Pollution Problems in Koya City due to Private Electrical Generators

Hayder H. Abbas, Fakhri H. Ibraheem and Ahmed A. Maaroof

Department of Chemical Engineering, Faculty of Engineering, Koya University, Koya KOY45, Kurdistan Region – F.R. Iraq

Abstract— **Koya city, like any other city in the world, faces a critical environmental problem which is global warming and the increase in the rate of production of gaseous pollutants. This research is involved with the negative effects of private Electrical Power Generators (EPGs) on the environment in Koya City. The environmental pollutants resulted from EPGs were investigated by performing an actual study on land for the number of (EPGs), types, and distribution. Koya city is divided into 18 quarters. The investigation covers a period from 2009 to 2017, included. The production of power was increased due to the increase in the number of generators and supplying hours. The power production in 2009 was 23,850 megawatt (MW) whereas it was 49,635 MW in 2017. The amount of fuel consumed in 2009–2017 was relatively increased from 30,000 to 62,500 barrel/year. The total amount of pollutants was increased by about 108% during the period 2009–2017. The results showed that the most significant increase in pollutants was carbon dioxide (CO_2). The annual amount of (CO_2) emitted in 2009 was 6588 tons whereas it has increased in 2017–13710 tons. The conclusion of this study was that the highest pollution occurred in the center of Koya City in Nabeel quarter, which represented 22% of the whole pollutants.**

Index Terms — **Air pollution, Diesel power generator, Emission, Environment, Pollutants.**

I. Introduction

The current work was conducted to collect data on the number of private power generators that are in use in Koya city to estimate the type of pollutants, and to analyze the impact of their emission on the community. Koya city is one of the oldest districts in the Kurdistan region of Iraq. It is considered a bridge between the Governorate of Erbil and Sulemani. The city is surrounded by five sub-districts (Taq Taq, Shoresh, Ashti, Sktan, and Segrdkan) and it is located 620 m above sea level (Iraq, n.d.). In general, there are two means for supplying public electrical power to residential areas in both Iraq and Kurdistan region including Koya city. It is either supplied from national local public generators or by private generators. Many of the private generators are old and emit considerable amounts of hazardous pollutants. This study divides Koya city to 18 quarters, as shown in Fig. 1. The number of local generators in each district is different as a result of different population density in each quarter (Ali, et al., 2015). Electricity is a major requirement for sustainable development (Dorji, 2015).

The operational status of private generators varies depending on their lifetime and their degradation. Quantities and types of liberated polluting gases depend on the operational status of these generators and the quality of fuel used (Faiz, et al., 1995: Faiz, et al., 1996: Faiz, et al., 1997). The more efficient the burning process inside the generator chamber, the better power production is as well as the low quantities of liberated toxic gases, especially carbon monoxide (CO). Some generators use heavy and light diesel as fuel and some are depending on benzene. The generator which uses low fuel density liberates low amount of polluting gases. The amount of sulfur in fuel leads to a higher concentration of sulfur oxides (SO_x). The higher accumulated concentrations of polluting gases in limited areas like Koya City have a bad impact on the public health of people. The use of non-clean fuel increases the amount of carbon particulate in the environment which causes respiratory diseases. In general, the fuel specifications are not stable due to different suppliers. It is shown from the investigations that the use of light diesel oil is common. Estimation of the amount of pollutants depends on the standard fuel emission factor (EF) from the internal combustion engine (Criteria Air Pollutant and Greenhouse Gas Emission Factors, 2014).

The main pollutants' emissions from local electrical power generators (EPGs) are: Carbon dioxide (CO_2), CO, SO_x, nitrogen oxides (NO_x), carbon black (CB), and mass particulate (MP).

The controlling of the combustion process leads to minimize the emissions (Larsen, 1966: Krebs, 1971: Faiz, et al., 1995).

Globally, electrical power generation emits approximately 10 billion tons of CO_2 per year. Since the Industrial Revolution, the concentration of CO_2 in the atmosphere has risen by approximately 40% due to fossil fuel combustion. CO_2 has been declared a health risk to humans and scientific research indicates that it is the leading cause of climate change and rising temperatures on the planet (Spadaro, et al.,

ARO-The Scientific Journal of Koya University
Volume VII, No.2 (2019), Article ID: ARO.10538, 9 pages
DOI: 10.14500/aro.10538
Received 12 June 2019; Accepted 02 December 2019
Regular research paper: Published 20 December 2019
Corresponding author's e-mail: Ahmed.maaroof@koyauniversity.org

