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HEALTH HAZARDS AMONG WORKERS ENGAGED IN COINAGE INDUSTRY

By

Siha MS, Mohammed RS, Fouad MM, and El-Gammal SE

Department of Occupational and Environmental Medicine, Faculty of Medicine, Cairo University

Corresponding author: *Mohammed RS* ***.Email:*** *rateba.said@kasralainy.edu.eg*

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Abstract

Introduction: Coinage industry is an industrial facility which manufactures coins that can be used as currency. Many metals are used in this industry as: Copper, Aluminum, Nickel, Zinc, Silver, and Gold. **Aim of Work:** To study the health hazards among workers engaged in the manufacture of coinage industry with special emphasis on the health effects due to the exposure to Copper and Aluminum. **Materials and Methods:** The study population consisted of forty-two personnel engaged in one of coinage industry factory in Cairo /Egypt and were exposed to copper and aluminium; and a comparison group of 42 no exposed personnel . A medical history was taken physical examination and laboratory investigations including serum copper and aluminum, CBC, urea, creatinine and liver enzymes (AST/ALT) were done. **Results:** The present study showed adverse health effects among the exposed workers including some hematological manifestations, allergy, eye and skin symptoms, abdominal pain in addition to bone ache and memory problems. Laboratory investigations revealed statistically significant higher copper and aluminium levels in the exposed group's serum compared to the control group. As regards liver and kidney function tests; despite being within normal range of value but statistically significant differences were found being higher among the exposed group. Complete blood count values including hemoglobin , platelet and total leucocytic count were within normal values but total leucocytic count was found statistically significantly low among the exposed group. **Conclusion and Recommendations:** The study detected elevations of serum copper and aluminium among the exposed workers in coinage industry associated with some adverse health effects. Medical exams before hiring and on a regular basis for personnel who are exposed including clinical examination and measurement of serum level of copper and aluminum, CBC, liver, and kidney functions tests.

Key words: Coinage industry, Aluminum, Copper, Liver and kidney functions.

Introduction

Coinage industry is an industrial facility which manufactures coins that can be used as currency. It also produces badges, buttons, and precision parts with small or polished surface features. It takes place at elevated temperature using a kind of stamping. The process was performed either manually, what is called hammered coinage, or by machine-struck coinage (milled coinage). Many metals are used in this industry as Copper, Aluminum, Nickel, Zinc Silver, and Gold (Lohne et al., 2010).

The most common element in the earth's crust is aluminium (Al), which is widely dispersed across it. Al is seldom found in its elemental form in nature because of its strong reactivity. It exists in mixtures with other elements, most frequently with silicon, fluorine, and oxygen. It has been demonstrated that Al accumulates in all mammalian tissues, although it preferentially accumulates in the brain, liver, kidneys, and bones. Its toxicity destroys tubular kidney cells and causes glomerular filtration failure. It causes anaerobic respiration, oxidative stress, and decreased ATP synthesis in the liver, which accelerates the development of obesity, type II diabetes, and hepatic steatosis (Othman et al., 2020). Al is associated with numerous brain disorders, including multiple sclerosis, Parkinson's disease, and Alzheimer's disease, although the relationship between Al and neurodegenerative diseases is debatable (Inan-Eroglu and Ayaz, 2018). One of the key micronutrients, copper (Cu) is required for many different metabolic activities in living cells. Even though it is an essential element, it is harmful in high concentrations. Upper respiratory tract irritation, metallic taste, nausea, and metal fume fever can all result from exposure to copper vapors. While ingestion of large amount of Cu causes gastrointestinal distress (nausea, vomiting, abdominal pain) and anemia. Chronic exposure to copper leads to symptoms of diarrhea, headaches, and in severe cases, renal failure (Gerhardsson, 2022).

Aim of Work

To study the health hazards among workers engaged in the manufacture of coinage industry with special emphasis on the health effects due to the exposure to Copper and Aluminum.

