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Original scientific paper

Harmful Chemicals in the Work Environment

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Abstract: For hospital personnel, a number of harmful chemicals exist. The paper deal with very different harmful chemicals, but all chemicals are important and continuing problems where the risks to health, if uncontrolled, are serious. In the research was used descriptive statistical operations and multivariate statistical method, factor analysis (FA), i.e. principal component analysis (PCA). An analysis of 24 organic and inorganic parameters was performed. Results of the correlation analysis suggest that these pollutants pairs might have similar sources or have been affected by similar factors. PCA she confirmed that the mutually correlated elements constitute a group of elements with a similar origin.

Key words: harmful chemical, workplace, hospital

INTRODUCTION

There are many situations in which workers are exposed to various chemical components in the work environment. The era after the nineteenth century is one in which various organic compounds were also synthesized (Yu et al., 2016). Many strong chemicals are used in healthcare settings, for a variety of reasons: to treat patients; to clean, disinfect, and sterilize surfaces and supplies; and to kill insects and other pests (Luoma, 2006). Exposure to potentially hazardous chemicals is a fact of life for health care workers (Stellman, 2011). Chemical hazards (harmful chemical) can be found a hospital, from the laboratory to the operating room to hospital rooms, in laboratory work and other activities. Carbon dioxide is often considered a nontoxic asphyxiant gas that can displace the oxygen required to sustain life, it has significant physiological effects. One such effect is increased respiration. At 10 vol% severe symptoms of labored breathing make normal speech difficult or impossible. Unconsciousness occurs after one to several minutes exposure to 10–15 vol%. Above 15%vol, loss of consciousness occurs in less than one minute (Hedlund & Madsen, 2018). Carbon monoxide is a non-irritating, odorless, and tasteless gaseous pollutant (Langston et al., 2010) that may be emitted into the environment from anthropogenic or natural sources (Fazlzadeh et al., 2015). Carbon monoxide poisoning is the most common form of gaseous poisoning (Yu et al., 2016). Exposure to carbon monoxide leads to various health effects through affecting cardiovascular system, lungs, and blood and central nervous systems (Fazlzadeh et al., 2015). Benzene, known for its nervous system, skin and renal effects, may be found in laboratories, depending upon analytical methods used. Formaldehyde, used in dialysis units, may cause eye, respiratory and dermatologic problems, and other adverse effects. Other irritants that may induce central nervous system problems (xylene, isopropyl alcohol (Isopropanol)) may be found in cytology laboratories (Clever, 1981). Nitrous oxide is the most commonly used inhalation anesthetic in dentistry and is commonly used in emergency centers and ambulatory surgery centers as well (Becker & Rosenberg, 2008). Nitrogen dioxide is a reddish-brown heavy gas that has a sharp, harsh odor at higher concentrations, but may be clear and odorless at lower, but still harmful, concentrations. Cases of harmful exposures are often initially associated with mild symptoms of respiratory irritation, which subside upon termination of exposure, or may even be asymptomatic, with fatal complications (lung edema) developing hours later (Hedlund & Madsen, 2018). Because of relatively lower solubility in water, it reaches deep in the lung, at the level of the bronchioles and alveoli (Yu et al., 2016). Sulfur dioxide binds to steam from water in the air and forms sulfuric acid mist. The mist is inhaled and causes airway injury and obstructive lung diseases. Hydrogen chloride, which is widely used as hydrochloric acid, is a gas at a normal temperature and binds to steam from water in moist air and forms the mist that causes airway injury after inhalation (Yu et al., 2016). Ethylene oxide (Acetaldehyde), used to sterilize equipment that cannot be autoclaved, was linked with the development of cancer. These changes have not decreased in workers removed from exposure for one year. Studies are now underway to evaluate the effects of ethylene oxide on male fertility. Employees are also provided respiratory protection to decrease exposure further (Clever, 1981). Hazardous substances in the workplace can come in any form from solids and liquids to gases and powders. No matter its physical state, they can all be dangerous. These chemicals can be inhaled, ingested, injected or absorbed into the body and once inside, can affect multiple organs and organ systems (Nwaobia, 2019).

The environment in the workplace changes with time. Once, occupational diseases occurred from exposure to toxic compounds at high levels; however, now the levels have decreased in developed countries because of preventive methods. The control and management of chemical hazards in hospitals must be based on classic principles of good occupational health practice (Yu et al., 2016, Yassi, 2019).

