Effect of Mercuric Chloride on Glutathione (GSH) level in Plasma and Cytosolic Fraction of Human blood

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ABSTRACT

Elemental Mercury is the main ingredient in dental amalgams and in plasma-derived medicinal products and in other many medicines, but mercury is a neurotoxin and can harm human health if exposed. Thus, it is interesting to study the effect of mercurric chloride on the glutathione (GSH). The effect of mercuric chloride on the chemical status of the glutathione (GSH) in the whole blood has been studied using U.V Spectrophotometer by using Ellman's method. The effect of mercurric chloride on the chemical status of glutathione (GSH) was checked in whole blood with the passage of time. It was found that there is a profound effect of decreasing the concentration of reduced glutathione (GSH) in whole blood, as the time has passed. The decrease in the glutathione level was dependent on concentration and time of interaction dependent, probably, due to oxidation of glutathione (GSH) to corresponding disulphide (GSSG). In this paper, the effect of mercuric chloride on thiol/GSH level was discussed *in vitro,* which in principal may present a model of *in vivo* reaction. This study can also help in a way to achieve the idea that the acute toxicity of the metal can be neutralized by the reduced glutathione (GSH).

Keywords: Mercury (Hg), Reduced Glutathione (GSH), Oxidize Glutathione (GSSG), Whole blood, Ellman's Method, 5, 5-Dithiobis, 2-Nitrobenzoic Acid (DTNB).

INTRODUCTION

Glutathione (g-glutamylcysteinylglycine, GSH) is a sulfhydryl (-SH) antioxidant, antitoxin, and enzyme cofactor. Glutathione is found in animals, plants, and microorganisms, and, being water-soluble, it is found mainly in the cell cytosol and other aqueous phases of the living system. [1, 2, 3] Great interest has been placed recently on glutathione, (GSH) the major nonprotien thiol (NPSH) in cell [3,4], due to its varied biochemical, physiological and pharmacological activities that include; drug metabolism, cellular protection against electrophilic attack of chemical and/or its metabolites [5]. Glutathione (GSH) is known to participate critically in various detoxification reaction including the deactivation of electrophilic drugs and carcinogenic metabolites by formation of GSG-S conjugates[4,6,7,8]. Glutathione is present inside cells mainly in its reduced (GSH) form. In the healthy cell GSSG, the oxidized (electron-poor) form rarely exceeds 10 percent of the total cell glutathione (GSH). Intracellular GSH status appears to be a sensitive indicator of the cell's overall health, and of its ability to

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resist toxic challenge. Experimental GSH depletion can trigger suicide of the cell by a process known as apoptosis [9, 10].

Elemental mercury is the main ingredient in dental amalgams. Mercury (I) chloride (also known as calomel or mercurous chloride) has traditionally been used as a diuretic, topical disinfectant, and laxative. Mercury is normally excreted from the body by being bound to Glutathione, and then excreted with the bile into the small intestine. A study[11] found that young monkeys had a much lower level of glutathione, and the level of glutathione is closely correlated with their ability to excrete mercury. This is believed to also hold true in human children, such that there would be almost no excretion of mercury during the first six months of life, and it would likely take years to reach full production of glutathione.

There have been two studies [12, 13] which have consistently demonstrated that children with autism have low levels of cysteine. Cysteine is the precursor to making glutathione, so low cysteine levels would result in low glutathione levels. Two of those studies also measured the level of glutathione in plasma, and found that it was approximately 50% lower in children with autism compared to age-matched controls. One of those studies [12] measured the oxidation of glutathione, and found that children with autism had a higher ratio of oxidized (inactive) glutathione, presumably due to oxidative stress.

Mercurric chloride has electron capturing capacity and GSH has potent electron-donating capacity, as indicated by the high negative redox potential of the GSH/GSSH "redox couple" ($E'0 = -0.33v$)[14]. Its high redox potential renders (GSH) both a potent antioxidant and a convenient cofactor for enzymatic reactions that require readily available electron pairs [15]. The reducing power of GSH is a measure of its free radical scavenging, electron-donating, and sulfhydryl-donating capacity.The reduced glutathione molecule consists of three amino acids - glutamic acid, cysteine, and glycine-covalently joined end-to-end. The sulfhydryl (-SH) group, which gives the molecule its electron-donating character, comes from the cysteine residue. mercuric chloride has an affinity for the glutathione (GSH) present in the aqueous phases of blood. This affinity is mainly formed between metal and sulfhydryl groups of proteins [16]. This affinity can cause a depletion of the reduced form glutathione (GSH) in the blood, but with the depletion of the glutathione (GSH), GSH synthesizing systems start making more GSH from cysteine via the γ-glutamyl cycle but the GSH is usually not effectively supplied. However, if GSH depletion continues because of chronic metal exposure [16, 17, 18], then the pharmacologically metal can be harmful in nature to the body defense system. The following study makes a design to see the effects of mercuric chloride, in respect of time and concentration, on the chemical status of glutathione (GSH) in the whole blood.

