AJMB
Avicenna Journal of Medical Biochemistry
Avicenna J Med Biochem, 2023; 11(1):41-45. doi:10.34172/ajmb.2023.2430
http://ajmb.umsha.ac.ir

Original Article

The Effects of Lead on Some Markers of Liver and Kidney Functions of Lead Recycling Factory Workers are Mediated Through Increased Oxidative Stress

Christian Ejike Onah[1*], Chinwemma Florence Onah[2], Stephen Monday Suru[3], Chinedu Michael Olisah[4], Alfred Friday Ehiaghe[1], Chukwuemeka Emmanuel Ogbodo[1], Wuraola Serah Nnaemeka[3], Ukamaka Ann Ijeomah[5], Chukwuemeka Samuel Meludu[3], Chudi Emmanuel Dioka[6]

[1]Department of Medical Laboratory Science, Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Awka, Nigeria
[2]Department of Nursing Services, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Nigeria
[3]Department of Human Biochemistry, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Awka, Nigeria
[4]Department of Medical Biochemistry, Faculty of Basic Medical Sciences, Chukwuemeka Odimegwu Ojukwu University, Uli, Nigeria
[5]Department of Biochemistry, Faculty of Natural and Applied Sciences, Nasarawa State University Keffi, Nigeria
[6]Department of Chemical Pathology, Faculty of Medicine, Nnamdi Azikiwe University, Awka, Nigeria

Article history:
Received: February 21, 2023
Revised: March 27, 2023
Accepted: April 5, 2023
ePublished: June 28, 2023

***Corresponding author:**
Christian Ejike Onah,
Email: ce.onah@unizik.edu.ng

Abstract

Background: Lead is a highly toxic metal of great public health importance.

Objectives: This cross-sectional study was conducted to evaluate the kidney and liver function status and the markers of oxidative stress among lead recycling factory workers in Anambra State, Nigeria.

Methods: A total of 82 subjects (41 experimental and 41 control subjects) aged 20-60 years were recruited in this study. Lead levels in whole blood were measured using atomic absorption spectrometry. Serum malondialdehyde (MDA) and uric acid levels as well as the activities of glutathione S-transferase (GST), alanine transaminase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and γ-glutamyltransferase (γ-GT) were measured using the spectrophotometric method. Superoxide dismutase (SOD) and catalase activities were determined using colorimetric method and Berthelot's and Jaffe slot methods were used to measure urea and creatinine levels, respectively.

Results: The mean activities of SOD, GST, and catalase as well as estimated glomerular filtration rate (eGFR) were significantly lower in lead recycling workers compared with control group ($P<0.05$), whereas the mean activities of ALT, AST, ALP, and γ-GT, as well as blood lead, MDA, urea, creatinine, and uric acid levels significantly increased in lead recycling workers ($P<0.05$). Furthermore, blood lead level was found positively correlated with MDA and creatinine levels but negatively with eGFR and GST levels ($P<0.05$). MDA level showed positive and negative correlations with creatinine and eGFR ($P<0.05$), respectively.

Conclusion: This study revealed significant alterations in the levels of some biochemical and oxidative stress parameters in liver and kidney in lead recycling factory workers and showed a possible link between oxidative stress and the toxic effects of lead on the kidney and liver.

Keywords: Lead, Antioxidants, Oxidative stress, Kidney, Liver, Enzymes

Please cite this article as follows: Onah CE, Onah CF, Suru SM, Olisah MC, Ehiaghe FA, Ogbodo EC, et al. The effects of lead on some markers of kidney, liver, and cardiovascular system of lead recycling factory workers mediated through increased oxidative stress. Avicenna J Med Biochem. 2023; 11(1):41-45. doi:10.34172/ajmb.2023.2430

Background

Lead, whether ingested or inhaled, is a highly toxic metal that affects practically all body organs and systems (1). In Nigeria, there are numerous small-scale and medium-scale industries and occupational workers (auto-mechanics, electricians, welders, painters, panel beaters, and the like) that use lead-based materials. Some of these industries have no workplace regulations for lead exposure. However, the extensive use of lead has led to serious public health issues, exposure to humans, and environmental damage in many regions of the world (2-4). Workers are typically exposed to lead by the inhalation of lead particles produced by burning lead-containing products during unofficial recycling, smelting, stripping leaded paint, and using leaded gasoline (5).

