Exploring Waste Tyres Problems and Sustainable Waste Management in the Tunisian Context

ABSTRACT

Aims and Place of Study: Waste tyres represent one of the environmentally damaging fractions of the solid waste stream in Tunisia, where the problem of inefficient waste tyre management is endemic. This is easily identified by the piles of accumulating tyre waste located on both sides of many streets and in illegal places. therefore, the efficient management of this solid waste category is important given the large quantities generated annually. The difficulties represented by waste tyres in waste management stem from the physical and chemical characteristics of the tyres. Significant environmental problems can also arise due to improper management and disposal of waste tyres. Nevertheless, Global North countries have made progress in waste tyres management needs by implementing more efficient innovative recovery and recycling methods, and restrictive regulations regarding the management of waste tyres. However, in many Global South countries, including Tunisia, the management of waste tyres has not received adequate interest, and the waste tyres' processing, treatment and disposal are still nascent. In recent years, worldwide but especially in some EU countries, several measures and methods for managing waste tyres, including other principal alternatives for managing end-of-life tyres defined in the waste hierarchy, prevention, re-use, recovery and recycling, have been adopted and applied. These measures and methods are designed to minimize serious threats to both human life and the natural environment.

Methodology: This study attempts to establish the actions of stakeholders who have the responsibility for waste tyre management as an aspect of solid waste in Tunisia. This study also assesses and analyses important aspects of waste tyres management in Tunisia. A combination of two methods is employed in the present investigation: qualitative and quantitative, to determine the factors influencing the effective performance of tyre waste management practice in Tunisia. Data for the present research study was gained using relevant published literature, scientific journals, academic sources, other third sector sources such as government statistical data, and research derived from governments and other agencies and field observations. In addition to the semi-structured interviews with stakeholders involved in waste management, other interviews with actors including governmental, private, academic institutions and NGOs were carried out.

Results and Conclusion: The outcomes of this investigation and assessment are a wide-range outline concerning the participants that are important in tyre waste management and a set of aspects affecting the management of waste tyres. The information provided by this study is very critical for reviewing and updating the methods and tools to update waste tyres data and trends to improve tyre waste management system efficiency and suggesting management options of recovering and recycling this waste stream that is most sustainable and beneficial to the environment from a life cycle assessment (LCA) perspective, for the Tunisian context. About current Tunisia's waste tyre management systems, they have to be improved by introducing specific legislation, with sustainable finance, on the disposal of waste tyres and forming schemes to oversee and manage the country's waste tyre activities. The research has enabled the researcher to produce a set of recommendations to improve the management of waste tyres sustainably in Tunisia.

Keywords: Waste Tyre, Sustainable, Waste Management, Tunisian Context.

1. INTRODUCTION

1.1 Background

Global population growth is increasing and is expected to rise from 7.4 billion today to 9.7 billion by 2050 (United Nations, 2017); almost all of this future growth will be in the Global South, especially in Africa, Asia and Latin America (Carvalho, 2006; Gribble, 2012). Rapid population growth, along with urbanization, has contributed to increased productivity and consumption, which has aggravated waste production and accumulation, the management of which has become a major worldwide challenge, particularly in the Global South where this issue is one of the main topics for public discussion (Al-Khatib et al, 2010; Vujic et al., 2015). The world today has changed

dramatically for its inhabitants with a shift toward living in cities and these shifts have fallen in line with increases in the global population (Thorns, 2017). Lee (2015) emphasized that the percentage of the world's population in urban areas has significantly increased and the trend towards urbanization is still ongoing, citing that 54% of the world's population were living in cities in 2014, with some 70% expected by 2050. The largest increase is within cities in Global South countries that contributed to rapid urbanization and development (Grimm et al., 2008). Mobility and transport are two of the main factors that have contributed to the shift toward urbanization, where the concentration of population and economic activity generates new demand for transport services, particularly in vehicles (including cars, trucks and buses) (Grimm et al., 2008).

1.2 What Drives Waste Tyre Generation in the Context of Tunisia?

This study's primary context is the Republic of Tunisia, located on the Mediterranean coast of North Africa, with a population of nearly 10.98 million people in 2014. Neighbouring countries comprise Algeria to the west and southwest and Libya to the southeast; the country has a lengthy Mediterranean coastline and Tunis is the capital city of Tunisia. Growth in the number of waste tyres generated in Tunisia has been driven by the evolution of the transport movement, to strengthen its socio-economic performance; Tunisia opted for a strategy to promote a gradual integration into the global economy by giving an important role to the transport sector in order toit into an efficient system with a high-quality infrastructure (African Development Bank [ADB], 2010). Linking cities to each other by transportation networks is one of the main factors that contribute to the process of development and growth in terms of social-economic aspects (Duranton et al., 2014). Tunisia itself has nine international airports with an estimated capacity of 19.05 million passengers a year, and 8 ports including La Goulette, Bizerte, Sousse, Sfax, Gabes, Skhira, Rades and Zarzis, stretching along the coastline and open for international activity (European Environment Agency 2014). In terms of the transport of goods or passengers, they are distributed on the northern, eastern and southern coasts at distances from 60 to 120 km; in addition to a road network of 20,000 km, there are 370 km of motorway and 2,256 km of railways (European Environment Agency 2014). Achour and Belloumi (2016) state that the Tunisian transport infrastructure is undergoing modernisation and renovation. Shahbaz et al. (2015) further explain that the road network has contributed to the process of movement of people between regions, and currently contributes more than 80% of the transport of goods between regions throughout the territory. Such vehicles recorded an average annual growth rate of 6.1% over the 1997-2006 period, with some 86% of this growth representing informal usage, whilst 13.5% represent heavy vehicles (Achour & Belloumi, 2016). This is a disease in the rate of car use (Mraihi et al., 2013). Overall, rate of passenger car ownership (cars per 1000 inhabitants) increased from 32 in 1990 to 173 in 2014 (Achour & Belloumi, 2016; Organisation Internationale des Constructeurs d'Automobiles [OICA], 2016; Abbes & Bulteau, 2018). The Tunisian statistics illustrate the evolution of fleet vehicles between 2008 and 2012, as shown in Table 1.

Table 1. The Evolution of Fleet Vehicles in Tunisia

Year	2008	2009	2010	2011	2012
Vehicle Type	Number	Number	Number	Number	Number
Automobiles	772315	810931	851478	894052	938755
Light Trucks	320826	336868	353711	371397	389967
Heavy trucks	75189	78949	82897	87041	91393
Tractors	128720	135156	141913	149009	156459
Others	14640	15372	16141	16948	17795
Total	1311690	1377276	1446140	1518447	1594369

Source : Ministère de l'Equipement de l'Environnement (MEE), (2013)

The continuous increase in the production of cars and trucks has resulted in a continued increase in the rate of generation of waste tyres (Jacob et al., 2014). In Tunisia, with a population of around 11 million, the number of cars has increased substantially in the last decade to reach over 938,755 cars in 2012. This quantity represents the number of cars registered officially, as reported by the Ministère de equipment MEE (2013). This amount of cars has led to an increase in the rate of accumulation of waste tyres throughout the country. However, no current official data on the number of stockpiled waste tyres in Tunisia is available. In contrast, the estimated quantities of waste tyre generation globally are about 1.5 billion (Pilusa & Muzenda, 2016). For example, the EU produced an estimated 4.5 million tonnes of new tyres in 2010, with 289 million units of tyres being replaced per year (ETRMA, 2011). In the same way, in the United States, about 500 million units of waste tyres were generated in 2007, with about 128

million units of used tyres already stockpiled. In addition, in South Africa, about 60 million units of scrap tyres are disposed of annually across the country (Pilusa & Muzenda, 2016).

