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PROPOSED STUDIES UPON EXHAUST GASES

Since the effects of acute episodes of exposure to engine exhaust gases (1)upon the aged, the chronically ill, those with degenerative or cardio-vascular diseases,(2)upon the well being of people in later years and (3)upon the life span of human beings, have not been studied, it is desirable to establish levels of tolerance to these contaminants.

One phase of these studies should include toxicologic and physiologic studies of exhaust gases from both reciprocating and diesel engines.

Since exposure to this type of general atmospheric pollutant may continue for 18 to 24 hours per day as contrasted with 7 or 8 hours under conditions of industrial air pollution, it is wise to consider the relationship of tolerance of animals and men in terms of intermittent and continuous exposure to low concentrations of these exhaust fumes, in which clinical and functional tests may be applied.

Before prolonged exposure is investigated, certain short term experiments with animals could be conducted to ascertain unknown basic facts in relation to the combined effects of multiple pollutants at higher levels. This might serve as a practical guide in an attempt to eliminate (by catalytic oxidation or absorption) from the exhaust those substances

which are most potent physiologically.

A standard uniform gasoline should be employed in the engine in brief and prolonged studies. Selected saturated aliphatic hydrocarbons should be studied separately and in combination to ascertain whether the combustion products of two materials of the same type give a resultant toxicity that is equal to the sum of the two or more or less than this value. This might be considered from the standpoint of (1) 2 hydrocarbons each with an even number of carbon atoms, (2) 2 materials each with an odd number of carbon atoms and (3) one hydrocarbon with an even number of carbon atoms and the other containing an odd number of carbon atoms. The relationship of straight and branched chain hydrocarbons might be considered. The toxic effects of unsaturated and ring hydrocarbons could be considered.

The vapors of aldehydes, ketones and peroxides might be studied in a similar manner both as individual compounds and combinations of materials with the same functional group.

The combined effects of the vapor of 2 materials with different functional groups should be considered.

It should be determined whether the toxicity of the vapor of one or more of these compounds is enhanced or decreased in the presence of finely divided particulate matter (fumes, mists, smokes).

A similar pattern might be followed in the case of

diesel fuel, in which many of the materials of decomposition might be in common.

The selection of specific compounds would be dependent upon the composition of the actual exhaust gases as determined by practice and experimentation.

In all studies analysis of the air should be performed and selected tissues of animals should be studied pathologically. Mortality, growth curves, tissue weights, clinical and functional tests, as well as the fate of the materials in the body should be studied whenever applicable.

Such studies do not supplant but rather compliment sensory, carcinogenic and epidemiologic studies.

Such studies eventually lead to the establishment of a safe level of these pollutants and dispel certain fears of the unknown.

1. IDEAS ON THE ASSESSMENT OF THE CONTRIBUTION TO ILL HEALTH MADE BY THE PRODUCTS DERIVED FROM THE USE OF AUTOMOTIVE FUELS

F. F. H.

Statements have been made, particularly in the Los Angeles area, that the exhaust gases from automotive equipment may be in large part responsible for the irritant effects of the smogs in that area, and that they may have contributed materially to the mortality encountered in the episodes of smog in London. The automotive industry must be prepared to answer these charges with facts obtained by experimentation. It should learn the effects of its waste products, under normal meteorological conditions, quite apart from those that have given rise to smogs. It can do this only by an experimental study of the potential harmfulness of its products upon animals, just as of recent years certain groups in the chemical industry have been doing prior to the introduction of new chemicals which may affect the health of its workers, or as was done prior to and since the introduction of tetraethyl lead into gasoline.

Before describing the sort of program that is envisioned, it may be said that the attempts which have been made to explain the various factors which may have contributed to the morbidity or mortality associated with exposure for brief periods of a few days to smogs, as at Donora, London, or Los Angeles, have served only to confuse the issue of the responsibility of the automotive industry. They have all been complicated by other factors, such as the presence of other industrial pollutants or of the products of combustion of other fuels used for

heating. They have, however, served to demonstrate the presence of certain factors which must be taken into account in any study designed to assay the contribution of the automotive industry. These include (a) the fact that the exposure has been more or less continuous throughout the duration of the episode, so that values for threshold concentrations proposed by industrial hygienists on the basis of the exposure of normal animals for 7 hours per day, on 5 days per week, may not be applicable; (b) the human morbidity and mortality have occurred chiefly among the aged and among those affected by cardiac or respiratory diseases; (c) the possibility of synergistic action between the various pollutants appears to have been rendered likely; (d) certain photochemical reactions, at least in the Los Angeles area, are believed to have given rise to the presence of aldehyde, peroxide, and perhaps other intermediate compounds, whose transitory existence may contribute to toxicity; (e) the presence of liquid or solid particulate matter may have affected the results.

