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Research Article

The Effects of Electronic Waste Burning on Lead Concentration in Water and Blood in South West Hebron: Descriptive-Comparative Study

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The burning of electronic waste constitutes a major public health problem in South west Hebron -Southern Hebron Governorate – in which electronic waste burning is prevalent. This descriptive comparative study aimed to investigate the effect of electronic waste burning on the concentrations of lead in human blood and water samples (n=104) in South west Hebron as an exposed region with the town of Halhul as a control. Results showed that 39% and 55% of participants supported that electronic waste burning has an impact on municipal and natural resource's water. Moreover, 69% did not think that burning affects the taste of water, while 72.2% did not think that such burning affects the smell of water. Water and blood samples from exposed regions had higher lead concentrations level than those not exposed with mean of (3.30PPb versus. 2,74PPb) and (46.34PPb versus. 31.6PPb) respectively. Electronic waste burners had a higher lead concentration (55PPb) than those not burning (39PPb). However, hemoglobin level was higher among none exposed (12.19PPb) than exposed (11.28PPb) regions. The burning of electronic waste affects both health and environment. Therefore, upgrading knowledge and education about the damages and impact of burning of electronic waste on human health are considered the first step in overcoming this problem.

Keywords: Electronic waste, Palestine, Lead concentration, E-waste burning, Hebron, South west Hebron, water natural resources, heavy metals, Hemoglobin level, toxic substances

INTRODUCTION

Electronic waste (E-waste) is a collective name for all electronic devices which have been expired of their useful life periods like discarded computers, computer peripherals, mobile phones, televisions, and others. E-waste has increased the total waste volume and after dismantling and burning, it releases various toxic and carcinogenic gases and metals which are posing a threat to human health and also contaminate the environment (Kowsar, Khan *et al*. 2010).

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E-waste is becoming a major global problem because of two primary characteristics. First, waste is hazardous, containing various toxic substances that cause health damage and serious pollution upon disposal. Second, there is a rapid generation of e-waste due to low initial cost and higher disposal rate. When new models of computers, stereos and televisions are produced, the old ones are discarded, as in India alone, in 2010 there was 0.4 million tons of e-waste produced that is expected to rise to 0.5 and 0.6 in 2013 and 2014 respectively (Needhidasan, Samuel *et al*. 2014).

The main risks to human health arise from the presence of heavy metals in E-waste, flame retardants and other potentially hazardous substances.

E-waste has been a problem of great concern not only for the government but also for the public due to their hazardous material contents (Cui and Forssberg 2003, Liu, Niu *et al*. 2008). South west Hebron is considered the main Hub for processing of E-waste produced in south West Bank, It is not only the locally generated waste but also includes E-waste coming from other parts of 1948 occupied territories. The processing of this E-waste includes dismantling, fragmentation, and burring of the cables to harvest precious metals like the copper. One of the main pollutants coming out of burring of this Electronic-waste is the increased lead concentration, which has a variety of health-damaging effects on humans and environment (Pinto 2008).

Informal electronic waste recycling includes the dismantling of end-of-life electronics to retrieve valuable elements with primitive techniques, without or with very little technology to minimize exposure or protective equipment, allowing the emission of dangerous chemicals (Wong, Duzgoren-Aydin *et al*. 2007). Formal electronic waste recycling facilities use specifically designed equipment to safely remove recyclable materials from obsolete electronics while protecting workers from adverse health effects. Workers at formal or semiformal recycling centers are still at risk of exposure at low doses of heavy metals toxicity (Yu, Gao *et al*. 2006).

Shen *et al*. (Shen, Lavi *et al*. 2004) have investigated the health impacts from exposure to the processing of imported electrical waste in China. The study performed tests on workers who worked in open air workshops in one town, the study also tested residents from this town, including children, and a control group of residents and children from another town who was also recruited for this study. The study found differences in blood biochemistry, and the measure of immune system functioning between workers and residents of the town, and differences between tests of workshops workers as compared to residents of the control town.

In Palestine, there is a lack of information about the effect of this informal business of Electronic-waste processing and mainly burning on population health. Represented in the possibility of increased heavy metals concentrations in blood (which some of them are carcinogenic), especially lead, that had not been studied in that area.

