Heliyon 8 (2022) e09040

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Evaluation of hematological indices among insecticides factory workers

Fatemeh Nejatifar [a], Mohammad Abdollahi [b], Mirsaeed Attarchi [c,*], Zahra Atrkar Roushan [d], Alireza Etemadi Deilami [e], Maryam Joshan [a], Fateme Rahattalab [a], Niloofar Faraji [a], Hamid Mohammadi Kojidi [a]

[a] Razi Clinical Research Development Unit, Razi Hospital, Guilan University of Medical Sciences, Rasht, Iran
[b] School of Pharmacy and Pharmaceutical Sciences Research Center (PSRC), The Institute of Pharmaceutical Sciences (TIPS), Tehran University of Medical Sciences (TUMS), Tehran, Iran
[c] Inflammatory Lung Diseases Research Center, Razi Hospital, Guilan University of Medical Sciences, Rasht, Iran
[d] Department of Biostatistics, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran
[e] Department of Occupational Health, Rasht Health Center, Guilan University of Medical Sciences, Rasht, Iran

ARTICLE INFO

Keywords:
Insecticides
Occupational exposure
Hematologic tests
Chronic toxicity

ABSTRACT

Insecticides are commonly used pesticides in the world. Chronic exposure to insecticides has adverse effects on various human body organs. In this study, hematological findings were assessed in workers in an insecticide manufacturing plant. Hematological parameters and clinical symptoms were recorded in 99 workers exposed to insecticides and 107 workers not exposed to them in a cross-sectional study. Assessment of the hematological results showed a higher prevalence of thrombocytosis in the exposed group than the non-exposed group ($P < 0.05$). Mean white blood cell (WBC) and platelet counts, anisocytosis of red blood cells (RBCs), and neutrophils to lymphocytes ratio (NLR) were significantly higher in the exposed group compared to the non-exposed group ($P < 0.05$). Prevalence rates of headache, itchy skin, cough, and sleep disorders were higher in the exposed group than in the non-exposed group ($P < 0.05$). Chronic exposure to insecticides can alter hematological parameters in the normal range. Occupational exposure to insecticides may increase WBCs, platelet count, NLR, and red cell distribution width (RDW). It can also cause thrombocytosis. Complete blood count (CBC), as an inexpensive and accessible tool, can help monitor workers' health status exposed to insecticides properly.

1. Introduction

Insecticide use seems unavoidable in the modern agriculture system. As a result, numerous employees might be at the risk of occupational exposure to insecticides, including farmers and workers in pesticide manufacturing plants. However, the chronic effects of exposure to insecticides have not been thoroughly studied yet. In Iran, 18.5 million hectares are cultivated by 3.4 million farmers who are exposed to insecticides [1]. Insecticides are the most widely used pesticides (accounting for 94.5% of the total). Annual pesticide use has dramatically risen in Iran since 2000 reaching 27000 tons in 2003–2004. Pesticide manufacturing plants have increased in the recent decade, exposing a more significant number of workers to insecticides. The health effects of pesticide exposure have become a controversial and challenging issue in the present decade. Pesticide exposure may have numerous effects on human health. The available information suggests that pesticides can have long-term adverse effects on the reproductive, neurological, respiratory, and hematopoietic systems in humans. Moreover, long-term exposure to pesticides may also cause various types of cancer, including multiple myeloma, leukemia, and non-Hodgkin lymphoma [2].

Numerous meta-analyses have assessed the relationship between pesticide exposure and the risk of leukemia. For example, the odds ratio estimated for leukemia by Merhi et al. [3] and Van Maele-Fabry et al. [4] were 1.35 and 1.2, respectively. Perrotta et al. assessed the relationship of occupational exposure to pesticides and multiple myeloma in two case-control studies, and their estimated odds ratios for this disease were 1.5 and 1.6 [5,6]. Another study investigated hematological and biochemical parameters of farmers in Spain in 2016. The results showed that hemoglobin levels and RBC count, and WBC count significantly increased in the case group compared to the control group. The results also showed a significant increase in platelet count in the group exposed to high levels of pesticides compared to the group exposed to low levels of pesticides ($P < 0.05$) [7].

