Egyptian Journal of Occupational Medicine, 2018; 42 (3) : 383-398

HEALTH IMPACT OF EXPOSURE TO COPPER AND ZINC AMONG WORKERS IN A METAL DIE CASTING FOUNDRY IN 10TH RAMADAN CITY

By

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Abstract

Introduction: Little information is present regarding health impact of copper and zinc exposure among metal die casting workers in Egyptian foundries. **Aim of work:** 1-To measure blood levels of zinc and copper among the studied groups, 2- To measure the prevalence of respiratory hazards among exposed workers and their impact, 3-To identify other health problems due to copper and zinc exposure such as anemia and respiratory disorders, and lastly 4- To correlate such problems with blood levels of zinc and copper. **Material and Methods:** A comparative cross-sectional study was conducted among 60 male workers, 30 of them were the exposed group involved in processes like melting. The other 30 were chosen from the administrative departments in the same foundry as the reference group. All workers were interviewed using questionnaire for occupational history, respiratory and other symptoms. Blood samples were taken to measure serum copper and zinc, hemoglobin (Hb), and white blood cells counts (WBCs). Ventilatory functions were assessed too. **Results:** The study showed no significant difference in the blood levels of zinc and copper among the studied groups. However, symptoms related to copper and zinc toxicity were significantly more prevalent among the exposed group, like respiratory symptoms, symptoms regarding skin, throat and eye irritation, metallic taste in the mouth and exhaustion. Symptoms suggestive of metal fume fever including flue like symptoms, arthralgia, fever, and leukocytosis were more prevalent among the exposed workers, but without significant difference. There was no significant correlation between copper and zinc blood levels and other findings such as; Saint George Respiratory Questionnaire scores, Peak Expiratory Flow Rate scores, mean Hb, and WBCs level. **Conclusion:** Although there was no significant difference

in blood levels of zinc and copper among the studied groups, exposed workers were complaining of different symptoms, one of which was respiratory symptoms that had a significant impact on their social and psychological functioning.

Keywords: Copper toxicity, Zinc toxicity, Foundry hazards, Die casting, Metal fume fever and Respiratory symptoms.

Introduction

Die casting is one of the oldest methods used to shape metals. The metal or metal alloy is melted, then poured into a prepared mold and allowed to cool. The molded piece is then removed from the mold and processed further by one or more of a great variety of processes (Woodard et al, 2006). Die casting has many applications; being used in many manufactures including automobile industry, business machines, and toys (Rajput, 2007). The four principal metals, with different alloy compositions, that are commonly hot- or cold chamber die cast are aluminum, zinc, magnesium and copper-base alloys (Laukli et al, 2004). In die casting industry, workers are exposed to metals through inhalation of fumes of molten metals, skin contact, and even ingestion (NOHSC, 1989).

Zinc, which is one of the components used in this industry, can affect the health of workers. Its normal blood range is 50–100 μg/dl, while the toxic manifestations are seen when the oral intake is more than 1000 mg/day (Vasudevan et al, 2011). Acute Toxicity is usually seen in welders due to inhalation of zinc oxide fumes and results in metal-fume fever which is; an acute 24– to 48–hour illness characterized by influenza–like symptoms including fever, chills, sweating, weakness, headaches, muscle aches, and dryness of mouth and throat (ACGIH, 1999). Chronic toxicity may cause gastric ulcer, pancreatitis, anemia, nausea, vomiting and pulmonary fibrosis (Vasudevan et al, 2011). The reproductive system may be affected too, and the developing fetus may be damaged (NJDHSS, 2007).

Copper is considered to be a respiratory irritant. Its normal blood level is 70–150 μg/dl (Vasudevan et al, 2011). Inhalation of copper fumes has been shown to induce irritation of the upper respiratory tract, associated with metal fume fever (ACGIH, 1999). Chronic health effect due to occupational

exposure to copper fumes may include general malaise, anorexia, nausea, vomiting, and hepatomegaly. Contact dermatitis, pulmonary granulomas, and pulmonary fibrosis have also been described (Warrell et al, 2003). It also causes permanent skin and hair color changes (NIOSH, 1981). Roberts et al, 2015 found that workers exposed to chronic copper dust at concentrations ranging from 111 to 464 mg/m3, suffered from neurological changes, digestive disorders, and pulmonary complications.

