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RESEARCH ARTICLE

Air Quality Assessment: A Statistical Approach to Stationary Air Monitoring Stations

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Manuscript Info ***Abstract***

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Air pollution has become an increasingly important environmental issue in Iraq. High levels of suspended particulates have become a common parameter of many regions. Air pollution is a serious environmental health threat to humans. Adverse effects range from nausea, difficulty in breathing and skin irritations, to birth defects, immuno-suppression and cancer. The pollutants for which sampling and analytical techniques discussed are O_3, CO_2 and Temperature. Samples were collected from two stations in Baghdad city for 2 years (2012 & 2013). The study assesses levels and variations of Ozone (O_3), carbon Dioxide (CO_2) and the Temperature, using stationary environmental monitoring stations in Baghdad, Iraq. Analysis of variance (ANOVA) Two way confirmed significant variations in monthly observations. Also, t-test for difference of means as two independent samples showed that except for CO_2 in Al-Andulis air monitoring station all the other air quality parameters do not show significant difference. The study shows a need for constant urban air quality monitoring in Baghdad, Iraq.

INTRODUCTION

The rapid growth of Baghdad city in last years has resulted in significant increase in environmental pollution. Hence, effective and coordinated measures for controlling pollution need to be put in place without delay for the city (Salah, 2011). At the end of the 2003 war, Baghdad's infrastructure was seriously degraded (Allaa et al., 2012 (a)). That of the causes of increased concentrations of heavy metals in the air is the occurrence of dust storms which carry dust storms amounts of dust containing heavy metals from the surface of land passing through, causing high concentrations of total suspended particles and that was mostly exceeding the specific national proposal and thus increasing the concentrations of heavy metals (Allaa et al., 2013). Baghdad's dusty atmosphere is resulting air pollution caused by drought that continued for several seasons (ODD, 2010). Air pollution describes the concentrations that cause damage to humans, plant, animal life, human-made materials and structures. According to US EPA the air pollution and air pollutant are defined (US EPA, 2009). With respect to Urban Air Pollution, the meteorological conditions that effect transport and dispersion take place in the so-called planetary boundary layer (Ekman layer), roughly the lower 1000 m of the atmosphere. Within this layer, wind speed and wind direction are influenced by the roughness of the surface and the vertical height of flows (Seinfeld and Pandis, 1998). The United Nations Environment Programme (UNEP) also says air pollution, resulting from burning oil and aggravated by war, is cause for concern (Allaa et al., 2012 (b)).

Ozone is a highly oxidative compound formed in the lower atmosphere from gases (originating to a large extent from anthropogenic sources) by photochemistry driven by solar radiation. Owing to its highly reactive chemical properties, ozone is harmful to vegetation, materials and human health. In the troposphere, ozone is also an efficient greenhouse gas (WHO, 2008). Ground-level ozone is a public health concern. Prolonged exposure to low-level ozone concentrations is as harmful to human health as exposure to higher levels for shorter durations. It inflames lung tissues

and can cause coughing, chest pains, and asthma. Children are most at risk from exposure to ozone because they play and exercise outdoors during the months ozone concentrations are highest. The elderly are also susceptible (ADEQ, 2013). Most important among these processes is combustion of fossil fuels and biomass which produces carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs), black carbon (BC) aerosols, and sulfur oxides (SO_x, comprised of some sulfate aerosols, but mostly SO_2 gas which subsequently forms white sulfate aerosols) (Ronald et al., 2005).
Surface temperature inversions play a major role in air quality, especially during the winter when these inversions are the strongest. The warm air above cooler air acts like a lid, suppressing vertical mixing and trapping the cooler air at the surface. As pollutants from vehicles, fireplaces, and industry are emitted into the air, the inversion traps these pollutants near the ground, leading to poor air quality (EPA, 1947).

2. Objectives and Approach

The objective of this study is to assess Baghdad's air quality. This comprised an assessment of Baghdad's air pollution levels by O_3, CO_2 and Temperature and evaluates air quality in Baghdad City.

