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HEMATOLOGICAL PARAMETERS OF LEBANESE AND SYRIAN REFUGEES LIVING IN PROXIMITY OF DEIR KANOUN RAS EL AIN DUMP IN LEBANON

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Abstract

Anemia is one of the most common diseases that are associated with pollutants exposure. A complete blood count test (CBC) can determine the presence of abnormal hematological parameters and diagnose many serious preventable disorders including anemia. To assess the associations between exposure to pollutants and hematologic parameters among Lebanese inhabitants and Syrian refugees, who were exposed to toxic fumes emanating from Deir Kanoun Ras El Ain dump, a population-based study involving 679 Lebanese and Syrian Refugees living in the three villages Deir Kanoun, Klayleh and Smaiyeh was carried out. Blood samples were collected in EDTA tubes. CBC tests were performed and differences were statistically analyzed between different villages, sexes, nationalities, and age groups. Many blood parameters showed abnormal levels indicating hematological disorders including anemia, infections, allergy, and inflammation. Similar trends of abnormal CBC parameters were observed among the three villages. The highest percentage of abnormal erythrocyte parameters was found in Klayleh, while for leukocyte parameters, the highest was in Smaiyeh. Significant differences were observed between sexes and nationalities that may be associated with low income, environmental pollution and poor hygiene. This paper investigates and highlights the associations of living in a polluted area and the abnormal trends of CBC parameters. They emphasize the damaging effect of Deir Kanoun Dump on all inhabitants of the surrounding region calling for immediate intervention from the Lebanese government to find solutions.

Keywords

Complete blood count; Hematological parameters; Anemia; Pollution; Dump

1. INTRODUCTION

The global burden of disease is greatly attributed to the exposure of environmental pollution. Anemia, respiratory and cardiovascular diseases are common forms of disease burden that are associated with exposure to pollutants (Brook et al., 2010; Nakhlé et al., 2015; World Health Organization, 2010), and it is estimated that up to 90% of cancer incidence can be attributed to non-heritable mutations caused by lifestyle and the environment (Arnand et al., 2008; Hubal, 2009). Air and water pollution are the major sources of harmful substances that can easily reach the bloodstream through nasal and oral routes, and thus exert distinct harmful effects on different organs without necessitating a bio-transformation (Brook, & Rajagopalan, 2009). Several studies have proven that such pollutants have been incriminated in a vast array of deleterious consequences on blood cells that are highly sensitive to environmental pollutants (Cinnirella, Hedgecock, & Sprovieri, 2014). For instance, some heavy metals like lead, arsenic, chromium, mercury, cadmium, and zinc, interfere with the normal formation of red blood cells, damage cellular membranes, interfere with cell metabolism, and shorten cell survival (Karakatsani et al., 2010). Such detrimental effects can lead to damaged RBCs as well as reduced hemoglobin concentrations and hematocrit that subsequently cause clinical anemia (Lund et al., 2011). In turn, anemia is implicated in adverse health conditions such as mortality (Ezekowitz, McAlister, & Armstrong, 2003), deteriorated functional status (Denny, Kuchibhatla, & Cohen, 2006), and cognitive disorders that include Alzheimer's disease (Atti, Palmer, Volpato, Zuliani, Winblad, & Fratiglioni, 2006). Therefore, a complete blood count (CBC) could serve as a powerful diagnostic tool for the diagnosis of a number of serious preventable health conditions (Barger, 2003; Elvidge, Matthews, Gregory, & Hoogendoorn, 2013; Saadat, & Bahaoddini, 2004).

In Lebanon, Deir Kanoun Ras El Ain harbored for the last 20 years one of the worst dumps in the country (Haydar, 2015). Wastes from all the surrounding villages including domestic, industrial and medical were dumped and burnt over the years in this village. Inhabitants of Deir Kanoun and the surrounding villages were exposed to toxic fumes evolving from this dump. The waste problem was even more exacerbated by the presence of Syrian refugees living in the region. The dump is surrounded by agricultural lands. Effluents from Deir Kanoun dump leak into a running canal that is used for irrigation. More importantly, recent studies by Borjac *et al.*, revealed the presence of alarming levels of toxic heavy metals and organic compounds in soil and water samples collected from dump and canal sites (Borjac et al., 2019, 2020). Some of the inhabitants of these villages and the majority of the Syrian refugees' children swim and sometimes drink from the canal. Overall, the inhabitants of these villages belong to the low economic level (Geoflint, 2017). Education levels vary and illiteracy is common in a large part of the region. Cancer, respiratory and other diseases have also increased over the past few years to abnormal levels generally in Lebanon and specifically in the villages near Deir Kanoun dump (Aoun, Saleh, Waked, Salamé, & Salameh, 2013; Borgie et al., 2015; Green Area, 2015; Kobrossi, Nuwayhid, Sibai, El-Fadel, & Khogali, 2002; Salameh et al., 2012). The majority of these diseases may be assessed by blood analysis. This study aimed to analyze the complete blood count (CBC) of 679 Lebanese and Syrian participants living in Deir Kanoun and two surrounding villages, Klayleh and Smaiyeh, who were exposed to high levels of toxic fumes emanating from the dump.

2. METHODOLOGY

After signing a consent form agreeing to enroll in the study, blood samples were collected in EDTA tubes from Lebanese and Syrian, male and female, participants aged 10 and above, living in the three villages Deir Kanoun, Klayleh and Smaiyeh. The total number of the Lebanese inhabitants in Deir Kanoun Ras El Ain village, that harbors the dump, is 3800. It shelters 451 registered Syrian refugees. Klayleh possess the highest population number among the studied villages with 6000 inhabitants and it shelters 1300 registered Syrians. Smaiyeh is the smallest village that was most affected by the fumes emanating from the dump due to its location. Its total Lebanese inhabitants numbered 2000 and it shelters only 70 registered Syrians (data obtained from the head of each municipality). Six hundred seventy-nine participants were involved in this study. The sampling criterion was random and the percentage of population was 5% with 95% confidence level and 4% margin of error. Consents of guardians were taken for under-aged participants. Lebanese participants were inhabitants of the villages. Syrian participants included the ones who lived in the regions for at least one year.

2.1.Procedure

Blood samples were sent directly to a private ISO certified medical laboratory in Tyr, Lebanon and analyzed on Sysmex hematology analyzer. Demographic data were collected in a well-studied questionnaire. Relevant data including age, weight, height, medical history, smoking, blood pressure, and time spent in open air were recorded. Around 200 blood samples were collected from each region in EDTA coated tubes. Blood samples were kept in an ice box and brought to the laboratory for blood analysis directly the second day after collection. The automatic Sysmex XS-800i blood analyzer was used. Computerized report of the analyzed blood was obtained, and the reference values provided by the laboratory where the analyses took place were used in the statistics presented herein. These reference values were based on the machine used, as values differed slightly from lab to lab and machine to machine. IRB approval of the study was obtained from Beirut Arab University.

