Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

The Effect of Electrical Substations and Cellular Communication Towers on Oxidative Stress and Thyroid Gland Hormones

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Abstract

Electromagnetic radiation has been reported to induce toxicity to many organs of the human body. Electrical substations and cellular communication towers are important sites which emit a continuous electromagnetic radiations of wide spectrum. Radiation is one of the important exogenous sources of free radicals and reactive oxygen species (ROS), which can cause oxidative stress. While elevated ROS cause oxidative damage, the antioxidants are able to reduce these toxic effects. We have aimed to investigate the oxidative stress, antioxidant and thyroid function in the serum of workers at electrical substations and cellular communication towers. The study was included 40 men from electrical substations, 40 men from cellular communication towers, and 40 men from sites away from these two foundations used as control for the study. Total oxidant status (TOS) and malondialdehyde (MDA) were evaluated as oxidative stress markers, while total antioxidant capacity (TAC) and glutathione (GSH) were evaluated as antioxidant markers. The thyroid function was determined by evaluating thyroid stimulating hormone (TSH), triiodothyronine (T3) and thyroxine (T4). The results have shown significant ($P<0.05$) elevated levels of TOS and MDA encountered by significant reduced levels of TAC and GSH in the serum of electrical substations and cellular communication towers workers. The most significant alteration was seen in the serum of electrical substations workers. Thyroid function was observed to be normal in both electrical substations and cellular communication towers workers, despite that TSH was significantly higher in electrical substations workers compared to the other two groups.

keywords: Radiation, TOS, TAC, MDA, GSH, Thyroid hormones;

1. Introduction

Oxidative stress is a situation of imbalance between the oxidants and antioxidants in the living systems [1]. The oxidants are often free radicals and reactive oxygen species (ROS); the latter are highly reactive oxygen containing species that may be a free radical substances (e.g., superoxide anion and hydroxyl radical) or non-radical substances (e.g., hydrogen peroxide and peroxy nitrate) [2-5]. The ROS are produced normally in human body system at physiological conditions, which perform a beneficial function in redox messaging [6, 7]. Nevertheless, the ROS exhibit an oxidative properties that results in damaging the macromolecules of the cells, such as lipid peroxidation, protein oxidative damage, nucleic acid oxidative damage (DNA and RNA), which all leads to cell apoptosis and pathological conditions [8]. The lipid peroxidation is a process by which the ROS and free radicals are causing an oxidative damage to the lipids (triglycerides, cholesterols, or arachidonic acid) [9]. Lipid peroxidation are widely used as indicator of oxidative stress by measuring on of the end products, called, malondialdehyde (MDA) [10]. The ROS can produced by multiple locations within the body, including mitochondria [11], lysosomes [12], cytochrome p450 [13], and some processes such as the activity of xanthine oxidase [14] and NADH oxidase [15]. However, there are exogenous sources of ROS that can be a direct affectors to the development of oxidative stress, including radiation, heavy metals, smoke, and insecticides [8].

The body contains a wide spectrum of materials that act to neutralize and detoxify the oxidative effects of ROS [16]. These materials are called antioxidants [17, 18]. The antioxidant material can be produced endogenously such as superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), uric

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Receive Date: 27 May 2022, **Revise Date:** 03 July 2022, **Accept Date:** 08 August 2022, **First Publish Date:** 08 August 2022
DOI: 10.21608/EJCHEM.2022.141247.6173

acid, and glutathione (GSH) [19]. Also, antioxidants are provided exogenously from diet such as vitamin C, vitamin E, vitamin A, carotenoids, polyphenols, flavonoids, etc [20]. Hence, the oxidative stress can be developed as either elevated ROS levels, reduced antioxidant level, or both [1, 21].

Electrical substation and electrical transmission lines are containing ultra-high voltage electricity are reported to emit electromagnetic radiation to the surrounding environment [22]. Additionally, electromagnetic radiation has been observed in mobile towers [23]. The documents have shown that the exposure to electromagnetic radiation is involved in the progression of oxidative stress [24]. Furthermore, the reports have indicated that electromagnetic exposure can cause energy absorption in certain parts of the body, including the thyroid gland [25]. This exposure may cause alteration to the thyroid function. Therefore, we have aimed to investigate the oxidative stress, antioxidant, and thyroid hormones in the serum of workers at electrical substations and cellular communication towers, and evaluate the health risks of these two important foundations. The oxidative stress was measured by using MDA, and total oxidant status (TOS) as indicators, while the antioxidant were measured by using GSH and total antioxidant capacity (TAC) as indicators. The thyroid hormones were included thyroxine (T4), triiodothyronine (T3) and thyroid stimulating hormone (TSH).