- To evaluate air quality in Baghdad City.
- To assess air pollution in Baghdad City.
- To Define standards or guidelines for allowable concentration of these pollutants, consistent with public health protection.

3. Study area

Baghdad city is located in central of Iraq within the sector of flat sedimentary plain. The borders of the municipality of Baghdad encompass fourteen an administrative unit, eight in Rusafa (east of Tigris river) and six in Karkh (west of Tigris river), and area of the municipality of Baghdad (870 km^2). Advantage of the characteristics of study area is essential extremism great in temperature, few precipitations, few relative humidity and high brightness of the sun. Baghdad population is more than (6 millions) with governmental statistics (Bassim et al., 2010). According to UN figures, around 150 million tons of dust and gas pollutants, various other spread annually in the air, and the transport is the main source of air pollution, where a 40% of all sources of air pollution and this percentage can be up to more than 60% for a city like Baghdad with increase the number of vehicles operating with gasoline and traffic congestion large harmful emissions will result in accumulation to a deterioration is evident in the quality of air, as well as the accumulation of the amount of greenhouse gases that cause global warming, all that damage the ecological balance of the ecosystem, while can be an industrial pollution and emissions resulting from the use of generators for more than 30% (Allaa et al., 2013). The trends of ozone are assumed to be due photochemical ozone production from anthropogenic trace gases and biomass in Iraq and several researchers are investigated (Al-Saadi, 1999) which founded that the concentrations of carbon dioxide are higher than the acceptable levels especially in the industrial regions around Baghdad city, also (Affaj, 2000) studied the distributions of the concentrations of polluted gases such as CO_2 and hydrocarbons and found that the concentrations of these gases are higher than the international and national permission levels.
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 relatively considerable levels of hydrocarbons (HCs), carbon monoxide (CO), and volatile organic compounds (VOCs). Diesel engines are relatively high emitters of oxides of nitrogen (NOx) 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_{10}), and 60–80% of fine particulate ($PM_{2.5}$) inventory (Sanchez, 1997).

4. Data procurement

Samples were collected from two stations in central of Baghdad city as shown in Fig. 1, the stations is:

- **Ministry of Transport in Al-Allawi:** It is located under the influence of pollutants from vehicle exhaust due to being at the center of the capital city; also it's so close from the central terminal for passenger inside Baghdad and to other cities out of Baghdad. In this location are measured concentrations of total suspended particles and concentrations of dust falling.

- **Baghdad Environmental Directorate in A-Andulis Square:** It is location in service and trade area in addition to residential area and a number of other activities. Also the most important sources of pollution here is exhaust of vehicles due to traffic density and the presence of Highway at a distance (800 m) from the monitoring station, which is increasing pressure in the load pollution affecting the quality of ambient air, especially in working days. Located near of the monitoring station the city centre (Bab Al Sharqi) largest area for shopping. Where is measured in total suspended particles and dust falling on this location (Allaa et al., 2013).

5. Methodologies

5.1 Estimation of significant difference by Student's t-test

A *t*-test is any statistical hypothesis test in which the test statistic has a Student's t-distribution if the null hypothesis is true. It is applied when sample sizes are small enough that using an assumption of normality and the associated z-test leads to incorrect inference.

Suppose we want to test if two independent samples x_i (i=1, 2... n_1) and y_j, (j=1, 2… n_2) of sizes n_1 and n_2 have been drawn from two normal populations with means μ_x and μ_y respectively (Allaa et al., 2012 ©; Gupta et al., 2000).

$$t = \frac{x' - y'}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where: $x' = \frac{1}{n_1}\sum_{i=1}^{n} x_i \quad , y' = \frac{1}{n_2}\sum_{j=1}^{n} y_j$

And $S^2 = \frac{1}{n_1 + n_2 - 2}\left[\sum (x_i - x')^2 + \sum (y_j - y')^2\right]$

If

$$|t| < t_{0.05, n_1 + n_2 - 2}$$

Then the means do not differ significantly

The student's t-test is performed at 95% significance level. The value of $t_{0.05,\ n-1}$ is evaluated from the t-distribution tables and then compared with the t value obtained from the formula given above. If $|t| < t_{0.05,\ n-1,}$ then it is concluded that the two means i.e. the sample mean and the population mean do not differ significantly.