SPSS for Windows (version 23.0, SPSS Inc., Chicago, IL, USA) was used for data analysis. Statistical analyses are presented as mean with standard deviations. Statistical significance was tested using t-tests and ANOVA. Statistical significance is reported as * for p-value between 0.05 and 0.01, ** for p-value between 0.01 and 0.001, *** for p-value less between 0.001 and 0.0001, and **** for p-value less than 0.0001.

3. RESULTS

3.1. Demographic Data

Table 1 shows the gender distribution of participants among the three villages and their nationality. Percentages of participants were as follows: 37% Lebanese Females, 21.8% Syrian Females, 23.3% Lebanese Males, and 17.5% were Syrian Males.

Table 1: Number of Lebanese and Syrian Male and Female Participants in the Study.

Village	LF	LM	SF	SM	Total
Klayleh	93	31	75	73	272
Deir Kanoun	75	46	66	40	227
Smayieh	86	81	7	6	180
Total	254	158	148	119	679

LF= Lebanese Female, LM= Lebanese Male, SF= Syrian Female, SM= Syrian Male

Participants were grouped by age: between 10 and 20, between 21 and 40, between 41 and 60, and above 60 years. The total number of male and females and their percentages are summarized in Table 2. The percentages of the participants whose age ranged between 10 and 20 years of age and between 41 to 60 were very close (28.1 and 27.3 respectively), the percentage of participants whose age ranged between 20 to 40 was 35%. Only 9.6% of the participants were above 60 years of age.

Table 2**:** Age Distribution among All Participants in the Villages under Study.

AGE Distribution			Village				
			Klayleh	Deir Kanoun Ras AL Ain	Smaiyeh	Total	%
10 - 20 years	Sex	F	37	9	16	92	13.5
		M	33	38	28	99	14.6
	Total		**70**	**77**	**44**	**191**	**28.1**
21 - 40 years	Sex	F	63	48	35	146	21.5
		M	39	25	28	92	13.5
	Total		**102**	**73**	**63**	**238**	**35.0**
41- 60 years	Sex	F	52	41	25	118	17.4
		M	27	18	22	67	9.9
	Total		**79**	**59**	**47**	**185**	**27.3**
> 60 years	Sex	F	16	13	17	46	6.8
		M	5	5	9	19	2.8
	Total		**21**	**18**	**26**	**65**	**9.6**
TOTAL	Sex	F	168	141	93	402	59.2
		M	104	86	87	277	40.8
	Total		**272**	**227**	**180**	**679**	**100**

3.2. Hematological Parameters of all Participants

Mean values of the different hematological parameters obtained from the Sysmex Analyzer are provided in Table 3. All reference ranges were obtained from the medical laboratory that performed the analysis.

Table 3: Levels of hematological parameters of all individuals involved in the study.

Parameter	Mean ±SD (N=679)	Reference Range
WBC (10^3/µL)	7.56 ±1.9	4-10
RBC (10^6/µL)	4.84 ±0.51	4-4.5
HGB (g/dL)	13.67 ±1.68	12-16
HCT (%)	41.8 ±4.53	37-46
MCV (fl)	86.42 ±7.64	80-96
MCH (pg)	28.32 ±2.64	27-33
MCHC (g/dL)	32.71 ±2.29	33-36
PLT (10^3/µL)	260.8 ±71.32	150-450
RDW-SD (%)	40.25 ±3.35	39-46
PDW (fl)	16.34 ±2.79	8.3-25
MPV (fl)	12.37 ±1.03	8.3-15.5
P-LCR (%)	44.76 ±8.41	11.9-66.9
PCT (%)	0.32 ±0.07	0.15-0.62
NEUT (%)	57.64 ±21.33	40-70
LYMP (%)	33.46 ±8.26	20-45
MONO (%)	5.52 ±1.43	2-8
EO (%)	3.16 ±2.85	1-4
BASO (%)	0.784 ±0.48	0-1

Abbreviations: WBC= white blood cells count, **RBC**= red blood cells count, **HGB**= hemoglobin, **HCT**= hematocrit, **MCV**= mean cell volume, **MCH**= mean cell hemoglobin, **MCHC**= mean cell hemoglobin concentration, **PLT**= platelet count, **RDW-SD**= red cell distribution width, **PDW**= platelet distribution width, **MPV**= mean platelet volume, **P-LCR**= platelet large cell ratio, **PCT**= plateletcrit, **NEUT**= neutrophil percentage, **LYMP**= lymphocyte percentage, **MONO**= monocyte percentage, **EO**= eosinophil percentage, **BASO**= basophile percentage.

Abnormalities in several hematological parameters are illustrated in Figure 1, which shows the number of individuals with lower and higher than the normal values of the major CBC parameters. Thus, when the data from individuals were examined, we noted that many had lower than the normal levels of HGB (13.5% of all population), HCT (11%), MCV (12.4%), MCH (23.5%), MCHC (60.2%), PLT (4.3%), and RDW (38.1%). In contrast, many inhabitants had higher than the reference values of WBC (10.6%) and RBC (10.1%) counts, HCT (16.3%), NEUT (7%), LYMP (7.5%), MONO (5.1%), EO (23.8%), and BASO (18.1%).

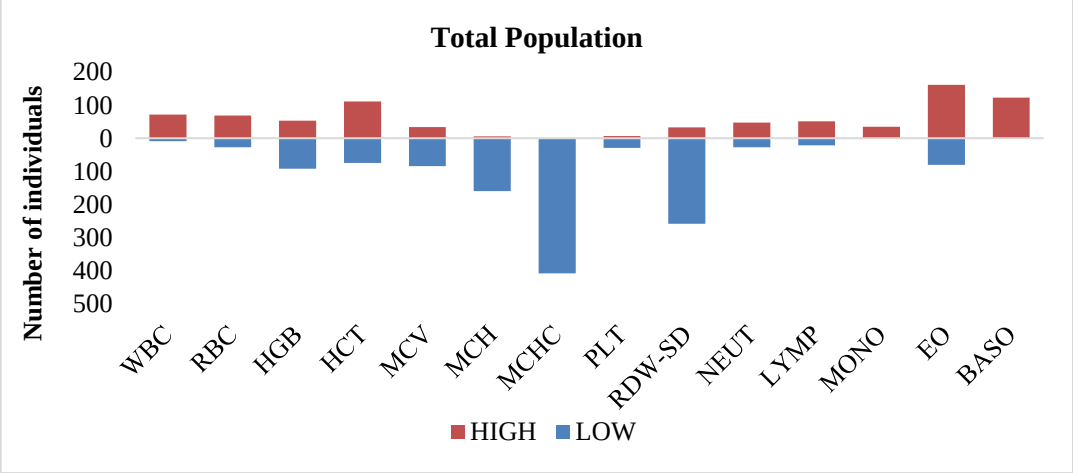

Fig.1: Number of individuals with higher and lower than the normal values of blood parameters in all villages.