* Corresponding author.
E-mail address: attarchi602@gmail.com (M. Attarchi).

https://doi.org/10.1016/j.heliyon.2022.e09040
Received 30 September 2021; Received in revised form 6 January 2022; Accepted 28 February 2022

Identical numbers of farmers in the case group (n = 50) and the control group (n = 50) were examined in a case-control study in Thailand. Sixty percent of the farmers had more than 10 years of work experience. The mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and mean corpuscular hemoglobin (MCH) were significantly lower in the case group compared to the control group ($P < 0.05$) [8]. Eighty-three people who were exposed to pesticides and 98 people who were not exposed to pesticides were recruited in a cross-sectional study in Mexico in 2011. The results showed significantly lower hemoglobin and hematocrit levels and significantly higher platelet count in the case group compared to the control group [9].

An equal number of male farmers exposed to pesticides (n = 54) and healthy male farmers not exposed to pesticides (n = 54) were enrolled in a case-control study in southeastern Iran in 2012. The findings showed that the hematologic parameters had values in the normal ranges. Still, platelet count, RBC count, and hematocrit and hemoglobin levels were higher in the case group compared to the control group [10]. Given the widespread use of pesticides in Iran in the past decade and the absence of sufficient evidence on the health effects of these compounds on the Iranian population, researchers in this country should pay more attention to the diseases that are more likely to be caused by exposure pesticides. However, few studies have assessed the long-term effects of exposure to pesticides on diseases, especially those affecting the hematopoietic system, in Iran. Therefore, the present study assessed hematological parameters in the workers employed in an insecticide manufacturing plant in Iran.

2. Material and methods

2.1. Population and type of study

All the workers of the insecticide production line were enrolled as the exposed group and those in the packaging and loading units and the security guard personnel with no experience in the insecticide production line who were not exposed to insecticide (were not farmers, etc.) were recruited as the non-exposed group in a cross-sectional study in 2020. Inclusion criteria were at least 6 months of work experience [5], and exclusion criteria were incomplete occupational medical records, liver diseases, cardiovascular diseases, and cancers. All the participants were male. Demographic data, including age, height, weight, smoking experience, work experience, marital status, and education level, were collected using a checklist. This research design was approved by the Ethics Committee of Guilan University of Medical Sciences with the ethics code of IR.GUMS.REC.1399.632. Informed consent forms were collected from all the participants.

2.2. Types of insecticides

Documents related to the different types of insecticides, their environmental monitoring of the production halls and of the other units in the facility were collected in coordination with the Occupational Health and Safety and Environmental Protection (HSE) unit. Table 1 presents the concentrations of the insecticides in the indoor air in the workplace. Three types of insecticides were produced in the facility, namely organophosphate, carbamate, and pyrethroid insecticides. Only the concentration of carbaryl (a carbamate insecticide) was above the occupational exposure limit (OEL), and the concentrations of the other insecticides were below the OEL (Table 1). The concentrations of insecticides were negligible in the other units.

2.3. Medical examinations

The examinations included the medical records of the workers and the physical examinations. Symptoms of chronic pesticide poisoning were studied by studying the physical examinations and the medical records of the workers with the emphasis on the respiratory system (cough, shortness of breath, etc.), the neurological system (fatigue, tremor, cramps, sleep disorders, etc.), and the cutaneous system (skin redness, itching, etc.). The blood pressure measurement and blood sampling time performed between 7 am and 8:30 am just before the start of work. Measurements were performed with each subject sitting in a chair after a break of at least 5 min. Measurements within 30 min after eating or strenuous physical activity or smoking were avoided. Systolic and diastolic blood pressure were measured twice with a 10–12 cm × 40 cm cuff on a standard mercury sphygmomanometer. In this study, we used the average of two blood pressure measurements. Inclusion criteria of pesticide sprayers (exposed subjects) include male pesticide sprayers with age group of 18–60 years, and pesticide sprayers must have at least six months previous experience in spraying operations in the field. Also, due to the fact that this study is cross-sectional one, it was not possible to determine the persistence of symptoms, so having symptoms at the same time of the study was assessed.

Table 1. The main insecticides and their quantities in the insecticide production unit of the facility.

Pesticide	Group	Conc. (mg/m^3)	TLV-TWA (mg/m^3)
Carbaryl	Carbamate	0.79	0.5
Bendiocarb		0.05	0.1
Fenvalerate	Pyrethroid	1.25	5 (OSHA)
Cypermethrin		1.55	5 (OSHA)
Permethrin		Negligible	None
Allethrin		Negligible	None
Malathion	Organophosphate	0.1	1
Chlorpyrifos		0.06	0.1
Total dust	Dust	4.1	10

2.4. Parameters of hematologic

Hematological parameters included: RBC, Hb, HCT, MCV, PLT, red blood cell distribution width (RDW), erythrocyte sedimentation rate (ESR, mm/h), WBC, the absolute count of neutrophils (NEUT, $X \times 10^3$ μL), lymphocytes (LYM, $X \times 10^3$ μL), basophils (Baso, $X \times 10^3$ μL), monocytes (Mono, $X \times 10^3$ μL), and eosinophils (Eso, $X \times 10^3$ μL). The ratio of neutrophils to lymphocytes (N/L) was also calculated.

