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Project Summary

Exposure and Release Estimations for Filter Press and Tray Dryer Operations Based on Pilot Plant Data

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This Project Summary discusses the findings from a pilot plant facility using a stationary tray dryer and a plate-and-frame filter press which were operated as part of the joint research effort between the U.S. Environmental Protection Agency (EPA) and Southwest Research Institute. The worker exposure data, chemical release data, and observations from the pilot plant experiments expand the database for making engineering assessments of Premanufacture Notice (PMN) materials which are fine solids (powders) and wet filter cakes.

Worker exposures and chemical releases associated with a plate-and-frame filter press and a stationary tray dryer were studied in a pilot plant. The equipment was representative of that in a chemical manufacturing plant; the filter press was previously used at a chemical plant, and the dryer trays were the same size used by dye manufacturers. A randomized series of eight experiments identified the most influential variables for inhalation exposure during operation of the tray drying unit, which used approximately 100 kg of calcium carbonate. The range of conditions studied in the eight experiments provide inhalation exposure data with more than two orders of magnitude for evaluating the impact on a PMN of the physical properties, the activities performed, and the worker's technique.

The worker inhalation exposure for the tray dryer unit operation was controlled by the tray unloading activity; 92% of the time weighted average (TWA) was attributable to the tray unloading exposure even though this task only took 30% of the worker's time. Even when the filter press was operated, the tray unloading activity dominated. The pilot plant tray dryer TWA ranged from 1.59 to 18.1 mg/m^3 and averaged 7.28 mg/m^3. The inhalation exposures associated with powders were greater than those for wet filter cakes. The worker technique could double the inhalation exposure and in some cases be responsible for more than an order of magnitude difference. The particle size distribution affected the physical properties of the filter cake and caused mixed results. Small particles gave higher inhalation exposures during the cake removal stage, but the large particles gave higher inhalation exposures during the tray unloading stage. Excellent linear correlations between inhalation exposure and effective generation rate for the large range of pilot plant conditions indicate potential success for building an inhalation exposure model based on generation rates.

Chemical releases for the tray drying unit operation for powders and filter cakes were 0.7 to 1.5 wt% of the batch size in the pilot plant. The chemical release for the disposal of used filter media ranged from 0.37 to 0.85 wt% of the batch size. Worker dermal exposures for cake removal were 0.039 to 0.60 mg/cm^2, for tray loading were 0.0076 to 0.063 mg/cm^2, and for tray unloading were 0.0048 to 0.067 mg/cm^2.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project

that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

As one component of Section 5 of the Toxic Substances Control Act (TSCA), the EPA must estimate the exposures (inhalation and dermal) and releases associated with the manufacturing of a new chemical. To assist engineers making these estimates, EPA has compiled historical, 8-hr TWA inhalation exposure data for various job classifications. The PMN includes a process flow diagram and estimates of the number of workers and time required to perform a given task. Based upon this information, EPA must select a job classification which most closely relates to the PMN and then extrapolate the 8-hr TWA to the new chemical. Inhalation exposure data for unit operations would improve the workplace inhalation exposure estimations.

Dermal exposure estimations suffer from a lack of sufficient historical data for workplace dermal exposures. Several experimental research efforts have been conducted for EPA with liquid compounds to obtain dermal exposure data; however, until now the data obtained on dermal exposure to powders has not been specifically directed at improving the PMN review process information.

Historical chemical release data are not available to the PMN reviewer on a unit operations basis. Guidelines for estimating releases to water and disposal of filter media to landfill or incineration have been developed for the PMN system; however, a more complete database of chemical releases is needed.

Research began in August 1986 to (1) improve estimates for workplace exposures and chemical releases and (2) explore the feasibility of developing predictive models for chemical releases and worker exposures for filtration and drying unit operations. These two unit operations were selected because of their high frequency of appearance on PMN forms. Ten principal equipment types were considered within the unit operations (six kinds of filtration equipment and four kinds of drying equipment). Filter presses and tray dryers were selected for study because of their high potential for inhalation exposure. Because of the expense and inability to identify appropriate manufacturing sites for data collection, it was decided to do the studies on a pilot plant scale.

