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TOXICOLOGICAL IMPACTS OF HEAVY METALS UPON THE RESIDENTS AND WORKER OF BRICK KILNS, IRAQ

Sara Gatea Fayyadh Al-Omairi[1]*, Sarhan R. Sarhan[2] and Jameel S. Al-Sarai[3]

[1*]Department of Agriculture, College of Science, University of Wasit, Wasit, Iraq.
[2]Departement of Pharmacology, College of Veterinary Medicine, University of Wasit, Wasit, Iraq.
[3]Department of Biology, College of Science, University of Wasit, Wasit, Iraq.

Abstract

Brick kilns and their occupational hazards are an extremely less studied area of research. Hence, this study carried out to investigate the health effects of air pollution on the exposure individuals (workers in and residents around) to the clay brick kilns of two districts (Al-Hay and Badra) in Wasit province, Iraq. Totally 200 (150 exposures, and 50 controls) blood samples were collected during November/2018 to May/2019, and tested to detect the levels of heavy metals (HMs) [cadmium (Cd) and lead (Pb)], antioxidant enzymes [catalase (KatA), superoxide dismutase (SODs), and glutathione peroxidase (GPx)] and malondialdehyde (MDA). The findings of both districts were revealed on significant increases ($P<0.05$) in levels of Cd in tested sera of adults (Females and males), but not children ($P>0.05$) of exposure group when compared to control group. Regarding to Pb, significant increases ($P<0.05$) were seen in adults and children of Al-Hay, as well as in adults but not children of Badra ($P>0.05$). In both districts, the results of exposure group were showed significant decreases ($P<0.05$) in levels of KatA, SODs, GPx, and significant increases ($P<0.05$) in levels of MDA. However, the findings of adults and children as well as females and males were showed significant differences ($P<0.05$) in their values. Significant decreases ($P<0.05$) in RBCs count and Hb concentration of exposure group comparing to control group were confirmed in this study.

***Key words*:** Heavy metals, Brick kiln, Worker, Resident, Iraq

Introduction

Air pollution (AP) is an important serious source of public health impacts and climatic changes in rural areas and urban areas, worldwide (Fullerton *et al.,* 2008; Smith *et al.,* 2014). Clay bricks is consider as one of the most utilized building materials which made usually in a traditionally small-scale industries, in which, a highly polluting activity is produced into the atmosphere with serious health hazards to their residents (Bhanarkar *et al.,* 2002). Different air pollutants were observed to be emitted as a result of inefficient fuel combustion involving carbon and nitrogen dioxides, and fine particulate matter that a mixture of sulfate, nitrate, black organic carbon (Rasheed *et al.,* 2015). In less developed countries, the indoor and outdoor continues exposure of these pollutants is accounting to be responsible for many respiratory problems and deaths (Chauhan and Johnston, 2003). In addition, heavy metals (HM) such as cadmium (Cd) and lead (Pb) or their compounds emitted from brick kilns to the environment have led to a sharp increase in contamination of soil and water (Robinson, 2009). Although there maximum standard limits, the potential toxicity of these metals still widely diffusive (Aziz *et al.,* 2008). Long-term exposure to low levels of Cd or Cd compounds leads to a buildup in lung damage, fragile bones, and possible kidney diseases; whereas, the ingestion or inhalation of high levels cause severe damage to the lung, and severely irritates the stomach (Sinha *et al.,* 2008; Martin and Griswold, 2009). As it used in several produces, exposure to high Pb levels can affect every organ and system in the body resulting in many disorders such as anemia, weakness, decreased performance, damage to the brain and kidney, and probable cancer (Papanikolaou *et al.,* 2005; Martin and Griswold, 2009).

The interactions between APs and living tissues due to HMs have been accumulated to cause disturbances in pro-oxidant and anti-oxidant balance, as well as to cell damage (Jan *et al.,* 2015). However, many enzymes such as catalase (KatA), superoxide dismutase (SODs), and glutathione peroxidase (GPx) having a role in protection

***Author for correspondence :** E-mail : albwjanat@gmail.com, srashid@uowasit.edu.iq

Table 1: Concentration of HMs in sera of study population in brick kilns of Al-Hay district.

Factor	Exposure group				Control group	P-Value
	Adult		Children			
	Female	Male	Female	Male		
Cd	17.368±2.456 [a]	16.636±2.300 [a]	4.954±0.687 [b]	5.006±0.603 [b]	1.370±0.665 [b]	0.05*
Pb	16.566±1.926 [a]	19.081±1.823 [a]	6.676±1.027 [b]	6.894±0.796 [b]	0.605±0.612 [c]	0.05**

Variation in horizontal letters meaning a significant variation (P<0.05).

Table 2: Concentration of HMs in sera of study population in brick kilns of Badra district.

Factor	Exposure group				Control group	P-Value
	Adult		Children			
	Female	Male	Female	Male		
Cd	17.150±2.162 [a]	17.756±1.985 [a]	5.395±0.574 [b]	5.106±0.734 [b]	1.370±0.666 [b]	0.05*
Pb	17.987±2.082 [a]	17.094±1.802 [a]	7.125±0.633 [b]	6.484±0.791 [b]	0.605±0.612 [c]	0.05**

Variation in horizontal letters meaning a significant variation (P<0.05).

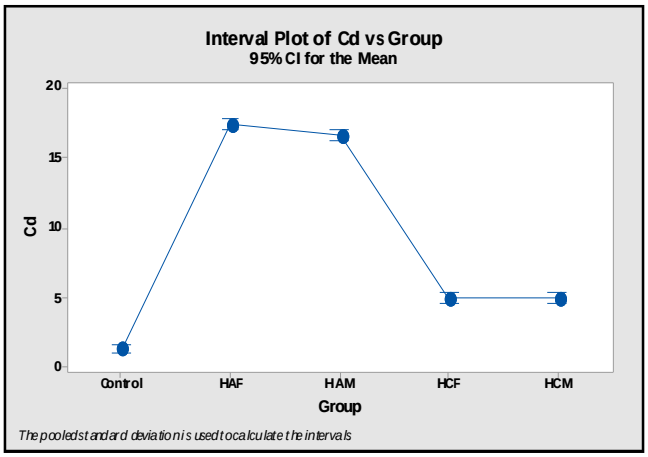

Fig. 1: Interval plot of Cd versus different groups in brick kilns of Al-Hay district.

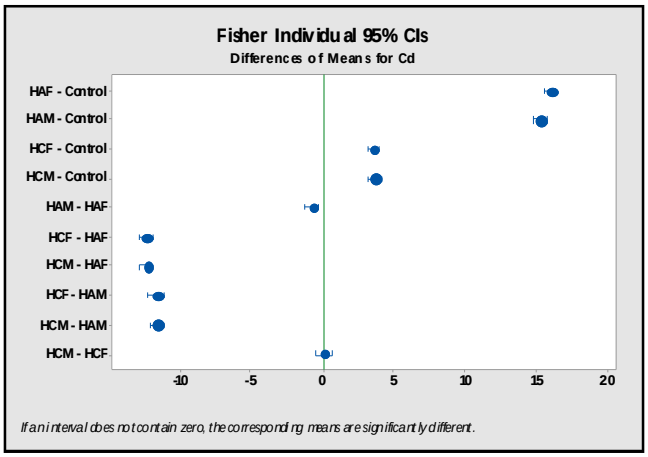

Fig. 3: Fisher's Pairwise comparisons for Cd in brick kilns of Al-Hay district.

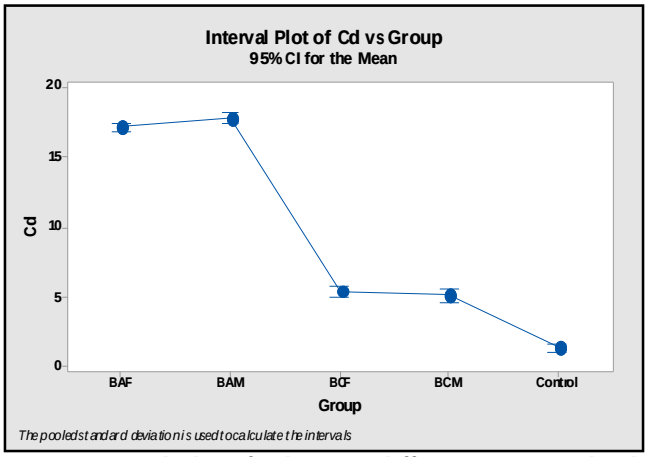

Fig. 2: Interval plot of Cd versus different groups in brick kilns of Badra district.

