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Study of the impact of the transport sector on air pollution in the Tunisian Sahel

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***Abstract*— The transport sector contributes significantly to global air pollution. For the purpose of safeguarding public health and maintaining the environment, it is essential to continue study in this area in order to develop appropriate policies and solutions to reduce pollution emissions.**

This investigation focused on the Sahel region of Tunisia's transportation sector emissions. The results for road transportation demonstrated that the emissions values in Sahel cities (Sousse, Monastir, and Mahdia) rely on vehicle types, fuel, and roads. In comparison to Monastir and Mahdia cities, Sousse is the most polluted city.

Significant emissions from several ship types were seen at Sahel region ports when comparing the cruise phase of shipping to the maneuvering and hotelling phases.

At Monastir and Enfidha-Hammamet Sahel region airports, different types of aircraft produced large amounts of pollutants, NOx and CO, compared to other pollutants, throughout an LTO cycle.

***Keywords*— Air pollution, Maneuvring phase, Hotelling phase, Cruising phase, LTO cycle.**

I. INTRODUCTION

Due to its negative effects on the environment and human health, air pollution is a serious concern for both researchers and government agencies [1, 2].

The World Health Organization (WHO) estimates that both in urban and rural regions, outdoor air pollution causes millions of deaths each year [3].

Increased air pollution emissions may result from an increase in the fleet size of vehicles and the resulting fuel consumption. Therefore, the creation of a thorough vehicle emissions inventory (VEI) is necessary for a particular study region. This can help researchers and states create plans for reducing pollutant emissions in urban areas [4].

Additionally, certain activities must be taken, including those related to urban growth and the selection of construction and road development locations.

Vehicle emissions were the main contributor to air pollution and its harmful consequences on human health, especially in metropolitan areas, according to a study by Peng Wang et al. When it comes to pollutant emissions, which worsen air quality, traffic bottlenecks are known to be a contributing cause. In order to examine the effects of congestion on air quality and health, the study suggests a novel methodology [5].

Siti Haslina Mohd Shafie, Mastura Mahmud, et al. studied gaseous pollutants such carbon monoxide (CO) and nitrogen oxide (NOx) emitted by various classes of motor vehicles in the tropical metropolis of Kuala Lumpur. They also looked at particulate matter (PM10) emissions from exhaust and non-exhaust sources. Newly registered passenger cars were shown to be the major source of PM10 emissions. Passenger cars produced greater CO and NOx emissions in 2014 than they did in 2010 in terms of gaseous pollutants [6].

To measure the effects of air pollution brought on by emissions from mobile sources, Ruipeng Tong et al. conducted a study in a Beijing metropolitan area. MOVES, a model for simulating vehicle emissions, was employed by the researchers. Following that, two PM2.5 exposure scenarios were modeled using an atmospheric dispersion model. The findings indicated that, compared to weekends, weekdays had higher average vehicle PM2.5 emission levels, particularly during peak hours [7].

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A study by Pul Yu et al. looked at various techniques for detecting car emissions, such as measurements in a lab, measurements in traffic, and measurements in a tunnel. They looked at the variables that affect how emissions from driving vehicles are assessed, taking into account the road environment and the operating characteristics of the vehicle [8].

The performance of the road network and vehicle exhaust emissions in the Palembang neighborhood of Beringin Janggut were examined in a study done by Achmad Rizki Pratama, Joni Arliansyah, and others. In order to compute vehicle exhaust emissions, they used EnViver software and Vissim to simulate traffic. To improve the performance of the road network and lower overall vehicle exhaust emissions, the researchers proposed two different solutions: Alternative 1, which involves rearranging the parking lot, and Alternative 2, which involves separating lanes for public and private vehicles. In this regard, Alternative 1 was found to be more effective than Alternative 2, [9].

According to the study by Xiaowei Song et al., automobile emissions are a significant cause of air pollution, necessitating immediate action to protect the environment. The research was conducted in the Chengdu-Chongqing Urban Agglomeration (CCUA), a less developed area of southwest China with a high vehicle density. This study aimed to create 10 air pollutant emission inventories from automobiles over a number of years, then analyze that data to create eight different scenarios for emission control legislation. The eradication of non-compliant vehicles was found to be the most successful policy for lowering pollutant emissions (NOx, PM2.5, PM10, etc.) among the scenarios examined [10].

