FREQUENCY OF PERSISTENT ORGANIC POLLUTANTS IN SERUM SAMPLES OF ELECTRONICS WORKERS IN SHARKIA GOVERNORATE, EGYPT

Hebatalla M Aly[1], Reham B Ibraheem[1], Reem M Mahmoud[2], Ahmed Ismail[3], Sarah M Hussein[1]

[1]Department of Public Health, Community, Occupational and Environmental Medicine, Faculty of Medicine, Suez Canal University, Egypt.

[2]Department of Clinical Pathology, Faculty of Medicine, Suez Canal University, Egypt.

[3]Department of Pharmacognosy, Faculty of Pharmacy, Fayoum University, Egypt.

ABSTRACT

Background: Persistent Organic Pollutants (POPs) are toxic chemicals that persist in the environment, bioaccumulate in living organisms and pose a threat to human health and the environment. They can cause a range of health problems, including cancer, developmental and reproductive effects, and immune system damage. This study aims to assess the frequency of detection of POPs among electronics workers. **Subjects and Methods**: The study included 155 electronics workers. Blood samples were collected from all participants and tested for 6 categories of POPs which are dioxins, furans, polycyclic aromatic hydrocarbons (PAH), hexachlorobenzene, bromo derivatives and polychlorinated biphenyls (PCBs) by using gas chromatography coupled with mass spectrometry (GC/MS). **Results:** Approximately 78% of participants showed POPs in their serum samples and two-thirds of polluted workers had more than one congener up to 13 different POPs congeners detected in the same sample. The most frequent category detected in participants was furans (62%), followed by PAH (61%). POPs were detected among 84% of blue collars compared to 54% of white ($p < 0.001$). Body mass index, blood pressure, random blood sugar and glycated hemoglobin were evaluated in a comparative manner between participants with detected POPs and those without, but the difference was not statistically significant. **Conclusion:** There is high frequency of POPs detection in serum samples of workers in electronics industries which reflects high exposure either occupationally or environmentally. Further studies should be performed to track the source of exposure and start prevention strategy. Follow-up of participants to detect any complications related to POPs.

Keywords: *Persistent organic pollutants (POPs), furans, polycyclic aromatic hydrocarbons (PAH), electronics workers.*

Corresponding author: Dr. Hebatalla Mohamed Aly
Email: *dr.hebatalla@gmail.com*
https://orcid.org/0000-0003-3949-6480

INTRODUCTION

Persistent Organic Pollutants (POPs) are a group of chemical substances that are characterized by their persistence in the environment, long-range transport, potential for bioaccumulation, and toxicity. These properties lead to a wide range of negative impacts on human health, wildlife, and ecosystems ***(EPA, 2009).***

POPs are a major global environmental health concern because they are resistant to degradation, can travel long distances, and accumulate in the food chain, leading to potential human exposure through food, air, and water. Moreover, they can cause a range of health problems, including cancer, developmental and reproductive effects, and immune system damage ***(Fitzgerald et al., 2014)***.

Some POPs as polychlorinated biphenyls (PCBs) are considered endocrine disruptors and are linked to type 2 diabetes and prediabetes ***(Lee et al., 2011; Evertt et al., 2011)***. International efforts have been made to reduce the presence of POPs in the environment, including the Stockholm Convention on Persistent Organic Pollutants, which is a treaty signed by over 170 countries, with the aim of eliminating the production and use of certain POPs ***(Fitzgerald et al., 2014)***.

Some common types of POPs include ***(Miniero et al., 2015)***:

- Dioxins and Furans: They are by-products of combustion processes and industrial activities such as plastic and wood burning, and pesticide production.
- Polychlorinated Biphenyls (PCBs): Used in the manufacture of electrical equipment, paints, and adhesives.
- Hexachlorobenzene (HCB): Used as a fungicide in agriculture and an intermediate in the production of other chemicals.
- Pesticides: Some pesticides, such as DDT, are persistent in the environment and have been linked to adverse health effects, including cancer and endocrine disruption. Other insecticides as lindane and chlordane are also classified as persistent organic pollutants (POPs) due to their persistence in the environment and toxicity to wildlife and humans.
- Brominated flame retardants: Used in electronics equipment, building materials, and textiles.

