American Industrial Hygiene Association Journal

ISSN: 0002-8894 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/aiha20

Air sampling and analysis of trimellitic anhydride

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To cite this article: JOHN PALASSIS , JUDD C. POSNER , EDWARD SLICK & KAREN SCHULTE (1981) Air sampling and analysis of trimellitic anhydride, American Industrial Hygiene Association Journal, 42:11, 785-789, DOI: 10.1080/15298668191420701

To link to this article: https://doi.org/10.1080/15298668191420701

Trimellitic anhydride (TMA) is collected from air on a DM-800 (PVC-copolymer) membrane filter. The filter is extracted with methanol and the volume of the extract is reduced by evaporation; BF_3/methanol is then added to the extract to form the TMA trimethyl ester. The BF_3 adduct is precipitated with a combination of reagents and the supernatant solution is injected into a gas chromatograph equipped with an FID. The unknown concentration of samples is determined from a calibration curve. The range of the method is 19 to 96 μg/sample with a pooled relative standard deviation of 8%. The recovery of TMA from DM-800 filters was quantitative. This new method uses a one-step derivatization procedure and has a detection limit of 2 μg; the ester derivative is stable for at least two days and has a retention time of less than 8 minutes. This method may also be applicable to other organic anhydrides and carboxylic acids.

Air sampling and analysis of trimellitic anhydride

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introduction

In 1978 the National Institute for Occupational Safety and Health (NIOSH) issued a Current Intelligence Bulletin(1) alerting the industry that "trimellitic anhydride (TMA) be handled as an extremely toxic agent in the workplace". Exposure to this compound may result in noncardiac pulmonary edema, immunological sensitization and irritation of the pulmonary tract, eyes, nose and skin.(2) Some distinct symptoms are rhinitis, asthma and "TMA-flu" as termed by the workers. This "flu" is usually accompanied by malaise, cough, hard breathing, chills, fever, muscle and joint aches.(1) The 1980 Threshold Limit Values (TLV) of the ACGIH suggested a 0.04 mg/M^3 limit. Currently, there is no OSHA exposure standard or NIOSH recommended standard for TMA. The Amoco Chemicals Corporation, the only domestic producer of TMA, suggested a limit of 0.05 mg/M^3 or less for susceptible individuals.

NIOSH estimated(1) that 20 000 American workers are currently at risk of exposure to TMA in its various applications. TMA is used as a curing agent for epoxy and other resins, in vinyl plasticizers, paints and coatings, polymers, polyesters, agricultural chemicals, dyes and pigments, pharmaceuticals, surface active agents, modifiers, intermediates and specialty chemicals.

In the past two years, numerous requests have been received in this NIOSH laboratory for technical assistance to provide analytical methods for TMA and other organic anhydrides. A literature search for the analysis of TMA did not reveal any specific published analytical method for TMA. Usually, organic anhydrides are hydrolyzed, esterified and analyzed by HPLC or GLC.(3) Another method calls for direct analysis of HPLC after hydrolysis.(4) Earlier research in NIOSH resulted in an analytical method for TMA using a published esterification procedure;(5) because that method did not meet certain qualification criteria, it was not included in the NIOSH manual of analytical methods. The purpose of this study, therefore, was to develop a simple, rapid, quantitative method for TMA. Such a method would involve the direct conversion of TMA to trimethyl trimellitate, which could be quantitated by gas chromatographic techniques.

The "Air Sampling" and "Experimental" procedures described in this paper are final recommendations which are based on this research.

air sampling

Personal exposures to both total and respirable particulates of airborne TMA can be determined. The total particulates are collected on 37-mm diameter, 0.8 μm pore size PVC-copolymer membrane filter (Gelman DM-800) contained in a three-piece, closed-faced cassette. The respirable particulate fraction (<10 μm aerodynamic equivalent diameter) can be collected on the same type of filter contained in a two-piece cassette mounted on a 10-mm cyclonic separator. Each filter is supported by a cellulose backup pad. The one-and-two stage samplers are attached to the worker's shift lapel at the breathing zone; air is pulled through the sampler by means of a personal sampling pump operating at 1.7 L/min.

experimental

apparatus

The analysis of TMA as trimethyl trimellitate was performed with a Perkin-Elmer Model 3920 gas chromatograph equipped with a flame ionization detector, glass-lined injection port and linear temperature programmer. The chromatograph was connected through an A/D converter to a Hewlett-Packard Model 3354 GC-computer system which calculated peak areas and retention times. The chromatograms were plotted with a 1-mV full scale strip-chart recorder.

