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Quantitative Determination of Formaldehyde in Air in Selected Laboratories in the University of the Philippines Manila-Philippine General Hospital

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Abstract. Formaldehyde, the simplest and most reactive of all aldehydes, offers a wide variety of uses and applications. In the Philippines, it is mostly encountered in hospitals and laboratories. However, there is still no occupational limit set in the country for formaldehyde in air for people constantly exposed to the chemical. This study aims (1) to measure the formaldehyde levels in the ambient air in selected laboratories of the University of the Philippines Manila and (2) to determine whether the formaldehyde levels exceed the limits set by the US Occupational Safety and Health Administration. Sample collection was done using adsorbent set-ups, one employing 0.05% dinitrophenylhydrazine in 2N HCl solution and another employing silica gel saturated with 0.05% dinitrophenylhydrazine. Formaldehyde levels were measured via UV-Vis Spectrophotometry. The concentrations determined were compared to occupational limits set by the US Occupational Safety and Health Administration (0.75 ppm). Results show that almost all formaldehyde air levels exceeded the 0.75 ppm limit and that concentration increases over time. Furthermore, the results of a paired t-test suggest that the absorbing efficiency of the two set-ups employed do not differ. It can be concluded that health hazards may occur to people exposed and working in the areas tested. Further studies should be made and a survey of adverse health effects in the exposed population is recommended. Furthermore, aside from institutional policies, a national policy setting the occupational limit for this chemical must be formulated.

Keywords: Formaldehyde, Dinitrophenylhydrazine, UV-Vis Spectrophotometry, Occupational Safety

1. Introduction

1.1. Background of the Study

Formaldehyde (CH_2O), the most simple and reactive of all aldehydes, is a colorless, reactive and readily polymerizing gas at room temperature. It is normally encountered as an aqueous solution, formalin, which is used as a disinfectant, an antiseptic and a tissue-fixing and embalming fluid [1]. It has a pungent suffocating odor that is recognized by most human subjects at concentrations below 1 ppm. Exposure to formaldehyde by inhalation is associated with eye, nose and throat irritation.

In 2006, the International Agency for Research on Cancer (IARC) of the World Health Organization classified formaldehyde as carcinogenic to humans based on sufficient evidence in humans and in experimental animals [2]. Formaldehyde has also been recently included in the 12th edition of the U.S. Department of Health and Human Services Report on Carcinogens of 2011 as a known carcinogen [3]. Causality is indicated by consistent findings of increased risks of nasopharyngeal cancer, sinonasal cancer, and lymphohematopoietic cancer, specifically myeloid leukemia among individuals with higher measures of exposure to formaldehyde in terms of exposure level and duration. IARC also concluded that there is a strong but not sufficient evidence for a causal association between leukemia and occupational exposure to

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formaldehyde. The United States has set the legal occupational limit for short-term (<15 mins.) exposure to formaldehyde is 2ppm, and the longer term limit (>15 mins.) is 0.75ppm [4].

Despite of the known hazard of formaldehyde to humans, the Philippines has not set an occupational limit of formaldehyde in air for people frequently exposed to this toxicant in their workplace. In addition, to the best of the researchers' knowledge, studies of formaldehyde concentration determination are not available in the country. Teachers, students and pathologists are commonly exposed to formaldehyde inside laboratories and are therefore at high risk of developing adverse effects after inhalation and dermal exposure. Thus, determination of formaldehyde concentration in air is of great interest and importance.

1.2. Statement of the Problem

The study will be guided by the following research questions: 1) What are the concentrations of formaldehyde in air in selected surgical pathology laboratories of the Department of Laboratories of University of the Philippines Manila- Philippine General Hospital and in the biology laboratory of University of the Philippines Manila College of Arts and Sciences? and 2) Do the formaldehyde concentrations in the said laboratories exceed the Occupational Safety and Health Administration limit of 0.75 ppm?

1.3. Objectives

The study aims to achieve the following:

General Objective:

1. To determine the levels of formaldehyde in air in the selected University of the Philippines Manila laboratories

Specific Objectives:

1. To assess the formaldehyde levels based on Occupational Safety and Health Administration limit of 0.75 ppm

2. To use an improvised method of sample collection.

1.4. Hypothesis

The formaldehyde concentration in the selected laboratories in the University of the Philippines Manila does not exceed the OSHA limit of 0.75 ppm.

1.5. Significance of the Study

Formaldehyde is a known health hazard and is carcinogenic but the Philippines has not set an occupational limit for it. The study can be a source of information since similar studies in the country are limited. The findings of this study can also be supporting evidence of policy making to ensure safety of people frequently using formaldehyde.

