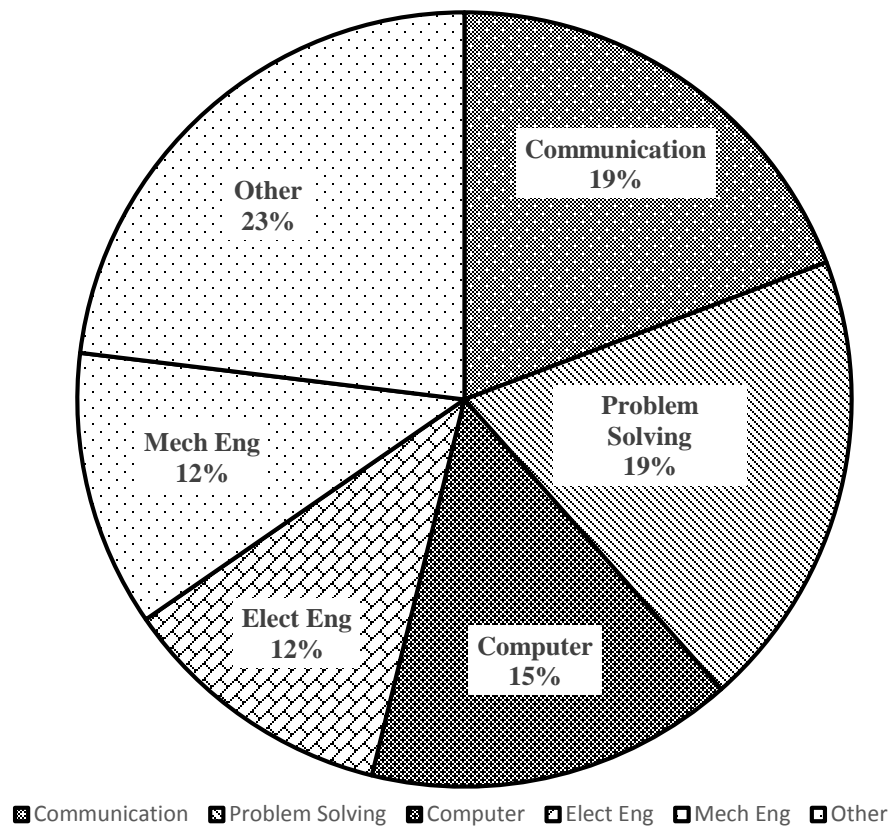


Figure 20; Required critical skills at WWT plants.

6.1.7. Employee and trainee satisfaction with training offered

Both the municipalities and their WWT employees are satisfied with the kind of training being offered with 59% respondents completely satisfied, 27% mostly satisfied and only 14% partly satisfied with 0% expressing any form of dissatisfaction, Figure 21. Given that training is provided by only one development partner, across all the surveyed municipalities, a lack of competition could be playing a role in the levels of satisfaction expressed. Most trainees are also able to apply the skills acquired from the training offered.

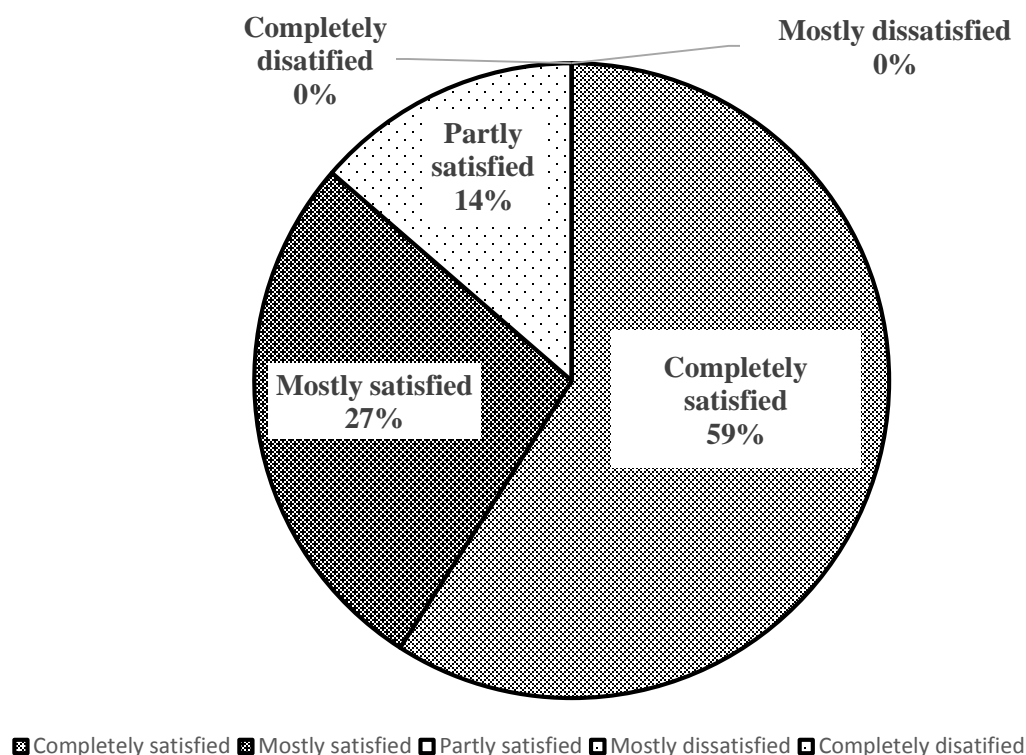


Figure 21; Trainee satisfaction with the training provided.