5.2 Estimation of variability by ANOVA – 2 way (space and time)

The ANOVA test is used to test the equality of variances of several normal populations. Let X_{ij} (j=1,2,…,n) be a random sample of size n_i from the normal population N(μ_i, σ_i^2), i=1,2,…,k. We want to test the null hypothesis (Allaa et al., 2012 ©; Gupta et al., 2000):

$H_0 = \sigma\ 1^2 = \sigma\ 2^2 = \sigma^2$ (unspecified), with μ_1, μ_2

(unspecified) against the alternative hypothesis:

H1: σ_i^2 (i=1, 2) are not equal; $\mu_{1,}$ μ_2 unspecified

$$F = (m\,(n-1)s_1^2)/(n(m-1)s_2^2)\_\ F(m-1,n-1)$$

$F1 = F_{m-1,n-1}(1-\alpha/2)$ and $F2 = F_{m-1,n-1}(\alpha/2)$

If $F2 < F < F1$

Thus the variances do not differ significantly.

6. Results

The student t-test shows in the table (1) for the Al-Andulis air quality monitoring station, except for CO_2 samples all the air quality parameters show no significant differences.
The student t-test shows in the table (2) for the Al-Allawi air quality monitoring station, all the air quality parameters show no significant differences.

The ANOVA test is done for the parameters (O_3, CO_2 and Temperature) for the years 2012 and 2013. For all the cases where F2<F<F1 the variance has consistent values and for any other condition the test fails.

Fig. (1) Baghdad map with air quality monitoring stations.

Table (1) Al-Andulis air quality monitoring (2012-2013)

2012				2013		
Months	**O_3**	**CO_2**	**Temp.**	**O_3**	**CO_2**	**Temp.**
WHO	**0.08**	**250**	**-**	**0.08**	**250**	**-**
Standard	**PPM in 8-hrs**	**PPM**	**°C**	**PPM in 8-hrs**	**PPM**	**°C**
January	0.01	378	13.9	0.02	401	15.3
February	0.02	399	14.6	0.03	420	15.2
March	0.03	398	17.3	0.03	410	19.1
April	0.04	397	29.6	0.05	405	30.5
May	0.03	398	34.3	0.02	411	35.7
June	0.03	402	37.9	0.04	415	40.2
July	0.04	391	40.6	0.04	408	42.4
August	0.02	394	37.7	0.03	410	42.2
September	0.03	401	36.2	0.04	420	38.7
October	0.02	448	31.3	0.03	460	35.3
November	0.02	447	22.4	0.04	455	25.6
December	0.02	450	17.7	0.03	465	18.5
Mean	0.026	408.583	27.792	0.033	423.333	29.892
Std	0.009	24.777	10.005	0.009	22.869	10.654
t_test	-1.920	-5.936	-0.5	/	/	/
t0.95,22	2.075	2.075	2.075	/	/	/
ltl	$t< t_{0.05,22}$	$t> t_{0.05,22}$	$t< t_{0.05,22}$	/	/	/

Table (2) Al-Allawi air quality monitoring (2012-2013)

	2012			2013		
Months	**O_3**	**CO_2**	**Temp.**	**O_3**	**CO_2**	**Temp.**
WHO	**0.08**	**250**	**-**	**0.08**	**250**	**-**
Standard	**PPM in 8-hrs**	**PPM**	**°C**	**PPM in 8-hrs**	**PPM**	**°C**
January	0.03	450	15.1	0.04	465	14.1
February	0.03	460	16.3	0.03	478	15.3
March	0.05	435	18.4	0.04	450	20.2
April	0.05	445	32.1	0.05	455	32.5
May	0.04	429	36.7	0.04	448	37.4
June	0.04	457	39.3	0.05	464	40.2
July	0.05	459	42.4	0.05	486	48.5
August	0.04	455	41.7	0.04	478	45.3
September	0.05	460	38.5	0.05	468	42.4
October	0.04	478	34.2	0.04	475	35.3
November	0.03	535	25.5	0.05	466	26.3
December	0.04	520	18.9	0.04	476	15.5
Mean	0.041	465.250	29.925	0.043	467.417	31.083
Std	0.008	31.858	10.462	0.007	11.889	12.424
t_test	-0.27	-0.22	-0.25	/	/	/
t0.95,22	2.075	2.075	2.075	/	/	/
ltl	$t< t_{0.05,22}$	$t< t_{0.05,22}$	$t< t_{0.05,22}$	/	/	/

