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Research Article

AIR VOLATILE ORGANIC COMPOUNDS (VOCS) CONCENTRATIONS, CLINICAL HEMATOLOGY AND BIOCHEMISTRY IN WORKERS OCCUPATIONALLY EXPOSED TO VOCS

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ABSTRACT

Context: Volatile organic compounds (VOCs) are one of the most important pollutants in the air that can lead to a broad range of adverse health effects. One of the sources of VOCs is their emissions during copper concentration in copper factories.

Aims: To evaluate the concentration of VOCs in the concentration plant of a copper factory and the impact of these pollutants on worker's health.

Settings and Design: This was a cross-sectional study in a concentration plant of a copper factory.

Methods and Material: Gas chromatography-mass spectrometry was used for measurement of VOCs in the air samples collected by activated charcoal tube. Additionally, urine and fasting blood samples were taken for urinalysis and routine Hematological and biochemical tests of kidney and liver functions.

Statistical analysis used: data were analysed using the student's t-test for difference of mean by Graph pad Prism foe windows (version 6.07)

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Results: Fourteen VOCs were identified in the air samples and all parameters except alkaline phosphatase, blood sugar, bilirubin, and monocytes, lymphocytes, and eosinophils counts were significantly increased.

Conclusions: The average exposure of workers to VOCs did not exceed the current TWA. However, evidence of subtle, sub-clinical and pre-pathologic early blood, liver, and kidney dysfunction was evident in exposed individuals.

Keywords: copper factory, gas chromatography-mass spectrometry, hematology and biochemical parameters, occupational exposure, volatile organic compounds

INTRODUCTION

Production units of a copper factory involve the mine, concentrator, smelter, refinery, foundries, and leaching [1]. After extracting, during the concentrating process workers are exposed to some Volatile organic compounds (VOCs) including Benzene, Toluene, Nonane, Isopropyl alcohol, 4-Methyl-2-pentanone, 1-Hexanol, n-Butyl acetate, p-Xylene, 2-Nonanone, 5-Nonanone, Decane, Undecane, Dodecane, and Ethyl carbamothioic acid O-isopropyl ester [1].

VOCs as major components of urban air pollution evaporate and easily get into the atmosphere at room temperature [2]. VOCs enter the body easily and therefore pose health risks from long-term exposure to even low concentration levels (as low as 0.05 ppm) [3].

Exposure to some kinds of VOCs leads to immune system disorders, liver and kidney damage, and hematological changes [4-8]. VOCs exposure decreases RBC and PLT in peripheral blood, while increases AST, ALT, ALP and creatinine in serum [4, 9].

The aim of this study was first to assess presence and concentration of air pollutants and secondarily to evaluate their effects after exposure in the workers. Therefore, the concentration of VOCs and some hematological and biochemical parameters in workers of the copper concentration plant were measured. Our assumption is that occupational exposure to VOCs in the workplace might provoke toxicities, particularly at chronic long-term exposure.

SUBJECTS AND METHODS

Place of study

Concentration plant of copper factory includes the primary and secondary grinding, flotation cells, and molybdenum unit. At the end of the concentrator 2, the dry copper concentrate is transferred to the smelter unit.

Air sampling

Sampling and sample analysis were done according to the methods of National Institute for Occupational Safety and Health (NIOSH)[10] and American Environmental Protection Agency (EPA)[11].Air samples were collected by activated charcoal tubes (GK 26-16 SKC, 84, PA, USA) that were connected to the pump with a flow of 200 ml/min from 12 locations of the concentration plant. Sampling was done for 8 h in a day and repeated three times in each location.

Gas chromatography

Extraction of compounds from the surface of activated carbon was conducted with carbon disulfide 1 ml (CS2). The analysis of the extracted sample was performed with a gas chromatograph (HP, Agilent Technologies Co. Ltd.) equipped with a mass selective detector. The split / split less injector was operated at 220 °C with the purge flow closed for 30 s. Helium (ultrapure, 99.999%, flow: 0.67 ml /min) served as carrier gas. 25m * 0.22 mm I.D.column (DB-1701و Agilent Technologies Co. Ltd.) was used for separations of compounds. The following temperature program was used: 35 ° C for 10 min, ramp at 5 ° C /min to 150 ° C, held for 0.1 min, 20 ° C / min to 200 ° C, held for 10 min. The MS temperature was 230 ° C.

The investigated workers

Forty male workers from concentration plant aged between 20 - 40 years were enrolled into this study and informed about the study objectives. Selected workers must have worked for 4 - 6 h a day with at least a two-year history of employment. Subjects who smoke and suffer from known chronic diseases were excluded. After getting written consent, demographic data were collected using questionnaire and interview. As a control group, forty age-matched men who were not working in copper processing plants were recruited from the same region. The experimental protocol was approved by the institutional ethics committee of Kerman University of Medical Science (No.: ir.kmu.rec.1395.156).

Blood sampling

At the end of a workday, venous blood was drawn either in EDTA blood tubes for hematology study and in dry test tubes for the biochemical profile. The dry and EDTA blood tubes were then centrifuged at, respectively, 3000 g for 5 min and 5000 g for 20 min. Plasma and serum samples were collected, labeled, and kept in the freezer -80 °C.