The health consequences of lead exposure do not

depend on the environmental media or sources such as food, water, soil, or air but depend on the cumulative dose of lead and the vulnerability of the individual person exposed (6). These dysfunctions include central and peripheral nervous systems (7), haematopoietic system (8), cardiovascular system (9), kidneys (10, 11), liver (11), and male and female reproductive system (12). Elevated levels of lead have been reported among workers in various factories in this study region in the past (13,14) with varying degrees of hazardous effects on different organs (15).

Studies have demonstrated that laboratory animals exposed to lead experienced an increase in lipid peroxidation or a decrease in their antioxidant defense mechanisms (16,17). Yiin and Lin demonstrated a significant increase in the production of malondialdehyde (MDA) or thiobarbituric acid reactive substance when lead was incubated with linoleic, linolenic, and arachidonic acids (18). However, the exact mechanism by which lead causes oxidative stress is still not entirely understood. Nonetheless, several mechanisms have been proposed through which lead could cause oxidative stress. They weaken the antioxidant defense system of the cells by lowering glutathione, interfere with some essential metals, make cells more susceptible to oxidative damage by altering the integrity of the membrane and the composition of the fatty acids, and inhibit the activity of sulfhydryl-dependent enzymes or antioxidant enzymes (19).

Lead leads to a high incidence of renal dysfunction, which is marked by alterations in the glomeruli and tubulointerstitial tissue and causes chronic kidney failure, hypertension, and hyperuricemia (20). It affects renal functions primarily via cell membrane damage (21), which might be due to oxidative damage by changing the membrane integrity of the kidneys. In addition, many studies have reported increased levels of alanine transaminase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and gamma-glutamyl transferase (GGT) (22). This has been largely attributed to the degeneration of liver cells by necrosis, leading to the leakage of these enzymes into circulation (23).

However, most of the previous studies conducted on lead exposure among occupational workers have not linked the markers of organ damage with oxidative stress. Consequently, the current study was conducted to assess the oxidative stress markers and their relationship with some biochemical parameters of the liver, cardiovascular, and kidney functions in lead recycling workers.

Materials and Methods

Study Sites

This research was conducted in one of the lead recycling factories in Anambra State, Nigeria. Analyses of biochemical parameters were conducted at the facilities of the Department of Chemical Pathology, Nnamdi Azikiwe University Teaching Hospital, Nnewi.

Study Population

This cross-sectional study involved a total of 82 subjects which were divided into two equal groups, namely, experiment and control groups. The experimental group comprises 41 male lead-recycling workers aged 20-60 years who gave their written informed consent. A total population sampling method was employed, and only the subjects that did not meet inclusion criteria or did not give written informed consent were excluded from the study. These subjects have actively worked for 1-20 years in one of the lead recycling factories. Their work involved melting used battery cells using high-temperature furnace to remove impurities and then remolding them into lead bars which will be used in manufacturing new batteries. Likewise, the control group comprises 41 male subjects with the same age range as the experimental group. They were civil servants whose occupations do not expose them to lead. For comparative purposes, they resided in the same domestic vicinity of the experimental subjects. The purpose of matching them in terms of residential area was to cancel out other sources of lead exposures such as water, inhalation of exhaust fume, and the like, thus differentiating them only based on their occupation.

Inclusion Criteria

Both apparently healthy experimental male individuals who were occupationally exposed to lead and apparently healthy control male subjects who were not occupationally exposed to lead were recruited into the study with written informed consent.

Exclusion Criteria

The study excluded those who had a history of chronic conditions, including diabetes mellitus, cardiovascular disease, kidney disease, and the like as well as those who were taking any medications such as vitamins or mineral supplements that could affect the results.