2.5. Statistical analysis

Mean, standard deviation, frequency, and percentage were used in descriptive statistics, the Shapiro-Wilk test to check the data for normality, and the Mann-Whitney test to compare the quantitative variables since data distribution was not normal. Chi-square test and Fisher's exact test were used to compare the frequency of clinical symptoms in the exposed and non-exposed groups. Chi-square analysis and Fisher's exact tests were used to assess the relationship of work experience (history of exposure to insecticides) with thrombocytosis. The participants were divided into two groups with more than and less than eleven years of work experience. Odds ratios (OR) with 95% confidence intervals (CI) were calculated to assess the relationship of exposure to insecticides with thrombocytosis. The significance level was $P < 0.05$.

3. Results

3.1. Demographic findings

Nighty-nine workers in the insecticide production unit were recruited as the exposed and 107 personnel in the other units as the non-exposed groups. All the participants were male. Their mean age 38 years (ranging from 22 to 66 years), average work experience 11.19 years (ranging from 2 to 28 years), and mean body mass index (BMI) 25.94 kg/

m^2 (ranging from 19 to 41 kg/m^2). Among them, 165 workers (80.1%) were married, and 42 (20.4%) had a smoking history. A comparison of demographic parameters in the two exposed and non-exposed groups is shown in Table 2. The Shapiro-Wilk test was used to check data normality, and Mann-Whitney and Chi-square tests to compare demographic variables since the assumption of data normality was rejected. There were no statistically significant differences between the exposed and non-exposed groups in terms of average age, work experience, BMI, history of smoking, and marital status ($P > 0.05$) (Table 2).

3.2. Clinical examination

The Shapiro-Wilk test was used to check data normality. Data distribution was not normal. Therefore, Mann-Whitney and Chi-square tests were used to compare the clinical variables. Clinical examination revealed that mean systolic blood pressure values in the exposed and non-exposed groups were 125.45- and 124.95-mm Hg, respectively. This difference was not statistically significant ($P > 0.05$). The mean diastolic blood pressure values in the exposed and non-exposed groups were 80.15 and 79.81-mm Hg, respectively. The difference was not statistically significant ($P > 0.05$). The prevalence rates of headaches, itchy skin, cough, and sleep disorders were significantly higher in the exposed group than the non-exposed group ($P < 0.05$). The prevalence rates of headache in the exposed and non-exposed groups were fourteen (14.14%) and four (3.73%), respectively. The difference was statistically significant (OR = 4.24, 95% CI: 1.34–13.36, P = 0.012). The prevalence rates of itchy skin in the exposed and non-exposed groups were eleven (11.11%) and three (2.83%), respectively. The difference was statistically significant (OR = 4.32, 95% CI: 1.27–16.02, P = 0.025). The prevalence rates of cough in the exposed and non-exposed groups were nineteen (19.20%) and eight (7.50%), respectively. The difference was statistically significant (OR = 2.93, 95% CI: 1.22–7.16, P = 0.019). The prevalence rates of sleep disorders in the exposed and non-exposed groups were twelve (12.12%) and four (3.74%), respectively. The difference was statistically significant (OR = 3.53, 95% CI: 1.10–11.41, P = 0.035).

3.3. Hematological findings

The Shapiro-Wilk test was used to check data normality. Data distribution was not normal. Therefore, the Mann-Whitney test was used to compare the hematological variables. The mean values of PLT, RDW WBC, neutrophil, basophil, eosinophil, and NLR in the exposed group were significantly higher than the non-exposed group ($P < 0.05$) (Table 3). Eleven workers (5.34%) suffered from thrombocytosis (PLT> 450×10^3 μL), and the prevalence of thrombocytosis in the exposed group was significantly higher than the non-exposed group (P = 0.05) (Table 4). There was a significant relationship between work experience and the prevalence of thrombocytosis. The prevalence of thrombocytosis in the group with more than 11 years of work experience was significantly higher than the group with less than 11 years of work experience (P = 0.017) (Table 4). The average year of work experience in the group with an incidence of thrombocytosis (22.44 years) was significantly higher than the group with no incidence of thrombocytosis (11.14 years) ($P < 0.001$).