  According to The World Health Organization (WHO); Dioxins and furans are toxic chemicals that are produced as by-products of various industrial processes, such as the incineration of wastes, the production of pesticides and herbicides, and the manufacture of certain chemicals. They are also produced as a result of natural processes, such as forest fires and volcanic eruptions. Dioxins and furans are highly persistent in the environment and can accumulate in the food chain, including in human tissues. They are classified as persistent organic pollutants (POPs) due to their long half-life in the environment and their ability to bioaccumulate in living organisms. Exposure to dioxins and furans can have a range of adverse health effects, including cancer and endocrine disruption ***(WHO, 2016)***.

  WHO, (2016) has classified dioxins as highly toxic and carcinogenic to humans. As a result, measures have been taken in many countries to reduce human exposure to dioxins and furans, including regulations on emissions from industrial processes and restrictions on the use of certain chemicals.

THE AIM OF THE WORK

This study was conducted to assess the frequency of detection of 6 categories of POPs among workers in electronics industry.

SUBJECTS AND METHODS

Ethics

The study was approved by institutional research ethics committee with approval number (4146) on 27/ 4 / 2020.

The study procedures are in accordance with the guidelines of Helsiniki declarations of the world medical association, on human experimentation.

Study design

Descriptive cross sectional study design. This is the 1st phase of a research project in which we assessed frequency of 6 categories of POPs in serum samples of workers in electronics industries then in the 2nd phase, we assessed the relation between biphenyls (PCBs and PBBs) and type 2 diabetes though assessment the difference in levels of RBS and HbA1c as indicators of glycemic control among positive workers compared to negative workers.

Study setting and population

All workers in electronic companies in the industrial area of 10th of Ramadan city, Egypt represented our sampling frame then, we chose 3 companies by simple random method. A complete list of workers from the each of the 3 companies was obtained then, 52 workers were selected from each company list by simple random method. One sample was lost due to tube break during transport to give a total of 155 participants entered the analysis. In phase 2, three participants were excluded because they were diabetics before the start of the study.

Methods

Data were collected by using:

- Structured interview questionnaire (inquired about socio-demographic characteristics, occupational and medical history),
- Measurements: blood pressure, weight and height measurements and,
- Collected blood samples for assessment of POPs, random blood sugar and glycated