OBJECTIVES

The primary aim of this study was to measuring concentration chemical hazards and evaluation results using multivariate statistical method such as this factor analysis (FA), i.e. principal component analysis (PCA) to evaluate of harmful chemical contamination of workplace air. Analyzed parameters (harmful chemical) are: Carbon dioxide (CO_2), Carbon monoxide (CO), Dinitrogen monoxide (N_2O), Methan (CH_4), Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Acetaldehyde (C_2H_4O), Propionaldehyde (C_3H_6O), Formaldehyde (CH_2O), Benzene (C_6H_6), Toluene (C_7H_8), Ethylbenzene (Xylene) (C_8H_{10}), Isopropanol (C_3H_8O), Ammonia (NH_3), Acrolein (C_3H_4O), 3-Oxobutanol ($C_4H_8O_2$), Phenol (C_6H_5OH), Pyridine (C_5H_5N), Carbon disulfide (CS_2), Trichloroethylene (C_2HCl_3), Styrene (C_8H_8), Hydrogen chloride (HCl), Methanol (CH_3OH) and Ethanol (C_2H_5OH).

Measuring was performed in the clinical hospital "St. Luke the Apostle" in Doboj (Republic of Srpska, Bosnia and Herzegovina). Clinical hospital "St. Luke the Apostle" in Doboj, purpose and organization represents regional health facility type, which provides inpatient and consultative specialist healthcare secondary and tertiary levels, partly for approximately 270 000 inhabitants in eight municipalities in Doboj region.

MATERIAL AND METHODS

Study area:

Subject of the research is to determine the concentration chemical hazards in the clinical hospital "St. Luke the Apostle" in Doboj, which is located in the Republic of Srpska (Bosnia and Herzegovina). The present study on was carried out in Doboj in February 2018.

Chemical hazards measurement:

Measurements chemical hazards were performed with a GasMet DX4030. Gasmet™ DX4030 is an IR gas analyzer for ambient air analysis. It is designed for applications where up to 25 compounds need to be monitored in ambient air. Examples include leakage detection and various industrial hygiene applications (monitoring of VOC's, TIC's, anesthetic gases, etc.). Detection principle is molecular spectroscopy. Detection method is mid-infrared Spectroscopy.

Statistical analysis:

Statistical data processing while determining relationship between analyzed parameters was calculated with correlation analysis. With Bivariate Correlations study (Spearman's, Pearson's and Kendall rank correlation coefficient test) was performed. A significance level of p value < 0.05, $p < 0.01$ and $p < 0.001$ was used. Descriptive statistical operations have been applied into analysing of the measured data. The following multivariate statistical methods were used in data analysis: principal component analysis (PCA). The Excel 2016, JASP 0.8.5.1 software for statistical data processing.

RESULTS AND DISCUSSION

In Table 1 all of the data were first processed for descriptive statistical analysis. As can be seen, CO_2 is the chemical hazards with the highest mean concentration (39.3 ppm), and then followed by the CO_2, NH_3, CO, N_2O, C_3H_8O, C_2H_5OH, HCl, C_7H_8, C_8H_{10}, C_5H_5N, CS_2, C_3H_6O, C_6H_6, C_2H_4O, SO_2, CH_4, NO_2, $C_4H_8O_2$, CH_3OH, CH_2O, C_2HCl_3, C_6H_5OH, C_8H_8 and C_3H_4O, their mean concentrations are 39.3, 2.36, 2.35, 2.14, 1.41, 1.32, 1.29, 1.06, 1.04, 0.92, 0.77, 0.68, 0.65, 0.63, 0.57, 0.57, 0.56, 0.47, 0.44, 0.42, 0.42, 0.37, 0.19 and 0.13 ppm, respectively (Table 1). Analyzes of chemical substances in the working atmosphere have revealed increased mean concentrations of C_3H_4O in the air that exceed the maximum limit values compared to national standard (JUS.Z.BO.001:1991). In some measuring points exceedances and other parameters were recorded.

Skewness and Kurtosis were used to test the normality of a given data set. Skewness is less than -1 or greater than 1 and the distribution is highly skewed, except for $C_4H_8O_2$ and C_5H_5N. Skewness test for all analysing parameters shown that data distribution is not normal. Similarly confirms and Kurtosis test.