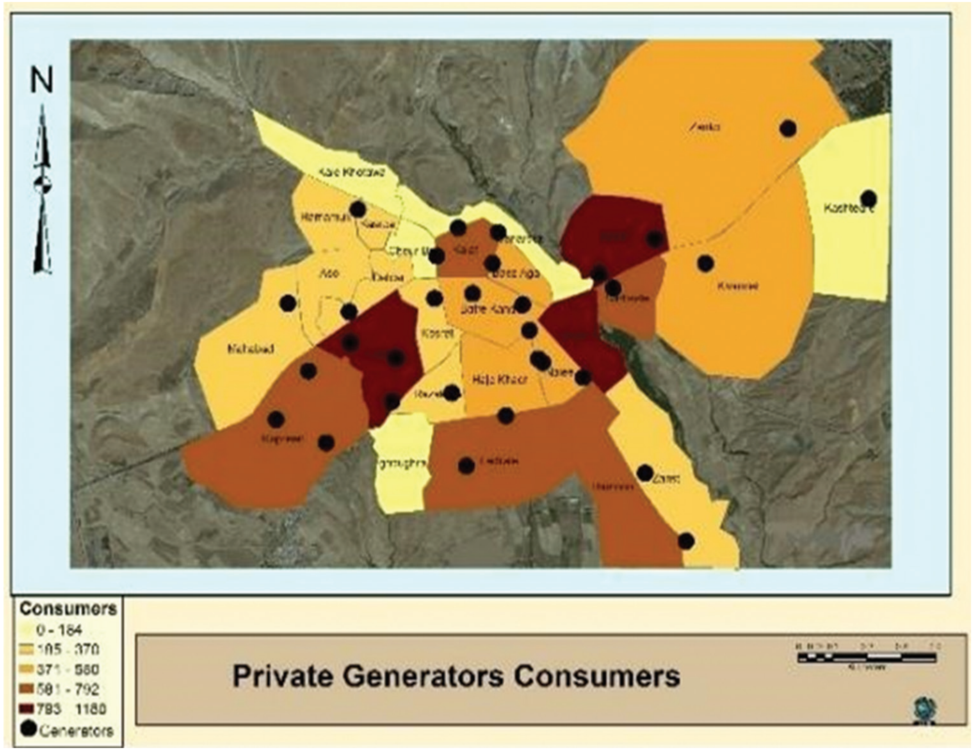

Fig. 1. Koya city quarters and the distribution of electrical diesel generators (Erbil Governorate, 2018).

2000: Mishra, 2004: Pulles and Appelman, 2008: Ou, et al., 2011).

The bad effect of emissions from burning fossil fuel on the environment is a big problem. For instance, inhalation of air containing high levels of sulfates in combination with certain other emissions can accelerate the probability of premature death. In combination with water, sulfur dioxide forms acids which have a corrosive effect on a variety of materials (Ball, and Frei, 1999: Rashad and Hammad, 2000: Holdren, et al., 2000: Baxter, 2001: Demin, 2002).

Pollution due to increasing numbers of power generators in Erbil, indicating an increase in the number of used generators by 76.1% for 10 years between 2003 and 2012 (Jassim, et al., 2013), whereas the pollutants amount due to electrical generators in whole of Iraq has doubled during the period from 2005 to 2014 (Jassim, et al., 2016).

II. EPGs in Koya City

The distribution of private generators across Koya quarters depends on their population, as shown in Table I. The amount of electrical power generation in Koya city has doubled during the period 2009–2016, according to Table II. The system of supplying power was modified gradually for the second half of 2016–12 h/day. In 2017, major of Koya quarters used the modified supplying system, which has led to increase the productivity, as shown in Fig. 2. The amount of fuel required to fulfill the extra operative hours was also increased to double, as shown in Fig. 3.

The power factor for the used generator is between 0.9 and 0.8; it is considered 0.8 due to the bad generator condition.

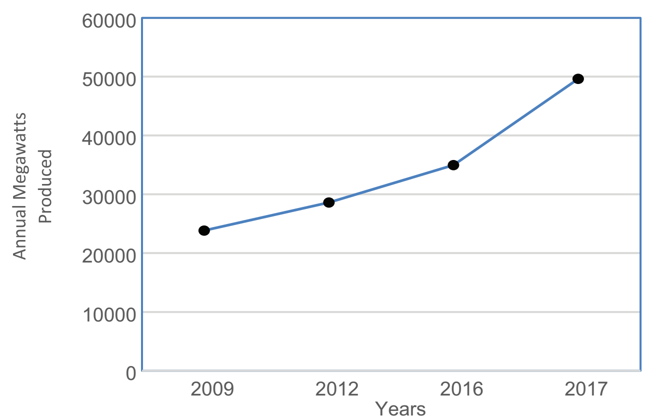

Fig. 2. Rate of increase of produced power during the period 2009–2017.

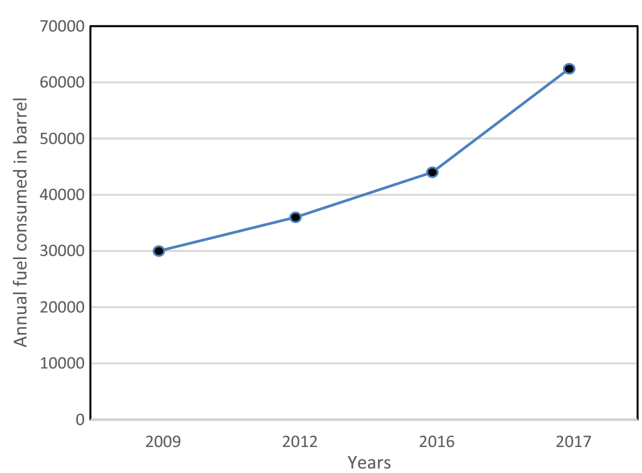

Fig. 3. Rate of increase of diesel fuel during the period 2009–2017.

http://dx.doi.org/10.14500/aro.10538

Therefore, the total power produced in 2009 is 13920 × 0.8 = 11136 Kwt, and similarly for 2016 is 13762 Kwt. The generators in 2009 to mid-year 2016 are working 6 h/day, whereas it is increased gradually during the second half of 2016. In 2017, most of the generators were put on work for 12 h daily. The average fuel consumption is 0.2 l for each Kwt. Table II shows the annual power production in megawatt and the fuel consumption in barrel per year.

Fig. 2 shows the annual rate of increase of power in megawatt (MW). Fig. 3 shows the rate of increase of fuel demand.