As the majority of E-waste burning activities are taking place in South west Hebron. This study is trying to measure the effect of E-waste burring on the level of lead concentration in blood and water samples from springs, at the same time studying the anemia status in this area as a secondary byproduct of potential lead poisoning which is consistent with the findings of Fonte, et al., (2007) who have reported .similar anemia as a result of lead contamination due to battery recycling.

The objectives of the study is to measure the concentration level of lead in water springs resources, and in the human blood in exposed and non-exposed areas, and to measure the hemoglobin level in exposed and non-exposed areas. The results of this study will highlight the health risks of E-waste disposal and E-waste burning in the target area, which may underline the importance of a national plan for proper healthy disposal and management of E-waste, towards better health protection of the population and the environment in the targeted area.

MATERIALS AND METHODS

Research settings

This study was conducted in South west Hebron (case area) with total population of 10,649 and Halhul village (control area) with a total population 29,222 (Palestinian Central Bureau of Statistics 2016).

SAMPLING AND POPULATION

Sample size

Sample size was calculated using the Medclac software. Variable that were requested by this software were adopted from the study of Kutllovci *et al*., 2014 as the software asked to fill those variable based on previous studies in the similar field. So according to the software 36 participants in each group of the case and control was suggested. The researchers extended this number to 50 participants in each group to end up with total sample size of 100 in both groups

Sampling methods

Simple random sampling method was used after dividing the areas into a distance that equals x/ r. where x is the length of the main road and the r is the target value of sample size (this method was developed by the researchers to guarantee the geographical coverage of the whole area of South west Hebron which is situated around the main street) That will allow us to take a sample that represents the village population from West to East. And if