Foundries in Egypt started to face problems since the application of the environmental law, which put special conditions for the waste products and emissions from the different industries. As foundries are less compatible with that law; foundries spaces became restricted, as a result; pressure increased on this industry causing many labors to migrate to other professions or forming random non-licensed groups away from supervision, producing products that are unapproved, and harmful to health (Chamber of metallurgical industries, 2015).

The current study was conducted to investigate the health aspects of foundry workers, since few studies discussed exposure to copper and zinc in this group of population especially in Egypt.

Aim of work

1) To measure blood level of zinc and copper among metal die casting workers and compare them with matched controls. 2) To measure the prevalence of respiratory hazards among exposed workers and their impact on activity level, social and psychological functioning. 3) To identify other health problems such as anemia, leukocytosis, and dermal inflammations, that may result from zinc and copper exposure, and lastly 4) To correlate such problems with blood levels of zinc and copper.

Materials and Methods

Study design: It is a comparative cross-sectional study.

Place and duration of the study: The study was conducted among Egyptian workers in a foundry in 10th Ramadan city. There were approximately 80 workers in all departments. The study was done during the period from January 2017 to June 2017.

Study sample:

Sample size: Sample size was calculated using STATA® version 11 program, setting the type-1 error (α) at 0.05 and the power (1-β) at 0.8. Results from a previous study showed that mean concentration of blood level of copper in workers exposed to copper is 201.14 ± 93.8 μg/dl (Alkhatib, 2014), while copper levels in normal controls were 105.3 ± 50.2 μg/dl (Fatemi, 2012). Calculation according to these values produced a minimal sample size of (30) workers for each group.

The exposed group: The exposed group was simple randomly selected and included 30 male foundry workers, working in this job more than 5 years and exposed mainly to copper and zinc fumes and dusts. They were involved in the following processes; melting metals, molding preparations, and those who worked in finishing steps.

The unexposed group (control group): Another 30 but unexposed subjects working in the same foundry in the administrative departments such as; management, human resources, marketing, sales, transportation, and kitchen were randomly selected and matched the exposed workers regarding socio-demographic level and special habits, with the exception of not having history of occupational exposure to copper and zinc fumes and dusts.

- Exclusion criteria: Workers with pre-employment chest diseases and those with regular multi vitamins were excluded from the study.

Study methods:

All participants were subjected to:

1. **An interview questionnaire** that inquired about thorough medical history and occupational history with emphasis on duration of exposure, previous job, personal protective devices usage, in addition to socio-demographic data and special habits. On the other hand, some questions specific to symptoms related to copper and zinc exposure like throat, nose and eye irritation, headache, arthralgia, fever, metallic taste, exhaustion and skin rash were also included.
2. **Saint George Respiratory Questionnaire (SGRQ)** which is a well-established, standardized questionnaire for measuring

impaired health and perceived well-being in chronic airway disease (Jones et al, 1992). It consists of two parts with 16 questions. Part one produces the symptoms score, and part two the activity and impacts score. It was used in the current study to assess the respiratory symptoms and their impact on the social, the psychological and the activity level among workers.

3. **Peak Expiratory Flow Rate device (PEFR):** were used to investigate the obstructive air way diseases. Three measures were obtained which was : before working last day of the week, after working that day and before working the first day in the week after.

4. Investigations :

Blood sample was drawn from the workers in each group for measuring:

- Copper and zinc blood levels using the atomic absorption spectrometer A Analyst 600, with AS/800 auto sampler.

- Complete Blood Count (CBC) was also done for all participants to detect anemia and leukocytosis, using the Coulter LH 750 analyzer.

Consent

All workers agreed to participate in the study after appropriate clarification regarding confidentiality of data, the objectives of the study and the type of tests they will undergo.

Ethical approval

Also, approval of Ethical Committee of Faculty of Medicine, Ain Shams University was obtained prior from starting the study.

Data Management

The collected data was revised and was completed and cleaned, coded, tabulated and was introduced to a PC using Statistical Package for Social Science (SPSS 15.0.1 for windows; SPSS Inc, Chicago, 2001). Data was presented as Mean and Standard deviation (± SD) for quantitative parametric data, and Median and Interquartile range for quantitative non- parametric data. Frequency and percentage was used for presenting qualitative data. Suitable analysis was done according to the type of data obtained. Student T Test or Mann Whitney test was used to analyze quantitative data while Chi square

test and Fisher exact test was used to analyze qualitative data. . "p" values less than 0.05 ($p<0.05$) were considered statistically significant.