2. Experimental

2.1. *Subject and samples*

The study was approved by the Scientific and Ethical Committee at the Department of Chemistry, Mustansiriyah University, and it was included 40 people who worked at electrical substations collected from the electrical substations at Ministry of Electricity – the General Company of Baghdad Electricity Distribution, with age range 19-60 year, and other 40 people who worked at communication towers their age range 26-55 year. Additional 40 people were completely healthy (their age range 21-55 year) and apart from these two sites were volunteered as control for the study. The subjects were all males and collected from November 2021 to January 2022.

All of the participants were volunteered for blood donation, then the blood was allowed to clot in tubes and then were centrifuged at 1500 xg for 10 minutes and the separated serum was stored in four Eppendorf tubes and stored at -20 °C until analysis.

2.2. *Methods*

The levels of TSH, T3, and T4 were evaluated by using cobas e411 analyzer (Roche, Germany). The rest parameters were measured by using spectrophotometric methods. MDA was evaluated according to Benge and Aust [26], Erel method was used to determine total oxidant status value in the samples [17], and the TAC was also evaluated according to a method developed by Erel [17]. The GSH level was obtained by using Ellman method [27]. The levels of TAC, TOS, MDA, and GSH levels were determined by using a spectrophotometer model PD-303 APEL (Japan).

2.3. *Statistical analyses*

Statistical Package for the Social Sciences (SPSS) software version 26.0 was used with Microsoft Excel 2016 to perform the statistical processes on the obtained data. Analysis of variances (ANOVA) was used for the compression among control, electrical substations workers, and cellular communication towers workers, and was followed by the post-Hoc highest significant difference (HSD) test for the compression between each two groups. The correlation between variables was analyzed by using Pearson’s correlation coefficient (r).

3. Results

The results are shown in the form of mean ± SD. The data of age, BMI, and smoking distribution are listed in Table 1. The differences of age were non-significant ($P>0.05$) among the control (39.90±9.28 year), workers at the electrical substations (42.98±10.15 year), and workers at the cellular communication towers (40.15±8.17 year).

The BMI differences were non-significant ($P>0.05$) among control (26.44±2.87 $kg.m^{-2}$), workers at the electrical substations (26.86±3.32 $kg.m^{-2}$), and the workers at cellular communication towers (27.87±3.04 $kg.m^{-2}$). It should be noted that not all cases in the three groups were in the overweight category (BMI 25-29.99 $kg.m^{-2}$)

Chi-square test indicate non-significant ($P>0.05$) differences in the number of smokers among control (35%), workers at electrical substations (40%), and workers at cellular communication towers (35%).

The results of TSH, T3 and T4 are shown in Table 3-2, in the form of mean±SD. The level of TSH was significantly ($P<0.05$) elevated in workers at electrical substations (2.13±1.02 mIU/mL), compared to control (1.66±0.51 mIU/mL) and workers at cellular communication towers (1.48±0.68 mIU/mL). The differences of TSH between control and workers at cellular communication towers were non-significant

(P>0.05). The differences in the levels of T3 were non-significant (P>0.05) among control (1.91±0.56 nmol/L), workers at electrical substations (2.02±0.33 nmol/L), and workers at cellular communication towers (2.10±0.36 nmol/L). The differences in the levels of T4 were non-significant (P>0.05) among control (95.97±10.43 nmol/L), workers at electrical substations (96.72±17.77 nmol/L), and workers at cellular communication towers (102.31±15.83 nmol/L).

The level of MDA was significantly (*P*<0.05) elevated in the serum of electrical substations workers (1.51±0.61 µmol/L), and cellular communication towers workers (1.03±0.43 µmol/L), compared to control (0.473±0.12 µmol/L). Furthermore, the level of MDA obtained for electrical substations workers was significantly (*P*<0.05) higher than that for cellular communication towers workers.

The level of TOS was significantly (*P*<0.05) elevated in the serum of electrical substations workers (8.90±1.99 µmol H_2O_2 Eq./L), and cellular communication towers workers (4.84±1.42 µmol H_2O_2 Eq./L), compared to control (1.42±0.59 µmol H_2O_2 Eq./L). Furthermore, the level of TOS obtained for electrical substations workers was significantly (*P*<0.05) higher than that for cellular communication towers workers.

The level of TAC was significantly (*P*<0.05) reduced in the serum of electrical substations workers (0.70±0.34 µmol vit. C Eq./L), and cellular communication towers workers (1.05±0.36 µmol vit. C Eq./L), compared to control (1.82±0.47 µmol vit. C Eq./L). Furthermore, the level of TAC obtained for electrical substations workers was significantly (*P*<0.05) lower than that for cellular communication towers workers.

The level of GSH was significantly (*P*<0.05) reduced in the serum of electrical substations workers (602.3±264.8 µmol/L), and cellular communication towers workers (1868.3±313 µmol/L), compared to control (2609.3±458.8 µmol/L). Furthermore, the level of GSH obtained for electrical substations workers was significantly (*P*<0.05) lower than that for cellular communication towers workers.