Piotr Holnicki's research work was concerned with the analysis of the impact of the modernization of road traffic on The focus of Piotr Holnicki's research was on the evaluation of how the modernization of road traffic would affect air pollution in the Warsaw metropolitan area in Poland. The Calpuff model was employed by the researcher to estimate the population's exposure to these pollutants and to simulate the average yearly concentrations of NOx, CO, PM10, and PM2.5. The findings indicated that the primary contributor to the NOx and CO levels in the city's air was the traffic. A vehicle emissions reduction scenario was developed using Euro emissions standards, based on the supposition that the fleet of vehicles would be updated and that Euro 6 emission standards would be adopted. The models showed that lowering emissions from passenger cars, trucks, vans, and transit buses resulted in a decrease in NOx concentrations. However, modernizing gasoline-powered vehicles was the key factor in the improvement of air quality in terms of CO concentrations. When the suggested scenario was put into practice, the population's exposure to air pollution was significantly reduced [11].

An investigation on how the use of automated vehicles may affect emissions and fuel usage in the road transportation industry was conducted by Zelalem Birhanu Biramo et al. As a result of variances in how acceleration and speed are used, their findings show that drivers' driving actions have a considerable impact on emissions and fuel consumption. Especially in metropolitan areas, researchers looked into the employment of programmable automated vehicles as a potential fuel-saving measure. The amount of carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), particles (PMx), and nitrogen oxides (NOx) emissions were significantly reduced at the grid level in their most optimistic scenario, when all vehicles are replaced by fully automated vehicles [12].

There have been notable decreases in vehicle emissions of lead (Pb), nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM), and nitrogen oxides (NOx) in recent years. These developments were made feasible by the creation of sophisticated emissions after-treatment technology for gasoline and diesel cars, allowing compliance with ever-stricter laws. Despite an increase in vehicle mileage, these initiatives have led to a complete decrease in the emissions of the fleet now on the road. In cities all around the United States and Europe, these actions have significantly improved the air quality [13].

Air emissions from shipping have received increasing attention due to their impact on air quality and their contribution to environmental problems. Some nations keep track of the air quality in their port systems, concentrating on certain criteria toxins [14]. Research shows that living close to a port has a negative impact on human health and the environment [15].

During the combustion of marine fuels, significant emissions of air pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NOx), fine particulate matter (PM), volatile organic compounds (VOC), carbon dioxide carbon (CO_2), and sometimes heavy metals are generated.

The most polluting phase in maritime transport is often the combustion phase of fuels in ship engines. This includes not only main propulsion when sailing at sea, but also other shipping-related activities, such as keeping engines running when stopping in ports (known as "hotelling"). ") and ship maneuvers.

Although there are other ways to calculate emissions, the Tier 3 technique was chosen because it gives information on how different ship activities, including as maneuvering, hotelling and cruising, affect emissions [16].

However, it is important to note that emissions vary depending on several factors, including the type of fuel used, engine design, applicable regulations, and measures taken to reduce emissions, such as the use of fuels low sulfur content and the implementation of emission reduction technologies [17]. Ships maneuvering or waiting in ports can also contribute significantly to local emissions, particularly if engines are left running for extended periods.

Bacalja et al. have noticed that it is crucial to take into account the variables during the maneuvering and hoteling phases in the city port when developing city strategies to improve the

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efficiency of maritime transport (line ships) and the use of more environmentally friendly fuel, which may help in the future to reduce emissions [18].

Each year, millions of tonnes of pollutants from air transport are released into the atmosphere and can spread widely and quickly. Their impacts on human health and the environment are more significant, especially in the lower atmosphere.

Known as the LTO cycle, these crucial phases of aircraft landing and take-off are referred to. Because they are linked to high-power operations that produce large amounts of pollutants, these phases are especially crucial in the analysis of aviation-related air emissions.

There have been numerous studies of LTO emissions calculated using various techniques. Less data is needed to estimate emissions using an approach based on total fuel usage [19].

Another approach which is based on LTO numbers (number of landing and takeoffs) and the emission factor (EF) per LTO [20].

The majority of airport emissions are NOx but CO is another contaminant to be concerned about. The discharges of only 8.0% of the overall pollutants were made up of HC, SO_2, and PM, which were all quite small amounts [21, 22].

Despite little change in their proportions, NOx and CO accounted for 91.3% of the total emissions and were the predominant emitters [23].

II Method and Materials

The calculation methodology for road transport

In our investigation, we calculated vehicle transport emissions using COPERT, a computer program created by the European Commission (EC).

