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Considerations in Evaluating Emissions From Consumer Products

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Abstract - While several indoor air quality studies suggest consumer products (e.g., aerosol sprays, paint strippers, etc.) can be significant sources of volatile organic compounds, until recently characterizing emissions from consumer products has received relatively little attention. Many considerations that must be addressed in designing studies of consumer product emissions are similar to those addressed in studies of the emissions from building materials and combustion appliances. These similarities are discussed and, in addition, the considerations unique to studies of consumer product emissions are discussed with reference to an ongoing study of consumer products that contain methylene chloride. These unique considerations include bulk chemical analysis, the form of the product (e.g., liquid, aerosol, or paste) and the related consumer usage pattern. The issue of personal exposure of the product user versus the average area concentration resulting from product use must be considered, as well as the challenge of incorporating results into predictive models that adequately treat the effect of different usage patterns. Finally, post-study considerations, such as exploring new issues discovered in the study, studying similar products, and validating predictive models through extension into field studies are summarized.

Key word index: Consumer product, emissions, indoor air quality, methylene chloride, personal exposure, source characterization, ventilation.

INTRODUCTION

While several indoor air quality studies suggest that consumer products can be significant sources of volatile organic compounds (De Bortoli *et al.*, 1984; Lebreton *et al.*, 1984), characterization of emissions from consumer products has received relatively little attention. This is in strong contrast to the characterization of emissions from combustion appliances (Johnson *et al.*, 1984; Leaderer, 1982; Traynor *et al.*, 1982) and building materials (Girman *et al.*, 1984; Molhave, 1982), where numerous chamber studies have been conducted. In this paper, considerations necessary for evaluating emissions from consumer products in laboratory studies are presented.

Although a broad definition of consumer products could include many combustion appliances and some building materials, a narrower definition as used in the National Academy of Sciences monograph, *Indoor Pollutants* (National Research Council, 1981) is employed in this paper. As used here, it is limited to expendable products in small containers which are readily available in retail outlets. In this context, consumer products are items such as cleaning/polishing products, insecticides, painting/finishing/refinishing products, personal grooming products, hobbyists' products, and deodorizers/disinfectants.

Many considerations that must be addressed when designing studies of emissions from consumer products are similar to those addressed in other types of indoor air quality studies. These similarities include: defining the potential health hazard; establishing study goals; assessing analytical instrument and chamber capabilities;

pretesting and establishing the experimental procedures; and establishing quality assurance/control objectives. There are, however, additional considerations that are unique to studies of consumer product emissions.

These unique considerations in protocol development are discussed with reference to an ongoing study of consumer products that contain methylene chloride (CH_2Cl_2). This study, supported by the U.S. Consumer Product Safety Commission (CPSC), was undertaken by Lawrence Berkeley Laboratory (LBL) to resolve uncertainties about the exposure consumers can receive by using consumer products containing CH_2Cl_2 . LBL is conducting a controlled study in an environmental chamber to measure both the airborne concentrations produced by the use of these products and the exposures of individuals using them. Development and testing of a model for both average area concentration and personal exposure is an important goal of this study.

In discussing considerations for studies of consumer products, eight major tasks are defined. While the order of presentation of the tasks is reasonable, it is not a rigid prescription. Certain tasks should be accomplished before starting the next task; however many tasks can be accomplished in parallel or, as is often required, in an iterative fashion.

TASK ONE: DEFINE THE POTENTIAL HEALTH HAZARD

Many interrelated factors must be considered in defining the potential health hazard of a particular product or class of products:

the chemical composition of the product; the toxicity of the compounds contained in the product; an estimate of airborne concentrations and exposures produced by the use of the product; the market penetration (either at the present time or expected in the future due to changing market conditions); and an estimate of the population potentially at risk.

This task should not be confused with actually *developing* an estimate of a health risk due to use of a product. This would be premature since too many parameters are not sufficiently well known. Rather, the goal at this stage is to judge whether the potential risk is large enough to warrant a detailed study.

This initial task is similar for most indoor air pollutant source characterization studies. In some respects, this task is more easily completed for consumer products than for other indoor air pollutant sources such as combustion appliances, building materials, or smoking, since consumer products generally have labels describing their chemical content. However, these labels, while useful as a guide, are not necessarily comprehensive and chemical analyses are usually required.

A good example of defining a potential health hazard is provided by CH_2Cl_2 , a chemical widely used by consumers. More than half of a million pounds of CH_2Cl_2 are produced annually in the U.S., primarily for use in paint strippers and aerosol finishes. The chemical composition of these products is readily obtained. For example, semi-paste paint strippers contain up to 90% CH_2Cl_2 and aerosol finishes with CH_2Cl_2 generally contain 20-40% of this chemical. Market data also exist for these products, although these data are not

discussed here.