Table 3 contains the correlation between oxidative stress parameters and other variables in the study in electrical substations workers. These workers have shown that MDA was correlated positively and weakly with TAC and GSH. Also, GSH was correlated positively and weakly with TAC, and negatively with TSH. While cellular communication towers workers have shown a positive moderate correlation between TOS and MDA (Table 4).

4. **Discussion**

The subjects were selected on the bases of standard criteria, in which the control and tested groups were in comparable age, BMI and smoking distribution, to eliminate the influence of these parameters on the results of the study, especially, the oxidative stress. Baumann *et al.* (2016) [28], have reported that age enhance the accumulation of ROS, which leads to oxidative stress. Furthermore, Wonisch *et al.* (2012) [29], have indicated that the increase of age and BMI associate with an increase in the oxidative stress status, a reduction in the capacity of antioxidants, and deteriorate the health condition. Additionally, smoking is quite common exogenous of ROS production, and the development of oxidative stress [30].

Table 1: Demographic presentation of the study subjects

Parameter	Control	Electrical substation	Cellular towers	p-value
Age (year)	39.90±9.28	42.98±10.15	40.15±8.17	0.259
BMI (kg.m-2)	26.44±2.87	26.86±3.32	27.87±3.04	0.107
Smokers %	35%	40%	35%	0.866

Table 2: Clinical parameter's outcomes

Parameter	Control	Substations	Towers	p-value		
				A	B	C
TSH (mIU/mL)	1.66±0.51	2.13±1.02	1.48±0.68	0.018	0.562	0.001
T3 (nmol/L)	1.91±0.56	2.02±0.33	2.10±0.36	0.529	0.126	0.650
T4 (nmol/L)	95.97±10.43	96.72±17.77	102.31±15.83	0.973	0.147	0.223
MDA (µmol/L)	0.473±0.12	1.51±0.61	1.03±0.43	0.0001	0.0001	0.0001
TOS (µmol H2O2 Eq./L)	1.42±0.59	8.90±1.99	4.84±1.42	0.0001	0.0001	0.0001
TAC (µmol vit. C Eq./L)	1.82±0.47	0.70±0.34	1.05±0.36	0.0001	0.0001	0.0001
GSH (µmol/L)	2609.3±458.8	602.3±264.8	1868.3±313	0.0001	0.0001	0.0001

A: p-value of comparison between control and electrical substations workers; B: p-value of comparison between control and communication towers workers; C: p-value of comparison between electrical substations and communication towers workers.

Table 3: Correlation between oxidative stress and other variables in the serum of the workers at electrical stations

Variables	MDA		TOS		TAC		GSH	
	r	P	r	P	r	P	r	P
MDA	-	-	0.008	0.959	0.388*	0.013	0.332*	0.036
TOS	0.008	0.959	-	-	0.082	0.614	0.055	0.734
TAC	0.388*	0.013	0.082	0.614	-	-	0.477*	0.002
GSH	0.332*	0.036	0.055	0.734	0.477*	0.002	-	-
TSH	-0.085	0.602	-0.184	0.256	0.047	0.771	-0.365*	0.020
T3	-0.061	0.709	-0.152	0.348	-0.130	0.423	0.037	0.819
T4	-0.168	0.299	-0.132	0.415	0.076	0.639	-0.040	0.804
Age	-0.076	0.642	-0.041	0.801	0.188	0.245	-0.051	0.765
BMI	0.110	0.499	-0.254	0.114	0.116	0.475	0.003	0.986

Table 4: Correlation between oxidative stress and other variables in the serum of the workers at communication towers

Variables	MDA		TOS		TAC		GSH	
	r	P	r	P	r	P	r	P
MDA	-	-	0.523*	0.001	-0.070	0.668	-0.115	0.481
TOS	0.523*	0.001	-	-	0.072	0.658	0.102	0.531
TAC	-0.070	0.668	0.072	0.658	-	-	-0.237	0.142
GSH	-0.115	0.481	0.102	0.531	-0.237	0.142	-	-
TSH	-0.008	0.962	-0.052	0.749	0.107	0.511	-0.124	0.446
T3	0.001	0.993	-0.125	0.444	-0.076	0.641	0.039	0.810
T4	0.066	0.685	0.059	0.719	-0.095	0.558	-0.083	0.611
Age	0.175	0.332	0.149	0.358	0.094	0.562	0.006	0.969
BMI	-0.022	0.892	0.065	0.689	0.305	0.056	0.026	0.875

