

43,039

BFG TECHNICAL DOCUMENT
STAFF TECHNICAL SERVICES REPORT NO. 402
B. F. Goodrich Chemical Company
A DIVISION OF THE B. F. GOODRICH COMPANY
DEVELOPMENT CENTER

COMBUSTION TOXICOLOGICAL TESTING
PART 5:
EVALUATION OF A SERIES OF SYNTHETIC AND NATURAL PRODUCTS
BASED ON INCAPACITATION RESPONSE
AND ANALYTICAL COMBUSTION GAS DATA

*Not correct due
to DOC length*

by
G. F. Smith
W. C. Bachtel (Corporate Toxicology)

Date Completed: July 13, 1977
Department No.: 5026

Date Issued: August 10, 1977
Project No.: 2352

DISTRIBUTION

Akron

W. N. Johnson
*R. W. Strassburg
J. N. Powell, Jr.

ALTC

A. L. Schuler
L. B. Crider
R. R. Bloor
*J. A. TePas - C. W. Kothelmer
*R. M. Kreeger
*L. P. Arnold - E. J. Lison
R. J. Meyer - (3)
C. E. Fleming
H. M. O'Hara
J. E. Smith
G. A. Smith - C. E. Tolmanek
R. A. Smith

INT. SEC. - (2)
*R. J. Smith - R. N. Stein
*D. E. Wright - W. N. Sherwood

Cleveland

R. D. Scott - R. A. Krueger
B. M. G. Zwicker - M. E. Roba
P. J. Donat - J. C. Sealy - E. J. Schm
*E. W. Harrington - A. W. Clements - G. F. Krmar
F. E. Krause
W. E. Becker
E. L. Kent
K. Greene - H. R. Rex
*G. B. Osborne
*B. Ramsey
C. L. Blackfan
A. S. Ambrose
H. Schneiderer
*J. P. Malone
R. D. Savage
N. D. Friedberg

Cleveland

G. Talley
J. D. Tansilli
P. A. Raquet
R. B. Downey
C. R. Carter
J. P. Morrill
D. P. Knechtges
J. A. Stahl
R. C. Wilging

Brecksville

*R. J. Fawcett
*G. E. Thompson
C. H. Lufter
*H. Tucker - A. R. Siebert - J. A. Glass
R. K. Schlatter
D. E. Ley
E. D. Dickens
A. W. McRae
W. J. Kroenke

* Summary Copy.

43020

22614001

BFG21956

ABSTRACT

The NBS is playing a key role in the development of a first generation bioassay combustion-inhalation testing protocol for the acceptance of materials. A protocol will be ready in September, 1977. In January, 1977 we reviewed the results of our bioassay testing program with M. Birky of the NBS. As a result of the meeting, M. Birky asked us to quantitatively evaluate a series of materials. Therefore, we have tested Geon 8750 (rigid PVC), polychloroprene, Geon 8750 with zinc ferrocyanide, Estane 58360 and red oak wood by incapacitation bioassay testing. I will summarize the results of this work in this report. Based on the mass of material which induces 50% incapacitation, the materials are ranked as follows (best performing material listed first): Geon 8750 > Estane 58360 > polychloroprene > wood > Geon 8750 + ZPC > polychloroprene + ZPC. In the case of Geon 8750, polychloroprene and red oak wood, carbon monoxide has been found to play the dominant role in inducing the incapacitation responses. In the case of Geon 8750 + ZPC and polychloroprene + ZPC, hydrogen cyanide appears to play the most important role in inducing incapacitation. In the case of Estane 58360, the combination of carbon monoxide and hydrogen cyanide may be the two most important components in inducing incapacitation.

22614002

BFG21957

Table of Contents

	<u>PAGE</u>
I. Objectives.	1
II. Conclusions	1
III. Introduction.	2
IV. Discussion.	3
1.) Apparatus - Procedure	3
2.) Developing Dose-Response Curves	5
3.) Comparison of Materials	10
4.) Analytical Data	13
5.) Relationship of Dose of Specific Components of Combustion Products to Mortality Hazard	16
6.) Relationship of Dose of Specific Components of Combustion Products to Incapacitation Hazard.	36
V. Future Plans.	39
VI. References.	40

22614003

BFG21958

List of Tables

		<u>PAGE</u>
TABLE I	Biological Response to the Products of Combustion.	6
TABLE II	Mass of Material Which Induces a 50% Response for Various Bioresponses.	9
TABLE III	Time to Incapacitation Associated With the Mass of Material Which Induces 50% Incapacitation.	11
TABLE IV	Hazard Index Values Calculated From Data in Table II and Table III.	12
TABLE V	Ranking of Materials Based on Mass Which Induces 50% Response for Various Bioresponses	14
TABLE VI	Mass of Material Which Induces a 50% Response for Various Bioresponses.	14
TABLE VII	Analytical and Biological Dose Data	17
TABLE VIII	Dose for 50% Bioresponse.	34
TABLE IX	% CO-Hb at 50% Incapacitation	39

List of Figures

FIGURE 1	Dose Response Curve for Geon 8750	8
FIGURE 2	Relationship of % CO-Hb to Atmospheric CO	37

22614004

BFG21959

I. Objectives

The objectives of the current round of bioassay testing are:

- 1.) To evaluate a series of polymeric and natural materials on the basis of the incapacitation and mortality bio-response.
- 2.) To couple analytical gas measurements to combustion bioassay testing.
- 3.) Assess the role of specific toxicants in observed bio-responses.