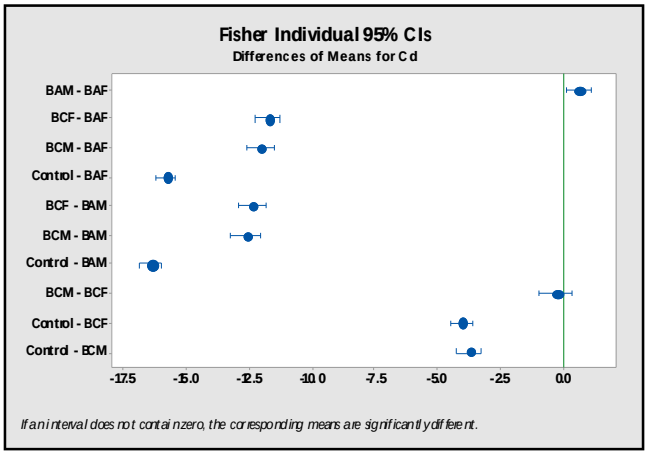

Fig. 4: Fisher's Pairwise comparisons for Cd in brick kilns of Badra district.

of the body against the oxidant injury of oxidative stress (Evans and Halliwell, 2001; Irshad and Chaudhuri, 2002). Malondialdehyde (MDA) is one of the many reactive electrophile compounds that resulted from degradation of polyunsaturated lipids by reactive oxygen species (Ayala *et al.*, 2014). MDA that reacts with deoxyguanosin and deoxyadenosine forming DNA products and causing in toxic stress in cells, is used as a biomarker to measure the level of oxidative stress in biological sample (Marnett, 2002; Grotto *et al.*, 2009). To estimate the levels of HMs in biological samples, the most widely analytical approaches described are the atomic emission

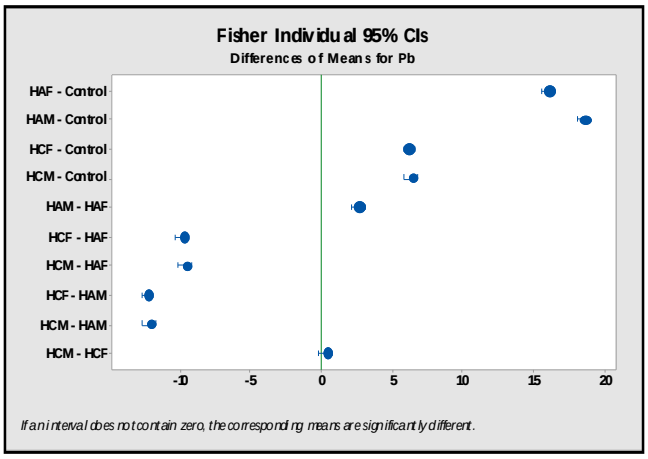

Fig. 5: Fisher's Pairwise comparisons for Pb in brick kilns of Al-Hay district.

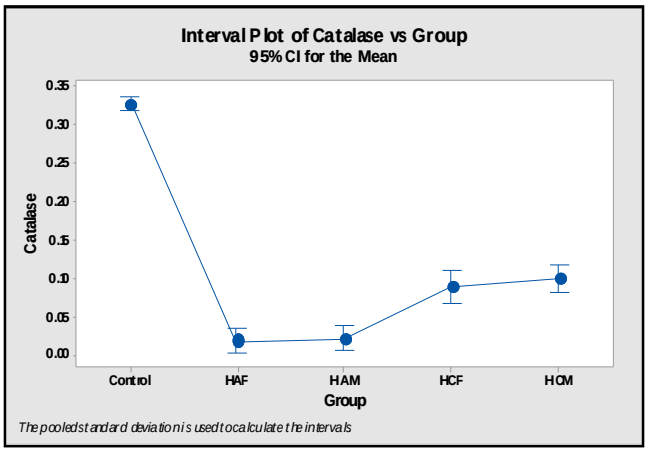

Fig. 7: Interval plot of KatA versus different groups in brick kilns of Al-Hay district.

Table 3: Concentration of antioxidants and MDA in sera of study population in brick kilns of Al-Hay district.

Factor	Exposure group				Control group	P-Value
	Adult		Children			
	Female	Male	Female	Male		
KatA	0.019±0.024 [c]	0.023±0.027 [c]	0.090±0.062 [b]	0.099±0.067 [b]	0.327±0.074 [a]	0.05 **
SODs	384.8±193.6 [d]	493.2±143.5 [c]	768.0±86.9 [b]	794.3±77.2 [b]	1547.4±561.3 [a]	0.05 ***
GPx	0.131±0.065 [b]	0.141±0.055 [b]	0.096±0.053 [c]	0.094±0.056 [c]	0.398±0.062 [a]	0.05 **
MDA	0.230±0.134 [b]	0.246±0.125 [b]	0.167±0.121 [c]	0.191±0.160 [c]	1.309±0.549 [a]	0.05 **

Variation in horizontal letters meaning a significant variation (P<0.05)

Table 4: Concentration of antioxidants and MDA in sera of study population in brick kilns of Badra district.

Factor	Exposure group				Control group	P-Value
	Adult		Children			
	Female	Male	Female	Male		
KatA	0.020±0.020 [d]	0.022±0.024 [d]	0.096±0.054 [c]	0.103±0.059 [b]	0.327±0.073 [a]	0.05 ***
SODs	524.2±167.8 [c]	494.6±143.4 [c]	782.72±62.13 [b]	831.2±58.6 [b]	1547.4±561.3 [a]	0.05 **
GPx	0.138±0.061 [b]	0.153±0.059 [b]	0.113±0.050 [b]	0.096±0.054 [c]	0.398±0.062 [a]	0.05 **
MDA	0.257±0.132 [b]	0.283±0.129 [b]	0.178±0.112 [d]	0.219±0.211 [c]	1.309±0.549 [a]	0.05 ***

Variation in horizontal letters meaning a significant variation (P<0.05).

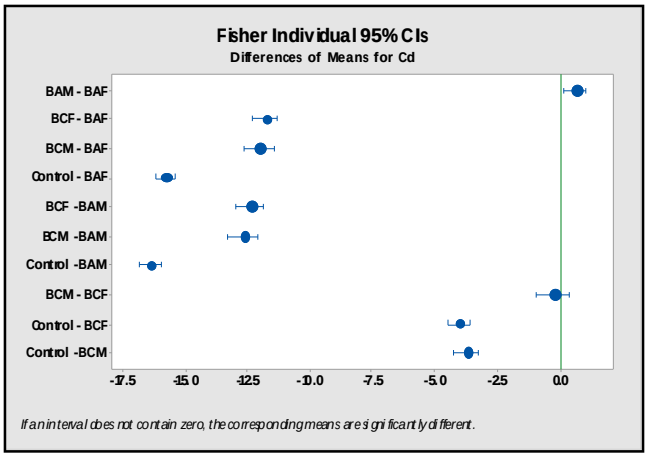

Fig. 6: Fisher's Pairwise comparisons for Pb in brick kilns of Badra district.

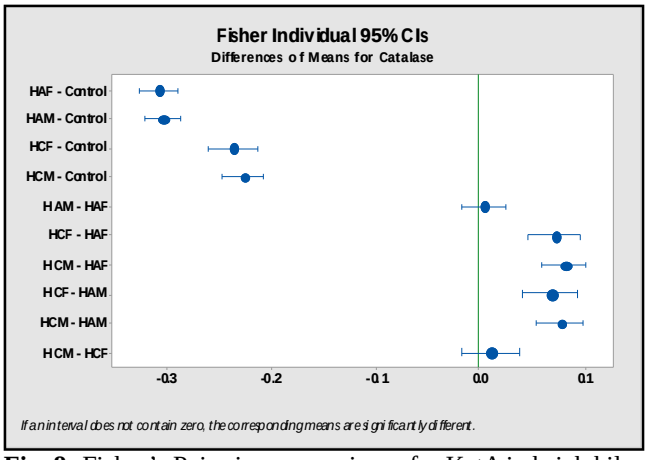

Fig. 8: Fisher's Pairwise comparisons for KatA in brick kilns of Al-Hay district.

spectrometry (AES) and atomic absorption spectrometry (AAS), (Rao *et al.*, 2002; Afridi *et al.*, 2006).