3.3. Region-related Findings

The means for CBC parameters of individuals in different villages are presented in Table 4. Results showed that Smaiyeh inhabitants had significant higher mean RBC (4.91 × 10^6/µL versus 4.81× 10^6/µL, p-value <0.05), hemoglobin (HGB, 13.84 g/dL versus 13.51 g/dL, p-value <0.05), hematocrit (HCT, 42.39% versus 41.34%, p-value <0.05), red cell distribution width (RDW-SD, 40.75% versus 39.87%, p-value <0.01), and eosinophil percentages (EO, 3.5% versus 2.89%, p-value <0.05) than those of Klayleh inhabitants.

Table 4: Levels of Hematological Parameters of Individuals Living in Klayleh, Deir Kanoun and Smaiyeh Villages.

Parameter	Reference Range	Klayleh (N=272)	Deir Kanoun (N= 227)	Smaiyeh (N= 180)	P-value
		Mean ±SD	Mean ±SD	Mean ±SD	
WBC (10^3/µL)	4-10	7.568 ±1.85	7.63 ±1.91	7.46 ±1.97	0.583
RBC (10^6/µL)	4-4.5	**4.818 ±0.53**	4.82 ±0.49	**4.91 ±0.5**	**0.045 (*)**
HGB (g/dL)	12-16	**13.516 ±1.83**	13.73 ±1.6	**13.84 ±1.53**	**0.046 (*)**
HCT (%)	37-46	**41.34 ±5.16**	41.88 ±4.08	**42.39 ±3.98**	**0.0212 (*)**
MCV (fl)	80-96	85.98 ±9.59	86.82 ±5.85	86.58 ±6.15	0.62
MCH (pg)	27-33	28.212 ±3.1	28.5 ±2.27	28.25 ±2.3	0.88
MCHC (g/dL)	33-36	32.76 ±3.35	32.74 ±1.21	32.61 ±1.06	0.561
PLT (10^3/µL)	150-450	258.68 ±70.2	267.36 ±75.12	255.72 ±67.78	0.656
RDW-SD (%)	39-46	**39.87 ±3.34**	40.31 ±3.41	**40.75 ±3.26**	**0.005 (**)**
NEUT (%)	40-70	56.69 ±8.9	59.316 ±34.28	56.94 ±10.34	0.784
LYMP (%)	20-45	34.02 ±7.94	33.154 ±7.91	33.01 ±9.12	0.213
MONO (%)	2-8	5.432 ±1.5	5.64 ±1.43	5.52 ±1.3	0.52
EO (%)	1-4	**2.89 ±2.25**	3.21 ±2.84	**3.5 ±3.57**	**0.026 (*)**
BASO (%)	0-1	0.776 ±0.57	0.766 ±0.37	0.817 ±0.46	0.42

Note: Numerical data in **bold** indicates statistically significant values upon comparing Smaiyeh to Klayleh. No statistical significance was obtained between Deir Kanoun and the other two villages.

In Klayleh, results showed abnormalities in many parameters (Figure 2). Parameters including HGB, HCT, MCV, MCH, MCHC, and RDW showed lower than the normal levels. HGB and HCT levels were lower than the normal in 21.3% and 18% of the Kalyleh participants. Regarding MCV, MCH, MCHC and RDW, their levels were low as well in 16.5%, 25%, 64% and 45.2%, respectively. In contrast, WBC and RBC counts showed higher values than the normal in 11% and 10%, respectively. Similarly, the levels of leukocytes: NEUT, LYMP, MONO, EO, and BASO levels were higher than the normal levels. For the agranulocytes, the percentage of participants with high levels of LYMP and MONO were 6.6 and 5.8% respectively. As for granulocytes, the percentage of participants with high NEUT, EO, and BASO levels were 7%, 21.3%, and 18% respectively. This suggests high levels of infections and allergy in this region.

In Deir Kanoun, the CBC results showed similar trends to those observed in Klayleh except for HCT. The percentage of participants with lower levels of HGB, MCV, MCH, MCHC, and RDW were 12.7 %, 9.2%, 21.6%, 39%, and 56.4% respectively. The percentage of participants with abnormal levels was higher in Klayleh than in Deir Kanoun. On the other hand, higher than the normal values were evident in WBC and RBC counts, HCT, and various leukocyte levels. The percentage of participants with higher than the normal levels of WBC, RBC, HCT were 11%, 8.4% and 15.4%, respectively. Regarding leukocytes, the percentage of participants with high NEUT, LYMP, MONO levels were 6% each. Besides, the percentage of participants with high EO and BASO levels were 26.4% and 16.7%.

In Smaiyeh, the results of CBC showed similar trends to the two other villages. Erythrocyte parameters such as HGB, MCV, MCH, MCHC, and RDW levels were lower than the normal values in a number of individuals. The percentage of participants with low HGB, MCV, MCH, MCHC, and RDW levels were observed in 8.3%, 11%, 24.4%, 62.7%, and 28.8% respectively. However, higher than the normal values were observed in WBC and RBC counts, HGB, HCT, RDW as well as in leukocyte levels. The percentage of participants with high WBC, RBC and HCT levels were 9.4%, 12.2% and 20%, respectively. Moreover, the percentage of participants with high NEUT, LYMP, EO, and BASO levels were 7.7%, 11.1%, 24.4%, and 20%, respectively. Compared to the other two villages, Smaiyeh had the highest percentage of participants with abnormal leukocyte levels.