There is concern about consumer exposure to CH_2Cl_2 from these products, since CH_2Cl_2 retained in inhalation is metabolized to carbon monoxide, which can lead to anoxic stress from elevated levels of carboxyhemoglobin (Ratney *et al.*, 1974; Stewart *et al.*, 1972). In addition, a recent animal-inhalation laboratory study has associated increased incidence of carcinoma with exposure to CH_2Cl_2 (Peer Review Panel, National Toxicology Program Board of Scientific Councilors, 1985). These facts strongly suggest that there is a potential health risk that is worth investigation.

TASK TWO: ACQUIRE APPLICATION TECHNIQUE AND USAGE PATTERN INFORMATION

In completing this task, the goal is to acquire sufficient information about product application and use to assure that the product is used realistically in test situations. The term "application technique" is used to denote the detailed method employed by the consumer when using the product. Information on the application technique employed in using a paint stripper might include "Use a single brush stroke, applying in one direction only. Wait at least ten minutes before scraping." Since consumer products are found in a number of different forms including aerosols, liquids, semi-pastes or gels, pastes or waxes, and solids, a broad range of application techniques must be anticipated.

In contrast to this, usage pattern information is broader in

scope. It would, ideally, include such data as amount used, frequency of use, typical room volumes and air exchange rates where the products are used, the frequency with which consumers increase ventilation by opening windows and/or doors, and the size and types of objects to which the products are applied.

There are several ways to acquire information about application techniques and usage patterns. Manufacturing trade associations for the product type may share their market research data about techniques for application and how consumers actually use the product. User surveys are another, probably better, method of acquiring information. These range from structured surveys with questionnaires to informally questioning colleagues and acquaintances about their personal use of specific products. However, the best and most readily available source of information is probably manufacturers' information sheets and the instructions printed on product containers. These are, after all, the source of information most often used by consumers.

For the Methylene Chloride Study there are two major product types with very different forms: paint strippers, which are primarily semi-pastes, and aerosol finishes. Information about application techniques and product usage was acquired through informal surveys (including personal experience on the part of the researchers and program managers) and manufacturers' information sheets and instructions on product containers.

TASK THREE: ESTABLISH STUDY GOALS

This task allows the greatest latitude and accordingly, the greatest creativity for researchers and program managers, since a wide range of choices are available to shape the direction and goals of the study. Initially, it must be decided if the study should be biased toward a "worst case" use or toward a more typical product use or both. A worst case scenario may be appropriate when acute health effects are of interest and are likely to occur within the population with some frequency. A typical use scenario may be more appropriate for chronic health effects or to estimate the typical exposure of larger populations.

Very often, source characterization is a primary goal and this characterization can be done with respect to time (in which case the form of the product and the method of application are important); with respect to temperature (where the form of the product may be important); with respect to the ventilation rate (or perhaps with respect to local air flows near the product and user); and/or with respect to other environmental parameters.

Another decision must be made regarding measuring area concentrations versus personal concentrations or both. The person using the product can receive an exposure far different than would be predicted from an area concentration taken in the same room. The concentration gradients in rooms where consumer products are being used may be large and therefore, may have a strong effect on personal exposures. This may lessen the importance of area concentrations in the absence of a model correlating personal exposure to area

concentrations and increases the importance of personal sampling.

Of course, as discussed previously in Task Two, the application technique can affect emissions from a consumer product. Therefore, it must be decided if the effect of this source of variability is to be measured.

Finally, the goals must be prioritized. Because of limited resources, the scope of a study must usually be restricted in some way. The actual decisions as to which goals will be pursued need not be made at this time, but they should be prioritized.

In the Methylene Chloride Study, for example, the focus of the study was to be typical use, not worst case. It was further decided that source characterization with respect to time and ventilation was most important and that the effects of temperature and humidity would be studied later, if at all. While characterizing the emission of CH_2Cl_2 would receive the most attention, the emission of other major solvents such as toluene would also be monitored. The average area concentration and personal exposure were judged, at this point, to be equally important and the study would attempt to measure both. The ventilation rates to be used were both low, 0.5 air changes per hour, and high, 3.0 air changes per hour. These ventilation rates correspond to the situation when a consumer takes no action to increase ventilation while using the product and the situation when windows are opened. (A consumer could also, in some situations, take the object to be painted or stripped outside. However it ceases to be an indoor air quality problem under these conditions and, more importantly, is not an option in cases when the object is a permanent fixture, e.g., a floor,

kitchen cabinets, or wall panels.) While the panels to be paint stripped in this study were to be primed and painted at least a month before the experiments with two coats of enamel paint, which tends to be difficult to remove, they were to be modest in size (compared to wall panels, kitchen cabinets or a floor) and they were to be relatively smooth (compared to lathe-turned legs or a carved piece of furniture) and therefore easily stripped. Overall, the choices made tended to correspond more to typical, not worst case, use of the product.

