1984

Formaldehyde levels in the health care environment /

Mark L. Rollins
University of Massachusetts Amherst

FORMALDEHYDE LEVELS IN THE HEALTH CARE ENVIRONMENT

A Thesis Presented

By

MARK LEE ROLLINS

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

September 1984

Department of Plant and Soil Science

FORMALDEHYDE LEVELS IN THE HEALTH CARE ENVIRONMENT

A Thesis Presented

By

MARK LEE ROLLINS

Approved as to style and content by:

Warren Litsky, Ph.D., Chairman of Committee

Salvatore R. DiNardi, Ph.D., Member

Gary S. Moore, Dr. P.H., Member

Allen V. Barker, Ph.D., Head
Department of Plant and Soil Science

ABSTRACT

In recent years concern has grown over the quality of indoor air, and its possible effects on human health. Particular interest is given to the chemical Formaldehyde, and the concentrations found in the domestic and health care environments.

Because of this a study was initiated to determine the Formaldehyde concentration in the air of various health care institutions.

Sampling was done in three institutions: a nursing home, a hospital, and a university health service. In the nursing home the average concentration of Formaldehyde was 88 PPB in a patient room, 127 PPB in a hall, and 145 PPB in a lounge. The average concentrations in the hospital were 155 PPB in a patient room, 32 PPB in a hall, and 68 PPB in a solarium. The university health service was found to have Formaldehyde levels of 180 PPB in a patient room, 192 PPB in a hall, and 200 PPB in a lounge.

TABLE OF CONTENTS

LIST OF TABLES

ILLUSTRATIONS

C H A P T E R I

INTRODUCTION

Formaldehyde is a one-carbon compound (HCHO) which at room temperature is normally in the highly reactive gaseous state and is characterized by a pungent odor.

In 1982, approximately six billion pounds of Formaldehyde were produced in the United States (1). Most of this was used in the production of Urea-, Phenol-, Acetal- and Melamine-formaldehyde resins. These resins are used as adhesives in the manufacture of particle board, veneers and plywood; and in the production of insulating materials, plastics, textiles, protective coatings, paper and rubber products. In addition, Formaldehyde is used in the manufacture of industrial chemicals, agricultural products, leather goods and as a preservative for cosmetics, drugs, vaccines, fumigants and disinfectants (2).

The commercial form of Formaldehyde (Formalin) is a 37 to 50 percent aqueous solution which is stabilized against polymerization with 1 to 15 percent methanol. Formaldehyde is also available as a solid linear polymer containing 5 to 9 percent water.

Formaldehyde can be released indoors from any of the aforementioned products (3). It is also a component of cigarette smoke (4).

As indicated above, indoor concentrations of Formaldehyde are of great interest to the health care industry, especially in nursing

homes, hospitals, and other patient facilities. Within these confines a unique situation exists in that one is treating ill or infirm individuals who are already under physical stress. While a healthy person may easily tolerate Formaldehyde levels up to 3.0 parts-per-million (PPM), patients who are ill may be far less tolerant (5). This is especially true for those suffering from respiratory ailments, or asthmatic patients (5).

Because of this situation and the lack of definitive data regarding the amounts of Formaldehyde in the air of health care facilities, the present study was undertaken.

C H A P T E R I I

LITERATURE REVIEW

Humans are susceptible to adverse health effects from acute Formaldehyde exposure. Between 0.1 PPM up to 3.0 PPM, most experience an irritation of the eyes, nose and throat (5, 7). This is characterized by sneezing, tearing, shortness of breath, nausea, sleeplessness, tightness of the chest and excess phlegm (8). Cases have also been reported where asthma has been attributed to exposure to low levels of Formaldehyde (6, 9). In terms of exposure to higher concentrations (4-5 PPM), it has been reported that this can be tolerated for 10 to 30 minutes, after which pulmonary edema and death can result. From 10.0 PPM to 20.0 PPM respiration becomes difficult, and exposure to levels at or above 50.0 PPM can cause pulmonary edema and pneumonitis (10).

While Formaldehyde is extremely reactive and could very well be the subject of a comprehensive discussion regarding the dynamics of chemical reactions, the following have been selected to illustrate the chemical interplay of Formaldehyde with such products as water, ammonia, amines and amids: components of all biological systems (11).

$$HCHO + H_2O = CH_2(OH)_2 \qquad (a)$$

$$RNH_2 + HCHO = RNHCH_2OH \qquad (b1)$$

$$RNHCH_2OH + R'NH_2 = RNHCH_2NHR' + H_2O \qquad (b2)$$

$$RCONH_2 + HCHO = RCONHCH_2OH \quad (c1)$$

$$RCONHCH_2OH + R'CONH_2 = RCONHCH_2NHOCR' + H_2O \quad (c2)$$

These reactions are of concern because of the occurrence of Nitrogen compounds (DNA, RNA, Amino Acids and Proteins) in all biological systems. It is not surprising, therefore, that the chronic effects of Formaldehyde exposure have been under investigation.