6.1.8. Skill development challenges

Lack of funds with 34% mention by respondents, Figure 22, is biggest challenge faced by both employees and the municipalities. The lack of funds is further worsened by the preference given to employees at portable water treatment plants some of the municipalities, thus depriving the employees at WWT plants of the little funds available. Another challenged faced with 28% mention, is in the form of training offered which in some instances is not relevant to waste water treatment operations. While in some municipalities training is offered, the lack of career growth after successful training is a demotivating factor for employees to take up the training opportunities. Poor communication of training opportunities to staff and lack of right equipment for effective treatment are other major challenges faced in skill development.

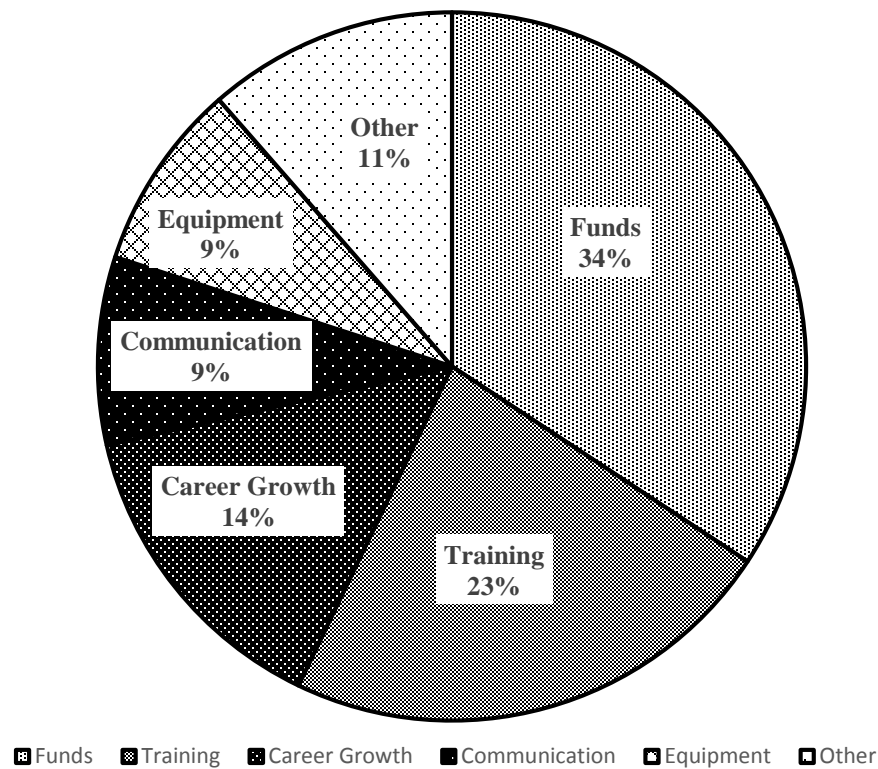


Figure 22; Skill development challenges

6.1.9. Age and gender distribution of WWT employees

The age of an employee plays an important role in skill development and running of the plant as some of the duties involves physical involvement. Most elderly employees due for retirement due for retirement would not be suitable for training as well as running of the plant. From, Figure 23, the age group with the highest number of employees was 30-49 years of age with 32% mention followed by, 40-49, 50-59 and 60+ age groups with 24, 21% and 10% mentions, respectively. The high number of employees above 50 years of age, representing 21%, is a worrying trend given that they are nearing retirement and may not be able to effectively carry out plant operations, in addition to not being suitable for further training targeting long-term operations of the plant. The low number of employees aged less than 30 with 13% mention could also signify lack of interest from young people in waste water treatment jobs. Most of the employees, Figure 24, at the wastewater treatment plants in the municipalities are of the male gender with 72% representation. This is a representation of all the employees including labourers, who are of the female gender in most cases, in addition to a few lady operators, process, controllers and supervisors. Majority of the operators and supervisors/managers are of the male gender.