TABLE I
Distribution of Power Generators Over Koya Quarters in 2009 and 2016

Quarter name	Generators in 2009			Generators in 2016		
	Number	Generator capacity KVA	Total KVA	Number	Generator capacity KVA	Total KVA
Mahabad	1	450	450	1	450	450
Deldar	1	250	250	1	250	250
Rapreen	1	250	550	1	350	1050
	2	150		2	350	
Kosrat	1	300	800	1	300	800
	2	250		2	250	
Kakon	1	250	1090	1	250	2540
	2	150		2	350	
	3	180		3	330	
	0	0		4	150	
Bafre Kandel	1	250	945	1	250	945
	2	250		2	250	
	3	65		3	65	
Razkare	1	300	300	1	300	300
Kasra	1	315	315	1	315	315
Faderale	1	500	1000	1	500	1000
	2	250		2	250	
Zinast	1	250	600	1	350	1950
	2	175		2	350	
	0	0		3	300	
Zanko	1	250	250	1	250	250
Khandel	1	275	275	1	275	275
Kashteary	1	250	250	1	250	250
Kalat	1	260	1610	1	260	1610
	2	300		2	300	
	3	250		3	250	
Azadi	1	500	1100	1	500	1100
	2	300		2	300	
Sarbaste	1	550	550	1	550	550
Nalee	1	192	3317	1	192	3317
	2	650		2	650	
	3	275		3	275	
	4	250		4	250	
Harmota	1	250	250	1	250	250
Total	52		13,920	59		17,202

TABLE II
Amount of Electrical Power Generation in Koya City through the Period 2009–2016 (Erbil Governorate, 2018)

Year	Power produced in MW	Fuel consumed in barrel/Year
2009	23850	30000
2012	28620	36000
2016	34984	44000
2017	49635	62434

MW: Megawatt

Fig. 4 shows the increase in demand of power distributed over Koya city quarters for the period from 2009 to 2017.

III. Pollutants' Emissions from EPGs

Several different rules regulate emissions criteria of pollutants and hazardous air pollutants (HAP) from fuel-burning systems. The applicability and specific emission limit in each regulation is generally a function of system thermal size (million British thermal units [MBTU] per hour) of heat input (MBTU/h) or MW of electricity output, fuel type, combustor design. A major source of HAP is defined as any stationary source or group of stationary sources located within a contiguous area. Most EF data were provided in units of pound (lb) of emissions per volume of fuel for gas or liquid fuels and in units of lb of emissions per ton of fuel for solid fuels. Lower heating values (LHVs) were used to convert these EF to a lb/MBTU basis. Table III shows the EF used for diesel fuel type based on LHV. The specification of diesel oil that is used to determine this EF is different from our diesel oil specification especially for sulfur content; it contains from 0.1% to 0.5%, whereas Iraqi diesel standard specification limit is high, it is 1% maximum for Grade A and 2.5% for Grade B. The actual EF in Koya city was determined according to actual sample tests.

More than 50 generators were investigated in this study; they were distributed over 18 quarters. The EF was estimated according to lb/MBTU (Criteria Air Pollutant and Greenhouse Gas Emission Factors, 2014). Each MBTU = 0.293 MW/H, therefore, it is easy to estimate the amount of MBTU produced for years 2009–2017. As a sample for estimation for 2009, the amount of power produced was 23850 MW, therefore the amount of MBTU produced = 23850/0.29 = 82241, and so on for other years. Table IV shows the amount of MBTU produced during the period 2009–2017.

The estimation of CO_2 pollutant in 2009, for example = 82241 MBTU × 176.6 (lb/MBTU) × (0.4536 (Kg/lb) /1000 (Kg/ton)) pollutant of CO_2 = 6536 tons, and so on for other pollutants.

TABLE III
Diesel – Fueled Turbine Emission Factors (lb/MBTU)

Pollutants	lb/MBTU
CO_2	176.6
NO_x	0.558
SO_2	0.1215
CO	0.00431
Particulates	0.534
CB	0.092

CO_2: Carbon dioxide, CO: Carbon monoxide, SO_2: Sulfur dioxide, CB: Carbon black, MBTU: Million British thermal units

TABLE IV
Amount of MBTU Produced through the Period 2009 –2017

Year	MBTU/Year
2009	82241
2012	98689
2016	120634
2017	171154

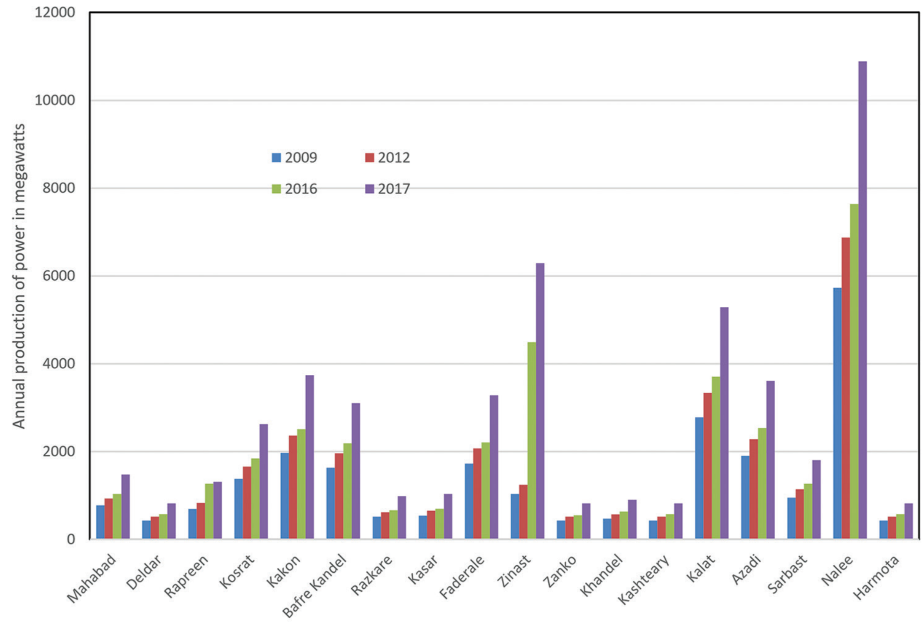

Fig. 4. Power produced in Koya city quarters through the period 2009–2017.

