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OXIDATIVE STRESS INDICES OF ORGANOPHOSPHATES PESTICIDES AMONG AGRICULTURAL WORKERS AT MIT-GHAMR DISTRICT, EGYPT

Raghda Ali Elshamy[1]*, Aida Abdel Hamid Hassan[1], Safaa Abd El-Moez El-Naggar[1], Mahmoud Abd elghany Nomier[2], Dalia Abdallah El-Shafei[1]

[1] Industrial Medicine and Occupational Health Department, Faculty of medicine, Zagazig University, Egypt

[2] Forensic Medicine and Clinical Toxicology Department, Faculty of medicine, Zagazig University, Egypt.

*Corresponding author:
mr_forever08@yahoo.com

ABSTRACT

Background: Organophosphates pesticides (OPs) exert their toxicity on the body through inhibition of Cholinesterase Enzyme (ChE) in the nerve and muscle tissues. Inhibition of cholinesterase itself cannot account for the wide range of disorders that have been reported following OPs exposure as **oxidative stress** has been implicated as one of the mechanisms for the adverse health effects of OPs exposure.

Aim of the study: To study oxidative stress among agricultural workers through assessment of blood level of Butyl Choline Esterase enzyme (BuChE), as an indicator of exposure to OPs, assessment of blood level of Malondialdehyde (MDA), as an indicator of oxidative stress, and erythrocyte activity of Superoxide Dismutase (SOD), as an indicator of antioxidant activity and identification of occupational and personal risk factors that may be associated with oxidative stress among agricultural workers.

Subjects and methods: A comparative cross sectional study was conducted among 48 agricultural workers exposed to OPs and 48 subjects non-exposed to OPs. Both two groups were subjected to a structured questionnaire included questions about Socio-demographic and Occupational history, followed by laboratory investigations to measure BuChE, MDA and SOD.

Results: This study showed that the median level of MDA was significantly higher among exposed group compared to non-exposed group, while the median levels of BuChE and SOD were significantly lower among exposed group compared to non-exposed group. The level of BuChE, MDA and SOD were significantly correlated with each other and with work duration (years), number of worked hours/day, hours of spraying pesticides/day. Non-usage of personal protective equipment (PPE) and lack of washing facilities increased the risk of abnormal MDA and SOD. Duration of work (years) and number of worked hours / day were the significant predictors for abnormal oxidative indices.

Conclusion: The study concluded that exposure to OPs can induce abnormal oxidative stress indices among agricultural workers. So, it is recommended to do regular screening of agricultural workers, design strategies that can reduce pesticide exposure, provide PPE all time and encourage workers to take antioxidants regularly.

Keywords: Oxidative Stress Indices, Organophosphate Pesticides, Agricultural workers, Egypt

INTRODUCTION

Egypt as one of the most populous countries in Africa depends mainly on agricultural activities as major sources of national income of Egypt, contributing up to 14.5 % of Growth Domestic Production (GDP). Therefore, pesticides are frequently used in Egypt to control and prevent pests [1]. Pesticides are defined by Food and Agriculture Organization (FAO) of the United Nations as any chemical substance or organism or device used to attack, inhibit, control and/or get rid of pests, plants (weeds), animals, and insects that cause harm to crops [2]

Pesticide use in crop production worldwide was increased nearly twenty fold from 1960 to 2000 and further increased from 1.0 billion tons in 2002 to 1.7 billion in 2007. During 2010 and 2014, the mean pesticide cost/benefit was 0.645 g pesticide use (total) / kg crop production, and the mean annual pesticide use (total) was to be 2.784 kg / kg crop production [3].

Worldwide, approximately five billion tons of pesticides are consumed annually, among which organophosphate (OPs) and carbamate insecticides present (70%), dithiocarbamate fungicides present (18%) and phenoxyl herbicides present (12%) [4].

Organophosphates pesticides exert their toxicity on the target through inhibition of Cholinesterase Enzyme (ChE) in the nerve and muscle tissues. Inhibition of cholinesterase itself cannot account for the wide range of disorders that have been reported following OPs pesticides exposure as oxidative stress has been implicated as one of the mechanisms for the adverse health effects of OPs pesticides exposure [5].

Oxidative stress is a term used to describe various hazardous processes resulting from an imbalance between the excessive formation of Reactive Oxygen Species (ROS) and/or Reactive Nitrogen Species (RNS) and limited antioxidant defenses [6]. Oxidative stress induced by pesticides, either by overproduction of free radicals or by alteration in antioxidant defense mechanisms, including detoxification and scavenging enzymes [7].

Pesticides results in production of reactive oxygen species which in turn brings down the antioxidant levels and their defense against oxidative damage in the cellular system. Lipids, proteins and nucleic acids are targeted due to this imbalance and cellular signaling pathways are affected. Oxidative stress and reactive oxygen species induce the long-term health effects such as carcinogenesis, neuro-degeneration, cardiovascular, respiratory, renal, endocrine and reproductive problems [8].