Table 2. Assessment of demographic variables in the exposed and non-exposed groups in a pesticide manufacturing plant.

Variable		Exposed group	Non-exposed group	P-value
Age (year)	Mean ± SD	38.56 ± 7.98	37.57 ± 7.53	0.31
Work experience (year)		11.23 ± 6.48	11.17 ± 5.97	0.97
BMI (Kg/m^2)		26.05 ± 3.32	25.84 ± 3.40	0.68
Marital status N (%)	Marriage Single	76 (78.4) 21 (21.6)	89 (83.2) 18 (16.8)	0.47
Smoking N (%)	Yes No	20 (20.2) 79 (79.8)	22 (20.6) 85 (79.4)	0.99

Table 3. Comparison of hematological parameters between the exposed and non-exposed groups in the pesticide manufacturing plant.

Parameter	Exposed group	Non-exposed group	P-value
	Mean ± SD	Mean ± SD	
RBC ($X\times10^6$ μL)	5.45 ± 0.46	5.29 ± 0.50	0.138
Hb (g/dL)	15.37 ± 1.21	15.07 ± 1.04	0.161
HCT (%)	45.54 ± 3.23	45.75 ± 2.49	0.078
MCV (fL)	85.93 ± 4.11	86.89 ± 3.46	0.072
RDW (%)	13.24 ± 1.15	11.96 ± 0.83	0.001
WBC ($X\times10^3$ μL)	7.17 ± 1.70	6.65 ± 1.50	0.026
NEUT ($X\times10^3$ μL)	4.45 ± 1.05	4.01 ± 0.90	0.008
LYM ($X\times10^3$ μL)	2.17 ± 0.31	2.08 ± 0.35	0.068
Mono ($X\times10^3$ μL)	0.24 ± 0.05	0.23 ± 0.05	0.298
Eos ($X\times10^3$ μL)	0.16 ± 0.03	0.16 ± 0.07	0.027
Baso ($X\times10^2$ μL)	0.02 ± 0.03	0.01 ± 0.01	0.002
N/L	2.05 ± 0.36	1.91 ± 0.25	0.029
PLT ($X\times10^3$ μL)	266.01 ± 83.41	232.46 ± 47.75	0.001

4. Discussion

Insecticides can have adverse effects on various human body organs. These effects may be due to occupational exposure to insecticides. An investigation on Health symptoms related to pesticide exposure has illustrated that occupational exposure to pesticides can be associated with a higher prevalence of respiratory and muscular symptoms. AChE (an enzyme that terminates the neurotransmitter acetylcholine at neuromuscular junctions and cholinergic brain synapses) activity, which known to be a biomarker of exposure to occupational exposure and carbamates, was a biomarker of exposure to occupational exposure and carbamate [11]. A study by Mwabulambo has demonstrated that 95% of pesticide applicators reported the handling of organophosphorus pesticides. Physical weakness was the most commonly reported neurological symptom (57.1%), followed by sweating and headache (40.7%), anorexia and depression (29.3%), and irritation (26.4%). rice field. About 27% of pesticide sprayers had acetylcholinesterase levels below the limit [12]. The hematological parameters were compared in the exposed (chronic exposure to insecticides) and non-exposed groups. The mean WBCs, neutrophils, basophils, NLR, RBCs (anisocytosis), and platelet counts were significantly higher in the exposed group compared to the non-exposed group ($P < 0.05$). Although most previous studies examined the hematologic parameters for acute poisoning, a limited number of them assessed chronic occupational exposure. WBC counts were significantly higher in the exposed group in this study, which was consistent with those of the previous studies [7, 13, 14] and could be due to immune response to insecticides exposure. A statistically significant increase was detected in WBCs (neutrophils and basophils) in the exposed group compared to the

Table 4. The relationship between the prevalence of thrombocytosis and exposure to pesticides and work experience in a pesticide manufacturing plant.