TABLE V
Diesel Oil Test Results

No.	Date	Sulfur content mass %	Specific gravity sp. gr.	Flash point (Closed Pensky-Martens) °C	Water content vol. %	Sediment content vol. %
1	January 17	0.6437	0.836	58	0.0053	0.0241
2		0.8791	0.826	58	0.009	0.0294
3		0.5547	0.815	55	0.0055	0.0265
4	February 17	0.8771	0.832	58	0.0066	0.0147
5		0.8619	0.83	57	0.0095	0.0103
6		0.6003	0.827	61	0.0073	0.0365
7		1.4614	0.823	46	0.0088	0.0317
8		0.7484	0.832	60	0.0073	0.0201
9		0.8665	0.835	60	0.0132	0.0337
10		0.8447	0.841	59	0.0044	0.0184
11	March 17	0.8243	0.836	62	49	0.021
12		0.879	0.839	58	0.0069	0.0197
13		0.7242	0.834	59	0.0044	0.0176
14		0.5659	0.819	52	0.0033	0.008
15		1.0303	0.837	58	0.0088	0.0044
16		0.5245	0.825	62	0.0027	0.0066
17		0.7893	0.822	61	0.0044	0.0057
18	April 17	1.0613	0.835	62	0.0033	0.009
19		0.7782	0.821	62	0.0055	0.0072
20		0.8532	0.822	60	0.0097	0.022
21	May 17	0.7721	0.82	60	0.0033	0.0115
22		0.5419	0.828	57	0.0046	0.0334
23		0.6382	0.825	58	0.0088	0.0232
24		0.7705	0.82	60	0.0088	0.0555
25	June 17	0.5608	0.824	60	0.0044	0.034
26		1.0129	0.831	61	0.0176	0.0414
27		0.8104	0.819	57	0.023	0.031
28		0.852	0.819	50	0.0084	0.0141
29	July 17	0.6414	0.812	58	0.0154	0.0147
30		0.6801	0.823	60	0.0044	0.0265
31		0.7003	0.814	63	0.0066	0.0088
32	August 17	0.6216	0.802	58	0.0144	0.0176
33		0.712	0.808	64	0.0066	0.0117
34		0.8437	0.811	58	0.0055	0.0066
Average		0.7802	0.825	58.59	0.0078	0.0205
Standard deviation		0.221	0.0074	3.9953	0.0026	0.0101

http://dx.doi.org/10.14500/aro.10538

IV. Practical Lab Tests Data

More than 30 samples of diesel fuel that is actually used in private electrical generators were tested. The samples distributed over 8 months from January 2017 to August 2017. The tests include sulfur content as mass percent, specific gravity, flash point to determine its burning efficiency, water, and sediment content as volume percent. Table V shows the test results.

The standard deviation (Ϭ) of the results shows that there is no big tolerance between the data through 8 months except flash point which it reaches about 4 and this is normal due to rough mixing the diesel by volatile material to improve burning efficiency. The complete fuel burning means oxidizing occurs to all pollutant elements such as sulfur, nitrogen, and carbon. The low value of Ϭ means the average value can be accepted as a real actual number.

TABLE VI
Annual Pollutants Emitted in Koya City through the Period 2009–2017

Year	CO_2 tons/year	NO_x tons/year	SO_2 tons/year	Particulates tons/year	CB tons/year	CO kg/year	Total
2009	6588	21	62.8	20	3.4	161	6695
2012	7906	25	75.4	24	4.1	193	8034
2016	9663	31	92.1	29	5.0	236	9821
2017	13710	43	130.7	41	7.1	335	13933

CO_2: Carbon dioxide, CO: Carbon monoxide, SO_2: Sulfur dioxide, CB: Carbon black

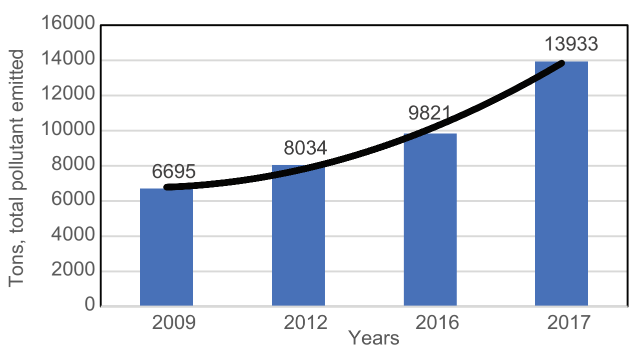

Fig. 5. Rate of increase of emitted pollutants in Koya city between 2009 and 2017.