Materials and Methods

Study design: this is a comparative cross sectional analytical study.

Place and duration of the study: the study was conducted in a coinage industry factory located in Cairo, Egypt from April to June 2022.

Study sample: The study population was divided into two groups: An exposed group consisted of fifty workers who were the whole population exposed to copper and aluminum in their work. Only forty-two workers agreed to participate in the study and fulfilled the inclusion criteria with age ranged from 18-60 years old and duration of employment from 3 to 37 years. A control group of forty-two subjects were selected from the administrative department of comparable age, gender, and socioeconomic status, and had no history of occupational exposure to copper and aluminum. Inclusion criteria: workers occupationally exposed to copper and aluminum with at least one year duration of work and agreed to participate in the study. Exclusion criteria: workers who refused to participate in the study and who were complaining of diseases related to liver, kidney and psychological disturbances.

Study methods: The studied population was subjected to

A-Questionnaire: Workers were interviewed face-to-face through a detailed questionnaire and personal, occupational, medical, family histories were taken.

B-General and systematic clinical examinations were done.

C- Laboratory investigations: Using a dry plastic disposable syringe and a vein puncture, 10 cc of venous blood were extracted from each individual in an entirely aseptic manner. A tube containing seven cubic centimeters (cc) of blood was left to clot, and the serum was separated using a centrifuge to measure the level of copper and aluminum as well as to determine the results of tests for liver and kidney function. For a complete blood count, an additional three cc of blood was given in a tube containing dipotassium ethylene diamine tetra acetic acid (EDTA). All samples were transported in a special container on the same day to be analyzed in the laboratory.

C.1) Complete blood count (CBC): An automated analyzer conducted a complete blood count. The component that counted cells in the blood measured the quantity and variety of cells (flow Cytometry) (Chabot-Richards and George , 2015).

C.2) kidney function tests: Determination of serum urea done by Berthelot method. (Mišić et al., 2021) while determination of serum creatinine using Jaffe kinetic method (Kerns E et al., 2015).

C.3) Liver function tests: Alanine amino transferase (ALT) and Aspartate amino transferase (AST) serum levels were analyzed using enzymatic rate detection by colorimetric method (Tag-Adeen et al., 2018).

C.4) Serum levels of Copper (Cu) and Aluminum (AL): The instrument utilized was an ICP-MS/MS Model 8800 (Inductively coupled plasma mass spectrometer). It's a form of mass spectrometry where the sample is ionized using an inductively coupled plasma. The excited atoms release light at specific wavelengths (Huang and Beauchemin, 2003).

Consent

After outlining the purpose and significance of the investigation, the population under study gave their oral consent. Throughout the sample collection,coding,testing,and recording of the outcomes, strict confidentiality was upheld.

Ethical Approval

Every process followed the guidelines outlined in the Helsinki Declaration. The Research Ethics Committee (REC), Faculty of Medicine, Cairo University, Egypt, and the Occupational and Environmental Medicine Department's ethical committee both authorised the study.

Data Management

The collected data were coded and input into a computer using the statistical package of social science software (SPSS) version 23. For quantitative variables that were regularly distributed, the mean and standard deviation (SD) were utilised; for qualitative variables, the number and percent; and for quantitative variables that were not normally distributed, the median and range. For regularly distributed quantitative data, the independent sample t-test was used to compare the groups; for non-normally distributed quantitative variables, the non-parametric Mann-Whitney test was employed. Chi square (2) test was used to compare categorical data of qualitative factors. When the expected frequency is less than five, an exact test was utilised in its place. To determine whether there were any linear relationships between the quantitative variables, correlations (r) were calculated. P-values below 0.05 were regarded as statistically significant.

Results

Table (1): Socio-demographic characteristics and general manifestations of the studied sample.

