

# Evaluation of the spatial distribution of shared electrical generators and their environmental effects: Case Study in Baghdad-Iraq

Ali A Al-Waeely\*, Salah D. Salman\*, Wasan K. Abdol-Reza\*, Miqdam T Chaichan\*\*, Hussain A Kazem\*\*\* and Hakim S. Sultan Al-Jibori\*\*\*\*

Corresponding author (E-mail): [hakimss.soh@cas.edu.om](mailto:hakimss.soh@cas.edu.om)

**Abstract**— Air pollution is considered to be the dangerous type of pollution, due to its direct effects on human's life. Vehicles combustion and exhausts cause increments in the lead, sulfur and carbon monoxide concentrations. These gases affect human health and environment sector which clarified by increasing respiratory system diseases and anemia pulmonary tuberculosis. It also affects animals and plants in addition to buildings.

Iraq has suffered for decades from lack in electricity. Iraqi people compensated this lack by using a private household generator or a shared generator operating at a neighborhood level. The increased number of shared generators, with its high generating capacity, in addition to using engines which are not designed for this purpose, have generated an extreme environmental problems.

In this study, Al-Sader City (which is a largest city in Baghdad-Iraq and considered one of the highest population densities) was chosen as a case study to evaluate the efficiency of spatial distribution of the electrical generator and their environmental effects on this city as an example for all Iraq.

**Index Term**— Air pollution, Al-Sader City, Questionnaire, sample and shared Electrical generators

## I. INTRODUCTION

In developing countries, population is growing; increasing industrialization, high energy demand in addition to the bad environmental organization, low efficient technologies and high traffic density resulted in new issues to be addressed, the air quality. This has been a concern of mankind since centuries. The large increase in the use of fossil fuel resulted in major air pollution episodes in the many cities (Legreid, 2006). These factors together with a new and important factor exist in some developing countries like Iraq and Lebanon. These countries suffer from lack of sufficient electricity availability for modern life. This condition caused high dependence on domestic generators to block the need for electricity shortage. These generators were additional effective and new factors for air pollution that increases man health for environmental hazards.

In the industrialized countries this problem has been overcome by establishing a strong regulation on fuel characteristics (as lead and sulfur content), reducing polluted industry in urban areas, and better combustion and after treating technologies. But, till now the industrialized countries have large problems with air pollution in urban areas because of the increasing road traffic and non-road engines utilities. The high amounts of particulate matter from stationary combustion and diesel fueled engines are thought to be responsible for thousands of early deaths each year (Boldo et al. 2006), at the same time, the ozone mixing ratios have adverse effects on crops, human health and materials (Heck et al. 1984; Tidblad et al. 2004; Bergin et al. 2005).

In Iraq, despite considerable increments in generating electricity capacity in recent years, it is still far from being sufficient to meet demand. It is estimated that the peak Capacity available in 2011 was around 9 GW while the required capacity to meet the demand was 15 GW, resulting in a lack of around 6 GW more than available capacity. It must be taken into consideration that an increase in demand must be occurred as a result of new developments in the country to ensure adequate supply of power (Kazem, 2012). To try and fill some of the electricity supply gap, around 90% of Iraqi households supplement the public network with private generators, either a private household generator or a shared generator operating at neighborhood level (IKN, 2012). It can be estimated that in 2011 shared generators accounted for 3 terawatt-hours (TWh), on top of the 37 TWh of consumption that came from the grid. In central Baghdad alone, in 2009 survey estimated that approximately 900 megawatts (MW) of private generation were available for use (Parsons Brinckerhoff, 2009a). Private generators currently play an important role in reducing Iraq's shortfall in electricity supply (helping to reduce the number of blackouts) and also to bring benefits in terms of flexibility and providing electricity access to rural areas (Parsons Brinckerhoff, 2009b).

An additional challenge in Iraq is that electricity demand is seasonal, with the highest peak occurring in the summer months as a result of very high temperatures in much of the country. During the summer, peak hourly electricity demand could be expected to reach levels around 50% above the average demand level, increasing the gap between grid-based electricity supply (operating at capacity) and demand (UN, 2012 & World Bank, 2012). The generation providers from household and shared generator sources are difficult to quantify. Most of these generators are using diesel engines especially the higher power generators. Diesel engines yield

Ali A Al-Waeely Author is with: \*Geography Dept., Ibn Rushed Collage, Baghdad University, Baghdad, Iraq

\*\* Machine and Equipment Dept., University of Technology, Baghdad, Iraq

\*\*\* Faculty of Engineering, Sohar University, Sohar, Sultanate of Oman

\*\*\*\* College of Applied Science-Sohar- Sultanate of Oman

relatively considerable levels of hydrocarbons (HCs), carbon monoxide (CO), and volatile organic compounds (VOCs). Diesel engines are relatively high emitters of oxides of nitrogen (NO<sub>x</sub>) and particulate matter (PM) (Chaichan, 2013). Sanchez reported that non-road heavy-duty engines (primarily diesel engines) accounted for approximately 40% of inhalable ambient particulate (PM<sub>10</sub>), and 60–80% of fine particulate (PM<sub>2.5</sub>) inventory (Sanchez, 1997).