The suggested cut-off values of TSH at physiological conditions is 0.35 mIU/mL as the lower limit and 4.5 mIU/mL as the upper limit, while most normal people have TSH level range 0.5-2.5 mIU/mL [31]. In the current study, TSH level was significantly elevated in the serum of electrical substations workers, although it did not exceed the suggested normal range. Kunt *et al.* (2016) [32], have reported that workers at electrical stations have normal serum levels of TSH, but reduced levels of free T4 compared to the control of their study. The workers have suggested that long exposure to electromagnetic radiation in the environment of high-voltage electric transmission lines may have risk on thyroid function, and involved in the development of hypothyroidism. The study of Kunt *et al.* supports the current results, in which the mild increase of TSH level at the workers of electrical substations in this study, may be a part as risk factor for developing hypothyroidism at the future. While the results of thyroid function in workers at the cellular communication towers was found to be in normal range with non-significant differences compared to control, a disagreement was found with Baby *et al.* (2017) [25], who have examined the association between the exposure to electromagnetic radiation of mobile phones and the level of serum TSH. The workers have indicated a positive relationship, in which the severe exposure to mobile phone radiation may lead to a hypothyroidism. Another disagreement was found with Koyu *et al.* (2005) [33], who showed that when rats were exposed to 900 MHz of electromagnetic radiation, the levels of thyroid function hormones were reduced significantly.

The results have shown an increase in the level of lipid peroxidation, and total oxidative damage associated with a decrease in the level of reduced glutathione and total antioxidant capacity in the serum of electrical substations workers and cellular communication towers workers. The worst conditions were observed for electrical substations workers. Tiwari *et al.* (2015) [34], have studied the effect of exposed to high-voltage environment on oxidative stress in the workers at electrical substations. The authors have indicated that the workers at electrical substations were exhibited elevated levels of DNA oxidative damage, MDA and nitric oxide, which, collectively, constitute major problem on public health of these establishments. The results of Tiwari *et al.* is in agreement with the results of the present study. Kunt *et al.* (2016) [32], have reported that workers at electrical stations have shown significant elevated levels of TOS associated with significant low levels of TAC. Accordingly, the authors have attributed this shift of oxidative status to the high electromagnetic frequencies which found in electrical substation environment. The results of Kunt *et al.* is in agreement with the results of the present study. Partial agreement was found with Hosseinabadi *et al.* (2021) [35], who have examined the status of oxidative stress in the serum of electric power generating stations. The authors have observed an elevated levels of MDA, but the level of TAC was non-significantly different compared to the control of their study. Moreover, the study has included SOD and Catalase antioxidant enzymes. Both enzymes were at elevated levels in workers compared to control. The authors have attributed this imbalance to the exposure to extremely low frequency electromagnetic fields. In the study of Gulati *et al.* (2018) [36], lipid peroxidation and the activity of enzymatic antioxidants were investigated in people on continuous expose to the environment of cellular communication towers. The authors have observed significant elevated levels of MDA accompanied with significant reduction in the activities of SOD and catalase. Furthermore, authors have indicated that an association of genetic polymorphism of antioxidant genes with genetic damage in human population whom exposed to radiations emitted from mobile towers. The results of Gulati *et al.* are in agreement with the substantial observations in the present study. Gulati *et al.* (2020) [37], have indicated a significant role of radiofrequencies emitted from cellular communication towers on oxidative stress. The authors have observed that high expose to these frequencies involved in increasing the production of ROS in human's lymphocytes. The results of Gulati *et al.* are in agreement with the substantial observations in the present study. Akkam *et al.* (2020) [38], have investigated the influence of electromagnetic radiation from cellular communication towers on human health in Jordin. The authors have indicated a direct effect of these radiations on the activity of glutathione S transferase, and the influence had increased with the increase of expose duration. But, the authors have observed non-significant differences in TAC level with non-exposed people.

5. Conclusions

The results have shown a progressive level of oxidative stress (increase in the levels of MDA and TOS) encountered by a significant reduction in the antioxidants (decrease in the levels of GSH and TAC) in both electrical substations workers and cellular communication towers workers. The direct exposure of these two sites on prolonged time would drive diverse health risks. The health risks of these two important infrastructures can be attributed to the fact that they are rich in electromagnetic radiation which can enhance the production of ROS and free radicals within the body, resulting in the development of oxidative stress. Despite that, the thyroid hormones were on normal function, the health problems may reach other systems of the body. The information of the effects of electrical substations and cellular communication towers on human health is still insufficient and further works are needed.

6. Conflicts of interest

There are no conflicts to declare.

7. Acknowledgments

The authors would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad, Iraq.

8. Abbreviations

Malondialdehyde (MDA), reduced glutathione (GSH), standard deviation (SD), thyroid stimulating hormone (TSH), triiodothyronine (T3), thyroxine (T4), reactive oxygen species (ROS), total oxidant status (TOS), total antioxidant capacity (TAC), body mass index (BMI).

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