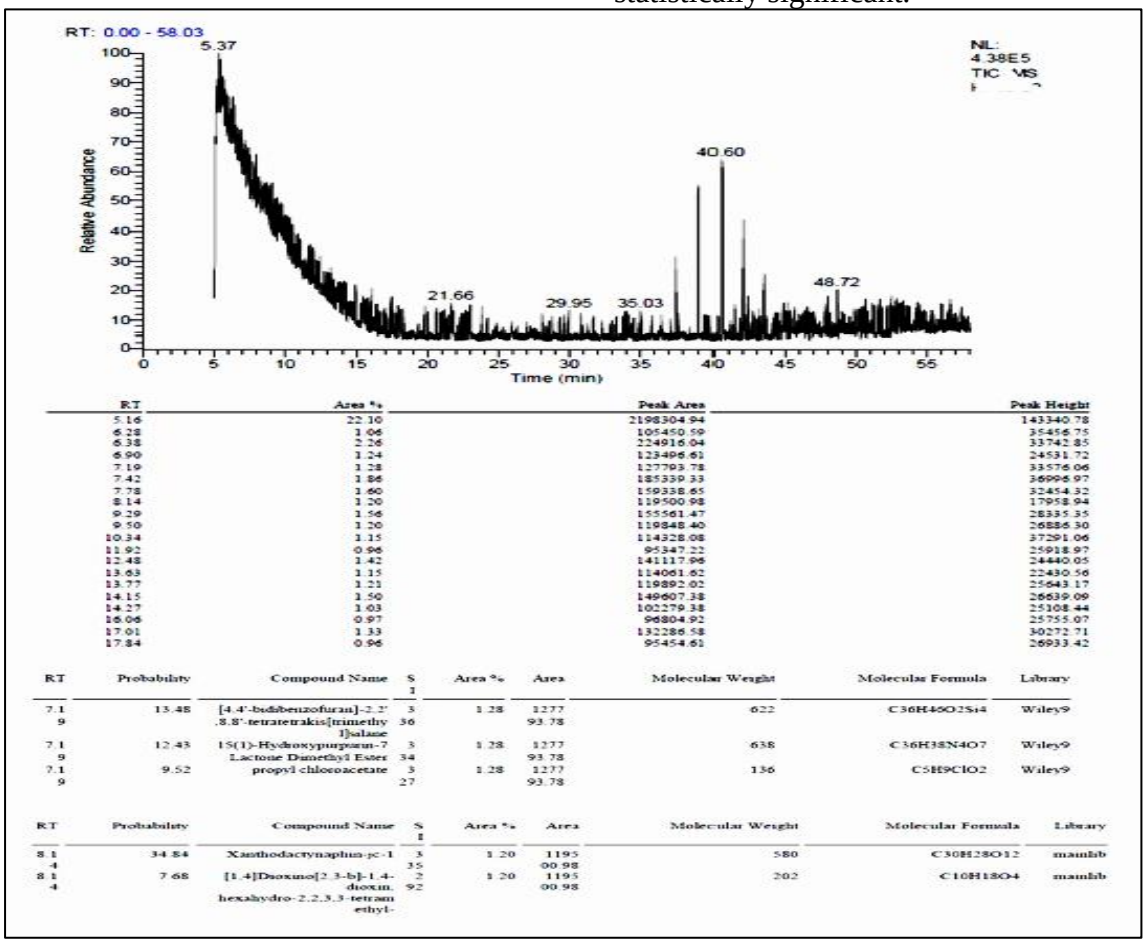
haemoglobin. Five ml of blood were collected from each participant and were divided into 2 tubes. One was for blood sugar and HbA1c testing. The 2nd tube was sent to central toxicology laboratory of the faculty of Science - Suez Canal university wher it was centrifuged, prepared and stored for further analysis by GC/MS.

- GC/MS analysis was performed in the national research centre, analytic method summary; Trace GC Ultra / ISQ Single Quadruple MS, USA with TG-5MS fused silica capillary column. Helium gas was used as the carrier gas at a constant flow rate of 1mL/min. The temperature of the MS transfers line and injector was fixed at 280 ^{o}C. The oven temperature was set to start at 50 °C (hold for 2 minutes), increase to 150 °C at a rate of 7 °C/min, then to 270 °C at a rate of 5 °C/min (hold for 2 minutes), and finally to 310 °C as a final temperature at a rate of 3.5 °C/min (hold for 10 minutes).

A tentative identification of the compounds was performed based on the comparison of their relative retention time and mass spectra with those of the NIST, WILLY library data of the GC/MS system. Random blood sugar and HbA1c testing was done by fully automated auto analyzer Cobus C501. More details of laboratory analysis methods are discussed in phase 2 manuscript. Part of GC/MS of a participant with dioxin and furan in his sample is shown in **figure (I)**.

STATISTICAL ANALYSIS

All data were coded and entered in SPSS version 25. Quantitative data were presented as mean and standard deviation while qualitative data were presented as frequency and percentage. Data normality was tested by Kolmogrov Smirov test and all laboratory tests and blood pressure reading were not normally distributed. The difference between workers with detected POPs and those without were assessed by Mann Whitney U test and the difference in detection between blue collars and white collars was tested by Chi square test. P value<0.05 was considered statistically significant.



RT	Area %	Peak Area	Peak Height
5.16	22.10	2198304.94	143340.78
6.28	1.06	105450.59	35456.75
6.38	2.26	224916.04	33742.85
6.90	1.24	123496.61	24531.72
7.19	1.28	127793.78	33576.06
7.42	1.86	185339.33	36996.97
7.78	1.60	159338.65	32454.32
8.14	1.20	119500.98	17958.94
9.29	1.56	155561.47	28335.35
9.50	1.20	119848.40	26886.30
10.34	1.15	114328.08	37291.06
11.92	0.96	95347.22	25918.97
12.48	1.42	141117.96	24440.05
13.63	1.15	114061.62	22430.56
13.77	1.21	119892.02	25543.17
14.15	1.50	149607.38	25639.09
14.27	1.03	102279.38	25108.44
16.06	0.97	96804.92	25755.07
17.01	1.33	132286.58	30272.71
17.84	0.96	95454.61	26933.42