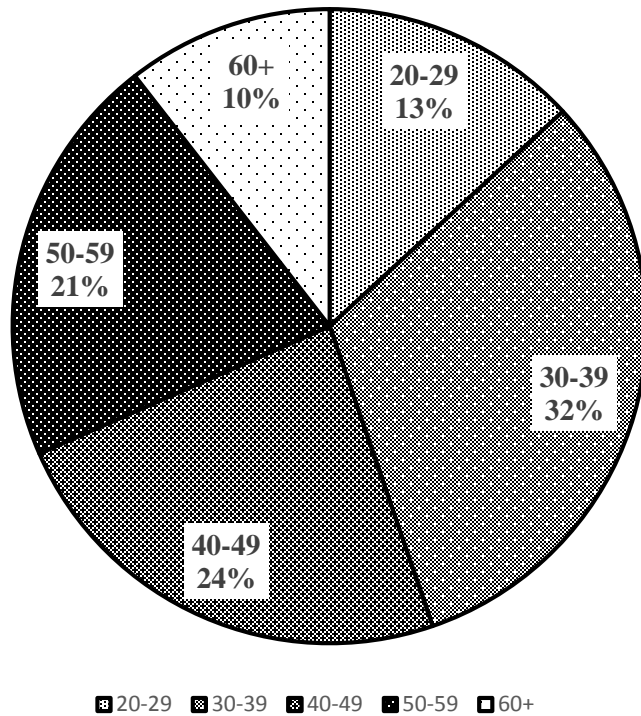


Figure 23; Employees age distribution

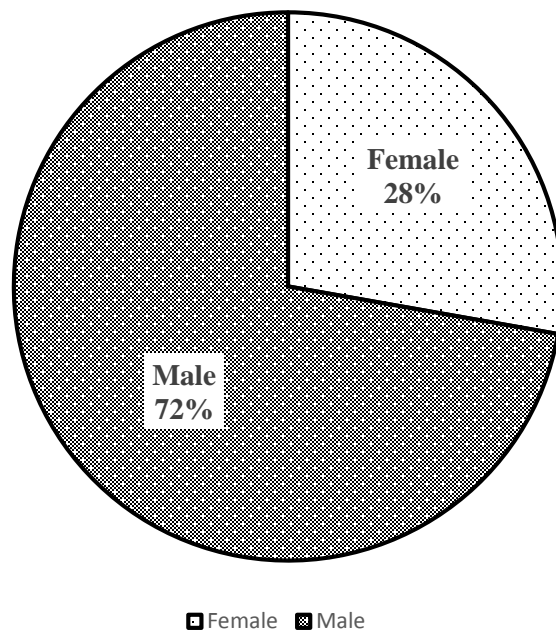


Figure 24; Gender distribution of employees

6.2. General findings

- Most of the treatment plants visited are highly understaffed with only one operational shift against three as recommended by the DWA for all the classes (A, B and C) of plants.
- Few plants comply with the number of required shifts, but still fail to fully comply with the minimum number of employees required per shift based on the classification of the plant.
- Both staffed and under-staffed plants are faced with the challenge of underqualified employees in terms of NQF ratings and required skills. Some of the employees are yet to be registered/rated by DWA.
- Most plants still have employees with lower than matriculation qualification (NQF level 3), making their formal training and development difficult due to communication problems. Formal education (matriculation and post matriculation qualifications) is a must have for employees at the WWT plants.
- Having sanitation and water under the same department has led to neglect of sanitation services by some municipalities as evidenced in Lekwa and Albert Luthuli municipalities where training opportunities are only given to staff in water treatment.
- There is poor communication of training opportunities to staff at wastewater treatment plants.
- Training offered is majorly technical based and in most cases is intended at improving NQF level ratings of the employees, at the expense of developing an all-round skilled individual.
- Training for wastewater treatment employees in most of the municipalities is offered by the same private trainer, Mahube Training Development. The trainer cannot offer holistic training that would result in workers with new and emerging operating techniques and technologies such as green treatment operations.
- The training materials used are inadequate for effective development of skills for wastewater treatment.
- There is little or no training offered on wastewater related skills such as ICT, safety, water care, environmental management and problem solving, in all the municipalities visited.

- Lack of funding, identification of right candidates for training and lack of job and promotion opportunities of the trained personnel, are the major challenges faced in skills development.
- Most plants have no green technologies and practices in place hence no training in green skills.
- Formal training does not necessarily lead to competency, required skills and knowledge. Some experienced employees despite having no formal qualification showed great competency and knowledge of the process.
- Most of the employees however, without metric or any formal qualification did not portray a good understanding of the process despite having a wealth of experience. This is majorly because of the terminologies in which the process can be explained.
- Most municipalities do not have on job trainers or assistance that would ensure seamless transfer and application of skills learnt from the classroom to the plant.
- Some of the plants have process controllers above 50 years of age making their capacitation a challenge, as they are about to retire and are also faced with literacy incompetency.

6.2.1. Matlosana Municipality

Matlosana municipality in North West province has four WWT plants namely, Klerksdorp, Orkney, Stilfontein and Hartbeesfontein. Klerksdorp, class A rated, is the largest plant with a capacity of 36 ML/day. Orkney and Stilfontein plants with 20 and 12.3 ML/day capacities are class B rated while Hartbeesfontein, the smallest, with a capacity of 4.5 ML/day is class C rated. Data for skills audit was collected from Klerksdorp, Orkney and Stilfontein during a meeting at the municipal head offices between the research team and the respective plant managers, followed by a plant visit to Klerksdorp by the research team. The four treatment plants are highly understaffed with few employees possessing low qualifications.

6.2.1.1. Summary of findings

The municipality has four wastewater treatment plants each managed by a qualified operator (Level 4-5, Department of Water affairs ratings). The operators are in charge of operational, managerial, technical, supervision and maintenance of the daily running of the plants. Klerksdorp wastewater treatment plant in Matlosana, has ten employees (trained and untrained) assisting the operator in running the plant. Some of the employees have matric certificates while others do not.

The employees are in most cases contracted as pump station attendants and truck drivers, leaving the running of the plant solely to the operator. Some of the employees despite not having formal training demonstrated high level of competence, majority of the untrained however, had low levels of competence.

Employees with a national diploma qualification showed high level of competency than those with lower qualifications. Workplace experience gained in some cases has not led to increased competency. Some of the employees without matric are not able to read and write, and are not well conversant with the English language. Currently there is no training in place for plant operators for wastewater treatment skills. The trainings offered are only administrative thus not job related. The plant operators have never been taken for job related training since employment. Moreover information on training opportunities is not communicated in time. Poor relationship between municipality management and wastewater treatment workers was also identified.