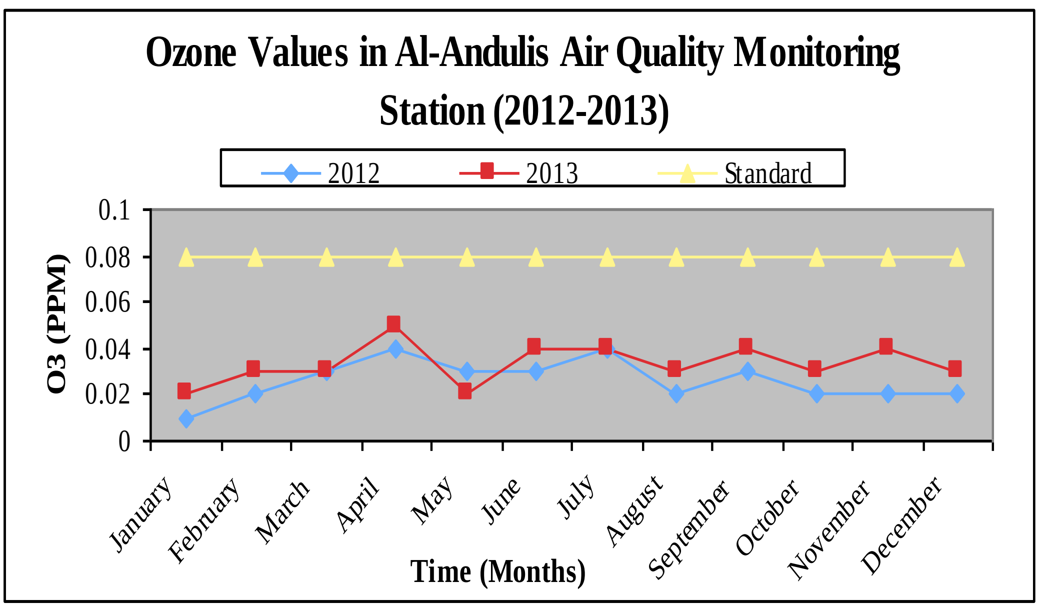

Fig. (2) Ozone values in Al-Andulis air quality monitoring station (2012-2013)

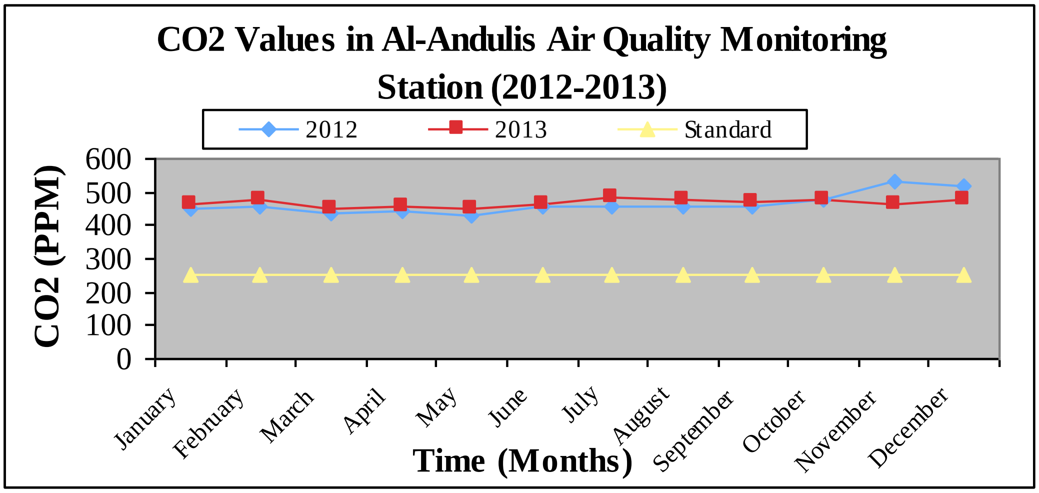

Fig. (3) CO_2 values in Al-Andulis air quality monitoring station (2012-2013)