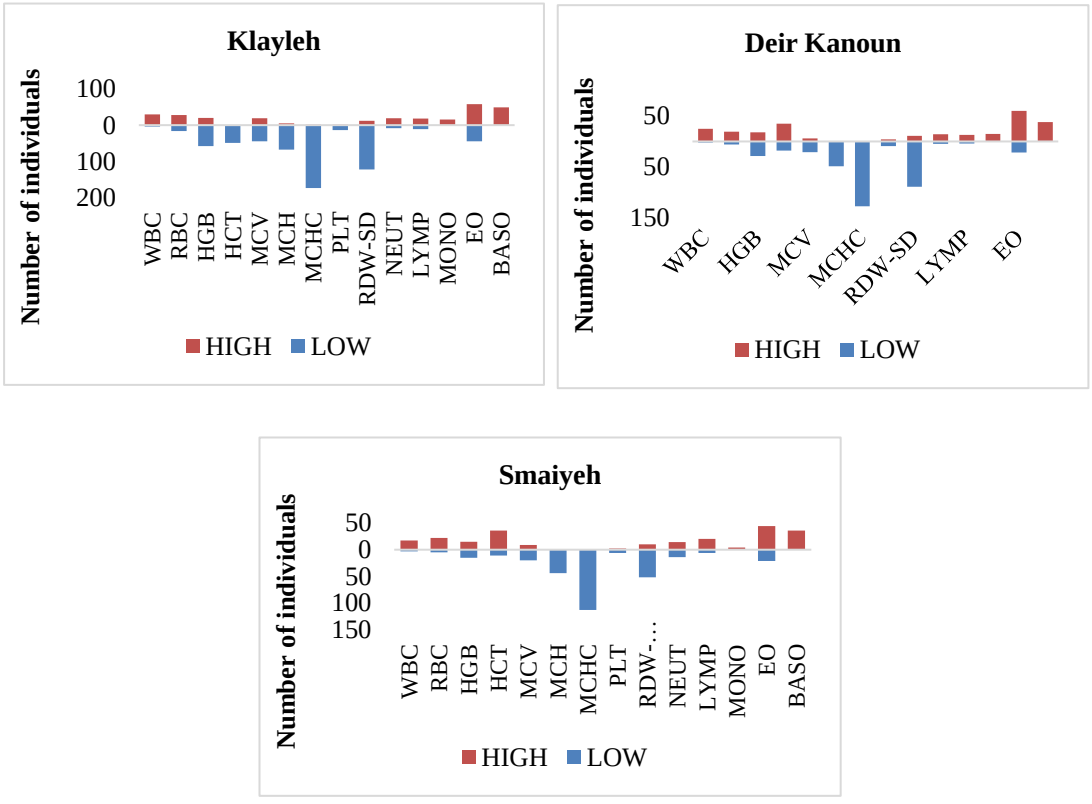

Fig.2: Number of individuals with higher and lower than the normal values of blood parameters in Klayleh, Deir Kanoun and Smaiyeh villages.

3.4. Nationality-related Findings

Table 5 shows the levels of different blood parameters of the Lebanese and Syrian inhabitants in the three villages. The means of these groups were well matched; however, there was a statistically significant difference in WBC, LYMP, BASO, and PLT. Mean WBC and LYMP counts of Syrian inhabitants were significantly higher (p-value <0.0001 and <0.05 respectively) than those of the Lebanese inhabitants. These data suggest that the Syrians were more prone to infection due to their residency in camps in open air. However, the level of basophiles was higher in Lebanese (p-value <0.05) compared to Syrian inhabitants indicating higher rate of allergic reactions.

Table 5: Levels of the Hematological Parameters of Lebanese and Syrian Participants.

Parameter	Lebanese (N=412)	Syrian (N=267)	P-value	Reference Range
	Mean ±SD	Mean ±SD		
WBC (10^3/µL)	7.33 ±1.88	7.92 ±1.89	**<0.0001 (****)**	4-10
RBC (10^6/µL)	4.82 ±0.48	4.87 ±0.55	0.211	4-4.5
HGB (g/dL)	13.66 ±1.56	13.69 ±1.86	0.82	12-16
HCT (%)	41.66 ±4.38	42.01 ±4.76	0.326	37-46
MCV (fl)	86.72 ±6.33	85.95 ±9.29	0.199	80-96
MCH (pg)	28.34 ±2.46	28.29 ±2.9	0.809	27-33
MCHC (g/dL)	32.77 ±2.8	32.63 ±1.14	0.437	33-36
PLT (10^3/µL)	255.24 ±72.47	269.38 ±68.78	**0.011 (*)**	150-450
RDW-SD (%)	40.43 ±3.15	39.97 ±3.64	0.081	39-46
NEUT (%)	58.58 ±26.28	56.18 ±9.48	0.152	40-70
LYMP (%)	32.91 ±8.26	34.31 ±8.2	**0.03 (*)**	20-45
MONO (%)	5.57 ±1.43	5.46 ±1.42	0.326	2-8
EO (%)	3.19 ±3.21	3.1 ±2.19	0.688	1-4
BASO (%)	0.815 ±0.47	0.735 ±0.49	**0.033 (*)**	0-1

The trend of abnormal blood parameters of the Lebanese and Syrian participants is shown in Figure 3. Among all the Lebanese participants, CBC results showed that a large number of individuals have lower than the normal levels of several parameters. The percentage of participants with lower levels of HGB, HCT, MCV, MCH, MCHC, and RDW were 11.4%, 10%, 11.4%, 24.3%, 60.4%, and 34.7% respectively. While, the percentage of participants with higher levels of WBC, RBC, HCT, NEUT, LYMP, MONO, EO, and BASO were 8.5%, 7.7%, 14.3%, 6.5%, 8.5%, 4.6%, 21.8%, and 19.4% respectively.

Upon comparing the abnormal parameters of the Lebanese participants to those of the Syrians, similar trends were observed; yet, the number of individuals with abnormal levels was higher among Syrian refugees. The percentage of participants with lower than normal levels of HGB, HCT, MCV, MCH, MCHC, and RDW were 16.8%, 13.1%, 13.8%, 22.4%, 60%, and 43.4% respectively. However, the percentage of participants with higher than normal values of WBC, RBC, HCT, NEUT, LYMP, MONO, EO and BASO were 13.8%, 13.8%, 19.5%, 7.5%, 6%, 6%, 27%, and 16.1% respectively.