Mention of company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

TABLE I
Statistical Analysis of TMA Calibration Curve Data

μg/Filter	Number of Samples	Mean of Peak-Area Units	Standard Deviation	RSD
19.2	6	35 026	1 188	0.032
48	7	111 256	7 997	0.072
96	7	207 557	21 232	0.102

Pooled RSD = 0.076

TABLE II
Statistical Analysis of TMA Calibration Curve Data

μg/Filter	Mean Peak-Area Units	Calculated Peak-Area Units	95% Confidence Limits	% Deviation from Line
19.2	35 026	35 106	± 85	0.23
48	111 256	105 490	±2792	-5.2
96	207 557	222 798	±7588	7.3

Slope = 2444 ± 100 at 95% Confidence Limits
Y-Intercept = -11818 ± 2004 at 95% Confidence Limits

The analytical column consisted of 1/8 in. stainless steel tubing (274-cm-long x 2-mm-I.D.) packed with 60/80 mesh Tenax-GC porous polymer material obtained from Applied Science Labs., Inc., State College, PA. The carrier gas was dried and purified with a molecular sieve and charcoal cartridges placed serially in the carrier gas line. High temperature GC injection septa were used. An ultrasonic bath was used to facilitate filter extraction. Glass test tubes (13 x 100 mm) with teflon-lined screw caps were used as reaction vessels for the esterification procedure. An air evaporator/concentrator manifold was utilized to reduce the filter-extract volume in the test tubes.

reagents

- Methanol, reagent grade, Burdick & Jackson Labs. Inc., Muskegon, MI 49442
- Boron trifluoride/methanol mixture 14% w/v Supelco Inc., Bellefonte, PA 16823
- n-Pentane, reagent grade, Burdick & Jackson
- Pyridine, reagent grade, Burdick & Jackson
- Trimellitic anhydride (1,2,4-Benzenetricarboxylic anhydride), Aldrich Chemical Company, Inc., Milwaukee, WI 53233
- Diethyl ether, reagent grade, Burdick & Jackson
- Helium, compressed gas, from local supplier
- Laboratory compressed air and hydrogen (electrolytically generated)
- Pyridine mixture, a 7:3 pyridine/pentane v/v mixture was prepared in a screw-capped tube
- TMA stock solution, 0.01 M, prepared by dissolving 0.4803 g trimellitic anhydride in 250 mL methanol in a volumetric flask — equivalent to 1.92 μg/μL

preparation of standards

Using the 0.01 M TMA stock solution, six calibration standards per level of concentration were prepared by pipetting 10, 25 and 50 μL into test tubes; this was equivalent to 19.2, 48 and 96 μg of TMA, respectively, at each level. The cap was screwed tightly on each tube after the addition of TMA. Each sample was derivatized in the test tube as follows:

derivatization

A 125 μL BF_3/methanol aliquot was added to each sample in the tube. The tube was capped tightly and was placed in a water bath (97 °C) for 20 minutes; then was removed and allowed to cool to room temperature. The following solvents were added to the tube: 50 μL diethyl ether, 50 μL pentane, and 50 μL of the pyridine mixture. The tube was capped between solvent additions to prevent solvent evaporation and was shaken gently. With the addition of the pyridine mixture, a white precipitate formed which is the complex $BF_3 \cdot$ pyridine. Two minutes later, the supernatant sample was ready for GC analysis. No centrifuging was necessary.

filter treatment-extraction

A field or a spiked filter sample was placed in a 50-mL beaker with 3 mL methanol. The beaker was covered with a watch glass and was placed on a hotplate (65 °C) for one minute. The beaker was then removed and, still covered to prevent water contamination, was placed in the ultrasonic bath for one minute.