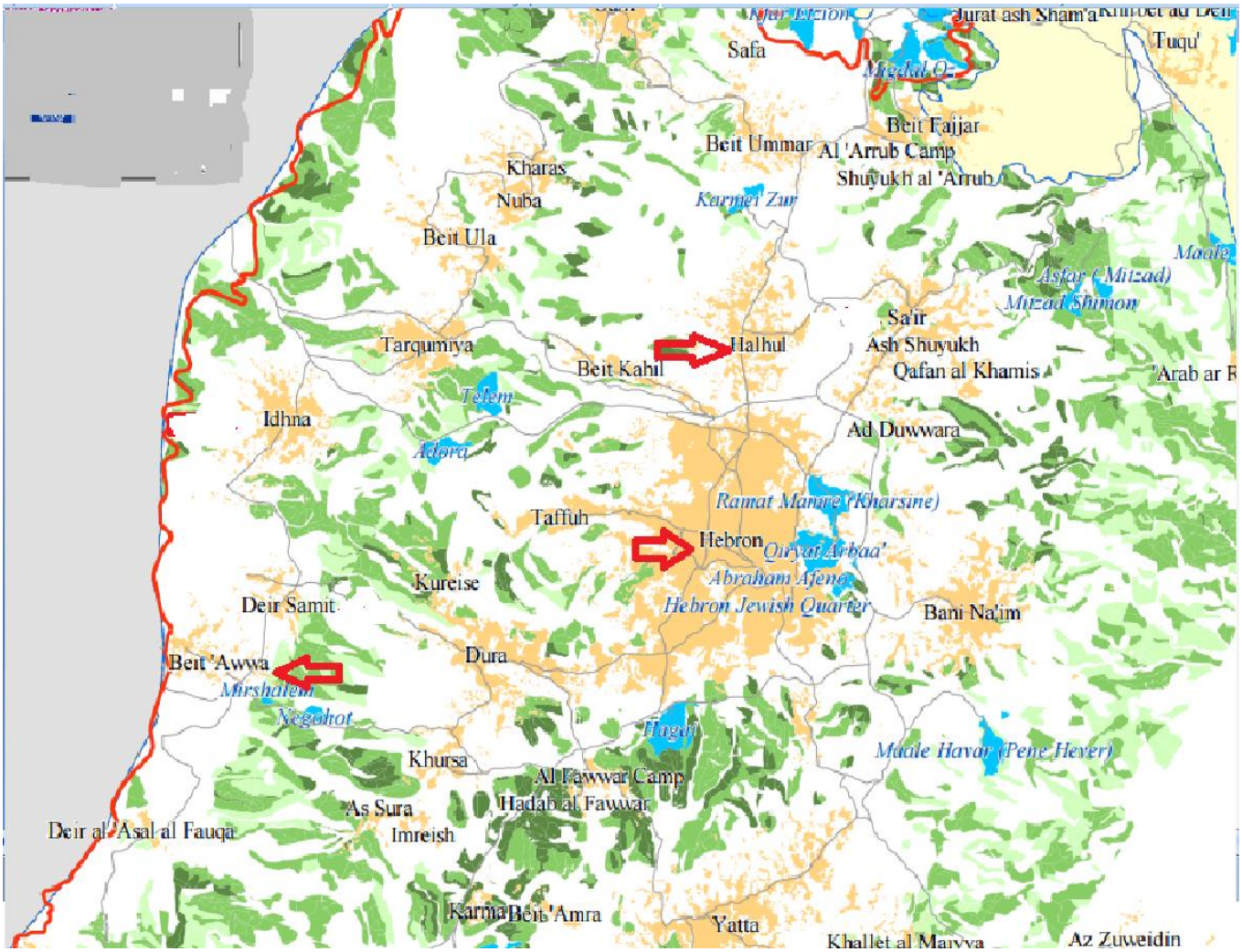

Figure 1: Map shows target Area (South west Hebron) and Control Area (Halhul)

one potential participant refused to participate, the next house was taken. Participation in this study was based on a criteria saying that people should be residing in South west Hebron villages and aged over 18 until 80 years, those who were residing in the past out of South west Hebron, over 80 years old or less than 18 were excluded from this study

RESEARCH METHODOLOGY

Design

A descriptive comparative design was used in this study. The purpose of using this design is to generalize from a sample. It has advantages because of the quick in terms of time of data collection, the data are collected at the same time, and is cost effective and convenient (Creswell and Creswell 2014).

The difference of this design from case-control study design, even though they look similar, that the case-control studies concentrate of occurrence of outcome and diseases, while this type of studies is looking at exposure of risks and its potential descriptive.

Tools of data collection

For the purpose of answering the questions of this research, the researchers used different tools.

Data capturing sheets

The data were collected from the participants included anthropometric data, data related to burning behavior, health, and medical history, also, they had questions that indicate the populations perspective on the effect of burning on water quality and trends of prevalence of cancer, respiratory disease, miss-courage, allergy, and other socioeconomic variables. In addition, they included information about the frequency and the intensity of burning of E-waste in their areas.

Blood tests

To analyze the hemoglobin and the concentration of lead in blood ICP machine at Al-Quds University labs was used. The Agilent Technologies 7500 Series ICP- MS (Agilent 7500) can measure trace elements as low as one part per trillion (ppt) and quickly scan more than 70 elements to determine the composition of an unknown sample with

Mass Hunter Workstation software that automates the analysis and accurately interprets the resulting data.
The operating conditions are as follows: nebulizer gas (argon) flow rate: 0.9 L/min, auxiliary gas (argon) flow 0.3 L/min, plasma (Argon) gas flow: 15 L/min, reaction gas flow (helium) 4mL/min, lens voltage 7.25 V, and ICP RF power: 1100 W.

Procedure of data collection

After permissions were granted from the Ministry of Health, the multiphasic health research started as following:

- Building up of the research questionnaires and data capturing sheet
- Contact with local authorities in the South west Hebron.
- Allocation of the participants from the case and control areas took place.
- Explanation about the research was given and consent form was signed
- Data capturing sheet was filled with the participants before asking the sample.
- Then blood samples were withdrawn, and serum had been separated and sent to Al-Quds University labs for analysis of heavy metal concentration. Also HB was analyzed at the spot of collection using portable CBC device.
- Water samples was collected from all water springs in the case area, and compared to the control springs. Then sent for analysis for heavy metals concentration at Al-Quds University Labs.
- Water samples from domestic sources were collected from house tape water.
- Samples were kept in ice and sent to Al-Quds University lab.