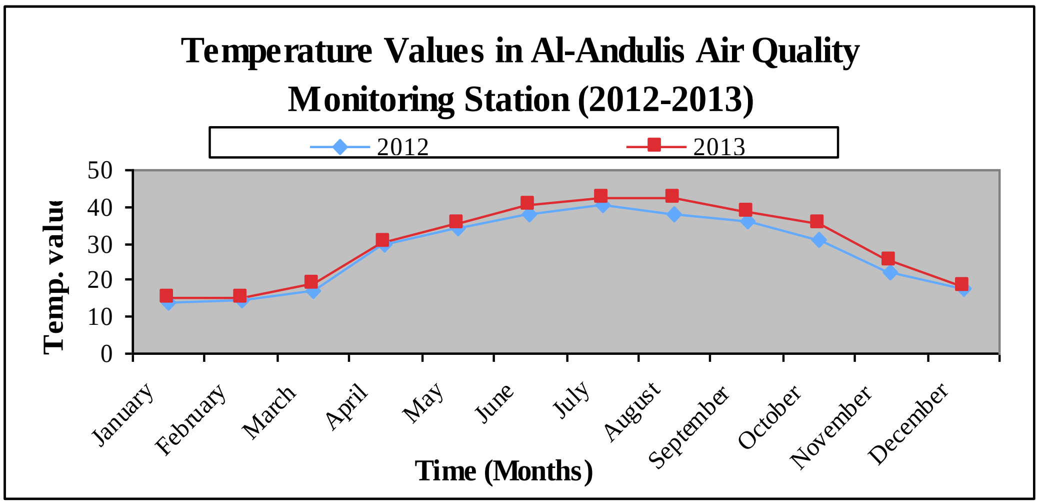

Fig. (4) Temperature values in Al-Andulis air quality monitoring station (2012-2013)

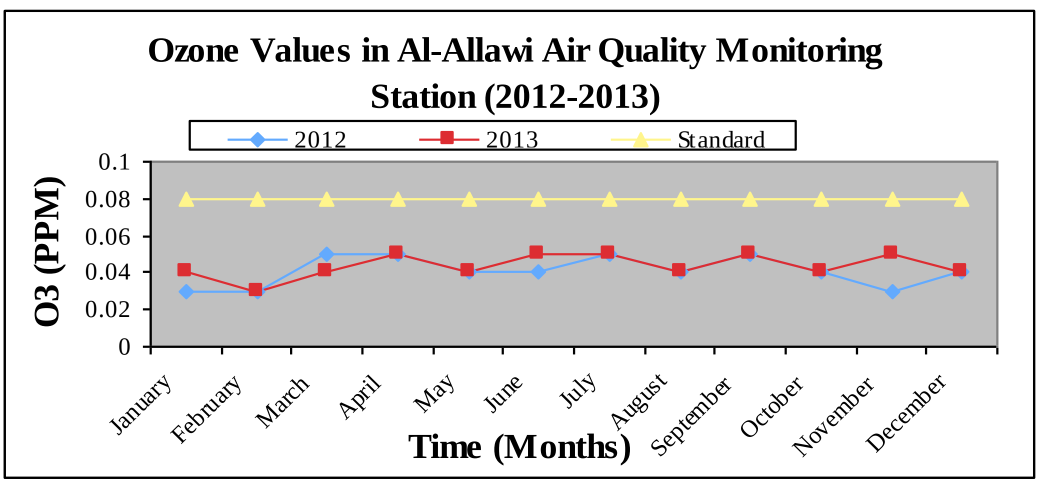

Fig. (5) Ozone values in Al-Allawi air quality monitoring station (2012-2013)