In beginning the program, animals should be exposed continuously to the exhaust gases suitably diluted with air from some selected fuel. The type of automotive equipment selected should be operated in the laboratory, and both it and the type of fuel should be varied from time to time as the results dictate. The first experiments should be performed at as great a concentration as seems possible in view of the determined CO concentration. In subsequent experiments the concentrations should be reduced stepwise until a safe concentration has been found. The exposure might well be continuous for about 20 hours per day, and the food and drink provided might well be allowed to become contaminated to

eliminate the objections to factor (z) in the preceding paragraph. The motor might be operated in a room separated and sound-proofed to prevent interference with the sleeping habits of the animals. Item (d) might be covered in some experiments by inserting an ultraviolet source in the duct for incoming air. In certain experiments, it might be necessary to remove CO catalytically, in order to be able to study the effects of less toxic components of the exhaust gases than would otherwise be possible.

Either the research laboratories of the automotive industry or The Kettering Laboratory might undertake a reasonably complete study of the chemical nature of the exhaust gases, fractionating them in classes of unburned hydrocarbons, and, in the case of the combustion products, into water-soluble products - acidic, basic, aldehydic or ketonic in nature - as well as the class of pyrolysis products soluble in organic solvents. The toxicity of each of these classes could be studied by some appropriate method of administration in order to get an approximation of the extent to which each may contribute to the problem. At some time a decision could be made as to the extent of the further work that may be advisable.

It might be profitable to study certain individual members of one or other of the various classes listed above, both separately and in conjunction with other members or the same of another class. In particular, the influence of particulate matter on the toxicity of specific associated materials might be measured to form as estimate of the importance of factors (c) and (e).

The methods being developed by our epidemiologic staff for the study of the influence of air pollution upon the health of persons with cardiac or respiratory disease in an industrial community might be adapted to the study of the contribution made by the products of the automotive industry, if a suitable non-industrial area with sufficient traffic flow could be located.

2. PROPOSED TOXICOLOGIC INVESTIGATION OF THE EFFLUENTS FROM MOTOR VEHICLES

J. F. T.

Since the effects of acute episodes of exposure to engine exhaust gases (1) upon the young, the aged and the chronically ill, and (2) upon the well being and the life span of human beings, have not been investigated, it is desirable to establish levels of tolerance to these contaminants. One phase of these investigations should include the extension of toxicologic information concerning the exhaust gases from both reciprocating and diesel engines.

Since exposure to this group of general atmospheric pollutants may continue for 18 to 24 hours per day as contrasted with 7 or 8 hours under conditions of industrial air pollution, it is wise to consider the relationship of tolerance of animals and men in terms of intermittent and continuous exposure to low concentrations of these exhaust fumes, in experiment in which clinical and functional tests may be applied.

Before prolonged exposure is investigated, certain short term experiments with animals could be conducted to ascertain unknown basic facts in relation to the combined effects of multiple pollutants at higher levels. This might serve as a practical guide in an attempt to eliminate (by catalytic oxidation or absorption) from the exhaust those substances which are most potent physiologically.

A standard uniform gasoline should be employed in the engine in brief and prolonged experiments. Selected saturated aliphatic hydrocarbons should be studied separately and in combination to ascertain whether the combustion products of two materials of the same type give a resultant

toxicity that is equal to the sum of the two or more or less than this value. This might be considered from the standpoint of (1) 2 hydrocarbons each with an even number of carbon atoms, (2) 2 materials each with an odd number of carbon atoms and (3) one hydrocarbon with an even number of carbon atoms and the other containing an odd number of carbon atoms. The relationship of straight and branched chain hydrocarbons might be considered. The toxic effects of unsaturated and ring hydrocarbons could be considered.