Sample Collection

Six milliliters of blood sample were collected from each subject after 10-12 hours of overnight fasting, and four milliliters were dispensed into a sterile plain container and allowed to clot and retracted. The blood was centrifuged at 3000 rpm for 10 minutes to separate the serum, which was then kept at -20°C for the analysis of all the biochemical and oxidative parameters. The remaining two milliliters of whole blood were dispensed into an ethylenediamine tetraacetic acid container for the determination of blood lead level.

Laboratory Methods

Superoxide dismutase (SOD) was assayed by the colorimetric method of Misra and Fridovich (24), while catalase activity was determined by the colorimetric method of Sinha (25). Further, glutathione-s-transferase (GST) activity and MDA were determined

spectrophotometrically as described by Habig et al (26) and Gutteridge and Wilkins (27), respectively. Atomic absorption spectrometry was used to measure the amount of lead in whole blood according to the Hessel method (28). The AST and ALT activities were estimated using the spectrophotometric method by Bergmeyer et al (29), while ALP activity was measured using the spectrophotometric method by Schlebusch et al (30). In addition, γ-GT was determined using the spectrophotometric method of Persijn and van der Slik (31), and serum urea was determined by Berthelot's method described by Kassirer (32) using a commercial kit from (Randox, UK). Moreover, serum creatinine was determined by Jaffe's method as described by Laron (33) using a commercial kit from (Randox, UK), while uric acid was determined via the spectrophotometric method described by Kageyama (34).

Statistical Analysis

For statistical analysis, the Statistical Package for Social Sciences (SPSS) version 21 was utilized. In terms of the variables, mean and standard deviation were used. The significance of the mean difference between the two independent variables was determined using the independent student *t* test. To evaluate the degree of relationship between two independent groups, Pearson's correlation test was used, and the significance level was set at $P<0.05$.

Results

The mean level of blood lead and MDA significantly increased in lead recycling workers than in control subjects ($P<0.001$). However, the mean serum activities of SOD, GST, and catalase significantly decreased in lead recycling workers than in the control group ($P<0.001$), respectively (See Table 1).

When compared to the control group, the mean levels of urea, creatinine, and uric acid were significantly higher in the lead recycling workers ($P<0.001$) in each case; however, the mean level of estimated glomerular filtration rate (eGFR) was significantly lower ($P<0.001$) in the lead recycling workers, as depicted in Table 2. When compared to the control group, the mean serum activities of the liver enzymes (ALT, AST, ALP, and GGT) were significantly higher in the workers at the battery recycling factory ($P<0.05$), as illustrated in Table 3.

The blood lead levels correlated negatively with eGFR and GST in lead recycling workers ($P<0.05$). However, blood lead levels in lead recycling workers correlated positively with their MDA and creatinine levels ($P<0.001$). In addition, MDA correlated positively with creatinine levels but negatively with eGFR in lead recycling workers ($P<0.001$), as seen in Table 4.

Discussion

In this study, workers who recycled lead had higher blood lead levels. This result supports the idea that occupational exposure raises blood lead levels in exposed people. The important statistical finding of a higher blood lead level in this study is consistent with the numerous reports of related investigations (13,14). The results revealed significant decreases in the serum activities of SOD, catalase, and GST as well as a significant increase in the serum level of MDA in the lead-exposed group. These findings suggested increased oxidative stress in lead-exposed individuals.

Table 1. Blood Lead Level, Serum MDA, and Some Enzymatic Anti-oxidants in Lead Recycling Workers and Control Subjects (Mean ± SD)

Parameters	Lead Recycling Workers (n = 41)	Control (n = 41)	t-value	*P* value
Lead (µg/dL)	46.27 ± 11.51	15.88 ± 6.82	14.542	< 0.001*
MDA (nmol/mL)	5.37 ± 1.08	3.49 ± 0.82	8.875	< 0.001*
SOD (U/mL)	2.05 ± 0.39	2.87 ± 0.72	-6.431	< 0.001*
GST (U/L)	4.30 ± 1.36	6.58 ± 2.43	-5.220	< 0.001*
Catalase (U/mL)	11.85 ± 2.38	20.04 ± 5.28	-9.057	< 0.001*

MDA: Malondialdehyde; SOD: Superoxide dismutase; GST: Glutathione-s-transferase; SD: Standard deviation.
* Significant.

