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Full Length Research Paper

Air Pollutant Emissions, Bird Strike and Noise levels in Small Airports: A Case of Eros Airport, Namibia

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Abstract
In this study, the levels of air pollutant emissions, bird strike incidences and noise, and the environmental monitoring techniques used were assessed for regulatory compliance and sustainability of the airport. Secondary data was used to calculate the greenhouse gas (GHG) and air pollutant emissions associated with electricity consumption, and flight activity (take-off and landing) at the airport. The air pollutant emissions were determined in decreasing order as CO, SO2, TSP, VOCs, PM10, NOx and Benzene; and the GHG emissions were obtained in the range of 13.5 to 20.6 tonsCO2e.The study has also shown that the landing and take-off emissions at the airport are composed of 50% CO, 26% CO2, 22% NOx, and 2% SO2.Primary data on noise levels were obtained from sound meter measurements. The average noise measurements were all above 80dB which is an unsafe exposure to noise. The aircraft noise results were compared to the South African, World Bank and ICAO standards which were all exceeded. The bird strike monitoring technique used by the Airport and the associated remedial strategies derived from the results yielded more than 40% reduction for the year 2013 and 2014.

Keywords: *Air pollutant emissions, GHG emissions, Noise levels, Bird strike, Monitoring techniques, Eros Airport.*

Introduction

Transportation is an essential contributor to the health and well-being of the nation's economy. Within the transportation sector, aviation has evolved into the fastest, safest, and most far-reaching transportation mode in little more than a century (FAA, 2015). Air transportation is increasingly becoming one of the pillars of socio-economic growth in all parts of Africa and Namibia is no exception (Ohaeri, 2014).

Emission of greenhouse gases (GHGs) and their implications to climate change have sparked global interest in understanding the relative contribution of the transport industry. The Federal Aviation Administration (FAA, 2005) reported that aircraft emissions, depending on whether they occur near the ground or at altitude, are considered local air quality pollutants or greenhouse gases. Aircraft produce the same types of emissions as road transportation. Aircraft jet engines, like many other vehicle engines, produce carbon dioxide (CO2), water vapor (H2O), nitrogen oxides (NOx), carbon monoxide (CO), oxides of sulfur (SOx), unburned or partially combusted hydrocarbons (also known asvolatile organic compounds (VOCs)), particulates, and other trace compounds (FAA, 2005).

Aviation wildlife hazards include birds on the ground and in flight, terrestrial animals (e.g., deer, cattle, camels), and even airborne animals such as fruitbats. This study only reports on bird strike incidences that occur most often on the ground or at low altitude, and are usually benign. Nicholson and Reed (2011) noted that aviation bird-strike hazard is aglobal and industrywide issue affecting all aviation stakeholders, including pilots, mechanics, airlines, airport operators, airtraffic controllers, wildlife personnel and the traveling community. Bird strikes can have significant economic and occasional safety consequences for flight operations. The researchers also reported that Pilots and operators need to be knowledgeable about the hazard, and flight crews should use facts, data, and standard operating procedures to reduce the potential for and consequences of a bird strike.

Aviation and typical community noise levels near airports are not comparable to the occupational or recreational noise exposures associated with hearing loss. Hence annoyance has always been considered the single most significant effect associated with aviation noise (ACRP, 2008), till in the last decade when researchers including Eriksson et al. (2007) suggested a potential relationship between aviation noise levels and hypertension or ischemic heart disease at noise levels as low as 50 dBALeq. Sleep disturbance is also a common effect described by most noise-exposed populations and the complaints of community in the vicinity of Eros Airport are often justified.

Eros Airport is Namibia's busiest airport that handles general aviation around the country and is a member of the International Civil Aviation Organization (ICAO). The Airport is situated in the vicinity of residential areas and the central business district of the city. Typically, airport environments comprise a complex mix of emissions sources including aircraft, ground support equipment (GSE), terminal buildings and ground vehicular traffic. According to ICAO (2011), there is often an associated complex mix of existing regulations and standards covering many of the sources of emissions that are present at airports (e.g. aircraft engines, transport vehicle engines, power/heat generating plants and aircraft maintenance facilities). Together with regional, international and local authorities, all airports including the Eros airport have an important task of taking air quality measurements, implementing corrective plans and programmes, and informing the general public of matters pertaining to local air quality conditions. The aim of this study is thus to determine the level of air pollutant emissions, bird strike incidences and noise at Eros Airport, and to assess the monitoring techniques used. The results of this study are intended to guide the airports in developing countries to adopt and implement the concept of green airports.