Groups	Thrombocytosis		Adjusted OR	%95 CI	P-value
	Yes	No			
Exposed (N-%)	9 (9.10)	90 (90.90)	4.752	0.978–23.089	0.05
Non-exposed (N-%)	2 (1.87)	105 (98.13)			
Work experience >11 years	10 (10.75)	83 (89.25)	12.568	1.564–100.981	0.017
Work experience ≤11 years	1 (0.01)	112 (99.99)			

Fisher's exact test.

non-exposed group ($P < 0.05$). Tang et al. showed an increase in neutrophil counts in acute organophosphate and paraquat poisoning [15]. Wafa et al. reported higher WBC counts (monocytes and lymphocytes) in farmers [16]. Cortés-Iza et al. [14] and Fareed et al. [17] noticed higher monocyte counts in those chronically exposed to insecticides. These results were consistent with those of the present study. A significant increase was detected in monocyte counts in most studies [14, 15, 16]. Monocytes are involved in chronic inflammation. Basophil counts increased in the present study, which could also be explained by the chronic inflammation process that is expected in insecticide exposure. Platelet count significantly increased in the exposed group in our study, which was in agreement with the results of previous studies [10, 13, 14, 15, 16, 17, 18]. Abu Mourad reported a significant increase in the mean platelet counts in Palestinian farmers compared to the control group ($P < 0.05$) [19]. The prevalence of thrombocytosis was 9.09% in the exposed group in our study—platelet production increases in cases of inflammation and high oxidative stress. Wafa et al. [16] also showed that long-term exposure to insecticides was accompanied by oxidative stress. The prevalence of thrombocytosis was higher in the participants with more years of work experience in our study, which could indirectly suggest the level of exposure to insecticides. However, it lacked an acceptable confidence interval range, which could probably be resolved by using a larger sample size. Of course, the mean work experience in the group with thrombocytosis was significantly higher than the group with no incidence of thrombocytosis. A study suggested that organophosphorus and carbamate pesticides can affect megakaryocyte formation by cholinergic receptors, which can reduce MPV. However, neither the exact effect of cholinergic substances on megakaryocyte formation nor the receptors that may mediate these effects have been identified [20]. Also, in another study, it has been reported that in patients with acute pesticide poisoning, hemoperfusion caused impaired platelet aggregation with incomplete platelet activation, which was associated with decreased thrombin formation with increased fibrinolysis [21]. Al-Sarar et al. found no difference in hematological parameters between the exposed and the non-exposed groups except for white blood cell increased in the group exposed to the insecticides. The difference might be due to differences in the type of insecticides and durations of exposure to them [22].

In our study, a significant increase was detected in the mean NLR in the group chronically exposed to insecticides compared to the control group. Defne Dundar et al. suggested that NLR could be used as a prognostic factor for pesticide poisoning [23]. Previous studies showed elevated NLRs in cases of pesticide poisoning [22, 23, 24]. Moreover, animal studies demonstrated that chronic exposure to chlorpyrifos increased NLR [25]. As mentioned earlier, exposure to pesticides causes inflammation and oxidative stress. Previous studies reported that NLR served as a strong prognostic indicator for inflammation [26, 27].

In our study, RBCs increased in the group exposed to insecticides than the non-exposed group, but the difference was not significant. Oxidative stress shortens RBC lifespan. As a result, bone marrow increases the production of RBCs to compensate for the shortened lifespan of RBCs. RBCs also increase in case of heavy metal poisoning. The mechanism of insecticide poisoning might be similar to that of heavy metal poisoning. RDW reflects the degree of heterogeneity of erythrocyte volume. Numerous studies have reported an increase in RDW levels in cases of inflammation [28] and oxidative stress [29]. Acute pesticide poisoning causes oxidative stress-dependent inflammatory responses accompanied by the production of free radicals and dysfunction in the body's antioxidant defense mechanism [30, 31]. Elevated RDW also serves as a prognostic marker for chronic inflammation and high oxidative stress [32]. Inflammation and oxidative stress are also involved in the pathophysiology of organophosphate poisoning, which leads to the elevation of inflammatory cytokines, including interleukin-8 and β1 [32,33]. Oxidative stress and inflammation prevent RBC maturation. Chronic exposure to organophosphate and other insecticides is also associated with oxidative stress in people [34]. Increases in RDW in the exposed group compared to the control group in this study may be due to inflammation and oxidative stress caused by exposure to pesticides. These results were consistent with those of the studies by Soltaninejad [33] and García-García et al. [7]. Insecticide exposure increases sensitivity of erythrocytes and lymphocytes to oxidative stress and shortens their lifespan, which causes anisocytosis and lymphopenia. This eventually increases neutrophils and decreases lymphocytes in cases of inflammation, which increases NLR. Chronic exposure to insecticides was likely to cause changes in hematological parameters in the normal range in this study. The mean WBC and platelet counts, NLR, and RDW significantly increased in the exposed group compared to the non-exposed group. The prevalence of thrombocytosis also significantly increased in the exposed group compared to the non-exposed group. The difference in the results of previous studies could be due to the type of study, exposure to different types of pesticides, pesticide concentration, and duration of pesticide exposure. Previous studies assessed the relationship between exposure to pesticides and various hematopoietic cancers. A meta-analysis (a review of 14 studies published between 1984 and 2004) showed that occupational exposure to pesticides increased the risk of leukemia in adults by 1.4- fold [4]. Van Maele-Fabry et al. reviewed 17 cohort studies published between 1979 and 2005 in a meta-analysis and reported that occupational exposure to pesticides increased the risk of leukemia in adults [35]. However, no case of cancer was detected in this study, which might be due to the type of study and the healthy worker effect. It is recommended to create a registry network for those exposed to pesticides to determine the long-term side effect. The prevalence of headaches, itchy skin, cough, and sleep disorders was significantly higher in the exposed group than the non-exposed group in this study ($P < 0.05$). These results were consistent with those of the previous studies [9, 19, 36]. Most of the hematological parameters were inside the normal ranges in this study, which is a challenging clinical finding. However, alterations in several hematological parameters were detected in the exposed group compared to the control group. The healthy worker effect can be neutralized in a format of a longitudinal study with longer follow-up, which may help obtain more significant clinical results. Nevertheless, a higher prevalence of thrombocytosis was detected in the exposed group compared to the non-exposed group. Therefore, it is recommended that hematological parameters be assessed in periodic occupational health examinations in shorter intervals. It might also be necessary to arrange biological monitoring of workers exposed to insecticides. This was a cross-sectional study with relatively small sample size. Therefore, it is recommended to perform a prospective study with larger sample size.