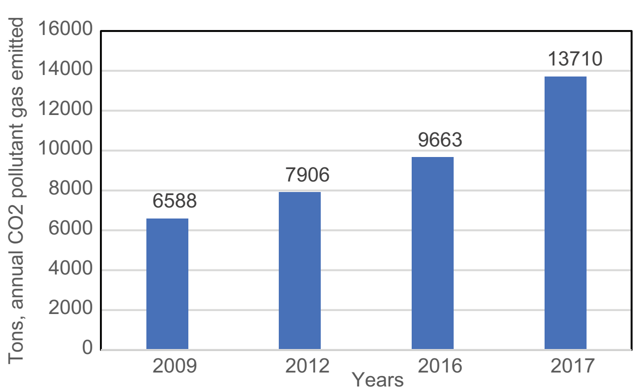

Fig. 6. Rate of increase of carbon dioxide pollutants emitted in tons during the period 2009–2017.

The equipment used for the tests are:

- X-ray sulfur meter, TANAKA, model RX-360 SH, energy dispersive X-ray fluorescence method, which is an accurate, non-destructive, economical and yet quick method prescribed in ISO 8754 and ASTM D4294-03
- Flash point by Pensky-Martens closed cup Automatic by TANAKA AGT 7 and manually
- Hydrometer set kit for determining the density
- Centrifugal separator, according to ASTM D1796, ASTM D4007 to determine water and sediment content and certified using high-precision separating funnel.

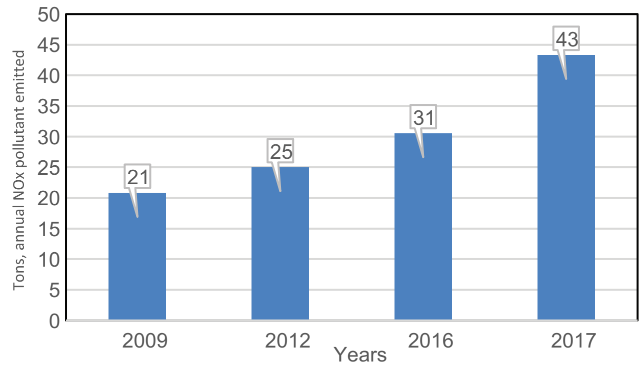

Fig. 7. Rate of increase of nitrogen oxides pollutants emitted in tons during the period 2009–2017.

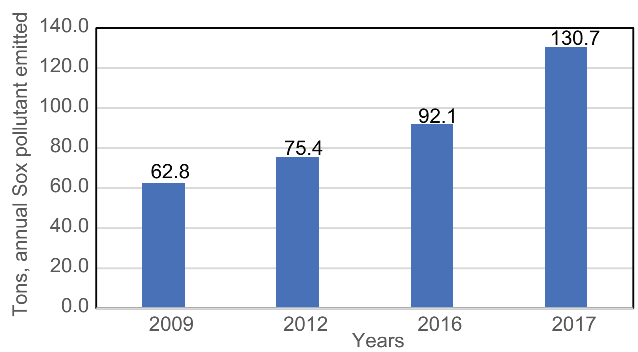

Fig. 8. Rate of increase of SO_2 pollutant emitted in tons during the period 2009–2017.

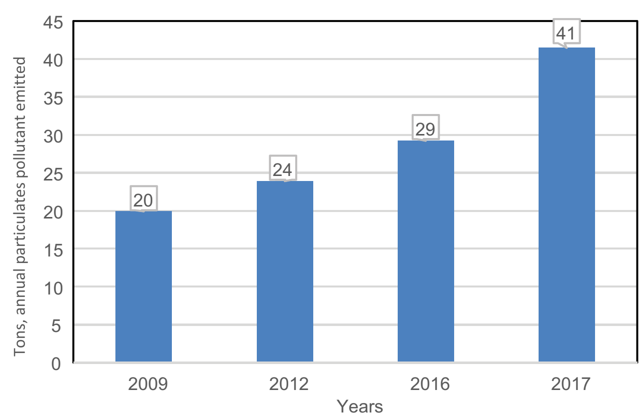

Fig. 9. Rate of increase of particulates emitted in tons during the period 2009–2017.

To determine the actual amount of SO_x liberated, consider the average value of sulfur content 0.7802% in 1-l fuel is combusted completely:

$S+O_2 \rightarrow SO_2$, which means one mole of sulfur (32 g atomic weight) reacted with 1 mole of oxygen (32 g molecular weight) to produce one mole of sulfur dioxide gas SO_2 (64 g of Sulfur dioxide).

The actual average fuel consumption in Koya generators are 0.2 l for 1 KWH.

It is known that each MBTU = 0.293 MW/h, therefore, to produce 0.29 MW/h (290 KW) in Koya city, it is required 0.2 × 290 = 58 l diesel fuel, which is equal to 58 × 0.825 (average sp. gr.) = 47.85 kg diesel fuel. The actual amount of sulfur in fuel = 47.85 × (0.7802/100) = 0.373 kg which is equal to 11.7 gmole. Most of the sulfur is oxidized to SO_2. Referring, to the chemical equation, 11.7 gmole of SO_2 is liberated which is equal to 749 g (1.684 lb); therefore, the actual EF value for SO_2 is 1.684 lb for each MBTU.

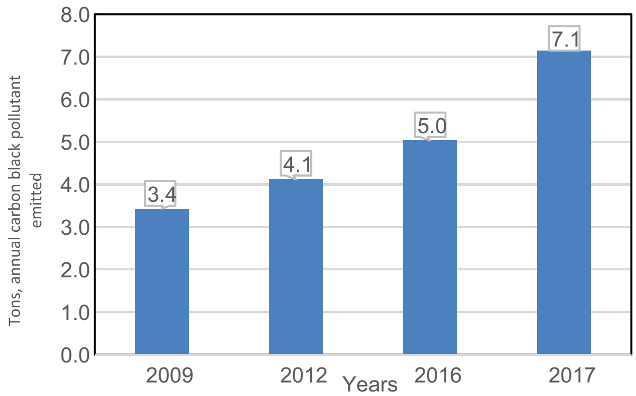

Fig. 10. Rate of increase of carbon black pollutant emitted in tons during the period 2009 – 2017.