In line with this study, Soltaninejad et al (35) as well as Vaziri et al (36) reported a decrease in the activities of some enzymatic antioxidants involved in defense against oxidative stress such as SOD and catalase. Haleagrahara et al also reported a decrease in the activity of GST in lead-exposed group (37). Several other studies carried out on lead-exposed animals also found an increase in lipid peroxidation or a decrease in antioxidant defense mechanism (38, 39).

In this study, levels of serum creatinine, urea, and uric acid significantly increased, while the level of estimated creatinine-based GFR decreased in individuals involved in lead recycling. Additionally, there were significant positive correlations between the levels of blood lead and serum creatinine as well as MDA and serum creatinine.

Raised serum ALT and AST activities which are indicators of hepatocellular damage and raised serum ALP and GGT activities which are indicators of hepatobiliary damage were observed in the lead recycling workers in the current study. This could be due to the lead accumulation in the liver and its ability to exert oxidative damage to hepatic cell membranes causing the leakage of these enzymes into the circulation (26). The results of this investigation were consistent with those of Dongre et al who found that automobile employees had higher transaminase (ALT and AST), ALP, and GGT activity compared to control subjects (37).

However, the present work also demonstrated a significant inverse relationship between blood lead levels and estimated GFR as well as between MDA and eGFR. These findings point to the fact that there exists a link between oxidative stress and the effects of lead poisoning on the kidney. This is consistent with other research that claims lead-induced oxidative stress is one of the major contributory elements to the development of lead toxicity (40).

Table 2. Serum Levels of Kidney Markers in Lead Recycling Workers and Control Groups (Mean ± SD)

Parameters	Lead Recycling Workers (n = 41)	Control (n = 41)	t-value	*P* value
Serum urea (mmol/L)	4.70 ± 0.83	3.30 ± 0.77	7.972	< 0.001*
Serum creatinine (μmol/L)	98.02 ± 16.91	85.17 ± 12.70	3.892	< 0.001*
eGFR (mL/min/1.73m²)	81.43 ± 19.89	120.48 ± 20.01	-8.862	< 0.001*
Serum uric acid (μmol/L)	321.50 ± 73.06	257.31 ± 54.69	4.504	< 0.001*

eGFR: Estimated glomerular filtration rate; SD: Standard deviation.
* Significant.

Table 3. Serum Liver Enzymes in Lead Recycling Workers and Control Groups (Mean ± SD)

Parameters	Lead Recycling Workers (n = 41)	Control (n = 41)	t-value	*P* Value
ALT (U/L)	18.67 ± 9.25	8.62 ± 4.28	6.311	< 0.001*
AST (U/L)	35.61 ± 11.21	19.37 ± 7.63	7.670	< 0.001*
ALP (U/L)	93.97 ± 20.73	78.91 ± 19.79	3.365	0.001*
γ-GT (U/L)	36.48 ± 29.41	25.42 ± 8.28	2.318	0.023*

ALT: Alanine transaminase; AST: Aspartate aminotransferase; ALP: Alkaline phosphatase; γ-GT: γ-glutamyltransferase; SD: Standard deviation.
* Significant.

Table 4. The Correlation between Blood Lead levels and Creatinine, eGFR, MDA, and GST in Lead Recycling Workers and Control Subjects

Parameters	Lead Recycling Workers		Control Subjects	
	(r)	*P*-value	Lead (r)	*P*-value
Blood lead vs. creatinine	0.666	< 0.001*	0.058	0.738
Blood lead vs. eGFR	-0.327	0.037*	-0.108	0.531
Blood lead vs. MDA	0.540	< 0.001*	0.391	0.019
Blood lead vs. GST	-0.316	0.044*	-0.052	0.767
MDA vs. creatinine	0.556	< 0.001*	-0.076	0.636
MDA vs. eGFR	-0.546	< 0.001*	0.006	0.970

Note. eGFR: Estimated glomerular filtration rate; MDA: Malondialdehyde; GST: Glutathione-s-transferase.
* Significant.