The vapors of aldehydes, ketones and peroxides might be studied in a similar manner both as individual compounds and combinations of materials with the same functional group.

The combined effects of the vapor of 2 materials with different functional groups should be considered.

It should be determined whether the toxicity of the vapor of one or more of these compounds is enhanced or decreased in the presence of finely divided particulate matter (fumes, mists, smokes).

A similar pattern might be followed in the case of diesel fuel.

The selection of specific compounds for investigation would be dependent upon the composition of the actual exhaust gases as determined by practice and experimentation. In investigating the effects of individual or combined materials, the composition of the air to which animals are exposed should be determined by analysis of the contents of the chamber, and selected tissues of the animals should be examined for pathological changes. Mortality, growth curves, tissue weights, clinical and functional abnormalities, as well as the metabolic fate of the materials

should be determined so far as these may seem to be fruitful of useful information.

Such investigations lead eventually to the establishment of criteria for safety or danger in relation to exposure to these pollutants, thereby tending to dispel the fear of the unknown.

3. APPROACHES TO THE QUESTION OF THE POTENTIAL INDUCTION OF CHRONIC DISEASE BY PROLONGED INHALATION OF THE PRODUCTS OF THE COMBUSTION OF HYDROCARBONS

A. W. H.

Public fears seem to guarantee the continued existence of this question until convincing data are assembled to prove that the situation is in hand. Hence, it seems evident that we should take an active part in investigating certain aspects of the problem which we are especially equipped to handle. Those phases of the work which can be carried out better in an industrial laboratory should be coordinated with our own work by suitable liaison and consultation.

The location and epidemiological study of occupational groups whose working environment places them in the above-average-risk category should be one of our essential efforts. Pertinent groups would include not only those exposed to the gasoline or diesel exhausts directly, but also special groups whose exposure to particular components of exhaust gases is abnormally high, e.g., coke oven operators exposed to polycyclic hydrocarbons.

Our chemical attack on the composition of these materials should be closely coordinated with the epidemiological and toxicological programs. The latter should deal primarily with the mixtures produced by burning fuel mixtures of known composition in an engine under controlled operating conditions. It will probably be desirable, if feasible, to separate the carbon monoxide and steam from the less volatile components and expose animals to the latter only. Having found proper conditions

for producing pertinent toxic effects in a reproducible manner from such mixtures and having produced a chemical picture of their composition, then modifications in operating conditions (engine or fuel) should be introduced to alter the composition in a known fashion. The effect of these changes on toxicity would then be determined. By such stepwise procedures and related testing of pure compounds, it should be possible to establish which components of engine exhausts are responsible for which toxic effects, at the same time developing some information on desired direction of change in engine operation to reduce the toxicity of the products of combustion.

The question of carcinogenic effects on the human respiratory tract, hematopoietic system, and central nervious system will require both the abovementioned epidemiological studies and the development of suitable experimental methods. Initial efforts are being taken in a program to learn more about the apparent relation between chronic irritation (e.g., heavy smoking) and the risk of bronchiogenic carcinoma. The question has been posed, and is being investigated, concerning the possible role of metaplasia of bronchial epithelium in increasing the susceptibility of this tissue to polycyclic aromatic hydrocarbons (normally present in smoking exhausts, particularly of diesel engines). If an adequate study of material from necropsies suggests or demonstrates a direct relation between the extent of metaplasia and susceptibility to bronchiogenic carcinoma, then we shall seek an experimental animal whose lung can be prepared for subsequent exposure to carcinogen by first inducing a certain amount of metaplasia.

The relation between benzene and leukemia should prove to be an

important toehold. Gerarde's short-term studies of the toxic effects of benzene on the blood-forming tissues of rats should be followed up by more porlonged experiments involving larger groups of animals. Catalytic reforming is becoming so important a supplier of aromatics for blending high octane gasolines to keep up with the horsepower race that we may well find the oxidation of benzene and its homologues to be one of our major sources of toxic intermediates in engine exhausts. Hence we should develop as an experimental method for inducing leukemia with benzene/one of our important steps in this project.