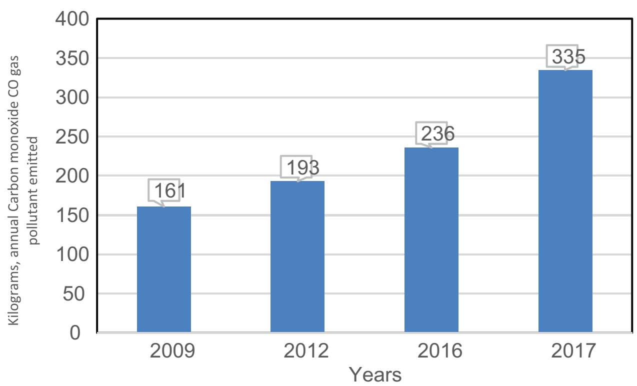

Fig. 11. Rate of increase of carbon monoxide poison gas pollutant emitted in kilograms during the period 2009–2017.

V. Main Contribution and Results

The amount of different kinds of pollutants emitted from local generators during the period 2009–2017 is shown in Table VI. It is clear that the pollutants' emissions were increased considerably since 2009 especially the CO_2 emissions, where it has jumped from 5452 tons in a year to more than a double in 2016, and in 2017 it reached 24,900 tons.

According to Fig. 5, the rate of pollutant emissions between 2009 and 2017 (9 years) is doubled. The amount of produced power was doubled compared to 2009.

Fig. 6 shows the rate of increase in the CO_2 during the 9 years. It has increased from 6588 to 13,710 tons, which represents 108%.

Fig. 7 shows the rate of increase in the NO_x during the 9 years. It has increased from 21 to 43 tons, which represents 105%.

Fig. 8 shows the rate of increase in SO_2 during the 9 years. It has increased from 21 to 43 tons, which represents 105%.

Fig. 9 shows the rate of increase of particulates pollutant emitted during the 9 years. It has increased from 62.8 to 130.7 tons, which represents 109%.

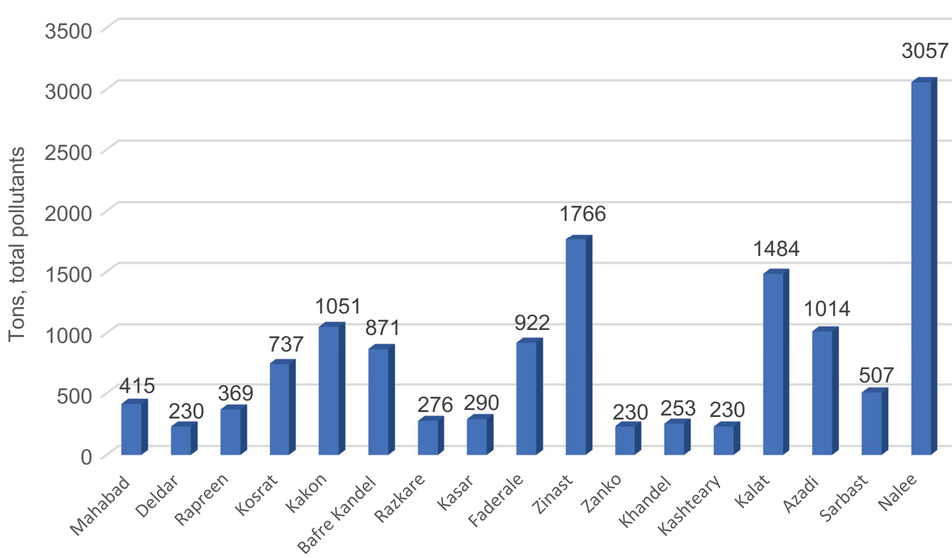

Fig. 12. Total pollutants amount in tons distributed over all quarters in 2017.

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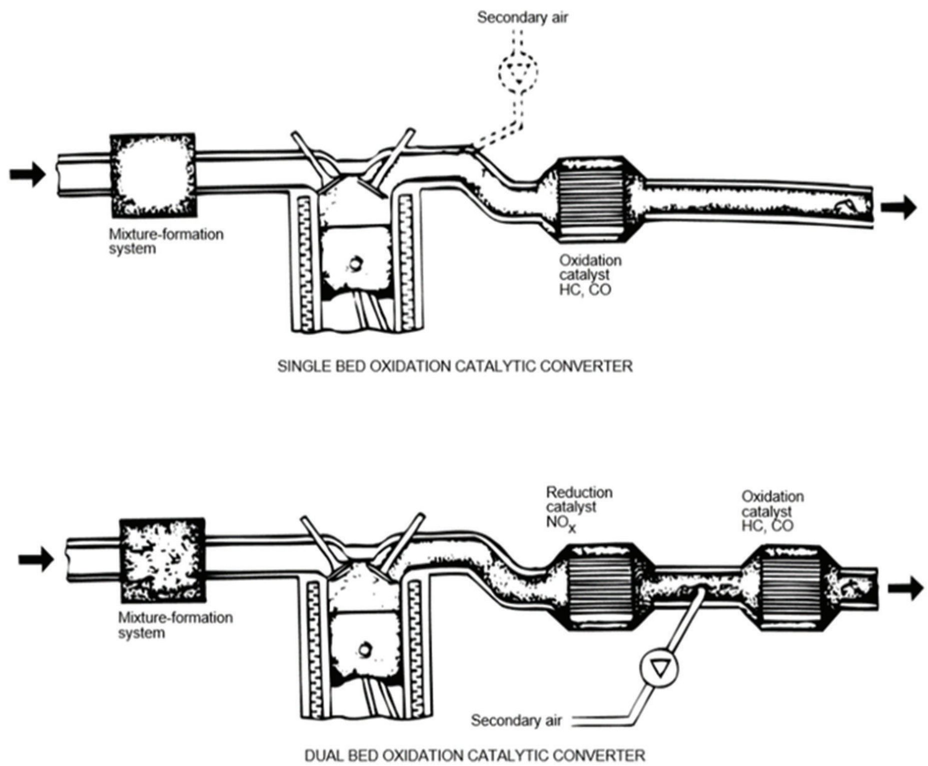