The COPERT model analyzes many sorts of pollutants and classifies vehicle types in great detail.

With the use of the COPERT calculation, it is feasible to calculate the global emissions of a number of road pollutants and a number of heavy metals, including lead, cadmium, and copper [24].

The calculation methodology for maritime transport

The nature and degree of consumption of fuels used by ships have a direct impact on atmospheric emissions generated by maritime transport.

The quantities of air pollutants emitted by maritime transport are proportional to the quantity of fuel consumed, according to an emission factor.

They can be calculated by the following formula:

$$Ei = Sj,k,l*Tj,k,l*Fi,j,l \quad (1)$$

With j: The fuel.

K: The type of ship.

L: The type of engine.

Sj, k,l: Daily fuel consumption.

Tj, k, l: Number of days in navigation.

Fi, j, l: Average emission factor of pollutant i.

The daily fuel consumption Sj,k,l is calculated using the following formula:

$$Sj,k,l=Cj,k*0.8 \text{ (in the cruising phase)} \quad (2)$$

$$Sj,k,l=Cj,k*0.4 \text{ (in the maneuvering phase)} \quad (3)$$

$$Sj,k,l=Cj,k*0.2 \text{ (in the hoteling phase)} \quad (4)$$

With Cj,k is data that changes with each type of ship.

And Tj,k,l is calculated by the following formula:

$$Tj,k,l=distance*average\ speed.$$

The distance differs according to each phase and the average speed is a data which also differs according to each ship type.

To evaluate the quantities of pollutants emitted, simply multiply the quantity of fuel consumed by these emission factors.

The quantity of fuel consumed can be obtained by modeling vessel activity in order to estimate their consumption.

The calculation methodology for air transport

Carrying out an emissions inventory can be based on the theoretical calculation of the flows of pollutants emitted into the atmosphere. This is the product of the activity and the emissions factors which are presented by the following equation:

$$Es, a,t = Aa, t * Fs,a \quad (5)$$

E, the emission relating to substance s and activity a, during time t.

A, the quantity of activity relative to activity a during time t.

F, the emission factor relating to substance s and activity a.

In the air transport sector, there are two calculation methods for quantifying atmospheric emissions. The first method is determined from average fuel consumption per aircraft type. The second method is calculated from the number of “LTOs” for each type of aircraft.

In our methodology we will apply the second method since the data necessary for this method are available.

This method provides an order of magnitude of emissions for a given area and is presented below by:

$$E(X) = \sum N \text{ (LTO cycle) aircraft } Y * FEX \text{ aircraft type} \quad (6)$$

E(X): emissions of pollutant X (kg).

N (LTO cycle) aircraft.

Y: the number of LTO cycles for the aircraft type Y considered.

FEX: the emission factor for pollutant X considered per LTO cycle.

The LTO is the “Landing – Take-off” cycle.

This cycle breaks down the various operations of the aircraft on and around the airport into four phases: approach, taxiing, take-off and climb.

This theoretical cycle constitutes the basis of the study area.

The LTO cycle for each aircraft is data that can be obtained at the airport. While the emission factors are standard data available in international documents.

II. Results

Emissions in the Sahel region from road transport

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In this section of our research, we will concentrate on five roadside pollutants for the Sahel region of Tunisia: CO, NOx, VOC, PM10, and PM2.5.

According to fig.1, Sousse is the most polluted city in the Sahel with a value of 43% for all pollutants, followed by Monastir with a value of 37%, and Mahdia, which has a value of 21%, is the least polluted. This result can be attributed to the two cities of ousse and Monastir's higher levels of commercial, educational, and tourist activity than Mahdia city.