Hematological parameters

Hematologicalparameters including hemoglobin (HB) (gr dL-1), hematocrit (HCT) (%), red blood cell (RBC) (*109 L-1), white blood cell (WBC) (*1012 L-1), and platelet (PLT) (*109 L-1) were measured in venous blood samples by Sysmex hematology analyzer(Sysmex, KX-

21N, Japan). For neutrophils (NOT) count, lymphocytes (LYM) count, monocytes (MON) count, eosinophils (EOS) count, blood smears were prepared and stained with Giemsa and observed with a light microscope (OLYMPUS, CX31, Japan) at 100x magnification.

Biochemical parameters

Serum biochemical parameters including blood sugar (BS) (mg %), cholesterol (CHOL) (mg dL-1), triglyceride (TG) (mg dL-1), blood urea nitrogen (BUN) (mg dL-1), creatinine (Cr) (mg dL-1), uric acid (U.A) (mg %), aspartate aminotransferase (AST) (mg dL-1), alanine aminotransferase (ALT) (mg dL-1), alkaline phosphatase (ALP) (mg dL-1), direct bilirubin (Bili D) (mg dL-1) and total bilirubin (Bili T) (mg dL-1) were measured by Mindray chemistry analyzer (Mindray, BS-400, china).

Statistical analysis

In this research, we enrolled 40 workers in each group to detect an effect size of 0.85, with a power exceeding 80% for a two-sided significance level of 5%. The statistical analysis of the data was done using the student's t-test for difference of mean by Graph pad Prism foe windows (version 6.07). P less than 0.05 were taken as significant.

RESULTS

Type and Concentration of VOCs

Fourteen compounds were identified in the air samples of the concentration plant. Higher and lower concentration, respectively, belonged to 1-hexanol (0.31 ppm) and O-isopropyl ethylthiocarbamate (0.32 ppm) and toluene (0.01 ppm). The identified organic compounds with its retention time were presented in Table 1. On the other hand, concentration of these VOCs in break room, north flotation cells, south flotation cells, secondary mill, southern stone mill, mill 7, between 4 and 5 mills, 5 mill charge, east ball mill and the control room was less than 0.01 ppm.

Hematological and biochemical parameters

The results showed all hematological and biochemical parameters significantly changed compared with the control group. Amounts of RBC, HB, and HCT were significantly increased in the workers. An increase in PLT counts were founded in the exposed workers, but not significantly. The result also showed a significant decrease in WBC counts (MON, LYM, and EOS) in the workers, but the number of NOT in workers was significantly higher than the control group (Table 2). All biochemical parameters except ALP, BS, Bili D, and Bili T were significantly increased in the workers as shown in Table 3.

DISCUSSION

VOCs are unpleasant products of industrial activities in the manufacturing of chemical, petrochemical and metallurgical [12]. In a study was done by Vatani et al. it was found that workers are exposed to a large concentration of VOCs during the concentrating process in the copper factory. The concentration of benzene and toluene were reported, respectively, 0.761 and 0.0726 ppm in environmental air samples and 0.0188 and 0.0025 ppm in personal air samples [1]. This study revealed environmental exposure to fourteen VOCs (Table 1) in the ambient air of the copper concentration plant, but these concentration was very lower than what reported by Vatani et al.. The satisfactory working conditions by replacing the higher quality solvents may be the main reason for reduction of VOCs concentration in the concentration plant. The concentrations of O-isopropyl ethylthiocarbamate and 1-hexanol have been found to be higher and the concentration of toluene was lower than all identified VOCs in the ambient air. Although the concentration of VOCs was lower than time-weighted average, but since VOCs enter the body easily through the air, long-term exposure to even low concentration levels of these pollutants can pose health risks in human (as low as 0.05 ppm) [3].

In the current study, a significant increase in RBC and a significant decrease in MON counts were seen in the workers. Qingshan Qu et al. reported a reduction in both RBC and WBC counts in a study on Chinese workers-exposed to a concentration of 0.08-54.5 ppm of benzene [13]. The reason for this inconsistency in results is the height of factory, 2524 metersabove sea level. As the height of sea level increases, atmospheric pressure decreases, which affects humans by reducing the partial pressure of oxygen and increase in production of RBC as a compensatory mechanism [14].

In agreement with our study, Tunsaringkarn et al. during evaluation of health status of male gasoline station workers in Bangkok revealed an increase in HB and a decrease in HCT [15, 16]. HB levels above normal can be the consequence of elevation of the RBC counts. Reduction in HCT shows that the volume of RBC compared with the total blood volume (RBC and plasma) decreased but it was still in the normal range.