A green airport is one that carries out all the environmental monitoring practices and has environmental management plan and systems in place (Sim, 2014). Green airports are expected to engage in sustainable practices including green buildings, green construction, green transportation, resource (energy and water) efficiency, wildlife management, monitoring of air quality and greenhouse gas emissions, and life-cycle assessment.

Materials and Methods
Eros is an airport close to the inner capital city of Namibia Windhoek (Figure 1) which is situated at about 5 km from the central business district. The airport is enclosed by mountains and thus has limited runway length. Eros Airport handles general aviation within the country and also to neighboring Southern African Developing Community (SADC) countries.

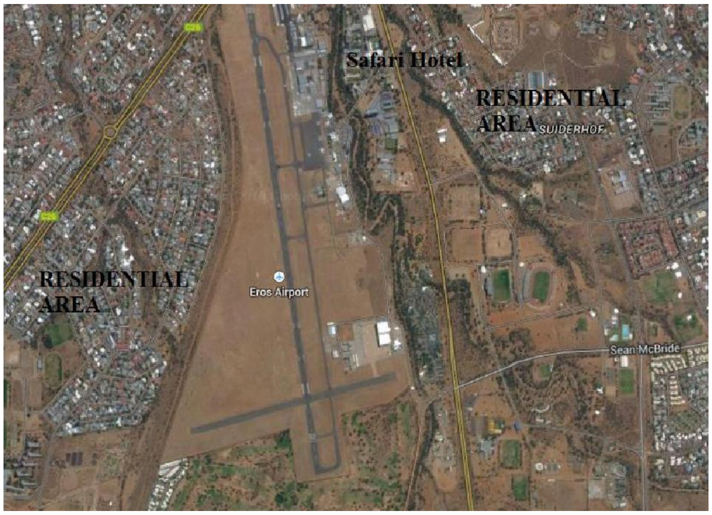

Fig 1: The location of Eros in Windhoek, Namibia

Table 1 shows summary of monitoring methods used by selected Airports worldwide. Eros Airport does not have effective monitoring methods for air emissions and aircraft noise. However the bird strike monitoring methods seem to be effective.

In this study, different methods were used to collect data for each environmental aspect. Interviews were conducted with airport employees to get an overview of the environmental monitoring techniques used. Secondary data on bird strike incidence with the aircrafts and bird identification were obtained from the Chief of Fire, Wildlife and Bird Committee. The energy consumption data were obtained from the airport Finance Office in the form of municipality bills. Calculations for the air emissions were carried out by applying conversion factors obtained from IPCC (2006) and DEFRA (2010).

Primary data on aircraft noise were obtained by measuring the aircraft noise in the field with a sound meter. The measured aircraft noise was further converted to EPNdB by applying the formulae reported by ICAO (1993). Aircraft noise was measured at three different reference points namely the fly-over, side-line or lateral and approach as prescribed by ICAO (1993). The take-off has two measurement points namely, the side-line/lateral point and fly-over point. The approaching/ landing aircraft has only one measurement point. All measurements were taken when the wind speed was less than 5 m/s. The highest sound level was recorded as soon as the aircraft flew by because the aircraft flies by fast and the sound level meter quickly stabilizes back to the background sound in less than 60 seconds of the aircraft impact.