6.2.1.2. Requirements

- Employees are in dire need of training on new trends in wastewater treatment operations and technologies.
- The municipality should employ superintendents to be in charge of the plant and thus relieve the operators of managerial duties.
- For effective running of the plants, full-time employment of qualified technicians, operators, artisans and electricians is needed.
- Training programmes related to wastewater treatment should be introduced.
- Effective communication of wastewater training opportunities should be communicated timely.
- A good working relationship should be established between the plant operators and the municipality management.
- Shift operations should be properly implemented with complete rotational staff.

6.2.1.3. Recommendations

- Formal staff training through courses in operation and maintenance of plant.
- Partnership with relevant training providers that can provide effective and up to-date training.

- Effective communication of available training programs to staff members.
- Introduction of shift operations with the right number of operators per shift and a qualified level 4 NQF rated shift supervisor.
- Identification and training of competent employees without formal training.
- Facilitation of NQF rating for all the employees.

6.2.2. Lekwa municipality

Lekwa municipality in Mpumalanga province has two WWT plants namely Standerton and Morgenzon. The audit team visited Standerton treatment plant, which is the largest of the two in terms of treatment capacity with a class A rating. Management of the treatment plants is done under the department of water and sanitation based at the municipality headquarters. The municipality focuses more on portable water than wastewater.

6.2.2.1. Summarised findings

Standerton wastewater treatment plant is run by two operators with level two ratings. Effective running of the plant requires three operational shifts with at least four operators per shift. There are ten support staff employed as groundsmen having level 2 qualifications yet they have not been promoted to operation of plant. Most training opportunities given are given to staff at portable water treatment plants with little focus WWT operators. Only one level 2 rated employee, the senior operator, with over 25 years of experience has only been taken for training once. Due to lack of proper management infrastructure, the treatment plant is not effectively run with poor monitoring in place. The plant also lacks an office where the staff can organise and plan their work schedules.

6.2.2.2. Requirements

- Superintendent to manage the plant.
- Employment of more operators.
- Equipped office with IT facilities such as internet and telephone connections.
- Training programs for the operators for the effective operation of the automated system.
- Introduction of shift operations with qualified operators and complete shift operational staff.

6.2.2.3. Recommendations

- Immediate employment of a superintendent to manage the plant operations and the 10 already trained operators to work during the shifts.
- Establishing and equipping an office for the staff.
- Focusing shift to sanitation and if possible creating a sanitation department.
- Training and retaining the operators in place for the purposes of improving their NQF rating and wastewater treatment operations.
- Establishing a laboratory and employing a qualified technician for management.
- Partnering with training institutions for employees skill development.

6.2.3. Albert Luthuli municipality

Albert Luthuli municipality in Mpumalanga province has both wastewater and portable water treatments under one central department of water and sanitation. The department is in charge of running of the municipality's five WWT plants namely Badpass, Carolina, Kromdraai, Eerstehoek and Mayflower. The audit team held a meeting at the municipality headquarters and thereafter visited Carolina WWT.

6.2.3.1. Summary of findings

The municipality has in the recent years focused majorly on portable water treatment at the expense of wastewater. However, water and sanitation department is set to be split into two departments for effective management of sanitation. Training of staff at treatment works is organised at the municipal level. Due to the focus that has majorly been on portable water, 40 operators taken for skill development training so far are all based in portable water treatment plants. There is a plan in place for training and deploying operators to the WWT plants in the municipality including Carolina plant, which has only two unrated operators. The plant with a treatment capacity of 1.4 mega litres (class C) does not have process controllers, engineers, artisans or technicians.

6.2.3.2. Requirements

- There is urgent need of qualified operators (process controllers and technicians) for effective running of the plant.
- Superintendent to be in charge of the daily operation of the plant.
- Training for the unclassifiable operators.

- Engineers, artisans and maintenance personnel.

6.2.3.3. Recommendations

- Immediate training and deployment of operators/process controllers.
- Immediate shifting of focus to sanitation.
- Formal training on plant operation and maintenance for the operators.
- Introduction of shift operations for effective running of the plant.
- Employment of general works to be trained on the job

6.2.4. Westonaria local municipality

Westonaria municipality in Gauteng province has only one WWT plant namely Hannes van Niekerk.

6.2.4.1. Summarised findings

Hannes van Niekerk WWT plant with a maximum of 37 ML capacity, a class A plant, has one superintendent in charge of the plant and an operator in charge of the daily running of the plant. The plant is unattended at night as the sole operator only works during daytime. There is no qualified technician or operator onsite. The sole operator has no formal training, but can effectively run the plant due to the practical experience gained. The plant has two units, a newly built fully automated modern plant and an old manually operated plant. The modern plant can be effectively managed by one operator per shift. Running of the old plant however, may require more operators per shift. Staff at the plant are inadequately equipped with no phones, internet connectivity and other office materials. Biogas production is intended in the near future calling for the need of skilled personnel for running and maintaining the digesters. There are no mechanical and electrical technicians, process controllers and fitters. Several challenges faced in skills development including; communication breakdown, skills identification and lack of funding.

6.2.4.2. Requirements

- Qualified operators, fitters, mechanical and electrical engineers, and artisans.
- Formal training for the operators on wastewater treatment operations.
- Equipped offices with internet and phone connectivity.