Statistical analysis

Data collected were entered into the SPSS program using version NO 20, then descriptive statistics were used to show the mean concentration of heavy metals in cases and control groups. Shapiro wilk test was used to test the normality of data, to decide on parametric and none parametric tests for analysis. Independent sample T- test was used to highlight the difference of mean concentration in cases and control, so that for the hemoglobin level and concentration of heavy metals in both exposed and none exposed areas. Where data was not normal, Mann Whitney none parametric test was used.
Correlation spearman r was used to investigate the correlation between continues (none normal) variables and level of heavy metal from one side, and the level of Hemoglobin on the other side.

Ethical considerations

The participants were requested to sign a consent form, codes were used in analysis, and commitment that the results will be used for scientific reasons only was declared, participation in this study was a voluntary and all participants will be informed by the findings of this study.

RESULTS

As shown in figure 2, this study is focusing on the outcome of processing of the e-waste coming form 1948 occupied territories and being burned in the area of South west Hebron.

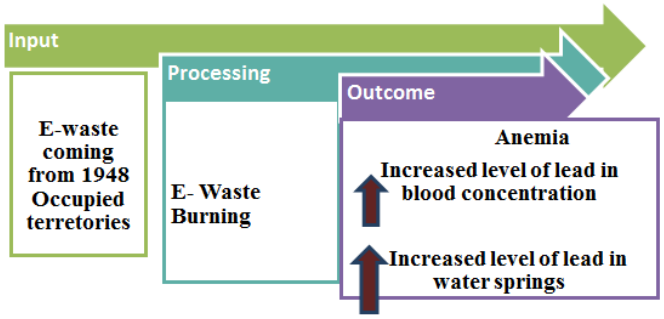

Figure 2: Electronic waste conceptual framework

As show on in table (1), the average age of case group was 35.87, as compared to 38.46 in control with the majority of both cases and control below college or University educational level.

Table 1: socioeconomic variables of the participants

	Case (N=50)	Control (N=50)
Age average (SD)	35.87 (13.54)	38.46 (8.16)
Males	90%	90%
Females	10%	10%
High school and below	70%	64%
College/University of above	30%	36%

Population point of views on E-waste burning

In this subsection the researcher presents below some of the results of the questionnaire distributed for people living in the case areas, about their views of the effect of E-waste burning on water from their own point of view.

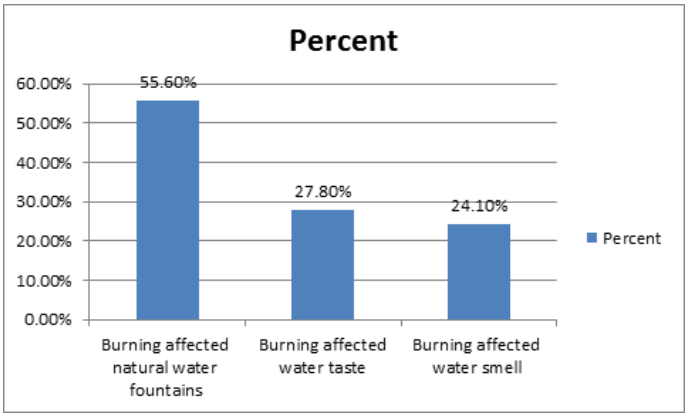

Figure 3: Perceived effect of E. waste from point of view of population living in South west Hebron

As shown in figure 3 around 55.6% thinks that E. waste burning affects the quality of fountain water (Springs

water), around 28% either agree or strongly agree that the E. waste burning affects the taste of water , while around 24% either agree or strongly agree that the E. waste burning affects water smell

Lead concentrations water and blood in cases and control

As shown in table 2 the mean and standard deviation for the water springs sample, shows that there is a statistically significant increase of Pb concentration in springs of water in the case area as compared to the Pb concentration in the control springs water ($p< 0.05$). The Pb concentration in both case and control areas, in terms of domestic drinking water does not statistically differ significantly between case and control ($p>0.05$). Also a statistically significant difference with $p < 0.05$ is shown in table (2) between blood level concentration of lead (Pb) in between cases and control, where cases had a statistically significant increase in blood level lead. At the same time comparing the lead concentration in between workers and population showed a statistically significant increase in lead concentration among workers in E, waste when compared to Population living in the same exposed area ($p<0.05$)