The bottom of the watch glass was rinsed with 1 mL methanol which was collected into the beaker. The filter was lifted with tweezers above the methanol level and was rinsed slowly on both sides with two 3-mL aliquots of methanol while collecting the methanol rinsings in the same beaker. The filter was rolled and squeezed with the tweezers against the inside wall of the beaker to remove any methanol retained by the filter; then the filter was discarded.

The beaker containing the methanol rinsings was placed on the hotplate (55 °C), and the methanol volume was reduced by evaporation to less than 5 mL. The reduced methanol volume was transferred to a clean test tube. The beaker was rinsed two times with methanol, and the rinsings

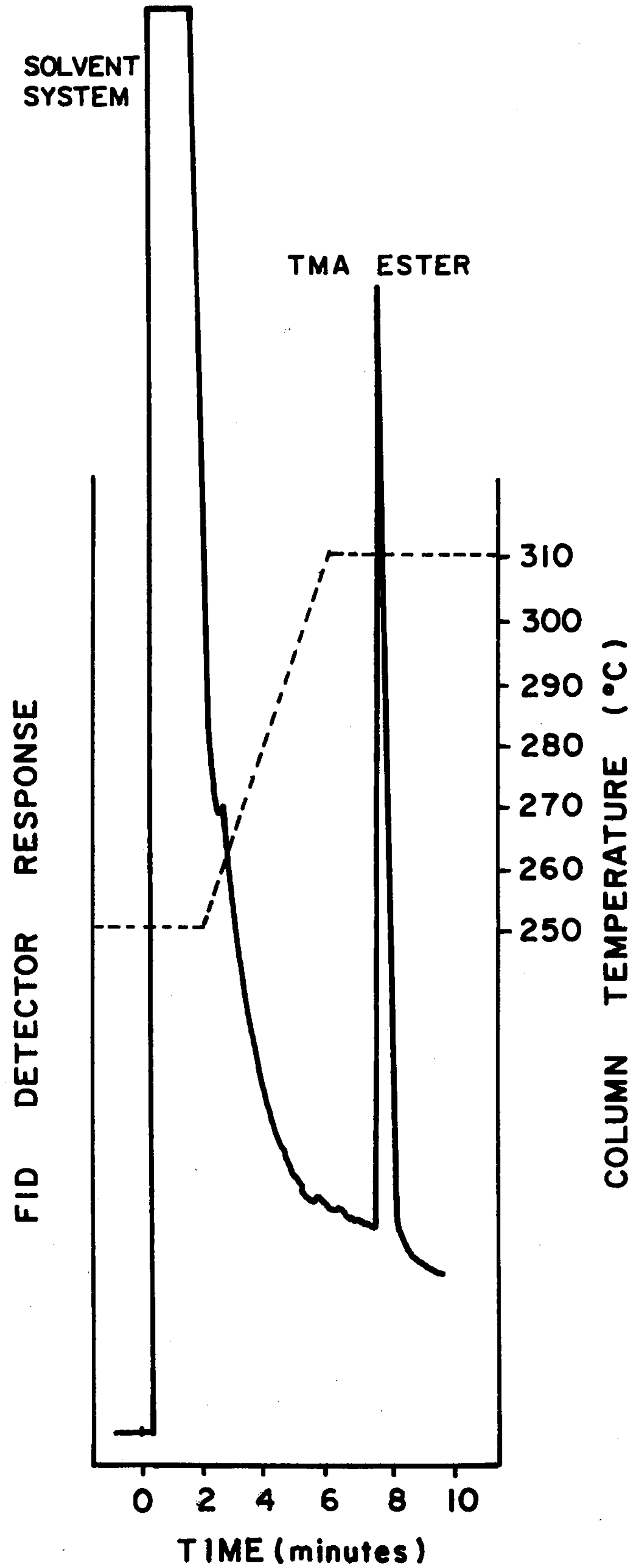

Figure 1 — Gas chromatographic separation of a 96- μg TMA ester sample, using a 274-cm (9 ft.), 2 mm-I.D. column packed with 60/80 mesh Tenax-GC, at 32 x 10 attenuation.

were collected in the test tube. The methanol in the test tube was evaporated to near dryness — about 10 μL — by blowing warm air over the methanol surface with the use of the evaporator manifold. For comparison, 10 μL of methanol were added to an empty test tube to indicate the volume to which the samples should be reduced. The sample was then ready for derivatization.