1.6. Scope and Limitations

Collection of formaldehyde samples only represents the amount of formaldehyde in the air. The analysis was limited in the surgical pathology section, specifically in the cutting room and tissue processing room of the department of laboratories of the University of the Philippines Manila- Philippine General Hospital as well as in the RH 323 biology laboratory of University of the Philippines Manila College of Arts and Sciences. The specific effects of formaldehyde on the health of the individuals exposed to it were not covered by the study. The materials that were used in the analysis only simulated the materials in the standard methods.

2. Methodology

2.1. Study Design

The study is a true experimental study. The sample collection was done in the surgical pathology section, specifically in the cutting room (PGH-C) and tissue processing room (PGH-TP) of the department of laboratories of the University of the Philippines Manila- Philippine General Hospital (UP-PGH) as well as in the RH 323 biology laboratory of University of the Philippines Manila College of Arts and Sciences (UP

CAS). The quantitative sample analysis was done in the University of the Philippines Manila College of Pharmacy.

2.2. Sample Collection and Sample Preparation

The sample collection was done for two days. Two set-ups, which served as sample collection devices, were placed in each of the mentioned laboratories. The first set-up comprised of polypropylene container with silica gel saturated with 2N HCl/0.05% 2,4-Dinitrophenyhydrazine (DNPH) reagent covered by fine mesh screen. The second set-up comprised of the 2N HCl/0.05% 2,4-Dinitrophenyhydrazine (DNPH) reagent in a container likewise covered by fine mesh screen. The set-ups were placed in areas not near the ceiling nor the walls nor floor to ensure air circulation. The set-ups were left in the laboratories for four hours for the first day. The next day, a new set of set-ups were left in the laboratories for eight hours. The sampling set-ups were transported in a cooler and were put in the freezer until analysis [5].

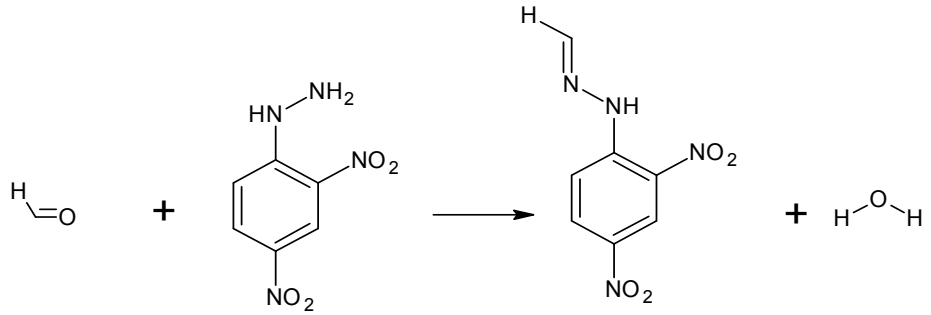
The hydrazone was desorbed from the sampler of the first set-up by acetonitrile; the desorption was done by addition of 20 mL of acetonitrile to 20 g of the silica gel-DNPH sampler and filtration. The solution was analyzed with Genesys UV Spectrophotometer at 360 nm [5].

The second set-up, utilizing DNPH reagent only, likewise underwent spectrophotometric determination. Five mL of the DNPH reagent used in the sample collection was added with 15 mL of water, 15 mL DNPH TS, 5 mL of methanol and 15 mL of chloroform. The mixture was shaken for 1-2 minutes and the chloroform layer was subjected to spectrophotometric analysis at 529 nm. The sample detection limit is 100 ppb (100ng/mL)[6].

Control silica gel-DNPH and DNPH only samplers served as blank for the spectrophotometric analysis. Standard solutions at varying concentrations of formaldehyde at 1.11 ppm, 2.04 ppm, 2.59 ppm and 4.01 ppm were used to generate a standard absorbance curve. The control and standard solutions were prepared for analysis in the same way as the sample solutions.

3. Results and Discussion

Formaldehyde reacts with DNPH in the presence of a strong acid as catalyst to form a stable hydrazone derivative as seen in this chemical reaction:



formaldehyde (2,4-dinitrophenyl)hydrazine formaldehyde (2,4-dinitrophenyl)hydrazone

Fig. 1: Chemical reaction of formaldehyde and dinitrophenylhydrazine

The reaction proceeds by nucleophilic addition to the carbonyl followed by 1,2-elimination of water to form the 2,4-diphenylhydrazone derivative. The derivative obtained by the samplers was analyzed spectrophotometrically [5].