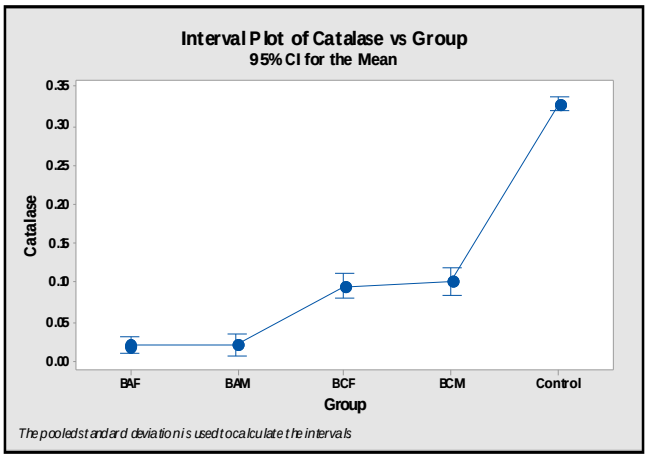

Fig. 9: Interval plot of KatA versus different groups in brick kilns of Badra district.

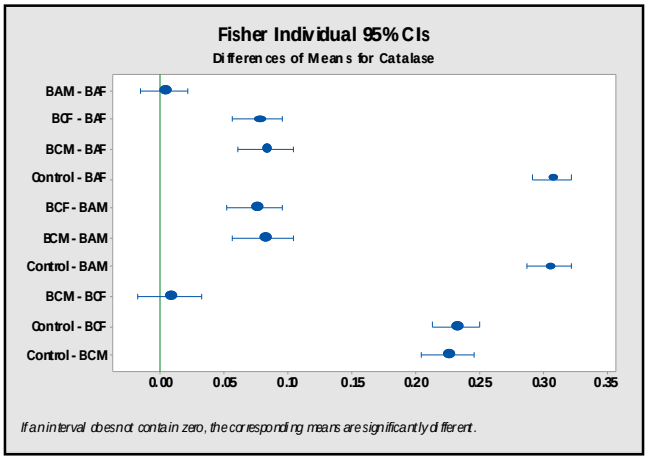

Fig. 10: Fisher's Pairwise comparisons for KatA in brick kilns of Badra district.

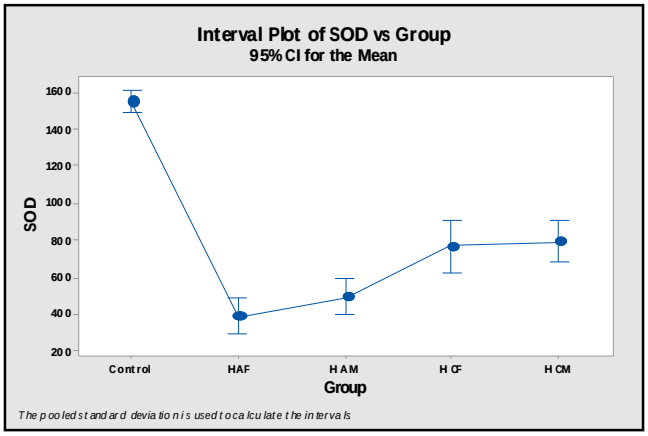

Fig. 11: Interval plot of SODs versus different groups in brick kilns of Al-Hay district.

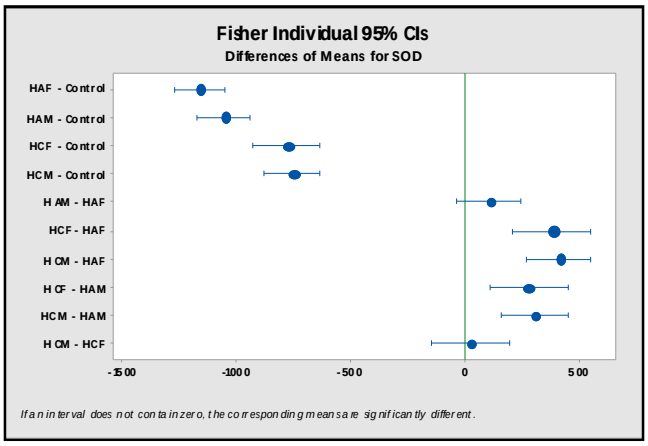

Fig. 12: Fisher's Pairwise comparisons for SODs in brick kilns of Al-Hay district.

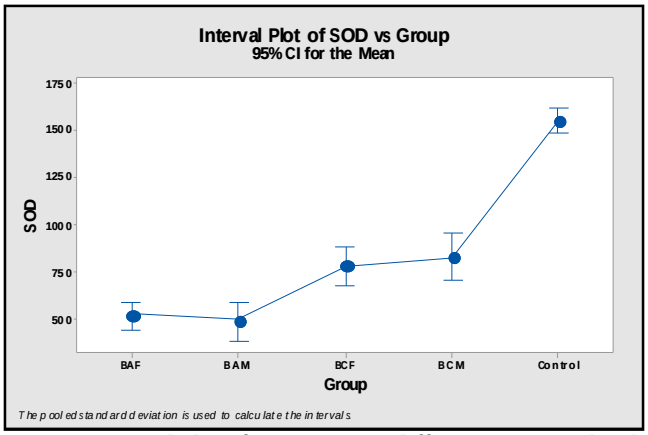

Fig. 13: Interval plot of SODs versus different groups in brick kilns of Badra district.

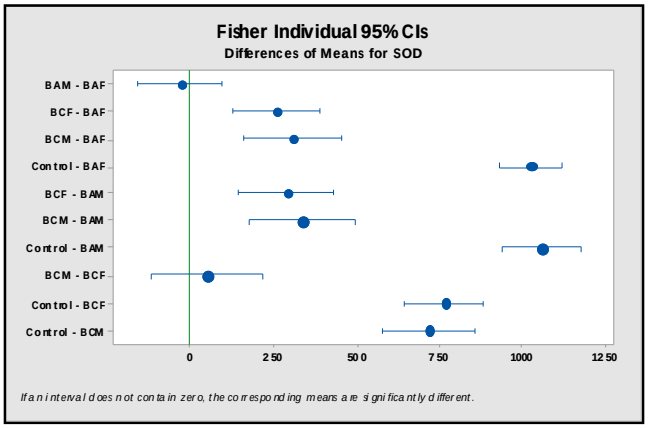

Fig. 14: Fisher's Pairwise comparisons for SODs in brick kilns of Badra district.

Many reports identified and quantified that AP is associated directly with the disability-adjusted life years (DALYs) and premature deaths (Gulland, 2002; Maji *et al.*, 2017). However, the health effects of AP in Iraq has hindered by lack of detailed data about exposure and illness outcome. Hence, the current study aims to detect the levels of HMs (Cd and Pb), antioxidants (KatA, SODs, and GPx) and MDA in sera of workers in and residents around the clay brick kilns of Wasit province, Iraq. Association to hematological parameters, red blood cells (RBCs) count, and hemoglobin (Hb), was also evaluated.

Materials and Methods

Ethical approval: The study was performed under license of the scientific and ethical committee of College

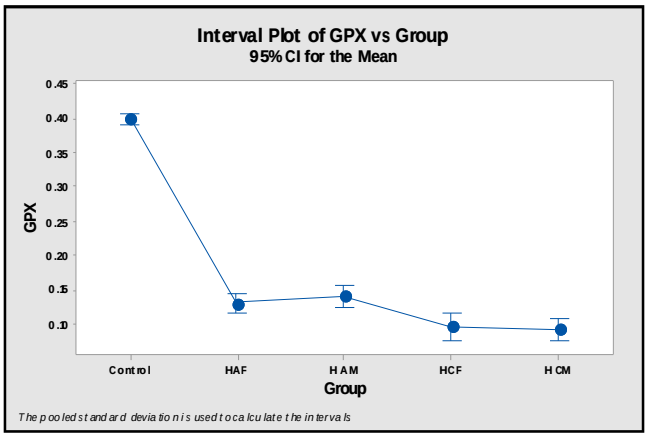

Fig. 15: Interval plot of GPx versus different groups in brick kilns of Al-Hay district.