SUBJECTS AND METHODS

Study design and settings: A comparative cross sectional study was conducted at Mit Ghamr district, Dakhlia governorate in the period from October 2016 to December 2018.

Target groups: Exposed group included agricultural workers exposed to OPs pesticides on performing their job. Non-exposed group which included relatives, friends and neighbors of the participants who were working as drivers, seller men, carpenters and employees, and not exposed to OPs pesticides at their current occupation nor even had a past occupational history of exposure to OPs pesticides.

Sample size: Calculated through Open-EPI, according to the following collected data: The mean of malondialdehyde (MDA) level among pesticide applicators was 0.458 (±0.03) u/mg protein and among non-exposed group was 0.489 (±0.07l) u/mg protein [9], the power of precision was 80%, and the confidence interval was 95%, so the sample was 96 participants (48 exposed and 48 non-exposed workers).

Sample technique: Multistage random sampling, firstly Mit-Ghamr district was divided in to 40 villages, then five villages were selected by simple random sampling (Kom Elnor, Sempo, Dkadose, Damas, Sanafa), then at each village workers in their agricultural areas were selected by cluster random sampling.

Data collection: All participants in the study were subjected to a structured questionnaire which was used to collect information about Socio-demographic data such as age, marital status, level of education, income and smoking habits. Occupational history such as, duration of work (years), number of worked hours/ day, type of used pesticides, frequency of pesticides exposure, hours of spraying pesticides, usage of personal protective equipment (PPE), presence of washing facilities and facility of agricultural association. Laboratory investigations were done for both groups by measuring Butyl Choline Esterase Enzyme (BuChE) to assess exposure to OPs pesticides, Malondialdehyde (MDA) to assess oxidative stress status and Superoxide dismutase (SOD) activity to assess antioxidant status. Blood samples were collected by a trained medical assistant using sterile syringes. Four ml venous blood were collected and divided into2 halves. Half of the blood collected into tubes containing potassium Ethylenediaminetetraacetic acid (k-EDTA) for measuring of SOD. The other half of the blood collected in plain glass tubes and was left to clot, serum was obtained to measure BuChE and MDA. The samples were measured by Spectrophotometry in molecular biology department of scientific research center, Faculty of Medicine, Zagazig University. BuChE activity was determined by the method of **Knedel and Bottger** [10], where Butyl Cholinesterase hydrolyses butyrylthiocholine to give thiocholine and butyrate, the reaction between thiocholine and 2-nitrobenzoic acid (DTNB) gives 2-nitro-5-Mercaptobenzoate, a yellow compound which can be measured at 405 nm, and the reference range of BuChE is 3500 -8500 U/L. MDA was estimated by the method of **Ohkawa et al.** [11], where Thiobarbituric acid (TBA) reacts with Malondialdehyde in acidic medium at temperature of 95°C for 30 min to form thiobarbituric acid and the absorbance of the resultant pink product can be measured at 534 nm, and the reference range of MDA is 0.12 - 1.71 nmol/ml. SOD was estimated by the method of **Nishikimi et al.** [12], which relies on the ability of the enzyme to inhibit the phenazine methosulphate-mediated reduction of nitroblue tetrazolium dye, and the reference range of SOD is164 – 240 u/ml. These indices were considered abnormal when exceeding the normal ranges.

Data management: The collected data were entered, checked and statistically analyzed using SPSS program (Statistical Package for Social Science) version 22.0 [13]. For the statistical calculations, data coding was done, and qualitative data were represented as frequencies and percentages, Chi-square test (χ 2), Fisher Exact test were carried out for testing the association between the qualitative data (Risk and Outcome). Quantitative data were presented as median and compared using Mann-Whitney-U test. Correlations were tested by pearson test. Multiple linear regression analysis was conducted to identify the predictors of each indicator. The test results were considered significant when p-value ≤ 0.05.

Ethical Considerations:

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 [14]. Institutional Review Board (IRB) of the Faculty of Medicine, Zagazig University approved the study protocol (No. 2761). An informed consent was obtained from all participants of this study and they were told about the aim of the study, and were informed that the data would be used for scientific purposes only.

RESULTS

The exposed and non-exposed groups were comparable as regards age, marital status, the level of education and income. More than half of the workers in both groups were current smokers, 53.9% of smokers of exposed group have been smoking for 20 to less than 30 years, while 46.9% of smokers of non-exposed group have been smoking for 10 to less than 20 years. Smokers in both groups were smoked two and more packs /day and all those differences between both groups were statistically not significant. Fifty two percent of the workers of exposed group worked for 20 to less than 30 years, while 47.9 % of workers of non-exposed group worked for 10 to less than 20 years. More than half of the workers in both groups worked for 8 to less than 12 hours/day, and all those differences between both groups were statistically not significant.