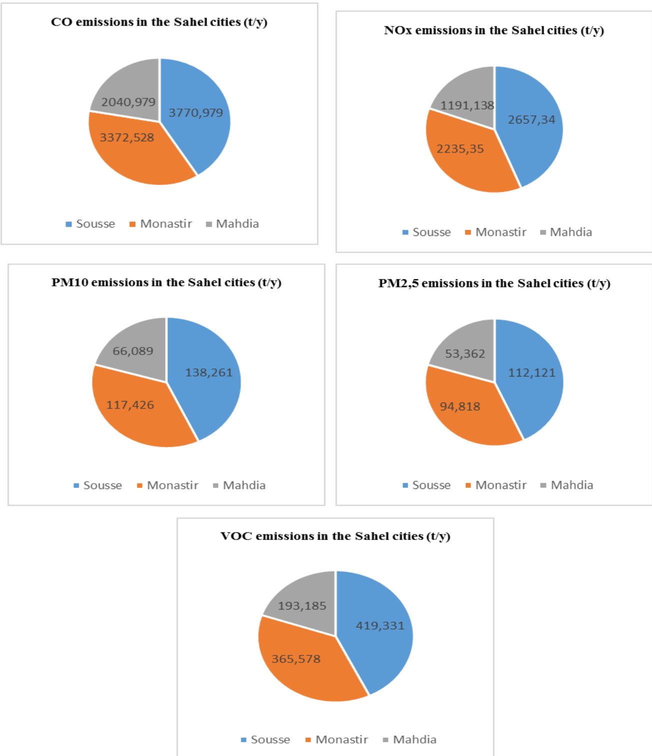

Fig.1 Pollutants emissions in the Sahel region.

CO emissions

According to Fig. 2, CO emissions from vans are larger than those from private vehicles, but little CO emission is found from other modes of transportation. The road most susceptible to pollution and emissions is the urban region, followed by the rural area, while emissions on the highway are low.

It has also been shown that gasoline vehicles produce more CO than diesel vehicles. This is a result of the traffic congestion, particularly in urban areas.

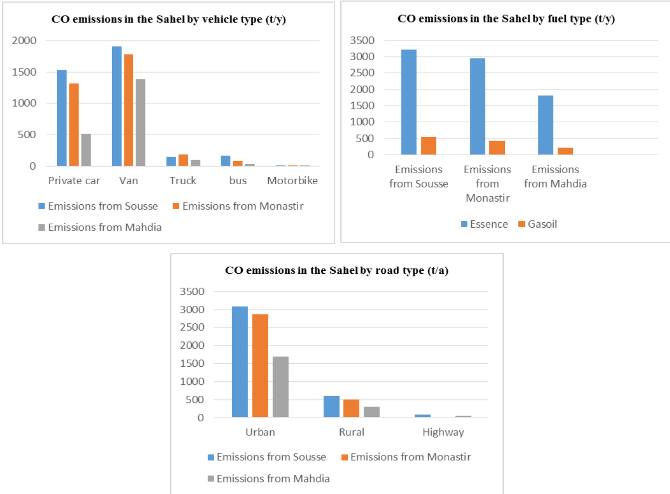

Fig.2 CO emissions by vehicle, fuel and road types.

Nitrous oxide emissions

Fig.3 shows that the NOx emissions from trucks are more significant than those from private cars and vans, with high values for the emissions from buses, particularly in Sousse, and extremely low values for the emissions from motorcyclists.

In all cities, NOx emissions from diesel vehicles are greater than those from gasoline vehicles.

In comparison to rural areas, metropolitan areas emit significantly more NOx, while highways emit very less NOx.

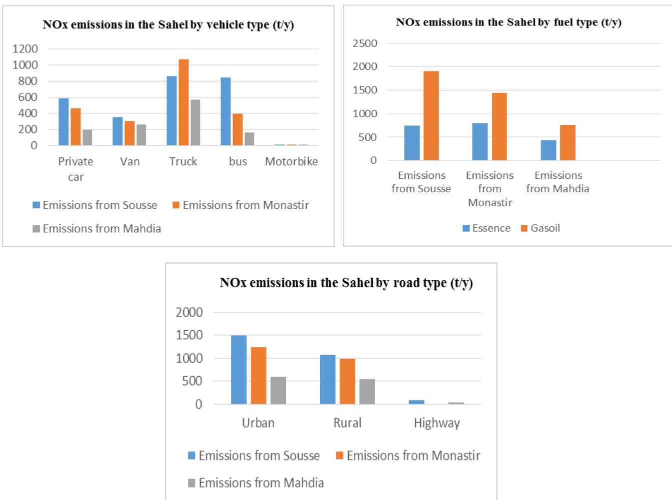

Fig.3 NOx emissions by vehicle, fuel and road types.

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Emissions of VOCs

Fig.4 shows that VOC emissions from private vehicles are larger than those from vans, while those from trucks and buses are lower in quantity, and motorcycle emissions are negligible. Compared to diesel automobiles, gasoline vehicles emit more VOCs. Compared to rural roads and highways, the metropolitan region is the most polluted location.