RT	Probability	Compound Name	S	Area %	Area	Molecular Weight	Molecular Formula	Library
7.19	13.48	[4,4'-bidibenzofuran]-2,2',3,3',8,8'-tetratetrakis[trimethylsilane	36	1.28	1277 93.78	622	C36H46O2Si4	Wiley9
7.19	12.43	1S(1)-Hydroxypurpuran-7 Lactone Dimethyl Ester	34	1.28	1277 93.78	638	C36H38N4O7	Wiley9
7.19	9.52	propyl chloroacetate	27	1.28	1277 93.78	136	C5H9ClO2	Wiley9

RT	Probability	Compound Name	S	Area %	Area	Molecular Weight	Molecular Formula	Library
8.14	34.84	Xanthodactynaphin-pc-1	35	1.20	1195 00.98	580	C30H28O12	mainlib
8.14	7.68	[1,4]Dioxuno[2,3-b]-1,4-dioxin, hexahydro-2,2,3,3-tetramethyl-	92	1.20	1195 00.98	202	C10H18O4	mainlib

Figure (I): Part of GC/MS tracing of a participant with dioxin and furan in his serum sample

RESULTS

One hundred and fifty-five participants were enrolled in the current study who were working in electronics industry in 10th of Ramadan city, Egypt. Socio-demographic characteristics of participants are shown in **table (1)**. Six groups of persistent organic pollutants were assessed in serum samples of all participants which were (dioxins, furans, polycyclic aromatic hydrocarbons (PAH), hexachlorobenzene, bromo derivatives and polychlorinated biphenyls (PCBs). The frequency of POPs detection among samples of study participants is shown in **figure (1)**. One hundred and twenty-one participants (78.1%) had POPs in their serum. About one-third of participants positive for POPs had only one congener in their serum while the remaining two-thirds had more than one congener up to 13 different congeners detected in the same sample **(Figure 2)** with median and IQR equals 2, 3 respectively. The frequency of each of the 6 POPs classes among positive participants is shown in **table (2)**. The most frequently detected POP was furans detected in 61.9% of positive followed by PAH detected in 61.2%. The least detected class was PCBs which was detected in only 2 samples.

Table (1): Socio-demographic characteristics of participating electronics workers (n =155)

Characteristic	Frequency	Percentage
Age in years		
• 20 – 40	99	63.9
• > 40 – 60	56	36.1
Mean ± SD	37.3 ± 8.7	
Marital status		
• Single	17	11
• Married	138	89
Education		
• Illiterate	2	1.3
• Read and write	1	0.6
• 1ry / preparatory education	8	5.2
• 2ndry / technical education	106	68.4
• University education	33	21.3
• Postgraduate education	5	3.2
Occupation		
• Blue collar	124	80
• White collar	31	20
Duration of work in years		
• < 5	24	15.5
• 5 – 10	28	18.1
• > 10	103	66.5
Mean ± SD	13.1 ± 6.9	
Smoking status		
• Non-smoker	109	70.3
• X smoker	6	3.9
• Current smoker	40	25.8
Chronic diseases		
• No	133	85.8
• Yes	22	14.2
✓ Hypertension	11	7.1
✓ Diabetes mellitus	3	1.9
✓ Heart diseases	1	0.6
✓ Dyslipidemia	4	2.6
✓ Thyroid diseases	1	0.6
✓ Liver diseases	4	2.6
✓ Renal diseases	2	1.3
✓ Allergies	8	5.2
✓ Others	2	1.3