2. LITERATURE REVIEW

2.1. Tyre Definition

A tyre is a pneumatic covering encircling a wheel, made of natural rubber or synthetic rubber or a combination of both, whether new, used or re-treaded. It is made from the following ingredients: rubber, carbon black, silica, metal, textile, zinc oxide, sulphur, copper compounds, cadmium, lead and organic halogen compounds and some additives like solvents, age resistors, vulcanizing agents, softeners, fillers and processing aids in varying proportions depending on whether it is a car or truck tyre (United Nations Environment Programme (UNEP), 2013; Mushunje et al., 2018).

2.1.1. Definition of Terms for Used Tyres or Waste Tyres

In the context of this study, used tyres and waste tyres are termed as follows:
'Used tyres' - are tyres which had been used on motor vehicles and replaced but still have an economic life (i.e. have the minimum characteristics that enable them to be used again). Used tyres are also sometimes termed as 'part worn tyres'. In other words, the used tyre has not reached the final waste stream for disposal, and may be reused, or retreaded (Limbachiya & Roberts, 2004; Nkosi et al., 2013). 'Waste tyres' - are tyres that cannot be reused for their original function and have reached their end-of-life stage, therefore needing to be disposed of. The point at which a tyre becomes waste hinges on when it is 'discarded'. Waste tyres are also sometimes termed as 'part worn tyres' that cannot be reused for the same original purpose but can be used as raw material or for energy production (Limbachiya & Roberts, 2004; Nkosi et al., 2013).

2.1.2. Tyre Disposal Issues and Trends of Reclamation Methods

The disposal of tyre waste in landfills causes many problems, as tyre waste occupies a large space of land and it is not biodegradable. From this point of view, the waste tyre represents a fire hazard that releases carbon monoxide and carcinogens like benzene, polluting the air with toxic smoke and contaminating the local environment as the ash settles. Based on this, many Global North countries, including the EU, have banned tyre disposal in landfills (UNEP, 2011). The waste tyres are classified, according to Basel Convention as stated by UNEP (2000), as a hazardous material, which falls under the scope of the category of waste listed in annexe 1 of the hazardous material because it contains about 1.5% by weight of hazardous substances. Table 2 illustrates Annex I: Constituents contained in tyres.

Table 2 Substances Contained in Tyres

Convention constituent	Chemical name	Remarks	Content (%weight)
Y22	Copper compounds	Alloying constituent of the metallic reinforcing material (steel cord)	Approx. 0.02
Y23	Zinc compounds	Zinc oxide, retained in the rubber matrix	Approx. 1
Y26	Cadmium	On trace levels, as cadmium compounds attendant substance of zinc oxide	Max. 0.001
Y31	Lead compounds	On trace levels, as an attendant substance of zinc oxide	Max. 0.005
Y34	Acidic solutions or acids in solid form	Stearic acid, in solid form	Approx. 0.3
Y45	Organ halogen compounds other than substances in Annex I to the Convention	Halogen butyl rubber	Content of halogens Max. 0.10

*Estimated for a 7kg car tyre. Source: UNEP (2011).

Reducing the environmental impact of waste tyres and increasing sustainability has become an important waste management issue, and it is necessary to address the problem of accumulation of waste stocks Jacob et al., 2014). In this regard, the European Council Directive 2008/98/EC defined Waste Management as “collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites" (European Council, 2008). Similarly, Gilpin (1996, p. 201) defined waste management as “purposeful, systematic control of the generation, storage, collection, transportation, segregation, processing, recycling, recovery and disposal of solid waste in a sanitary, aesthetically acceptable and economical manner”.

Tyre products used in the passenger car, truck and aeroplane industries are responsible for waste tyre generation in large quantities. In Global South countries, waste tyres are rarely a priority for waste stream management, meaning large amounts of waste tyres end up in landfills or open environments (Jacob et al., 2014). In addition, Elnaas et al. (2015) expressed that in many Arab countries, waste management is in its infancy, and is characterized by a high percentage of uncollected waste, with most of the waste directed to open or uncontrolled dumpsites. This may relate to an absence of adequate policies, clear legislation and strong regulations. They suggested that many of the common barriers which hinder legal and policy arrangements in Global South countries (within Low and Middle-income countries), such as waste legislation, are fragmented into different laws, causing the lack of many important elements such as technologies and enforcement mechanisms. However, the increase in tyre production and the expansion of vehicle use, and the lack of recycling or recovery of such wastes, are major issues in Tunisia and Global South countries, which needs tackling. This drives the need for an appropriate policy with plans and strategies to set a more sustainable system for waste tyre management (Elnaas et al., 2015). These challenges could be addressed through the introduction of sustainable waste management practices based on the waste hierarchy, with greater emphasis on waste prevention. Waste hierarchies are used worldwide, including in EU member countries as an option for managing waste based on the principles of sustainability (UNEP, 2011).

A waste hierarchy ranks waste management options according to what priority is most useful to the environment. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal. The Global North countries, such as the EU member countries, apply the waste hierarchy principles for tyre waste management within a wider framework of integrated solid waste management (ISWM) systems, and through using policies and strategies that emphasise waste prevention, reuse, recycling, recovery, and safe disposal for tyre waste sustainably. The policy is represented in using instruments such as Economic, Direct regulative and Communicative instruments to achieve solid waste reduction. Although Tunisia has adopted the concept of integrated SWM (Haouaoui & Loukil, 2009), it still suffers from the indiscriminate disposal of waste tyres. In Tunisia presently, waste tyres are disposed of in a random way, i.e. in the open environment. There are no estimated indicators of the quantity of tyre waste that is produced each year in the country or methods of their disposal, despite the trend of increasing new-vehicle registrations annually in the country, which increases the end-of-life tyres (ELTs) that entering disposal routes annually. Waste tyres could be regarded as a constituting threat to human and environmental health, which are found in illegal dumpsites across the country. As a consequence, waste tyres litter the country, which is uselessly stockpiled or disposed of at unsuitable disposal sites and is often handled by the informal chains operated by “scavengers”, recovery companies and scrap dealers. This situation is compounded by the absence of effective policy instruments in the country, such as a producer responsibility or a taxation system that represents sustainable finance with proper legislation to guide, control and regulate the disposal, storage, utilization and recycling of this “tyre waste” in a sustainable manner (GIZ and SWEEP-Net, 2014; Gargouri et al., 2016). It has been emphasised by Connor et al. (2013) that the waste tyre management systems in the global South countries are inefficient.

This research was therefore motivated by the need to fill the above gaps in knowledge by generating qualitative and quantitative data on waste tyre management as an aspect of SWM in Tunisia that could underpin future waste tyre management strategies and policies in the country. Gaps identified include:

- A lack of knowledge surrounding the extent of the waste tyre problem in Tunisia, particularly around the flow of tyres and their origin, including;
- A Lack of data concerning waste tyre generation.
- The environmental burdens of waste tyre disposal have not been adequately explored and are poorly understood.
- A gap surrounding the best options to treat tyre waste in the Tunisian context; at present, there is no formal system

- A general lack of academic research exploring stakeholder views towards the problem, along with potential solutions. At present, there are no studies within the North African context around tyre waste management.