Results demonstrated that the workers in exposed group used malathion, parathion and dimethoate (20,8%, 20,8% and 8.4% respectively) however, 50.0% of workers used more than one type of pesticides **(Figure 1)**.

Figure (2): showed that 47.9% of exposed workers spray pesticides monthly, about 69% of the studied agriculture workers didn't use PPE and 60% of the studied agriculture workers didn't have washing facilities after pesticides use.

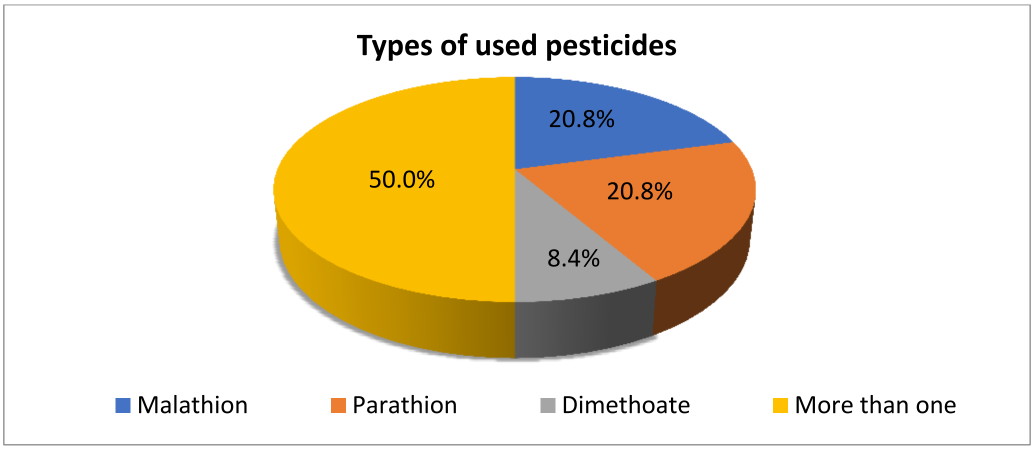

Figure 1 Frequency of types of used pesticides among studied agricultural workers

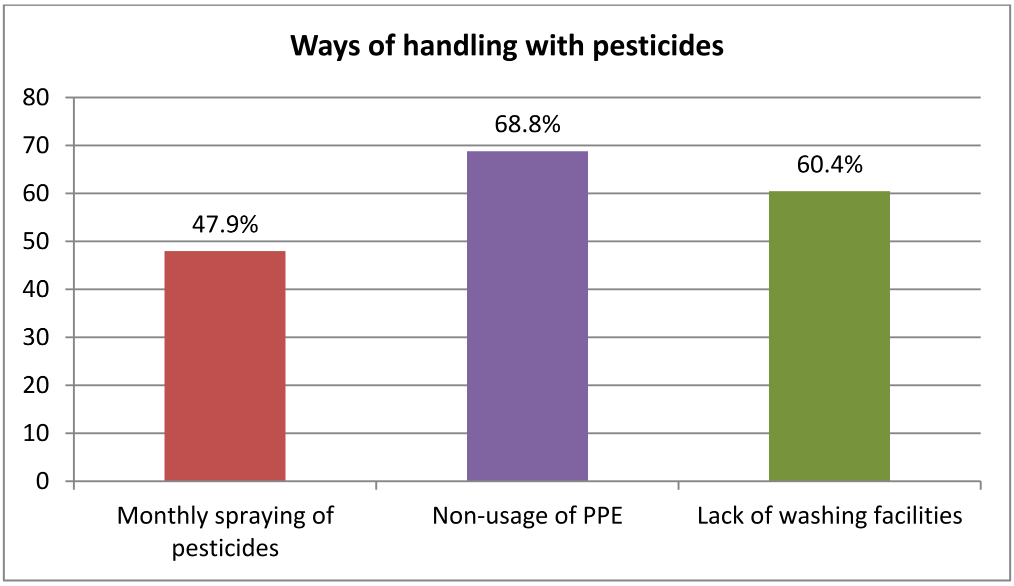

Figure 2 Frequency of ways of handling with pesticides among studied agricultural workers.