Formaldehyde has been shown to have teratogenic effects: that is, an effect on the developing embryo. As early as 1968, Gofmekler exposed pregnant female rats to Formaldehyde levels of 0.0, 0.012, and 1.0 mg/M^3 (12), and showed that pups from both exposure groups had livers and lungs which weighed less than those from the control group. Again in 1969 Gofmekler examined the livers and kidneys of pups born to female rats exposed to 1.0 mg/M^3 of Formaldehyde (13). He found that those from the exposure group had changes in the liver, including an increase in epithelial cells in the bile duct. The kidney changes included casts in the lumina of some tubules and alteration of the renal tubules. There was also noted an involution of the thymus lymphoid tissue, and a disintegration of lymphocytes in pups from the exposure group. In a dietary study, pregnant beagles were fed levels of Hexamethylenetetramine (HMT) amounting to 600 and 1250 PPM (14). HMT is an antimicrobial food additive which degrades to Formaldehyde and Ammonia in the presence of protein, or in the acid medium of the digestive tract (15). It was found that while 600 PPM had no discernible effect (14), 1250 PPM of HMT had a noticeable effect on the beagle pups. In the 1250 PPM exposure group there was a greater percentage of stillborn pups, and those that survived grew at

a less-than-normal rate. In humans, Formaldehyde was shown to have teratogenic and adverse reproductive effects. Two female exposure groups of 130 fabric trim shop finishers and 316 fabric warehouse inspectors were compared with one control group of 200 industrial goods saleswomen (16). The atmospheric concentrations of Formaldehyde in the trim shops ranged from 1.5 to 4.5 mg/M^3; the warehouse levels ranged from 0.05 to 1.0 mg/M^3. Forty-seven and one-half percent of the exposure groups had menstrual disorders, as compared to 18 percent of the control group. Those who were pregnant in the exposure groups had twice as many instances of intrauterine asphyxiation and a greater percentage of babies with low birth weights.

Formaldehyde has also been shown to have mutagenic properties. In one study, Drosophila larvae were fed Formaldehyde-treated food which resulted in a 6 percent occurrence of sex-linked recessive lethal mutations, against 0.2 percent for a control group (17). Formaldehyde-treated food has also produced mutations in the alcohol dehydrogenase (ADH) gene of Drosophila (18). Injections of weak Formaldehyde solutions into adult Drosophila have also produced sex-linked recessive lethal mutations but at a much lower frequency than those for Formaldehyde-treated food (19,20).

The potential carcinogenicity of Formaldehyde has also been investigated. In an inhalation study, groups of 240 rats (120 males and females per group) were exposed to 0.0, 2.1, 5.6 and 14.1 PPM of Formaldehyde. After 24 months, the cancer totals were inventoried by

autopsy. Exposure to 14.1 PPM resulted in 93 nasal squamous cell carcinomas, four squamous papilloma, three adenomatous polyps, and two carcinomas of the respiratory epithelium. Two of those exposed to 5.6 PPM developed nasal squamous cell carcinomas, four developed adenomatous polyps, and one developed carcinoma of the respiratory epithelium. Two in the 2.1 PPM exposure group developed adenomatous polyps (21). In another inhalation study, groups of 240 rats or mice (120 males and females per group) were exposed to Formaldehyde levels of 0.0, 2.0, 5.6 and 14.3 PPM (22). Formaldehyde-induced lesions were noted in the nasal cavity and trachea. After 27 months, the cancer totals were as follows; in the 14.3 PPM exposure group, 103 rats and 2 mice developed nasal squamous cell carcinomas, as well as 2 rats in the 5.6 PPM exposure group.

Because Formaldehyde is a strong irritant and is considered a potential carcinogen in humans, concern has been voiced in recent years as to what the airborne concentrations are in the workplaces and places of habitation. When a high concentration of Formaldehyde exists in a workplace, it can be dealt with using established industrial hygiene techniques. These techniques include the use of ventilation systems, containment of the source, filtration, absorbance, and substitution of other chemicals. In many places of habitation or in health care facilities it is often difficult to cope with formaldehyde, since the levels would never approach those of an industrial process which employs Formaldehyde directly and very often no one is aware that a given product contains or releases Formaldehyde

(23).

Various groups have recommended occupational standards for Formaldehyde. The National Institute for Occupational Safety and Health (NIOSH) has suggested a workplace limit of 1 PPM (24). The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended a threshold limit value (TLV) of 2 PPM. A TLV is the concentration which it is believed the majority of workers may be repeatedly exposed eight hours each day with no adverse effect (25). The Occupational Safety and Health Administration (OSHA) is the only Federal agency authorized to set and enforce standrds. For this purpose, OSHA has set a 3 PPM permissible exposure limit (PEL) for Formaldehyde, for an eight hour workshift, a ceiling concentration of 5 PPM, and a peak concentration of 10 PPM (26).

C H A P T E R I I I

METHODS

For the purposes of this study three sampling locations were chosen: a hospital, a nursing home, and a university health service. Ten samples were taken from three different areas inside each institution: a patient room, a corridor in a patient area, and a patient common area, such as a lounge or solarium. In all areas, the ceiling heights ranged from 2.5 to 3 meters. The patient rooms were all approximately 7 by 4 meters, with a volume of around 65,000 liters. The solarium/lounge areas varied from 9 by 5 to 11 by 8 meters, giving an approximate volume between 100,000 and 200,000 liters. The corridors varied in length, from 3 by 6 to 3 by 12 meters, for an approximate volume between 45,000 and 90,000 liters. The air temperature was taken at the beginning and end of each sample. The average was used in the calculation of the PPM concentration of Formaldehyde in the air. During each sampling period it was also noted if anything was occurring which might elevate the levels of Formaldehyde, such as smoking or use of a disinfectant.