2.2. Research Justification and Motivation

Currently, many Global South nations are facing the challenges of managing waste tyres, a problem which keeps on growing due to the increased importation of cars and tyres. There are about 19.3 million tonnes of used tyres produced annually in the world (Labaki and Jeguirim, 2017), and this will increase in the coming years with the expected growth of the world's motor vehicle fleet. Very often in Global South nations, there are no legal framework and industrial infrastructure to address the issue of waste tyre collection, legal stockpiling, recycling and even disposing of waste tyres in an environmentally safe and sound manner (Muzenda and Popa, 2015). Waste tyres, if not managed properly, can cause negative effects on the community and environment. Already, waste tyres are affecting the social well-being of Tunisian communities in terms of being a source of inconvenience, and distortion of the aesthetic view when dumped on the side of the roads and public spaces. Tyre waste has the potential to lead to tyre fires, which produce acid smoke harmful to humans and the environment, as well as leave behind an oily residue. Tyre fires are not extinguishable and in some instances burn for several weeks, which are then costly. Socially, the communities do not see tyre waste as their responsibility and in this, they are not willing to interfere with them (Sienkiewicz et al., 2012)

2.3. Global North Countries, Especially the EU, Provide Good Lessons that can be applied in the Tunisian context and other Similar Countries

This researcher focuses on the experiences of many countries over the world, especially EU member countries, particularly those located in the Mediterranean sea basin; the so-called Mediterranean Europe countries (such as France, Spain, Italy, Greece, and Portugal) in the field of waste management, and the policy of waste management, including legislation, regulations, and the systems that have been developed and implemented in these countries. Thus, many Mediterranean Europe countries have testimonies of success in waste management, making it a good example in the context of ISWM, particularly for the waste tyre management in the context of Tunisia.

The waste management policy in the context of the EU provides good lessons that can be applied in the Tunisian context, by considering that the EU (especially Mediterranean Europe countries) is a neighbour and partner of the five Maghrebi countries (Algeria, Libya, Mauritania, Morocco and Tunisia), which share links in terms of historical, cultural and linguistic ties with Europe (European Commission, 2016), particularly colonial ties, such as Tunisia has with France (Mckay, 1945). In this regard, the EU is providing financial support for the European Neighbourhood Policy (ENP) through a dedicated European Neighbourhood and Partnership Instrument (ENPI). It targets various areas of cooperation including sustainable development and the environment, supporting jointly agreed reform priorities in the ENP Action Plans (Neubauer, 2008).

The EU concluded Euro-Mediterranean Association Agreements between 1998 and 2005 with the southern Mediterranean countries. These agreements effectively provide a suitable framework for North-South political dialogue. They also serve as a basis for the gradual liberalisation of trade in the Mediterranean area and set out the conditions for economic, social and cultural cooperation between the EU and each partner country (Spiteri et al., 2016). Thus, the EU offers the best opportunity for change to occur in Tunisia, through knowledge exchange activities linked to such agreements.

The EU is already supporting Maghreb countries and other Southern Mediterranean partners to strengthen environmental protection and the fight against climate change through a range of bilateral measures as well as through the Horizon 2020 initiative on the de-pollution of the Mediterranean Sea. In light of this, North Africa can benefit from the EU experience with different waste streams. However, the presence of heterogeneity in the region does not prevent the follow-up a step-by-step approach according to concrete “starting points” about waste management within these countries could turn out to be most useful (European Commission, 2016). Moreover, (Neubauer, 2008) has emphasised that many ents of the EU waste legislation are apt to improve the waste management situation in the Eastern and Mediterranean Neighbouring Countries and Russia.

Tunisia was the first Mediterranean country in North Africa to sign an Association Agreement with the EU, in July 1995. Tariff dismantling under the Agreement was completed in 2008, with the resulting Free Trade Area, the first between the EU and a Mediterranean partner. Recently, in April 2016, the deep and comprehensive negotiation round for the Free Trade Area took place between the EU and Tunisia. This negotiation and its discussions covered a wide range of issues, including services and sustainable development and bringing Tunisian legislation closer to that of the EU in trade-related areas (European Commission, 2016). The EU is Tunisia's largest trading partner,

accounting for 62.8% of its trade in 2015 when 71% of Tunisia's exports went to the EU. In addition, Tunisia is a part of the Euro-Mediterranean Partnership (EMP), also known as the Barcelona Process.

2.4. Overview of Waste Tyre Problems

Waste tyre generation is considered one of the most significant environmental issues because of the fire hazards tyres represent and the environmental and public health risks as a result of their chemical and physical components if not managed properly (Martı´nez et al., 2013). The discarding of waste tyres in Europe increased from 2.1 million tons in 1994 to 3.3 million tons in 2010 (Sienkiewicz et al., 2012). Illegal discarding of waste tyres may occur due to a lack of specific regulations and/ or because recycling is not economically attractive (Martı´nez et al., 2013), a practice that is prevalent in Global South countries such as Tunisia. Consequently, the disposal of waste tyres is considered an increasing economic and environmental burden that needs an immediate solution (Martı´nez et al., 2013). From an environmental point of view, waste tyres are considered a place for rodents, snakes and mosquitoes to inhabit, and additionally, tyres take up a lot of land space (Sienkiewicz et al, 2012; Martı´nez et al., 2013). Table. 3 illustrates some negative environmental hazards relating to the mismanagement of waste tyres.

2.4.1. Human Health Problems

Disease-carrying mosquitoes are the most important public health risks worldwide. Dengue fever infection is one of the most important arbovirus diseases in humans, causing sudden fever and acute pains, and threatening more than 2.5 billion people. It is endemic in many regions of the world such as Africa, the Americ Easterntern Mediterranean, SE Asia, and the Western Pacific (Reschner, 2008; Getachew et al., 2015). Waste tyres are a convenient place for the growth and breeding of mosquitoes when to multiply and spread all over the world, and the movement of used tyres between countries contributes to the introduction of non-native species such as mosquitoes.

2.4.2. Fire Hazards

Tyres are also considered raw materials for chemical materials, as construction materials as a type of solid fuel because they contain a high density of energy at 29-37 MJ kg. However, the chemical materials present in tyres such as carbon, sulphur, rubber, oil, and benzene are flammable mahus, tyre storage and reuse require care requirement on to avoid fire risks because the burning of tyres pollutes the soil and groundwater (Downard et al., 2015). In addition, burning can generate gaseous emissions such as sulphur oxides (SO2), carbon monoxide, and polynuclear aromatic hydrocarbons (PAHs), all of which pose significant risks to human health in the event of exposure through inhalation. Moreover, uncontrolled tyres may cause a fire that is difficult to extinguish, causing widespread damage. Despite warnings and legislation urging caution towards fire hazards from waste tyres, many accidents are still occurring. For example, the largest tyre fire happened in 1983 in Virginia, United States, where about 7 million waste tyres burned and the fire continued for nine months, which caused pollution of the local air and water (Virginia Department of Environmental Quality [VDEQ], 2016). Although European laws have banned the full storage of tyres, according to the directive 2003/35/EC and Directive 2006/12/EC of the European Parliament and the Council on waste, fire incidents persist as shown in Table. 3.

Table 3 Level of Environmental Problems Sources: The author; VDEQ (2016)

Environmental impact	Illustration
Soil & Water contaminations The burning of tyres can easily contaminate the soil and water as well as cause loss of vegetation and the ecosystem as a result of soil erosion due to the lack of vegetation in the area. This photo cited by the Virginia Department of Environmental Quality illustrates the event of burning tyres in Frederick County near Winchester in 1983, which continued for nine months (VDEQ, 2016)	 Source: VDEQ, 2016. Waste Tyre Pile Cleanups. www.deq.virginia.gov.

Earth pollution & health hazards Illegal disposal of waste tyres is leading to an accumulation of waste and encourages the development of illegal dumpsites, which create a mixed waste, causing distortion of the aesthetic view of the natural environment, and creating a convenient haven for rodents, insects and mosquitoes.	 Illegally dumping waste tyres in the residential area in Tunisia leads to the create illegal dumpsite sites mixed with other waste   **The photo was taken by the author.** Waste tyres take a long time to degrade and as a result, they will remain in the illegal dumpsite for a long time, causing various impacts on the environment.