MATERIALS AND METHODS

Materials

Sodium hydroxide (Fluka AG), L.glutathione (GSH) (Fluka), 5,5-dithiobis,2-nitrobenzoic acid (DTNB) (Sigma), Potassium dihydrogen phosphate (Merck), HCl 35% (Kolchlight), mercuric chloride (BDH, Germany), Sodium chloride (Merck), Disodium edetate (Riedel Dehean AG sleeze hannover), Chloroform (Merck), Ethanol (Merck), Water for Injection (Elixir Laboratories), Distilled water (double distilled), U.V 1601 spectrophotometer (Shimadzu), pH meter : Model NOV-210 (Nova scientific company Ltd. Korea), Oven: memmert model U-30,854 Schwabach (Germany), Magnetic stirrer, hot plate 400(England), Micropipettes 200 µl, 500 µl, 1000 µl which were used of socorex swiss (Finaland), Sortorius balance, Centrifuge (H-200, Kokusan Ensink company Japan), Eppendorf's tubes (Plastic, 10l), Siliconized glass test tubes, sterile pyrogen, Free disposable syringes (B.D), fresh human volunteer blood (three healthy volunteers of 20-25 years of age), and Disposable rubber gloves (Otsuka, Japan), were used in this research work.

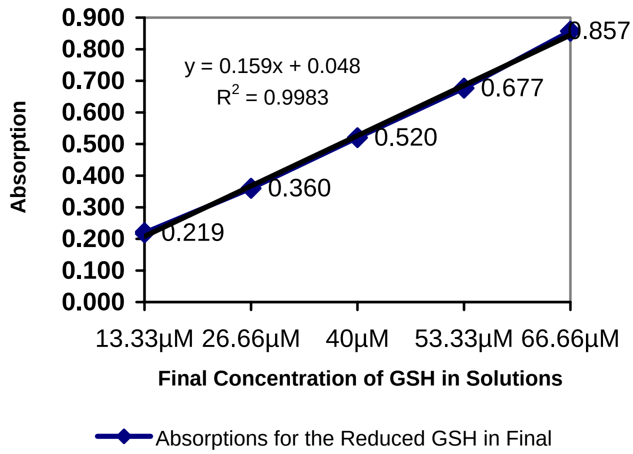
1- Standard Curve for Glutathione.

Different concentrations have been made from 1mM solutions of glutathione (GSH) and 0.2ml (200µl) of them was added to 2.3ml (2300µl) of phosphate buffer pH 7.6, followed by the addition of 0.5ml (500µl) of 1mM 5, 5-

dithiobis, and 2-nitrobenzoic acid (DTNB) stock solution. The mixtures were shaken thoroughly and incubated for 5 minutes. Absorbances were taken after 5 minutes at fixed wavelength of 412nm.

The absorption of 5,5-dithiobis,2-nitrobenzoic acid (DTNB) blank solution, prepared by adding 0.5ml(500µl) of 1mM 5, 5-dithiobis, 2-nitrobenzoic acid (DTNB) stock solution in 2.3ml (2300µl) of phosphate buffer pH 7.6 was also obtained at fixed wavelength of 412nm.

A real absorbance was obtained by subtracting the absorbances of 5,5-dithiobis,2-nitrobenzoic acid (DTNB) blank solution from the absorbances of glutathione (GSH) plus 5,5-dithiobis,2-nitrobenzoic acid (DTNB) mixtures with different concentrations of glutathione (GSH). Standard curve was obtained as shown in figure (1).