A notation from R. T. in our petroleum technology laboratory is attached hereto as a matter of interest.

3 (a). NOTE ON THE COMPOSITION OF ORGANIC MATERIALS IN LOS ANGELES DUST

R. T.

The tarry portion of three samples of Los Angeles dust had been extracted by benzene. We subjected the extracts to fractionation to determine the relative amounts of certain classes of organic compounds, as indicated in the attached table. The procedures employed included extraction with aqueous bases and acid, and chromatography of the materials remaining in the organic phase.

Accuracy - The accumulated experimental errors may have totaled as much as 2 mg. in the case of certain of the factions. Further, some overlapping of subdivisions was to be expected. Hence, none of the apparent differences in composition between the three samples is to be regarded as significant.

Summary - The tarry materials extracted by benzene from three samples of Los Angeles dust contain approximately 50 per cent of essentially neutral compounds, about 40 per cent of organic acids and related polar compounds, and a trace of organic bases. The nature of the samples received for analysis does not permit any estimate of the quantities of gasoline hydrocarbons or their volatile derivatives which may be present in Los Angeles dust.

COMPOSITION OF PORTION OF LOS ANGELES DUST EXTRACTABLE BY BENZENE
All Fractions as Percentages of Extract

Sample Number (Station Number)	Sample Size (grams)	Volatiles	Phenols	Organic Bases	Organic Acids and Highly Water Soluble Compounds				Neutral Compounds	Recovery[4]	Chromatographic Fractions of Neutral Compounds						
					Total[3]	Organic Acids[2]	Dibasic Acids, Alcohols, etc.[2]	More polar Organics[1,2,3]			Saturates	Alkyl benzenes etc.	2 and 3 ring aromatic hydrocarbons	Pyrene and other hydrocarbons	4 and 5 ring aromatic hydrocarbons (traces over 5)	Total Polynuclear Aromatic hydrocarbons[3]	Strongly held Compounds, mostly non-hydrocarbons
1 (4)	.537	10	6	.5	31	11	15	5	48	96	15	2	2-3	<1	2	5-6	20
1 (3)	.238	3	3	<1	42	13	11	18	47	96	21	3	2.6	.7	2.2	5.5	13
4 (3)	.089	7	3	3(?)		3	8		54	78	21	3	2	<1	3	5	21

1. This class may include organic bases which partition into aqueous $NaHCO_3$ rather than into benzene.
2. To a certain extent, these subdivisions overlap.
3. Weights calculated by difference rather than measured directly.
4. Summation of classes underlined.

4. SUGGESTED PROGRAMS FOR THE INVESTIGATION OF AIR POLLUTION WITH SPECIAL BUT NOT EXCLUSIVE REFERENCE TO MOTOR VEHICLES

J. C.

1. The nature of the air pollutants needs to be determined in a comprehensive manner. Any program of sampling which is used should supply information concerning the diurnal variations as well as the averages and ranges of the concentration of a number of specific pollutants.

2. Because of the wide publicity given the apparently unique findings of the Los Angeles basin, the program should compare the findings in that area with those which characterize certain other heavily industrialized cities.

3. In each city to be investigated, several sampling sites should be chosen; one of these, at least, should be situated in a heavily industrialized area, while others should be related to heavy motor traffic and to situations free of both industry and motor traffic.

4. Sampling programs should be operated on a year round, continuous basis, and tied in with meteorological observations such as temperature, rainfall, wind direction and velocity, height of inversion layer, and the amount of sunshine, etc.

5. Whenever possible, continuous recorders should be employed for the determination of contaminants. Equipment is available for the continuous recording of the concentrations of O_3, SO_2, CO and haze.

6. Some of the pollutants will need to be collected by intermittent sampling techniques for more specific identification and measurement.

7. The loading of the atmosphere by particulate matter and the nature of the latter should be determined from material collected at each station by means of a large volume sampler, operated for 24 hours. Analysis of these samples should include the determination of the total weight of particulate matter, total organic or benzol extractable material, acidic ions, such as sulfate, nitrate, chloride, fluoride and phosphate, and as many metallic constituents as possible. The latter should include lead, beryllium, arsenic, chromium, vanadium, and other potentially toxic metals.