Recently, the independent newspaper reported that a fire broke out at a tyre graveyard near Madrid. This disaster caused the evacuation of more than 9,000 people from a large housing complex because of the escalation of the toxic black clouds sent out by the raging fire (Clendenning & Giles, 2016). UNEP (2013) has explained that tyre fires in the open air omit black smoke, carbon dioxide (contributing to the greenhouse effect), volatile organic compounds and hazardous pollutants, such as polycyclic aromatic hydrocarbons, dioxins, furans, hydrochloric acid, benzene, polychlorinated biphenyls, arsenic, cadmium, nickel, zinc, mercury, chromium and vanadium. Finally, it can be concluded, as presented above, that the composition of the tyres predetermines the properties of the tyres and their effect on the environment. At the end of their life cycle, tyres are of great environmental concern, especially when disposed of with traditional methods such as a landfill. The disposal of the waste tyres at the landfill is not only an environmental and public health hazard but also a waste of valuable materials and energy. After taking a closer look at the chemical and physical tyre composition with their production and consumption patterns, positive trends of prolonged tyre life span and tyre manufacturers' involvement in the whole life cycle can be observed.

2.5. Progress and Trends in Solid Waste Policies and Strategies in EU Countries

The European Commission presented Directive 2008/98/EC on waste (Waste Framework Directive), which defines the basic concepts and definitions related to waste management, such as definitions of waste, recycling, and recovery. EU countries have post-industrial economies, which are characterised as politically stable, and have a high level of human development, including high income per capita (World Bank, 2008; Klugman, 2010). Over the last 40 years, a transition has occurred in the EU towards sustainability in waste management, since the first Waste Framework Directive in 1975. In this regard, the EU has included waste policy provisions for improving the environmental impacts of waste through stringent procedures, as well as setting a conscious goal for the use of waste as a resource (Pires et al., 2011). The EU policy and strategy of waste have been developed by the Waste Framework Directive issued in 1975 to establish integrated SWM systems as part of the broader plan for the EU's policy for sustainable development. For example, the EU adopted a sustainable development strategy immediately after Agenda 21 was published, which aims to continuously improve the quality of life for our present and future generations (Hawkins & Shaw, 2004; Pires et al., 2011). Waste policy at the EU level focuses on adopting the waste hierarchy by promoting reuse and recycling while enhancing waste prevention (CEC, 2005). Figure 1 illustrates the outcomes of the SWM strategies' success in the EU, in particular for tyre waste between the years 1996-2010. In this regard, there were more than 24 million tonnes of used tyres managed in an environmentally sound manner, which resulted in the year 2010 disposing only of 4% of waste tyres produced into landfill, against 96% put to other purposes (38% energy recovery, 40% material recycling, 8% re-treading, and 10% re-use /export) (ETRMA, 2011). In general, SWM strategies have transformed into an effective model that achieved their objectives in the reduction of waste disposal to landfills through increases in the recycling rate (Skovgaard et al., 2008). Environmental impacts of waste are highly dependent on its size, characteristics, and how it is managed (Michaud et al., 2010). Effective waste management in terms of recycling or energy recovery can contribute to the reduction of the volume of waste consigned to landfill. This leads to reducing the proportion of greenhouse gas emissions to "negative", and therefore, this could partially offset the emissions that occur with the extraction of raw materials or during manufacturing

products, which contributes to meeting the [1]Kyoto targets (Skovgaard et al., 2008). For instance, Life-Cycle Analysis (LCA) has demonstrated that recycling innovations and technologies have comprehensive environmental benefits for many types of waste (Michaud et al., 2010). Therefore, there is a need for a regulatory approach that ensures regulations on paper can be implemented effectively in practice (Van de Klundert & Anschutz, 1999).

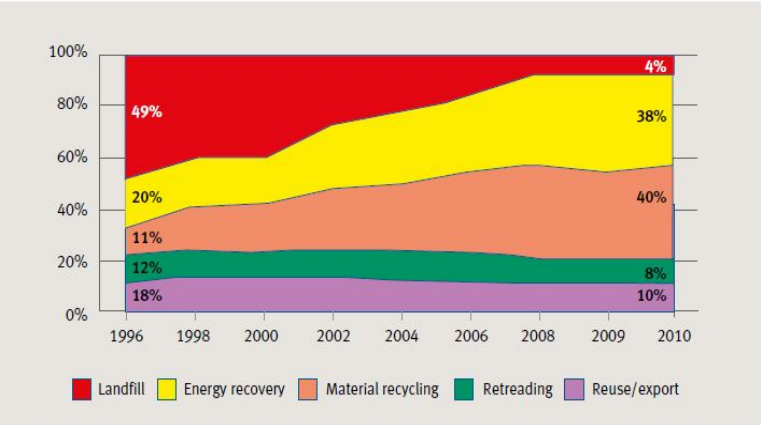

Figure 1. Evolution of the Management of Waste Tyre Recovery in Europe Source: ETRMA (2011)

2.6. The Institutional Framework and Legislation or Legal Framework Governing the Management of Waste Tyres

2.6.1. Current Situation of Solid Waste Management (SWM) in Tunisia

The SWM sector in Tunisia has been recognized as a vital policy area in general efforts undertaken to enhance and improve the country's living conditions. One of the most visible effects of the 2011 uprising in Tunisia had been mountains of uncollected rubbish throughout the country, both in the rich and poor neighborhoods. As a result, the situation has become familiar to all citizens (Loschi, 2019). In Tunisia, rapid population growth along with urbanization has contributed to increased productivity and consumption, which is the most common cause of the SWM crisis (Chaabane et al., 2019). Urbanization has been shown to promote economic growth and improve the livelihood of people, but it can also increase environmental pollution, such as the mismanagement of solid waste. In this regard, Bakari et al. (2017) studied the correlation between the negative effect of pollution and economic growth in Tunisia. The study concludes economic growth and the environment are linked because all economic activity is based on the environment. The results indicate that after years, indeterminate pollution will negatively affect economic growth. Therefore, the Tunisian State needs to demonstrate economic policies and instruments to protect against the worsening of the future effects of pollution. These policies and strategies are unlikely to end pollution definitively, but at least reduce it to the minimum level. Meanwhile, Jebli et al. (2015) recommend that Tunisia should use waste in energy generation, as this eliminates waste from tourist zones and increases the number of tourist arrivals, leading to economic growth.

Recently, Tunisia has realized that its SWM status does not fulfil its sustainable development targets and decided to shift toward a system of ISWM. Despite the efforts made by the authorities, SWM still faces many challenges in Tunisia, such as the lack of legislation, lack of financing, lack of human resources and knowledge, lack of availability of primary data in terms of SWM, inappropriate technologies, the influence of the informal sector, different reports that give different values and projections, and the indifference of civil society, which are the main common issues with regards to SWM facing Tunisian decision-makers (Loschi, 2019; Chaher et al., 2020). Reports by Loschi and Chaher et al. indicate that many reforms in Tunisia still need to be targeted in terms of policy, strategy, institutional set-up, legal framework, private sector participation and integration of informal markets into the formal economy. Urgent action is required to set up an integrated system for SWM that includes a tyring waste management system for Tunisia. According to the report published by GIZ and SWEEP-Net (2014), in 2012 Tunisia produced more than 2.423 million tons of solid waste, of which the deposit of waste tyres represented about 15,000 tons/year (about a million units) and the final destination of these products is not well known. In the same context, in June 2019, the World Wildlife Fund (WWF, 2019), an environmental pressure group, published a report about plastics pollution in Tunisia, urging its government to prioritise "improving waste management capacity and monitoring, and encouraging consumers to reduce consumption." According to the report, titled *Stop the plastic*

flood, a guide for policymakers in Tunisia, in 2016 the country recycled only 4% of its plastic waste, with 76% discharged into landfill or open dumps. Much of the plastic waste flows into the Mediterranean Sea, and the WWF estimates around 80,000 tons of this end up in Tunisia's environment each year "due to challenges with waste management." Despite its involvement in waste generation, the informal sector also plays the main role in waste collection for most waste generated. For instance, waste packaging from the paper and cardboard industry remains an informal sector; it offers at least 5.000 jobs throughout the country, and this applies also to tyre waste, where the management of this sector remains to this day informal (GIZ and SWEEP-Net, 2014).