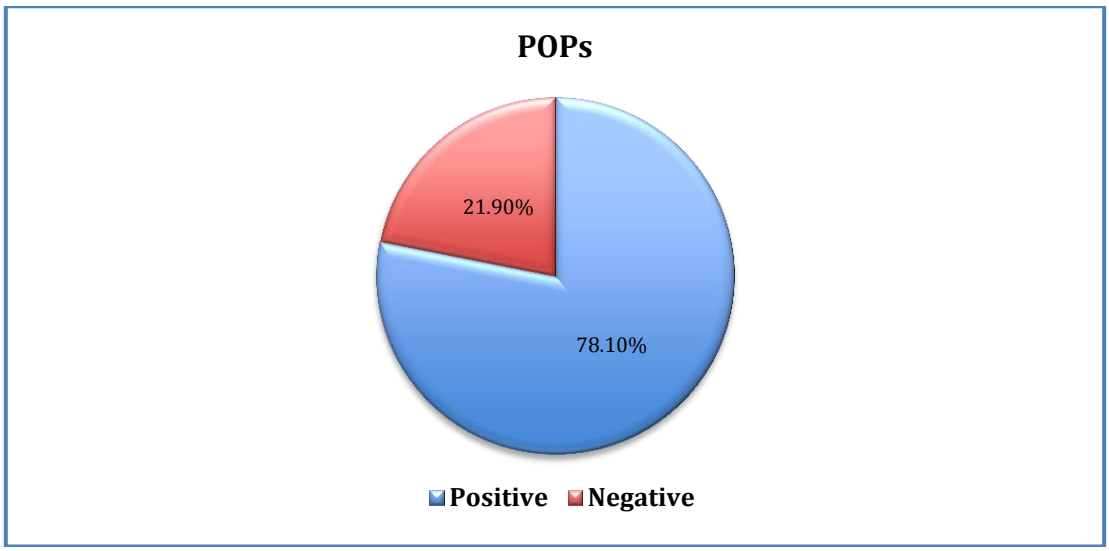


Figure (1): Frequency of detection of POPs among studied electronics workers (n = 155).

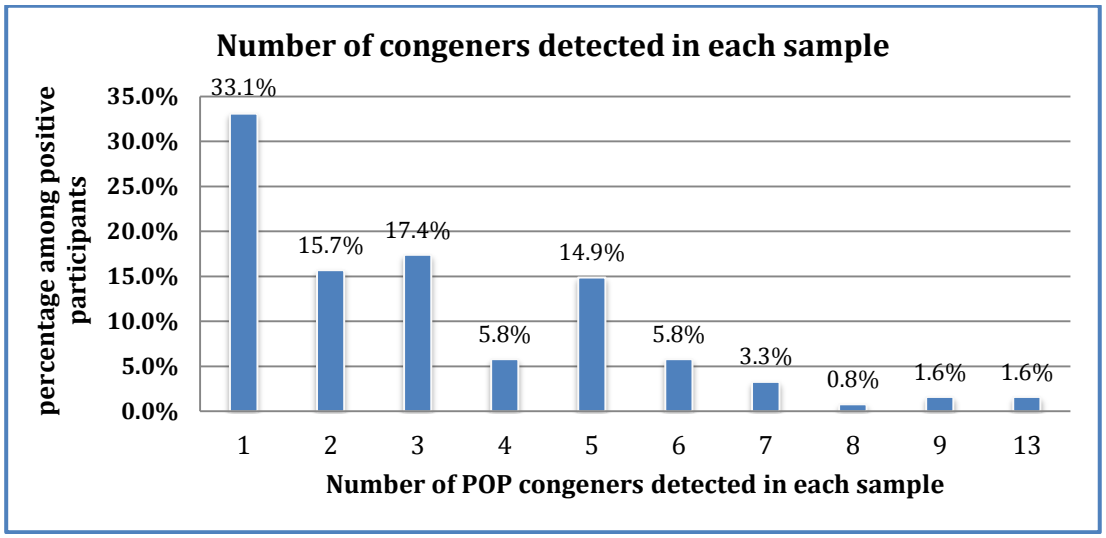


Figure (2): Number of different POPs congeners detected in each serum sample of positive participants (n =121).

Table (2): Frequency of each class of POPs among positive participants (n = 121)

POPs categories	Frequency	Percentage
Dioxins	5	4.1
Furans	75	61.9
Polycyclic aromatic hydrocarbons (PAH)	74	61.2
Hexachlorobenzene	46	38
Bromo derivatives	46	38
Polychlorinated biphenyls (PCBs)	2	1.6

Detection of POPs was higher among blue collars compared to white collars **(Figure 3)** and this was statistically significant (p<0.001).Socio-demographic characteristics of participants with detected POPs in their serum samples are shown in table 3. As shown in **table (3)** participants characteristics were very close to overall sample characteristics.