Samples were collected between November 1, 1983 and January 9, 1984. The samples were taken during the hours of 7:00 A.M. and 9:00 P.M.

Air sampling was performed using an impinger sampling train. The

sampling pump used was an MSA personal sampling pump calibrated and set to run at 1 liter per minute (LPM). All tubing in the sampling train was FEP Teflon. Two 30 milliter impingers were used. They were connected in series, and each contained 20 milliters of distilled, deionized water for every sample. With the impingers in series, the collection efficiency is 95% (24). The sampling apparatus was placed on a cart or chair to elevate it between one-half to one meter above the floor. When possible, the samples from a patient room were taken in an empty room, so as not to inconvenience patients or staff.

Analysis of samples was carried out using the modified pararosaniline method for determining the concentration of Formaldehyde in air (27). To analyze each sample a 2.5 milliter aliquot was placed into a one centimeter cuvette, to which was added 0.25 milliters of the acidified Pararosaniline reagent. To this was added 0.25 milliters of a 0.1 gram/100 milliters Sodium Sulfite reagent. The cuvette was capped and shaken to insure complete mixing, and developed in a 25^{o}C water bath for one hour. After developing, the samples were read using a Coleman 124 double beam U.V. and visible spectrophotometer (Perkin & Elmer) set at 570 nanometers. Each sample was read against a distilled water blank. All associated glassware was acid washed and rinsed with distilled, deionized water prior to use.

C H A P T E R 1 V

RESULTS

Data

The following tables are a listing of individual measurements for Formaldehyde in each of the three institutions studied. Since the modified pararosaniline method has a lower detection limit of 25.0 parts-per-billion (0.025 PPM), values obtained that were lower than this were not included in the figuring of averages (27).

Location	Room	Hall	Lounge
	130	164	191
	96	142	122
	62	231	215
Formaldehyde	65	236	167
levels in PPB	62	145	142
	99	153	186
	131	54	150
	106	58	120
	73	40	84
	58	47	110
Mean	88	127	149
Median	84.5	143.5	146
Standard Deviation	28.1	74	41
Variance	792	5483.3	1686.5

Ambient (outside) Formaldehyde levels: 29 PPB

Table 1. Nursing Home Formaldehyde Levels.

Location	Room	Hall	Solarium
	276	31	131
	281	16*	62
	138	25	78
Formaldehyde	99	27	31
levels in PPB	133	41	44
	105	25	70
	120	37	24*
	112	10*	58
	164	36	5*
	124	33	4*
Mean	155	32	68
Median	128.5	29	62
Standard Deviation	67.5	5.9	32
Variance	4560	35.3	1025.5

Ambient (outside) Formaldehyde levels: 10* PPB

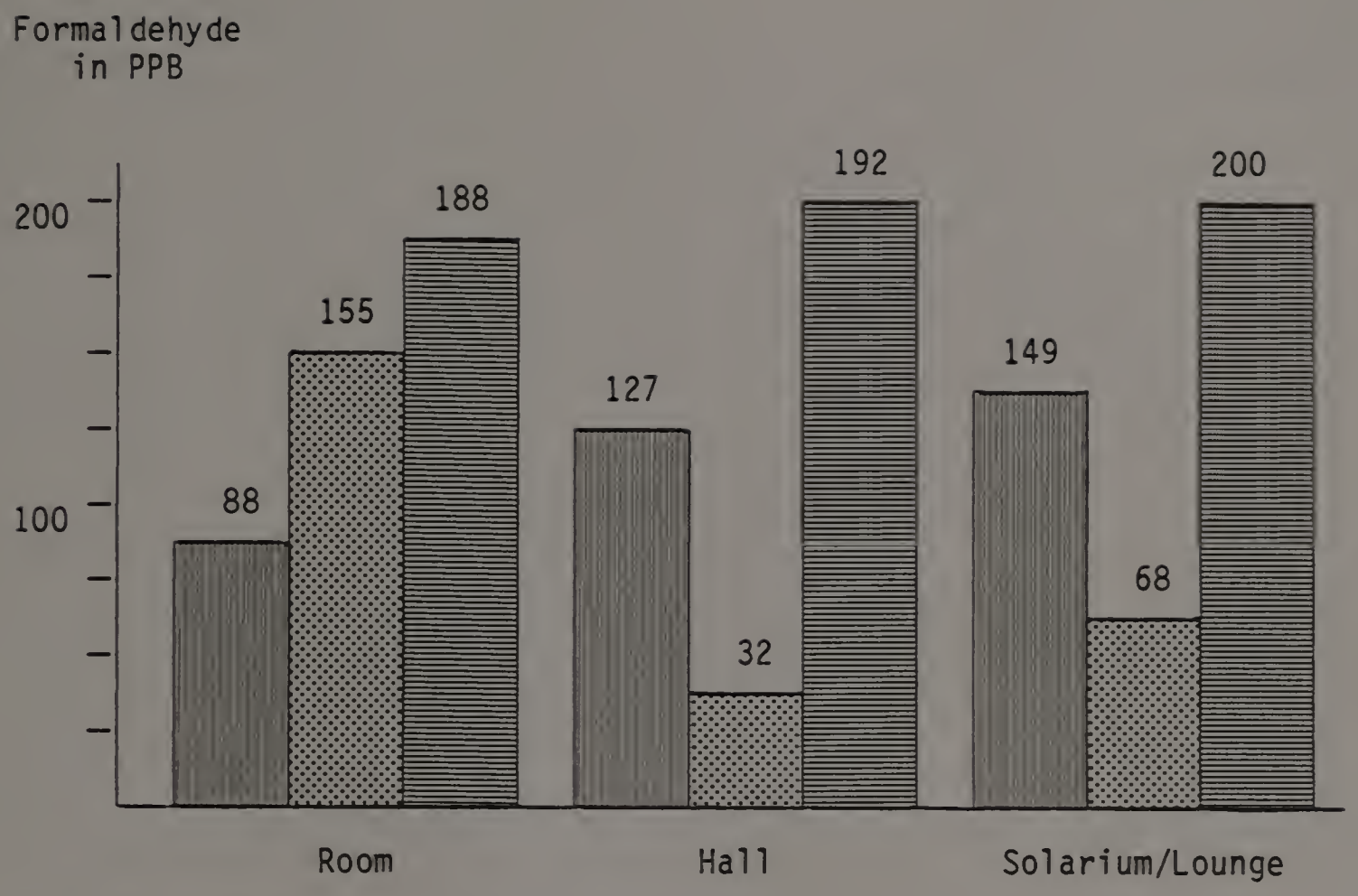
* These levels were below the lower limit of detection.