As a result for no specialized study about the effect of large electricity generators that operates by diesel fuel. This study aimed to investigate the spatial distribution efficiency for shared generators at Al-Sader City as a sample of other cities in Baghdad. This city was chosen due to its huge population and the high numbers of residential units of small areas.

## II. METHODOLOGY

### A. Studied area borders

Studied area border represented by Al-Sader city border that extended as a rectangle from northeast to southwest as in the map demonstrated in **Fig. 1**, with an area of 30 km<sup>2</sup> (Baghdad municipality, 2005). It extended from Al-Jaish canal from the west to the dusty levee at the east, boarded by Al-Shaab district from north and New Baghdad district from the south. The studied area was chosen in accordance with two standards:

*First:* The largest concentration in using shared generators.

*Second:* The largest population in the studied area.

The time borders were represented in the year 2013.

### B. Human data of Studied area

This data can be represented by (Al-Sader city council, 2008):

- 1) Al-Sader population reached about (2 000 000 people), distributed on all the city area which is divided into 82 sections and 72 residential district.
- 2) The population in each district reached about 25 000 people.
- 3) The residence unit's number in each district reached 1250 units.
- 4) The shared electricity generators reached 661 generators distributed to fuel stations that supplied it with fuel. Al-Hussainia fuel station supplies 333 generator, Bab Al-Sheikh station supplies 85 generators, while Al-Qanah station supplies 55 generators and Al-Methaq station supplies 187 generators. **Fig. 2** represents the spatial distribution map for the generators on Al-Sader districts.
- 5) The generator number reached 10 generators in one district, putting in mind the residential district that covers more than one section.



Fig. 1. Al-Sader City borders- Iraq

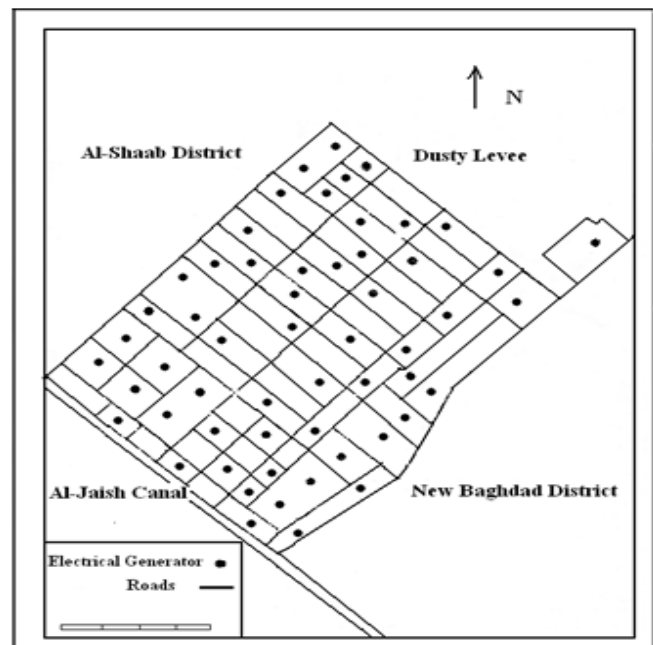


Fig.2. Spatial distribution of electrical generators in district of Al-Sader City

## III. INVESTIGATION PROCEDURE

The investigation took two stages:

*First Stage:* Office work period: in this period the primary data and information were collected and prepared from specialized municipality and government departments, in addition to preparing the maps.

*Second Stage:* Fieldwork period: Two kinds of questionnaires were designed for the studied area.

- The first one was concerned with the generator owners, 60 application forms were distributed to these owners as a sample of 661 generators which are the total number of generators distributed in all Al-Sader area. The applications were distributed in contrast of district number in the city, due to the homogeneity of the studied society from one side and the widest area of the Al-Sader sections and the huge population that caused many troubles in the survey process.

• 500 families were chosen as the studied community sample (which population exceeded Two million persons). 500 application forms were distributed to these families. This sample was chosen due to the homogeneity of the studied society and the economic and social conditions similarity. After gathering the application forms they were classified and studied. The received data percentages of each question were calculated and analyzed in tables and statistical figures.

IV. RESULTS AND DISCUSSION

From the analysis of the generators owners' questionnaire it can be seen that 76.6% of the participants are residences while 24.4% are commercial shops as shown in Fig. 3. At the following figure (Fig.4) declares that the higher rate of generators operation hours is 8 hours for 78.2% of the tested sample group, while for 6 hour group operation it was 15% for and 6.8% for 10 hour group. Table I, represents the electrical unit's rate that is given to each participant in the electrical generator service. The survey shows that 100% participants have taken 5 amps for all generators.