Table 1: Monitoring methods used at different airports

	Eros Airport	OR Tambo International Airport (Sim, 2014)	Cairo International Airport (MB Consultant, 2009)	Narita International Airport (Japan Today, 2014)
Energy conservation	- Use of energy saving bulbs	-Use of natural light -Use of energy efficient lighting (LED) -Energy management monitoring	-	- Use of co-generation system - Use of LED lighting
Air quality management	No monitoring	-Installed air quality systems, - Use of public transport -Slot management	-Installed air quality monitoring stations	-Installed air quality monitoring stations
Aircraft noise management	- Night flight restriction.	-Noise contours; -Track aircraft noise complaints -Flight tracking systems, etc.	-Installed noise measurement systems -Noise monitoring systems etc.	-Installed noise monitoring stations - Monitoring flight corridors -Engine run-up noise mitigation -Soundproofing
Bird Strike	-Classification of all observed bird strike -Use of trained personnel - Grass cutting to a certain height	-Use of dogs to deter birds -Use of bird radar -Bird Identification	-Classification of all expected birds -Plan of action to combat wildlife on runway	-Series of test and research still ongoing

Results and Discussion

GHGs and Air Pollutant Emissions

Energy Consumption

The monthly electrical energy consumption data presented in the Figure 2 below was determined from utility bills provided by the Airport Office.

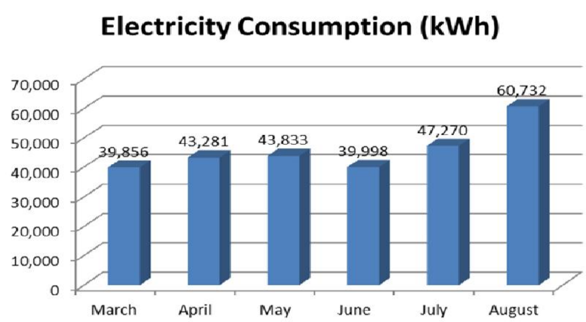

Fig 2: Monthly Electricity Consumption

From the above figure it can be seen that the month of August recorded the highest consumption with 60,732 kWh and March recorded the least monthly consumption (39,856 kWh). The electricity consumption is affected by the administration work in the passenger terminals, lighting of the runway and the beacon light of the airport, passenger and aircraft movement, and other daily activities of the airport. Previous research by Reddy (2014) indicates that 68% of energy consumption is by heating, ventilation and air-conditioning, 17% is consumed by lighting, 12% by equipment load and 3% is the result of concessionaries power consumption.

Information on energy consumed by the aircrafts in the form of fuel was obtained from the fuel deport through interviews with fuel depot manager and the researcher. It was noted (from records review) that on average aircrafts at Eros airport consume 600,000 liters of Aviation gas (AV Gas) for big aircraft such as Air Namibia and the Falcon, and 140,000 liters of Jet A-1 fuel for small aircrafts i.e. Cessna 172 that are mainly used by the different schools of aviation.

Emissions from Electricity Consumption

An amount of 0.59 kg of coal is needed to produce 1 kWh of energy. This value is also dictated by the type of boiler being used and the calorific value of the coal. Thus a factor of 0.59 kg coal/kWh was used to determine the amount of coal consumed during electricity production.

The GHG emissions presented in Table 2 were calculated using consumption data and emission factors (CO2 = 0.33587, CH4 = 0.00006, and N2O = 0.00291 kgCO2e/unit) reported by DEFRA (2010).

Table 2:GHG Emissions from Electricity Consumption in kg CO_2

	Consumption (kWh)	CO_2	CH_4	N_2O	Total Emissions
MARCH	39,856.00	13,386.43	2.39	115.98	13,504.80
APRIL	43,281.00	14,536.79	2.6	125.95	14,665.34
MAY	43,833.00	14,722.19	2.63	127.55	14,852.37
JUNE	39,998.00	13,434.13	2.4	116.39	13,552.92
JULY	47,270.00	15,876.57	2.84	137.56	16,016.97
AUGUST	60,732	20,398.06	3.64	176.73	20,578.43
Sum		92,354.17	16.5	800.16	93,170.83

The air pollutant emissions from combustion of 1 kg of coal were reported by Friedl et al. (2004) as 19 g SO_2, 1.5 g NOx, 5 g VOCs, 4.1 g PM10, 14.7 g TSP, 187.4 g CO and 0.0134 g Benzene. These pollutants (see Table 3) also act as GHG pre-cursors, adding to formation through chemical transformations in the atmosphere.

Table 3: Air Pollutant Emissions associated with electricity consumption.