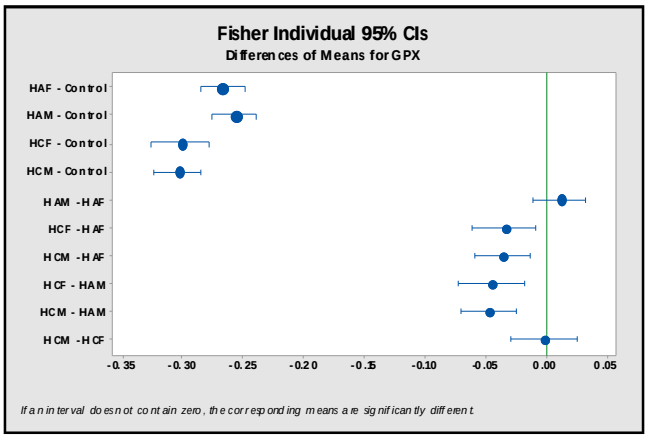

Fig. 16: Fisher's Pairwise comparisons for GPx in brick kilns of Al-Hay district.

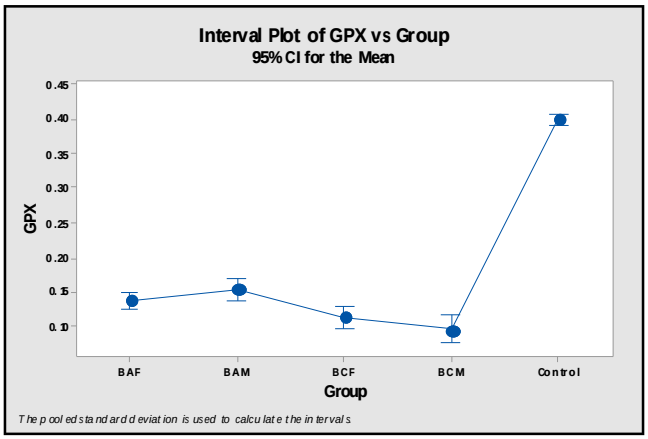

Fig. 17: Interval plot of GPx versus different groups in brick kilns of Badra district.

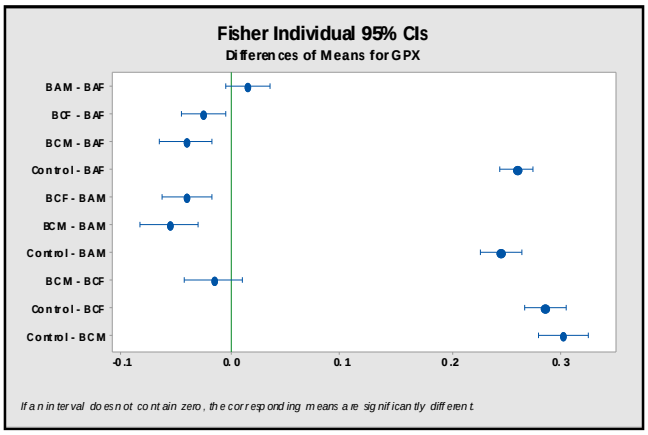

Fig. 18: Fisher's Pairwise comparisons for GPx in brick kilns of Badra district.

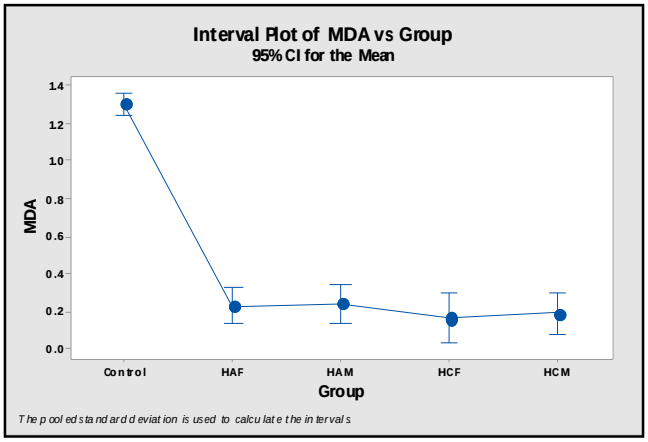

Fig. 19: Interval plot of MDA versus different groups in brick kilns of Al-Hay district.

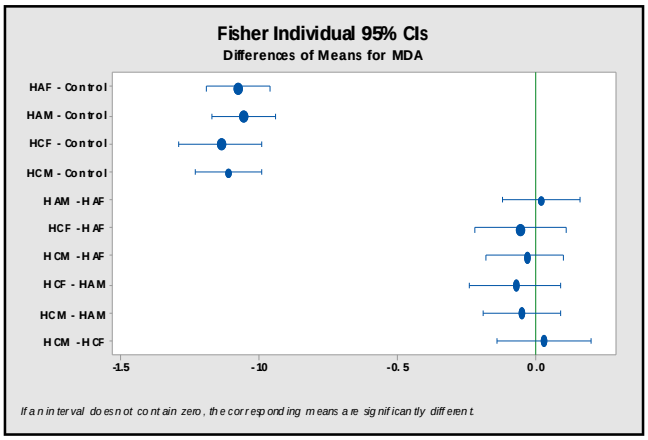

Fig. 20: Fisher's Pairwise comparisons for MDA in brick kilns of Al-Hay district.

of Sciences / Wasit University.

Sampling: At active clay brick kilns located in two districts (Al-Hay and Badra) in Wasit province/Iraq, a total of 200 individuals (150 workers and residents, and 50 controls) were subjected to present study during November/2018 to May/2019. From each person, 5ml of venous blood were drained under aseptic conditions into an anticoagulant (EDTA) gel tubes. Individuals of this study were divided into different groups based on their ages, sexes, residence time in regions of brick kilns.

Laboratory analysis: According to method described by (Lee *et al.*, 2012; Madiha *et al.*, 2018), HMs (Cd and Pb) were measured. Following the manufacturer instructions of assay kits (Abcam, England), the concentrations of antioxidants (KatA, SODs, and GPx) and MDA were detected colorimetrically.

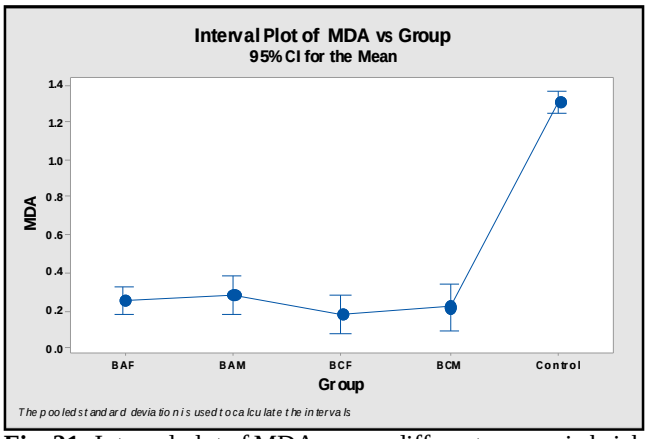

Fig. 21: Interval plot of MDA versus different groups in brick kilns of Badra district.

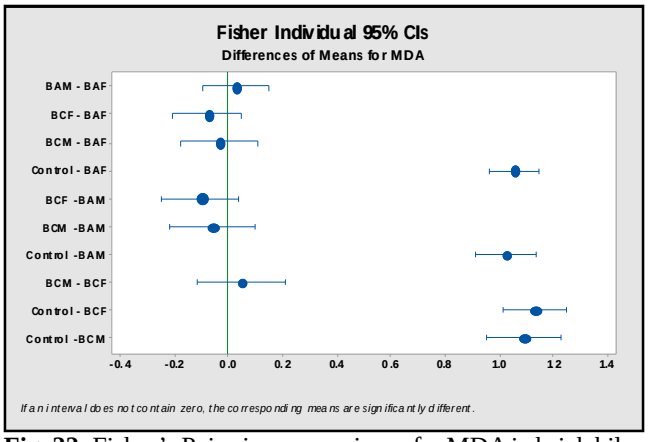

Fig. 22: Fisher's Pairwise comparisons for MDA in brick kilns of Badra district.