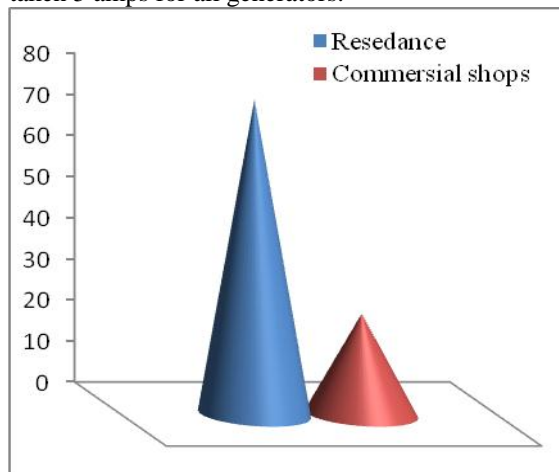


Fig. 3. Generators service participants' type

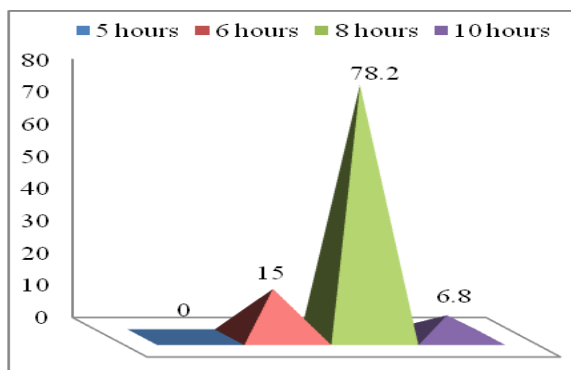


Fig. 4. Generators daily operation rate (hours)

TABLE I  
ELECTRICAL UNITS (AMPS) GIVEN FOR EACH PARTICIPANT

	2 amps	3 amps	4 amps	5 amps	Total
Number				60	60
Percentage				100%	100%

Fig. 5 represents the generators electric capacities in kVA. The generators with 350 kV ranked the higher participants

36.8% with 22 generators. The 250 kV generators ranked the second number of participants with a rate of 26.6% (16 generators). The 200 and 150 kV generators ranked 18.3% each (11 generators). One can imagine the emitted exhaust gases from these generators operation with this huge number considering that the diesel fuel received for 100 kV generators varied between 1300 lt/month and reaching 6500 lt/month for 350 kV generators.

Fig. 6 illustrates that the 150 kV generators have the highest participants (31.6% of the studied cases) with 19 generators, while generators of 200 kV have 30% of the participants with 18 generators (30% of the studied cases). For 100 kV generators the participants were 26.6% with 16 generators and at last the 250 kV generators have 11.8% with 7 generators. This means that more than 88% of the participants are included within (100 – 200) kV, which means that the generators with medium capacities are the dominants.

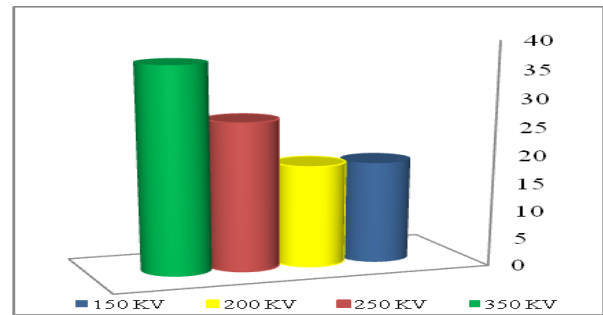


Fig. 5. Generators electric capacity (kVA)

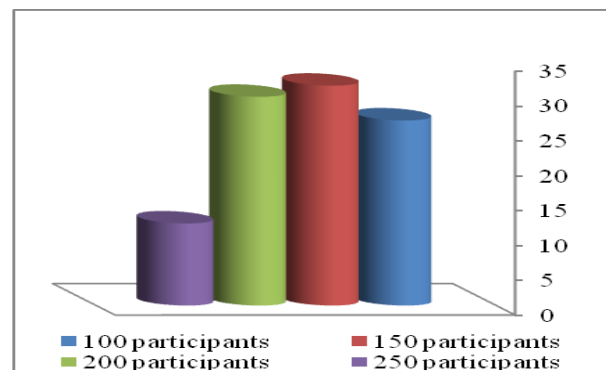


Fig. 6. Participants in the Generators

Table II illustrates that 56 generators (93.2% of the studied cases) are designed for this service. The rest (6.8%) was not designed for this service but modified in local markets. The modified generators generate less electricity with higher fuel consumption and emissions

TABLE II  
GENERATORS DESIGN FOR THIS SERVICE

	Yes	No	Total
Number	56	4	60
Percentage	93.2	6.8	100%

**Table III** manifests that the used water quantities in generator operation for a day. This quantity was 100 lt/day for 40% of the studied cases (24 generators), followed by 150 lt/day for 16 generators (26.6% of the studied cases). The 200 lt/day group with 21.6% of the studied cases (13 generators) and for 250 lt/ day and more the rate was 11.8% (7 generators). This water quantity differs depending on generators capacity as well as on year seasons. For 150 kV generators, in the summer season the used water reaches its maximum quantity which is 250 lt/day and more, while at winter season it reduces to its minimum quantity.