	Consumption (kg)	SO_2	NOx	VOC	PM_{10}	TSP	CO	Benzene
		0.019	**0.0015**	**0.005**	**0.0041**	**0.0147**	**0.1874**	**1.34E-05**
March	22,319.36	424.07	33.48	111.60	91.51	328.09	4,182.65	**0.30**
April	24,237.36	460.51	36.36	121.19	99.37	356.29	4,542.08	**0.32**
May	24,546.48	466.38	36.82	122.73	100.64	360.83	4,600.01	**0.33**
June	22,398.88	425.58	33.60	111.99	91.84	329.26	4,197.55	**0.30**
July	26,471.2	502.95	39.71	132.36	108.53	389.13	4,960.70	**0.35**
August	34,009.92	646.19	51.01	170.05	139.44	499.95	6,373.46	**0.46**
Sum		**2,925.68**	**230.97**	**769.92**	**631.33**	**2,263.55**	**28,856.45**	**2.06**

The air pollutant emissions associated with electricity consumption at the airport were measured in decreasing order as CO, SO2, TSP, VOCs, PM10, NOx and Benzene. The average contribution of each air pollutant to the total air emissions can be presented in percentages as 81% CO, 8% SO2, 6% TSP, 2% PM10, 2% VOC, 1% NOx, and <1% Benzene (Kgabi et al., 2014).

Aircraft Air Emissions

The aircrafts at Eros A irport consume two different types of fuel namely the aviation gas (AVGas) for high jet engine aircraft that fly at high altitudes and the propeller jet engines consuming the Jet A fuel. The aviation gas (AVGas) fuel is used by aircrafts with turbo fan engine and the Jet A fuel is used by aircrafts with turboprop engine. This type of engines burn fuel differently, which means that their engine emissions will be different. Table 4 shows the emissions released during the landing and take-off cycle by the aircrafts. The emission calculation factors for gases released to the atmosphere during combustion were reported by ICAO (2006) for the turbofan as 3.16, 6.18, 2.69 and 0.31 kg/LTO for CO2, CO, NOx and SO2 respectively; and 0.64, 2.97, 0.3 and 0.07 kg/LTO for turboprop engines (ICAO, 2006).

Table 4: Landing and take-off emissions per monthly average consumption

	Emission factor (kg)	Emission per type of fuel	
		JETA-1 60000kg	**AVGAS** **140000kg**
CO2	3.16	1896000	**442400**
CO	6.18	3708000	**865200**
SO2	0.31	186000	**43400**
NOx	**2.69**	**1614000**	**376600**

The percentage contribution per type of emission for the two engine types is depicted in Figure 3.

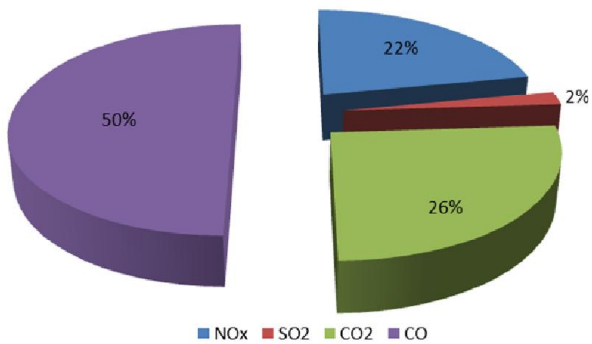

Fig 3: Landing and take-off emissions for JET A-1 and AVGas

Aircraft Noise Levels

Figure 4 shows a comparison of the noise levels measured to the standards. The aircrafts from the school of aviation produce the loudest noise when compared to the Air Namibia Embraer (135dB) and NDF falcon 900B. This is because they fly at lower altitudes and they have propeller fans. This agrees with studies done by Federal Aviation Administration that found propeller aircraft to be louder than other aircrafts.

The loudest noises from all the three aircrafts were recorded at the Approach reference point (2000m to the runway threshold for landing aircrafts). This is because at this point the aircrafts are descending from higher altitudes to lower altitudes in order to maintain the safe height for landing.