Results

This study included (30) male exposed workers to copper and zinc and (30) matched unexposed subjects from the same foundry working in administrative departments. The two groups were matched as regard work duration and personal characteristics including age, marital status and smoking. The mean age among the exposed group was 32 ±9.3. Seventy three percent were married; and about 33% were smokers. This was comparable to the non- exposed group where their mean age was 35.9 ± 8.1. Seventy percent were married; and about 27% were smokers. The mean duration of the current job among exposed workers was 8.2 ± 8.7 with a median of 7 years compared to 7.98 ± 7.86 with a median of 6 years among non- exposed. Personal protective devices (PPD) usage was studied also among the exposed group revealing that they were used most of the times among 66.7% of exposed workers (data not tabulated).

Table (1): Comparison between two studied groups as regard blood levels of zinc and copper.

Blood level (µg/dl)	Studied groups		Mann-Whitney Test	p
	Exposed Mean ±SD	Non-exposed Mean ±SD		
Cu (µg/dl)	90.43 ± 26.57	89.10 ± 32.92	432.0	.790
Zn (µg/dl)	92.37 ± 29.86	95.24 ± 62.79	412.0	.574

Table (1) showed that there was no statistical significant difference between the two studied groups ($p>0.05$) as regard blood levels of zinc and copper. All participants were within the normal ranges for both copper and zinc.

Table (2): Comparison between both studied groups as regard Saint George Respiratory Questionnaire (SGRQ) scores.

SGRQ scores	Exposed	Non-exposed	Mann-Whitney Test	p
	Mean ±SD	Mean ±SD		
Symptoms score	30.93 ± 17.44	22.52 ± 15.25	314.0	**.046 ***
Activity score	14.41 ± 17.49	12.74 ± 19.50	343.5	.096
Impacts score	15.94 ± 13.38	6.83 ± 11.45	224.0	**.001****
Total score	17.37 ± 13.42	11.20 ± 13.25	309.0	**.037 ***

*: Significant **: Highly significant

Table (2) showed that there was a highly significant difference in the impacts score being high among the exposed group compared to their control (15.94 ± 13.38 versus 6.83 ± 11.45). For symptoms and total score, a significant difference was also noticed being higher among the exposed group than the non- exposed one ($p<0.05$). No significant difference was found in activity level scores among both studied groups ($p>0.05$).

Table (3): Comparison between both studied groups as regard different symptoms related to copper and zinc exposure.

Medical symptoms		Studied Groups				Chi-square	p
		Exposed		Non-exposed			
		No	%	No	%		
Throat irritation	**Yes**	17	56.7%	5	16.7%	10.33	**.001****
	NO	13	43.3%	25	8303%		
Nose irritation	**Yes**	22	73.3%	17	56.7%	1.83	**.176**
	NO	8	26.7%	13	43.3%		
Eye irritation	**Yes**	16	53.3%	7	23.3%	5.71	**.017***
	NO	14	46.7%	23	76.7%		
Skin irritation	**Yes**	12	40.0%	2	6.7%	9.31	**.002****
	NO	18	60.0%	28	93.3%		
Headache	**Yes**	20	66.7%	22	73.3%	0.31	**.573**
	NO	10	33.3%	8	26.7%		
Joints and muscle pain	**Yes**	19	63.3%	15	50.0%	1.08	**.297**
	NO	11	36.7%	15	50.0%		
Fever	**Yes**	8	26.7%	6	20.0%	0.373	**.542**
	NO	22	73.3%	24	80.0%		
Metal taste in mouth	**Yes**	21	70.0%	6	20.0%	15.1	**.000****
	NO	9	30.0%	24	80.0%		
Exhaustion	**Yes**	17	56.7%	9	30.0%	4.34	**.037***
	NO	13	43.3%	21	70.0%		
Flu like symptoms	**Yes**	20	66.7%	18	60.0%	0.287	**.592**
	NO	10	33.3%	12	40.0%		
Difficult breathing	**Yes**	23	76.7%	9	30.0%	13.1	**.0001****
	NO	7	23.3%	21	70.0%		

*: Significant **: Highly significant

Table (3) showed that there was a highly significant difference between the two studied groups as regard throat irritation, skin irritation, metal taste in mouth, and difficult breathing with higher rates among exposed. Also, a significant difference was noticed in eye irritation and exhaustion related to work, being higher among exposed workers.

Table (4): Comparison between both studied groups as regard PEFR (Peak Expiratory Flow Rate).