TABLE III  
WATER QUANTITIES USED IN GENERATORS OPERATION PER DAY

	100 lt/day	150 lt/day	200 lt/day	250 lt/day	Total
Number	24	16	13	7	60
Percentage	40	26.6	21.6	11.8	100%

The selection of the generators location was not designed on the basis for this purpose as shown in **Fig. 7**, 45 generators (which equal 75% of the studied cases) were chosen as a result of the need of the distinct and 15 generators' location (which equal 25% of the studied cases) were modified to suit it and its accessories.

**Fig. 8** manifests that the area occupied by each generator and its accessories varies between 10 m<sup>2</sup> (16 generators stand for 26.6% of the studied cases), 20 m<sup>2</sup> (13 generators equals to 21.6 % of the studied cases), 25 m<sup>2</sup> (11 generators stand for 18.4% of the studied cases), and 20 generators occupied 35 m<sup>2</sup> which equals to 33.4% of the studied cases.

The fitting of generators locations was studied in **Fig. 9**, which shows that the increasing noise ranked the higher percentage (56.6%) with 34 generators. The effect of exhaust gases on residences ranked 25% of the studied cases (15 generators). The last was to the effect of generators oils and fuel on the health deflation net which ranked 18.4% with 11 generators. It was declared during the study that many of the generators owners replace diesel fuel that they received from government with alternative materials that emit more emissions than what diesel fuel emits. They mix black oil with water and use this mixture as fuel.

The analysis of **Fig. 10** clarifies that the maximum percentage of generators location was near residential units in the amount of 33 generators (55% of the study cases). Also 26.6% of the studied cases were near schools (16 generators), 13.4% of the studied cases (8 generators) near social services, and 3 generators as much as 5% of the studied cases were near health-centers.

**Fig. 11** declares that 76.6% with 46 generators are located near places for emissions discarding, followed by 16.6% of the studied cases (10 generators) throw their dirt in the health deflation net. The last percentage was 6.8% for 4 generators which throw their emissions in the streets and uncovered ditches.

A second questionnaire was made (Appendix II) by choosing 500 families as a sample for the studied community which

population exceeds 2 million people. The distributed questionnaire application form concluded 13 questions. The families were chosen according to their homogenous conditions and the similarities in their social and economic circumstances. After collecting the questionnaire forms and analyzing the data and classifying it, the following results were deduced.

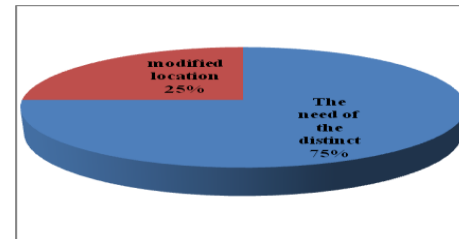


Fig. 7. Generators location selection

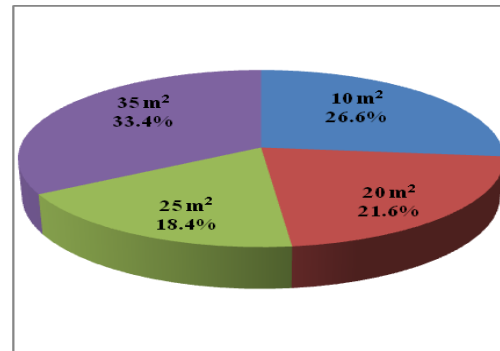


Fig. 8. The area occupied by the generator and its accessories

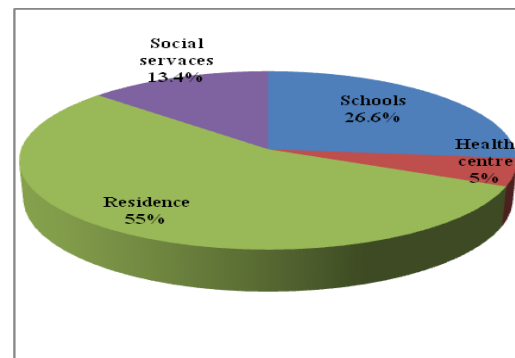


Fig. 9. Generators location

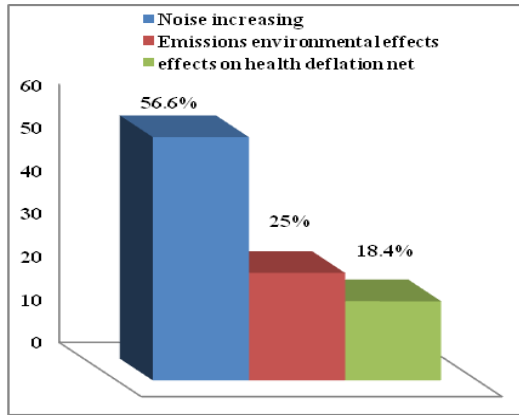


Fig. 10. Generators locations suitability for residences

**Fig. 12** represents the residential unit types in Al-Sader city. The houses with two floors were 221 houses (44.8%), while the houses with one floor were 169 houses (33.8%). Followed by half houses with 90 houses (18%), and at last the apartments in a building were 20 (4%). This stands for the largest part of the participants live in houses.