2.6.2. Regulatory and Legal Framework

Waste management has always been one of the strategic pillars in the environment policy of different governments in Tunisia. The longer-term orientation adopted by recent administrations is designed to enhance and actualize the environmental framework and protect the environment. From the legal aspect, this policy has led to a different set of regulations developed since 1975. The following are the main relevant laws and decrees worth mentioning in this respect (Dridi & Khraief, 2011):

- The cornerstone legislation on the Communities entrusting waste collection in communal areas to municipalities was enacted in Law 1975-33 of 14/05/1975.
- The cornerstone legislation on waste control and its management was enacted in Law 96-41, dated 10/06/1996: amended by the Law 2001-14 of January 30, 2001, on waste control, management, and disposal.
- The legislation on establishing the pollution abatement fund (FODEP) was enacted in Law 92 – 122.
- The legislation on the code of local taxation was enacted in Law n°97-11, of 3 February 1997.
- Decree N° 2317-2005 of 22/8/2005: Establishing a national agency for waste management and establishing its mission, administrative and financial organization, as well as the modalities of its operation.

The concerning waste control, management, and disposal indicate that:

"Professionals must undertake to create, on their initiative or at the initiative of the competent authorities, systems for the recycling and re-packaging of waste and its re-use, recovery and valorization. Producers, manufacturers and suppliers shall be required to participate in any scheme to collect, transfer or valorize certain kinds of waste and canning waste. The competent authorities may, under the conditions stated by them, enforce the delivery of such waste or any other waste to the institutions or interests designated by them and under the conditions laid down by them."

"The producer, manufacturer, or carrier is responsible for the recovery of waste that is generated by the materials or products manufactured or marketed by them. The competent authorities may additionally request them to remove such waste and, wherein appropriate, contribute to recovery and removal scheme from other similar products."

Furthermore, some frameworks are specific to particular types of waste. In this regard, the specific frameworks form the sectors, which are defined according to the types of waste of a homogeneous composition or nature and their approved remedy procedures. Establishing the sector requires identifying the following four components:

1. The regulatory component that describes the nature and characteristics of waste in the sector
2. The institutional component that specifies the various political institutions engaged in the management of the sector
3. The technical component that determines the intervention conditions for the collection and remediation of the waste in the sector
4. The financial component that identifies the sector's funding method to ensure its sustainability. A sector should be capable to generate added value irrespective of any subsidy and be self-financed.

2.6.3. Financing and Economic Factors

Tunisia's central government is participating in finance waste management through the state budget and from international support in the form of subsidies and grants to develop infrastructure via National Agency for Waste Management [Asociación Nacional de Grandes Empresas de Distribución (ANGED)]. Municipalities cover recurring costs like maintenance and private sector contracts. Moreover, Municipalities also finance the collection and transport of waste to transfer stations and landfills. The municipal resources are collected via local taxes, where the rate of recovery represents only 27% (GIZ and SWEEP-Net, 2014).

In this regard, Chaabane (2020) stated that Tunisia's finance system for waste management is mainly characterized by the absence of financial incentives and effective cost recovery mechanisms. The use of economic instruments to manage solid waste requires an integrated approach to waste management and a reduction of uncontrolled landfills. Compared to uncontrolled landfills, controlled landfills are a costly but necessary option to limit spillovers and

ensure sustainable development (Dridi and Khraief, 2011). Waste management is a shared responsibility between several stakeholders on the national and local levels. The key officials involved in the waste management responsibilities are:

- At the national level as directly involved: Ministry of Local Authorities and Environment (MLAE) (Formerly Ministry of Environment and sustainable development [MESD]), National Agency for Waste Management (ANGED), while the Ministry of Industry and the Ministry of Finance etc. are to a lesser degree involved in the system of waste management.
- At the local level, the municipalities are the governing body in charge of waste management, as stipulated by law No. 96-41 related to the control, management, and disposal of waste;
- Waste producers under the framework of Law N° 96-41 (Polluter Pays) are also responsible for waste management: this is represented in the different waste recovery systems such as ECOLEF, ECOZIT, ECO Batteries, etc., (Mahjoub et al., 2020; GIZ and SWEEP-Net, 2010; 2014)

In Tunisia, Municipalities (urban and rural areas) are the main authorities responsible for SWM operations in terms of the collection and transportation of the collected mixed waste to the transfer stations, while ANGED is responsible to transport waste from stations to landfill and managing it. Moreover, ANGED affiliates are responsible for the collection and recycling of packaging materials, used oil, and batteries. In industrial areas, the Groups of Maintenance and Management (GMGs) are liable for the collection and transportation of non-hazardous wastes, operating as associations to organize activities around the industrial area to ameliorate the quality of life and rehabilitate the contaminated sites (Mahjoub et al., 2020).

3. RESEARCH METHODOLOGY

3.1. Methodological Approach

The purpose of this study is to investigate waste tyre management practice as an aspect of solid waste in Tunisia and to understand the nature and causes of the tyre waste problem and the environmental issues associated with this waste stream. The diverse nature of the data required and the various sources collected from them make the mixed approach appropriate. In accordance with this methodological approach, research instruments associated with both qualitative and quantitative data collection approaches were combined, comprising interviews, field observations and documentary analysis After carefully considering the research objectives, the nature of the data required for the analysis and the predominant conditions in the field of the research, it became apparent that the most ideal approach to gathering satisfactory data for the research would be a combination of the methods of both qualitative and quantitative approaches. This is because the greatest portion of the data required was qualitative and could best be acquired through interviews, while others were quantitative and accordingly, could be obtained from secondary sources. Moreover, parts of the data were physically observable and could be collected through direct field observation. There was likewise a range of published information such as newspaper articles, reference books, academic journals, and other publications that could yield valuable and useful information for the research study. Taking this perspective into account, the researcher ended up persuaded of the usefulness of combining two different methods, namely both qualitative and quantitative approaches, in my endeavour to collect the data required for this research study. Therefore, the study used interviews, field observation, documentary analysis and secondary data sources, drawing on the strengths of combining methods to improve the quality and validity of the data.

3.2. Interviews

Interviewing is one way to collect valuable and useful data from people who have relevant experience and knowledge, through a one-to-one verbal exchange between the researcher and interviewee (Hay, 2005). The interview technique is considered more useful because most people are more willing to talk in an interview than the case would be if they were asked to write responses or fill out a questionnaire (Robson, 1993). In addition, this technique is useful because it is ‘introspective’ and allows participants to report on themselves, their views, practices, beliefs, interactions and concerns (Freebody, 2003). The interviewer attempts to elicit information from persons by asking predetermined questions (Longhurst., 2010). In this regard, Barriball and While (1994) argue that the formulation and sequence of all questions directed in standardised interviews are the same, and hence the difference in answers is not the result of a difference in questions, it is a result of the difference in the perspectives of participants involved in the interview. Consequently, Denzin (1989) clarifies that a semi-structured interview affords the interviewer the opportunity to change the words but not the meaning of the questions provided, which acknowledges that not each word has the same meaning to each participant and not each participant will utilise the

same vocabulary. Therefore, one of the advantages of the interview technique it creates the opportunity for interviewees to ask for clarification when they do not understand a question, just as the interviewer can ask for clarification or elaboration about the answers that the interviewee provides. Thus, there is a surety that all questions will be answered or, at least, there will be an attempt at an answer by the person interviewed (once he/she can permit sufficient time for the interview), which secures a high response rate (Freebody, 2003). The purpose of conducting interviews was to obtain data from several stakeholder groups in the study as shown in Table4. These were:

- Officials of public and research institutions (MESD, ANPE, CITET, ANGED, CERTE).
- A former official of the Al Zahra municipal council.
- Business owners /operators and staff of the private sector.