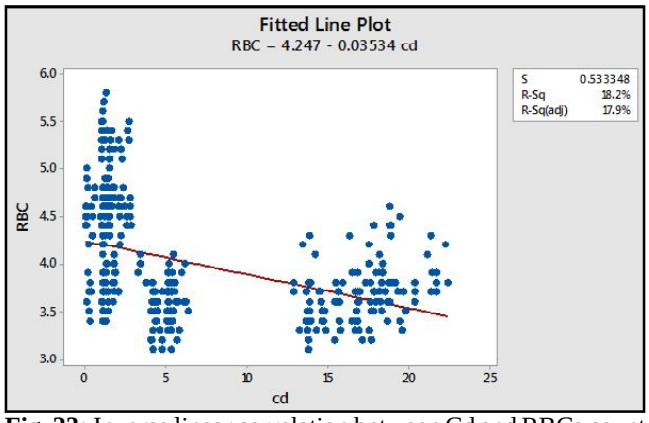

Fig. 23: Inverse linear correlation between Cd and RBCs count in blood of workers in brick kilns of Al-Hay district.

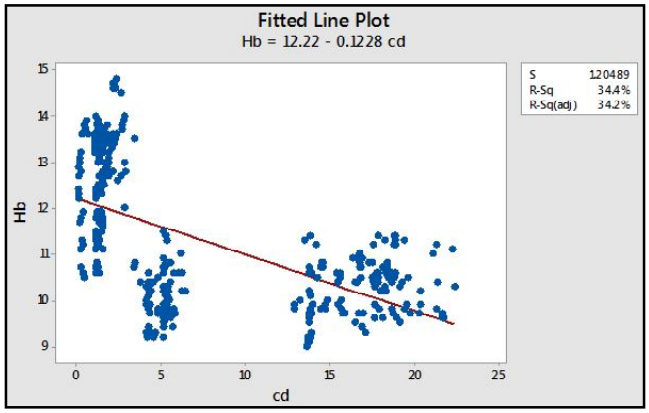

Fig. 24: Inverse linear correlation between Cd and Hb concentration in blood of workers in brick kilns of Al-Hay district.

Table 5: Coefficient correlation of hematology to HMs, anti-oxidants and MDA in exposure group of brick kilns in Al-Hay district.

	Pb	Cd	RBCs	Hb	SODs	GPx	MDA
Cd	0.95 ***						
RBCs	-0.51 ***	-0.43 ***					
Hb	-0.68 ***	-0.59 ***	0.81 ***				
SODs	-0.74 ***	-0.70 ***	0.50 ***	0.65 ***			
GPx	-0.70 ***	-0.63 ***	0.63 ***	0.79 ***	0.67 ***		
MDA	0.186 ***	0.167 ***	-0.52 ***	-0.72 ***	-0.60 ***	-0.75 ***	
KatA	-0.84 ***	-0.79 ***	0.63 **	0.77 **	0.71 ***	0.78 ***	-0.80 ***

Significance * (P<0.05)

Table 6: Coefficient correlation of hematology to HMs, anti-oxidants and MDA in exposure group of brick kilns in Badra district.

	Pb	Cd	RBCs	Hb	SODs	GPx	MDA
Cd	0.96 ***						
RBCs	-0.43 ***	-0.37 ***					
Hb	-0.66 ***	-0.60 ***	0.70 ***				
SODs	-0.74 ***	-0.70 ***	0.38 ******	0.63 ***			
GPx	-0.70 ***	-0.65 ***	0.48 ***	0.78 ***	0.66 ***		
MDA	0.65 ***	0.60 ***	-0.40 ***	-0.70 ***	-0.60 ***	-0.74 ***	
KatA	-0.86 ***	-0.82 ***	0.48 ***	0.75 ***	0.72 ***	0.79 ***	-0.79 ***

Significance * (P<0.05).

Hematology was performed using an automated blood analyzer (Sysmex KX-21N, Germany).

Statistical analysis: All obtained data were analyzed using the computerized Microsoft office excel (Version 2013), Minitab (Version 17) and IBM SPSS (Version 24), and the study results were expressed as Mean ± Standard errors (M±SE). One-way ANOVA is used for examining the degree of significance between study groups. Differences were considered significant at a probability of P<0.05 (Kim, 2017).

Results

In a total of 200 sera, the findings were revealed on significant differences (P<0.05) in values of exposure groups in comparing to control group, (Table 1, 2). Significantly, the levels of Cd in adults (Females and males) of both districts were showed a higher elevation (P<0.05); whereas, no significant variation was seen in children (P>0.05). Regarding to Pb, significant increases (P<0.05) were seen in adults and children of Al-Hay, as well as in adults

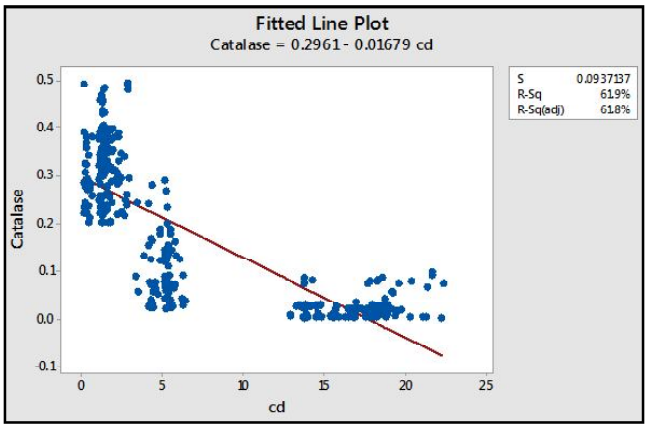

Fig. 25: Inverse linear correlation between Cd and KatA in blood of workers in brick kilns of Al-Hay district.

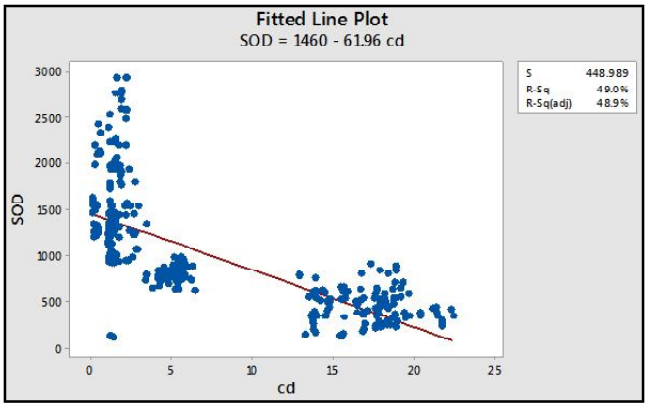

Fig. 26: Inverse linear correlation between Cd and SODs in blood of workers in brick kilns of Al-Hay district.

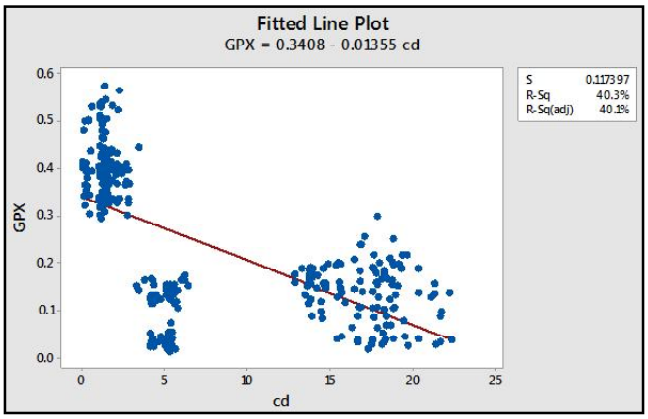

Fig. 27: Inverse linear correlation between Cd and GPx in blood of workers in brick kilns of Al-Hay district.