PEFR measurements	Studied Groups		Student t test	P
	Exposed Mean ±SD	Non-exposed Mean ±SD		
PEFR before work last day	530.33 ± 102.21	502.00 ± 67.69	1.445	.155
PEFR after work last day	515.67 ± 109.50	505.33 ± 74.59	1.667	.101
PEFR before work first day	553.67 ± 112.97	511.00 ± 69.94	1.759	.085

Table (4) revealed that there was no significant difference in PEFR measurements between the two studied groups.

Table (5): Comparison between both studied groups as regard laboratory (Lab) data.

Lab data	Studied Groups		Statistical tests	p
	Exposed	Non- exposed		
	Mean ±SD	Mean ±SD		
HB level	15.67 ± .71	15.91 ± 1.04	1.04	.302
WBCS	7.72 ± 2.81	7.56 ± 2.05	0.26	.796
	No. (%)	No. (%)		
Anemia				
Yes	0 (0.0) %	0 (0.0) %	-	-
NO	30 (100.0) %	30 (100.0) %		
Leukocytosis				
Yes	3 (10.0) %	1 (3.0) %	Fischer	.612
NO	27 (90.0) %	29 (96.7) %		

As shown in table (5), leukocytosis was more prevalent among the exposed group compared to the controls (10%, versus 3% respectively), but no significant difference was found ($p>0.05$). There was no anemia in both studied groups. No significant difference in mean hemoglobin and white blood cells counts was detected between both studied groups.

There was also no significant difference correlation between zinc and copper blood levels and the Saint George Respiratory Questionnaire, PEFR, HB level, and WBCs between the two groups of the study (data not tabulated).

Discussion

Personal characteristics of the two groups were matching each other with no significant difference as regards age, marital status and smoking habits ($p>0.05$).

As regard blood copper level; the current study showed no significant difference between both exposed and non-exposed groups (90.43 ± 26.5 versus 89.10 ± 32.9) µg/dl ($p>0.05$) (Table 1). All participants were within the normal blood range which is 70–150 µg/dl as reported by (ACGIH, 1999).

Similar results were seen in a study performed by Guojun et al. 2004 among welders who found no significant difference in blood copper levels between both exposed and non-exposed groups (75.26 ± 19.14 versus 74.64 ± 16.13) µg/ dl.

As regard blood zinc level, there was also no significant difference between exposed and non- exposed group (92.37 ± 29.86versus 95.24 ± 62.79) µg/d (Table 1), all participants were within normal range which is (50–100 µg/dl) as reported by ACGIH, 1999. These results were in agreement with Guojun et al. 2004 who found no significant difference in mean zinc blood level among welders and their controls (69.37 ± 8.1 versus 73.45 ± 15.00) µg/dl.

Concerning the respiratory hazards due to copper and zinc exposure; there was a statistically significant difference in the mean symptoms score from Saint George Respiratory Questionnaire (SGRQ) being higher among exposed group (score of 31) compared to their control (Score of 22) (Table 2). Current study also showed that exposed group had more respiratory symptoms such as difficult breathing and throat irritation (76%, and 57% respectively), compared to their control (30%, and 17% respectively), and this was statistically significant ($p<0.05$).

The current results were in agreement with Jayawardana et al,

1997 who found that brass workers were at a significantly higher risk compared to their control group of developing respiratory symptoms. Moreover; Barceloux, 1999 reported that inhalation of high concentrations of ZnCl2 resulted in chemical pneumonitis and adult respiratory distress syndrome among exposed personnel.

As regards the different symptoms related to copper and zinc exposure; skin irritation, eye irritation, throat irritation, metallic taste in mouth and feeling exhausted after work; all were significantly more prevalent among the exposed group compared to the non-exposed one (Table 3). These findings were attributed to the very poor work place environment the workers exposed to, with heavy clouds of dust and fumes surrounded them, also safety precautions were not probably applied as almost one third of the workers (33%) were not using protective devices in their work.

The present results agreed with Jayawardana, 2004 who found that brass workers who were exposed to copper and zinc fumes suffered more from itchy eyes, tearing, fatigue and distaste. Similarly, a study conducted in Iran found that eye burning and redness was significantly more frequent among the exposed group working in a galvanization plant (Aminian et al, 2015).

As regard skin irritation; the current result was inconsistent with that found by Agren in which applying a 25% zinc oxide patch (2.9 mg/cm2) on human skin for 48 hours did not cause any kind of dermal irritation (Agren, 1990). The difference in such result could be attributed to the presence of copper particles in addition to zinc which was reported in previous studies to cause skin disorders in the form of skin rash, itching, contact dermatitis and skin discoloration due to copper allergy (Simon et al; 2013and Vania , 2017).