6.2.4.3.Recommendations

- Immediate employment of more process controllers/operators.
- Institution of formal training programmes for operators.
- Equipping of staff offices.
- Introduction of operational shifts.

6.2.5. *Emfuleni local municipality*

Emfuleni municipality, in Vaal Triangle on the southern boundary of Gauteng province, operates three WWT plants viz; Leeuwkuil, Sebokeng and Rietspruit. The audit team held a meeting with the municipality management and was thereafter granted a visit to the three plants. Sebokeng plant with a design capacity of 100 Ml/day is the largest plant of the three and is registered as class A plant with DWA. Leeuwkuil with a capacity of 36 Ml/day is registered as a class B plant same as Rietspruit.

6.2.5.1.Summarised findings

Sebokeng WWT plant being a class A plant has three shifts with 4 operators and a supervisor. The shift operators have level 1-2 qualifications including the supervisor which falls short of the DWA regulation of level 4 qualifications for shift supervisor. The plant is managed by a superintendent and two assistants all with level 5 qualifications. The plant is currently well staffed with the right number of operators, artisans, fitters and process controllers. However most of the employees are not qualified for their designated jobs. The staff members are currently being trained by a private trainer (Mahube Training and Development) for the purposes of equipping them with the right qualification. The quality of the training service providers however, has not met the expectations of the employees and the employer. The training material used is of low standard thus not leading to a holistically trained individual.

In addition to the private training, the municipality has partnered with Rand Water, which has deployed qualified operators to assist in skills transfer and on job training to the staff in the three WWT plants. The skills transfer has however, proved futile in some of treatment plants. Some of the employees do not possess basic qualification such as a matric certificate making their training very difficult due to poor understanding. Lack of proper understanding of the process by employees has led to demotivation as evidenced by absenteeism from work and lack of interest for

learning. Most of the employees with tertiary qualifications such as diploma and certificate, have great understanding of the treatment process in addition to being interested in their work. They also have an interest to further their skills on wastewater treatment operations and management.

6.2.5.2.Requirements

- Level 4 rated shift supervisors
- Employment of laboratory technicians and clerks to assist in running the plants.
- Qualified artisans, plumbers, millwrights operators, artisans, fitters, engineers (chemical and mechano-electrical) and class 5 process controllers
- Training on water care related courses and safety management
- Training on management courses, communication, problem solving and computer skills
- Computer, problem solving, mathematical, management and analytical skills
- Language and literacy skills
- Training operators on chlorine handling, flow balance and biofilter operations

6.2.5.3.Recommendations

- Timely, frequent and orderly training should be offered including refresher courses.
- More than one training partner should be engaged by the municipality. Training should cover all water care related skills including management, communication, problem solving, and IT skills.
- Adequate funds should be availed towards training.
- Right equipment for wastewater treatment and process monitoring should be installed.
- On job training and skills transfer from highly qualified personnel.
- Job opportunities and promotions should be given to successfully trained staff members.
- Refresher courses to enhance the already gained skills.
- Study leave should be provided to employees undergoing training especially during examinations.

6.2.6. Madibeng local municipality

Madibeng (meaning place of water) local municipality is located in Bojanala Platinum District in the North West province. Madibeng just like other local municipalities which are water service authorities, is responsible for the operation of WWT plants within its area of jurisdiction. The

municipality has one class B WWT plant (Brits), and three class C plants (Lethabile, Haarbeespoort and Mothotlung). A visit was made by the research team to Bojanala District head office followed by a site visit of Brits wastewater treatment works. All the four plants are operational with three shifts of operation. The plants are under the management of a senior superintendent with level 6 NQF rating. In addition to the superintendent, there is also a chemist in charge of a central laboratory responsible for weekly analyses of the samples taken from the four plants.

6.2.6.1. Summarised findings

Brits wastewater works is a class B plant under the management of a superintendent. Employees of the plant have formal tertiary qualification (BTech, Diploma, Water Care) except the general workers. The plant has three operational shifts within a 24 hour cycle. The shifts are managed by process controllers with NQF level 2-3 ratings and diploma qualifications. Each shift also has a plant operator with level 1-2 ratings, a fitter and a millwright. The plant is considerably well staffed with the rightfully qualified staff. Training of the staff is done manually by Maube and Khulanonke training developments. The training is majorly on the technical aspect and is mostly intended towards upgrading the NQF level ratings of the employees.

6.2.6.2. Requirements

- Level 4 process controllers to be in charge of shifts.
- Employment of more electricians and mechanical technicians.
- Staff require training on safety and first aid operations.
- Training on basic pump operations.
- Training on water quality and treatment management.
- Training on computer skills and scientific reporting.
- Training on acid mine drainage and sludge handling.
- Motivation of staff

6.2.6.3. Recommendations

- The municipality should partner with more institutions that provide training of soft skills such as management and computer applications.

- Immediate employment of level 4 process controllers and plant operators for effective running of the treatment works.
- Employment of lab technician to manage laboratory operations at the plant.
- Additional plant operators, artisans, fitters and millwrights should be appointed.
- Basic training on treatment operations, water care and pump operations for the general workers.