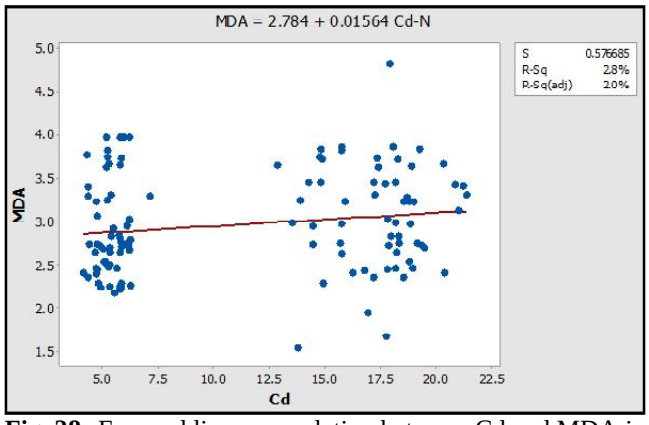

Fig. 28: Forward linear correlation between Cd and MDA in blood of workers in brick kilns of Al-Hay district.

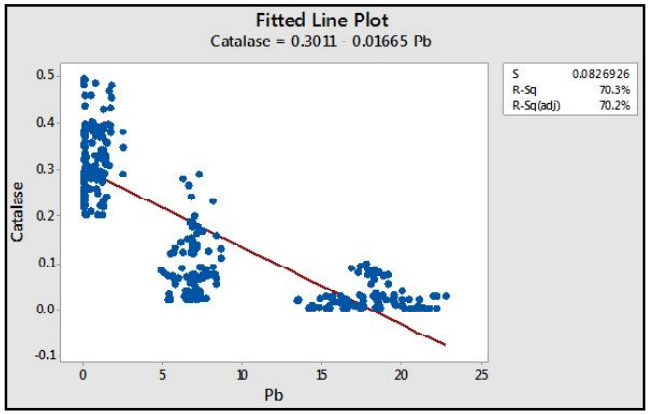

Fig. 29: Inverse linear correlation between Pb and KatA in blood of workers in brick kilns of Al-Hay district.

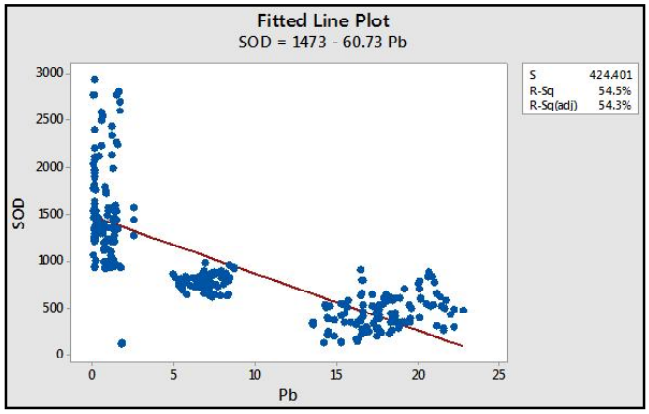

Fig. 30: Inverse linear correlation between Pb and SODs in blood of workers in brick kilns of Al-Hay district.

but not children of Badra (P>0.05). Interval plot of Cd and Pb versus different groups in brick kilns of Al-Hay and Badra districts in addition to Fisher's pairwise comparisons were clarified respectively (Figs. 1-6).

Concerning to concentration of anti-oxidants and MDA, the results of exposure group in both Al-Hay and Badra districts were showed significant decreases (P<0.05) in KatA, SODs, GPx, and significant increases (P<0.05) in MDA levels when compared to control group (Table 3, 4). However, the findings of adults and children population were reported significant differences (P<0.05) in their values. Interval plot of anti-oxidant and toxicant versus different groups in brick kilns of Al-Hay and Badra districts in addition to Fisher's pairwise comparisons were clarified respectively (Figs. 7-22).

The statistical analysis for hematological parameters (RBCs and Hb) of study population in both districts found that there were significant decreases (P<0.05) in RBCs

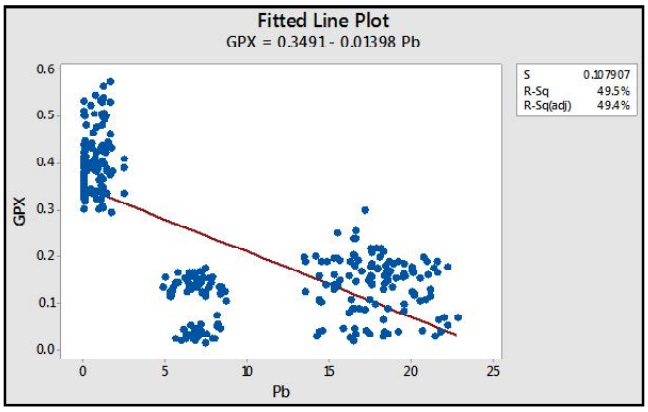

Fig. 31: Inverse linear correlation between Pb and GPx in blood of workers in brick kilns of Al-Hay district.

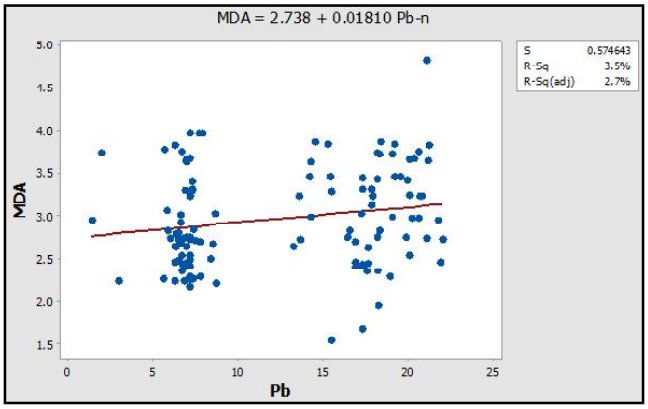

Fig. 32: Forward linear correlation between Pb and MDA in blood of workers in brick kilns of Al-Hay district.

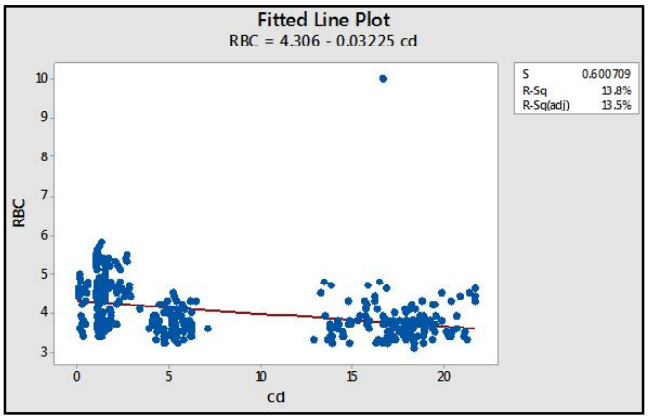

Fig. 33: Inverse linear correlation between Cd and RBCs count in blood of workers in brick kilns of Badra district.

count and Hb concentration in blood of exposure group comparing to control group. Also, there a coefficient correlation (r) was detected between the blood parameters, HMs, anti-oxidant enzymes and toxicant (Table 5, 6; Figs. 23-44).

Discussion

Brick kilns in developing countries are considered as one of the most important source of pollution. It's concluded that ambient AP due to brick kilns in the rural

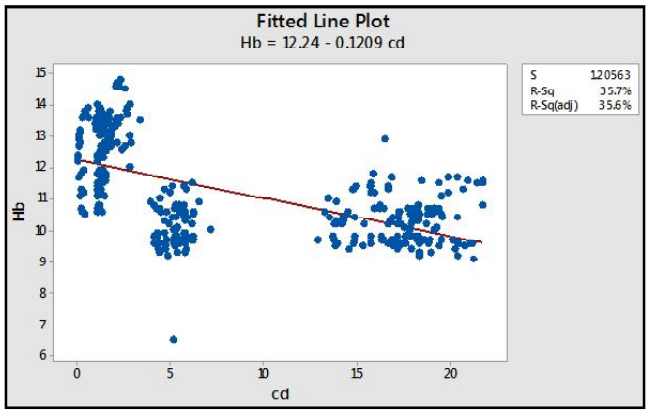

Fig. 34: Forward linear correlation between Cd and Hb concentration in blood of workers in brick kilns of Badra district.