Table 2: Difference in lead concentration among cases and control, in water and blood

Element	Status	Mean	Std. Deviation	Std. Error Mean	t	P
Pb level in domestic water	Domestic water control	2.1	1.7	0.3	0.504	0.523
	Domestic water case	1.7	3.5	0.6		
Pb level in springs water	Springs water control	2.74	5.08	1.60	5.14	0.00
	Springs water case	3.30	6.80	1.56		
Pb level in Blood	control	31.76	1.7	0.3	0.504	0.523
	Cases	46.34	3.5	0.6		
Pb level in blood workers Vs population	Population	46.34	21.99215	3.31544	-.588	0.045
	Workers	55.0	82.46094	26.07644		

Comparison of blood level lead to WHO standards

Testing the normality by Shapiro Wilk test, shows that the data when the cases are tested alone is normally distributed, so we applied one sample t-test to investigate the significance of difference of current concentration of lead in blood with WHO standards of (20 ppb) , that the current concentrations are significantly higher than WHO standers $p< 0.05$ (table 3).

Table 3: One-Sample Test for difference in lead concentration between cases and WHO standards

	Test Value = 20					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Pb.conc	4.140	53	.000	26.34	11.5586	33.2836

Factors correlated with high lead

As shown in table 4 that there was a statistically significant positive correlation between the lead concentration in blood and the monthly frequency of burning and statistically significant negative correlation in between the distance of home from the closest burning site ($p<0.05$).

Table 4: factors correlated with lead concentration in blood

Monthly frequency	Correlation Coefficient	.543*
	Sig. (2-tailed)	.016
Distance from burning site	Correlation Coefficient	-.423*
	Sig. (2-tailed)	0.035

Differences in lead upon categorical variables

There were no gender differences in terms of Pb concentration in blood or any other factors like the direction where the participants lived in the area in terms of west , east, north, south ($p<0.05$).

Hemoglobin level in cases and control

Analysis of the difference between hemoglobin in case and in control according to t-test shows in figure 4 that there is a lower hemoglobin value in the case (11.28 SD = 3.1) as compared to the control (12.19 SD 3.2) , $p< 0.05$.

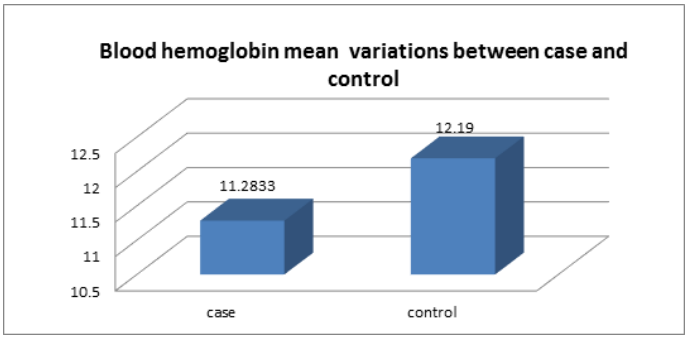

Figure 4: Blood hemoglobin variations between case and control

Variables correlated with Hemoglobin in blood

There was a statistically significant positive correlation between distance of first burning site from home and the Hb level of blood, while in terms of Pb concentration as shown in table (5), here was a statistically significant negative correlation between Pb concentration in Blood and blood level of Hb.

Table 5: Factors correlated with less hemoglobin in blood

Distance burn with hemoglobin	Correlation Coefficient	.075	.349*
	Sig. (2-tailed)	.610	.014
Pb / hemoglobin concentrations	Correlation Coefficient	1.000	-.501
	Sig. (2-tailed)		.0145

DISCUSSION OF THE RESULTS

The inhabitants of Beit Awaa in the health survey mainly disagreed with the fact that the E-waste burring affects their domestic household water quality taste and smell. The reason behind that may be that South west Hebron just as other villages in that area, are getting their water from pipes from the municipal authorities, which may justify why the people in that area were not mainly worried on their domestic house hold water. On the contrary of the domestic water, people do worry about the effect of burning on the water wells, as it collects water from the roofs which are in direct contact with smoke of burning, that may be eventually end up at the water wells, and contaminate it with the black smoke components of flame retardants and lead in particular.