Conclusion

This study revealed significant alterations in the levels of some biochemical parameters of the liver, kidney, and oxidative stress in lead recycling factory workers. The harmful effects of lead on the kidney and liver may, however, be related to MDA (a marker of oxidative stress) levels.

Authors' Contribution

Conceptualization: Christian Ejike Onah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Data curation: Christian Ejike Onah, Chukwuemeka Samuel Meludu.
Formal Analysis: Christian Ejike Onah, Chukwuemeka Emmanuel Ogbodo
Funding acquisition: Christian Ejike Onah, Chinwemma Florence Onah, Stephen Monday Suru, Chinedu Michael Olisah, Alfred Friday Ehiaghe, Chukwuemeka Emmanuel Ogbodo, Wuraola Serah Nnaemeka, Ukamaka Ann Ijeomah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Investigation: Christian Ejike Onah, Chinwemma Florence Onah, Chinedu Michael Olisah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Methodology: Christian Ejike Onah, Chinwemma Florence Onah, Stephen Monday Suru, Alfred Friday Ehiaghe, Chukwuemeka Emmanuel Ogbodo, Wuraola Serah Nnaemeka, Ukamaka Ann Ijeomah.
Project administration: Christian Ejike Onah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Resources: Christian Ejike Onah, Chinwemma Florence Onah, Stephen Monday Suru, Chinedu Michael Olisah, Alfred Friday Ehiaghe, Chukwuemeka Emmanuel Ogbodo, Wuraola Serah Nnaemeka, Ukamaka Ann Ijeomah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Software: Christian Ejike Onah, Chukwuemeka Emmanuel Ogbodo.
Supervision: Chukwuemeka Samuel Meludu and Chudi Emmanuel Dioka.
Validation: Christian Ejike Onah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Visualization: Christian Ejike Onah, Chinwemma Florence Onah, Stephen Monday Suru, Chinedu Michael Olisah, Alfred Friday Ehiaghe, Chukwuemeka Emmanuel Ogbodo, Wuraola Serah Nnaemeka, Ukamaka Ann Ijeomah, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.
Writing–original draft: Christian Ejike Onah, Chukwuemeka Emmanuel Ogbodo, Chinwemma Florence Onah, Alfred Friday Ehiaghe, Ukamaka Ann Ijeomah.
Writing–review & editing: Chukwuemeka Emmanuel Ogbodo,Stephen Monday Suru, Chukwuemeka Samuel Meludu, Chudi Emmanuel Dioka.

Competing Interests

None.

Ethical Approval

The Ethics Committee of the Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nnewi Campus granted their clearance for this study with the approval number FBMS/EC/004/2014.

Funding

This research is self-sponsored.

References

1. Helmenstine AM. What Makes Lead Poisonous. 2012. www.chemistry.about. com/od/howthings workfaqs/f/leadpoisoning.htm. Accessed March 20, 2021.
2. World Health Organization Factsheet. Lead Poisoning and Health. 2013. Available at: https://www.who.int/mediacentre/factsheets/fs379/en/. Accessed April 3, 2021.
3. Okpogba AN, Ogbodo EC, Amah UK, Mounmbegna EP, Obi-Ezeani CN, Iwuji JC. Evaluation of some heavy metal levels in blood of lead acid battery manufacturing factory workers in Nnewi, Nigeria. Indian J Pharm Pharmacol 2020;7(2):82-94.
4. Amah UK, Madu NK, Ahaneku JE, Ahaneku GI, Onah CE, Onuegbu JA, et al. Evaluation of nephrotoxic effect of lead exposure among automobile repairers in Nnewi Metropolis.