	Exposed (No=42) Mean ±SD	Control (No =42) Mean ±SD	p value (Independent t – test)
Age/years	48.95±6.3	46.02±9.07	0.09
Duration of employment / years	21.69±8.93	20.52±8.73	0.083
Smoking amount / day / years	264.33±274.47	53.33±133.59	**< 0.001****
	No. (%)	**No. (%)**	**p value** (Chi- square test)
Sex: Male Female	40 (95.20) 2 (4.80)	35 (83.30) 16.70))7	0. 156
Smoking status: Current Non -smoker Ex – smoker	18 (42.90) 16 (38.10) 8 (19.00)	6 (14.30) 35 (83.30) 1 (2.40)	**< 0.001****
Present medical history	**Exposed (No=42) No. (%)**	**Control (No =42) No. (%)**	**p value**
Chronic fatigue	12 (28.60)	1(2.40)	**0.001**[1]**
Allergy presence: Yes NO	15 (35.70) 27 (64.30)	7(14.30) 35(85.70)	**[1]*0.023**
Eye Redness Pain	15 (35.70) 14 (33.30)	0 (0.00) 1(2.40)	**<0.001**[2]** **<0.001**[1]**

*: Statistically significant **: Highly statistically significant [1]: Chi- square test [2]: Fisher's exact

Table (1) showed there is no statistically significant difference between the exposed and control groups regarding age, sex, and duration of employment. There are highly statistically significant differences between both groups as regards smoking status; 42.9% of the exposed group were current smokers. General manifestations showed statistically significant differences between both groups as regard suffering from chronic fatigue, allergy, and eye pain and redness.

Diabetes, hypertension, oral manifestation, clubbing, pallor, and tremors were higher among the exposed group compared to the control, but it didn't reach the significant level. Neither of both groups reported history of weight loss and 78.6% of workers used PPE (results are not tabulated).

Table (2): Comparison of gastrointestinal, renal, skin and haematological systems manifestations among the studied groups.

	Exposed (No =42) No. (%)	**Control (No =42) No. (%)**	**p value**
Gastrointestinal manifestations:			
Indigestion and flatulence	10 (23.80)	2 (4.80)	**0.013*[1]**
Renal manifestations:			
Burning micturition	8 (19.00)	0 0.00	**0.005*[2]**
Loin pain	5 (11.90)	1 (2.40)	0.202[1]
Skin manifestations:			
Dry skin	15 (35.70)	1 (2.40)	**<0.001**[1]**
Eczema/dermatitis	12 (28.60)	0 (0.00)	**<0.001**[2]**
Hematological manifestations:			
Dyspnea	15 (35.70)	1 (2.40)	**<0.001**[1]**
Palpitations	9 (21.40)	0 (0.00)	**0.002**[2]**
Easy fatigability	12 (28.60)	1 (2.40)	**0.001**[1]**

*: Statistically significant **: Highly statistically significant [1]: Chi- square test [2]: Fisher's exact

Table 2 demonstrated a statistically significant difference between both groups regarding indigestion and flatulence as gastro intestinal manifestations, burning micturition as renal manifestations , dry skin and eczema, in addition to hematological manifestations as dyspnea, palpitations and easy fatigability (p value <0.05) .

Other gastro intestinal manifestations as nausea, vomiting, abdominal pain, heart burn, constipation, diarrhea and change in taste showed no statistically significant difference (results are not tabulated) .

Table (3): Comparison of central nervous system, musculoskeletal, cardiovascular and respiratory systems manifestations among the studied groups.