There was a statistically significant higher concentration of lead >10 PPb that found in springs of exposed as compared to the springs in the none exposed areas and this probably due to the leachate that is as a result of E-waste burning and practices. Further investigations should be done for leachate quality on all the springs in the area. There are hundreds of hub hazard burning sites that are informal and change the intensity of burning upon many variables. The problem with those sites, that when winter comes, the running water takes all the contaminated components of those burning sites, to groundwater, which may have in turn appeared on the way of contaminated spring water quality by higher lead concentration. Further investigation should be performed as there are other factors that may affect the concentration of lead in spring's water. The effect of this high concentration may be affecting the lead concentration in blood of people drinking from this water. as for the sample itself from the exposed areas, the more close the spring was to burning sites, the more concentration of lead was found, which shows a negative relationship between the distance from burning sites, and concentration of lead

According to the tests performed in case and control areas, it appeared that there is not statistically significant difference in terms of domestic water concentration of lead, and this result is not surprising, as the domestic water source is mainly from municipality pipes that usually originate from Bethlehem area, which has nothing to do with exposure to the effect of burning, this is why it showed no relation to the actions of burning, further investigation of the difference between water wells dependent population and municipal pipes dependent uses, may be beneficial to detect any difference in lead contamination.

There was a statistical significant difference of exposed areas lead concentration as compared to none exposed, even though when we compare both exposed and none exposed concentration against the level 20 PPb (announced by WHO, 2015 (WHO 2015. http://www.who.int/mediacentre/factsheets/fs379/en/)) we find that this score is high in both exposed and none exposed. Our results of lead concentrating in blood compares much better than the concentration of blood lead levels in Serbia, china, Bangladesh, and India (Wasserman, Liu *et al*. 2007, Wang, Tian *et al*. 2012, Kutllovci-Zogaj, Krasniqi *et al*. 2014). And at the same time, it is as a double as the blood lead concentration in USA (Jones, Homa *et al*. 2009).

The researcher assumes that the main reason behind this increase of blood lead concentration in exposed and none exposed may be due to the fact of burning of e-waste practices in this area, which supports many authors about the effect of burning on discharging toxic gases; specially lead (Cui and Forssberg 2003, Liu, Niu *et al*. 2008, Pinto 2008). At the same time the increased concentration in the none exposed areas, also indicates the presence of other environmental sources of pollution of lead in both the exposed and none exposed, may be due to that water pipes system for tape water as was reported by WHO (Fewtrell, Kaufmann *et al*. 2003) and Schock (Schock 1989), and petrol use of lead in petrol as was indicated by IPCS (IPCS. Inorganic Lead 1995), those two confounding factors that could not be controlled may be other contributing factors to this high concentration of lead in blood, and both represent an opportunity for further investigations and research to evaluate the extent of their effect on the current high levels of blood concentration of lead.

The implications of this high level of blood, that this should be worked against its further increase in order to prevent the possible consequences of high blood lead, as respiratory diseases, neural problems (Goyer 1990), cardiovascular complications (Nawrot, Thijs *et al*. 2002), immune system complications (Klaassen 2008), and above all cancer (Anttila, Heikkilä *et al*. 1995).

Many solutions could be advised that would decrease the more emission of lead in the air, like the striping of cables instead of burning the high content lead cables, covering those wires and cables or the possibility of having modern incinerators for less burning and more environmentally

friendly solutions of e-waste processing. The most of that the possibility of selective importing of E-waste from the Israel where out of a list of high toxic materiel to prevent to entry to Palestinian territories. In addition to that a public awareness campaign may help in decreasing the effect of burning on both population and workers. All those solutions may become possible through formalization of this business as it has many indicators that it is less harmful and less polluting for the surrounding environment (Yu, Gao *et al*. 2006).