Mixture taken at 412nm on UV spectrophotometer

Figure 1- Standard Curve for GSH + DTNB

By this correlation method, the concentration of GSH was found in different solutions by noting down the absorbances of GSH solutions at 412nm

Method

5 ml of human venous blood of volunteer was taken and treated with heparin to prevent clotting. The effect of mercuric chloride, (added to the whole blood) on the chemical status of glutathione (GSH) in plasma and cytosolic fraction was studied in terms of determination of concentration of GSH in mixtures by the well known Ellman's method [19]. Mixture of mercuric chloride and whole blood was prepared by taking equal volumes of stock solution of mercuric chloride and whole blood and keeping them in the refrigerator till used. The blood was then centrifuged on H-200 centrifuge at 10,000 rpm for two minutes. After centrifugation two layers of blood were formed. The upper layer was plasma and was removed with a pasteur pipette and the lower layer which was precipitated down was cytosolic fraction and placed in refrigerator till used.

Determination of GSH in Plasma

The assay of glutathione (GSH) with DTNB was performed following a standard Ellman's method[19] for plasma of blood. 2.3ml of potassium phosphate (0.2M,PH 7.6) buffer was taken in the cell and/or cuvete followed by the addition of 0.2ml aqueous solution or plasma. To it 0.5ml (DTNB) 5,5-dithiobis,2-nitrobenzoic acid (0.001M) in a buffer was added to that. An absorbance of reaction product in cuvette was read after 5 minutes at 412 nm using Shimadzu 1601 UV/Visible double beam spectrophotometer and GSH level was determined, from standard curve of reduced GSH obtained with 0.2, 0.4, 0.6, 0.8 and 1mM GSH concentrations.

Table (1): Effect of mercuric Chloride on the Chemical Status of Glutathione (GSH) in Plasma with time.

UV Spectrophotometer absorption readings of different solutions for GSH at 412nm Wavelength

S# No	Time Interval	Three Readings on Different Volunteers Blood Mixtures With mercuric Chloride			Average of 3 Readings	DTNB Blank (ABS)	Real absorbance* (ABS)	GSH Blank (ABS)	Real Absorbance for GSH Blank
		1st	2nd	3rd					
1	**0 min**	0.143	0.131	0.150	0.141	0.042	0.099	0.456	0.414
2	**30 min**	0.123	0.112	0.131	0.122	0.042	0.080	0.450	0.408
3	**60 min**	0.108	0.096	0.115	0.106	0.040	0.066	0.460	0.420
4	**90 min**	0.098	0.087	0.106	0.097	0.056	0.041	0.453	0.397
5	**120 min**	0.086	0.074	0.093	0.084	0.057	0.027	0.440	0.383
6	**150 min**	0.073	0.066	0.083	0.074	0.054	0.020	0.449	0.395

***** *Real Absorbance = Absorbance of Mixture - Absorbance of DTNB blank Solution*

Determination of GSH in Cytosolic Fraction

0.5ml of the red cell fraction, which was left after isolation of plasma, was taken and washed 2-3 times with 1ml of isotonic saline (0.9% NaCl) solution and lysed with an equal volume (1:1) of distilled water for one hour at $4C^0$. 0.6 ml of cold chloroform: ethanol (3:5 v/v) mixture at 0 C^0 was added to 2ml of lysed cells. Hemoglobin was precipitated followed by the addition of 0.3ml of distilled water. Clear supernatant (pale yellow) a cytosolic fraction of red cell was removed by pasteur pipette, after centrifugation as before, and analyzed for glutathione (GSH) level. The remaining method is the same as was used for the determination of glutathione GSH in plasma.

Table (2): Effect of mercuric Chloride on the Chemical Status of Glutathione (GSH) in Cytosolic Fraction (C.F) with time.

UV Spectrophotometer absorption readings of different solutions for GSH at 412nm Wavelength

S# No	Time Interval	Three Readings on Different Volunteers Blood Mixtures With mercuric Chloride			Average of 3 Readings	DTNB Blank (ABS)	Real absorbance* (ABS)	GSH Blank (ABS)	Real Absorbance for GSH Blank
		1st	2nd	3rd					
1	0 min	0.150	0.130	0.127	0.136	0.051	0.085	0.200	0.149
2	30 min	0.090	0.120	0.092	0.101	0.046	0.055	0.198	0.152
3	60 min	0.060	0.095	0.065	0.073	0.043	0.030	0.196	0.153
4	90 min	0.050	0.080	0.052	0.061	0.055	0.006	0.201	0.146
5	120 min	0.054	0.063	0.046	0.054	0.050	0.004	0.203	0.153
6	150 min	0.056	0.064	0.047	0.056	0.046	0.010	0.197	0.151