TASK FOUR: ASSESS INSTRUMENTAL AND FACILITY CAPABILITIES

Based upon the prioritized list of goals, the researchers must assess the resources available to conduct the study, in terms of both instruments and a chamber or other specialized facility. This is a straightforward task.

For the Methylene Chloride Study, a continuous IR analyzer with appropriate specifications was purchased to monitor both the personal and area concentrations on an alternate basis by means of sample line switching. (Sampling with charcoal tubes was originally considered for personal sampling, but was rejected for this phase of the study because of insufficient precision and time resolution.) A gas chromatograph (GC) was available but required reconditioning, and the installation of another column and gas loop sampling system. A chamber designed for studies of organic emissions (i.e., constructed of

suitable materials) was available. Its ventilation system was adequate in terms of air flow and size, but in its present state of construction, it lacked temperature and humidity control. However, since strict requirements were not established for these parameters, control could be accomplished simply by controlling the temperature and humidity of the laboratory housing the chamber.

Data acquisition systems and a host computer were available for logging of analog and digital input signals from the IR analyzer, the GC, and the environmental instrumentation but some software remained to be written.

TASK FIVE: WRITE PROTOCOL

In writing the protocol, all of the information collected regarding product types, application techniques, usage patterns, study goals and the analytical instrument and facility specifications are considered and brought together to construct a unified plan. The detailed experimental procedure is written, incorporating the specific instruments and the chamber capabilities. Calibration procedures are established in detail. Consideration should also be given to data acceptance standards. However, in research, as opposed to monitoring, it is inappropriate to set rigid standards for all types of data. Standards can be set for the limits of acceptable data for environmental parameters, for instrumental drift and for the precision of calibration data. However, setting standards for other data can be difficult due to lack of knowledge about the behavior of the source

and the effect of activity on the part of the person using the product.

Audit procedures should be set and written as part of the protocol. The audit can take two forms: internal where checks of instruments, procedures and data are conducted and recorded by the researchers themselves according to a formal plan; and external where an outside agency or individuals check the instruments, procedures and data.

A detailed checklist of specific actions to be executed before, during and after an experiment should be constructed from the key elements of the protocol. Writing the checklist at this time serves to insure that the protocol is practical and reasonable. However, the checklist should not be viewed as a static endpoint but, rather, as the first draft of document that will evolve as the researchers gain experience.

In the current example, the protocol for the Methylene Chloride Study was written by the LBL staff and sent to the CPSC for review. The protocol specified the instruments and the calibration procedures to be used. It established internal audit procedures and named a quality control officer. It described the sampling system, the ventilation rates, the environmental parameters, the substrate to be finished or stripped and incorporated, to the extent possible, manufacturers' instructions for product use. Incorporating the instructions for the use of paint stripper, in particular, required careful consideration. Paint stripper was to be applied sequentially to small sections (0.37 m^2) of a 1.5 m^2 panel. Stripper would set for a minimum of ten minutes prior to scraping. Tools, stripper containers

and paint scrapings would all be weighted so that the weight data could be used as a check of the emission rates developed through the use of a mass-balance, ventilation model. CPSC chose to obtain outside review of the protocol. Comments and suggestions from CPSC and the outside reviewers were incorporated into the protocol by LBL.

TASK SIX: PRETEST

The pretest period is one of the most interesting periods of a study because the learning curve is so steep. The products are selected for screening and subjected to bulk chemical analysis, generally by GC and/or GC/mass spectrometry. Based upon the results of the bulk analysis and market considerations, the specific products to be studied are selected. The performance of the analytical instruments is evaluated using the calibration procedures. During this period, more than one calibration system may be used as an overall check of one system against the other. Sampling systems are fabricated, if necessary, and/or tested. Data acquisition software is debugged, and the acquisition system is tested.

If at all possible, trial experiments should be conducted and concentrations measured. During these trial experiments, the product application technique is evaluated and standardized. This is especially important if more than one person will be applying the product during the experiments and measurement of the effect in variability of application technique is not a study goal. The overall experimental procedures are evaluated, as well as, the adequacy of the sampling

system and the analytical instruments employed. These trial experiments also provide data for testing data reduction and analysis schemes.

Often it is discovered that the protocol and checklist should be modified based upon the knowledge and experience gained in the pretest period.