Table 4. Key Stakeholder Respondents to the Interview

Category of main stakeholders	Actual participants selected for the study	Position
Public institutions with functions affecting solid waste management	• Ministry of Environment and Sustainable Development (MESD) • National Environmental Protection Agency (ANPE) • Tunis International Centre for Environmental Technologies (CITET) • National Agency for Waste Management **(**ANGED)	• Senior official at The General Directorate of the Environment and the Quality of Life • Engineer affiliate to Department of Environmental Assessment and Remediation Assistant Director of International Cooperation • A head of the west Management Department and two other officials.
Public institution related to driving licenses, vehicle registration, technical inspection, preview, acceptance and authentication.	Technical Agency of Terrestrial Transport (ATTT) affiliate of the Ministry of Transportation	• An official at the Technical Agency for Land Transport
Research institution	• The Water Research and Technologies Centre (CERTE)	• Research and Advisory
Producers of waste tyres for disposal	• Tyre importer, • local tyre traders and distributors, • garages and shops for repairing and replacement of new tyres, • scrapyard of vehicle (Dealer)	In this category, part of the participants represented the owners and the other part, the workers
Providers of waste disposal service	• Al Zahra Municipal Council • Informal waste collectors; landfill	• Former Member • Scavenger
Non-government organisation (NGO)	• Tunisian Organisation for Consumer Information (TOCI) • Environment and Heritage Society (EHS)	• Founder and member • Members (Engineers)

4. RESULTS AND DISCUSSION

This paper presents the results of an investigation concerning how tyre waste is managed in the study area by using a qualitative methods approach through interviews and field observations. The study was conducted to understand the current waste tyre management practice using field observations at workplaces and in the area surrounding or nearby the business activities, to gain an understanding of the real situation on the ground. Additionally, information was collected from interviews with stakeholders. Table 4.1 provides a summary of the methods adopted for data. With regards to the waste tyre arising in Tunisia for a certain period, the researcher used a quantitative method approach to estimate the waste tyre quantities disposed of for this period as shown in Table. 5.

Table 5. Method Used for Data Collection

Method code	Summary	No. of participants
OBS	Observations by the researcher in the study areas	6
MESD	Interview with the representative of the Ministry of Environment and Sustainable Development	1

ANPE	Interview with the representative of the National Environment Protection Agency	1
CITET	Interview with the representative of Tunis International Centre for Environmental Technologies	1
ANGED	Interview with the representative of the National Agency for Waste Management	3
WTRC	Interview with the representative of the Water Technologies Research Centre	1
FMACM	Interview with the Former Member of Al Zahra Council Municipal	1
TOCI	Interview with the representative of the Tunisian Organisation for the Consumer Information (NGO)	2
EHS	Interview with the representative of the Environment and Heritage Society (NGO)	2
Dealer	Interview with the waste generator (Dealer, garages and shops for sale and repair/ replacement of tyres) and informal waste collectors	13
SL	Interview with the representative of Scrapyard and landfill.	3

In suspect to interviews, where information or a quote is attributed to a particular participant this is denoted by an abbreviation code plus number in case of more than a participant from the same institution. For instance, in cases where more than one person per category/organisation/ institution was interviewed, participants are given the same abbreviation code plus a number e.g. (ANGED-1), (ANGED-2), (ANGED-3) and so on. Where applicable, this information has also been supplemented by secondary information that was recommended by those interviewed or subsequently found by the researcher.

Due to a mixed methodology being adopted there is a crossover and exchange of the data to tackle waste tyre management issues in terms of the tyre flow and generation of waste tyres in Tunisia to fulfil research objectives 1, 2 and 3. In addition, to reduce repetition between data obtained from a different group of interviewees and field observations, the results have been synthesized.

4.1. Waste Tyre Management in Tunisia

4.1.1. Sources of Tyre Waste Generators

Keeping tyres in good condition is crucial to driving safety because tyres provide the only contact point between the car and the road. Therefore, it makes good sense to pay attention to tyres in terms of their condition as much as using the car, by checking the tyre tread. Tread depth is extremely important; thus, when it reaches the legal level it becomes worn out. Tonnes of worn waste tyres are discarded across the country every year. Disposal of waste tyres is a challenging task because tyres have a long life and are non-biodegradable. The tyres become waste when they have worn out and are no longer suitable to use (Nkosi et al., 2013). The main generator of the waste tyre in the country context are dealers2 (importers, garages, car care shops and vehicle scrapyards). In this regard, one of the interviewees (Dealer-3) was a tyre dealer the researcher met to describe the process of how they are dealing with tyres when they become unusable. He stated, ‘‘*usually the customers leave their used tyres at garages or shops after replacing with a new one. Although there is no legal obligation to accept end life of tyres, it is customary in Tunisia that the services we provide customers include accepting to keep waste tyres on our premises".* On the other hand, the participants (Dealer-1, 6, 7, 9 and10) admitted that the undamaged replaced tyres that they accepted from customers that had a good body with enough tread depth were sorted to resell as second-hand tyres. One participant (Dealer-3) explained that there were three different categories of tyres to sell to customers (new tyres, second-hand tyres, and retreated tyres).

The interviewee (Dealer-6) stated that the new tyres which flow into Tunisia come from two sources: "*one source is locally manufactured and the other it's imported from abroad*". He continued to say that ‘‘*Imported tyres are either by legal channels or illegally by smugglers; this latter is illegally sold in the shops or garage, and sources of smuggled tyres come from the Tunisian border, either Algeria or Libya"*; these are the so-called informal activities. There are close links between informal economic activities and the smuggling of goods, including tyres, at the Tunisia border (Trabelsi, 2014). Concerning the formal trade as a source of tyres that flow into Tunisia, one participant (Dealer-13) described that the national manufacturer in Tunisia, known as the Society of Pneumatic Industries (STIP) was responsible for rubber tyre production and distribution. This company was founded in 1980 in the framework of an international-Tunisian partnership and it produces tyres for passenger cars and small trucks, and heavy-duty trucks and buses. The company owns two production units, one located in Masakin and the other located

[2] Tyre Dealers (Workshops) Tyre dealers refer to the tyre importer and workshops where consumers repair/change and discard their tyre in the shop. Therefore, these business premises are waste tyre generating sites.

in Manzil Bourguiba. As reported by the interviewee (Dealer-10), the company is manufacturing certain types of tyres, *"these types of tyres are not allowed to be imported from abroad by importers, where it is limited to be manufacturing locally only as a quota to encourage local manufacturers"*.However, other interviewees (Dealer- 9) and (TOCI-2) stated clearly that the company was in a financial crisis due to many reasons; one of those reasons was that the market was flooded with smuggled tyres from beyond the border, which affects formal tyre importers and local tyre manufacturers. Although, the interviewee (Dealer-10) emphasised that the company *"imposed quotas on the tyre dealers who wish to import tyres from abroad in exchange for the obligation to buy the number of tyres from Tunisian tyre manufacturers under the interest of promoting the national product"*. While the other source of tyre flows to Tunisia was through tyre importation ("traders"), who were the formal importers of tyres from abroad; they were subject to a series of measures to get a permit for the importation of these tyres. About this, the interviewee (ANGED-1) described, *"The importation of tyres from abroad is subjected to taxation with the requirement to obtain a permit or authorisation for each customs clearance process".*

4.1.2. The Informal Sector

The results in this section shed light on the informal sector in terms of informal tyre trading and informal recycling. The informal sector is also known as the "grey economy" or informal economy (Akintimehin et al., 2019), i.e. that part of the urban labour force that operates outside the formal labour market (Hart, 1973). The informal sector is on the increase in Global South countries, including Tunisia, and provides employment and income. The informal sector includes many workers who are self-employed and are earning a living through self-employment without being subject to payrolls, and thus are not taxed. Many informal sector activities within the grey economy are unrecorded, unrecognised, unprotected, unregulated and are in unsecured places that may face high levels of risk (Scheinberg & Savain, 2015). Examples of the informal sector include minor traders, small-scale producers, and a variety of casual jobs. In Tunisia, the informal economy represented 30 per cent of Tunisian GDP in 2010, which then increased to 38 per cent in 2013 (Trabelsi, 2014).