***** *Real Absorbance = Absorbance of Mixture - Absorbance of DTNB blank Solution*

RESULTS

Effect of mercuric chloride on the chemical status of glutathione present in whole blood was studied in terms of determination of concentration of glutathione (GSH) in plasma and cytosolic fraction after mixing the whole blood with 0.1mM concentration of mercuric chloride. As the time passed from 0 minute interval of time to 150 minutes, after mixing the whole blood with a specific concentration of mercuric chloride, it was seen that the normal concentration of glutathione (GSH) in plasma decreased with time as the blank mixtures of plasma showed the little variation of thiol status with each interval of time.

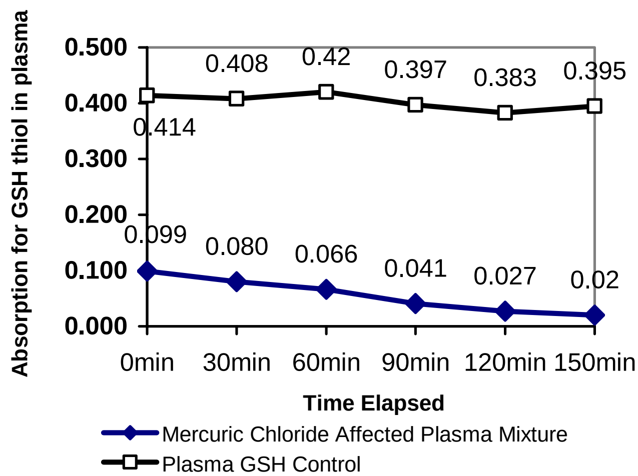


Figure (2): ***Time-Dependent Curves for $HgCl_2$ affected Plasma Thiol Level & Control Levels of Plasma Thiol levels.***

Table (3): Calculation for GSH Concentrations in Plasma

S/No.	Real Absorbance (ABS) of Plasma GSH depleted by mercuric Chloride.	Concentration of GSH (µM) Remained in Plasma of Whole Blood after depleted by mercuric Chloride.	Real Absorbance (ABS) of Plasma blank solution for GSH.	Concentration of GSH (µM) Remained in Plasma of Whole Blood after treated as blank.
1	0.099	0.317	0.414	2.293
2	0.080	0.198	0.408	2.255
3	0.066	0.110	0.420	2.331
4	0.041	0.00	0.397	2.186
5	0.027	0.00	0.383	2.098
6	0.020	0.00	0.395	2.174

Similarly, as the time passed from 0 minute interval of time to 150 minutes, after mixing the whole blood with a specific concentration of mercurric chloride, it was seen that the normal concentration of glutathione (GSH) in cytosolic fraction decreased with time as the blank mixtures of cytosolic fraction showed the little variation of thiol status with each interval of time.

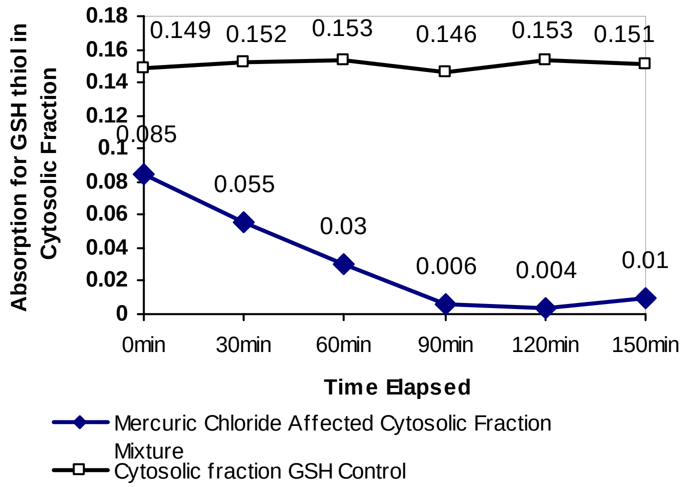


Figure (3): ***Time-Dependent Curves for $HgCl_2$ - affected CytosolicFraction Thiol Level & Control Levels of Cytosolic Fraction Thiol***

Table (4): Calculation for GSH concentrations in Cytosolic Fraction.