For the social conditions **Fig. 13** manifests that 70.6% (351) of the studied cases are married and 21% from them with the number of 105 are single. The divorced persons number was 22 (4.4% of the studied cases) while the widowers number was 20 (4% of the studied cases). This means that the most of the participants are families consuming more electrical units

**Fig. 14** shows that 10 person group occupied 37% as 185 families, followed by 8 persons' groups which were 115 families (23% of the studied cases). For 7 person group the percentage was 21.2% insomuch as 106 families while the rate was 18.8 for five person group as much as 94 families. These results indicate that the fewness of each person shares in the electrical unit of the single family. **Fig. 15** represents the number of rooms in the house for the studied cases. The study reveals that more than 5 rooms group took 44.4% with 222 families. The group of 4 rooms occupied 33.8% with 169 families. The two room group ranked 15% of the studied cases which was 75 families. At last the three room group occupied 6.8% as many as 34 families. Family income has a great influence on the amperes' they consume, **Fig. 16** represents this for current study contributors'. Families with income more than 250 US\$ occupied 33% of the studied sample (165 families). Families with income 200 US\$ were 27% (135 families) from the studied sample followed by 21% (105 families) with income about 150 US\$. At last, the families with income about 120 US\$ shared 19% (95 families) of the studied sample. These results state how extent this service has an influence on these families' monthly incomes, where the generators' fees become additional load must be paid. As a result living level for these families declined.

**Fig. 17** illustrates that the maximum monthly spending rate on electrical generator reached 50 US\$ for 351 families (70.2% of the studied sample). For 40US\$ the family number was 90 families (18%) followed by 7.4% of the tested sample (37

families) who pay 30 US\$. At last, the numbers of the families who pay 20 US\$ were 22, with 4.4% of the studied sample.