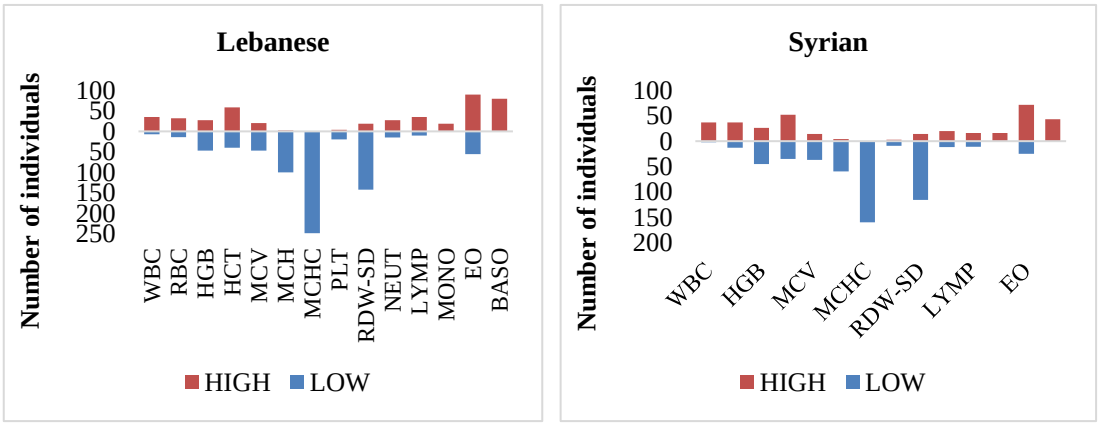

Fig.3: Number of Lebanese and Syrian individuals with higher and lower than the normal values of blood parameters.

3.5. Sex-related Findings

Table 6 shows the mean values of different hematological parameters among females and males.

Table 6: Levels of Hematological Parameters of Females and Males.

Parameter	Reference Range	Females (N=402)	Males (N=277)	P-value
		Mean ±SD	Mean ±SD	
WBC (10^3/µL)	4-10	7.42 ±1.92	7.76 ±1.85	**0.0216 (*)**
RBC (10^6/µL)	4-4.5	4.62 ±0.43	5.17 ±0.43	**<0.0001 (****)**
HGB (g/dL)	12-16	12.87 ±1.36	14.83 ±1.42	**<0.0001 (****)**
HCT (%)	37-46	39.76 ±3.93	44.75 ±3.64	**<0.0001 (****)**
MCV (fl)	80-96	86.41 ±7.79	86.42 ±7.42	0.9866
MCH (pg)	27-33	27.96 ±2.75	28.84 ±2.38	**<0.0001 (****)**
MCHC (g/dL)	33-36	32.25 ±1.13	33.39 ±3.21	**<0.0001 (****)**
PLT (10^3/µL)	150-450	267.42 ±77.3	251.19 ±60.49	**0.0035 (***)**
RDW-SD (%)	39-46	40.66 ±3.66	39.65 ±2.75	**0.0001 (***)**
NEUT (%)	40-70	59.26 ±26.55	55.28 ±9.09	**0.0166 (*)**
LYMP (%)	20-45	32.93 ±8.41	34.24 ±7.99	**0.0421 (*)**
MONO (%)	2-8	5.24 ±1.32	5.93 ±1.47	**<0.0001 (****)**
EO (%)	1-4	2.81 ±2.26	3.65 ±3.48	**0.00015 (***)**
BASO (%)	0-1	0.812 ±0.54	0.742 ±0.37	0.0611

Results showed that males had higher mean RBC (5.17 × 106/µL versus 4.62 × 106/µL), HGB (14.83 versus 12.87 g/dL), HCT (44.75 versus 39.76%), MCH (28.84 versus 27.96 pg), and MCHC (33.39 versus 32.25 g/dL) than females. The difference of these parameters by gender was statistically significant (p-value < 0.0001). Only RDW was significantly higher in females than males (40.66 versus 39.6%, p-value <0.001). Findings also revealed that males had higher mean values of WBC count (7.76 versus 7.42× 106/µL, p-value <0.05), LYMP (34.24 versus 32.9%, p-value <0.05), MONO (5.93 versus 5.24%, p-value <0.0001), and EO (3.65 versus 2.81%, p-value <0.001). The mean platelet count in males was significantly lower than that in females (251.1 versus 267.4 × 103/µL, p-value <0.001). In contrast, no gender difference was noticed for MCV and BASO parameters.

Figure 4 shows the trends of abnormal parameters among females and males. The percentage of female participants with lower than the normal values of RBC, HGB, HCT, MCV, MCH, MCHC, and RDW were 6.5%, 21.2%, 16.6%, 14%, 28.8%, 76.1%, and 35.6%, respectively. In contrary, the percentage of female participants with high levels of WBC, NEUT, LYMP, EO and BASO were 9.2%, 8.5%, 7.2%, 20.4%, and 19%, respectively.

Upon comparing the levels of abnormal parameters in females to those in males, similar trends were observed except for RBC count, HGB and HCT levels. The percentage of males with low MCV, MCH, MCHC, and RDW were 10.1%, 15.8%, 37% and 41% respectively. However, the percentage of males with high levels of WBC, RBC, HGB, HCT, NEUT, LYMP, MONO, EO and BASO were 12.6%, 21%, 18%, 37.5%, 4.7%, 8%, 8%, 7.2%, 28.8%, and 13%, respectively.

Overall, female participants had higher abnormal RBC parameters than male ones. However, no sex difference was observed in WBC parameters.

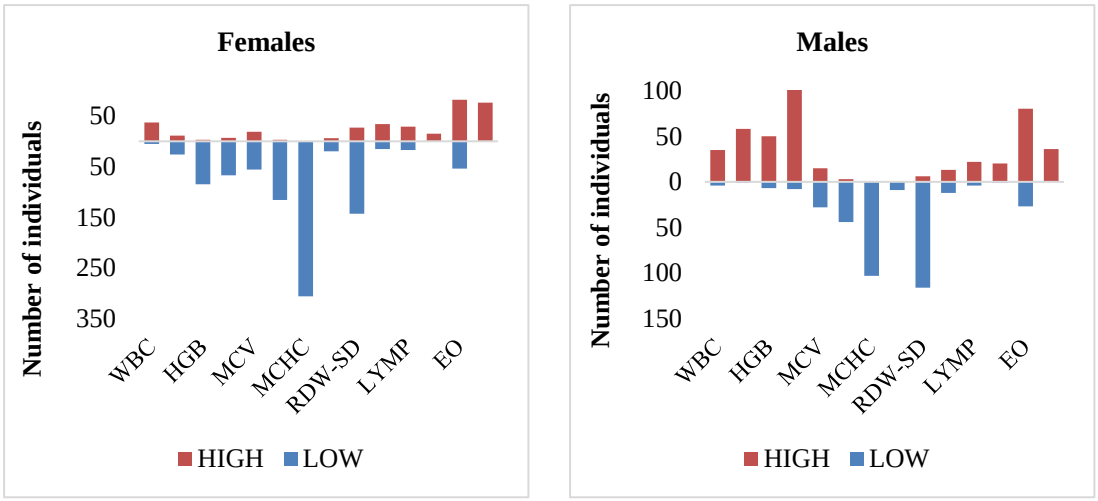

Fig.4: Number of females and males with higher and lower than the normal values of blood parameters.