Table 1. Descriptive statistical for analyzed parameters

	CO_2	CO	N_2O	CH_4	NO_2	SO_2	C_2H_4O	C_3H_6O	CH_2O	C_6H_6	C_7H_8	C_8H_{10}
Valid	25	25	25	25	25	25	25	25	25	25	25	25
Mean	39.3	2.35	2.14	0.57	0.56	0.57	0.63	0.68	0.42	0.65	1.06	1.04
Median	10.55	0.00	0.14	0.43	0.51	0.29	0.46	0.0	0.0	0.59	0.14	0.04
Std. Dev.	58.71	7.26	5.86	0.66	0.70	0.80	0.78	1.64	0.59	0.63	1.86	1.51
Variance	3447	52.72	34.29	0.43	0.50	0.64	0.60	2.7	0.34	0.4	3.48	2.29
Skewness	1.639	4.048	4.134	1.388	3.418	1.851	1.542	2.775	1.274	1.910	3.076	1.396
Kurtosis	1.44	17.27	18.40	1.66	14.77	2.69	1.48	7.01	0.75	5.32	11.47	0.87
Range	188.1	34.42	28.41	2.407	3.580	2.780	2.587	6.270	1.897	2.820	8.645	5.106
Maximum	188.1	34.42	28.41	2.407	3.580	2.780	2.587	6.270	1.897	2.820	8.645	5.106
Limit values	-	50	-	-	1	2	50	244	1.2	1	100	100

	C_3H_8O	NH_3	C_3H_4O	$C_4H_8O_2$	C_6H_5OH	C_5H_5N	CS_2	C_2HCl_3	C_8H_8	HCl	CH_3OH	C_2H_5OH
Valid	25	25	25	25	25	25	25	25	25	25	25	25
Mean	1.41	2.36	0.13	0.47	0.37	0.92	0.77	0.42	0.19	1.29	0.44	1.32
Median	0.23	0.12	0.05	0.0	0.13	0.56	0.12	0.12	0.0	0.68	0.0	0.0
Std. Dev.	2.98	6.8	0.2	0.59	0.95	0.99	1.34	0.57	0.59	1.59	0.76	2.94
Variance	8.91	46.17	0.04	0.35	0.90	0.98	1.80	0.33	0.35	2.51	0.57	8.66
Skewness	3.294	3.248	1.678	0.9540	4.644	0.7145	2.641	1.476	4.073	1.103	1.814	2.947
Kurtosis	11.90	9.53	1.42	-0.08	22.51	-0.59	7.70	1.34	17.97	-0.07	2.70	8.93
Range	13.55	26.23	0.6510	1.966	4.825	3.276	5.760	1.922	2.851	5.068	2.675	12.41
Maximum	13.55	26.23	0.6510	1.966	4.825	3.276	5.760	1.922	2.851	5.068	2.675	12.41
Lomit values	400	25	0.1	400	5	5	10	25	50	5	200	1000

In study, the Pearson's, Spearman's and Kendall's correlation was applied to find the relationship between the analyzed parameters. Correlation analysis indicated the relationship between: CO_2 and SO_2; CO and C_6H_6; CO and C_7H_8; NO_2 and NH_3; C_3H_6O and C_8H_8; C_3H_8O and CH_3OH and CH_3OH and C_2H_5OH (Table 2). Such results suggest that these pollutants pairs might have similar sources or have been affected by similar factors. Values of correlation analysis for other pollutants are moderate positive or not relevant and not relevant results are not shown in the table 2.