In this study, environmental monitoring was performed to measure insecticides, which of course cannot be the exact amount of exposure of workers to insecticides, and this was the limitation of our study. Naturally, it is better to do biological types of monitoring, such as measuring serum cholinesterase levels. Also, there are several factors making hematological changes, while in this present study, we mostly focus on insecticides effects on hematological changes.

5. Conclusion

This study showed that chronic exposure to insecticides might alter hematological parameters within the normal ranges. Therefore, occupational exposure might increase WBC and platelet counts, NLR, and RDW. Occupational exposure to insecticides can also cause thrombocytosis. Consequently, future investigations should undertake a main effort to evaluate the identity and the level of pesticides exposure and should control for the most possible potential confounders. However, our result supports the suggestion that exposure to a common pesticides, is a fundamental factor.

Ethical approval

This research design was approved by the Ethics Committee of Guilan University of Medical Sciences with the ethics code of IR.GUMS.REC.1399.632.

Consent to participate

Each participant gave written consent to use his/her data in a given research study.

Consent for publication

All authors approved the manuscript and agreed to be accountable for all aspects of this research.

Availability of data and material (data transparency)

Data will be made available on request.

Code availability (software application or custom code)

Not applicable.

Declarations

Author contribution statement

Fatemeh Nejatifar, Mohammad Abdollahi, Mirsaeed Attarchi, Zahra Atrkar Roushan, Alireza Etemadi Deilami, Maryam Joshan, Fateme Rahattalab, Niloofar Faraji and Hamid Mohammadi Kojidi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors are grateful to the workers and authorities of the plant under study and the Razi Clinical Research Development Center in Rasht that helped us carry out this study. The paper was extracted from MD Thesis of two medical students submitted in partial fulfillment of the requirements for MD degrees (Ms. Rahattalab and Ms. Joshan).