Fig. 13. Single and double bed oxidation catalytic convertor.

TABLE VII
POLLUTANTS AMOUNT DISTRIBUTION OVER KOYA CITY QUARTERS IN 2017

Quarter	MW	CO_2 tons/year	NO_x tons/year	SO_2 tons/year	Particulates tons/year	CB tons/year	CO kg/year	Total (tons/year)
Mahabad	1477	408	1.29	3.89	1.23	0.21	9.96	415
Deldar	821	227	0.72	2.16	0.69	0.12	5.53	230
Rapreen	1313	363	1.15	3.46	1.10	0.19	8.85	369
Kosrat	2627	726	2.29	6.92	2.19	0.38	17.71	737
Kakon	3743	1034	3.27	9.86	3.13	0.54	25.23	1051
Bafre Kandel	3103	857	2.71	8.17	2.59	0.45	20.92	871
Razkare	985	272	0.86	2.59	0.82	0.14	6.64	276
Kasar	1034	286	0.90	2.72	0.86	0.15	6.97	290
Faderale	3283	907	2.87	8.65	2.74	0.47	22.13	922
Zinast	6290	1737	5.49	16.57	5.25	0.91	42.40	1766
Zanko	821	227	0.72	2.16	0.69	0.12	5.53	230
Khandel	903	249	0.79	2.38	0.75	0.13	6.09	253
Kashteary	821	227	0.72	2.16	0.69	0.12	5.53	230
Kalat	5286	1460	4.61	13.92	4.42	0.76	35.63	1484
Azadi	3612	998	3.15	9.51	3.02	0.52	24.35	1014
Sarbast	1806	499	1.58	4.76	1.51	0.26	12.17	507
Nalee	10890	3008	9.50	28.69	9.10	1.57	73.42	3057
Harmota	821	227	0.72	2.16	0.69	0.12	5.53	230

MW: Megawatt, CO_2: Carbon dioxide, CO: Carbon monoxide, SO_2: Sulfur dioxide, CB: Carbon black

Fig. 10 shows the rate of increase of CB pollutants emitted during the 9 years. It has increased from 3.4 to 7.1 tons, which represents 109%.

Fig. 11 shows the rate of increase of CO poison gas emitted during the 9 years. It has increased from 161 to 335 kg, which represents 108%.

In 2017, the total amount of pollutants distributed over all Koya city quarters is shown in Fig. 12.

It is shown that the worst environmental condition is in Nalee, whereas the lowest pollutant is in Deldar, Zanko, and Kashteary. Table VII shows the amount of each pollutant distributed over all Koya city quarters in 2017.

VI. CONCLUSIONS

This research has come up with conclusions that the amount of electrical power produced has increased rapidly during the 9 years from 2009 to 2017. After midyear of 2016, a modified generator operating system was applied gradually which lead to higher production. Most of the generators use diesel fuel. The power production in 2009 was 23,850 MW whereas it was 49,635 MW in 2017. The total amount of pollutants has increased rapidly as a result of the increase in the production of electrical energy. It was 6695 tons in 2009 whereas its increased to 13,933 tons in 2017, which is 108% increase. The amount of fuel consumed in 2009–2017 has relatively increased from 30,000 to 62,500 barrel/year. The amount of different pollutants was estimated according to EF from diesel internal combustion engines. The pollution rate can be graded into the following pollutants CO_2, NO_x, SO_2, CO, solid particulates, and CB. The percent of sulfur content in Iraqi diesel is 1% maximum for Grade A and 2.5% maximum for Grade B which is higher by 3–10 times than what is used in Europe (0.1% – 0.3%). The actual EF is depending on determining the SO_2 pollutant amount. CO_2 was the major pollutant due to its highest EF. The annual amount of (CO_2) emitted in 2009 was 6588 whereas it has increased in 2017–13,710 tons. The solid pollutants such as MP and CB annual amount have increased from 20 and 3.4 tons in 2009 to 41 and 7.1 tons in 2017, respectively. The gaseous pollutant such as NO_x, SO_x, and CO annual amount liberated has increased from 21 tons, 62.8 tons, and 161 kg in 2009 to 43 tons, 130.7 tons, and 335 kg in 2017, respectively. The area of distribution for pollutants can be categorized into three sectors. The highest one was in the center of Koya City (Nalee quarter) which represents 22% of the whole pollutants amount. The second sector includes the quarters that emitted about 10% of the whole pollutants amount such as Zinast and Kalat. The third sector includes the quarter that emitted not more than 7% of the whole pollutants amount.