Table 2. Hospital Formaldehyde Levels.

Location	Room	Hall	Solarium
	393	384	393
	322	365	334
	138	196	269
Formaldehyde	113	251	292
levels in PPB	363	59	80
	77	55	94
	89	51	250
	76	202	91
	180	217	96
	129	144	103
Mean	188	192	200
Median	133.5	199	176.5
Standard Deviation	123.3	120	119.6
Variance	15215.7	14406	14296.8

Ambient (outside) Formaldehyde levels: 27 PPB

Table 3. Health Services Formaldehyde Levels.



Graph 1. A Comparison of Average Levels of Formaldehyde in the Three Health Care Institutions.

C H A P T E R V

DISCUSSION

As can be seen from the study data, the Formaldehyde levels ranged from below detectability (25 PPB) to a high of 393 PPB. The levels observed never approached the limits set by OSHA. This may be due in part to the age of the buildings and the type of insulation used. The hospital wing was built in 1959, the health service in 1972-1973 and the nursing home in 1967. The Formaldehyde content of any potential source, such as floor tile and plywood, has decreased over the years. This means that these older materials will contribute little if any to the indoor Formaldehyde levels. The type of insulation used can also contribute significant amounts of Formaldehyde. In all three institutions, an insulating material other than Urea-Formaldehyde foam insulation (UFFI) was used. Therefore, we can rule out the insulation as a Formaldehyde source. The disinfectants and cleansers used in each institution were also found not to contain Formaldehyde, in the form of Formalin. They did contain Tetrasodium Ethylenediamine tetraacetate (EDTA), which is known to have Formaldehyde as a contaminant (22). The other probable sources of Formaldehyde were the obvious ones: plastics, foam mattresses, synthetic clothing, and paper and rubber products.

The Formaldehyde levels measured could cause irritation to the

eyes and upper respiratory tract in humans. They could also aggravate an asthmatic condition. To a healthy employee this would only be a minor discomfort: indeed some individuals might not exhibit any symptoms. Furthermore, most employees work an average of 8 hours each day and are not being continuously exposed. The patient is the antithesis of this. Due to age or illness, or both, the patient is in a physically-stressed situation. This is especially true if a patient is suffering from respiratory ailments. The minor irritations that sometimes result from exposure to low levels of Formaldehyde might instead act synergistically with the illness(es) already present, causing major ramifications.

C H A P T E R V I

CONCLUSION

The modified pararosaniline method for the determination of Formaldehyde concentration in the air seemed well-suited for the use in locations such as health care facilities. The compact size of the sampling apparatus, the small (quiet) sampling pump needed and the relative immunity to false positive or negative readings support this. The levels of Formaldehyde measured indicate the presence of Formaldehyde in three different types of health care facilities. Readings never approached the OSHA standard, which indicates the patients in the institutions studied were not in any overtly hazardous situation. However, the potential for irritation to the respiratory system of both staff and patient exists, on the basis of individual measurements.

C H A P T E R V I I

RECOMMENDATIONS

There should be a concerted effort on the part of health care facilities to do everything possible to reduce the levels of Formaldehyde present. One method would be to air out or launder all new linens, curtains, foam mattresses, etc., before use in a patient's room. This would act to reduce the amount of Formaldehyde the material has available for release to the indoor environment. Small air purifier pumps containing chemical filters could also be used to remove the Formaldehyde already present.

By so doing, the Formaldehyde levels would reduced, and thus decrease the possibility of the patients being adversely affected by this one component of indoor air pollution.

BIBLIOGRAPHY

1. Atherton, M.J. "Formaldehyde," American Council on Science and Health pamphlet, November 1982.

2. Battelle Columbus Division. "Final Report on Product/Industry Profile and Related Analysis for Formaldehyde and Formaldehyde-containing Consumer Products." CPSC-C-78-0091, Battelle, Columbus, OH, February 1979.

3. Spedding, J. et al. "Indoor Air Pollution by Formaldehyde," Clean Air 14(3):35-38, August 1980.

4. Ayer, H.E. et al. "Irritants in Cigarette Smoke Plumes," American Journal of Public Health 72(11):1283-1285, November 1982.