The workers in this study showed to have more contamination of blood lead than did the control, this was referred to in many studies like in (Yu, Gao *et al*. 2006, Wong, Wu *et al*. 2007). Which may be due to the fact those workers are in direct contact of handling, touching, and breathing fumes coming out from cutting, dismantling and burning of this E-waste, which may put them in a position where they are more affected by the negative effects of exposure to lead through different routes, as their surrounding is much more toxic than the surroundings of the normal population, as it was indicated that the heaviest lead-contaminated zone in air after the burning of the E-waste is 75–100 cm above the ground as was pointed by Wang *et al*,(Wang, He *et al*. 2006), which may explain this increase in blood lead concentration. More safe procedures of processing may decrease this effect, as using gloves, masks, and using occupational health and safety codes of practice in their daily work, as it is in the formal level of the E-waste processing where those codes are strictly applied (Yu, Gao *et al*. 2006). This results of increases toxicity in workers as compared to population residing the area of E-waste processing supports the findings of Shen *et al* (Shen, Lavi *et al*. 2004) who also had the same findings.

In terms of hemoglobin concentration, it was shown that the exposed areas had less hemoglobin (11.28) than in none exposed area (12.19), and in further analysis there was a statistical significant correlation between the Pb concentration and the hemoglobin level in blood, and distance from closest burring site, the thing that supports the findings of Kutllovci *et al* (Kutllovci-Zogaj, Krasniqi *et al*. 2014) who did the study in Serbia, and at the same time our hemoglobin results were around 2.5 units less than his study. At the same time those results support the results of Hu *et al* (Englert and Höring 1994) who concluded that there is a negative correlation between blood hemoglobin level and the patella lead concentration. Despite the fact that anemia in general may have many other nutritional and health-related other reasons, it is a major finding that should be traced and followed up in further future investigations to decrease the negative effect of Anemia on children specially that they were not included in this study and that should be part of further studies in the future.

CONCLUSIONS

In this descriptive comparative study there were differences in lead concentration as compared to none exposed, in exposed areas to the process of E-waste processing and burning, the results of this study can be summarized by that the exposed areas had:

- Higher lead concentration in blood as compared none exposed.
- Workers in the field of the E-waste processing and burning had a higher blood lead concentration when compared to normal population.
- Higher concentration of lead in springs of water as compared to lead in the springs of water in the nine exposed
- Less blood hemoglobin as compared to hemoglobin in none exposed area.
- The less Hemoglobin was associated with more Pb concentration and the closest distance to the first burning site form residence.
- Pb concentration itself was associated with the monthly frequency of burning and the distance from the site of burning.
- Testing the domestic water Pb concentration did not show any significant difference of concentration between the exposed and none exposed areas.

Based on the findings, discussion and conclusion of this study the researchers recommend the following recommendations to be taken into considerations on the different levels of stakeholders and workers in the field, and the population.

1. Formalization of this business sector, towards regulation of the processing of imported E-waste, and fulfilling all the occupational and safety measures on the processing itself and on workers.
2. Emphasizing the importance of taking all measures to stop the burning of e-waste in this area by all means of enforcement by law.
3. Adopting the use of an environmentally and occupationally safe processing of this E-waste, that includes:
   a. Stripping instead of burning,
   b. Potential modern incinerators,
   c. Industrial areas that guarantee the fulfillment of all occupational and health safety measures in terms, of equipment, employment, and processing.
4. Initiating a public awareness about the negative effect of the primitive processing and burning of E-waste on the environment and human health
5. In the further research level
   - Investigating in farther research the effect of other sources of lead on the future lead concentration in the exposed area.

To include children in this future research as they are the most vulnerable sector of the community.

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AUTHORS CONTRIBUTION

This study was designed and developed by all authors. Akram Amro and Hadeel Tamimi collected all required data. Yaser Issa, Akram Amro, and Hadeel Tamimi participated in data cleaning, entry and analysis. All authors participated in final conceptualization of the report and approved it for submission.

CONFLICT OF INTEREST

All authors declared that there are no known conflicts of interest.

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