II. Conclusions

- 1.) The ranking of the performance of a series of materials depends on the type of bioresponse used in the evaluation.
- 2.) Based on the mass of material which induces 50% incapacitation, the materials are ranked as follows (best performing material listed first): Geon 8750 > Estane 58360 > polychloroprene > red oak > Geon 8750 with IFC > polychloroprene with IFC.
- 3.) Based on the mass of material which induces 50% mortality at the end of two weeks, the materials are ranked as follows (best performing material listed first): red oak > Estane 58360 > polychloroprene > Geon 8750 > polychloroprene with IFC > Geon 8750 with IFC.
- 4.) Incapacitation for Geon 8750 appears to be due to CO. Long term mortality for Geon 8750 appears to be due to HCl.
- 5.) Even though polychloroprene also generates HCl upon combustion, both mortality and incapacitation for polychloroprene appear to be mainly due to CO. Since on a gram for gram basis PVC generates only 2-3 times more HCl than does polychloroprene, a moderate reduction of HCl generation from PVC might substantially improve the combustion toxicological performance.
- 6.) Both mortality and incapacitation for red oak appear to be due to CO.
- 7.) Both mortality and incapacitation for Geon 8750 with IFC and polychloroprene with IFC appear to be due to HCN.
- 8.) Estane 58360 is fire retarded with polychloroprene. This appears to cause relatively high levels of HCN evolution upon combustion. Both mortality and incapacitation appear to be due to the combination of CO and HCN.

22614005

BFG21960

II. Conclusions - Continued

2. For all of the materials investigated so far, we have seen no evidence that HCl plays even a minor role in inducing incapacitation.

III. Introduction

We have recently completed a fifth round of bioassay testing of the combustion products of a series of natural and synthetic materials. This report describes the objectives of this work, the experiments, their results and the conclusions.

A few years ago several model building codes began to include rules for the regulation of materials based on combustion product toxicity. In most cases these restrictions did not go into effect because no test procedure was available for the evaluation of materials. Since the needed bioassay testing protocol did not exist, the National Bureau of Standards offered to develop a first generation test procedure before September, 1977. Merit Birky was given the responsibility of developing the protocol.

Part of the research for the development of the NBS bioassay testing protocol has been done by Professor Yves Alarie at the University of Pittsburgh. Using a sensory irritation model, Alarie has investigated the combustion products from a wide range of materials. In order to interpret the results of the experiments with combustion products, Alarie has also studied the sensory irritation response to a number of pure gases. Alarie has found, using the sensory irritation model, that HCl is one of the most irritating gases. Because of this, the combustion products of PVC are very irritating in Alarie's sensory irritation model. On the basis of Alarie's sensory irritation procedure, the performance of PVC would be judged very inferior to the performance of most other materials in common usage. Until very recently, Alarie's work has been the only research available to Birky in support of the development of the needed bioassay testing protocol. Because of this, Birky has been strongly influenced by Alarie's work and this has been reflected in preliminary versions of the protocol which Birky will release in September.

Although Birky has been strongly influenced by Alarie, this does not mean that Birky has placed any restriction on which groups he has given input to him. Therefore, last January we visited Alarie to review with him some aspects of our bioassay testing work. We believed that by revealing some of the results of our bioassay testing work that the results of Alarie's research would be brought into better perspective in Birky's view. Specifically, we wanted to familiarize Birky with our findings on the sensitivity of the ranking of a series of materials as a function of the details of the test procedure. In

22614006

BFG21961

III. Introduction - Continued

addition, our own work has shown that carbon monoxide is the most important component of the combustion products of PVC in inducing incapacitation in the rotating cage experiment. Finally, we included results from our work on PVC with Zinc Ferro Cyanide to demonstrate that the protocol which we have used will detect a "super toxic" material. We believed that the results of our experiences with this material would be of great interest and value to Birky because he has emphasized that an acceptable bioassay testing protocol must be sensitive to "super toxic" materials.

Birky was very interested in the correlation which we have found of incapacitation in the rotating cage with carbon monoxide, because he did not accept the implications of the result. Basically Birky believes that HCl is very important in inducing incapacitation or loss of useful function in a fire victim. Since our work has shown that carbon monoxide and not HCl is important in inducing test animal incapacitation in the rotating cage experiment, Birky views this bioresponse as inadequate. This reflects the influence which Alarie has had on Birky.