The concentrations of formaldehyde in air and the concentrations per m^2 were determined (Tables 2 and 4). The negative concentrations obtained for CAS (4 hours) and PGH TP (4 hours) for the Silica Gel-Dinitrophenylhydrazine set up may be due to the loss of sample during transport, storage or analysis. For both set-ups, the concentrations per m^2 for the tissue processing room had the highest values followed by the cutting room and lastly, the CAS biology laboratory:

Table 1: Formaldehyde concentration(ppm) per m^2 detected in the selected laboratories

	TIME PERIOD	SILICA GEL-DNPH (ppm per $m^{2)}$	DNPH SOLUTION (ppm per $m^{2)}$
CAS	4 hours	0.0000	0.0121
	8 hours	0.0154	0.0129
PGH C	4 hours	0.0301	0.0170
	8 hours	0.0960	0.0176
PGH TP	4 hours	0.0000	0.0831
	8 hours	0.8432	0.0925

Silica Gel-DNPH: TP8>C8>C4>CAS8
DNPH Solution: TP8>TP4>C8>C4>CAS8>CAS4

It was observed that at prolonged exposure i.e. at 8 hours duration, the concentration detected is larger. It was also observed that the concentration increases as the room area (m^2) decreases. It can also be noted that where there is poorer ventilation, the formaldehyde concentration is higher. Since the tissue processing room has the smallest area (9.6 m^2) among the laboratories, there may not be adequate air circulation which gave relatively high formaldehyde concentrations. In addition, it has only one active exhaust and has no windows, thus, air may become more concentrated inside the room.

On the other hand, the cutting room with the second largest area of 47.5 m^2 has the second least concentration of formaldehyde detected. It has eight 13.5" x 45" (equivalent to 3.0193 m^2) windows situated at the back portion of the room but not very near the working tables that are most frequently used. It also has 6 exhaust units. However, not all windows are kept open for ventilation and the exhaust system is not used all the time because it generates significant noise. The room has 3 air-conditioning units and an electric fan and the door is also open at times which could possibly increase air circulation driving air out of the room. Thus, smaller concentration was detected.

The RH 323 biology laboratory of CAS has the largest area of 76.36 $m^{2.}$ It has seven 17.5" x 47" (equivalent to 3.7145 m^2) windows at the back portion of the room. The door is kept open but not all of the windows. The room has 2 exhausts and 5 electric fans. Relative to its area, the ventilation system provides better circulation possibly driving air out and thus, the smallest concentration of detected formaldehyde.

DNPH may have also reacted with other aldehydes so the concentrations obtained may not be solely formaldehyde [5]. But since formaldehyde is the most reactive of all the aldehydes and ketones and the laboratories tested especially the pathology laboratories mainly use formaldehyde, it can be assumed that if not all, majority of that detected is formaldehyde.

The results from the silica gel-DNPH and HCl-DNPH set up are compared and to determine the difference between them, a paired t-test was performed. The test is basically performed to know whether the treatment applied to one set-up causes a significant change in its efficiency to absorb formaldehyde in air, as compared to the other. Stata/IC 12.0 was used in the statistical analysis; confidence level at 95% and α=0.05 were set, and the p-value was computed. The p-value after analysis is 0.5352, which is a value higher than the p-value set. The null hypothesis stating that "the mean difference is equal to zero" is taken. Therefore, through a paired t-test, it has been found out that there is no evidence that the absorbing efficiency of the silica gel-DNPH set-up is statistically different from that of HCl-DNPH set-up. This would mean that the affinity for formaldehyde in both set-ups is the same for each reagent used. It can be said that the same concentration of formaldehyde shall be observed in either set-up after sampling. One could not ascertain which has more adsorbent capabilities.

4. Conclusions and Recommendations

It can be concluded that almost all formaldehyde concentrations in air in the laboratories tested exceeded the 0.75 ppm limit, and that the general trend was that concentration increases with time. Health hazards to the personnel and students of the laboratories may occur since the formaldehyde levels in air exceeded the prescribed limit. Survey of adverse effects experienced associated with formaldehyde use and/or determination of formaldehyde in the biological fluid/s of the said personnel and students are recommended.

There is also no statistical difference between the adsorbing capabilities of the two set-ups. The determination of the formaldehyde adsorbing efficiency of the samplers is recommended. The use of commercially available samplers, High Performance Liquid Chromatography analysis, and other standard methods of analysis such as Gas Chromatography-Mass Spectrometry can be done to support the findings of this study. Recording the temperature and humidity of the room during the sampling period is also recommended since the volatility and solubility of formaldehyde in air is affected by the said parameters. The set-ups can also be placed in all of the corners and in the middle portion of the rooms to get more accurate samples that are representative of the rooms.

Based on the findings of the study, the researchers recommend the following to the hospital and school: (1) monitoring the exposure of employees and students to formaldehyde in laboratories (2) re-emphasizing the importance of control of hazards and protection from them (3) making it mandatory for students and employees to wear personal protective equipment in laboratories (4) installation of proper ventilations in rooms, and (5) limiting of access to regulated areas to authorized persons who have been trained to recognize the hazards of formaldehyde.

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