Body mass index, blood pressure measurements, random blood sugar and hemoglobin A1c level of participants with POPs are shown in **table (4)** and all of them did not differ significantly from other participants without POPs. About 86% of positive participants were overweigh (BMI ≥ 25) compared to (82.4%) among negative participants (p = 0.602).

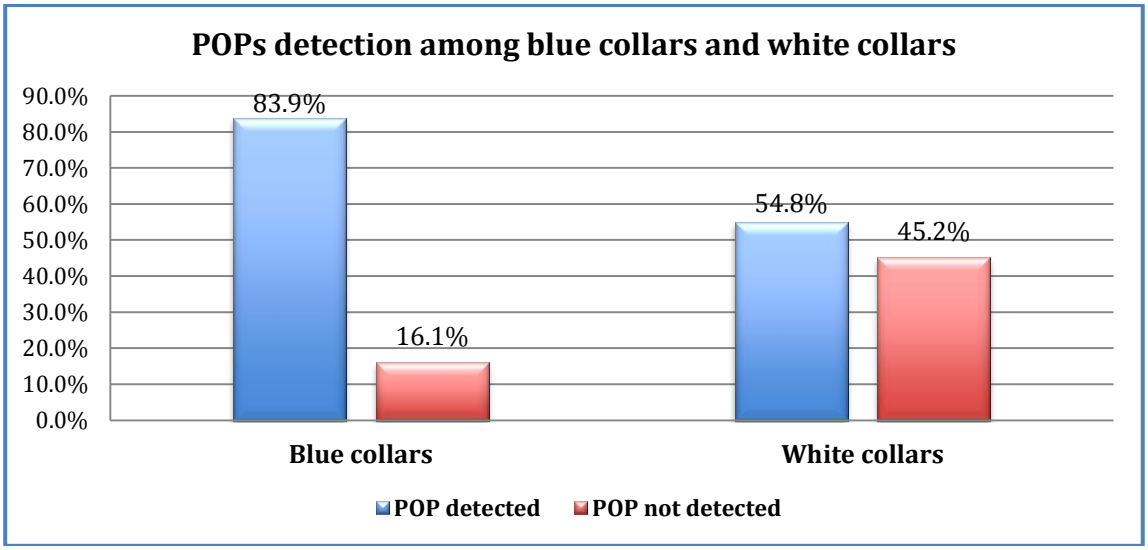


Figure (3): detection of POPs among blue collars and white collars among study participants (n = 155).

Table (3): socio-demographic characteristics of participants with detected POPs in their samples (n =121).

Characteristic	Frequency	Percentage
Age in years		
• 20 – 40	74	63.2
• > 40 – 60	47	38.8
Mean ± SD	37.8 ± 9.1	
Marital status		
• Single	12	9.9
• Married	109	90.1
Education		
• Illiterate	1	0.8
• Read and write	1	0.8
• 1ry / preparatory education	8	6.6
• 2ndry / technical education	89	73.6
• University education	18	14.9
• Postgraduate education	4	3.3
Occupation		
• Blue collar	104	86
• White collar	17	14
Duration of work in years		
• < 5	19	15.7
• 5 – 10	19	15.7
• > 10	83	68.6
Mean ± SD	13.4 ± 7.1	
Smoking status		
• Non-smoker	82	67.8
• X smoker	4	3.3
• Current smoker	35	28.9
Chronic diseases		
• No	102	84.3
• Yes	19	15.7
✓ Hypertension	8	6.6
✓ Diabetes mellitus	3	2.5
✓ Heart diseases	1	0.8
✓ Dyslipidemia	3	2.5
✓ Thyroid diseases	1	0.8
✓ Liver diseases	3	2.5
✓ Renal diseases	2	1.6
✓ Allergies	6	4.9
✓ Others	1	0.8

Table (4): BMI, blood pressure and blood sugar assessment of participants with detected POPs in their samples.