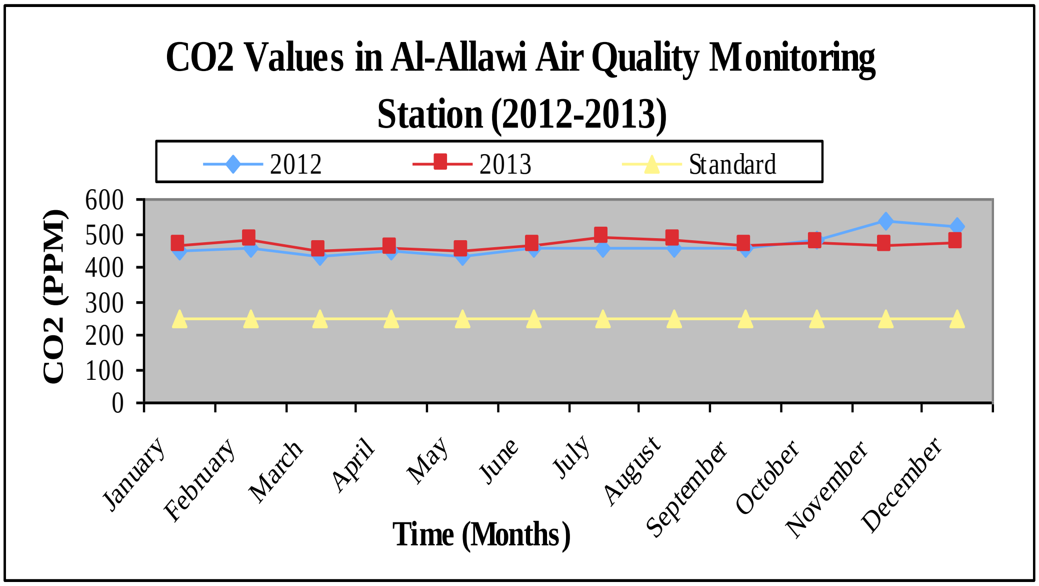

Fig. (6) CO_2 values in Al-Allawi air quality monitoring station (2012-2013)

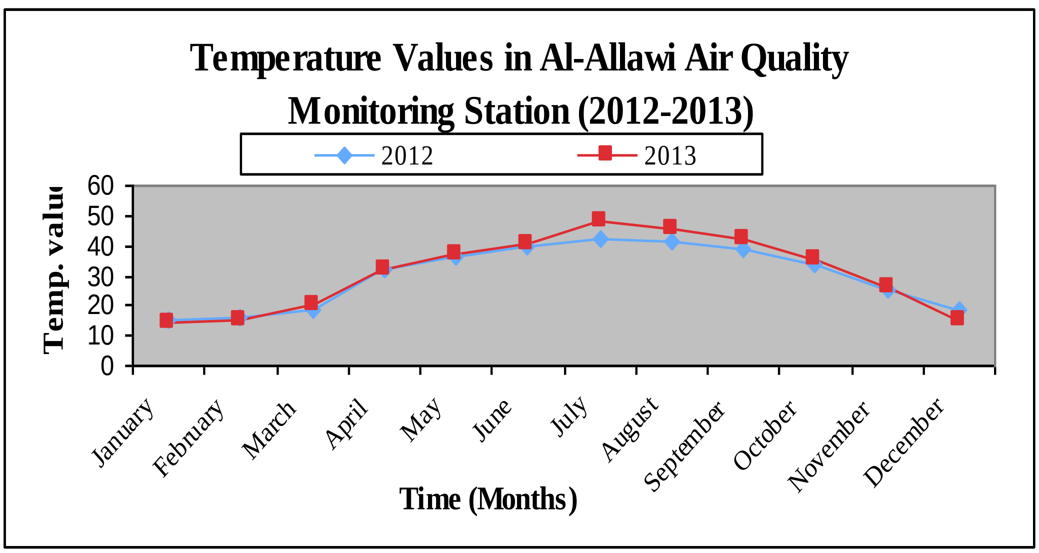

Fig. (7) Temperature values in Al-Allawi air quality monitoring station (2012-2013)