Procedure

A filter press was obtained which had been used in a chemical manufacturing process, and a new stationary tray dryer was purchased. In the pilot plant, a series of randomized experiments were conducted in a controlled environment (i.e., modified ventilation systems and one unit operation per room to prevent cross-contamination). During the pilot plant experiments, sampling protocols for effective generation rate, short term area concentration data, dermal exposures, and chemical releases were evaluated to identify whether the methods and prediction models would be practical for field work.

Calcium Carbonate was the chemical used in these experiments; because it is inexpensive, non-toxic, available in a range of particle sizes, and has low water solubility.

Eight experiments were performed utilizing a factorial design for two levels for each of three factors: two research technicians as operators, two size distributions of $CaCO_3$, and two initial conditions of the material. Regarding the last factor, the initial condition was either a dried powder or a filter cake (the latter was produced by processing a 10 wt% slurry of $CaCO_3$ in water through the plate-and-frame filter press). The drying experiments consisted of: loading approximately 100 kg of $CaCO_3$ onto 11 trays, drying the material in a mechanical convection oven, and unloading the dried material into a single container. The tray loading and unloading areas were located in a room that possessed a high air exchange rate and well-mixed air circulation, but no local exhaust ventilation systems.

As preparation for a pilot plant experiment with an initial condition of wet filter cake, the $CaCO_3$ was mixed with water in a 380-gal tank to give a 10 wt% $CaCO_3$ in water slurry. An 18-in. by 18-in., 15-chamber, plate-and-frame filter press was used to filter this slurry. The mixing and filtration activities were performed within a metal-frame building in an area which was separated from a warehouse by floor-to-ceiling black polyethylene sheets. No modifications were made to the general ventilation system in this filtration area.

A mechanical convection oven (Blue M Model DC-136C)* with an internal volume of 0.75 m^3 was used as the stationary-tray dryer. The oven was located in a second room which was significantly modified to provide a well-mixed, high exhaust turnover rate for the detailed study of generation rate. One tray dryer batch consisted of approximately 100 kg of $CaCO_3$ (dry weight basis) loaded onto eleven 94 x 48 cm trays.

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The factorial experiment was designed to study the response variable, worker inhalation exposure (mg of $CaCO_3$ / m^3 of air). The analysis of variance (ANOVA) tables were also developed for two other response variables, dose [(mg of $CaCO_3$) (minute) / (m^3 of air)] and mass of chemical spills [kg spill / kg product]. The dose variable is calculated by multiplying the inhalation exposure for a given activity (cake removal, tray loading, or tray unloading) and the activity's duration. Other response variables of interest for the pilot plant experiments were generation rate (mg $CaCO_3$ /sec), chemical release (kg of $CaCO_3$), and worker dermal exposure (mg $CaCO_3$ /cm^2 skin). These variables were assessed for linear correlations with various parameters.

Results and Discussion

One of the factors that can affect the airborne concentrations within a work area, and subsequently the inhalation exposure of the operators, is the ventilation characteristics of the work area. To enhance the evaluations associated with the generation rate models, the drying room was deliberately equipped with a ventilation system that would create a well-mixed air flow pattern inside the room. The drying room was designed to have an average room air exchange rate of 8.7 changes per hr and an average mixing factor of 1.03 which indicates perfect mixing conditions within the error range of the measurements. The air exchange rate and the mixing factor of the drying room may be better than those values found in typical industrial facilities. Conversely, the filtration room's average air exchange rate of 5.0 changes per hr and mixing factor of 0.88 are probably more consistent with the levels existing in actual chemical manufacturing plants.

To characterize a worker's inhalation exposure for an entire unit operation, the TWA exposure is commonly used. The TWA inhalation exposure to $CaCO_3$ incurred by the pilot plant workers during the tray dryer operation can be calculated using the following formula:

$$TWA = (t_L c_L + t_u c_u) / T$$

where:

t_L = time of the loading stage
c_L = calcium carbonate concentration measured in the breathing zone of the operator during the loading stage
t_u = time of the unloading stage
c_u = calcium carbonate concentration measured in the breathing

zone of the operator during the unloading stage

T = total time operator was involved with the tray dryer operation ($t_L + t_u$)

Since the operator was not present during the drying stage (i.e., the inhalation exposure was zero), this stage is not included in the TWA calculation. The geometric mean TWA inhalation exposure for the drying unit operation was 7.28 mg $CaCO_3/m^3$. The unloading activity accounted for 92% of the overall inhalation exposure even though it accounted for only 30% of operator's time. This compares with a previous in-plant study of a recessed filter press where 72% of the TWA inhalation exposure for the entire filtration operation was attributable to the cake removal stage even though only 15% of the operator's time was required for this activity. Therefore, for the two unit operations of interest, filtration and drying, one worker activity for each unit operation is attributable to the majority of inhalation exposures.