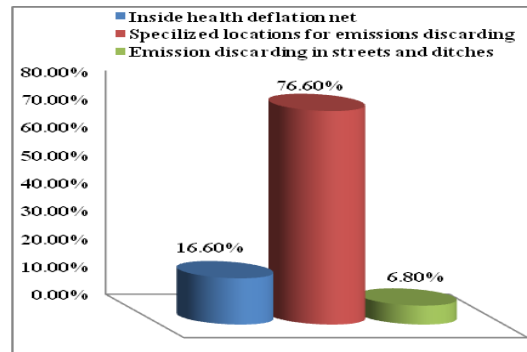


Fig. 11. Generators emissions discarding locations

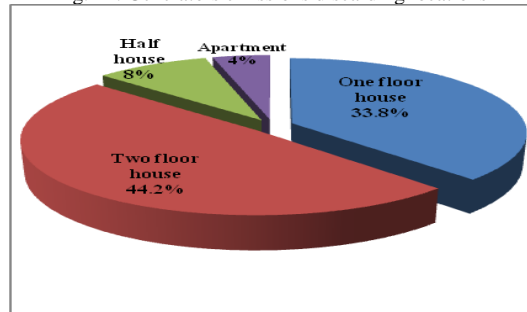


Fig. 12. Residential unit type

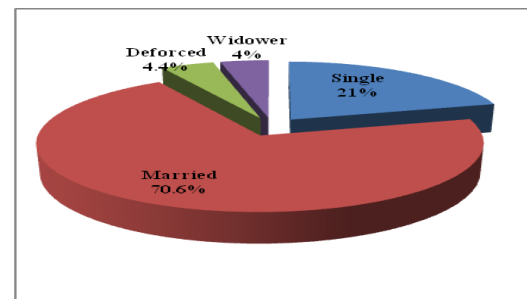


Fig. 13. Social conditions for residential units occupants

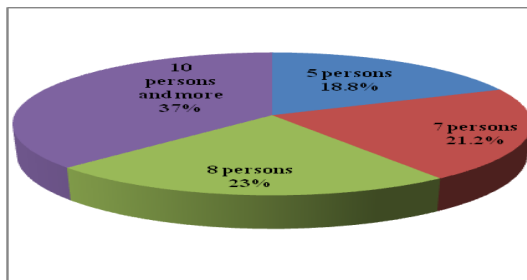


Fig. 14. Number of family persons in residential unit

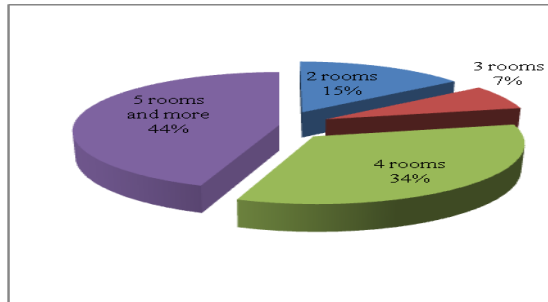


Fig. 15. Number of rooms in the residential units

The analysis of **Fig.18** illustrates that 395 families (79%) consume the maximum number of amps which it is 5 amps. Four amps consumer families with 13.6% from the studied sample ranked the second percentage in consuming electricity. For 3 amps 5.2% of the tested families (26 families), and for two amps only 11 families (2.2%) appear to use this low limit of electricity. The knowledge of the number of electrical equipment used depending on the shared generator service gives a good indication about comfortable condition for the studied sample families. **Fig. 19** reveals that using more equipment took 22.8% for 114 families, while 166 families (forms 33.2% of the studied sample) using 5 equipment. The families that use f equipments were 24.4% if the studied case forming 122 families. At last, the families using 3 equipments formed 19.6% of the studied cases with 98 families.

**Fig. 20** clarifies the electrical generator operation rate per day, where the maximum rate was 8 hours for 236 families with (47.2%), then 6 hours operation for 149 families with (29.8%). Fifty nine families utilize this service for 5 hours represents 11.8% of the studied cases. At last 56 families use 10 hour service forming 11.2 from the tested cases.

**Fig 21** details the distance from the electrical generator to the participants units. The 100 m group takes up 33.8% for 169 families, then 23.6% for 300 m group for 118 families. 200 m group ranked 22.4% for 112 families, followed by 20.2% for 500 m group which represents 101 families. This appears that there are no regulations or instructions or standards defining distance of such generators from living places.

**Fig. 22** manifests that the location of the generator is not fitted with residential unit, as 184 families (represent 38.8% of the studied cases) objected its location. The majority of the other families were undecided. The answer (almost) ranked 33.6% by 168 families, and (just fair) took 18% of the tested sample (90 families). The families that accepted its locations were only 58 families representing 11.6% of the studied sample.

How the electrical generator pollutants influence peoples' health? **Fig. 23** reveals that 220 families (44%) answered that high pollution. While 215 families stand for 43% of the studied case answered (medium pollution). At last, only 65 families (13%) answered (low pollution). The exhaust gases and noise harm effects are more recognized for the participants near it more than those farther away from it.

**Fig. 24** shows the effect of generators noise on participants. Yes was the answer of 425 families represents 85% of the studied cases. No was the answer of 15% of the studied case

representing 75 families. This result manifests the large environmental effects of these generators on human health. Producing legislations and lows limiting these generators noises is a serious issue.