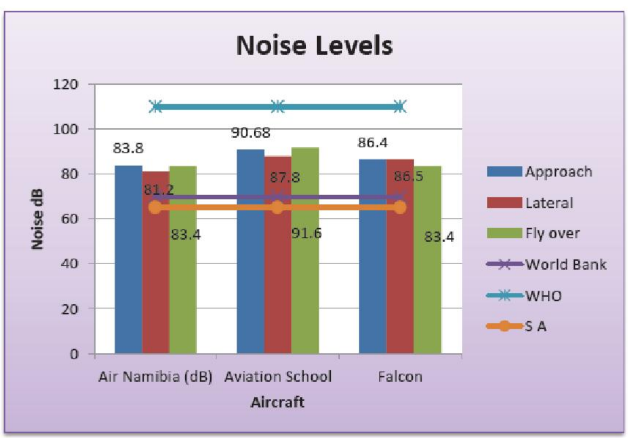

Fig 4: Aircraft noise levels

The aircraft noise was found to be within the WHO standards for ambient noise, but above the South African and World Bank standards. All the noise results are above 80dB, which is likely to cause temporary deafness. The data was further converted to EPNDB noise levels (Figure 5) so that it could be compared to the ICAO standards. The figures below indicate this comparison for each point of reference.

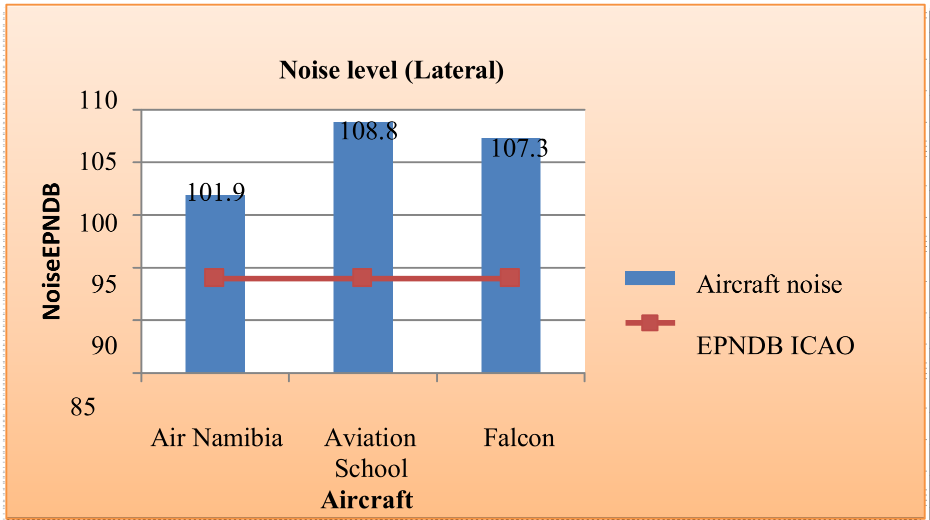

Fig 5: Lateral noise levels vs ICAO standards

The figure above clearly shows that all the aircrafts exceeded the ICAO noise limit at the lateral point. These measurements were taken for taking off aircrafts at a distance 450 m adjacent to the runway. Air Namibia has exceeded the standard the least, while the Aircrafts from the School of Aviation have more exceedances.