Other symptoms include: fever, joint and muscular pain and flu like symptoms were also more prevalent among the exposed group, but no significant difference was found. Those symptoms suggestive of metal fume fever which is common among workers exposed to zinc and copper fumes as reported in several previous studies (Gordon et al, 1992, Bodar et al ,2005 and Gardiner et al, 2007).

As regard the impact score in SGRQ, which assesses the psychological and social alteration due to respiratory symptoms; it was found that the mean value among the exposed group was significantly higher (16), compared to their controls (7) ($p<0.05$) (Table 2). This increase could be attributed to the higher respiratory symptoms among the exposed group. This finding means that exposed group showed more concerns regarding social functioning and psychosocial disturbances as a result of dealing with these symptoms with the surrounding people. Social functioning: in the form of being embarrassed in public due to the cough or breathing problem, or in the form of feeling that the condition is annoying family and friends. Psychological disturbances: in the form of being afraid or feeling panic when being unable to control the attack, or feeling out of control to the condition.

On the other hand, the activity score in the current study didn't show any significant difference between the two groups (Table 2). This means that those respiratory symptoms among sufferers did not alter their activity level. This could be attributed to two reasons, the healthy worker effect of having a fit worker for the job, and the fear of showing physical weakness that may affect the worker's job, despite their knowledge that the answers to the questionnaire were confidential.

When assessing the obstructive air way diseases in the two groups using the peak expiratory flow rate (PEFR); it was found that there was no significant difference in the measurements in the three timings of PEFR (Table 4). This could be attributed to the short duration of exposure to metal fumes, as in the current foundry, those melting processes took place only in two days of the week resulting in only 16 hours exposure a week. Sometimes, it was even lesser in duration as the economic situation in the country, at some point, caused lower work state during time of the study. It's highly recommended to re-conduct such procedures to assess pulmonary functions among those workers as the situation in Egypt becomes more stable and working days definitely increased. This result is compatible with Marcisz et al., 1998 and Matteo et al, 2018 who found no significant difference in the

pulmonary functions between the study groups working in a galvanizing plant and a color metal mill respectively.

As regard laboratory investigations; no cases of anemia were identified in both groups, for leukocytosis, results showed that it was more prevalent among the exposed group than the control one (10%, and 3% respectively), (Table 5) but with no statistically significant difference. This is inconsistent to Roney et al, who found that chronic occupational exposure to copper causes decreased hemoglobin and erythrocyte levels (Roney et al, 2011). Excessive copper exposure may induce hemolytic anemia by inhibition of the enzyme glucose-6 phosphatase (ATSDR, 2004).

The present study also showed no significant correlation between the levels of zinc and copper and the levels of Hb and WBCs counts (data not tabulated). Similar results were detected in Italy by Matteo et al, 2018 who found normal Hb levels and leukocytes counts in their study groups, and there was no correlation between mean serum zinc and copper levels and HB levels and WBCs counts.

Conclusion

Exposure to copper and zinc fumes in metal die casting foundry can cause harm to workers. Although blood copper and zinc levels among the studied groups were within normal ranges, exposed workers were complaining of respiratory symptoms which altered their social functioning and caused psychological disturbances. Also, several symptoms related to copper and zinc exposure such as skin, throat and eye irritation, metallic taste in mouth and feeling exhausted were significantly more prevalent among them. Other symptoms which mimic metal fume fever, also existed and they included flue like symptoms, arthralgia, fever, and leukocytosis, however no significant difference was found between the exposed and the control groups as regards the level of copper and zinc. No obstructive air way diseases were identified in the study group using the PEFR. The lower exposure duration (16 hours per week) strategy helped in maintaining zinc and copper levels in normal range, since Personal Protective Devices (PPD) weren't used by all workers.

Recommendations

Further studies should be conducted to measure air copper and zinc levels in that foundry and proper procedures should be applied to make sure that these levels are not exceeding the permissible exposure limit (PEL) recommend by (OSHA). In addition; health education program should be applied among exposed workers explaining to them different hazards related to copper and zinc exposure; also, the benefit of personal protective devices should be magnified to those workers to start using them regularly.

Conflict of interests

There were no conflict of interests.

Acknowledgment

The author would like to acknowledge the foundry management and human resources for approving to perform this study among their workers and for providing all the support needed to complete this work.

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