Table 2. Correlation between analyzed parameters

			Pearson			Spearman			Kendall		
			r		p	rho		p	tau B		p
CO_2	-	CO	0.582	**	0.002	0.208		0.318	0.152		0.324
CO_2	-	SO_2	**0.648**	***	< .001	0.245		0.237	0.165		0.263
CO_2	-	C_2HCl_3	0.424	*	0.035	0.414	*	0.040	0.316	*	0.035
CO	-	SO_2	0.564	**	0.003	0.487	*	0.014	0.411	**	0.009
CO	-	C_6H_6	**0.642**	***	< .001	0.302		0.142	0.231		0.135
CO	-	C_7H_8	**0.748**	***	< .001	-0.043		0.837	-0.046		0.774
CO	-	C_3H_4O	0.500	*	0.011	0.442	*	0.027	0.363	*	0.023
CO	-	HCl	-0.086		0.683	-0.503	*	0.010	-0.390	*	0.013
N_2O	-	$C_4H_8O_2$	0.568	**	0.003	0.149		0.477	0.123		0.430
N_2O	-	C_2HCl_3	0.509	**	0.009	0.273		0.187	0.208		0.172
N_2O	-	HCl	0.503	*	0.010	0.334		0.103	0.242		0.105
N_2O	-	CH_3OH	0.006		0.976	0.405	*	0.045	0.301		0.061
CH_4	-	C_7H_8	-0.257		0.216	-0.406	*	0.044	-0.320	*	0.039
CH_4	-	C_3H_8O	0.398	*	0.049	0.452	*	0.023	0.325	*	0.034
CH_4	-	NH_3	0.316		0.124	0.393		0.052	0.329	*	0.030
CH_4	-	C_8H_8	-0.291		0.158	-0.410	*	0.042	-0.340	*	0.046
NO_2	-	C_8H_{10}	-0.289		0.161	-0.403	*	0.045	-0.302		0.051
NO_2	-	NH_3	**0.725**	***	< .001	0.187		0.371	0.144		0.331
SO_2	-	C_7H_8	0.527	**	0.007	0.139		0.506	0.118		0.445
C_2H_4O	-	C_6H_5OH	0.543	**	0.005	0.245		0.238	0.169		0.254
C_2H_4O	-	HCl	0.294		0.154	0.427	*	0.033	0.301	*	0.044
C_3H_6O	-	C_8H_8	**0.649**	***	< .001	0.442	*	0.027	0.382	*	0.033
C_6H_6	-	C_2HCl_3	0.427	*	0.033	0.587	**	0.002	0.446	**	0.003
C_7H_8	-	C_8H_8	0.167		0.424	0.509	**	0.009	0.430	*	0.012
C_8H_{10}	-	C_3H_4O	0.604	**	0.001	0.584	**	0.002	0.451	**	0.004
C_8H_{10}	-	C_2H_5OH	0.436	*	0.029	0.131		0.531	0.118		0.469
C_3H_8O	-	NH_3	-0.102		0.628	0.399	*	0.048	0.274		0.068
C_3H_8O	-	CH_3OH	**0.745**	***	< .001	0.515	**	0.008	0.430	**	0.008
NH_3	-	C_2H_5OH	-0.117		0.577	0.424	*	0.035	0.335	*	0.032
C_3H_4O	-	CS_2	0.352		0.084	0.547	**	0.005	0.417	**	0.008
CS_2	-	C_2H_5OH	0.608	**	0.001	0.125		0.552	0.103		0.525
CH_3OH	-	C_2H_5OH	**0.620**	***	< .001	0.697	***	< .001	0.590	***	< .001

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

PCA's approach to data reduction is to create one or more index variables (components) from a set of measured variables. The relationships between data are mathematical, but they allow for several practical conclusions (Zgłobicki et al., 2018). Distribution of sample scores in PCA can indicate the influencing factors for the comprehensive variation of variables (Rivetti et al. 2017). Each new principal component explains a certain part of the total variance of the system. The first principal component (PC1) explains the maximal part of the system variation and each additional PC has a lesser contribution to the variance explanation (Nedyalkova & Simeonov, 2019). The primary output for a PCA shows the correlation between each variable of a principal component and the variable factors (RC1, RC2, RC3, RC4 and RC5), i.e. analyzed parameters are affected by five components (Table 3). Five principal component (PC) with eigenvalues and percentage variance for factors shown in Table 4.

The RC1 factor is related with organic solvents and waste combustion in hospital (C_3H_4O, C_6H_6, C_7H_8, CO, CO_2 and SO_2) and explained 16.16% of total variance. C_7H_8, CO, CO_2 and SO_2were strong positively loaded (>0.75). C_3H_4O and C_6H_6 were moderate loaded (0.75-0.50) (Liu et al., 2003) (Table 3 and 4). Only statistically significant loadings (> 0.70) are important for the modeling and interpretation procedure (Nedyalkova & Simeonov, 2019).

The RC2 factor, which included C_2H_5OH, C_3H_6O, C_3H_8O, C_5H_5N, $C_8H_{8,}$ CH_3OH and CS_2 was identified according to their coefficients in component matrix. The RC2 factor is in relation with the using an alcohol-based preparation in the hospital and explained 12.30% of total variance. Only CH_3OH was strong positively loaded (>0.75) (Table 3 and 4).

The RC3 factor (C_2HCl_3, $C_4H_8O_2$, C_8H_8, HCl and N_2O) is related with used anesthetic for medical and dental use. N_2O was moderate loaded (0.75-0.50). This factor explained 11.63% of total variance (Table 3 and 4).

The RC4 factor (C_2H_4O, C_2H_5OH, $C_4H_8O_{2,}$ C_6H_5OH, C_8H_{10} and CH_2O) explained 10.32% of total variance (Table 4), with eigenvalues 2.48. The RC4 factor was identified us chemicals used in medical procedures and as an ingredients in numerous treatments and laboratory applications. (Table 3 and 4).