Table (3) ANOVA test for O_3 values for the year 2012

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	std	Sy	F	F1	F2	
Al-Andulis	0.01	0.02	0.03	0.04	0.03	0.03	0.04	0.02	0.03	0.02	0.02	0.02	0.01	0.0	1.29	2.69	0.37	F2<F< F1
Al-Allawi	0.03	0.03	0.05	0.05	0.04	0.04	0.05	0.04	0.05	0.04	0.03	0.04	0.01	0.0	/	/	/	/
std	0.014	0.007	0.014	0.007	0.007	0.007	0.007	0.014	0.014	0.014	0.007	0.01	/	/	/	/	/	/
Sx	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	/	/	/	/	/	/
F	4.00	0.25	4.00	1.00	1.00	1.00	0.25	1.00	1.00	4.00	0.25	/	/	/	/	/	/	/
F1	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	/	/	/	/	/	/	/
F2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	/	/	/	/	/	/	/
	F2<F>F1	F2>F<F1	F2<F>F1	F2<F<F1	F2<F<F1	F2<F<F1	F2>F<F1	F2<F<F1	F2<F<F1	F2<F>F1	F2>F<F1	/	/	/	/	/	/	/

Table (4) ANOVA test for O_3 values for the year 2013

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	std	Sy	F	F1	F2	
Al-Andulis	0.02	0.03	0.03	0.05	0.02	0.04	0.04	0.03	0.04	0.03	0.04	0.0	0.01	0.0	1.76	2.69	0.37	F2<F<F1
Al-Allawi	0.04	0.05	0.04	0.06	0.04	0.05	0.05	0.04	0.05	0.04	0.05	0.0	0.01	0.0	/	/	/	/
std	0.014	0.014	0.007	0.007	0.014	0.007	0.007	0.007	0.007	0.007	0.007	0.01	/	/	/	/	/	/
Sx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	/	/	/	/	/	/
F	1.00	4.00	1.00	0.25	4.00	1.00	1.00	1.00	1.00	1.00	1.00	/	/	/	/	/	/	/
F1	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	/	/	/	/	/	/	/
F2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	/	/	/	/	/	/	/
	F2<F<F1	F2<F>F1	F2<F<F1	F2>F<F1	F2<F>F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	/	/	/	/	/	/	/

Table (5) ANOVA test for CO_2 values for the year 2012

Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**std**	**Sy**	**F**	**F1**	**F2**	
Al-Andulis	378	399	398	397	398	402	391	394	401	448	447	450	25	670	0.60	2.69	0.37	F2<F<F1
Al-Allawi	450	460	435	445	429	457	459	455	460	478	535	520	32	1107	/	/	/	/
std	50.9	43.1	26.2	33.9	21.9	38.9	48.1	43.1	41.7	21.2	62.2	49.5	/	/	/	/	/	/
Sx	5184	3721	1369	2304	961	3025	4624	3721	3481	900	7744	4900	/	/	/	/	/	/
F	1.39	2.72	0.59	2.40	0.32	0.65	1.24	1.07	3.87	0.12	1.58	/	/	/	/	/	/	/
F1	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	/	/	/	/	/	/	/
F2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	/	/	/	/	/	/	/
	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F>F1	F2>F<F1	F2<F<F1	/	/	/	/	/	/	/

Table (6) ANOVA test for CO_2 values for the year 2013

Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**std**	**Sy**	**F**	**F1**	**F2**	
Al-Andulis	401	420	410	405	411	415	408	410	420	460	455	465	23	571	3.70	2.69	0.37	F2<F>F1
Al-Allawi	465	478	450	455	448	464	486	478	468	475	466	476	12	154	/	/	/	/
std	45.3	41.0	28.3	35.4	26.2	34.6	55.2	48.1	33.9	10.6	7.8	7.8	/	/	/	/	/	/
Sx	4096	3364	1600	2500	1369	2401	6084	4624	2304	225	121	121	/	/	/	/	/	/
F	1.22	2.10	0.64	1.83	0.57	0.39	1.32	2.01	10.24	1.86	1.00	/	/	/	/	/	/	/
F1	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	/	/	/	/	/	/	/
F2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	/	/	/	/	/	/	/
	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F>F1	F2<F<F1	F2<F<F1	/	/	/	/	/	/	/