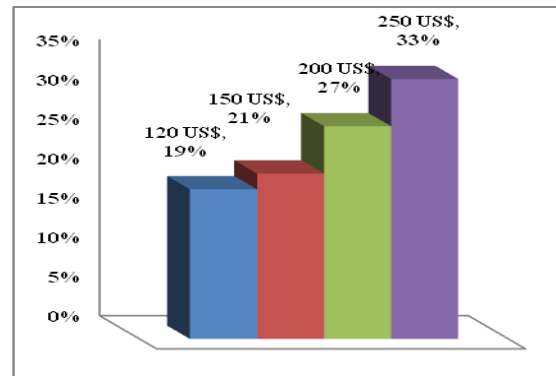


Fig. 16. Family monthly income rate

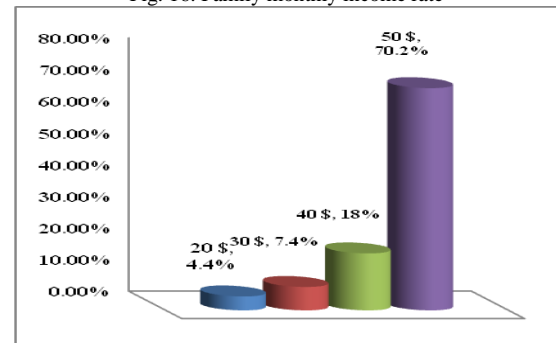


Fig. 17. what the family spends as fees for electrical generator

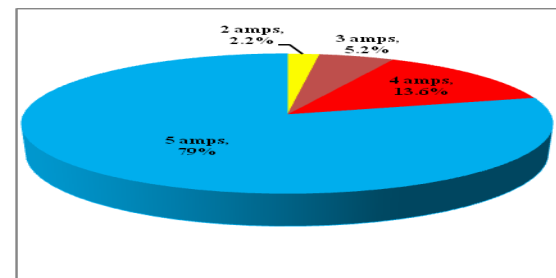


Fig. 18. Electrical units' rate consumed by the family

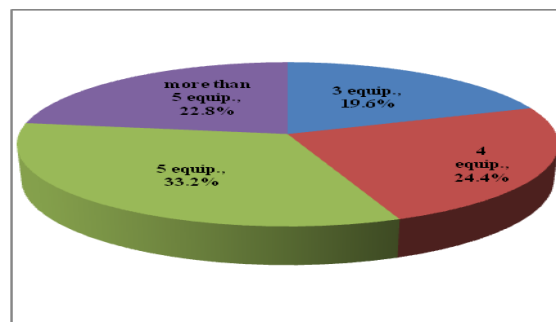


Fig. 19. Number of equipments that are operated using generator service

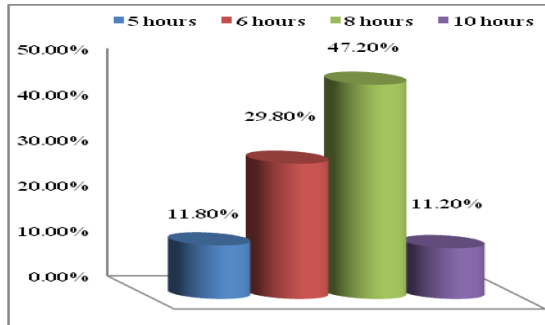


Fig. 20. Generator daily supplying rate

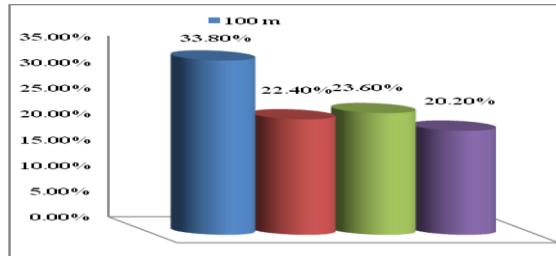


Fig. 21. The distance between generator and residence unit

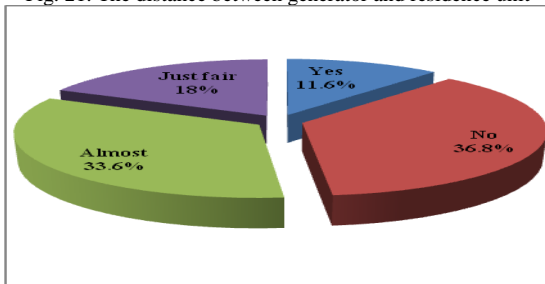


Fig. 22. Generator location fitting for families

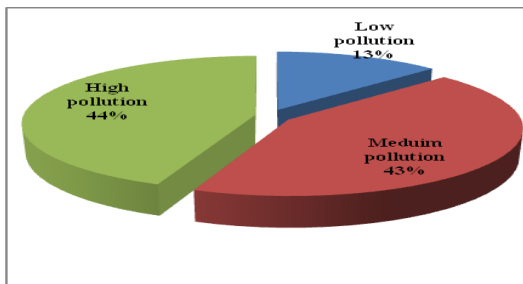


Fig. 23. Generator effect on participants' health

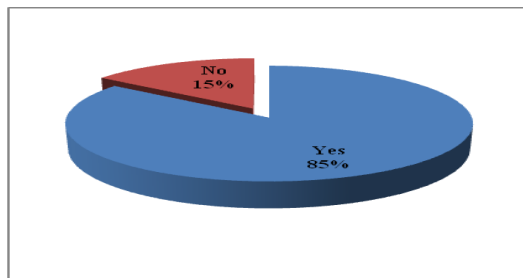


Fig. 24. Generator noise effects on participant

## v. CONCLUSIONS

In this field study two samples from Al-Sader city were taken to evaluate the environmental and health effects of shared

electrical generator operation in Iraqi cities to compensate electricity lack. The study results appear that:

- 1) The number of generators in one sector is 10 generators.
- 2) There is no single generator silencer type used in Al-Sader city.
- 3) Many of these generators throw their dirt in the health deflation pipes, causing many serious problems.
- 4) The location for all the generators in the study wasn't designed for this purpose. At the same time the area it occupies doesn't subjected for standards or regulations.
- 5) A High percentage of these generators lied near residence units and schools, causing noise and high pollution harm people health and city environment.
- 6) Although these generators introduce a vital service for Al-Sader city inhabitants, but unfortunately it increases CO<sub>2</sub>, CO, unburnt hydrocarbons, NO<sub>x</sub> and PM concentration in its zones. In addition to the weakness of health care, this problem becomes urgent and hazardous and needs rapid solutions.
- 7) The large number of participants in this service declares the huge lack of government electricity services in Al-Sader city, which is a high population density.
- 8) The results indicate that a part of the sample families consist of 10 or 8 persons, which reduce the individuals share from electrical energy.
- 9) The results show that the shared generators services take an effective part of families' income.
- 10) It is recommended to use renewable energy generator (i.e. photovoltaic system, concentrated solar power, etc).
- 11) It is recommended to use large generators instead of small and medium generators.
- 12) It is recommended to use natural gas generators instead of diesel and petrol generators.