4.2. The Situation of Awareness and Community Participation in the Field of Waste Management

In Tunisia, there is a worrying deterioration in terms of the waste tyre as an aspect of SWM in both urban and rural areas. This situation results from the waste producers and NGOs not being involved in waste management decisions because government laws or policies have not made it possible, especially in the era of the former regime before the revolution (MESD). One interviewee (FMACM) stated that the political scene in Tunisia after the revolution of 14 January 2011 has witnessed the transition of three successive governments. Meanwhile, the National Constituent Assembly for drafting a constitution has adopted a new basis for election of municipal councils, rural and regional councils, who are responsible for waste management, so "this waiting situation has caused an impediment in the establishment of the national programs for waste management". Besides, the interviewee (EHS-1,2) emphasised that the deterioration increased due to *"the situation of an unconscious absence of eco-citizenship behaviour and lack of citizens' responsibility in terms of disposing the waste into the environment, especially after the advent of the revolution in January 2011, which became a public phenomenon of disposing of waste randomly"*. Awareness is a critical success factor for effective participation and implementation of community activities. In this regard, the study revealed that the lack of awareness is one of the barriers to effective community participation. One interviewee (FMACM) pointed *out that "the absence of awareness and communication between the government and society, led to a state of indifference, therefore, the citizens began to believe that waste cleanliness is the responsibility of the government alone*". This result is identical to what the GIZ (2010) report indicates, in that the dynamics of "awareness, communication, and informatics after the revolution has turned into a miserable and timid situation for many reasons related to the laceration between the citizens and the administration, as well as the irresponsible behaviour of the citizens and waste producers".

The same interviewee (FMACM) explained that Tunisia after the revolution witnessed political transformations at the level of the country as this caused instability in municipalities, as a result of the dissolution of municipal councils to hold an election for new municipal councils and "this case contributed to creating a gap in the setup communication strategy due to the lack of experience in this field". Meanwhile, the interviewee (TOCI-1) emphasised that the ANGED did not set up "an information and communication plan adapted to the crisis". In this regard, Darwish. (2017) and Loschi (2019) stated that after the revolution, i.e. since 2011, and following the transformation that occurred at the political level of the country, Tunisia witnessed a substantial degradation of the environment caused by the mismanagement of solid wastes, which wreaked havoc on the urban and rural

environments resulting in hot spots of garbage and uncontrolled dumpsites. This status leads to the outbreak of environmental protests in Tunisia and indirectly fostered the diffusion of environmental mobilization. Therefore, punishing violators may become an urgent necessity and a duty to deal with along with the extension of the control system to restore its effectiveness in terms of transparency and social justice. On the other hand, the interviewee (CITET) highlighted that *"it is the time to focus on the awareness and education among citizens to encourage them to involve in waste management issues, and the establishment of transparency to promote environmental sustainability in all things".*

4.3. Impact of Waste Tyre on the Environment

Waste products and pollution are the unpleasant prices usually paid for urbanization and industrial development. The increasing pollution caused by the growing use of automobiles and other vehicles has become a cause for alarm around the world. However beneficial tyres may be to mobility, scrap tyres negatively affect the environment when improperly disposed of. In terms of the impact of waste tyre disposal on the environment and public health, the representative of ANPE recognized the effect on soil and underground water pollution as among the biggest impacts. The ANPE officer explained: *"There are no specific landfills (as one homogeneous type of waste) to dump waste tyre that should be subject to strict in terms of design and operation. Therefore, waste tyres are dumped on open spaces or in landfills; thus the tyres disposed of in landfills tend to rise to the surface, disrupting the protective final cover of closed landfills which may cause leachate leakages during the rainy season. This could enter the water source leading to underground water pollution and soil contamination"*. Furthermore, the researcher's observations accorded with the findings of Mahjoub et al. (2020), who emphasised there are several different types of liquid and solid waste, such as tyre waste and other industrial compounds, that are discharged in surface water, as happened in Melian stream. The representative of (WTRC) pointed out that the lack of control of open dumpsites can hurt the environment and public health, such as the burning of waste tyres or dumping them in open spaces to become a breeding ground for insects and rodents. The researcher observed such tyres were dumped randomly in open spaces, which became a place for insect breeding.

4.4. The Institutional Framework and Legislation or Legal Framework Governing the Management of Waste Tyres

4.4.1. Current Regulations and Policies on Waste Tyre Management

Waste management has always been one of the strategic pillars of the policy of the government in Tunisia. The future vision is to improve the framework and protect the environment. Since the late 1980s, the Tunisian government has enacted many laws and decrees to protect the environment and manage and mitigate pollution in general and more particularly, promote the sustainable management of waste, which with economic development is becoming a concern for the regulator as it can endanger both the human and the natural capital of the country. Dridi and Khraief (2011) expressed that the protection of the environment generally and waste management particularly, is currently a priority in Tunisia, to the extent that investments in environmental protection had reached 1.2% of GDP. In this context, the interviewee (MESD) clarified that Tunisia had been concerned with the environment since independence, but the pace of attention to legal issues and regulations had increased since 1988 with the creation of the National Agency for Environment Protection (ANPE). In 1991, Tunisia created for the first time a Ministry for the Environment. Besides that, the participants (MESD) and (ANGED) stated that Tunisia had ratified many important multilateral environmental agreements to promote environmental protection, such as the Kyoto Protocol and the Basel Convention. The interviewee (MESD) stated, *"One of the most important institutions affiliated to the ministry of environment that had a direct relation with waste management is the National Waste Management Agency (ANGED)"*, which was established by Decree No. 2005-2317 of 22 August 2005. Prior to this, in 1995 a framework law on waste management was promulgated. However, this framework law for waste management did not include provisions for waste tyres specifically. The interviewee (CITET) emphasised that at the time of data collection in Tunisia, *"there is no specific legislation controlling waste tyre disposal"*.

Waste tyres in Tunisia are considered to be non-biodegradable solid waste. Although most of the waste tyres are disposed of in dumpsites or open areas, the same interviewee said: *"There is no specific regulation to regulate waste tyres in terms of collection, transportation or recycling"*. The main law which controls waste management and disposal is the law 1996-41; this is the Organic Law of Commons entrusting waste collection in the communal areas to municipalities, as represented in the law 1975-33. There is also decree 726-1989 relating to rural councils