Int J Res Med Sci. 2014;2(3):1107-11. doi: 10.5455/2320-6012.ijrms20140893.
5. World Health Organization Factsheet. Lead Poisoning and Health. 2019. Available at: https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health. Accessed February 5, 2021.
6. Pokras MA, Kneeland MR. Lead poisoning: using transdisciplinary approaches to solve an ancient problem. Ecohealth. 2008;5(3):379-85. doi: 10.1007/s10393-008-0177-x.
7. Bressler J, Kim KA, Chakraborti T, Goldstein G. Molecular mechanisms of lead neurotoxicity. Neurochem Res. 1999;24(4):595-600. doi: 10.1023/a:1022596115897.
8. Dapul H, Laraque D. Lead poisoning in children. Adv Pediatr. 2014;61(1):313-33. doi: 10.1016/j.yapd.2014.04.004.
9. Lamas GA, Navas-Acien A, Mark DB, Lee KL. Heavy metals, cardiovascular disease, and the unexpected benefits of chelation therapy. J Am Coll Cardiol. 2016;67(20):2411-8. doi: 10.1016/j.jacc.2016.02.066.
10. Dioka CE, Orisakwe OE, Adeniyi FA, Meludu SC. Liver and renal function tests in artisans occupationally exposed to lead in mechanic village in Nnewi, Nigeria. Int J Environ Res Public Health. 2004;1(1):21-5. doi: 10.3390/ijerph2004010021.
11. Onah CE, Meludu SC, Dioka CE, Onuegbu AJ, Onah CF, Ajaghaku DL, et al. Amelioratory effect of methanolic leaf extract of moringa oleifera on some liver and kidney function and oxidative stress markers in lead-intoxicated rats. European J Med Plants. 2016;12(4):1-12. doi: 10.9734/ejmp/2016/23763.
12. Ronis MJ, Badger TM, Shema SJ, Roberson PK, Templer L, Ringer D, et al. Endocrine mechanisms underlying the growth effects of developmental lead exposure in the rat. J Toxicol Environ Health A. 1998;54(2):101-20. doi: 10.1080/009841098158944.
13. Okpogba AN, Ogbodo EC, Dike CC, Nwoko SO, Ugwu EC, Amah AK, et al. Evaluation of heavy metal levels in blood of cable manufacturing factory workers in Nnewi. Int J Clin Biochem Res. 2019;6(3):430-6. doi: 10.18231/j.ijcbr.2019.091.
14. Okpogba AN, Ogbodo EC, Ugwu EC, Dike CC, Nwoko SO, Amah AK, et al. Assessment of heavy metal levels in blood of metal forging factory workers in Nnewi, Anambra State, Nigeria. J Pharm Biol Sci. 2019;7(1):34-40. doi: 10.18231/j.jpbs.2019.006.
15. Okpogba AN, Ogbodo EC, Ezeugwunne IP, Analike RA, Amah AK, Ikimi CG, et al. Assessment of the renal function status in occupationally exposed people working in metal fabricating factory in Nnewi. Int J Pharm Chem Anal. 2021;7(1):54-60. doi: 10.18231/j.ijpca.2020.008.
16. Adegbesan BO, Adenuga GA. Effect of lead exposure on liver lipid peroxidative and antioxidant defense systems of protein-undernourished rats. Biol Trace Elem Res. 2007;116(2):219-25. doi: 10.1007/bf02685932.
17. Bokara KK, Brown E, McCormick R, Yallapragada PR, Rajanna S, Bettaiya R. Lead-induced increase in antioxidant enzymes and lipid peroxidation products in developing rat brain. Biometals. 2008;21(1):9-16. doi: 10.1007/s10534-007-9088-5.
18. Yiin SJ, Lin TH. Lead-catalyzed peroxidation of essential unsaturated fatty acid. Biol Trace Elem Res. 1995;50(2):167-72. doi: 10.1007/bf02789419.
19. Sharma V, Sharma S, Pracheta, Sharma S. Lead induced hepatotoxicity in male Swiss albino mice: the protective potential of the hydromethanolic extract of *Withania somnifera*. Int J Pharm Sci Rev Res. 2011;7(2):116-21.
20. Rastogi SK. Renal effects of environmental and occupational lead exposure. Indian J Occup Environ Med. 2008;12(3):103-6.