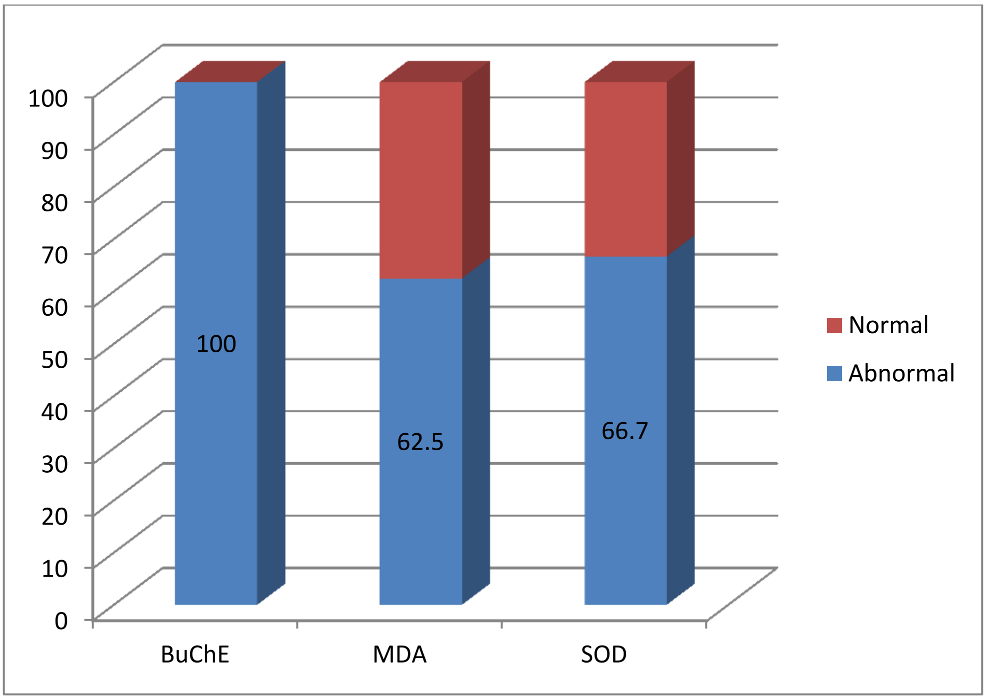

Figure 3 Frequency of levels BuChE & MDA & SOD among studied agricultural workers.

Table 1 Levels of BuChE, MDA & SOD among both exposed and non-exposed groups.

Biomarkers	**Exposed group N=48** Median (Range)	**Non exposed group N=48** Median (Range)	**Mann-Whitney**	**P –value**
BuChE	1069.03 (228.70 – 2853.34)	3990.62 (1000 - 6897.98)	8.09	0.000*
MDA	3.55 (1.58 - 6.60)	0.99 (0.23 - 4.56)	7.22	0.000*
SOD	135.49 (44.70 - 325.85)	251.54 (99.01 - 380.80)	3.92	0.000*

Table 2 Pearson correlation coefficient between some socio-demographic and job characteristics and levels of BuChE & MDA & SOD among exposed group.

Socio-demographic and job characteristics	**BuChE**		**MDA**		**SOD**	
	r	**P-value**	**r**	**P-value**	**r**	**P-value**
Age	0.25	0.08	0.13	0.37	0.17	0.25
Duration of smoking	0.19	0.32	0.02	0.85	0.22	0.28
No. of smoked cigarettes	0.09	0.63	0.12	0.44	0.14	0.49
Duration of work (years)	-0.32	0.02*	0.36	0.01*	-0.32	0.02*
No. of worked hours /day	-0.37	0.01*	0.41	0.004*	-0.33	0.02*
Hours of spraying pesticides /day	-0.43	0.002*	0.45	0.001*	-0.34	0.01*
BuChE	-	-	- 0.69	0.000*	0.51	0.000*
MDA	- 0.69	0.000*	-	-	-0.62	0.000*
SOD	0.51	0.000*	- 0.62	0.000*	-	-

Table 3 Effect of ways of handling pesticides on the level of MDA and SOD among exposed group.

Ways of handling pesticides	**Normal**		**Abnormal**		**OR (CI 95%)**	**p- value**
	NO.	**%**	**NO.**	**%**		
MDA: **Usage of Personal Protective equipment** Yes (n=15) No (n=33)	 9 9	 60.0 27.3	 6 24	 40.0 72.3	4.00 (1.11 – 14.47)	0.03*
Washing facilities Yes (n=19) No (n=29)	11 7	 57.9 24.1	 8 22	 42.1 75.9	4.32 (1.24 – 15.02)	0.02*
SOD: **Usage of PPE** Yes (n=15) No (n= 33)	8 8	53.3 2493	7 25	46.7 7597	3.57)1911 –1299 6(	0.04*
Washing facilities Yes (n=19) No (n=29)	10 6	52.6 2197	9 23	4794 7993	4.25)1919– 15919(	0.02*

(Only significant factors were presented in the table)

- The factors such as types of used pesticides, frequency of spraying pesticides, facility of agricultural association didn't significantly associated with abnormal MDA neither abnormal SOD.

Table 4 Multiple linear regression analysis for the significant predictors of abnormal BuChE, MDA and SOD.