3.6.Sex-related Findings among Lebanese and Syrian Inhabitants

Table 7 shows the mean values of different hematological parameters among Lebanese females and males, as well as Syrian females and males.

Table 7: Levels of hematological parameters on the basis of sex and nationality.

Parameter	Reference Range	LF (N=254)	LM (N= 158)	SF (N= 148)	SM (N= 119)	P-value
		Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	
WBC (10^3/µL)	4-10	7.2 ±1.87	7.53 ±1.88	7.81 ±1.96	8.06 ±1.79	• LF vs SF **
RBC (10^6/µL)	4-4.5	4.63 ±0.42	5.14 ±0.4	4.59 ±0.46	5.22 ±0.46	• LF vs LM ****
						• SF vs SM ****
HGB (g/dL)	12-16	12.96 ±1.33	14.79 ±1.2	12.73 ±1.41	14.88 ±1.67	• LF vs LM ****
						• SF vs SM ****
HCT (%)	37-46	39.87 ±4.01	44.53 ±3.3	39.57 ±3.8	45.05 ±4.04	• LF vs LM ****
						• SF vs SM ****
MCV (fl)	80-96	86.61 ±6.68	86.9 ±5.74	86.06 ±9.41	85.79 ±9.17	No Sig.
MCH (pg)	27-33	28 ±2.63	28.87 ±2	27.88 ±2.97	28.79 ±2.75	• LF vs LM **
						• SF vs SM *
MCHC (g/dL)	33-36	32.3 ±1.14	33.53 ±4.18	32.16 ±1.1	33.21 ±0.91	• LF vs LM ****
						• SF vs SM ***
PLT (10^3/µL)	150-450	261.16 ±78.34	245.72 ±60.9	278.16 ±74.52	258.46 ±59.41	• SF vs SM **
RDW-SD (%)	39-46	40.69 ±3.38	40 ±2.7	40.6 ±4.12	39.19 ±2.76	No Sig.
NEUT (%)	40-70	60.2 ±32.63	55.99 ±9.17	57.65 ±9.68	54.32 ±8.92	No Sig.
LYMP (%)	20-45	32.68 ±8.4	33.28 ±8.06	33.36 ±8.45	35.5 ±7.74	No Sig.
MONO (%)	2-8	5.31 ±1.33	5.98 ±1.49	5.13 ±1.32	5.86 ±1.46	• LF vs LM ****
						• SF vs SM ***
EO (%)	1-4	2.75 ±2.37	3.88 ±4.14	2.91 ±2.06	3.35 ±2.33	• LF vs LM ***
BASO (%)	0-1	0.841 ±0.52	0.773 ±0.38	0.764 ±0.57	0.7 ±0.35	No Sig.

LF= Lebanese female, LM=Lebanese male, SF= Syrian female, SM= Syrian male.
Statistical significance is reported as * for p-value between 0.05 and 0.01, ** for p-value between 0.01 and 0.001 and **** for p-value less than 0.0001.

The obtained findings illustrated that there were significant differences among females and males of the same nationality. The levels were significantly lower in females than males for both nationalities. It is noted that the WBC count was significantly higher in Syrian compared to the Lebanese females (p-value <0.01) most likely due to their living environment.

3.7. Age-related Findings

Table 8 and Figure 5 show the levels of the hematological parameters among the participants grouped by age and the significant differences among these groups respectively. Significant differences among age groups were observed in RBC count, MCV, MCH, MCHC, RDW, PLT, MONO, LYMP, and BASO (Figure 5).

Table 8: Levels of hematological parameters of participants grouped by age.

Parameter	Reference Range	Group A (10 to 20 years) (N=191)	Group B (21 to 40 years) (N=238)	Group C (41 to 60 years) (N=185)	Group D (> 60 years) (N=65)	P-value
		Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	
WBC (10^3/µL)	4-10	7.43 ±2	7.77 ±1.84	7.52 ±1.81	7.26 ±2.02	No Sig.
RBC (10^6/µL)	4-4.5	4.91 ±0.46	4.83 ±0.59	4.86 ±0.44	4.67 ±0.48	**Sig.**
HGB (g/dL)	12-16	13.7 ±1.6	13.66 ±1.85	13.71 ±1.63	13.53 ±1.41	No Sig.
HCT (%)	37-46	41.33 ±3.87	41.74 ±4.79	42.28 ±5.02	41.98 ±3.8	No Sig.
MCV (fl)	80-96	84.43 ±5.92	86.5 ±8.21	87.06 ±8.36	90.11 ±5.98	**Sig.**
MCH (pg)	27-33	27.91 ±2.4	28.39 ±2.78	28.4 ±2.77	29.05 ±2.27	**Sig.**
MCHC (g/dL)	33-36	33.29 ±3.88	32.66 ±1.18	32.37 ±1.11	32.21 ±0.97	**Sig.**
PLT (10^3/µL)	150-450	275.8 ±71.78	261.93 ±73.86	254.81 ±67.49	229.64 ±59.4	**Sig.**
RDW-SD (%)	39-46	39.21 ±2.68	40.02 ±3.57	41.19 ±3.41	41.47 ±3.14	**Sig.**
NEUT (%)	40-70	55.15 ±9.73	58.13 ±9.54	59.91 ±37.63	56.64 ±9.02	No Sig.
LYMP (%)	20-45	35.07 ±8.73	32.42 ±8.08	33.42 ±7.76	32.68 ±8.31	**Sig.**
MONO (%)	2-8	5.83 ±1.31	5.35 ±1.47	5.4 ±1.43	5.6 ±1.44	**Sig.**
EO (%)	1-4	3.03 ±2.68	3.15 ±2.61	3.12 ±2.49	3.66 ±4.61	No Sig.
BASO (%)	0-1	0.767 ±0.38	0.748 ±0.38	0.777 ±0.57	0.984 ±0.71	**Sig.**