References

[1] S. Mostafalou, S. Karami-Mohajeri, M. Abdollahi, Environmental and population studies concerning exposure to pesticides in Iran: a comprehensive review, Iran. Red Crescent Med. J. 15 (2013), e13896.
[2] S. Gangemi, E. Gofita, C. Costa, M. Teodoro, G. Briguglio, D. Nikitovic, et al., Occupational and environmental exposure to pesticides and cytokine pathways in chronic diseases (Review), Int. J. Mol. Med. 38 (2016) 1012–1020.
[3] M. Merhi, H. Raynal, E. Cahuzac, F. Vinson, J.P. Cravedi, L. Gamet-Payrastre, Occupational exposure to pesticides and risk of hematopoietic cancers: meta-analysis of case-control studies, Cancer Causes Control 18 (2007) 1209–1226.
[4] G. Van Maele-Fabry, S. Duhayon, C. Mertens, D. Lison, Risk of leukaemia among pesticide manufacturing workers: a review and meta-analysis of cohort studies, Environ. Res. 106 (2008) 121–137.
[5] C. Perrotta, A. Staines, M. Codd, S. Kleefeld, D. Crowley, T.M. A, et al., Multiple Myeloma and lifetime occupation: results from the EPILYMPH study, J. Occup. Med. Toxicol. 7 (2012) 25.
[6] C. Perrotta, S. Kleefeld, A. Staines, P. Tewari, A.J. De Roos, D. Baris, et al., Multiple myeloma and occupation: a pooled analysis by the international multiple myeloma consortium, Cancer Epidemiol. 37 (2013) 300–305.
[7] C.R. García-García, T. Parrón, M. Requena, R. Alarcón, A.M. Tsatsakis, A.F. Hernández, Occupational pesticide exposure and adverse health effects at the clinical, hematological and biochemical level, Life Sci. 145 (2016) 274–283.
[8] K. Suwannahong, A. Sridon, W. Pongstaporn, P. Thongmuang, Y. Sudjaroen, Biochemical and hematological status in rice farmers with chronic pesticide exposure, suphan Buri, Thailand, EXECUTIVE EDITOR 11 (2020) 1352.
[9] A.E. Rojas-García, I.M. Medina-Díaz, L. Robledo-Marenco Mde, B.S. Barrón-Vivanco, M.I. Girón-Pérez, J.B. Velázquez-Fernández, et al., Hematological, biochemical effects, and self-reported symptoms in pesticide retailers, J. Occup. Environ. Med. 53 (2011) 517–521.
[10] S.J. Emam, M. Salehcheh, M.H. Hughighizadeh, S.M.H.M. Jazayeri, Occupational exposure to pesticides among farmers, Pak. J. Med. Sci. Quar. 28 (2012) 120.
[11] R. Sapbamrer, S. Nata, Health symptoms related to pesticide exposure and agricultural tasks among rice farmers from northern Thailand, Environ. Health Prev. Med. 19 (2014) 12–20.
[12] S.G. Mwabulambo, E.J. Mrema, A.V. Ngowi, S. Mamuya, Health symptoms associated with pesticides exposure among flower and onion pesticide applicators in Arusha region, Ann. Glob. Health 84 (2018) 369–379.
[13] V.K.S. Aradhna Singh, Haematological alterations in sprayers occupationally exposed to multiple pesticides, Am.-Eurasian J. Toxicol. Sci. 6 (2014) 35–38.
[14] S.C. Cortés-Iza, A.I. Rodríguez, E. Prieto-Suarez, Assessment of hematological parameters in workers exposed to organophosphorus pesticides, carbamates and pyrethroids in Cundinamarca 2016-2017, Rev Salud Publica (Bogota) 19 (2017) 468–474.
[15] Y. Tang, L. Hu, G. Hong, D. Zhong, J. Song, G. Zhao, et al., Diagnostic value of complete blood count in paraquat and organophosphorus poisoning patients, Toxicol. Ind. Health 34 (2018) 439–447.
[16] T. Wafa, K. Nadia, N. Amel, C. Ikbal, T. Insaf, K. Asma, et al., Oxidative stress, hematological and biochemical alterations in farmers exposed to pesticides, J. Environ. Sci. Health B 48 (2013) 1058–1069.
[17] M. Fareed, M.K. Pathak, V. Bihari, R. Kamal, A.K. Srivastava, C.N. Kesavachandran, Adverse respiratory health and hematological alterations among agricultural workers occupationally exposed to organophosphate pesticides: a cross-sectional study in North India, PLoS One 8 (2013), e69755.
[18] W.Y. el-Sadek, M.H. Hassan, Chronic lymphocytic leukaemia in Egyptian farm workers exposed to pesticides, East. Mediterr. Health J. 5 (1999) 960–966.
[19] T. Abu Mourad, Adverse impact of insecticides on the health of Palestinian farm workers in the Gaza Strip: a hematologic biomarker study, Int. J. Occup. Environ. Health 11 (2005) 144–149.