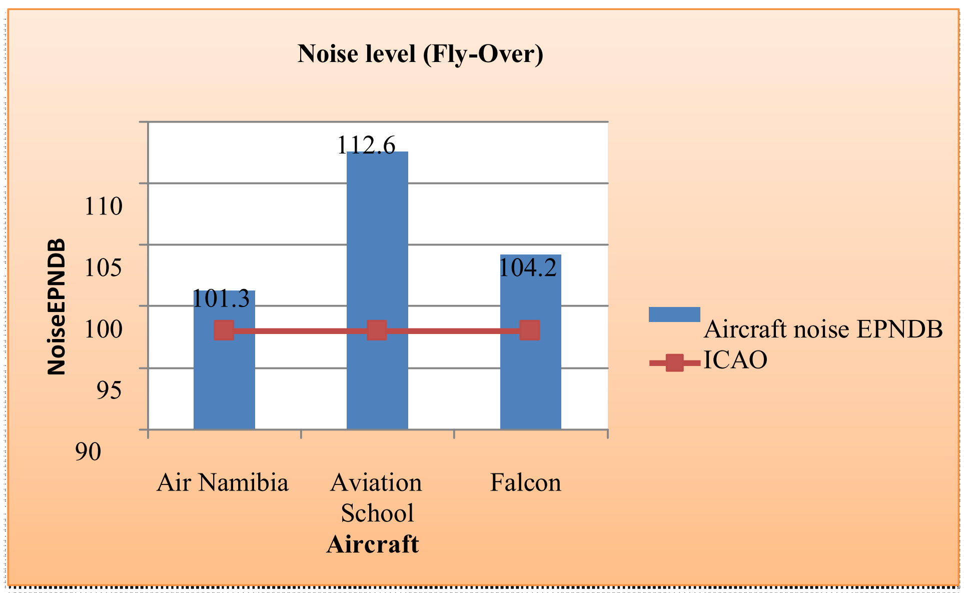

Fig 6: Fly-over noise levels vs ICAO standards

The figure above shows that all the aircrafts exceeded the ICAO noise limit at the lateral point, this measurement is taken for taking off aircraft at a distance of 6500 m from the start of roll. Air Namibia has exceeded the standard the least, with the aircraft from the school of aviation exceeding the limit the most.

The figure below shows that all the aircrafts exceeded the ICAO noise limit at the approach point. This measurement is taken for landing aircraft. It is worth noting that, though there is no physical monitoring of the air craft noise at the airport, there are restrictions to ensure compliance with the local regulations and guidelines. Operational hours for Eros airport are from 06h00 to 21h00. This restricts night flights from using the airport during late night hours.

The residents and business operators living close to the airports are informed of the operational hours of the airport, so that they are aware of the aircraft noise. The Airport also has noise abatement procedures followed by all the pilots that are flying the aircrafts from

Eros airport with the aim of reducing the aircraft noise to the surrounding areas.

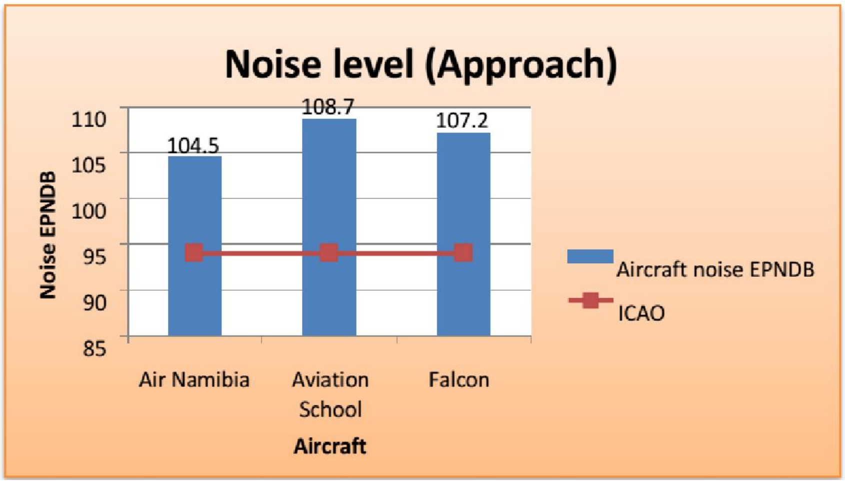

Fig 7: Approach noise levels vs ICAO standards

Bird Strike Incidences

The annual bird-strike averages are presented in Figure 8, showing at least 40% reduction from 2012 to 2014.

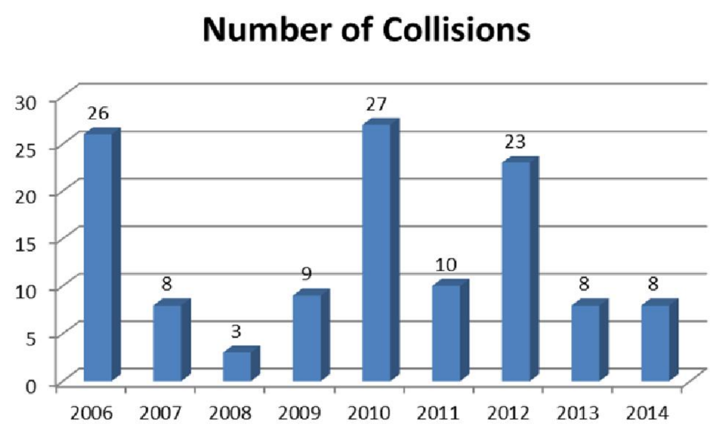

Fig 8: Annual Bird-strike Collisions

The bird-aircraft collisions presented in the above figure prompted the identification of bird species that has caused the collisions or near misses at the airport. Figure 9 and Figure 10 below show the identified bird species for the periods 2006-2010 and 2011-2014.