Table (7) ANOVA test for Temperature values for the year 2012

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	std	Sy	F	F1	F2	
Al-Andulis	13.9	14.6	17.3	29.6	34.3	37.9	40.6	37.7	36.2	31.3	22.4	17.7	10	109	0.91	2.69	0.37	F2<F<F1
Al-Allawi	15.1	16.3	18.4	32.1	36.7	39.3	42.4	41.7	38.5	34.2	25.5	18.9	10	119	/	/	/	/
std	0.85	1.20	0.78	1.77	1.70	0.99	1.27	2.83	1.63	2.05	2.19	0.85	/	/	/	/	/	/
Sx	1.44	2.89	1.21	6.25	5.76	1.96	3.24	16.00	5.29	8.41	9.61	1.44	/	/	/	/	/	/
F	0.50	2.39	0.19	1.09	2.94	0.60	0.20	3.02	0.63	0.88	6.67	/	/	/	/	/	/	/
F1	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	/	/	/	/	/	/	/
F2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	/	/	/	/	/	/	/
	F2<F<F1	F2<F<F1	F2>F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2>F<F1	F2<F<F1	F2<F<F1	F2<F<F1	F2<F<F1	/	/	/	/	/	/	/

Table (8) ANOVA test for Temperature values for the year 2013

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	std	Sy	F	F1	F2	
Al-Andulis	15.3	15.2	19.1	30.5	35.7	40.2	42.4	42.2	38.7	35.3	25.6	18.5	11	124	0.68	2.69	0.37	F2<F<F1
Al-Allawi	14.1	15.3	20.2	32.5	37.4	45.6	48.5	45.3	42.4	37.5	26.3	15.5	13	183	/	/	/	/
std	0.85	0.07	0.78	1.41	1.20	3.82	4.31	2.19	2.62	1.56	0.49	2.12	/	/	/	/	/	/
Sx	1.44	0.01	1.21	4.00	2.89	29.16	37.21	9.61	13.69	4.84	0.49	9.00	/	/	/	/	/	/
F	144	0.01	0.30	1.38	0.10	0.78	3.87	0.70	2.83	9.88	0.05	/	/	/	/	/	/	/
F1	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	3.825	/	/	/	/	/	/	/
F2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	/	/	/	/	/	/	/
	F2<F>F1	F2>F<F1	F2<F<F1	F2<F<F1	F2>F<F1	F2<F<F1	F2<F>F1	F2<F<F1	F2<F<F1	F2<F>F1	F2>F<F1	/	/	/	/	/	/	/

7. Conclusions

The following conclusions have been made based on the study:

- The Ozone (O_3) was with the limits of WHO and Iraqi standards and the student t-test shows in Al-Andulis air quality monitoring station and Al-Allawi air quality monitoring station no significant differences. Also Ozone shows in ANOVA two-way test (space and time) in 2012, except for the months of January, February, March, July, October and November all the other months show consistent values. All the results are consistent with respect to time. In 2013 shows, except for the months of February, April and May all the other months show consistent values. All the results are consistent with respect to time.
- The carbon Dioxide (CO_2) was out of the limits of WHO and Iraqi standards and the student t-test shows in Al-Andulis air quality monitoring station significant differences and Al-Allawi air quality monitoring station no significant differences. In ANOVA two-way test in 2012 shows except for the months of September and October and all the other months show consistent values. All the results are consistent with respect to time. In 2013 shows, except September all the other months show consistent values. The results are inconsistent with respect to time.
- Also after exam the temperature by student t-test shows in Al-Andulis air quality monitoring station and Al-Allawi air quality monitoring station no significant differences. And by ANOVA two way test shows in 2012, except for the months of March and July, all the other months show consistent values. All the results are consistent with respect to time. And in 2013 shows, except for the months of January, February, May, July, October and November, all the other months show consistent values. All the results are consistent with respect to time.

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