5. Griesemer, R.A., Chairman. "Report of the Federal Panel on Formaldehyde," Environmental Health Perspectives 43:139-168, February 1982.

6. Sakula, A. "Formalin Asthma in Hospital Laboratory Staff," Lancet 7939(2):816, October 1975.

7. Weber-Tschoop, A. et al. "Irritating Effects of Formaldehyde on Men," International Archives of Occupational and Environmental Health 39:207-218, 1977.

8. Schuck, E.A. et al. "Eye Irritation Response at Low Concentrations of Irritants," Archives of Environmental Health 13:570-575, 1966.

9. Harris, J.C. et al. "Toxicology of Urea Formaldehyde and Polyurethane Foam Insulation," JAMA 245(3):243-246, January 1981.

10. Fassett, D.W. "Aldehydes and Acetals," Industrial Hygiene and Toxicology. 2nd Rev. Ed. Vol. 11, F.A. Patty, Ed., Interscience, New York, NY 1963, pp. 1959-1989.

11. Kitchens, J.F. et al. "Investigation of Selected Potential Environmental Contaminants: Formaldehyde," U.S. Environmental Protection Agency, Washington, DC. Report No. ARC-49-5681, 1976.

12. Gofmekler, V.A. "Effect on Embryonic Development of Benzene and Formaldehyde in Inhalation Experiments," Hygiene and Sanitation (USSR) 33:327-332, 1968.

13. Gofmekler, V.A. et al. "Experimental Studies of Teratogenic

Properties of Formaldehyde Based on Pathological Investigations," Hygiene and Sanitation (USSR) 34:266-268, 1969.

14. Hurni, G. et al. "Reproduction Study with Formaldehyde and Hexamethylenetetramine in Beagle Dogs," Food and Cosmetics Toxicology 11:459-462, 1973.

15. Goodman, L.S., and Gilman, S., Eds. The Pharmacological Basis of Therapeutics, 5th ed. Macmillan Publishing Co., New York, NY, 1975, p.1006.

16. Shumilina, A.V. "Menstrual and Reproductive Functions in Workers with Occupational Exposure to Formaldehyde," Gigiena Truda I Professionalnye Zabolevaniia (Moskva) 12:18-21, 1975.

17. Auerbach, C. et al. "Genetic and Cytogenical Effect of Formaldehyde and Related Compounds," Mutation Research 39:317-361, 1977.

18. Benyajati, C. et al. "Formaldehyde Mutagenesis in Drosophila, Molecular Analysis of ADH-Negative Mutant," Mutation Research 111:1-7, 1983.

19. Sobels, F.H. "Mutation Tests with Formaldehyde-Hydrogen Peroxide Mixture in Drosophila," American Naturalist 86:109-112, 1954.

20. Auerbach, C. "Mutation Tests on Drosophila melanogaster with Aqueous Solution of Formaldehyde," American Naturalist 86:330-332, 1952.

21. Swenberg, J.A. et al. "Induction of Squamous Cell Carcinoma of the Rat Nasal Cavity by Inhalation Exposure to Formaldehyde," Cancer Research 40:3398-3402, 1980.

22. Kerns, W.D. et al. "Carcinogenicity of Formaldehyde in Rats and Mice After Long-Term Inhalation Exposure," Cancer Research 43:4382-4392, 1983.

23. Lachapelle, J.M. et al. "Formaldehyde in Household Cleaning Agents," Contact Dermatitis 7(3):166-167, 1981.

24. U.S. Department of Health, Education, and Welfare. "Occupational Exposure to Formaldehyde, Criteria for Recommended Standard," No. 757-009/46, December 1976.

25. American Conference of Governmental Industrial Hygienists. "Industrial Ventilation, a Manual of Recommended Practice," 16th Rev. Ed., Edwards Brothers, Ann Arbor, MI 1980, pp. 13-1 - 13-11.

26. National Safety Council. "Fundamentals of Industrial Hygiene," 2nd. Rev. Ed., J.B. Olishifski, Ed., National Safety Council Press, Chicago, IL 1979, p. 1141.

27. Miksch, R.R. et al. "Modified Pararosaniline Method for the Determination of Formaldehyde in Air," Analytical Chemistry 53(13):2118-2123, 1981.

28. Walker, F.J. "Formaldehyde," 3rd. Ed., R.E. Krieger Publishing, Huntington, NY 1975, pp. 486-7.

APPENDIX A

Preparation of Pararosaniline Stock Solution

Reagents:

1) 1N Hydrochloric acid (HCL). Dilute 83 ml of concentrated Hydrochloric acid, ACS Reagent Grade, to one liter with distilled water in a one-liter volumetric flask.
2) 1-Butanol.
3) Pararosaniline Hydrochloride, purchased from Aldrich (catalog no. 21,559-7).

Apparatus:

1) 2-liter separatory funnel (two).
2) 2-liter stoppered flask (two).
3) Magnetic stirrer.
4) Magnetic stirring bars.

Procedure:

I. Cleaning of Glassware.

All glassware was cleaned by soaking in a 5N Nitric acid solution for at least one hour. Rinsing was then done using distilled, deionized water. The glassware was dried in a 40^{o}C oven.