GC-analysis

The chromatographic conditions for the analysis were as follows:

Column temperature program: isothermal at 250 °C for two minutes, then 16°/minute to 310 °C and held at 310 °C for 4 minutes
Injection temperature: 315 °C
Detector temperature: 325 °C
Helium flowrate: 35 mL/min
Hydrogen flowrate: 53 mL/min
Air flowrate: 550 mL/min
Detector, attenuation: Flame Ionization, 16 x 10 and 32 x 10
Injection Volume: 5 μL
Retention Time: 7.5 minutes.

calibration curve

Because the total volume in each tube was different after the derivatization of the standards, i.e. 285, 300 and 325 μL for 19.2-, 48-, and 96-μg level respectively, a correction for the peak areas was made. The factors of 1.053 and 1.14 were used to multiply the areas of the standards at the 48 and 96 μg levels, respectively. A plot of the corrected peak areas of the standards versus concentration of TMA was made. Statistical analysis of the data was performed to determine the means, standard deviations, and the linear regression as calculated by the least squares method. These values were used in the construction of a calibration curve.

filter recovery determination

Using the 0.01M TMA solution, six DM-800 filters were spiked at each of the 19.2-, 48-, and 96-μg levels using 10-, 25- and 50-μL volumes, respectively. When each filter was dry, it was extracted, derivatized and analyzed. The resulting peak areas were converted to micrograms from the equation of the calibration curve.

results and discussion

Usually, the analysis of an organic anhydride involves hydrolysis of the anhydride to the corresponding carboxylic acid, extraction of the acid into organic solvent, and esterification of the acid, using one of many published procedures.

However, the object of this study was to develop a simple one-step esterification procedure which would eliminate the hydrolysis and solvent extraction steps. A literature search revealed esterification procedures which used various reagents: tetramethyl ammonium hydroxide/butyl iodide,(5) diazomethane,(6) trimethyl silylation,(7) dimethoxypropane,(8) methanol/sodium methoxide,(9) methanol/sulfuric acid,(10) and boron trifluoride (BF_3)/-methanol.(11,12) The results of the search indicated that the BF_3/methanol reagent would be a good candidate for TMA and that it has been used in the past for the esterification of fatty acids.