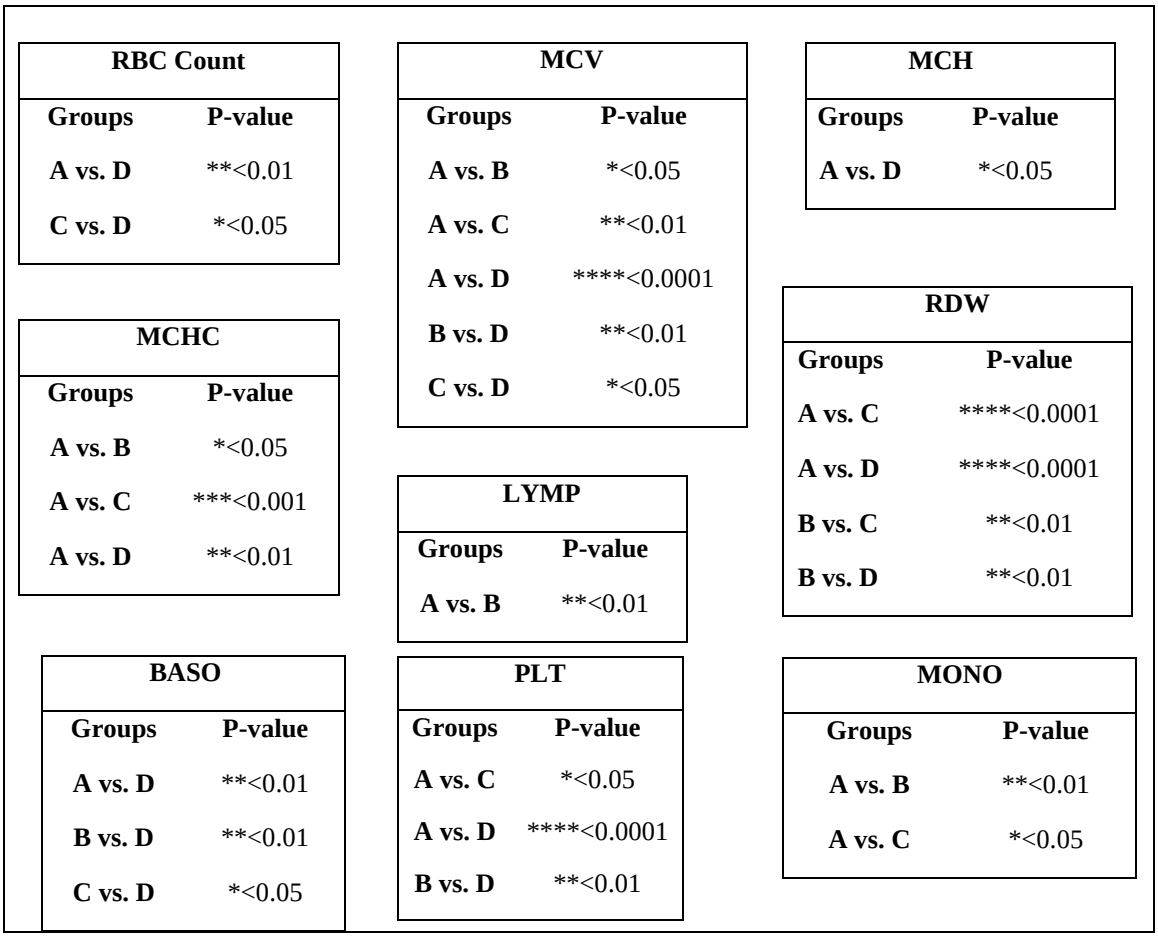

Fig.5: Blood parameters with statistically significant p-values among particular age groups.

Analysis of the hematological parameters among the young participants (Group A) indicates that this group had low levels of HGB (9.4%), HCT (10%), MCV(20%), MCH(30%), MCHC (42.4%), and RDW(47.6%). Furthermore, this group had high levels of WBC (10.5%), RBC (9%), NEUT (5.8%), LYMP (11%), MONO (6.8%), EO (22.5%), and BASO (16.2%). However, participants of Group D (the elderly) significantly had the lowest RBC and PLT levels, but the highest BASO levels, compared to other age groups.

4. DISCUSSION

This preliminary study presents the status of CBC parameters and suggests possible risks resulting from significant associations between exposure to pollutants and CBC abnormalities among Lebanese inhabitants and Syrian refugees exposed to fumes emanating from Deir Kanoun Ras El Ain dump that had been burning over periods of years (1997-2015).

Differential CBC provides important results to diagnose many hematological diseases. Erythrocytes play key roles in gaseous exchange carrying oxygen from lungs to tissues and carbon dioxide from tissues to the lungs for exhalation. Indices used to assess erythrocytes include the RBC count (millions of cells/L), blood hemoglobin (HGB in g/dL), and the hematocrit (HCT) (Greer, Arber, Glader, List, Means, & Rodgers, 2018). Our present study showed that a large number of individuals had lower than the normal levels of HGB and HCT. Most of these individuals were found to be inhabitants of Klayleh village. In addition, females, especially Syrians, had significant lower levels of HGB and HCT than males. Such low HCT and HGB levels commonly indicate the presence of anemia – that may be due to iron, vitamin deficiencies (B12 or folate), bone marrow suppression, hemorrhage or other chronic diseases.

CBC also includes other red cell parameters such as the mean corpuscular volume (MCV), the mean corpuscular hemoglobin (MCH), and the mean corpuscular hemoglobin concentration (MCHC). These parameters are crucial for evaluating erythrocyte disorders. The results of this study revealed that many individuals had low levels of MCV (12.4%), MCH (23.5%) and MCHC (60.2%). Upon comparing the % of individuals with low levels of these parameters between villages, the highest % was in Klayleh followed by Smaiyeh and the least % was in Deir Kanoun.

These low levels were equal among Lebanese and Syrian inhabitants, but lower in females than males. In fact, low MCV indicates microcytic anemia. Although MCH and MCHC are less important than MCV, viewing low levels of these parameters together indicate copper, vitamin C, B6, B12, folate, or iron deficiency (Sarma, 1990). In some cases, they are used as indicators of lead intoxication. Moreover, many studies reported that living in a region contaminated with garbage and dumps of wastes, can lead to low levels of erythrocyte parameters as these cells are sensitive to environmental pollution (Lund et al., 2011). This clearly explains our findings, where the effected individuals live near to one of the worst dumps in the country.

The red cell distribution width (RDW) is another erythrocyte index that mathematically describes the variation in the size of RBC, i.e. it is a numerical measure of anisocytosis. Our findings showed that the mean RDW of Klayleh inhabitants was lower than that of Smaiyeh inhabitants. In addition, it was increasing with age, and higher in females than males. Abnormalities in RDW were mainly found to be as lower than the normal levels in 38% of the total population. Most of these individuals were inhabitants of Klayleh village, and a large number of them were females. A high RDW indicates variations in RBCs size implying microcytic rather than macrocytic disorders. However, it was recently reported that even a low RDW, which indicates that RBCs vary very little in size, could still indicate macrocytic or microcytic anemia (George-Gay, & Parker, 2003).