Predictors	**B**	**S.E**	**t**	**P- value**
Butyl Choline Esterase: No. of worked hours /day R^2=0.42	-29.91	14.5	2.06	0.04*
Malondialdehyde: Duration of work/ year No. of worked hours /day R^2= 0.53	0.07 0.28	0.03 0.10	2.01 2.81	0.05* 0.007*
Superoxide Dismutase: Duration of work/ year R^2= 0.38	- 4.1	1.97	2.08	0.04*

(Only significant predictors were presented)

- Predictors were: duration of work, no. of worked hours /day, hours of spraying pesticides, non-usage of PPE and lack of washing facilities.

Table (1): demonstrated that the median level of MDA was significantly higher among exposed group compared to non-exposed group, while the median levels of BuChE and SOD were significantly lower among exposed group compared to non-exposed group (p-value = 0.000).

All workers in exposed groups showed abnormal level of BuChE (100%), while 62.5% of workers had abnormal MDA and 66.7% had abnormal SOD **(Figure 3)**.

There were no statistical correlations between age, duration of smoking and the number of smoked cigarettes and the levels of BuChE, MDA and SOD, while the level of MDA significantly increased with increased work duration (years), no. of worked hours/day and hours of spraying pesticides/day and decreased levels of BuChE and SOD, and the levels of SOD and BuChE enzyme were significantly decreased with each other's and with increased work duration (years), no. of worked hours /day and hours of spraying pesticides /day **(Table 2)**.

Non-usage of PPE and lack of washing facilities significantly increased risk of both abnormal MDA and abnormal SOD by about four times. (OR = 4.00 and 4.32) for MDA, and (OR = 3.57 and 4.25) for SOD **(Table 3)**.

Table (4): demonstrated that the duration of work(years) was the significant predictor for increased level of MDA and decreased level of SOD, and no. of worked hours/day was the significant predictor for decreased level of BuChE and increased level of MDA.

DISCUSSION

Oxidative stress as a possible mechanism of toxicity for pesticides has become a focus of toxicological research because it is considered as a critical pathophysiological mechanism in different human pathologies, including cancer, immunosuppression and neurodegenerative diseases that are associated with pesticide exposure [5]. There are many studies which depend on the metabolites of organophosphates pesticides as markers for exposure to these pesticides [15]. In our study; we estimated level of BuChE as a marker of exposure to OPs. The advantages of this biomarker for prediction of pesticides exposure may be because of their high sensitivity, easy measurement and depending on the level of exposure [16]. The results of the present study showed a significant decrease in BuChE levels in agricultural workers occupationally exposed to pesticides in comparison to the non-exposed group {1069 (228.70-2853.34)U/ml versus 3990 (1000-6897.98)U/ml) }, (p-value=0.000) **(table 1)**. This agrees with a study of **Mecdad et al.** in (Al-Salheya farms, Zagazig), which found that exposed agricultural workers recorded reduction in ChE level 1284.2 ± 245U/ml versus non-exposed group 6768.8 (±446.029) U/ml [7]. Also a lot of studies in Tunisia [17], Nigeria[9], Thiland [18] and India were in accordance with our results [19]. In contrast with this study, studies of **Ogut et al.** [20] and **Sudjaroen** [21] didn't observe any statistical significant difference between both groups as regard BuChE levels. This contrast may be as a result of different levels of exposure in different countries due to usage of PPE or having washing facilities afire pesticides use. Also, different methods of assessing exposure may be the cause of this contrast.

Oxidative stress, as said by **Addollahi et al.** plays an important role in the toxicity of various xenobiotics, including OPs, synthetic pyrethroid, organochlorine and carbamate pesticides, and more recently, Organophosphates free radicals (OFRS) have been implicated in the toxicity of pesticides. The ability of OPs to produce OFR may be due to their "redox-cycling" activity. They readily accept an electron to form free radicals and then transfer them to oxygen to generate superoxide anions and hence H_2O_2 through dismutation reaction [22]. If oxidants are not efficiently removed by antioxidant defense systems, they may react with biological macromolecules causing enzyme inactivation, DNA damage, and lipid peroxidation in tissues [5].

The present study revealed a significant increase in MDA level, the biomarker of lipid peroxidation, in exposed group in comparison to non-exposed group {3.55 (1.58 - 6.60) U/ml versus 0.99 (0.23 - 4.56) U/ml}, (p-value = 0.000) **(table 1)**. **Ayala et al.** study said that MDA has been used for many years as a convenient biomarker for lipid peroxidation and is one of the most popular and reliable markers to determine oxidative stress in clinical situations [23]. Furthermore, **Kisby et al. study** in USA reported that Serum MDA levels were 4.9 times and 24 times higher in farm workers and applicators, respectively, than in controls [24], also **Vidyasagar et al.** results were in line with our results [25]. Moreover, our results are in consistent with a recent Egyptian study of **Noshy et al** which was conducted in El Monofya governorate, and reported an increased MDA levels in farm workers and pesticides applicators than the controls [26]. Moreover, other studies support these result [7] [9] [14] [27]. In contrast, **Zepeda-Arce et al.** study which was conducted in Mexico among 139 men and 69 women who worked as OPs sprayers and divided in to reference, moderately exposed and highly exposed groups, revealed that MDA levels were not different among these study groups [5]. This difference may be due different levels of exposure to OPs.