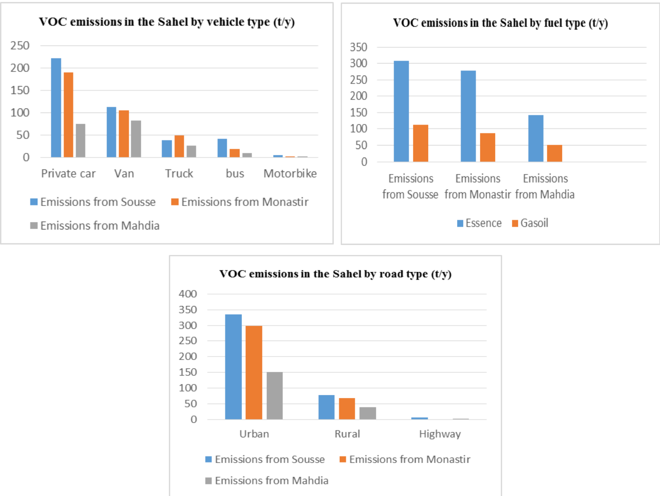

Fig.4 VOC emissions by vehicle, fuel and road types.

PM_{10} emissions

According to Fig.5, private vehicles produce more PM10 emissions than vans, trucks, and motorcycles combined, while buses and motorbikes produce very little PM10 emissions.
Diesel cars release more PM10 than gasoline cars, and we observe that metropolitan areas have higher pollution levels than rural areas and highways.

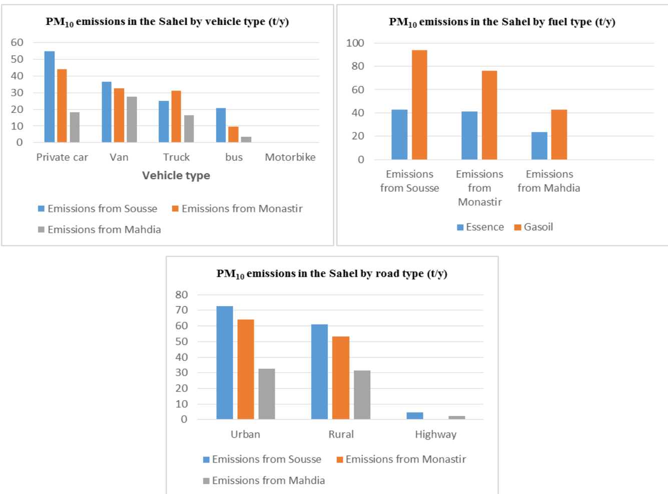

Fig.5 PM10 emissions by vehicle, fuel and road types.

$PM_{2.5}$ emissions

According to Fig.6, motorcycle emissions of PM2.5 are quite low, but those of vans, trucks, and buses are significantly higher.
Diesel vehicles emit more PM2.5 than gasoline-powered ones.
The urban region was more exposed to PM2.5 pollution than either the rural area or the highway.

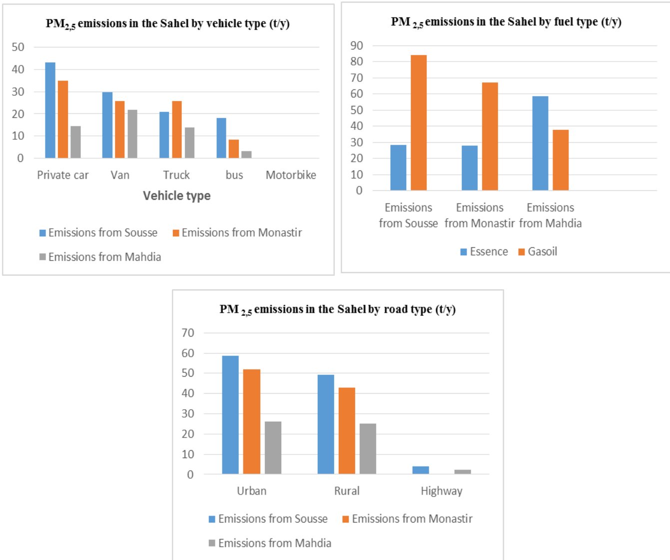

Fig.6 PM2.5 emissions by vehicle, fuel and road types.

Heavy metal emissions

Table 1 demonstrates that Sousse has larger heavy metal emissions than Monastir and Mahdia cities, while Mahdia city has the lowest emissions.

TABLE 1. The emission of heavy metals in the Sahel region.