Biochemical liver tests have been used in human studies to assess the effects of chemicals and drugs exposure [17]. Serum levels of AST and ALT were found to be elevated in the workers compared with controls, while the serum levels of ALP decreased in the workers. In a study was done by Jing Liu et al. personal exposure to VOCs (benzene, ethyl benzene, toluene, o-xylene, m-, p-xylene, and MTBE) increased ALP, ALT, AST and Bili T [18]. Neghab et al. founded that the amount of AST, ALT and Bili D increased significantly in workers of gas

stations exposed to benzene, toluene, and xylene mixture [19]. Langkulsen et al. in a study of 457 workers petrochemical plant in Thailand were also reported the same results [20]. The increased serum levels of these enzymes could be due to the overproduction or release of enzymes from the liver cells in response to stimuli of hepatocellular injury or cell death. The increased levels of these enzymes found in this study are consistent with other studies except serum level of ALP. ALP located in the cells lining of the biliary ducts of the liver is not specific for liver damage and reduction in this enzyme was observed in the study group, which indicates the absence of bile duct obstruction. Malnutrition, magnesium deficiency, hypothyroidism, and severe anemia are other reasons for lowering ALP level in serum that should be studied more [21].

On the other hand, the explanation of the increase in BUN, Cr, and U.A are probably related to the toxic effect of VOCs on renal functions. Accordingly, renal alterations were detected in the workers and in the animal exposed to VOCs [22-24].

Occupational exposure to sub-TWA levels of VOCs is associated with subtle, sub-clinical, prepathologic changes in the parameters of blood, liver, and kidney function.

More case-control and epidemiological studies with greater samples and longer duration of exposure are needed to confirm and evaluate long-term results and consequences of these changes.

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Table1. Mean airborne concentrations of volatile organic compounds (VOCs) in the concentration plant of the copper complex

VOCs	TWA (ppm)	Airborne level (ppm)	Retention Time (min)
Isopropyl alcohol	400	0.11	1.393
Benzene	0.1	0.08	2.063
4-Methyl-2-Pentanone	100	0.09	2.686
1-Hexanol	Not listed	0.31	2.857
Toluene	100	0.01	3.001
n-Butyl acetate	150	0.03	3.536
p- Xylene	100	0.02	4.351
Nonane	200	0.04	4.739
2- Nonanone	Not listed	0.04	5.82
5. Nonanone	Not listed	0.04	5.863
Decane	Not listed	0.06	6.3
Undecane	Not listed	0.03	7.865
O-isopropyl ethylthiocarbamate	Not listed	0.32	9.058
Dodecane	Not listed	0.04	9.348

Time-weighted average (TWA) according to national institute for occupational safety and health (NIOSH), (ppm= part per million)

Table2. Results of hematological factors in the control group and workers of the copper concentration plant

Variable	Worker	Control	P value
RBC	6.55 ± 0.123	5.83 ± 0.109	< 0.0001
WBC	5.028 ± 0.07596	5.624 ± 0.07205	< 0.0001
HB	16.52 ± 0.1218	15.33 ± 0.1676	< 0.0001
HCT	48.28 ± 0.4233	44.66 ± 0.9510	0.0008
PLT	210.6 ± 6.539	210.6 ± 6.539	0.4180
EOS	1.125 ± 0.1085	2.125 ± 0.1300	< 0.0001
MON	1.075 ± 0.1154	1.375 ± 0.09259	0.0460
LYM	28.45 ± 1.038	47.90 ± 1.132	< 0.0001
NOT	69.40 ± 1.064	48.80 ± 1.118	< 0.0001

Abbreviations: Hemoglobin (HB) (g dL^{-1}), hematocrit (HCT) (%), red blood cell (RBC) (*10^{9} L^{-1}), white blood cell (WBC) (*10^{12} L^{-1}), platelet (PLT) (*10^{9} L^{-1}), neutrophils (NOT) (%), lymphocytes (LYM) (%), monocytes (MON) (%), and eosinophils (EOS) (%)

Table3. Results of blood biochemical tests in the control group and concentration workers of the copper concentration plant

Variable	Worker	Control	P value
BS	95.50 ±2.754	97.38 ±1.982	0.5822
BUN	17.73 ±0.6335	14.25 ±0.4610	<0.0001
Cr	1.173 ±0.0114	1.105 ±0.0155	0.0007
U.A	5.963 ±0.1618	5.035 ±0.1527	<0.0001
TG	206.8 ±5.282	184.4 ±4.094	0.0013
CHOL	281.4 ±28.86	146.9 ±8.866	<0.0001
ALP	211.1 ±7.319	214.7 ±13.55	0.8196
AST	38.83 ±2.317	26.78 ±2.204	0.0003
ALT	31.65 ±1.053	23.98 ±0.9209	<0.0001
Bili D	0.1075 ±0.0055	0.1050 ±0.0050	0.7383
Bili T	0.6250 ±0.03819	0.5550 ±0.02319	0.1212

Abbreviations: blood sugar (BS) (mg %), blood urea nitrogen (BUN) (mg dL^{-1}), creatinine (Cr) (mg/dl), uric acid (U.A) (mg %), triglyceride (TG) (mg dL^{-1}), cholesterol (CHOL) (mg dL^{-1}), aspartate aminotransferase (AST) (mg dL^{-1}), alanine aminotransferase (ALT) (mg dL^{-1}), alkaline phosphatase (ALP) (mg dL^{-1}), direct bilirubin (Bili D) (mg dL^{-1}), and total bilirubin (Bili T) (mg dL^{-1})

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