6.2.7. Midvaal local municipality

Midvaal just like Emfuleni municipality is located in the Vaal Triangle along the southern boundary of Gauteng province. The municipality is serviced by two wastewater treatment works namely Meyerton and Vaal treatment works. Meyerton is the largest treatment with a capacity of 5 MI/day but is currently over capacitated at 14 MI/day making it a class B plant by operation. Expansion is however, currently being undertaken to mitigate the problems arising from over capacitation. A visit to the Midvaal head offices in Meyerton by the research office to explain the scope of this study, was followed by another visit to the Meyerton treatment work for data collection and fact finding mission. The municipality is currently training its wastewater employees for skills development and also to improve their NQF ratings by the DWA. Training is being done in conjunction with Mahube Training development as is the case with other municipalities. The training is technical and staff are able to apply the newly gained technical skills in their work places. Inadequate funding and lack of proper criteria for selection of candidates for training are some of the challenges faced by the municipality in skills development.

6.2.7.1. Summarised findings

Meyerton wastewater works is a class B plant managed by a senior process controller with level N3 qualification. The plant has a total of 15 employees including process controllers, electricians, general workers and operators. Both the operators and process controllers have formal tertiary education and are all rated by the DWA. The general workers however, do not possess neither metric certificates nor formal qualification. The plant has three operational shifts; morning, evening and night. Each shift is managed by a process controllers with NQF level 1-2 ratings. Morning shift is well attended while both the evening and night shifts are only attended to by the process controllers in-charge.

6.2.7.2. Requirements

- Electro-mechanical technicians for the running and maintenance of the plant.
- Process controllers and operators for effective running of the three shifts.
- Laboratory technicians with knowledge on microbiology.
- Training opportunities for interested employees.

6.2.7.3. Recommendations

- The municipality should avail more resources towards skill development
- Employment of more qualified process controllers and operators for adequate staffing and in preparation for the expanded works.
- Training of employees on other water care related skills such as management.
- Identification of the relevant training programmes for the employees by partnering with other training institutions such as universities.
- Motivation and capacitation of staff who are interested in further training.
- Training the general workers on general operations of wastewater treatment to enable their NQF rating.

6.3. General recommendations

Based on the plant by plant findings, general recommendations that could solve the skill development problems and gap experienced by the municipalities are given. Table 20 gives the required knowledge, skills and attributes for effective running of wastewater treatment plants. Other general recommendations include;

- Adequate staffing of the wastewater treatment plants with qualified NQF rated employees.
- Partnership with more than one training institutions for the purposes of offering both technical and soft skills.
- There is need to introduce training programmes that are in line with the emerging technologies and techniques such as green treatment procedures.
- Adequate funding towards skill development as well as promotion and employment opportunities for the successfully trained employees.
- Sanitation should be a department on its own and should be given same focus in not more as portable water.

- Fostering green research in water treatment, green innovations and waste recycling.

Table 20; Skills, knowledge and personal attributes required for WWT plants

Skills	Knowledge	Personal Attributes
✓ Mechanical, electrical and chemical	✓ Basic understanding of mechanical, plumbing, and electrical systems including pump operations	✓ Demonstration of sound work ethics
✓ Management and team leadership	✓ Management of water and sanitation systems	✓ Flexibility
✓ Analytical, problem solving, mathematical and decision making	✓ Basic plant operation and maintenance	✓ Awareness and sensitivity
✓ Literacy skills including reading and writing	✓ Applicable bylaws and procedures	✓ Dedication to the work
✓ Effective communication both verbal and listening	✓ Sampling and testing techniques	✓ Consistency and fairness
✓ Computer, stress and time management skills	✓ Sewer distribution and collection systems	✓ Good standards of conduct
✓ Green wastewater treatment operations		✓ Green values, attitude, ethics and practices

6.4. Conclusion

Lack of funds is the biggest challenge faced by both employees and the municipalities. Some municipalities have in the recent years focused majorly on portable water treatment at the expense of wastewater. There is a shortage of mechanical and electrical technicians, process controllers and fitters. Some employees do not possess basic qualification such as a metric certificate making their training very difficult due to poor understanding. The problem is aggravated by the fact that there is need to introduce training programmes that are in line with the emerging technologies and techniques such as green treatment procedures.

CHAPTER 7

7. Intervention strategies and priority issues

As discussed in preceding sections, the surveyed waste water treatment plants have not exhibited compliance with the Green Drop Certification, clearly indicating that the effluent from these plants pose potential risks to the environment into which they are released into. The second issue is that there are some WWT plants that utilise anaerobic digestion technology and produce biogas which is vented into the atmosphere. Biogas contains methane and carbon dioxide which are greenhouse gases and when vented into the atmosphere, contribute to global warming. Clearly this renders the processes to be '*non-green*'. On the other hand, if the biogas is utilised to produce bioenergy, this will significantly improve the processes' scores towards being considered green technology and sustainable development.

These issues raise concerns for immediate intervention. The interventions proposed will need to be aligned with Green Economy concepts which can then be translated into improved treated water quality, green energy production from biogas, green jobs and reduced environmental risks. By first looking at the green economy intervention strategy, focus areas can be developed to address issues such as operation of the WWT facilities and their performance in improving the quality of treated water, which will be addressed through empowering of operational staff through training and proper management of the facilities through maintenance and competent operation. Furthermore, the funding of these intervention strategies can proposed through circular and ecological economies such as recycling of treated waste water and bioenergy production.

7.1. Green economy concepts and priority issues

In waste water treatment, the concepts of green economy as discussed in Chapter 1 are interpreted as follows:

- Low or reduced carbon economy

By utilizing anaerobic digestion in waste water treatment processes and valorisation of produced biogas to useful energy will reduce the energy consumption of the WWT plants which is currently produced from coal. This will reduce electricity required by the plants and therefore a reduction of non-carbon cycle CO₂ emitted to the environment.