S/No.	Real Absorbance (ABS) of Cytosolic Fraction GSH depleted by mercuric Chloride.	Concentration of GSH (µM) Remained in Cytosolic Fraction of Whole Blood after depleted by mercuric Chloride.	Real Absorbance (ABS) of Cytosolic Fraction blank solution for GSH.	Concentration of GSH (µM) Remained in Cytosolic Fraction of Whole Blood after treated as blank.
1	0.085	0.229	0.149	0.630
2	0.055	0.041	0.152	0.649
3	0.030	0.00	0.153	0.656
4	0.006	0.00	0.146	0.612
5	0.004	0.00	0.153	0.656
6	0.010	0.00	0.151	0.643

The intensity in decrease in the reduced glutathione in plasma compartment of the whole blood was not such severe as in the case of cytosolic fraction. The curve obtained for reduced glutathione in cytosolic fraction as shown in Figure (2), showed that as the time passed, the concentration of mercuric chloride got increased in the red cell and its passage occurred through the red blood cell membrane, which ultimately caused the increased depletion of reduced glutathione with increased built-up of the concentration of mercuric chloride.

STATISTICAL ANALYSIS

Statistical analysis of the effect of mercuric chloride on the chemical status of (GSH) was also conducted on the plasma and cytosolic fraction GSH chemical status and concluded that using interval level gives 95% confidence.

The paired comparison t-test of plasma (GSH) blank & mercuric chloride-affected plasma (GSH) gave the decision that there is an affect of mercuric chloride on the chemical status of (GSH) in plasma of the whole blood as compared to blank plasma treatment.

Table (5): Statistical Analysis of Effect of Mercury on GSH chemical Status in Plasma of Whole Blood.

1- Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair	Mercury + Plasma	0.044	6	0.196292	0.080136
	BLANK Plasma	2.22283	6	0.086003	0.035111

2- Paired Samples Correlations

		N	Correlation
Pair	Mercury + Plasma *BLANK Plasma*	6	0.804

3- Paired Samples Test

		Paired Differences					t	df	t-Critical (1-Tail)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair	Mercury + Plasma *BLANK Plasma*	-2.178	0.137	0.056	-2.322	-2.035	-38.93	5	2.02

P<0.05

Similarly, the paired comparison t-test of cytosolic fraction (GSH) blank & mercuric chloride- affected cytosolic fraction (GSH) gave the decision that there is an effect of mercuric chloride on the chemical status of (GSH) in cytosolic fraction of the whole blood as compared to blank cytosolic fraction treatment.

Table (6): Statistical Analysis of Effect of Mercury on GSH chemical Status in Cytosolic Fraction (C.F) of Whole Blood.

1- Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair	Mercury +C.F	-0.10567	6	0.204098	0.083323
	BLANK C.F	0.641	6	0.017205	0.007024

2- Paired Samples Correlations

		N	Correlation
Pair	Mercury +C.F *BLANK C.F*	6	-0.049

3- Paired Samples Test

		Paired Differences					t	df	t-Critical (1-Tail)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair	Mercury +C.F *BLANK C.F*	-0.746	0.206	0.084	-0.962	-0.531	-8.89	5	2.02

P<0.05

DISCUSSION

There is an increasing interest in glutathione (GSH) due to its varied physiological and pharmacological properties including detoxification through participation in the redox system, activation of SH-enzymes, co-enzymatic action and conjugation.

Thus, it was of interest to study the interaction of this metal in vivo to establish further scientific data.

This scientific data about the interaction and the effect of mercuric chloride on the chemical modulation of (GSH) in whole blood will enable us to further understand the role of mercuric chloride and (GSH) and strengthen our knowledge about their therapeutic uses in treating many diseases.

The mercuric chloride induced the depletion of glutathione in the case of whole blood. The results obtained from the plasma and cytosolic fraction part of whole blood for the effect of mercuric chloride- on whole blood has a positive correlation between the time duration of mercuric chloride presence in whole blood and the depletion of reduced glutathione (GSH).

The results obtained from the cytosolic fraction part of the whole blood for the effect of mercuric chloride on the whole blood was also promising and showed that the mercuric chloride can cross the semi permeable membrane of the (RBCs) red blood cells, though not to a great extent, but can induce a change in the chemical status of glutathione (GSH) and cause a decrease in the concentration of reduced glutathione (GSH).

