INTRODUCTION

The concentration of airborne radioactive materials inside a room can vary widely from one location to another, sometimes by orders of magnitude, even for locations that are relatively close. Inappropriately placed air samplers can give misleading results and, therefore, the placement of continuous air monitors or samplers is a critical component in rapid and reliable detection of releases of radioactive materials.

Past researches and regulations have concluded that the best location of air sampler for consistent detection is the room exhaust ducts (1, 2). However, recent studies show that this is not always correct and placement of continuous air samplers at exhaust points do not always provide the optimal or the most reliable worker protection from airborne contamitites (3).

Proper placement of samplers is not always obvious and cannot be determined simply by observing the position of room air supply and exhaust vents. Additional considerations that affect airflow patterns include:

One. Heat loads that produce thermal currents which can alter airflow patterns significantly.
Two. The presence of large structures, equipment or partitions within the rooms which can produce areas with stagnant airflow conditions.
Three. The presence of opened or closed doors.
Four. Poorly designed ventilation systems which can cause bi-level or recirculating airflow.

Airflow pattern studies for locating air samplers should, therefore, be used. The significance of these studies and the use of the information obtained, depend on the purpose of sampling: for estimating worker intakes, warning of abnormally high concentrations, testing for confinement of sealed radioactive materials, etc.

Regulatory Guide 8.25 (4) suggests that an airflow study be conducted after any work-area changes, including the addition of structures, partitions, hoods, etc., changes in the ventilation system, or seasonal variations that might change airflow patterns. Regulatory Guide 8.25 also recommends a routine evaluation of fixed-location samplers - 10% evaluations each year - to determine if their locations are still appropriate.

The airflow patterns studies are mostly qualitative studies, which use smoke or aerosols that can be visually observed and recorded, but sometimes also quantitative methods, which use gas or aerosol tracers and provide measurements of dilution effects in the work area are used. Qualitative studies are generally adequate for placing of air samplers. The present work describes two studies performed on actual rooms: a smoke test study and a computer simulation.

QUALITATIVE SMOKE TESTS

Qualitative smoke tests were conducted inside rooms using a "KUPO Inc." smoke tube (D5050 fog machine). The tests were conducted without the presence of workers in the rooms, but under normal working conditions, including whether doors were open during normal operations, and ventilation operated in normal condition. During the tests, smoke was released at floor level and at an elevation of 1-2 meters, and its path was recorded on worksheet drawings of the room.

Generally, the tests revealed three types of airflow patterns inside the rooms:

- flow path with a definite stable direction,
- flow path which changes direction arbitrarily as a result of airflow vortices, and
- static/stagnant air.

Figure 1 shows pictures of a typical smoke test. In this test, after being released, the smoke flows to the left, indicating a definite airflow pattern from right to left.
Figure 1. Pictures of a typical smoke test. After being released (a), the smoke flows to the left (b), indicating an airflow pattern from right to left.
In some cases air flew in opposite directions at different heights within the same room. This typically occurred in rooms with poorly designed ventilation systems, where the air supply vent was located near the exhaust vent. Figure 2 presents an example of such a case. It shows smoke test results inside a room at a height of 1-2 meter. The overall dimensions of the room are 6.0x3.6x4.0 m. It contains two rows of containers and a pumping unit of 0.6x0.5x1.5 m. The ventilation air supply and exhaust vents are placed at a height of 3-meter near a door, which is generally closed. At 3-meter height the air flows from the supply vent toward the rear wall of the room where it is deflected back at 1-2 meter height in the direction of the air supply and exhaust vents. In such a case of a bi-level airflow, the proper air sampler placement depends critically on the height of the release point and the worker's breathing zone. According to the flow pattern, the appropriate location of an air sampler (which samples at a height of 1.5 meter) is near the door, as marked in the figure. This case emphasizes the significance of conducting airflow studies for location of air samplers.

Airflow velocity was measured at 4 locations inside the room at 1-meter height, as marked in figure 2 (in circles). The velocities were 0.10-0.11 m/s at all 4 points.

Figure 2. Smoke test results inside a room with a poorly designed ventilation system, at 1-2 meter height.
Figure 3 presents an example of a well designed ventilation system. The overall dimensions of the room are 10x6x4 m. It contains five working units with dimensions of 3x1x2 m and a control desk. The working units are potential contamination release sources. Three ventilation air supply vents are located at the ceiling and the exhaust vent is placed near the floor at one of the room's corners. The air flows throughout the room and at all elevations towards the exhaust vent. According to the flow pattern, the appropriate location of an air sampler is near the exhaust vent, as marked in the figure.

Figure 3. Smoke test results in a room with a well designed ventilation system, at 1-2 meter height.
COMPUTER SIMULATION MODEL

A computer simulation was also used to simulate airflow pattern inside the room shown in figure 2. The following assumptions, concerning the airflow, were made in the simulation model:

- The flow inside the room is steady state and incompressible.
- The flow regime is laminar (in future, simulations of turbulent models will be considered).
- The interaction of momentum between the particles and the air is negligible.
- The aerosol flow is dilute.
- The aerosols (dispersed phase) follow the air path (carrier phase) with the same velocity.
- The material properties are constant.

The governing equations of the airflow were the Navier-Stokes equations, and conservation of mass and momentum. The boundary conditions concerning the velocity components were:

\[ U_x(\text{inlet}) = 0.325 \text{ m/s} \]
\[ U_y(\text{inlet}) = 0.563 \text{ m/s} \]
\[ U_z(\text{inlet}) = 0.0 \]
\[ U_x(\text{on the walls}) = U_y(\text{on the walls}) = U_z(\text{on the walls}) = 0 \]

The equations were solved numerically using a commercial finite element CFD code, FIDAP 8.01. The 3-dimensional model consists of 54440, 8 mode elements with 50270 nodal points. Figure 4 presents the resulting flow field at a 1 m height cut-off plane through the room. The results are generally similar to the smoke test results, but additional details can be observed, as local airflow deflections. These deflections could not be observed during the smoke tests because of physical and visibility limitations. In addition, a detailed air velocity map is obtained.

Figure 4. Computer simulated flow field for a cut-off plane through the room at 1 meter height.
SUMMARY

Airflow pattern studies for locating air samplers inside workrooms were conducted using qualitative smoke tests. Some tests revealed cases in which the airflow path direction was different from the expected one, which were generally caused by a poorly designed ventilation system. The studies have shown that a ventilation system has a better performance when the supply and exhaust vents are not located on the same wall.

A comparison between a qualitative smoke test and a computer simulation was also performed. The computed and the measured paths of the airflow were in good agreement. The computer simulation indicated additional details which could not be observed when performing the smoke tests. Both the computer simulation and the smoke test showed that the appropriate location of an air sampler, for the chamber geometry checked, is near the door.

This study emphasizes the importance of conducting airflow pattern studies to locate air samplers appropriately.

REFERENCES