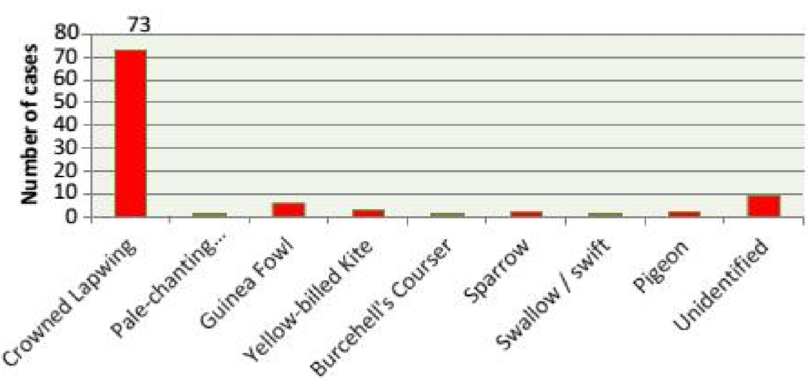

Fig 9: Bird strike incidences for 2006 - 2010

From Figure 9 above, it can be observed that the Crowned Lapwing is the most identified bird species at the airport with 73 cases reported over the years, followed by the unidentified birds with 9 cases and the Guinea Fowls with 6 cases.

For the 2011 - 2014 period (Figure 10), the Crowned Lapwing was still the most identified bird species at the airport with 45 cases, followed by the Guinea Fowls with 26 cases and unidentified birds the with 15 cases.

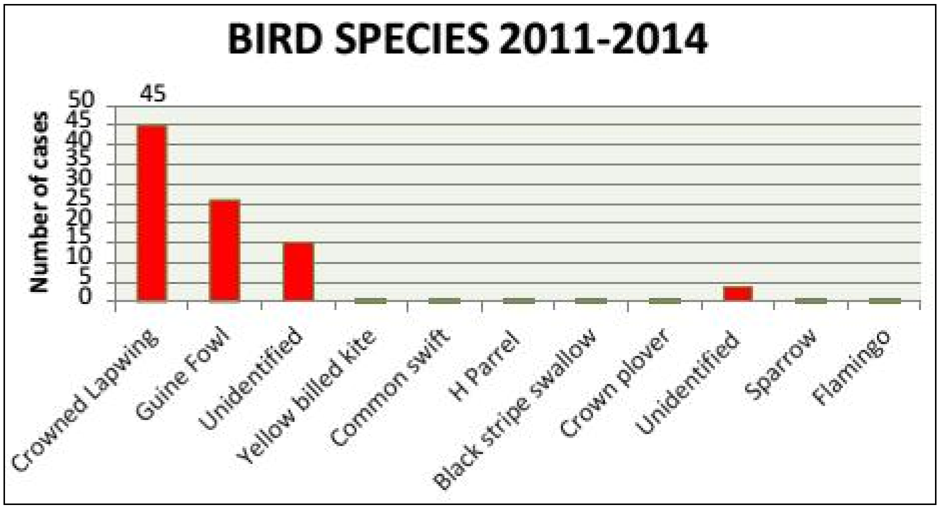

Fig 10: Bird Species (2011-2014)

A similar study conducted by Vimal and Gahlot (2014) in Nigeria also reported the Lapwing bird species as responsible for most of the bird collisions at Aminu Kano International Airport. The Guinea Fowls' occurrence in the vicinity of the airport is mainly from the golf course adjacent to the airport were they feed on plants bulbs.

Previous study conducted in Addis Ababa, Bole International Airport reported that the serious drawback with bird-strike monitoring techniques is that birds get used to them and the methods become ineffective shortly after their introduction (Yohannes and Woldu, 2000).