Hernandez et al. said that oxidative stress induced by pesticide exposure may result in inhibition of SOD activity, leading to accumulation of superoxide radicals [28]. A plausible mechanism of pesticides leading to inhibition of SOD activity is interaction of reactive oxygen species with the thiol group present at the catalytic center of the enzyme and previous studies have shown that superoxide radicals may inhibit CAT and GPx activities resulting in excessive production of hydrogen peroxide and inhibition of SOD [29]. The present study revealed that SOD was significantly lower among exposed group compared to non-exposed group, (p-value = 0.000) **(table 1)**, this is in agreement with **Vidyasagar et al.** who reported that RBC SOD was lower among exposed versus control group [25]. Other studies in India and Egypt showed the same reduction in the SOD activity in the exposed groups [19-26]. In contrast to these results, some studies found an elevation of SOD levels in exposed group like **Simoniello et al.** [30]. Also, an Iranian study of **Ahmadi et al.** revealed an increase in SOD level to 61.0% [31], and this is attributed to an activation of the compensatory mechanism through the pesticide-induced overproduction of reactive species [28].

The present study revealed that there were no statistical correlations between age, duration of smoking and the number of smoked cigarettes and the levels of BuChE, MDA and SOD **(table 2)**. This is in consistent with a study of **López et al.** who reported that exposure to pesticides was a determinant in the alternation of SOD, independent of age [29]. However, **Wafa et al.** found that there was a significant relation between changes in biological markers, and the farmers' age [17].

Smoking during pesticide spraying may increase the absorption of pesticides both through inhalation of the airborne particles and through oral ingestion of the pesticide particles attached to cigarettes [32]. In this study there were non-significant correlations between BCHE, MDA, SOD levels and smoking duration neither number of smoked cigarette **(table 2)**, and this agree with studies of **Lopez et al.** [29] and **Zepeda-Arce et al.** [5].

The present study revealed that level of MDA significantly increases with increased work duration(years), number of worked hours/day and hours of spraying pesticides /day **(table 2)**, this in consistent with a study of **Mecdad et al.** who found that MDA levels positively correlated with the duration of exposure to pesticides, and higher MDA levels in populations with permanent work as sprayers compared to those who reported temporary work as sprayers [7]. However, **Hernández et al.** study showed no significant correlation between oxidative stress biomarkers and years of exposure [28]. Regarding SOD and BuChE, it was found that both significantly decrease with increased work duration (years), number of worked hours /day and hours of spraying pesticides /day **(table 2)**, and this agree with studies of **Mostafalou and Abdollahi** [33] and **Surajudeen et al.** [9]. Moreover, **Noshy et al.** found a negative correlation between the inhibition in BuChE activities and the period of exposure to pesticides (day/year) in exposed workers [26]. The inverse correlation indicates that the longer the duration of exposure to OPs, the lower the ChE activity and the more the risk of adverse effect of OPs.

Correlations coefficient between the three oxidative stress markers revealed that a strong negative correlation between the level of MDA and level of BuChE (r = -0.69) (p-value = 0.000), and positive correlation between the level of Superoxide Dismutase and Butyl Choline esterase enzyme (r = 0.56), (p-value = 0.000) **(table 2)**, and these are in line with **Surajudeen et al.** [9], **Zepeda-Arce et al.** [5] and **Noshy et al.** [26] as all found an inverse correlation between BuChE and MDA activities. This suggests that the more depressed serum AChE activity in OP exposed farm workers, the higher the MDA level and the higher the risk of oxidative damage due to oxidative stress. In contrast, a study of **Ahmadi et al.** found that the inhibition in BuChE activity correlated with the increase in total anti-oxidant capacity [31], and these findings may be explained by the adaptive and defensive responses to the generated free radicals induced by pesticide exposure, respectively.

In bivariate analysis, Non-usage of PPE and lack of washing facilities significantly increased risk of abnormal MDA and SOD among the studied agricultural workers by about four times. The same results were documented by a study in Mexico of **Zepeda-Arce et al.** [5], so it is very important to educate agricultural workers how to use PPE, and to increase availability of washing facilities.

Finally in multiple linear regression analysis, the significant predictors for oxidative stress indices were duration of work (years) and number of worked hours/day. **Madani et al.** reported that biochemical and toxic damage induced by OPs will suggest an association with the labor conditions as working hours [34].