	Exposed (No =42) No. (%)	Control (No =42) No. (%)	p-value
Central nervous system:			
Low concentration	19 (45.20)	5 (11.90)	**0.001**** [1]
Numbness	11 (26.20)	1 (2.40)	**0.002**** [1]
Muscle weakness	7 (11.70)	0 (0.00)	**0.012*** [2]
Musculoskeletal system:			
Muscle ache/cramps	13 (31.00)	0 (0.00)	**<0.001****[2]
Arthritis	22 (52.40)	6 (14.30)	**<0.001****[1]
Bone ache	11 (26.20)	2 (4.80)	[1]***0.007**
Cardiovascular manifestations:			
Chest pain	11 (26.20)	0 (0.00)	**<0.001****[2]
Palpitations	9 (21.40)	0 (0.00)	**0.002****[2]
Orthopnea	2 (4.80)	0 (0.00)	[2] 0.494
Respiratory manifestations:			
Nasal irritation	14 (33.30)	2 (4.80)	**0.001****[1]
Sore throat	8 (19.00)	0 (0.00)	[2]***0.005**
Rhinitis	12 (28.60)	2 (4.80)	**0.003****[1]
Shortness of breath	15 (35.70)	1 (2.40)	**<0.001****[1]
Cough			
Dry	10 (23.80)	2 (4.80)	[2]***0.013**
productive	10 (23.80)	2 (4.80)	[1]***0.013**
Wheezes	8 (19.00)	0 (0.00)	[1]***0.005**

*: Statistically significant **: Highly statistically significant [1]: Chi- square test [2]: Fisher's exact

Table 3 showed statistically significant difference between both groups regarding symptoms of central nervous system, and musculoskeletal system affection, as well, chest pain and palpitation as cardiovascular symptoms, shortness of breath and nasal irritation as respiratory symptoms were higher among the exposed group.

Table (4): Comparison between laboratory investigations among the studied sample.

	Exposed (No =42) Mean ±SD	Control (No =42) Mean ±SD	p value Independent t – test
Serum copper (μg/dl)	104.91±24.33	73.57±10.86	**<0.001****
Serum aluminum (μg/l)	19.95±5.29	5.17±1.34	**<0.001****
Liver function tests:			
AST (U/L)	24.21±5.76	20.29±4.35	**0.001****
ALT (U/L)	25±7.63	22.69±5.36	0.112
Kidney function tests:			
Urea (mg/dl)	26.88±5.19	21.6±4.54	**<0.001****
Creatinine (mg/dl)	0.94±0.09	0.80±0.12	**<0.001****
Complete blood count tests:			
HB (gm/dl)	15.00±1.22	14.79±1.54	0.498
Total leukocytic count (TLC/mm^3)	7.12±1.87	7.85±1.49	**0.048***
Platelets (/mm^3)	242.33±51.53	267.31±65.24	0.055

*: Statistically significant **: Highly statistically significant

Table 4 showed a statistically significant difference between exposed workers and control regarding serum level of copper and aluminum (p-value<0.001), it was higher among the exposed group in which mean serum levels were 104.91 ± 24.33 (μg/dl) and 19.95 ± 5.29 (μg/dl) respectively**.** There were also statistically significant differences regarding liver function and kidney function tests (p-value< 0.001), despite being within normal range of value. Complete blood count values were within normal with significant difference between both groups regarding total leucocytic count (p-value <0.05); the exposed group was lower than the control. Other blood parameters showed no statistically significant difference although the level of platelets was lower among the exposed group compared to the control, but not to a significant level.

Table (5): Multivariate linear regression analysis to detect predictors of serum aluminum.

Model		Standardized Coefficients	t	p value	95.0% Confidence Interval for B	
		Beta			Lower Bound	Upper Bound
Serum aluminum mcg/L	(Constant)		4.550	**<0.001****	5.643	14.705
	Shortness of breath	0.363	2.957	**0.005***	1.247	6.680
	ALT (up to 50 U/L)	0.385	3.202	**0.003****	0.098	0.436
	Headache	0.284	2.385	**0.022***	0.601	7.378
	Nasal irritation	0.277	2.291	**0.028***	0.355	5.786

*: Statistically significant **: Highly statistically significant

Table 5 showed that shortness of breath (beta:0.363, 95%CI: 1.247,6.680), ALT (beta:0.385,95%CI :0.098, 0.436), headache (Beta:0.601, 95% CI :7.378, 0.284) and nasal irritation(Beta:0.277, 95%CI :0.355 ,5.786) were statistically significant (p-value <0.05)positive predictors for serum aluminum.