Measurement or lab test	Participants with detected POPs in serum	Participants without detected POPs in serum	*p*-value
BMI	29.5 ± 4.4	30.7 ± 6.7	0.283[1]
Systolic blood pressure	125.4 ± 15.8	126.8 ± 18.9	0.950[1]
Diastolic blood pressure	84.5 ± 10.1	83.8 ± 14.4	0.467[1]
Random blood sugar	123.5 ± 42.2	122.1 ± 33.4	0.767[1]
Hemoglobin A1c	4.5 ± 0.5	4.4 ± 0.5	0.524[1]

1. *Mann Whitney U test*

DISCUSSION

This study has been conducted as a first phase of a research project to assess six POPs in a serum sample of 155 electronics workers in Egypt then in the 2nd phase we evaluated the relation between biphenyls (chlorinated and brominated) and glycemic control (by random blood sugar and HbA1c) as early markers of type 2 diabetes. The current study showed that the study population is highly exposed to POPs whereas POPs were detected in nearly 80% of participants' serum samples. This finding is in concurrent with the conclusion of a systematic review that POPs have been detected in human biological fluids at alarming levels ***(Longo et al., 2021)***. Also, a study conducted on Luxembourg general adult population which detected 24 POPs by hair analysis in more than 50% of the sample. However, their methodology is quite different because they used gas chromatography coupled with tandem mass spectrometry to extract chemicals from hair after decontamination ***(Peng et al., 2021)***. Although the environmental exposure and analysis technique are different, both results showed high POPs levels which indicate alarming exposure levels.

Regarding occupational exposure to POPs in the current study, the POPs levels among blue collars were higher than white collars and this was statistically significant which indicates occupational exposure among electronics workers. This agrees with a review described POPs exposure from electronics waste and showed that electronics waste includes persistent organic pollutants which can contaminate the environment if not properly processed or recycled.

In addition, humans become exposed to electronics -waste constituents through inhalation, ingestion, and dermal contact ***(Alabi et al., 2021)***.

Regarding effect of POPs on blood pressure, BMI and diabetes, the current study did not show statistically significant difference among participants with POPs and participants with no detected POPs regarding BMI, blood pressure measurements, random blood sugar and hemoglobin A1c level. This is disagreed with a review describe the role of POPs on obesity, which showed that epidemiological data support a significant association between exposure to POPs and obesity and obesity-associated metabolic disorders (e.g., type 2 diabetes mellitus and metabolic syndrome) because POPs are considered environmental obesogens. This may be attributed to the increased frequency of overweight (85%) among our study participants regardless of their serum POPs status. However, the existing data are counted insufficient. So, further studies are needed to better characterize the effects of exposure to POPs in occurrence of obesity and other metabolic disorders ***(Aaseth et al., 2022)***.

Many studies have suggested that POPs exposure is considered an endocrine disrupting chemicals that may be associated with an increased risk of hypertension. However a meta-analysis summary, about POPs concentration and hypertension risk, was in partial alignment with our findings as it did not reveal significant relationship between the non-dioxin-like PCBs and the risk of hypertension, however, dioxin-like PCBs was significantly associated with

increased risk of hypertension ***(Park et al., 2016)***.

Although, POPs are lipophilic compounds which move with lipids and accumulate mostly in adipose tissue and human studies links low-dose POPs to an increased risk of type 2 diabetes. A review sum up epidemiological and experimental studies results on chlorinated POPs and type 2 diabetes. It showed that exposure to POP mixtures can increase risk of type 2 diabetes risk in humans. However, inconsistent statistical significance for individual POPs could arise because of distributional differences in POP mixtures among populations. In addition, relationship between POPs and obesity in humans are inconsistent ***(Lee et al., 2014)***.

CONCLUSION

There is high frequency of POPs detection in serum samples of workers in electronics industries reflecting high exposure either occupationally or environmentally. Blue collar workers are significantly more exposed to POPs than white collar workers and POPs have no significant effect on BMI, blood pressure or type 2 diabetes.

RECOMMENDATIONS

Further studies should be performed to track the source of exposure and start prevention strategies. Follow up of participants to early detect any complications related to POPs.

Limitation of the study

Electronics workers in Egypt are mainly males so gender difference cannot be taken in account in this study as all study participants were males. Quantification of concentration effect relationship should be considered in further studies.