Conclusion: The study concluded that exposure to organophosphate pesticides can induce abnormal oxidative stress indices among agricultural workers. The median level of MDA was significantly higher among exposed group compared to non-exposed group, while the median levels of BuChE and SOD were significantly lower among exposed group compared to non-exposed group. The levels of BuChE, MDA and SOD significantly correlated with each other's. Duration of work (years) and number of worked hours/day were the significant predictors for abnormal oxidative stress indices. So it is recommended to regular screening of agricultural workers, design strategies that can reduce pesticide exposure, provide PPE all time and encourage workers to take antioxidants regularly.

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REFERENCES

[1] Raslan A.A, Elbadry S and Darwish W.S. Estimation and Human Health Risk Assessment of Organochlorine Pesticides in Raw Milk Marketed in Zagazig City, Egypt Journal of Toxicology, 2018; 8. Avialable at:https://doi.org/10.1155/2018/3821797

[2] Hamzah A.A. The Toxicity of Inert Ingredients in Pesticide Formulations to Soil Bacteria. Adelphi University, ProQuest Dissertations Publishing, 2014. 1528258.

[3] Zhang WJ. Global pesticide use: Profile, trend, cost / benefit and more. Proceedings of the International Academy of Ecology and Environmental Sciences, 2018; 8(1): 1-27.

[4] Ye M, Beach J, Martin J and Senthilselvan A . Occupational Pesticide Exposures and Respiratory Health. Int J Environ Res Public Health, 2013; 10(12): 6442–6471.

[5] Zepeda-Arce R , Rojas-García A.E, Benitez-Trinidad A, Herrera-Moreno J.F, Medina-Diaz I.M, Barrou-Virance B.S et al. Oxidative stress and genetic damage among workers exposed primarily to organophosphate and pyrethroid pesticides. International Journal of Pharmaceutical and Clinical Research, 2017; 9(3): 205-209. 10.25258/ijpcr.v9i3.8319 doi: ISSN- 0975 1556. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/tox.22398

[6] Lobo V, Patil A, Phatak A and Chandra A. Free radicals, antioxidants and functional foods: Impact on human health. ncbi, 2010; 4(8): 118–126. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3249911/

[7] Mecdad A.A, Ahmed M.H, ElHalwagy M.E.A and Afify M.M.M et al. A study on oxidative stress biomarkers and immune modulatory effects of pesticides in pesticide-sprayers. Egyptian Journal of Forensic Sciences, 2011; 1(2): 93-98.

[8] Abou El-Magd S , Sabik LM and shoukry A. pyrethroid toxic effects on some hormonal

profile and biochemical markers among workers in pyrethroid insecticides company. Life Science Journal, 2011; 8(1): 311-322. http://www.lifesciencesite.com.

[9] Surajudeen Y.A, Sheu R.K, Ayokulehin K.M and Olatunbosun A.G. Oxidative stress indices in Nigerian pesticide applicators and farmers occupationally exposed to organophosphate pesticides. Int J Appl Basic Med Res, 2014; 4(1): S37–S40. doi: 10.4103/2229-516X.140730

[10] Knedel M and Bottger R. A kinetic method for determination of the activity of pseudocholinesterase (acylcholine acyl-hydrolase 3.1.1.8) Klin Wochenschr, 1967; 45: 325–7.

[11] Ohkawa H, Ohishi N and Yagi K. Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. Anal Biochem, 1979; 95(2): 351-359.

[12] Nishikimi M, Rao N and Yagi K. The occurrence of superoxide anion in the reaction of reduced phenazine methosulfate and molecular oxygen. Biochem. Biophys. Res. Commun, 1972; 46(2): 849-854.

[13] IBM Corp. IBM SPSS Statistic for windows, version 22.0.Armonk, NY 2013; IBM Corp.

[14] World Medical Association Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects: Bull. World Health Organ. Epub, 2001;74: 373–374. Available at: https://www.ncbi.nlm.nih.gov/pubmed/11357217

[15] Lee K.M, Park S.Y, Lee K, Oh S.S and Ko S.B. Pesticide metabolite and oxidative stress in male farmers exposed to pesticide. Ann Occup Environ Med, 2017; 29:5. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5331740/

[16] Lionetto M.G, Caricato R, Calisi A, Giordano M.E, and Schettino T. Acetylcholin esterase as a biomarker in environmental and occupational medicine: new insights and future perspectives. Biomed Res Int, 2013: 321213. Available at: https://www.hindawi.com/journals/bmri/2013/321213/abs/

[17] Wafa T, Nadia K, Amel N, Ikbal C, Insaf T, Asma K, et al. Oxidative stress, hematological and biochemical alterations in farmers exposed to pesticides. J Environ Sci Health B, 2013; 48(12): 1058-69. doi: 10.1080/03601234.2013.824285.