The three main factors (worker, particle size distribution, and material condition) significantly affected ($p < 0.05$) worker inhalation exposures for all three unit operation activities with the exception of the particle size distribution for the loading activity. In the performance of all activities associated with the stationary-tray dryer and the plate-and-frame filter press, Worker B consistently experienced higher inhalation exposures. During the removal of filter cake from the filter press, inhalation exposures were higher for the smaller particle size distribution. The particle size distribution had no significant effect on inhalation exposures during the tray loading activity. During the tray unloading activity, inhalation exposures to the larger particle size distribution were greater than those to the small particle size distribution. Finally, inhalation exposures to the powdered material (i.e., dry initial condition) for the tray loading and tray unloading stages were higher than for the material which was processed through the plate-and-frame filter press.

For the manual filter press and tray drying unit operations, one worker activity for each unit operation is attributable to the majority of inhalation exposures (92% of tray dryer TWA and 30% of the worker's time is associated with tray unloading activity).

When both filter press and tray drying unit operations are being performed, the inhalation exposures are overwhelmingly controlled by the tray unloading activity. The tray unloading inhalation exposure (8.63 to 49.4 mg/m^3) was one to two orders of magnitude greater than those received during the remaining tray dryer (0.20 to 2.38 mg/m^3 for tray loading and negligible for drying) and filtration (0.13 to 0.73 mg/m^3 for cake removal) operations.

In the tray dryer operations, worker technique, particle size distribution, and material condition significantly affect worker inhalation exposures and are each capable of producing a range of inhalation exposures greater than one order of magnitude.

Pilot plant tray dryer overall TWA inhalation exposure was 7.28 mg/m^3 with a range of 1.59 to 18.1 mg/m^3. It is conceivable that different workers and greater distinctions in $CaCO_3$ size ranges could make exposures even more variable. Consequently, data collection activities without development of predictive models will not provide the PMN reviewer with a reliable order of magnitude estimate for inhalation exposures.

Inhalation exposure concentrations are approximately the same for the cake removal (0.13 to 0.73 mg/m^3) and the tray loading (0.22 to 0.68 mg/m^3) activities for wet filter cakes which may imply that the physical principles responsible for generation of the aerosols are similar for these tasks.

Total chemical releases for the tray dryer unit operation when fine solids (powders) are being handled (0.7 to 1.5 wt%) are higher than the current PMN guidelines of 0.1% to 1.0% of batch size (i.e., product yield).

The mass of wet filter cake lost from trays during their transfer into and out of the dryer shelves is the greatest source for chemical releases during tray drying operations and are as high as 2.84% of product yield.

For filter cloths that are washed prior to disposal, the current PMN guideline for chemical releases to the landfill or incinerator (i.e., 0.5% of a batch) is an appropriate estimate for the amount of material retained within the filter cloth.

For unwashed filter cloths, the chemical release associated with cloth disposal is 0.7% of a batch.

Worker dermal exposures during cake removal operations (0.039 to 0.60 mg/cm^2 skin) are less than the criteria stated in current PMN guidelines (1 to 3 mg/cm^2 skin developed from contact with liquids).

The pilot plant data of 0.0076 to 0.063 mg/cm^2 skin for dermal exposures associated with tray loading activities can be used for PMN materials which are fine solids or filter cakes.

The pilot plant dermal exposures from activities associated with high temperatures (e.g., the tray unloading activity) are higher than the current PMN guidelines (the pilot plant exposures were 0.0048 to 0.067 mg/cm^2 skin and PMN guidelines advise "negligible" exposure). The dermal exposure during high temperature operations stems from fine solids falling into the worker's gloves, and from contamination between experiments since the gloves were not exchanged for new ones between experiments.

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The complete report, entitled "Exposure and Release Estimations for Filter Press and Tray Dryer Operations Based on Pilot Plant Data," (Order No. PB92-158450/AS; Cost: $43.00; subject to change) will be available only from:
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