The data was further analyzed (Figure 11) to determine the season/months having the most bird strikes. The bird strike occurrences results for Eros indicated that May and January recorded the most bird strike incident while September and July recorded the least. The difference could be attributed to the rainy season and availability of food and water in the area i.e. at the Golf Course and horse-riding areas that are close to the airport. A study by Hauptfleisch and Tsowaseb (2013) also confirmed that the risk of aircraft-wildlife collisions (AWCs) is much higher in the rainy season than in the dry season.

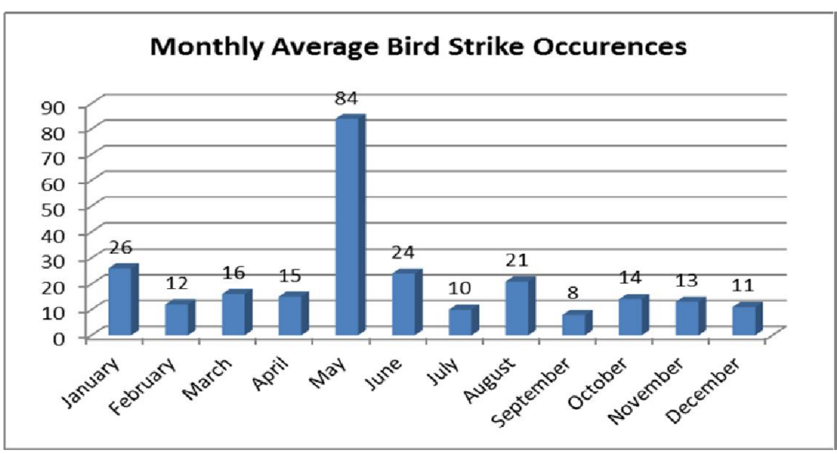

Fig 11: Average Monthly Bird Strikes for the period 2006-2014

In a study by Yohannes and Woldu (2000), the months of May and June had the least bird strike incidences. This however does not agree with what has been observed at Eros airport because the airport flight schedule at Eros remains the same throughout the year and has no effect on the monthly bird strike cases.

The bird strike data was further utilized to determine the probability (Table 5) of the species occurrence at the Airport.

Table 5: Risk assessment for the bird strike incidences

	Probability				
Severity	**Very high**	**High**	**Moderate**	**Low**	**Very**
Very high	3	3	3	**2**	**2**
High	3	3	3	**2**	**2**
Moderate	3	3	3	**2**	**2**
Low	**2**	**2**	**2**	**2**	**2**
Very Low	**2**	**2**	**2**	**2**	**2**

The risk level 3 because of the species such as the crowned lapwing, guinea fowls, unidentified birds, pigeon and yellow-billed kite have very highrisk level is very high as they have caused the most bird cases over the years. The species mainly occur in flocks, increasing their significance risk to theaircraft. The risk level 2 is linked to the common swift, HParrel, Sparrow and Flamingo as occurrences in the vicinity of the airport is minimal compared to risk level 3.

Conclusion
The levels of air pollutant emissions, bird strike incidences and noise at Eros Airport were measured successfully, and the monitoring techniques used were assessed. The air pollutant emissions associated with electricity consumption at the airport were measured in decreasing order as CO, SO2, TSP, VOCs, PM10, NOx and Benzene; and the GHG emissions were determined to be in the were obtained in the range of 13.5 to 20.6 tonsCO2e.The study has shown that the landing and take-off emissions at the airport are composed 50% CO, 26% CO2, 22% NOx, and 2% SO_2. The average noise measurements were all above 80dB which is unsafe exposure to noise. The aircraft noise results were compared to the South African, World Bank and ICAO standards which were all exceeded. The bird strike monitoring technique used by the Airport was found to be effective because the remedial strategies derived from the results proved to be making effect as they have yielded more than 40% reduction for the year 2013 and2014. Though the airport does not have noise monitoring techniques in place, the night flight restrictions as a way of reducing aircraft noise at night were noted.

Further studies on determining the amount and characteristics of the emissions from various aviation sources and their combined emissions at airports were recommended to give a complete picture of the environmental impacts.

Acknowledgement
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