- The green growth concept

The amount of biogas produced in domestic WWT plants will help develop a green economy concept where the sector of energy production can emanate, producing energy that can be fed into the local government grid.

- Green jobs

The biogas energy sector and the recycled high quality treated water will generate green job opportunities.

- Circular economy

With quality improvement, the treated water can be recycled for irrigation and other industrial uses, promoting safeguarding and sustainable use of our scarce and most precious resource.

- Ecological economy

From waste water treatment, an economy dependent on ecological principles and using ecological functions to contribute to both the economy and ecosystems by producing green energy and recycled water for agricultural and industrial use.

7.1.1. Priority Issue 1: Improving the treated water quality

The number one priority issue is to improve the treated water quality from the plants within the green economy context. Chapter 5 discussed the challenges and opportunities in implementing new and existing technologies to align the WWT sector with green economy concepts. With the quality of water improved, the treated water can be recycled to use in agriculture and other industries instead of discharging it into rivers and ponds. This will alleviate pressure on the use of our portable water resources and promote conservation.

7.1.2. Priority Issue 2: Biogas production in WWT plants

Although not very common in South Africa due to its high capital and operational costs, anaerobic digestion process is recommended as a treatment method that can be used for treatment of waste

water. This treatment method removes organic material in waste water by turning it into biogas. Instead of only producing carbon dioxide, this treatment method produces useful high energy gas which can be burned to produce heat energy or electricity. There are a number of WWT plants such as Sebokeng plant that uses anaerobic digesters (though not optimally) and releases the produced biogas into the atmosphere. Globally, methane from wastewater contributed an estimated 512 MMTCO₂E of methane emissions in 2010, accounting for approximately 7 % of total global methane emissions (U.S. EPA, 2012). An example of the WWT plant that produces biogas from its anaerobic digestion units is the Arrudas WWTP located in the city of Sabará, Brazil (Global Methane Initiative, 2013). The WWTP treats 280 ML/day of domestic waste water and produces 2.4 megawatts of electricity. For Sebokeng plant which treats 140 ML/day of domestic waste water, equivalent electricity production will be 1.2 megawatts capacity.

To translate this into price or cost of electricity, the biogas produced will amount to R21 million per year of electricity savings or sales (considering the unit price of R2/kWhr, Eskom 2015). Although this may not seem significant, there is a clear opportunity for energy production.

7.2. Training

In Chapter 6, lack of investment in human capital was highlighted with a detailed discussion of the low numbers in the staff requirement at the WWT facilities and in particular, lack of qualified technical staff was shown across all facilities studied. The first intervention strategy will be the revision of the implementation of the LGSETA's sector skills planning to include waste water treatment as a sector, not a division of water treatment.

7.2.1. Intervention Strategy 1: Sector skills planning for waste water treatment

Within its strategic objectives, the LGSETA has a programme to identify skills shortage of sectors and also to plan and manage actions for such skills shortage with the strategic objective being to facilitate and lead addressing those shortages. In financial year 2014/2015, LGSETA formed partnerships with eight (8) institutions of higher learning. As part of the skill planning programme, research into various sectors needed to be performed to provide knowledge about sector skills shortages. This current research is one of such proposed research studies. LGSETA will need to work with its higher education institution (HEI) partners to plan addressing the skills shortage in the waste water treatment sector with incorporation of green economy concepts and priorities.

7.2.2. Intervention Strategy 2: Learning programmes for waste water treatment

There are currently no formal green energy training programmes that have been developed for green economy in the waste water treatment sector. LGSETA has partnerships with HEI's that currently have focus centres in the fields of energy and water such as Centre for Renewable Energy and Water at the Vaal University of Technology (VUT). VUT already offers short courses in the water and waste water treatment. To be able to address the shortage of skills and learning programmes in WWT field, the short courses at VUT will need to be upgraded and skills programmes that are accredited by the LGSETA with rated NQF level certification. It also important to note that the South African Qualification Authority (SAQA) has already in place a number of registered qualifications in water and waste water treatment process operation, control and supervision for NQF levels 1 until 4 as listed (SAQA, 2016):

- NQF Level 1: Qualification ID 48495 - General Education and Training Certificate: Water Services
- NQF Level 2: Qualification ID 58951 - National Certificate: Water and Wastewater Treatment Process Operations
- NQF Level 2: Qualification ID 60169 - National Certificate: Water and Wastewater Reticulation Services
- NQF Level 3: Qualification ID 60155 - National Certificate: Water and Wastewater Reticulation Services
- NQF Level 3: Qualification ID 60190 - National Certificate: Water and Wastewater Process Control
- NQF Level 4 : Qualification ID 60189 - Further Education and Training Certificate: Wastewater and Water Reticulation Services
- NQF Level 4 : Qualification ID 61709 - Further Education and Training Certificate: Water and Wastewater Treatment Process Control Supervision

These qualifications can be used as platforms for development of sector specific learning programmes for waste water treatment if needed to be separated from portable water treatment. To

incorporate green economy, more unit standards that address green economy concepts, green technology and sustainable development will need to be developed and included as core curriculum content or electives.