Diurnal variation in the concentration of haze and certain metals can be determined from the analysis of material collected on paper tapes in automatic dust samplers, such as the A.I.S.I. smoke sampler.

8. The nature of the organic matter present in the particulate matter should be determined by appropriate methods. Such information would be useful to determine the contribution of automobile exhausts to air pollution. This part of the program should be tied in with a laboratory investigation of the products emitted by the automobile.

(In connection with items 7 and 8, it is of interest to note that our investigation of the particulate matter in Los Angeles from August through November of 1954 shows that, at times, the sulfate, nitrate and organics constitute more than 50% of the total particulate matter.)

9. The type of investigation indicated in 7 and 8 should be tied in with a program in which certain gaseous contaminants are also determined. The state of the sulfate, nitrate, or organic matter present as particulate matter may prove to be more annoying or damaging than the gaseous

precursors, such as SO_2, NO_2, and gaseous hydrocarbons, and the relationships between these materials should be established.

10. The program for the first year should be as comprehensive as is possible in only two cities, one of which should be Los Angeles. A special crew can be hired to man the station, or stations, in Los Angeles. Except for the information supplied by continuous recorders, all analyses should be made in a central laboratory by the same technical staff using approved standard methods.

11. Sampling and analytical methods should be reviewed periodically, and a research program for developing improved methods for collecting and analyzing polluted air should be a part of any program which is instituted.

12. Sites other than Los Angeles should be selected and changed if necessary following frequent review of the data being collected. Such reviews should also be used to decide the course of future investigations.

MEMORANDUM ON VARIOUS MEANS OF APPROACH TO THE INVESTIGATION OF ATMOSPHERIC POLLUTION AS IT RELATES TO THE EXHAUSTS AND OTHER EFFLUENTS FROM MOTOR VEHICLES

The present memorandum is not intended to give complete or detailed consideration to the problems of public health that arise out of this aspect of atmospheric pollution. Rather it is predicated on the fact that we in the Kettering Laboratory, among us, have a considerable background of knowledge and experience which we can tap when the time is ripe, and that the group to which this memo is directed also has much information at hand and a very considerable awareness of its own problems. Our purpose is to indicate certain rather broad pathways for investigation and to suggest which of these might first be entered, the main viewpoint being that the general set of problems will be with us for some time and that a long-term program of investigation would seem not only to be justified but necessary.

There are, we believe, certain basic aspects of the matter of atmospheric pollution by motor vehicles, which need to be looked at stepwise and systematically over some considerable period of time. It would seem wise to plan a program of work in such a way as to attack these broad problems as the primary body of the investigative program, and to provide for special experimental forays into collateral issues from time to time, as circumstances appear to justify or demand. The number one problem is toxicologic in character, using the term in its broad sense, as the methodology whereby much can be learned about the injurious effects of a substance or group of substances under highly varied con-

ditions. What are the effects of human exposure to the individual and collective components of the exhaust and other effluents at various levels of concentration and in various combinations? (The attack on this problem involves a fairly comprehensive knowledge of the components of the effluent streams, their physical and chemical states and their interactions with each other and with other materials in the general atmosphere under the conditions that may exist with respect to temperature, humidity, intensity of solar irradiation, etc. It is assumed that these matters would be investigated by others, as for example, by the technologists in industrial laboratories. But whether and by what means this is feasible and desirable is not clear. Certainly some degree of coordination of effort would be desirable for both technical and economical reasons.)

Brief memoranda on work of various types, prepared by several members of the staff of the Laboratory are inserted, essentially unchanged, at this point, merely as matters for consideration. Other ways of initiating this work could be suggested. It is of the greatest practical importance that it be recognized that little or no information is now available as to the combined effects of substances which individually are below the threshold of toxic concentration. This is one of the most fundamental defects of present toxicologic knowledge, and it must be met and dealt with in this general problem of air pollution.

The memoranda referred to above are attached hereto. They can be enlarged upon and a well defined program of investigation can be described, if and when it may seem to be justified. The cost associated with the prosecution of the program can also be estimated with reasonable precision on a time base. Reports and publications of previous relevant

items of work can be supplied, if these are required or if they will serve a useful purpose in illustrating the methods, scope and proficiency of the Laboratory.

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