II. Pararosaniline Solution Preparation.

750 ml of 1N HCL and 750 ml of 1-Butanol is placed in a 2-liter stoppered flask. A magnetic stirring bar is added, and the mixture is allowed to equilibrate for 24 hours. After equilibrating, the HCL and 1-Butanol are separated using a 2-liter separatory funnel. 1.5 grams of Pararosaniline Hydrochloride is added to 750 ml of the equilibrated HCL in a 2-liter flask. A magnetic stirring bar is added, and the

Pararosaniline is allowed to dissolve for 24 hours. After 24 hours, 400 ml of the equilibrated 1-Butanol is added to the flask. This is allowed to mix for 24 hours. After 24 hours, the mixture is transferred to a 20 liter separatory funnel, and extracted. The lower (aqueous) phase is saved in a 2-liter flask. The upper (organic) phase is discarded. The extractions are repeated four more times, with one 100 ml and three 50 ml portions of the equilibrated 1-Butanol. Each extraction is allowed to mix for 24 hours. After the final extraction, the lower (aqueous) phase is placed in a 1-liter flask, and labeled. This Pararosaniline reagent is used to develop the Formaldehyde samples.

APPENDIX B

Standardization of Formalin Solution

Reagents:

1) Formalin solution (37% w/w), purchased from Fisher Scientific (catalog no. F-79).
2) Formaldehyde solution 'A'. Dilute 3.0 ml of the 37% Formalin solution to one liter with distilled water.
3) Formaldehyde solution 'B'. Dilute 1 ml of standard solution 'A' to 100 ml with distilled water. This solution must be prepared fresh daily for use in preparation of the calibration curve (see Appendix C).
4) 1N Sodium Sulfite (Na_2SO_3). Weigh 31.5 g of anhydrous Sodium Sulfite (Fisher catalog no. S-430) and add to a 250 ml volumetric flask. Fill to the mark with distilled water.
5) 1N Hydrochloric acid. Dilute 83 ml of concentrated Hydrochloric acid, ACS reagent grade, to one liter with distilled water in a one-liter volumetric flask.
6) 1N Hydrochloric acid (HCL), standardized for titrations. This is prepared as in (5) above. This solution is standardized with 1N Sodium Hydroxide, which was previously standardized with Potassium Biphthalate.
7) 1N Sodium Hydroxide (NaOH). Weigh out 40.0 g of Sodium Hydroxide (ACS grade) in a 1-liter volumetric flask. Fill to the mark with distilled water.
8) 0.1N HCL. Dilute 1 ml of the standardized 1N HCL solution to 100 ml with distilled water.

Apparatus:

1) pH meter (Orion digital model 701) calibrated with pH 7.00 buffer solution.
2) pH electrode (Markson no. 739 combination electrode).
3) Magnetic stirrer.
4) Magnetic stirring bars.
5) 200 ml beaker.
6) Disposable eye droppers.
7) 25 ml volumetric pipette (three).
8) 50 ml graduated cylinder.
9) 100 ml beaker (three).
10) 25 ml burette (two).

Procedure:

I. Cleaning of Glassware.

All glassware was cleaned by soaking in a 5N Nitric acid solution for a least one hour. Rinsing was then done using distilled, deionized water. The glassware was dried in a 40^{o}C oven.

II. Standardization of Formaldehyde Solution 'A'

The pH meter is used as the indicator for all titrations performed. Approximately 100 ml of Formaldehyde solution'A' is neutralized (pH 7.00) with unstandardized 1N HCL while being stirred slowly with a magnetic stirrer. Next, 50 ml of 1N Na_2SO_3 is neutralized with unstandardized 1N HCL while being stirred slowly on a magnetic stirrer. A 25 ml aliquot of the neutralized Formaldehyde is then added to the 50 ml of neutralized Na_2SO_3

solution. This mixture is back-titrated with standardized 0.1N HCL to neutral pH. The titration is repeated at least two more times, and the results averaged. The average obtained is then used to calculate the concentration of Formaldehyde in solution 'A'.

Results:

The standardized HCL solution was 1.0064N. Therefore the 1:10 dilution was 0.10064N HCL. The average milliters used was 18.436. The following equation (28) is used to calculate the concentration of Formaldehyde in mg/ml.

$$CH_2O\ (mg/ml) = \frac{ml\ HCL\ X\ N\ HCL}{ml\ Formalin} X \frac{30.03\ mg/ml}{N}$$

Substituting in the known figures into the equation, we find that the concentration of Formaldehyde in solutin 'A' is 2.2287 mg/ml.

$$\frac{18.436\ ml\ HCL\ X\ 0.10064N\ HCL}{25\ ml\ Formalin} X \frac{30.03\ mg/ml}{N} = 2.2287\ mg/ml.$$

The concentration of Formaldehyde in solution 'B' is 0.01 times that of solution 'A'.

Solution 'A' = 2.2287 mg/ml

Solution 'B' = 0.022287 mg/ml

Solution 'B' = 22.287 µg/ml

APPENDIX C

Preparation of Calibration Curve

Reagents:

1) Pararosaniline stock solution. This was prepared in Appendix A.

2) Formaldehyde solution 'B'. Dilute 1 ml of standardized Formaldehyde solution 'A' to 100 ml with distilled water (see Appendix B). This solution must be made fresh daily for use in preparing the calibration curve.

3) Sodium Sulfite (Na_2SO_3) solution. Dissolve 0.1 grams in 100 ml of distilled water. This solution must be prepared fresh weekly.

Apparatus:

1) 1 centimeter cuvettes.

2) Perkin & Elmer Coleman 125 double beam U.V. and visible spectrophotometer (or equivalent) set at 570 nanometers.