The RC5 factor (C_3H_4O, $CH_{4,}$ NH_3 and NO_2) explained 9.99% of total variance (Table 4) and related with heating fats and oils at high temperature, plastic smoke and similar factor. These chemical are examples pulmonary irritants (Greenberg, 2003).

Table 3. Component loading for analyzed parameters, according to factor analysis

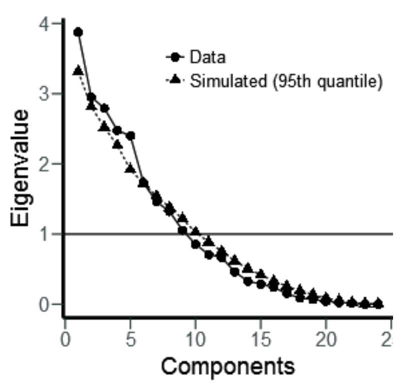
	RC 1	RC 2	RC 3	RC 4	RC 5	Uniqueness
C_2H_4O	.	.	.	-0.657	.	0.491
C_2H_5OH	.	0.658	.	0.523	.	0.303
C_2HCl_3	.	.	0.697	.	.	0.424
C_3H_4O	0.522	.	.	.	0.487	0.266
C_3H_6O	.	-0.439	.	.	.	0.543
C_3H_8O	.	0.746	.	.	.	0.366
$C_4H_8O_2$	.	.	0.500	0.516	.	0.395
C_5H_5N	.	-0.471	.	.	.	0.645
C_6H_5OH	.	.	.	-0.676	.	0.468
C_6H_6	0.574	.	.	.	.	0.661
C_7H_8	0.806	.	.	.	.	0.329
C_8H_{10}	.	.	.	0.552	.	0.444
C_8H_8	.	-0.402	-0.410	.	.	0.479
CH_2O	.	.	.	0.558	.	0.580

CH_3OH	.	0.905	.	.	.	0.209
CH_4	.	.	.	.	0.436	0.546
CO	0.905	.	.	.	.	0.136
CO_2	0.700	.	.	.	.	0.396
CS_2	.	0.491	.	.	.	0.487
HCl	.	.	0.772	.	.	0.360
N_2O	.	.	0.826	.	.	0.290
NH_3	.	.	.	.	0.849	0.289
NO_2	.	.	.	.	0.894	0.188
SO_2	0.822	.	.	.	.	0.208

Table 4. Eigenvalue and percentage variance for factors

PC	1	2	3	4	5	6	7	8	9	10	11	12
Eigenvalue	3.88	2.95	2.79	2.48	2.40	1.73	1.46	1.32	1.05	0.85	0.71	0.67
% variance	16.16	12.30	11.63	10.32	9.99	7.22	6.08	5.51	4.39	3.56	2.95	2.78

Graph 1. shows the PCA scree plot. Eigen values higher than one were taken as criterion for evaluating the principal components required to explain the sources of variance in the data. According to rotated oblique percentage variance, three factors explained 60.4% of the data total variance.



Graph 1. PCA scree plot

Measured values may have big impact in working environment and health of personnel in hospital and requires adequate management of chemical hazards in the workplace. Chronic toxicities by toxic substances at lower levels have not been elucidated yet. Thousands of novel chemical compounds are introduced in workplaces every year, and it is important to evaluate their risk by the current best scientific evidence before their use, not after the occurrence of occupational diseases (Yu et al., 2016). A comprehensive occupational health program is essential in health care settings to minimize the risk of occupational injury and illness in chemically exposed workers (Weaver, 1997).

CONCLUSIONS

The results of the measuring concentration of chemical hazards in hospital shown that contamination with different harmful chemical, but all hazards are important and continuing problems where the risks to health, if uncontrolled, are serious. Correlation analysis indicated the relationship between CO_2 and SO_2; CO and C_6H_6; CO and C_7H_8; NO_2 and NH_3; C_3H_6O and C_8H_8; C_3H_8O and CH_3OH and CH_3OH and C_2H_5OH. Such results suggest that these pollutants pairs might have similar sources or have been affected by similar factors.

Suggestions on reducing exposure to hazardous substances in hospital:

- where possible, perform the task without using hazardous substances
- where possible, substitute hazardous substances with less hazardous alternatives
- isolate hazardous substances in separate storage areas
- thoroughly train employees in handling and safety procedures
- provide personal protection equipment
- regularly monitor the workplace with appropriate equipment to track the degree of hazardous substance in the air or environment
- regularly consult with employees to maintain and improve existing safety and handling practices.

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