	Lead	Cadmium	Chrome	Nickel	Zinc
Sousse	33,48	0,156	12,399	1,967	105,16
Monastir	27,067	0,125	10,029	1,587	84,009
Mahdia	11,249	0,133	4,166	0,661	35,33

For each city, Fig.7 demonstrates that zinc emissions are larger than those of the other metals, followed by lead and chromium emissions, while low values are found for nickel and cadmium emissions.

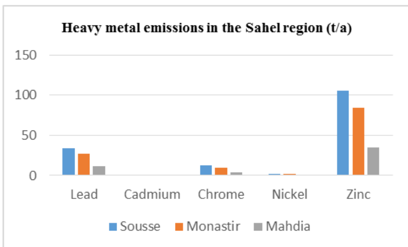

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Fig.7 Heavy metal emissions in the Sahel region.

Emissions in the Sahel region from maritime transport

In the Sahel zone, we found ports with varied activities such as marinas (Port El Kantaoui of Sousse and the port of Monastir), the commercial port of Sousse and fishing ports.

The pollutants emitted by maritime transport are CO_2, CO, SO_2, NOx, PM and VOCs.

The emissions of pollutants during the cruising phase are higher than the emissions during the maneuvering and hoteling phases, as shown in Fig.8.

Since ships sail between ports when they are in the cruise phase, they generate a significant amount of pollutants into the environment. At the maneuvering phase, ships maneuver in the port area, using less energy and releasing fewer pollutants than during the cruising phase. During the hoteling phase, there were fewer pollutants released because ships anchored at the quay and used less energy to run the handling equipment used to load and unload cargo in commercial ports.

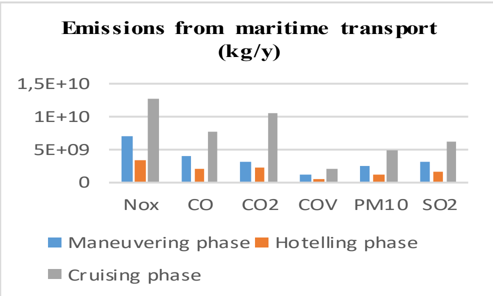

Fig.8 Emissions from maritime transport phases in the Sahel region.

Emissions in the Sahel region from air transport

In the Sahel region, there are two airports: Monastir international airport and Enfidha-Hammamet international airport.

We note that the rate of emissions in Monastir airport is a little higher than that of Enfidha-Hammamet airport.

According to Fig. 9, CO pollution has the highest emission, followed by NOx pollution. Low emission values for the other two pollutants, HC and SO_2, have been noted. The incomplete burning of kerosene for the LTO cycle produces significant amounts of CO and NOx.

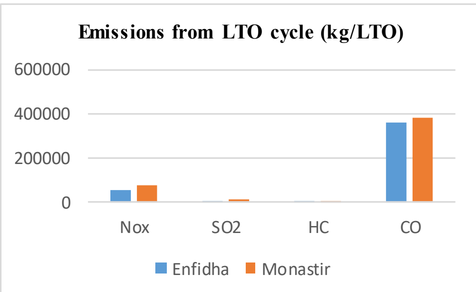

Fig.9 Emissions from LTO cycle air transport in the Sahel region.

III. Conclusion

In our study, we have calculated the pollutants emissions caused by the transport sector in the Tunisia Sahel region.

Data study for road transportation revealed the following:

- Private cars, trucks, and vans are the vehicles that generate the most pollution.
- The metropolitan region is the area most susceptible to air pollution, followed by the rural area, while the highway has a lesser percentage.
- Sousse city emits a greater amount of air pollutants than Monastir and Mahdia cities.
- In the Sahel region of Tunisia, Sousse is the most polluted city, followed by Monastir, while Mahdia is the least polluted.

We also computed the emissions produced by ships on the port quay and aircraft during an LTO cycle.

In relation to maritime transportation, we observed that:

- Significant pollution discharges from ships in the Sousse city port.
- Significantly higher emissions levels from the maritime transport during the cruising and maneuvering phases than the hotelling phase.

In terms of air travel, we saw:

- Air traffic at Monastir Airport releases somewhat more pollutants than at Enfidha-Hammamet Airport.
- Considerable emissions of NOx and CO pollutants from various aircraft types at the Monastir and Enfidha-Hammamet airports.

Every actor in society has a responsibility to protect the environment, including the government through its policies and laws as well as the population by changing their behavior and better understanding the severity of air pollution.

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