After hearing our presentation, Birky asked us to do some new experiments and to supply him with samples of PVC/ZPC, which would be tested by Alarie. Birky wanted us to test wood, PVC and urethane so that the relative performance could be determined. Since Alarie would be testing PVC/ZPC by sensory irritation, we believed it was essential to test this material by incapacitation in the rotating cage experiment for comparison. To demonstrate that the effect of ZPC is not exclusive to PVC but that it would operate in any acid gas generating polymer, polychloroprene and polychloroprene/ZPC were also tested. Birky's request to us to do these experiments indicated a genuine receptiveness to further input. Since an input to Birky's work is vital at this point, the experiments have been done. This report gives the results of the series of experiments done in response to Birky's request.

IV. Discussion

1.) Equipment - Procedure

The equipment, experimental conditions and procedure have been standardized since the third round of testing⁽³⁾. Three changes have been made: 1.) static animals have been changed; 2.) the heating unit has been rebuilt based on nichrome ribbon heating elements; and 3.) the squirrel cage air recirculation pump has been replaced with a peristaltic pump of the same air flow rate capacity.

43039

22614007

BFG21962

1.1 Apparatus - Procedure - (Continued)

The physical system consists of a 40 liter inhalation chamber and a 20 liter combustion chamber interconnected by an air circulation system. The experimental conditions are the same as previously used*. The partial recirculation of the atmosphere which is used in this procedure permits the fulfillment of three critical criteria: 1.) the animals are exposed to air no hotter than 32°C; 2.) test animal anoxia is prevented since the % O₂ does not go below 18%; and 3.) a pseudo-stable atmosphere of combustion products is generated. The duration of the exposure is fifteen minutes for each experiment. Since all exposures are of the same duration, meaningful comparisons of post exposure mortality data can be made. The fifteen minute time period of the experiment is important for another reason. During combustion, PVC releases HCl early, further heating results in the evolution of CO. It is important that the test animals be exposed to the products of all phases of the decomposition process. The fifteen minute exposure allows nearly complete combustion to occur.

The inhalation chamber holds six rotating cages on a common drive shaft. One animal is placed in each cage and the cages are rotated at six RPM by an electric motor. The bioresponses which were determined with their definitions are:

- 1.) Incapacitation - At the end of the 15 minute exposure, the number of animals incapacitated out of six was determined. The result is reported as a percent.
- 2.) Time to Incapacitation - The time at which incapacitation occurred was determined for each animal which became incapacitated. The time interval during which incapacitation occurred is reported.
- 3.) Mortality at End of Exposure - At the end of the exposure, the number of animals dead out of the original six was determined. The result is reported as a percent.
- 4.) Long Term Mortality - If at the end of the exposure at least two animals were not dead, enough were sacrificed so that two were available for % CO-Hb determination. The surviving animals were returned to holding cages for observation. Food and water were available. At the end of two weeks, the cumulative number of animals dead out of the original six was determined. Animals sacrificed for % CO-Hb were not included in the statistics. The result is expressed as a percent.

* 2.5 watts/cm², smoldering combustion, 8 liters per minute of 50% relative humidity fresh air enters the combustion chamber, 16 liters per minute transfers from the combustion to the inhalation chamber, 8 liters per minute returns from the inhalation to the combustion chamber, 8 liters per minute is exhausted.

22614008

BFG21963

1.) Apparatus - Procedure - Continued:

Two expressions of the mass of material used in each experiment are given: 1.) the actual weight of the sample used, and 2.) a concentration parameter -- the weight of sample consumed divided by the volume of atmosphere in the experiment. This parameter facilitates intercomparison of results from various types of apparatus by accounting for differences of volume. The volume of our experiment is defined as 180 liters $[40 + 20 + 15 \text{ minutes} \times (8 \text{ liters per minute flow rate})]$.

The results are shown in Table I.

2.) Developing Dose-Response Curves

The evaluation of the performance of a material is based on the mass of material which will induce 50% response. For a given material, as the mass increases, the percent of the exposed animals which will respond increases. A plot of the percent response versus the mass of material exposed is defined as a dose response curve. The mass of material which will induce 50% response can be obtained directly from such a curve. The numerical value of the mass of material which induces 50% response depends on: 1.) the specific bioresponse in question. intoxication, mortality, or other, and 2.) the properties of the material. . . . low or high toxic gas release. In a comparison of two or more materials, the material with the largest value of mass which induces 50% response is judged to be better or safer.

The intoxication bioresponse has been seen in our previous work to be a very sensitive response⁽³⁾. That is, a small increase of mass of material exposed will result in a change from 0% response to 100% animals responding. Ideally, dose-response curves are defined by non-zero non-100 percent responses. Experimentally this is a problem because several experiments may be required to locate it on a range of sample weights which will give the desired type of result. In order to have the best data possible to show to the National Bureau of Standards, for this round of testing we have taken special efforts to define the dose-response curves with non-zero, non-100 percent response data. This is illustrated in Figure I which shows the dose-response curve defined by the data from Table I for Geon 8750.

Table I shows the results for the mass of material which

22614009

BFG21964