[20] E. Varol, S. Ogut, F. Gultekin, Effect of pesticide exposure on platelet indices in farm workers, Toxicol. Ind. Health 30 (2014) 630–634.
[21] S. Park, M.I. Islam, J.H. Jeong, N.J. Cho, H.Y. Song, E.Y. Lee, et al., Hemoperfusion leads to impairment in hemostasis and coagulation process in patients with acute pesticide intoxication, Sci. Rep. 9 (2019) 13325.
[22] A. Al-Sarar, Y. Abo Bakr, G. Al-Erimah, H. Hussein, A. Bayoumi, Hematological and biochemical alterations in occupationally pesticides-exposed workers of Riyadh municipality, Kingdom of Saudi Arabia, Res. J. Environ. Toxicol. 3 (2009) 179–185.
[23] Z.D. Dundar, M. Ergin, R. Koylu, R. Ozer, B. Cander, Y.K. Gunaydin, Neutrophil-lymphocyte ratio in patients with pesticide poisoning, J. Emerg. Med. 47 (2014) 286–293.
[24] Naema Mahmoud Elhosarya ESA-E, Red Cell Distribution width, Nettrophil lymphocyte and platelet lymphocyte ratios as prognostic markers in acutely pesticides- poisoned patients, Egypt J. Forensic Sci. Appl. Toxicol. 18 (2018) 29–40.
[25] S. Ambali, A. Abubakar, M. Shittu, L. Yaqub, S. Anafi, A. Abdullahi, Chlorpyrifos-induced alteration of hematological parameters in Wistar rats: ameliorative effect of zinc, Res. J. Environ. Toxicol. 4 (2010) 55–66.
[26] C.P. de Jager, P.T. van Wijk, R.B. Mathoera, J. de Jongh-Leuvenink, T. van der Poll, P.C. Wever, Lymphocytopenia and neutrophil-lymphocyte count ratio predict bacteremia better than conventional infection markers in an emergency care unit, Crit. Care 14 (2010) R192.
[27] R. Zahorec, Ratio of neutrophil to lymphocyte counts–rapid and simple parameter of systemic inflammation and stress in critically ill, Bratisl. Lek. Listy 102 (2001) 5–14.
[28] M. Rondanelli, S. Perna, T.A. Alalwan, R. Cazzola, C. Gasparri, V. Infantino, et al., A structural equation model to assess the pathways of body adiposity and inflammation status on dysmetabolic biomarkers via red cell distribution width and mean corpuscular volume: a cross-sectional study in overweight and obese subjects, Lipids Health Dis. 19 (2020) 154.
[29] R.D. Semba, K.V. Patel, L. Ferrucci, K. Sun, C.N. Roy, J.M. Guralnik, et al., Serum antioxidants and inflammation predict red cell distribution width in older women: the Women's Health and Aging Study I, Clin. Nutr. 29 (2010) 600–604.
[30] M. Abdollahi, A. Ranjbar, S. Shadnia, S. Nikfar, A. Rezaie, Pesticides and oxidative stress: a review, Med. Sci. Mon. Int. Med. J. Exp. Clin. Res. 10 (2004) Ra141–R147.
[31] S. Tsuboi, K. Miyauchi, T. Kasai, M. Ogita, T. Dohi, T. Miyazaki, et al., Impact of red blood cell distribution width on long-term mortality in diabetic patients after percutaneous coronary intervention, Circ. J. 77 (2013) 456–461.
[32] M. Schäfer, F. Koppe, B. Stenger, C. Brochhausen, A. Schmidt, D. Steinritz, et al., Influence of organophosphate poisoning on human dendritic cells, Chem. Biol. Interact. 206 (2013) 472–478.
[33] K. Soltaninejad, M. Abdollahi, Current opinion on the science of organophosphate pesticides and toxic stress: a systematic review, Med. Sci. Mon. Int. Med. J. Exp. Clin. Res. 15 (2009) Ra75–90.

[34] L.J. Mbah Ntepe, R. Habib, N. Judith Laure, S. Raza, E. Nepovimova, K. Kuca, et al., Oxidative stress and analysis of selected SNPs of ACHE (rs 2571598), BCHE (rs 3495), CAT (rs 7943316), SIRT1 (rs 10823108), GSTP1 (rs 1695), and gene GSTM1, GSTT1 in chronic organophosphates exposed groups from Cameroon and Pakistan, Int. J. Mol. Sci. (2020) 21.

[35] G. Van Maele-Fabry, S. Duhayon, D. Lison, A systematic review of myeloid leukemias and occupational pesticide exposure, Cancer Causes Control 18 (2007) 457–478.

[36] G.J. Ohayo-Mitoko, H. Kromhout, J.M. Simwa, J.S. Boleij, D. Heederik, Self reported symptoms and inhibition of acetylcholinesterase activity among Kenyan agricultural workers, Occup. Environ. Med. 57 (2000) 195–200.