## REFERENCES

- [1] LEGREID G, OXYGENATED VOLATILE ORGANIC COMPOUNDS (OVOCs) IN SWITZERLAND: FROM THE BOUNDARY LAYER TO THE UNPOLLUTED TROPOSPHERE, SWISS FEDERAL INSTITUTE OF TECHNOLOGY, ZURICH, PHD THESIS, 2006.
- [2] Boldo E, Medina S, Apheis: Health impact assessment of long-term exposure to PM<sub>2.5</sub> in 23 European cities, *European Journal of Epidemiology*, vol. 21, No. 6, pp: 449-458, 2006.
- [3] Heck W W, Cure W W, Assessing impacts of ozone on agricultural crops-I- overview, *Journal of The Air Pollution Control Association*, vol. 34, No. 7, pp: 729-735, 1984.
- [4] Tidblad J, Mikhailov A A, Improved prediction of ozone levels in urban and rural atmospheres, *Protection of Metals*, vol. 40, No. 1, pp: 67-76, 2004.
- [5] Bergin M S, West J J, Regional atmospheric pollution and transboundary air quality management, *Annual Review of Environment and Resources*, vol. 30, pp: 1-37, 2005.
- [6] Kazem H A & Chaichan M T, Status and future prospects of renewable energy in Iraq, *Renewable and Sustainable Energy Reviews*, vol. 16, No. 1, pp: 6007-6012, 2012.
- [7] IKN (Iraq Knowledge Network Survey 2011), Iraq Central Statistics Organization/Kurdistan Region Statistics Organization/United Nations, Baghdad, 2012.
- [8] Parsons Brinckerhoff, Master plan for the KRG Electricity Sector, Parsons Brinckerhoff, Erbil, Iraq, 2009a.
- [9] Parsons Brinckerhoff, Final report on the survey of private generation in the Baghdad Governorate, Parsons Brinckerhoff, Baghdad, 2009b.

- [10] UN Inter-Agency Information and Analysis Unit, Landmines and unexploded ordnances factsheet in Iraq, United Nations, New York, 2012.
- [11] World Bank, Doing Business 2012: Doing business in a more transparent world, World Bank, Washington, DC, 2012.
- [12] Chaichan M T & Ahmed S T, Evaluation of performance and emissions characteristics for compression ignition engine operated with disposal yellow grease, International Journal of Engineering and Science, vol.2, No. 2, pp: 111-122, 2013.
- [13] Diaz-Sanchez D, The role of diesel exhaust particles and their associated poly-aromatic hydrocarbons in the induction of allergic airway disease, Allergy, vol. 52, pp: 52-56, 1997.
- [14] Baghdad municipality, Al-Sader City municipality Department, Permissions and License Department, Drawing Section, Unpublished data, 2005.
- [15] Al-Sader city council, Al-Sader First Zone, Continuation Department, Unpublished data, 2008

## APPENDIX II

### Questionnaire II

Dear Sir/Mrs.

This questionnaire is constructed for scientific research purpose that give general advantages for society by take knowledge in the effectiveness of electrical generators distribution. This data you introduce carefully for scientific research. We wish your high cooperation to serve our country and society.

Researchers

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#### Put right sign on your choice

- a. Residence unit type: a. one floor house    b. Two floor house  
c. Half house    d. Apartment
- a. Marriage status: a) Single    b. Married    c. Divorced    d. Widower
- 1- Individuals number in the family is:  
a. 5    b. 7    c. 8    d. 10 and more
- 2- Rooms number in the residence unit is:  
a. 2    b. 3    c. 4    d. 5
- 3- Families' monthly income in US\$ is:  
a. 120 \$    b. 150 \$    c. 200 \$    d. 250 \$ and more
- 4- Families' paying out on generators fees is:  
a. 20 \$    b. 30 \$    c. 40 \$    d. 50 \$
- 5- Generator amperes consumed by the family are:  
a. 2 amps    b. 3 amps    c. 4 amps    d. 5 amps
- 6- A Number of the electrical equipment operated by generator current are:  
a. 3 equip.    b. 4 equip.    c. 5 equip.    d. All house equipments
- 7- Electrical generator operation rate per day is:  
a. 5 hours    b. 6 hours    c. 8 hours    d. 10 hours
- 8- The distance of residential unit from the generator is:  
a. 100 m    b. 200 m    c. 300 m    d. 500 m and more
- 9- Is generators' location suitable for the residence unit?  
a. Yes    b. No    c. Almost    d. Just fair
- 10- Is there any influence of the electric generator on resident health regarding pollution?  
a. Low pollution    b. Medium pollution    c. High pollution
- 11- Is there any influence of the electric generator on resident health regarding noise?  
a. Yes    b. No