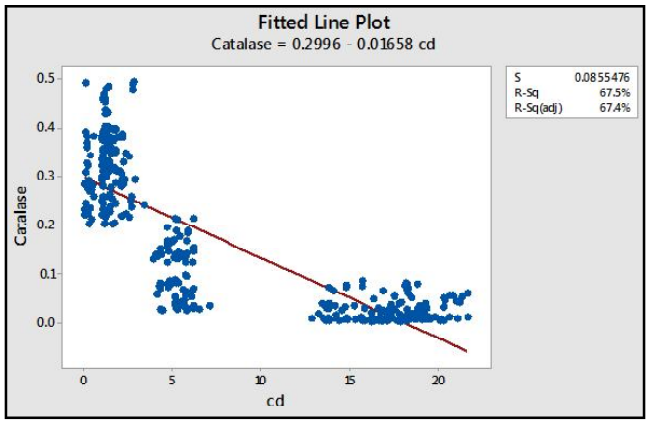

Fig. 35: Inverse linear correlation between Cd and KatA in blood of workers in brick kilns of Badra district.

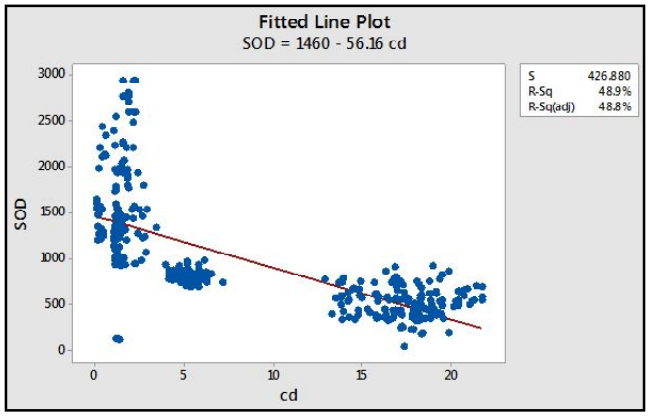

Fig. 36: Inverse linear correlation between Cd and SODs in blood of workers in brick kilns of Badra district.

areas is a real problem to human health and vegetation (Skinder *et al.*, 2014). HMs are one of the reported pollutants from brick kilns and are highly persistent, non-biodegradable in nature and are serious threat to the environment. When considering the different kinds of contaminants, HMs have especial dangerous due to their availability, toxicity, and permanence (Ishaq *et al.*, 2010). As little information was available about the intervention exposure levels of working and resident peoples in regions

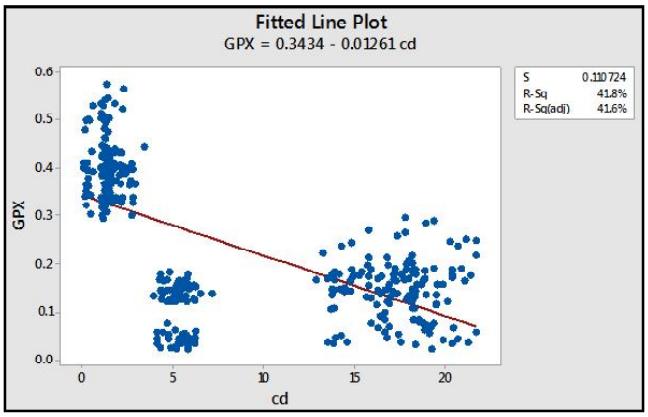

Fig. 37: Inverse linear correlation between Cd and GPx in blood of workers in brick kilns of Badra district.

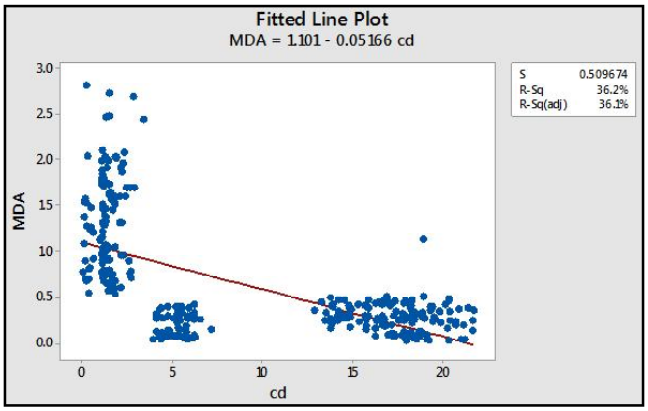

Fig. 38: Forward linear correlation between Cd and MDA in blood of workers in brick kilns of Badra district.

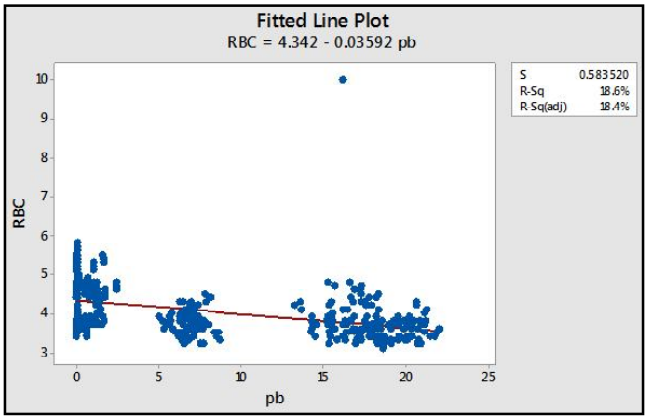

Fig. 39: Inverse linear correlation between Pb and RBCs count in blood of workers in brick kilns of Badra district.

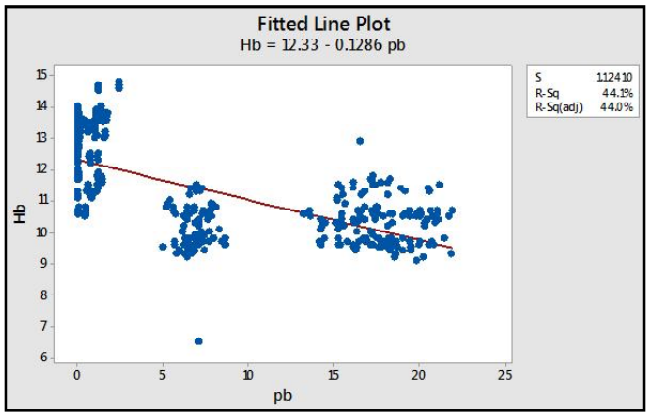

Fig. 40: Forward linear correlation between Pb and Hb concentration in blood of workers in brick kilns of Badra district.

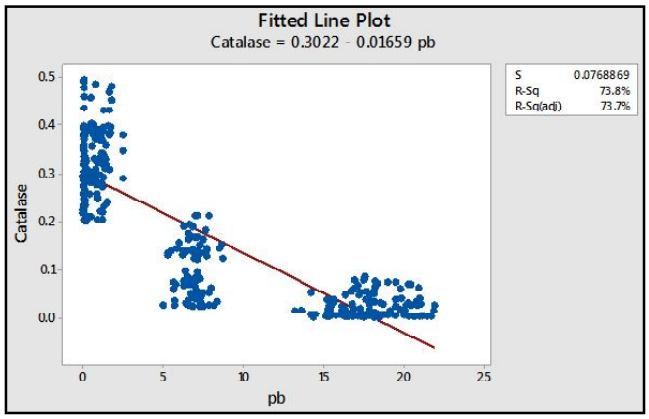

Fig. 41: Inverse linear correlation between Pb and KatA in blood of workers in brick kilns of Badra district.