Author contributions

Hebatalla M Aly contributed to the conception, design, material preparation, data collection, analysis and revision of the final manuscript. Reham B Ibrahim contributed in data collection and data entry. Reem M Mahmoud contributed in data collection (laboratory analysis of samples for random blood sugar and HbA1c). Ahmed Ismail contributed in data analysis of GC/MS results, methodology writing and final manuscript revision and editing. Sarah M Hussein contributed to material preparation, data collection and manuscript preparation.

All authors read and approved the final manuscript.

Competing Interests: "The authors have no relevant interests to disclose."

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مدى وجود الملوثات العضوية الثابتة في عينات مصل العاملين في مجال الإلكترونيات بمحافظة الشرقية، مصر

هبة الله محمد علي [١]، ريهام ابراهيم [١]، ريم محمود [٢]، أحمد إسماعيل [٣]، سارة محمد حسين [١]
[١]قسم الصحة العامة وطب المجتمع والطب المهني والبيئي- كلية الطب البشرى-جامعة قناة السويس- مصر.
[٢] قسم الباثولوجيا الإكلينيكية- كلية الطب البشرى- جامعة قناة السويس- مصر.
[٣] قسم العقاقير- كلية الصيدلة- جامعة الفيوم- مصر.

الملخص العربى

المقدمة: تعتبر الملوثات العضوية الثابتة مواد كيميائية سامة تدوم في البيئة، وتتراكم بيولوجيا في الكائنات الحية وتشكل خطرا على صحة الإنسان والبيئة. يمكن أن تسبب هذه الملوثات العضوية الثابتة مجموعة من المشاكل الصحية، بما في ذلك السرطان، والتأثير على التطور والإنجاب، كما يمكن أن تسبب تلف الجهاز المناعي.

الهدف: هدفت هذه الدراسة إلى تقييم مدي وجود الملوثات العضوية الثابتة بين العاملين في مجال الإلكترونيات في منطقة العاشر من رمضان بمحافظة الشرقية، مصر.

طرق البحث: مائة وخمسة وخمسين عامل في مجال الإلكترونيات انضموا إلي الدراسة حيث تم جمع عينات دم من جميع المشاركين واختبار وجود ست فئات من الملوثات العضوية الثابتة وهي الديوكسينات والفيورانات والهيدروكربونات العطرية متعددة الحلقات وسداسي كلورو البنزين ومشتقات البرومو وثنائي الفينيل متعدد الكلور باستخدام كروماتوغرافيا الغاز مقترنة بقياس الطيف الكتلي.

النتائج: أظهرت الدراسة أن الملوثات عضوية ثابتة موجودة في حوالي ٧٨% من عينات المشاركين ، كما وجد لدى ثلثي العمال الذين يعانون من وجود الملوثات عضوية ثابتة في عيناتهم أكثر من متجانس واحد يصل إلى ١٣ متجانساً مختلفاً للملوثات العضوية الثابتة في نفس العينة. كانت الفئة الأكثر شيوعًا التي تم اكتشافها لدى المشاركين هي الفوران (٦٢٪)، تليها الكربونات العطرية متعددة الحلقات (٦١٪). تم اكتشاف الملوثات العضوية الثابتة بين ٨٤% من ذوي الياقات الزرقاء مقارنة بـ ٥٤% من ذوي الياقات البيضاء وهذا الفرق له دلالة إحصائية. كما تم تقييم مؤشر كتلة الجسم وضغط الدم وسكر الدم العشوائي والهيموجلوبين السكري من خلال المقارنة بين المشاركين الذين تم اكتشاف ملوثات عضوية ثابتة لديهم وأولئك الذين ليس لديهم، ولكن الفرق لم يكن ذا دلالة إحصائية.

الخلاصة: معدل وجود الملوثات العضوية الثابتة في عينات مصل العاملين في الصناعات الإلكترونية كبير مما يعكس التعرض العالي سواء مهنياً أو بيئياً.

التوصيات: ينبغي إجراء المزيد من الدراسات لتتبع مصدر التعرض وبدء استراتيجية الوقاية. كما يجب متابعة المشاركين للكشف عن أي مضاعفات تتعلق بالملوثات العضوية الثابتة.