VII. Recommendations

We can advise the following recommendations:

a. The physical types of pollutants that liberated from burning fuels are gases such as SO_x, NO_x, CO_x, and solid like carbon particulate. The electrostatic precipitator can capture the particles only to specified size, whereas the liberated gases amount can be reduced using single or dual bed oxidation catalytic converter, as shown in Fig. 13 (Faiz, et al., 1997)
b. The burning fuel gases pollutant and warming of the environment are global problems. International conferences in Paris 2014 and Poland 2019 have discussed this problem in details and some rules were agreed to put on in front of big industrial countries to stop gradually the activities that lead to pollutants. The alternative sources of energy such as solar, large capacity fuel cells stacks, and geothermal were encouraged by global loans
c. Starting effective collaboration between environmental protection organizations and involved directorates and academic persons to submit limits for exhaust pollutants. The monitoring of diesel oil properties is required to control fuel specification and pollutant content. Reducing the sulfur content by installing desulfurization unit in petroleum refinery factories
d. It is known that clean fuel liberates low pollutant amounts; therefore, a cooperation between the petroleum organizations and private sector are required to modify the generators or replaced them gradually to generators that are fueled by gas like liquefied petroleum gas instead of diesel fuel
e. Increasing the green areas inside Koya city, specially the populated ones, is important to enhance better environmental conditions.

References

Ali, J.A., Abbas, H.H. and Khodakarami, L., 2015. Gas pipeline network design for Koya city: Case study. *International Journal of Energy Engineering*, 5(2), pp.17-24.

Ball, D. and Frei, C., 1999. *Health and Environmental Impacts of Electricity Generation Systems*. International Atomic Energy Agency, Vienna, Austria.

Baxter, M., 2001. Health and environmental impacts of electricity generation systems: Procedures for comparative assessment: International atomic energy agency, technical reports series No. 394, IAEA, Vienna, December, 1999 (STI/DOC/010/394 TRS 394), 193pp., price 630 Austrian Schillings (45.78 EUR) paperback, ISBN 92-0-102999-3. *Journal of Environmental Radioactivity*, 1(53), pp.121-122.

Criteria Air Pollutant and Greenhouse Gas Emission Factors., 2014. Eastern Research Group for Incorporation in GREET. *Systems Assessment Group Energy Systems Division*. Argonne National Laboratory, Illinois.

Demin, V.F., 2002. Health and environmental impacts of electricity generation systems: Procedures for comparative assessments. *Atomnaya Tekhnika za Rubezhom*, 4, pp.16-19.

Dorji, G., 2015. *Environmental Aspect of Electric Energy Generation*. Available from: https://www.researchgate.net/publication/296672956_Environmental_aspect_of_electric_energy_generation. [Last accessed on 2019 Feb 23].

Faiz, A., Gautam, S. and Burki, E., 1995. Air pollution from motor vehicles: Issues and options for Latin American countries. *Science of the Total Environment*, 169(1-3), pp.303-310.

Faiz, A., Weaver, C.S. and Walsh, M.P., 1996. *Air Pollution from Motor Vehicles: Standards and Technologies for Controlling Emissions*. The World Bank, Washington, DC.

Faiz, A., Weaver, C.S., Walsh, M., Gautam, S. and Chan, L., 1997. *Air Pollution from Motor Vehicles: Standards and Technologies for Controlling Emissions* (No. WB-0554/XAB). World Bank Group, Washington, DC, United States.

Holdren, J.P., Smith, K.R., Kjellstrom, T., Streets, D., Wang, X. and Fischer, S., 2000. *Energy, the Environment and Health*. United Nations Development Program, New York.

Koysinjaq|Unbelievable Kurdistan-Official Tourism Site of Kurdistan. Available from: http://www.bot.gov.krd/erbil-province/koysinjaq. [Last accessed on 2018 Jan 14].

Jassim, H.M., Fakhri, H.I., Hayfaa, A.J., 2016. Environmental impact of electrical power generators in Iraq. *International Journal of Engineering Technology, Management and Applied Sciences*, 4(3), pp.122-134.

Jassim, H., Kurdi, Y.A.A. and Al-Nidai, F.H.I., 2013. Environmental issues in Erbil city. *International Journal of Engineering Trends and Technology*, 4(8), 3509-3515.

Krebs, L.J., 1971. *Method and Means to Control air Pollution from Motor Vehicles and Motor Vehicle Engines*. U.S. Patent, No. 3,618,314.

Larsen, R.I., 1966. Air pollution from motor vehicles. *Annals of the New York Academy of Sciences*, 136(12), pp.277-301.

Mishra, U.C., 2004. Environmental impact of coal industry and thermal power plants in India. *Journal of Environmental Radioactivity*, 72(1-2), pp.35-40.

Ou, X., Xiaoyu, Y. and Zhang, X., 2011. Life-cycle energy consumption and greenhouse gas emissions for electricity generation and supply in China. *Applied Energy*, 88(1), pp.289-297.

Pulles, T. and Appelman, W., 2008. *Air Pollution from Electricity-generating Large Combustion Plants*. EEA Technical Report.

Rashad, S.M. and Hammad, F.H., 2000. Nuclear power and the environment: Comparative assessment of environmental and health impacts of electricity-generating systems. *Applied Energy*, 65(1-4), pp.211-229.

Spadaro, J.V., Langlois, L. and Hamilton, B., 2000. Greenhouse gas emissions of electricity generation chains: Assessing the difference. *IAEA Bulletin*, 42(2), pp.19-28.