3) Water bath, set at 25^{o} Celsius.

4) 5 ml pipettes.

5) 1 ml pipettes.

Procedure:

The standards are prepared by first pipetting 0.0, 0.025, 0.05, 0.10, 0.20, 0.25 and 0.30 ml of Formaldehyde solution 'B' into 1 cm cuvettes. Distilled water is added to each cuvette to make the volume up to 2.50 ml. The 0.25 ml of the acidified Pararosaniline reagent is added, and the cuvette is capped and shaked to insure complete mixing. After mixing, 0.25 ml of the Sodium Sulfite solution is added. The cuvette is placed in the 25^{o}C water bath, and allowed to develop

for one hour. The cuvettes can be read up to three hours after developing, but it is best to read them immediately.

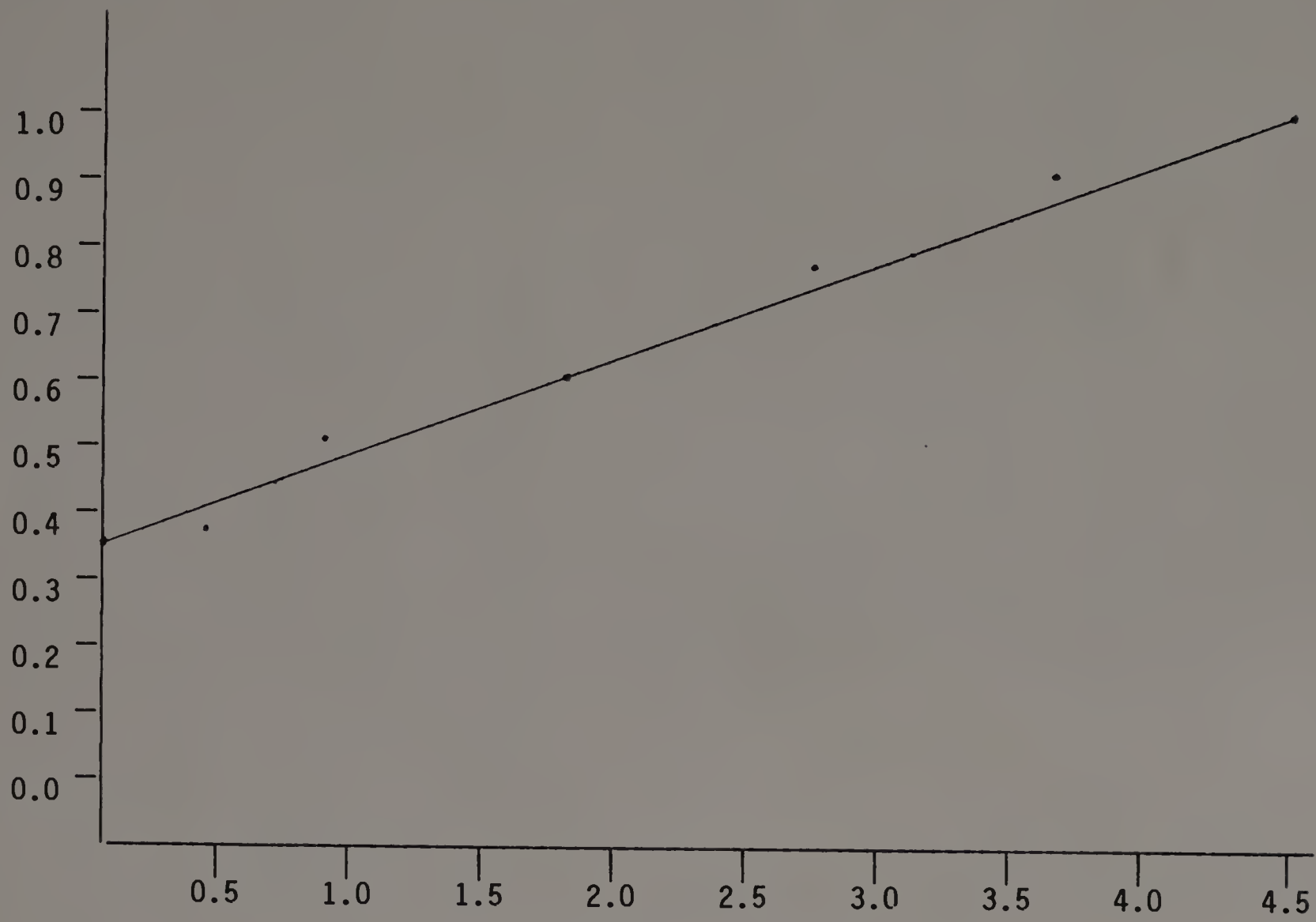
The standards are read against a distilled water blank, and the average of two readings is used in preparing the calibration curve.

No.	CH_2O ml	H_2O ml	$\bar{X}$ of 2 Absorb.	µg/2.5/ml CH_2O	µg/ml CH_2O	(µg/ml = µg in 2.5 ml divided by 2.5)
1	0.000	2.500	0.355	0.000	0.000	
2	0.025	2.475	0.379	0.450	0.180	
3	0.050	2.450	0.514	0.901	0.360	
4	0.100	2.400	0.620	1.801	0.720	
5	0.150	2.350	0.783	2.702	1.081	
6	0.200	2.300	0.921	3.602	1.441	
7	0.250	2.250	1.018	4.503	1.801	
8	0.300	2.200	1.117	5.403	2.161	

Least squares line:

X axis	Slope	Intercept	Correlation
µg in 2.5 ml	0.1470	0.35756	0.9951
µg/ml	0.3675	0.35760	0.9951

Table 4. Data for Calibration Curve Using Pararosaniline.