Predictors for serum copper were performed and there were no statistically significant predictors (results are not tabulated).

Discussion

Several previous studies demonstrated that exposure to heavy metals such as Aluminum (Al) (Riihimäki and Aitio, 2012) and copper (Cu) (Matamala et al., 2021) were associated with toxic effects on human health. To our knowledge these effects in coinage industry in Egypt have not previously investigated. Besides, the symptoms of combined occupational exposure to copper and Al had not been widely deliberated. Thus, the current study aimed to assess the health effects among some Egyptian workers in coinage industry occupationally exposed to Cu and Al. The study was done on 42 persons occupationally exposed to Cu and Al, with mean age 48.95 ±6.3, and mean duration of employment 21.69 ± 8.93 years matched regarding to age, sex and duration of employment to 42 administrative controls. Comparing exposed and control groups, symptoms like chronic fatigue, allergy, and eye symptoms (as redness and pain) were more relevant among the exposed group (Table 1). This was in line with a research work done by Larsson et al., 2007 that studied a group of workers exposed to Al (289) and detected that the exposed group experienced more ocular symptoms than the control group. Furthermore, Cai et al., 2009 who found that a 64-year-old industrial worker who had recently retired from a position requiring him to handle copper wire experienced eye irritation as a result of exposure to copper dust. In comparison to the control group, EL Safty and her colleagues , 2014; found a statistically significant increase in muscle fatigue among Egyptian copper smelters.

Regarding burning micturition, indigestion, flatulence, and abdominal pain, there was a statistical significance increase among the studied coinage workers (Table 2). In accordance, Pizzaro et al. 2007, from Santiago, Chile, did an experimental study on sixty adult, healthy women assigned to receive four concentrations of copper (Cu (II)) in their drinking water and found a correlation between copper exposure and gastrointestinal symptoms, such as diarrhea and abdominal pain.

The studied population had statistically significant skin manifestations including dry skin and eczema, in addition to hematological manifestations as dyspnea, palpitations and easy fatigability (Table 2). Similarly, Alkhatib et al. (2014) from Jordan observed that jewellery workers exposed to copper and nickel had prevalent eczema symptoms and Purello-D'Ambrosio and his colleagues , 2000 from Italy; detected aluminium allergy in a patient with occupational contact dermatitis. Also, Copper powder inhalation resulted in hemolytic anemia and hypoxemia in a 2 years-old child (Donoso et al., 2007). There was a statistically significant increase in the symptoms of central nervous system in the form of poor concentration, muscle weakness, and musculoskeletal system affection as muscle and bony pains and arthritis among the exposed workers (Table 3). This agreed to the findings of Buchta et al. 2005, who found that workers exposed to Al had notable neurological changes in their response times, eye-hand coordination, memory, and/or motor skills during performance tests. On the other hand, German researchers Schmid et al. (1995) found no appreciable changes in the bone mineral content (measured by osteodensitometry) of workers who had been exposed to Al powder for an average of 12.6 years.

Concerning copper, the experimental study conducted in India by Kumar et al., 2019 examined male Sprague Dawley rats exposed to copper sulphate and found that the rats› muscle strength was compromised. Animals given a higher dose of copper (20 mg/kg) showed more noticeable changes than those given a lower dose. In a different study, 2,827 schoolchildren who were exposed to copper from traffic pollution showed decreased reaction times in 263 of them, and high concentrations of copper in the striatum gray matter was seen in imaging. Additionally, it seemed that copper was connected to modifications in the neural tissue diffusion architecture (Pujol et al., 2016).

Among the exposed coinage workers, the most common respiratory and cardiovascular symptoms were nasal irritation, shortness of breath (dyspnea), and chest pain (Table 3).

Nasal irritation and dyspnea were statistically significant positive predictors of serum aluminum levels (Table 5). Results of the study done by Radon et al., 1999 was in harmony with the current results as they found that Al exposed workers in pot room had wheezes, dyspnea, and/or impaired lung function.