Moreover, CBC assesses WBC count including granulocytes (neutrophils, eosinophils, and basophils) and agranulocytes (lymphocytes and monocytes). In our study, the mean WBC count, LYMP and BASO levels in Syrian individuals were higher than those in Lebanese individuals. Similar mean differences were observed among sexes, where males had higher mean values of WBC, LYMP, MONO, and EO than females. As a matter of fact, menstruation and nutritional intake are the principal reasons for such lower values of hematological parameters in women compared to men (Murphy, 2014). Many studies indicate that women worldwide are at risk of being in a negative iron balance (Pluncevic Gligoroska et al., 2019), and being more prone to infections during menstruation (Oertelt-Prigione, 2012).

Also, abnormalities in WBC parameters were seen in a considerable number of inhabitants who had higher than the normal values of WBC count, EO, and BASO. These high levels of WBC indicate the presence of immune system disorders, which can include infections, inflammation, allergy, stress, and bone marrow disorders (Blumenreich, 1990). Among villages, Smaiyeh was the village with the highest percentages of individuals with abnormal high EO and BASO levels. This could be explained by the village's location with respect to the other two villages, which renders it more exposed to toxic fumes evolving from the dump. Also, the exposure of the three villages to dump-emanated pollutants cannot be identical due to the geographic localization and wind direction. Nationality-related findings showed that Syrian inhabitants had a higher number of abnormal high WBC, MONO and EO levels than those of Lebanese inhabitants. Indeed, Syrian inhabitants involved in this study were living in refugee camps where poor hygiene and unhealthy environmental conditions are more common. Furthermore, Lebanese participants had more abnormal basophil levels than Syrian participants. This is mainly due to the fact that Lebanese participants have lived in the area since birth, while Syrians have occupied the region for much shorter times (a minimum of 1 year to a maximum of the beginning of the Syrian war in 2011). Thus, the Lebanese participants were exposed for much longer period to toxic fumes evolving from burning the wastes in the dump. Besides, results showed that the elderly participants significantly had the highest BASO levels. In particular, high basophil levels indicate systemic allergy, chronic inflammatory and hypersensitivity reactions.

In addition to RBC and WBC indices, PLT count is one of the major CBC parameters that reflect individual's health state. In our study, results showed that a few number of individuals had a reduced PLT count. More crucially, results revealed that the elderly participants significantly had the lowest PLT levels. Data from the literature clearly indicate that the number of platelets decreases in oldness. Such reduction in elderly people is attributed to reduced hematopoietic stem cell reserve during aging (Biino, et al., 2013; Segal & Moliterno, 2006). Generally, low PLT count, also called thrombocytopenia, indicates a risk for serious bleeding, congenital disorders, marrow depression or infiltration, and megaloblastic anemia, depending on the severity of the case (Yilmaz, Eralp, & Ilcol, 2008).

Our findings suggest a substantial number of individuals with abnormal hematological parameters associated with low income, environmental pollution and poor hygiene (captured in our questionnaire as place of residence: apartment versus camp). It is very crucial to attribute abnormal CBC results to low income since the latter illustrates the inability of inhabitants to afford nutritional food or balanced diet. Although the effect of pollution on hematological parameters remains controversial, several studies reported an association between them that varies depending on the duration of exposure to pollutants, age, and sex of susceptible individuals. For instance, elderly individuals may show stronger associations than children and adolescents (Buka, Koranteng, & Osornio-Vargas, 2006; Poursafa et al., 2011). Yet, it is very important to study the effects of pollution on children, who receive higher dose of pollutants than adults, and this can provide preventive strategies for chronic diseases (Kim, 2004). Our findings also have shown that participants aged between 10 and 20 years, have abnormal levels of several hematological parameters.

Our results are consistent with another study by Saadat et al. (2004) which involves inhabitants of polluted areas of Masjid-Sulaiman in Iran. This region was contaminated by subsurface leakage of natural gas, and the study showed abnormal levels of various CBC parameters including high RBC count, HCT, HGB, and PLT count among exposed subjects compared to the control group. Moreover, a study by Ahmed et al. showed that a large number of people living in five different areas of Karachi showed lower than normal values of many blood parameters indicating various blood related diseases. This study suggested that poverty, poor hygiene and pollution were responsible for the observed blood related disorders in the population of Karachi (Ahmed, Rao, Siddiqui, Shaikh, & Ahmed, 2011).

All in all, evidence-based laboratory medicine, which involves CBC, is becoming a pivotal part of new clinical practices that are recommended by physicians to prevent, diagnose, treat and manage disease (Christenson, 2007). Although CBC helps in identifying abnormal levels of different blood parameters, it was shown that this test can show abnormal values in 5% of normal individuals (Bain, 1996). Hence, it should be noted that abnormal CBC values should take into consideration the individual base line values, sex, age, and race (Cowman et al., 2015). A study by Tefferi et al. (2005) showed that normal females have low RBC count and high PLT count as compared to males. Besides, some parameters were shown to be higher in Africans than Caucasians (Cheng, Chan, Cembrowski, & Van Assendelft, 2004). Thus, it is recommended that future studies include the race, age and gender of individuals upon performing CBC tests. However, our present study is a preliminary investigation to show the trends of abnormal CBC parameters among individuals living in a polluted area.

LIMITATIONS

This study has some limitations. The first limitation is the absence of a control group of inhabitants who live a little far from this landfill. However, relying on laboratory reference values is satisfactory and thus we believe that this flaw, based on similar studies in the literature, has not had a significant effect on the overall preliminary investigations. Another limitation is that additional factors such as smoking status and body mass index were not considered as they can affect certain blood parameters and pollutant toxicokinetics and toxicodyamics. Moreover, attributing the abnormal levels of blood parameters to the exposure to pollutants is hypothetical. Thus, further investigations are needed to provide assessments of certain pollutants/metabolites in the blood (or urine) samples. This will be our future work.

5. CONCLUSION

Our study shows a large number of individuals with abnormal levels of hematological parameters in three different villages that are in proximity to Deir Kanoun dump. Based on the parameter values, significant differences were reported among villages, sexes, ages and nationalities. Our findings suggest a damaging effect of Deir Kanoun Dump on all inhabitants of the surrounding region calling for immediate action from the Lebanese government to find solutions.

Competing interests

The authors declare that they have no competing interests.

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