entrusting waste disposal in rural areas to elected councils. According to law 1996-41 concerning waste management and disposition, this law addresses the management of all types of waste without mentioning waste tyre management more specifically, or the principles applied to the ELT. The concept of waste, by law 1996-41, explained Waste is all materials and things disposed of by the holder or intended to be disposed of or that need to be disposed of or to be removed, according to provisions of this law. Therefore, Tunisia has not defined an approach for tyre waste, i.e. for ELT (Legislation Portal Tunisia, 2015). Besides, the representative of the (ANPE) indicated in the interview there is a set of texts that strengthened the regulations indirectly related to waste tyres that represent environmental protection and the fight against pollution, including namely Law No. 95-70 on the conservation of water and soil and Law No. 2007-34 on air quality. He continued, saying that *"despite the existence of this law, it did not prevent the air, water and land of Tunisia from being polluted"*. This is due to the lack of enforcement of the law or the lack of follow-up by the competent authorities to execute this law. On the other hand, the interviewee (ANPE) admitted that despite the comprehensive legislative framework for waste management, this legislation did not refer to the obligations that must be followed by tyre waste producers or distributors to regulate the waste collection process and recycling requirements. In addition, not clarifying the division of roles between stakeholders and those involved directly or indirectly in tyre waste to manage it properly. It was observed that the activity of tyre dealers in Tunisia involved only the selling, repairing or fitting of tyres, limiting the accomplishment of environmentally sound objectives (OBS). Moreover, the interviewee (Dealer-10) stated, *"We as a distributor have no legal requirements to educate the general people about the problem of waste tyre management and we are not required to establish waste tyre collection logistics"*. Through the interviews with participants, it was found that there were no tyre collection centres created to accept and temporarily accumulate waste tyres disposed of by garages, shops or tyre distributors. Meanwhile, the participant (TOCI) clarified that the distributors were not under obligation to receive waste tyres when they sold new ones to the consumers. Therefore, this represents a huge obstacle to the behaviour change of consumers. In this regard, consumers are playing two roles in the life cycle of tyre waste: the customer and tyre waste holder. That is why the tyre waste management system cannot be efficient if consumers are not actively involved in it. They cannot contribute if they have no environmental awareness and information about it. Wilson (1996) underlined that Waste minimization from the source requires changes in the behaviour of people, either collectively or individually. Whatever policy measures are utilized, they will require support with coordinated information campaigns, both to advise people what they are required to do and to persuade them to do so.

4.4.2. The Institutional Framework in Tunisia

The government of Tunisia have various institutions involved in the management of waste; the National Agency for waste management (ANGED); and the local municipalities. They are both responsible for the collection, transportation and disposal of waste. The central government, through the Ministry of Environment and Sustainable Development, formulates waste management policies. However, the government have not adequately assumed full responsibility the waste tyre management as a subject of great environmental importance and has not introduced any approach that established the norms applied to waste tyre management, with the objective of waste prevention, development of collection activities and involvement in environmental actions of tyre stakeholders. Participant (FMACM) stated *".the waste is collected by the municipalities and contracted private sector companies. The government has not established waste tyres prevention or developed separate waste tyres collection systems and proper waste tyres treatment and disposal systems. Only plastic, paper, glass, and scrap metals have a noticeable recovery level, but with very limited recovery and recycling activities for waste tyres. The collection of the waste tyre is driven by informal collectors from disposal sites"*. Looking at these results, the policies in Tunisia do not extend any responsibility to tyre producers or retailers, suppliers and distributors for end-of-life tyres or suggest the establishment of a non-profit organization responsible for the management of those waste tyres. The participant (FMACM) indicated that no policy approach defined the disposal target of waste tyres; there was only policy defining broad approaches for management and handling practices of all the waste streams, without defined disposal targets or supporting or guaranteeing effective treatment options for the waste tyres.

On the other hand, an interview with another participant (CITET) indicated something noteworthy about the management of waste in Tunisia; namely the overlaps in roles suffered within urban councils and the ANGED in waste chain management, which was hampering the sector from achieving the objectives set during national actions and strategies. The interview with the participant representing a Former Member of Al Zahra Council Municipal (FMACM) stated that *"the tyres distributors, suppliers, garages and scrap dealers have not maintained any aspect of cooperation with other stakeholders, such as municipalities and regulators, to deal with specific environmental*

problems regardless of whether there is an economic incentive model for recovery and recycling activities of waste tyres". He continued by saying: *"As I told you, the decisions and responsibilities of waste tyres are left to consumers or waste tyre producers, either it was stockpiled illegally or disposed it of indiscriminately and abandoned in the environment"*. Moreover, there were no established partnerships for creating a waste tyre society and developing technical and economic aspects in the management of the waste tyre practice. There were no established management mechanisms, including material and auditing flows as well as inspecting and administrating systems for waste tyre management.

5. CONCLUSIONS

The present study provided a comprehensive investigation of stakeholders and many key aspects that affected the practice of waste tyres management in Tunisia. The research noted the problem largely results from the lack of government commitment to address the issue of tyre waste management. Tunisia faces issues of the flow of informal importation of poor-quality tyres by smugglers on borders. Imported informal tyres (smuggled tyres) are offered at low prices and without-quality-check-controls. Poor quality tyres increase waste tyre generation and accumulation. It could be inferred that the flow of smuggled tyres causes problems with tyre waste control in Tunisia, contributing to the problem of waste tyre management. The absence of adequate legislation created much illegal waste tyre dumping sites in different areas of Tunisia, where unemployed people use them for various purposes. The current state of unregulated disposal poses a serious threat to human health and the environment. There is an operational gap in the national approach to dealing with the regulation of tyre waste. It is therefore difficult to track and prosecute the perpetrators of any illegal dumping of tyre waste. Thus, it can be said that the existing policies, laws and regulations cannot address the issues of waste tyres in terms of storage, collection, transportation, and exploitation of the value and final disposal of waste tyres. Although used tyres are ultimately considered waste, the results also revealed that the tyre producers and community, in general, are unaware of the role of the government concerning waste tyre management.

The responsible authorities in the country have failed to promote partnership with the tyre waste producers or to involve them in the various aspects of waste management including needs assessment, financing, waste collection and final disposal. At the level of institutional frameworks in Tunisia, the Tunisian government has different institutions involved in waste management. The ANGED is responsible for the transportation and disposal of waste from transfer centres to landfills, while the municipalities are responsible for waste collection from the source and transporting it to the transfer centres. The central government through the Ministry of the Environment and Sustainable Development formulates waste management policies. However, the government has not taken full responsibility for tyre waste management as a matter of environmental importance and has not provided an approach to establish a model applicable to tyre waste management, prevent waste, and develop the collection, transportation and participation activities in their environmental actions with stakeholders. In summary, it should be noted that most of the major issues reflecting the current situation in the country, particularly the deficiencies in the management of tyre waste at the national level in Tunisia, are as follows:

- Exacerbation phenomenon of smuggling or informal trade of tyres in Tunisia.
- Waste tyre generation increases steadily and inevitably without treatment.
- The government has no involvement in regulating waste tyre management.
- Lack of commitment from participants and all stakeholders in waste tyre management.
- Lack of innovative engineering applications of waste tyres and recovery process.
- The absence of a systemic and consistent policy and legislation specifically mentioning guidelines for waste tyre management.
- The dearth of public awareness and capacity-building programmes.
- Lack of mandatory information and records available.

This study showed that an effective system is based on the technical, environmental, economic, legal and institutional aspects that should be present to ensure the overall efficiency of the system. New and innovative technologies and processes can easily take away a significant portion of scrap tyres from the environment and convert them into valuable materials, thus reducing the environmental impact associated with their dumping at landfills. In this regard, one of the interviewees (Dealer-3) was a tyre dealer the researcher met to describe the process of how they are dealing with tyres when they become unusable. He stated, ‘‘usually the customers leave their used tyres at garages or shops after replacing with a new one. Although there is no legal obligation to accept end life of tyres, it is customary in Tunisia that the services we provide customers include accepting to keep waste tyres on our premises". On the other hand, the participants (Dealer-1, 6, 7, 9 and10) admitted that the undamaged

replaced tyres that they accepted from customers that had a good body with enough tread depth were sorted to resell as second-hand tyres. One participant (Dealer-3) explained that there were three different categories of tyres to sell to customers (new tyres, second-hand tyres, and retreated tyres). The interviewee (Dealer-6) stated that the new tyres which flow into Tunisia come from two sources: "one source is locally manufactured and the other it's imported from abroad". He continued to say that ''Imported tyres are either by legal channels or illegally by smugglers; this latter is illegally sold in the shops or garage, and sources of smuggled tyres come from the Tunisian border, either Algeria or Libya"; these are the so-called informal activities. There are close links between informal economic activities and the smuggling of goods, including tyres, at the Tunisia border (Trabelsi, 2014).

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