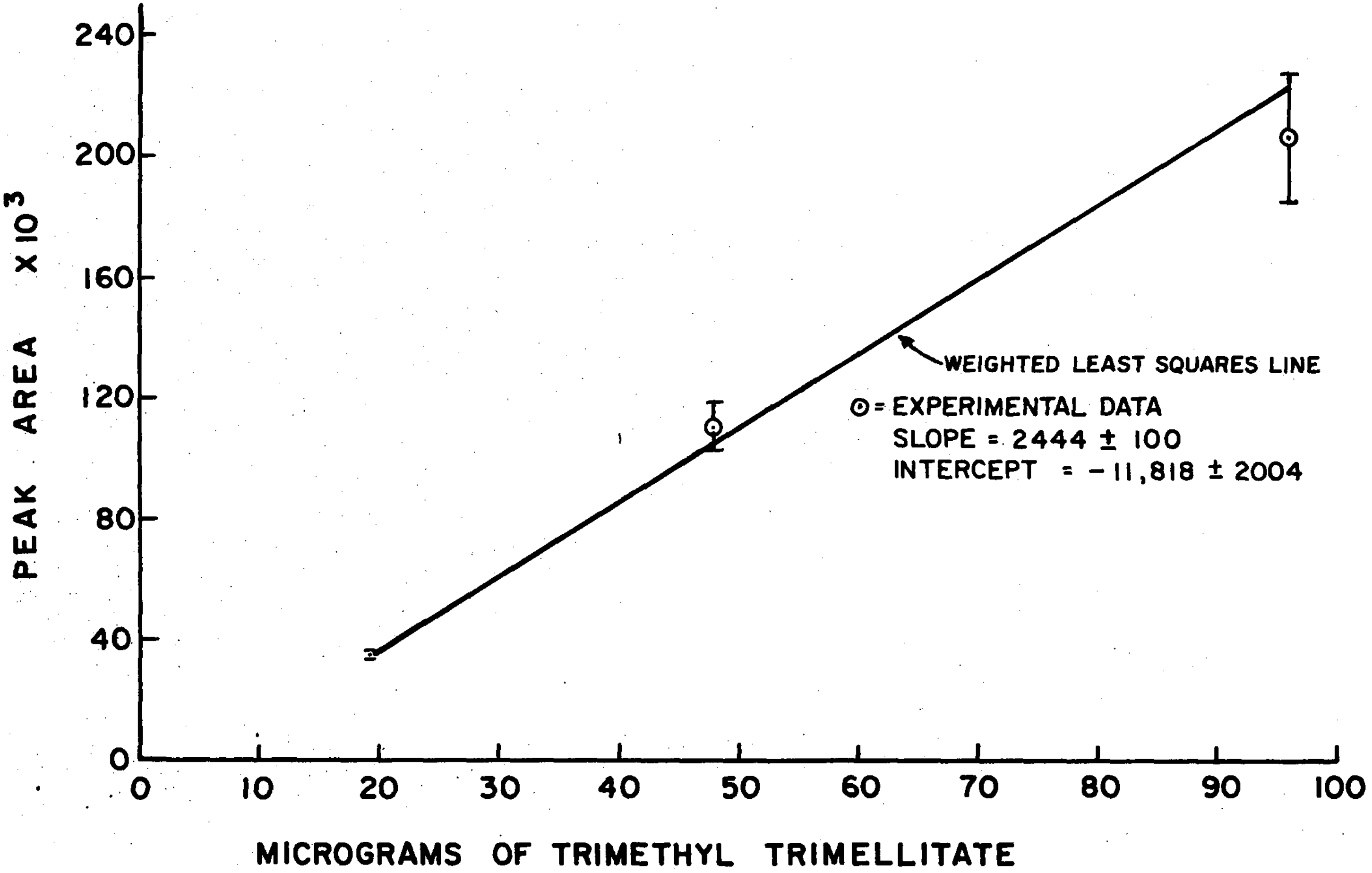

Figure 2 — Trimellitic anhydride calibration curve.

method development

A literature search conducted specifically for BF_3/ methanol disclosed a very simple and short procedure.(13) In this procedure, these researchers esterified small amounts (5-30 μg) of *organic acids* with 100 μL of BF_3/ methanol at 100 °C for 20 minutes; then they cooled the test tubes in an ice bath and added 40 μL of diethyl ether, 50 μL of pentane and 50 μL of a 1:1 pentane/ pyridine or triethylamine mixture. Phenanthrene was added as an internal standard, and the supernatant was analyzed by GC-FID using an OV-101 column. The improvement with this procedure is that the BF_3 adduct is precipitated with pyridine to form the stable BF_3 • pyridine complex,(14) which precipitates as a white solid; this way the need for multiple pentane extraction and evaporation is eliminated. The entire esterification, extraction and analysis is done in a single tube. This procedure was modified and tested with TMA,(15) and it is written in detail in the "Experimental" section of this paper.