21. Oberley TD, Friedman AL, Moser R, Siegel FL. Effects of lead administration on developing rat kidney. II. Functional, morphologic, and immunohistochemical studies. Toxicol Appl Pharmacol. 1995;131(1):94-107. doi: 10.1006/taap.1995.1051.
22. Nadia NO. The role of antioxidant properties of Celery against lead acetate induced hepatotoxicity and oxidative stress in irradiated rats. Arab J Nucl Sci Appl. 2013;46(1):339-46.
23. Jensen JE, Stainberg SE, Freese P, Marino E. Liver function tests. J Digest Disord. 2004;6:1-3.
24. Misra HP, Fridovich I. The role of superoxide anion in the autoxidation of epinephrine and a simple assay for superoxide dismutase. J Biol Chem. 1972;247(10):3170-5.
25. Sinha AK. Colorimetric assay of catalase. Anal Biochem. 1972;47(2):389-94. doi: 10.1016/0003-2697(72)90132-7.
26. Habig WH, Pabst MJ, Jakoby WB. Glutathione S-transferases. The first enzymatic step in mercapturic acid formation. J Biol Chem. 1974;249(22):7130-9.
27. Gutteridge JM, Wilkins S. Copper-dependent hydroxyl radical damage to ascorbic acid: formation of a thiobarbituric acid-reactive product. FEBS Lett. 1982;137(2):327-30. doi: 10.1016/0014-5793(82)80377-3.
28. Hessel DW. A simple and rapid quantitative determination of lead in blood. Atomic Absorption Newsletter. 1968;7(3):55-6.
29. Bergmeyer HU, Scheibe P, Wahlefeld AW. Methods for aspartate and alanine amino transferase. Clin Chem. 1979;125:1487.
30. Schlebusch H, Rick W, Lang H, Knedel M. [Standards in the activities of clinically important enzymes]. Dtsch Med Wochenschr. 1974;99(15):765-6. doi: 10.1055/s-0028-1107840. [German].
31. Persijn JP, van der Slik W. A new method for the determination of gamma-glutamyltransferase in serum. J Clin Chem Clin Biochem. 1976;14(9):421-7. doi: 10.1515/cclm.1976.14.1-12.421.
32. Kassirer JP. Clinical evaluation of kidney function--glomerular function. N Engl J Med. 1971;285(7):385-9. doi: 10.1056/nejm197108122850706.
33. Larsen K. Creatinine assay by a reaction-kinetic principle. Clin Chim Acta. 1972;41:209-17. doi: 10.1016/0009-8981(72)90513-x.
34. Kageyama N. A direct colorimetric determination of uric acid in serum and urine with uricase-catalase system. Clin Chim Acta. 1971;31(2):421-6. doi: 10.1016/0009-8981(71)90413-x.
35. Soltaninejad K, Kebriaeezadeh A, Minaiee B, Ostad SN, Hosseini R, Azizi E, et al. Biochemical and ultrastructural evidences for toxicity of lead through free radicals in rat brain. Hum Exp Toxicol. 2003;22(8):417-23. doi: 10.1191/0960327103ht385oa.
36. Vaziri ND, Lin CY, Farmand F, Sindhu RK. Superoxide dismutase, catalase, glutathione peroxidase and NADPH oxidase in lead-induced hypertension. Kidney Int. 2003;63(1):186-94. doi: 10.1046/j.1523-1755.2003.00711.x.
37. Dongre NN, Suryakar AN, Patil AJ, Rathi DB. Occupational Lead Exposure In Automobile Workers In North Karnataka (India): Effect On Liver And Kidney Functions. Al Ameen J Med Sci. 2010; 3(4): 284-292.
38. Adegbesan BO, Adenuga GA. Effect of lead exposure on liver lipid peroxidative and antioxidant defense systems of protein-undernourished rats. Biol Trace Elem Res. 2007;116(2):219-25. doi: 10.1007/bf02685932.
39. Bokara KK, Brown E, McCormick R, Yallapragada PR, Rajanna S, Bettaiya R. Lead-induced increase in antioxidant enzymes and lipid peroxidation products in developing rat brain. Biometals. 2008;21(1):9-16. doi: 10.1007/s10534-007-9088-5.
40. Xu J, Lian LJ, Wu C, Wang XF, Fu WY, Xu LH. Lead induces oxidative stress, DNA damage and alteration of p53, Bax and Bcl-2 expressions in mice. Food Chem Toxicol. 2008;46(5):1488-94. doi: 10.1016/j.fct.2007.12.016.