7.2.3. Intervention Strategy 3: Recognition of prior learning

In Chapter 6, it was indicated that due to lack of formal structured training programmes, a large number of technical personnel who gained competence and expertise due to years of workplace experience in the waste water treatment plant monitoring, operation and control; cannot be considered qualified nor be rated by the DWA as they are not in possession of formal training certificates. This presents an opportunity for a programme for recognition of prior learning by an accredited training provider.

As one of the strategic objective indicators for financial year (FY) 2014/15, LGSETA targeted to establish 3 centres for recognition of prior learning (RPL). There were no RPL centres established in FY 2014/15 and the target was not met. LGSETA should in the future engage its HEI partners for waste water treatment ensure that this sector is included in plans for establishment RPL centres. It would also be advisable to involve the HEI partners in the development and implementation of the RPL programmes. The SAQA qualification outlined in Section 7.2.2 are all accessible through RPL with the exception of 60190 and 61709. To facilitate recognition, rating and certification of personnel whose competence is attained through workplace experience, the LGSETA RPL Centre can collaborate with partnering HEI to develop a functional programmes.

7.3. Treatment Facility Management

Chapter 4 and 6 highlighted the inefficiencies in the operation of WWT plants due to poor management of human resources and maintenance of the facilities. Addressing of the management aspects will have to be done at local government or municipality level. First, the importance of waste water treatment will have to be emphasised, perhaps at government policy level. The performance of the WWT facility in terms of the quality of the treated waste water has to be made an important key performance aspect. In the current ideology, barely meeting the lowest bounds of performance indicators seems to be sufficient, and as shown from the research data most plants do not meet these limits.

Several reasons have been cited as the cause for this poor performance including lack of qualified personnel, general lack of personnel, poor maintenance and over-capacitation of the facilities, in most cases operating at 140% of the design capacity. These main issues will have to be addressed to enable the treatment facilities to achieve efficient performance.

7.3.1. Intervention Strategy 4: Human Resources requirements

Skills audit was performed at 13 of the sampled WWT plants. All of these plants were only running a dayshift with left unattended over other shifts. This was due to lack of personnel to rotate through three plus one (3+1) shifts to cover a 24-hour 7-days a week operation. For all the plants to operate efficiently, the DWA compliance human resources requirements will have to be met.

7.3.2. Intervention Strategy 5: Maintenance requirements

All WWT facilities that we studied in this research had at least one or more unit that was not functioning properly due to poor or lack of maintenance. Of great concern is that none of the facilities had green drop risk rating within the minimum limit low risk requirement of 50%. All the plant ranked from moderate risk to critical risk at a maximum of 100%. Although the cause of underperformance cannot be solely attributed to lack of maintenance as operation by unqualified personnel is also a contributing factor, it should be emphasised that maintenance to ensure that the plant is in working order will improve the performance significantly. There is no force of qualified personnel that can replace the need for good maintenance of the facility so the intervention is of critical importance.

7.3.3. Intervention Strategy 6: Retrofitting and capacity expansion

In a number of cases, WWT facilities were operating above their design capacity with throughput going as high as 140% of design capacity. Intervention has to be undertaken that in order to achieve design quality specifications, design capacity limits need to be honoured. More frequently, there were also some instances where some of the units were not operational and bypassed, thus overloading the performance of downstream processes. In such cases, retrofitting and expansion of downstream processes needs to be undertaken in order to allow additional performance in case of any bypassing of upstream processes.

7.4. Funding

7.4.1. Skills development and training

The funding required to identify and address skills shortage in the waste water treatment can be sourced from LGSETA through the skills development levy collected from the local government sector. In FY 2014/15, LGSETA surrendered R267 million to the national skills fund due to under-expenditure. This indicates that there is potential of funds availability for training in the local government sector.

7.4.2. WWT facility maintenance and human resources capacity building

The funding required upkeep the waste water treatment facility through maintenance and address the technology challenges in alignment with green economy as well building the human resources capacity to required levels can be sourced in numerous ways. At the forefront, the needs to be government interest and investment into green economy and sustainable development. Secondly, there are several off-takes from the adaptation of green economy by producing bioenergy from the biogas and recycling of treated water into agricultural sector and other industries. These offtakes will generate revenue that can fund part of the capital investment required to develop the facilities to required technological and operational standard.

7.5. Conclusions

To conclude the discussion on implementation of green economy in South African waste water treatment industry based on the research on a sample of WWT plants, the following priority issues can be drawn:

- The performance of the WWT plants need to be improved to produce treated water that meets quality requirements. None on the sampled plants meets the required standards for Green Drop Certification.
- For facilities that utilise anaerobic digestion, the produced biogas, which is a greenhouse gas, should be harvested to produce electricity. This will reduce the country's high carbon footprint due to its dependence on coal for power generation.

In order to address the above priority issues the following intervention strategies have been proposed:

a) LGSETA Intervention strategies

- i. Intervention Strategy 1: Sector skills planning for waste water treatment
- ii. Intervention Strategy 2: Development of learning programmes using existing SAQA qualifications
- iii. Intervention Strategy 3: Development and implementation of RPL programmes through existing partnerships with HEI's.

b) Local Government Intervention strategies

- i. Intervention Strategy 4: Increase skilled human resources capacity in the WWT sector
- ii. Intervention Strategy 5: Implement functional and continuous maintenance programme for WWT facilities
- iii. Intervention Strategy 6: Increase throughput capacities of the current WWT facilities to handle increased influent streams

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