Standards prepared using the Biondi procedure indicated that the ester was stable even after three days. After many injections were made on the SP-2100 column, the column started showing effects of decomposition, probably from the solvents that were injected with the ester. A 183-cm (6 ft.) 5% OV-17 glass column was packed. Standards were prepared and analyzed at different column programmed temperatures. Columnn bleeding was noticeable, the FID jet was plugging up, and peak size and separation were not good. It was decided to use Tenax-GC, a porous polymer material that contained no liquid phase. TMA standards prepared and analyzed two and three days later indicated no decomposition of the ester. The Tenax-GC column was used for the rest of the method development and indicated absolutely no signs of decomposition even at 310 °C temperature.

To be able to analyze up to 100-μg amounts of TMA, the Biondi procedure was changed as follows: the 100-μL aliquot of BF_3/ methanol was increased to 125 μL; the 50:50 pentane/ pyridine mixture was changed to 30:70 and the 40 μL aliquot of diethyl ether was raised to 50 μL. The cooling step using an ice bath was eliminated, and instead, the test tubes were cooled to room temperature. The injection volume was also changed from 1 μL to 5 μL to increase the sensitivity. Replicate TMA samples prepared and esterified for 10 and 20 minutes in a 97 °C water bath indicated upon gas chromatographic analysis that the ester peaks for the 20-min heating period were larger by a factor of two. Therefore, the 20-minute heating time, as recommended by Biondi, was chosen.

Twenty-one TMA standards prepared and esterified using the modified procedure indicated a pooled relative standard deviation (RSD) of 7.6% excluding one statistical outlier. A typical chromatographic separation of the TMA ester is shown in Figure 1. The weighted least squares, 1/(std. dev.)^2,

TABLE III
TMA Recovery Efficiency from DM-800 Filters

Number of Samples	Amount Spiked, μg	Averge Amount Recovered, in μg	Average Recovery	RSD
5	19.2	20.5±1.7	1.068±0.090	0.084
5	48	48.9±4.6	1.019±0.097	0.095
5	96	99.8±4.1	1.039±0.043	0.041

Average Recovery in All Levels = 1.042
Pooled RSD = 0.077

regression analysis was performed on the results of the calibration standards. Tables I and II show the results of the standard deviation and regression analysis. A graph of the calibration curve is depicted in Figure 2.

A recovery study involving 15 TMA spiked filters in the 19.2 to 96-μg range, indicated an average recovery of 104.2% and a pooled relative standard deviation of 7.7%. Table III shows the recovery results. It was noted that when a few spiked filter extracts were inadvertently evaporated to dryness, complete recoveries were still obtained. Therefore, based on this observation only, we suggest that it may be possible for one to completely dry the standards and field samples, thus, eliminating the correction factors.

This analytical method was also tested with maleic, succinic and phthalic anhydrides. Esterification tests involving each anhydride and mixtures of the anhydrides including TMA indicated that the maleic ester (dimethyl maleate) was eluting with the solvent peaks and could not be separated. The succinic ester (dimethyl succinate) peak was separated but the sensitivity for a 25-μg sample was not very good. The phthalic ester (dimethyl phthalate) was well separated from the TMA ester (trimethyl trimellitate) and had very good sensitivity. Future work will be concentrated in the separation of these four anhydrides and in the application of this method to additional organic anhydrides.

summary

A sampling and an analytical method for trimellitic anhydride (TMA) in air has been described. Briefly, TMA is collected from air with DM-800 (PVC-copolymer) filters. A filter is extracted with methanol and the methanol volume is reduced by evaporation. TMA in the filter extract is esterified in a single step using BF_3/methanol. In this procedure, there is no need for hydrolysis or multiple solvent extractions. All work is performed in a single test tube. TMA ester samples are stable for at least two days. The gas chromatographic analysis of the ester is accomplished in eight minutes utilizing a Tenax-GC column. Calibration curve standards in the range of 19.2 to 96 μg TMA indicated a linear correlation coefficient of 0.997 and a pooled analytical precision of 7.6%. Recovery studies of TMA from DM-800 filters indicated that TMA can be extracted with a 104.2% efficiency and 7.7% precision. This method may also be used for the analysis of other organic anhydrides.

acknowledgement

The authors gratefully acknowledge Mr. John Holtz for his valuable consultation and Mrs. Helen Fley for typing the manuscript.

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