[18] Hongsibsong S, Kerdnoi T, Polyiem W, Srinual N, Patarasiriwong V and Prapamontol T. Blood cholinesterase activity levels of farmers in winter and hot season of Mae Taeng District, Chiang Mai Province, Thailand. Environ Sci Pollut Res, 2015; 25: 7129. DOI 10.1007/s11356-015-4916.

[19] Fareed M, Kesavachandran C, Bihari V, Kamal R and Kuddus M. Oxidative stress and cholinesterase depression among farm workers occupationally exposed to pesticides in india. J. Environ. Biol, 2017; 38:305. doi: 10.22438/jeb/38/2/MS-188.

[20] Ogut S, Kucukoner E, Gultekin F and Gurbuz N. A Study of Long-Term Pesticide Application Amongst Agricultural Workers: Total Antioxidant Status, Total Oxidant Status and Acetylcholinesterase Activity in Blood. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 2015; 85(1): 155-159.

[21] Sudjaroen Y. Comparison of biochemical, hematological parameters and pesticide expose-related symptoms among organic and non-organic farmers, singburi, thailand. Asian J. Pharm, 2017; 11. doi: 10.22377/ajp.v11i01.1114.

[22] Abdollahi M, Mastafalow S, Pournourmohamnadi S and Shadnia S. Oxidative stress and cholinesterase inhibition in saliva and plasma of rats following subchronic exposure t malathion comound. Comp bio Biochem Physiol C. Toxicol Pharmacol , 2004; 133: 29-39.

[23] Ayala A, Mu~noz M.F and Arg€uelles: Lipid peroxidation: production, metabolism and signaling mechanisms of malondialdehyde and 4- hydroxy-2-nonenal. Oxidative Med Cell Longevity, 2014; 1–31.

[24] Kisby G.E , Muniz J.F, Scherer J, Michael R. L, Koshy M, Yoke W. K et al. Oxidative Stress and DNA Damage in Agricultural Workers. Journal of Agromedicine, 2009; 14(2): 206-214. Available at: https://www.ncbi.nlm.nih.gov/pubmed/19437279

[25] Vidyasagar J, Karunakar N, Reddy M.S, Rajnarayana K, Surender T and Krishna DR. Oxidative stress and antioxidant status in acute organophosphorus insecticide poisoning. Indian J Pharmacol, 2004; 36: 76-79.

[26] Noshy M.M, Saad-Hussein A and Shahy E.M : Assessment of Anti choline esterase Toxicity, Oxidative Stress and Antioxidant Status in Carbamate and Organophosphorus Pesticides-Exposed Agricultural Workers. Toxicological & Environmental Chemistry, 2017; 9(3): 205-209. Available at: http://www.tandfonline.com/loi/gtec20

[27] Gaikwad A.S, Karunamoorthy P, Kondhalkar S.J, Ambikapathy M and Beerappa R.

Assessment of hematological, biochemical effects and genotoxicity among pesticide sprayers in grape garden. Journal of Occupational Medicine and Toxicology ,2015; 10:11.

[28] Hernandez A.F, Marina L, Gil F, Rodriguz-Barranco M , Pla A and López-Guarnidoet O. Evaluation of pesticide-induced oxidative stress from a gene-environment interaction perspective. Toxicology, 2013; 307: 95–102.

[29] López O, Hernández A.F, Rodrigo L, Gil F , Pena G and Serano G.L, et al. Changes in antioxidant enzymes in humans with long-term exposure to pesticides. Toxicol. Lett, 2007; 171: 146–153. doi: 10.1016/j.toxlet.2007.05.004

[30] Simonian A.L, Good T.A, Wang S.S and Wild J.R. Nanoparticle based optical biosenses for the direct detection of organophosphate chemical warfare agent and pesticides. Anal Chim Acta, 2005 ; 534: 69–77.

[31] Ahmadi N, Mandegary A, Jamshidzadeh A, Mohammadi-Sardoo M, Salari E and Leyla Pourgholi L. Hematological Abnormality, Oxidative Stress, and Genotoxicity Induction in the Greenhouse Pesticide Sprayers; Investigating the Role of NQO1 Gene Polymorphism.Toxics, 2018; 6: 13

[32] Abdalla M.S, Saad-Hussein A, Salah K, El-mezayen H.A and Osman N.F.A. Effects of smoking on the oxidant/antioxidant balance and the blood lipids in pesticide sprayers. Toxicol Ind Health, 2012; 31: 173–178.

[33] Mostafalou S and Abdollahi M . Pesticides and human chronic diseases: evidences, mechanisms and prespectives. Toxicol Appl Pharmacol, 2013; 268: 157–177.

[34] Madani F.Z, Hafida M, Merzouk S.A, Loukidi B, Taouli K and Narce M. Hemostatic, inflammatory, and oxidative markers in pesticide user farmers. Biomarkers, 2016; 21: 138–145.

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