In 2015, Gehring and hiscolleagues demonstrated that forced expiratory volume in one second was negatively correlated with copper, while the incidence of asthma, prevalence of asthma symptoms, and rhinitis were positively correlated with copper.Regarding cardiovascular manifestations, Occelli et al., 2020 reported correlations between cardiovascular mortality and heart diseases and copper air pollution, and Costello et al., 2014 found an increase in the risk of ischemic heart diseases (IHD) among workers exposed to Al.

The studied coinage workers had statistically significant higher serum levels of copper and aluminum (Table 4). Coinage industry involves many metals as: Copper, Aluminum, Nickel, Zinc, Silver, and Gold, so workers in its manufacturing can be exposed to all these metals during the industrial process (Echavarren et al., 2016). A statistically significant difference regarding liver function and kidney function tests were observed among the studied exposed group compared to the control, despite being within normal range of value. Complete blood count values were within normal (Table 4). Bakour and his colleagues (2017) from Morocco found that aluminum significantly reduced hemoglobin and significantly elevated blood urea, transaminase, C-reactive protein, and monocyte count in rats. Haemolytic anemia, hemoglobinemia, methemoglobinemia, leucocytosis, and decreased reticulocyte count were the most frequent hematological side effects of copper exposure (Valsami et al., 2012). The most frequent consequence of copper exposure, according to the research done by Du and Mou (2019), was changes in liver enzyme activity, including lactate dehydrogenase (LDH), alanine aminotransferase (ALT), alkaline phosphatase (ALP), and aspartate amino transferase (AST).

According to Yu and his colleagues› findings, 2021, prolonged exposure to high copper concentrations may exacerbate oxidative stress liver injury by raising the plasma malondialdehyde(MDA) content and hepatic function index (ALT, AST, and ALP) while decreasing the activity of antioxidant enzymes linked to oxidative stress.

Correlating serum copper and aluminum among the coinage workers to socio-demographic and laboratory variables (renal and liver functions, complete blood counts and levels of Al and Cu in serum), serum copper showed no significant correlation to any (results were not tabulated) while serum aluminum had only statistically significant positive correlation to serum ALT (p-value< 0.009). Serum ALT was positive predictors for serum aluminum (Table 5).

However, Liu and his colleagues ,2020 discovered that plasma concentrations of aluminum, arsenic, barium, lead, molybdenum, rubidium, strontium, vanadium, and zinc were significantly associated with the decreasein kidney function among Chinese adults.

In contrast, Gaballah et al. (2013) found no significant changes in liver enzymes between the aluminum foundry workers and the healthy non-exposed subjects. Yang and colleagues , 2019; detected that renal function disturbance was significantly correlated with copper, rubidium, strontium, molybdenum, and plasma arsenic and molybdenum. This could be attributed to the exposure of different metals not only for Al and Cu.

Conclusion and Recommendations: From the present study, we found an elevation of serum copper and aluminium among the exposed workers in coinage industry associated with adverse health effects in the form of some hematological manifestations, allergy, eye and skin symptoms, abdominal pain, bone ache and memory problems. Furthermore, there was a statistically significant variation in the mean values of the kidney, liver, and CBC tests between the exposed workers and the control group. So we recommend pre-employment and periodic medical examination for the exposed workers including clinical examination; determination of Cu and Al levels, blood picture, serum creatinine and urea, liver enzymes for early detection of any adverse health effects.

Conflict of Interest

There are no conflict of interests

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References

1. Alkhatib AJ, Boran AM, Al-Hourani Z, Al-Balwi A, Muhammad M ,et al. (2014): Occupational exposure to nickel, cadmium and copper among

workers in jewellery manufacturing. Eur Sci J; 10(15): 159- 69.