Graph 2. Calibration Curve.

APPENDIX D

Equations for Calculating Formaldehyde Concentrations in Air

When a Formaldehyde sample is developed, there are two absorbance values for each sample, one from each impinger. These two values are used in the equation below, to calculate the total μgrams of Formaldehyde. The total μgrams is later used to calculate the PPM of Formaldehyde. The sample volume is 20 ml, the aliquot is 2.5 ml.

$$\text{total } \mu g = \mu g \text{ A } \frac{\text{sample vol A}}{\text{aliquot A}} + \mu g \text{ B } \frac{\text{sample vol B}}{\text{aliquot B}}$$

It is also necessary to calculate the volume of air from which the Formaldehyde was removed. For this, the volume sampled (60 L) and the temperature in degrees Kelvin (^{o}C + 273) are used in the equation below.

$$V_{corrected} = V_{sampled} \times \frac{298}{T}$$

When the total μgrams and corrected volume are known, they are used in the equation below, to calculate the PPM concentration of Formaldehyde.

$$PPM = \frac{\text{total } \mu g \times 24.47}{V_{corrected} \times 30.03}$$

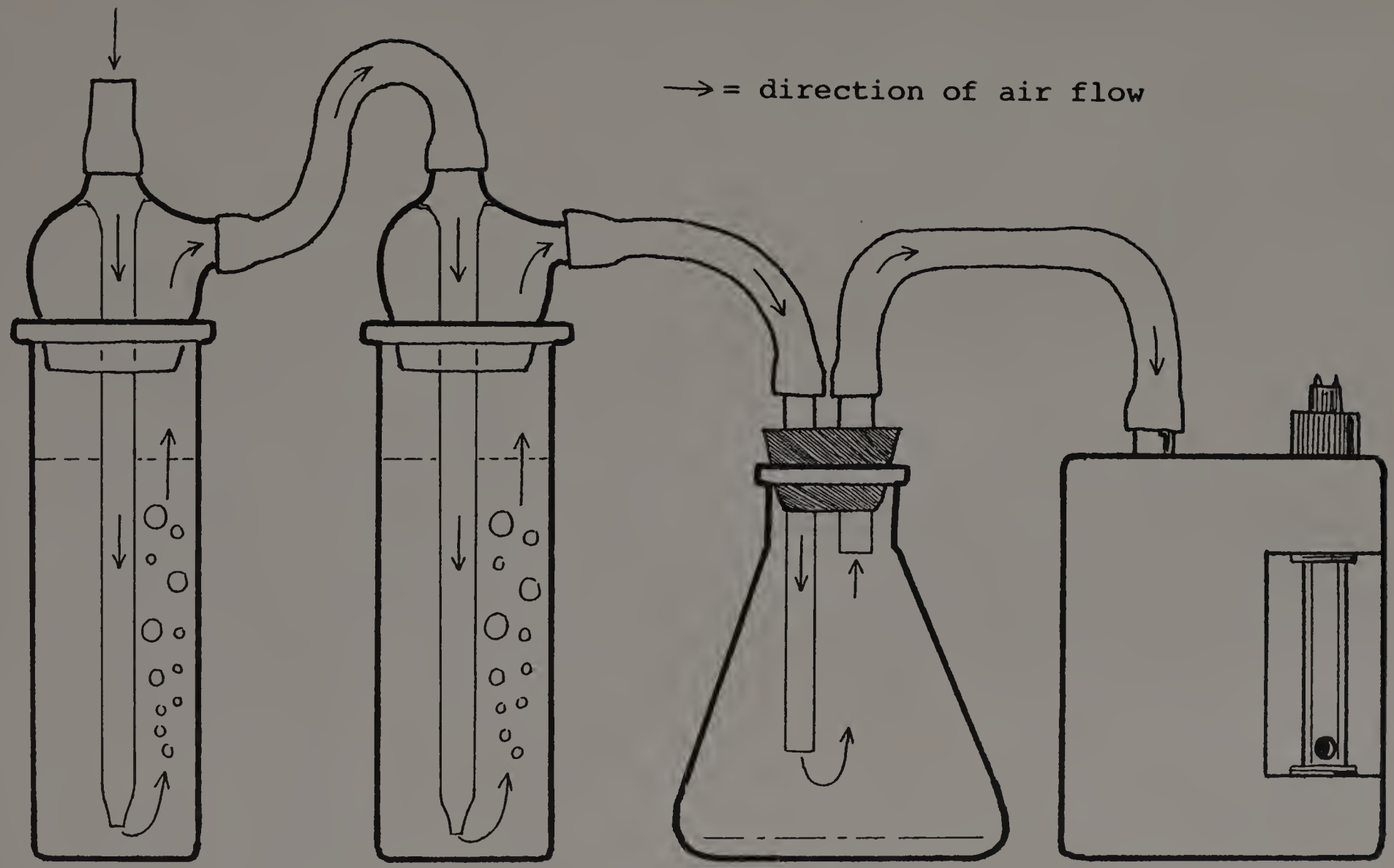


Illustration 1: Sampling Train Schematic.