The effect of mercuric chloride for its toxicological actions is recognized worldwide, the depletion of glutathione (GSH) by this metal proved a conjugation reaction between this metal and glutathione (GSH). So, the use of glutathione (GSH) from external source, in the case of toxicity to mercuric chloride, can greatly decrease the mercury metal ions in the body both in plasma as well as in cytosolic fraction of the human blood.

This study also provides the verification of studies conducted for the passage of metals across red blood cells membrane.

CONCLUSION

The tripeptide thiole glutamine (GSH) has facile electron-donating capacity, linked to it sulfhydryl (-SH) group. Glutathione is important water - phase antioxidant and essential co-factor for antioxidant enzyme. It provides protection also for the mitochondria against endogenous radicals. Its high electron-donating capacity combined with its high molecular concentration endows (GSH) with great reducing power, which is used to regulate a complex thiole-exchange system. Mercuric chloride caused a decrease in the concentration of reduced glutathione (GSH). Effect of mercury ions on the chemical status of glutathione was studied for time dependency and noted that the concentration of glutathione (GSH) gradually decreased as the time passes from 0 minute interval of time to 150 minutes in plasma and cytosolic fraction.

Aims and Objectives

1. Metal-based drug complexes have wide spectrum of pharmacological activities, which could have an effect on the status of glutathione (GSH) in vitro and in vivo biological systems. In view of these aspects, the present study was designed to achieve this purpose.
2. The effect of metal-based drugs and excipients, sed in wide range of pharmaceutical substances on glutathione (GSH) status in plsma and cytosolic fraction may add more information for a further understanding of the biochemistry of metal-based drugs and excipients.
3. The toxicity level of metal-based drug in reference to glutathione depletion can be measured in pharmaceutical laboratories with economical and instant procedures.
4. The oxidation reduction protocols that are used by the metabolism of the specific metals used in pharmaceutical substances.
5. Anticancer drugs based upon the metals substitutions can be designed in an effective way to reduce the adverse effects and increase the pharmacological actions of drugs.
6. The next step to this study will then be the

radioisotopic labeling of these metals to observe the behaviour and entrance of the metal in different tissues and cells and entering the different metabolism pathways and capacity to generate enzyme and co-enzymes by the help of thiol group in different tissues and ion transport systems.

7. The further advancement to this study can help to design such metal-based drugs which do not cause depletion of glutathione (GSH) to oxidize glutathione (GSSG), but can enhance the glutamyl peroxidase enzyme to yield the normal concentration of glutathione (GSH) in liver and cease the liver damage effect of those drugs.

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تأثير كلوريد الزئبق على مستوى مادة الجلوتاثايون في البلازما وفي الدم

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ملخـص

إن عنصر الزئبق هو المكون الرئيسي في مسوغات الأسنان وفي بعض المستحضرات الطبية ولكن عنصر الزئبق يسبب سمية في الأعصاب ومن الممكن أن يؤذي الصحة العامة إذا تعرض له الجسم.وعليه فمن المهم دراسة تأثير كلوريد الزئبق على الجلوتاثايون. لقد تم دراسة تأثير كلوريد الزئبق على التركيب الكيميائي لمادة الجلوتاثايون في الدم وذلك باستخدام طريقة (إلمان) وجهاز الطيف للأشعة فوق البنفسجية.

إن تأثير كلوريد الزئبق على الجلوتاثايون قد تم فحصه في الدم مع مرور الوقت وتم الوصول إلى أنه يوجد تأثير واضح لنقصان كمية الجلوتاثايون في الدم مع مرور الزمن.

وكان هذا النقصان في مستوى الجلوتاثايون في الدم يعتمد على تركيز والفترة الزمنية للتعرض لمادة كلوريد الزئبق وهذا ناتج عن أكسدة مادة الجلوتاثايون.

في هذا البحث يتم استعراض تأثير كلوريد الزئبق على مستوى الجلوتاثايون خارج الجسم والذي يمثل نموذج لتأثير هذا المركب في داخل الجسم. هذا وتساعد هذه الدراسة على معرفة سمية المركب لمستوى الجلوتاثايون في الدم حيث أن انخفاضه يؤشر على سمية مركب كلوريد الزئبق

الكلمـات الدالـة: زئبق، جلوتاثايون مختزل، جلوتاثايون مؤكسد، طريقة إلمان DTNB.

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