2. Bakour M, Al-Waili NS, El Menyiy N, Imtara H, Figuira AC, et al. (2017): Antioxidant activity and protective effect of bee bread (honey and pollen) in aluminum-induced anemia, elevation of inflammatory makers and hepato-renal toxicity. J Food Sci Technol; 54:4205-12.
3. Buchtaa M, Kiesswetterb E, Schäperb M, Zschieschec W, Schallerd KH et al. (2005): Neurotoxicity of exposures to aluminium welding fumes in the truck trailer construction industry. Env Toxicol Pharmacol; 19(3): 677-85.
4. Cai R, Zhang C, Ding W and Zhao J (2009): Corneal melting induced by a presumed copper containing foreign body. Clin Experiment Ophthalmol; 37(3): 328-30.
5. Chabot-Richards DS and George TI (2015): White blood cell counts: reference methodology. Clin Lab Med; 35(1):11-24. DOI: 10.1016/j.cll.2014.10.007. Epub 2014 Dec 4. PMID: 25676369.
6. Costello S, Brown DM, Noth EM, Cantley L, Slade MD et al. (2014): Incident ischemic heart disease and recent occupational exposure to particulate matter in an aluminum cohort. J Expo Sci Environ Epidemiol; 24(1):82-8.
7. Donoso A, Cruces P, Camacho J, Carlos Ríos J, Paris E et al. (2007): Acute respiratory distress syndrome resulting from inhalation of powdered copper. Clin Toxicol; 45(6): 714-6.
8. Du Y, and Mou Y (2019): The role of plasmapheresis in treating lethal cupric sulfate poisoning. Am J Med Sci; 357(4):338-42.
9. Echavarren AM, Jiao N and Gevorgyan V (2016): Coinage metals in organic synthesis. Chemical Society Rev; 45(16): 4445-7.
10. El Safty A, Rashed L, Samir A and Teleb H (2014): Oxidative stress and arsenic exposure among copper smelters. Br J Med Med Res; 4(15): 2955.
11. Gaballah IF, Helal SF, Rashed LA, and Abdelsamea AA (2013): Dyslipidemia and disruption of L-carnitine in aluminum exposed workers. Egypt J Occup Med; 37 (1): 33-46.
12. Gehring U, Beelen R, Eeftens M, Hoek G, De Hoogh K, et al. (2015): Particulate matter composition and respiratory health: the PIAMA Birth Cohort study. Epidemiology; 26(3):300-9.
13. Gerhardsson L (2022): Diagnosis and treatment of metal poisoning general aspects. In Handbook on the Toxicology of Metals (pp. 663-684). Academic Press.
14. Huang C and Beauchemin D (2003): Direct multi elemental analysis of human serum by ICP-MS with on-line standard addition using flow injection. J Anal Spectrom; 18 (8): 951-2.
15. Inan-Eroglu E and Ayaz A (2018): Is aluminum exposure a risk factor for neurological disorders? J Res Med Sci 6; 23:51. DOI: 10.4103/jrms.JRMS-921-17. PMID: 30057635; PMCID: PMC6040147.
16. Kerns E, Minnings K, Fiore M, Fiore M, Parekh RS, et al. (2015): Chronic kidney disease prevalence in Rivas, Nicaragua: use of a field device for creatinine measurement. Clin Biochem; 48(6): 456-8.
17. Kumar J, Sathua KB and Flora SJS (2019): Chronic copper exposure elicits neurotoxic responses in rat brain: Assessment of 8-hydroxy-2-deoxyguanosine activity, oxidative stress and neurobehavioral parameters. Cell Mol Biol; 65(1):27-35.
18. Larsson B, Karlsson JE and Nielsen J (2007): Respiratory and ocular symptoms in workers exposed to potassium aluminium-tetrafluoride soldering flux. Int Arch Occup Environ Health; 80: 627-33.
19. Liu Y, Yuan Y, Xiao Y, Li Y, Yu Y, et al. (2020): Associations of plasma metal concentrations with the decline in kidney function: A longitudinal study of Chinese adults. Ecotoxicol Environ Saf; 189: 110006.
20. Lohne O, Risvaag JA, Ulseth P and Lohne J (2010): The Mint in the Nidaros Archbishop´ s Palace. Coin production under Archbishop GauteIvarsson (1475-510).