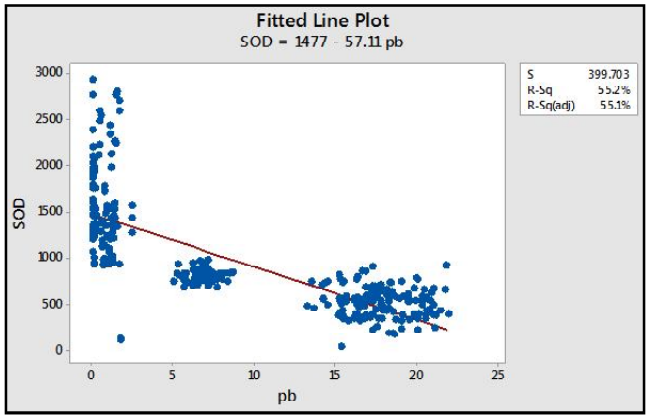

Fig. 42: Inverse linear correlation between Pb and SODs in blood of workers in brick kilns of Badra district.

of brick kilns in Iraq, this study was conducted to detect a number of baseline exposure levels in these category of population. The higher levels of Cd and Pb detected in sera of adults as well as children of present study indicate the outdoor and indoor exposure to Ap. However, the higher concentrations of HMs in adults when compared to children or control groups might be attributed to the fact that most brick workers are adults, and larger amounts of emissions can be inhaled, ingested or absorbed directly due to the prolonged period of exposure. The unsafe and hazardous exposure conditions could be often started in childhood (Sanjel *et al.*, 2016; Larmar *et al.*, 2017). Presumably, the release of HMs from brick kilns impacts direct and indirect adverse effects on people working or residing near especially the women and children (Skinder *et al.*, 2014). Environmental pollution by HMs can readily accumulate to toxic levels. The problems associated with the characterization of HMs in

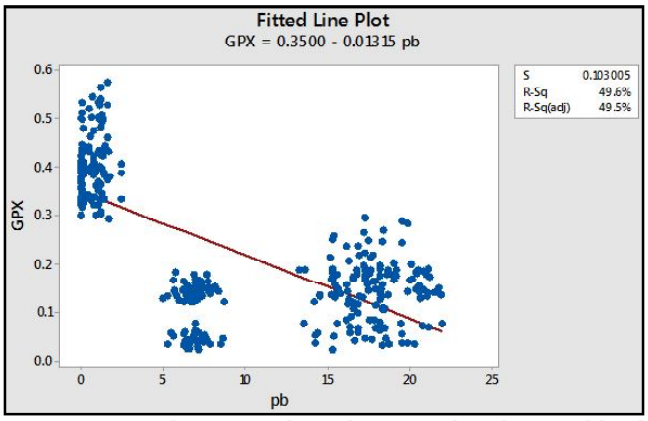

Fig. 43: Inverse linear correlation between Pb and GPx in blood of workers in brick kilns of Badra district.

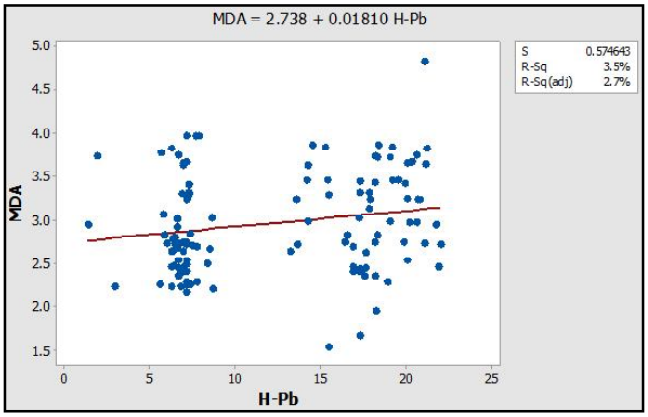

Fig. 44: Forward linear correlation between Pb and MDA in blood of workers in brick kilns of Badra district.

the majority of sites are often due to multiple sources of AP (Ismail *et al.*, 2012). In some areas, soil irrigated by polluted water results in accumulation of HMs in surface soil and increases the concentration of these toxicants that become available for plant uptake. When herbivores eat these plants, they get infected with the toxicities (Lafhaj *et al.*, 2008). Sikder *et al.*, (2015) showed that the availability of Cd and Pb is largely affected by the soil properties, and the increases of these metals are correlated with decreasing of soil pH. Although, Cd and Pb are both dangerous carcinogenic elements, Cd moves easily and faster than Pb to the food chain by soil to plant root absorption, and accumulates to appreciable amount in the living body without showing stress (Singh and Prasad, 2011). However, brick kiln workers and rural areas exposed to lower levels of Cd over might resulted in damages among reproductive and cardiovascular systems as well as in liver, bone, lung, and kidney. In children, it has been showed that Pb can cause a growth retardation, brain damage, abnormal metabolism and in some situation deaths (Hrudey *et al.*, 1995; Kaushik *et al.*, 2012; Sikder *et al.*, 2015).

One of the common ways applied to detect the damage induced by AP is the use of biochemical markers through evaluation of anti-oxidant system that neutralize constantly many types of toxicants such as free radicals, drugs, and toxic chemicals (Barata *et al.*, 2005). The failure of anti-oxidants to detoxify the excess production of toxicants can induce biochemical and physiological dysfunctions including an enzymatic inactivation, degradation of protein, peroxidation of lipid and DNA damage (Gómez-Oliván *et al.*, 2012). In this study, statistical correlation analysis showed that the levels of anti-oxidants and MDA were decreased significantly with increasing the concentration of Cd and Pb in sera of brick kilns' workers and residents. These findings are in competent with that detected previously (Gómez-Oliván *et al.*, 2012; Jahan *et al.*, 2016; Islam *et al.*, 2019). However, the degree and effect of toxicity of different HMs depend on many factors particularly age, health status, dose, duration, and rout of administration as well as nutrition (Chowdhury, 2009; Islam *et al.*, 2019).

KatA and SODs are functionally interconnected because SODs converts O^{2-} to H_2O_2 that eliminated by KatA. Pandey *et al.*, (2003) observed that the activity of KatA and SODs changes in conditions of AP since KatA-SODs enzymes represent the first line of oxidative stresses. Also, he demonstrate that the activity of KatA is decreased significantly post exposure to $PbCl_2$ and in less degree to $CdCl_2$. Cassini *et al.*, (2011) reported that the activity of KatA and SODs decreased according to exposure time. Islam *et al.*, (2019) indicated that the higher doses of toxic chemicals could increase or decrease the activity of GPx depending on the dose of toxicants. In addition, it has been showed that the higher concentration of Cd in food impact structural changes and fundamental processes leading to starvation effects and retardation in growth and survival (Nursita *et al.*, 2005; Wu *et al.*, 2006). Although the concentration of GPx can increase during the first days post exposure, cumulative effects of Pb can significantly inhibit this enzyme (Canesi *et al.*, 1999; Islam *et al.*, 2019).

Estimating end products of lipid perioxidation such as MDA serves as indication of the extent of oxidative damage to cellular structure (Sharma and Agarwal, 1996; Paick, 2003). Olaniyan *et al.*, (2018) detected a significant increases in testicular MDA in rats treated with CdCl2, and attributed this increases to concomitant free radicals generation by CdCl2, and to reduction the levels of anti-oxidant enzymes. Çelekli *et al.*, (2013) showed that Cd had a simulative effect on the production of MDA, and suggested that the increased accumulation of MDA is an important strategy for alleviating HMs-induced oxidative stress. While, Shah and Jain (2016) showed a significant elevation in levels of MDA in Pb exposed groups,

suggesting that Pb affected strongly on levels of anti-oxidant enzymes, and emphasized that effects is dose-dependent. We suggested that continues exposure to HMs and excess production of MDA may be caused by the exhaustion of anti-oxidants, consequent inability to catalyse the overproduction of H_2O_2 produced by Cd and Pb-induced hepatotoxicity. However, the activity of anti-oxidants could be changed radically during the start of exposure to HMs, and might be returned to normal levels for few days.

In this study, significant reduction in total RBCs count and Hb concentration was detected in workers in and residents near the brick kilns, and this decrease may be indicator of anemia. The study results might be attributed to increase fragility of RBCs due to intoxication, decrease RBCs-lifespan, or low production of RBCs and Hb. The statistical analysis used to determine the relationship between two variables, showed that there was high positive correlation between RBCs count and Hb to HMs, anti-oxidant enzymes and MDA. Various studies have shown that AP affect directly or indirectly on blood profile either by production of toxicants or disrupting of anti-oxidants and MDA (Flora *et al.*, 2008). Several reports found that the high levels of HMs and MDA have adverse affect significantly on the levels of vitamins (A, C, and E) and trace element (Cr, Fe, and Zn) of exposed workers, (Tovalin *et al.*, 2006, Jahan *et al.*, 2016; Alayunt and Tasgin, 2019).

Conclusion

This study concluded that the workers in and residents near the brick kilns are exposed to high concentration of heavy metals that clearly increase the risk of diseases development in adults, and premature death of children. In Iraq, despite the numerous health problems among brick kiln workers and resident population, the existence of occupational safety and health services are negligible. Understanding both chemical composition and concentration of pollutants emitted from clay brick kilns may be important for guiding future interventions to decrease exposures.

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Conflict of interest

There is no conflict to interest.

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