The bulk chemical analysis of paint strippers confirmed a high percentage of CH_2Cl_2 and lesser amounts of toluene and aliphatic alcohols. The bulk analysis of selected aerosol paints and other aerosol finishes showed lesser percentages of CH_2Cl_2 but larger amounts of toluene and, in some cases, minor amounts of other solvents.

A sampling system was fabricated that switched alternately between a personal sample taken near the breathing zone of the person using the product and an average area sample consisting of the sum of fifteen sampling locations in the chamber. These fifteen locations are located throughout the chamber at three different heights.

The IR analyzer was calibrated for CH_2Cl_2 using both the manufacturer's closed-loop injection system and a mass-flow controlled dynamic gas dilution system with certified gas standard mixtures. Agreement between techniques was excellent, but the dynamic technique was chosen for use in the experiments because of ease and speed of use.

Application techniques for paint strippers were standardized. Preliminary experiments demonstrated that CH_2Cl_2 emissions could be well characterized and that even short-term variations could probably be characterized. However, personal exposure concentrations appeared

to be highly variable and could not be tracked adequately when sampling was alternated between personal and average area locations. Therefore, it was decided to obtain a second IR analyzer so that both personal and average area concentrations could be measured continuously. The protocol was modified to reflect this change.

TASK SEVEN: CONDUCT STUDY

Once the necessary preparations have been made, completing this task is relatively straightforward and, again, is similar to most indoor air pollutant source characterization studies. If at all possible, the first experiments should be replicate experiments to quantify the reproducibility of the experimental procedure. For these experiments, the same person should use the product and every attempt should be made to duplicate events even if a later goal is to determine the effect of variations in application technique.

The remaining experiments are conducted after the replicate experiments are completed and the data are reduced. The average concentrations obtained in the experiments are incorporated into a mass-balance ventilation model such as has been used in combustion appliance studies (Traynor, Anthon and Hollowell, 1982). Because of the temporal variation of emissions from some consumer products, it may be necessary to use a version of this model that can address these variations (Traynor *et al.*, 1985). The model may require some modifications to adequately treat a unique data set.

The data from personal sampling can be used to calculate

personal exposures and these can be compared to exposures estimated from average area concentrations. A better method, which is still under development, is to derive transfer functions that empirically model the relationship between area concentrations and personal exposure.

The experiments for the Methylene Chloride Study are currently underway. It appears that the simpler version of the mass-balance ventilation model will be adequate to determine the emission rate of CH_2Cl_2 from aerosol finishes. However, it is unclear at this point whether a model that can treat temporal variations in emission rates will be necessary for the emissions from paint strippers or if the simpler model with an average emission rate will be sufficient. Personal exposures will also be calculated and an attempt will be made to derive transfer functions from the experimental data.

TASK EIGHT: POST-STUDY CONSIDERATIONS

If funding is available, the research may be extended to explore issues ignored because of limited resources; to explore new issues discovered in the study; to study similar products; or perhaps most importantly, to validate the model developed by conducting a field study.

For the Methylene Chloride Study, several additional issues have already been suggested by the results: the effect of temperature on emissions from these products may be of interest; concentration gradients could be important at low ventilation rates for these products

because of the evaporative cooling of the products and the high molecular weight of CH_2Cl_2 relative to air; or emissions from similar products could be studied. However, a choice has been made to investigate the effect of various surfaces commonly found in indoor environments such as carpets, drapes, and other furnishings on the removal rates of CH_2Cl_2 . Finally, the model will be validated in a limited field study.

PERSONAL PROTECTION

Personal protection for the researchers deserves special mention. Unlike studies of combustion appliances and building materials where it is not necessary for researchers to have prolonged exposures to emissions, consumer products by their nature often result in extended periods of exposure. There is little justification to expose researchers to potentially hazardous compounds when the overall goal of a study is to protect public health. They should be protected even if some accuracy is sacrificed.

In the Methylene Chloride Study, a pressure-demand breathing apparatus supplied by a cylinder of air outside the chamber is worn by the person using the product during the experiments. Because the mask exhausts air under the chin of the wearer, it may dilute the personal sample. Nonetheless, personal protection takes precedence. Disposable coveralls are worn during the experiment by the person using the product to prevent dermal contact. Viton gloves are also worn during the use of paint strippers.

SUMMARY

Considerations in evaluating emissions from consumer products have been discussed with reference to eight tasks that should be accomplished when conducting such a study: (1) define the potential health hazard; (2) acquire application technique and usage pattern information; (3) establish study goals; (4) assess instrumental and facility capabilities; (5) write protocol; (6) pretest; (7) conduct study; and (8) post-study considerations. These considerations are discussed using examples provided by an ongoing study of methylene chloride emissions from paint strippers and aerosol finishes. Emphasis is given to those considerations that are unique to studies of consumer products including the need for personal protection of the researchers.

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