DetKongeligeNorskeVidenskabersSelskabsSkrifter. file. Available at : Otto_Lohne_Jon_Anders_Risvaag_Pal_Ulseth%20(1).pdf.

21. Matamala PJ, Aguayo FF, Ascorra CP, and Ansoleaga ME (2021): Occupational Health in Chilean Copper Mine Workers: A Scoping Review of Literature (2008-2019). Revista Salud Uninorte; 37(3): 803-27.
22. Mišić ID , Mitić SS, Kostić DA, Tošić SB, Pecev-Marinković ET, et al.(2021): Kinetic-spectrophotometric approach to the modified Berthelot procedure for serum urea determination. Chem Pap; 75(2): 565-74.
23. Occelli F, Lanier C, Cuny D, Deram A, Dumont J et al. (2020): Exposure to multiple air pollutants and the incidence of coronary heart disease: A fine-scale geographic analysis. Sci Total Environ; 714:136608.
24. Othman MS, Fareid MA, Abdel Hameed RS and Abdel Moneim AE (2020): The Protective Effects of Melatonin on Aluminum-Induced Hepatotoxicity and Nephrotoxicity in Rats. Oxidative Medicine and Cellular Longevity Volume 2020, Article ID 7375136, 12 pages .https://doi.org/10.1155/2020/7375136.
25. Pizarro F, Araya M, Vasquez M, Lagos G, Olivares M, et al. (2007): Case study of complaints on drinking water quality: Relationship to copper content. Biol Trace Elem Res; 116(2):131-45.
26. Pujol J, Fenoll R, Macià D, MartínezåVilavella G, AlvarezàPedrerol M, et al. (2016): Airborne copper exposure in school environments associated with poorer motor performance and altered basal ganglia. Brain and Behavior; 6(6):e00467.
27. Purello-D›Ambrosio F, Gangemi S, Minciullo PL, Lombardo G, Ricciardi L et al. (2000):Aluminium allergy in a patient with occupational contact dermatitis. Allergo lImmunopathol; 28(2):74-5.
28. Radon K, Nowak D and Szadkowski D (1999): Lack of combined effects of exposure and smoking on respiratory health in aluminium potroom workers. Occup Environ Med; 56(7): 468-72
29. Riihimäki V and Aitio A (2012): Occupational exposure to aluminum and its biomonitoring in perspective. Crit Rev Toxicol; 42(10):827-53.
30. Schmid K, Angerer J, Letzel S, Sturm G and Lehnert G (1995): Use of bone mineral content determination by X-ray absorptiometry in the evaluation of osteodystrophy among workers exposed to aluminium powders. Sci Total Environ; 163(1-3):147-51.
31. Tag-Adeen M, Omar MZ, Abd-Elsalam FM, Hasaneen A, Mohamed MA, et al. (2018): Assessment of liver fibrosis in Egyptian chronic hepatitis B patients: a comparative study including 5 noninvasive indexes. Medicine; 97(6): e9781.
32. Valsami S, Stamoulis K, Lydataki E and Fountoulaki-Paparizos L (2012): Acute copper sulphate poisoning: a forgotten cause of severe intravascular haemolysis. Br J Haematol; 156(3):294.
33. Yang F, Yi X, Guo J, Xu S, Xiao Y, et al. (2019): Association of plasma and urine metals levels with kidney function: A population-based cross-sectional study in China. Chemosphere; 226:321-8.
34. Yu W, Liao J, Yang F, Zhang H, Chang X, et al. (2021): Chronic tribasic copper chloride exposure induces rat liver damage by disrupting the mitophagy and apoptosis pathways. Ecotoxicol Environ Saf; 212: 111968.