NILU : TR 15/94

NILU : TR 15/94
REFERENCE : E-94050
DATE : OCTOBER 1994
ISBN : 82-425-0613-2

A tracer study of the ventilation system in NILU's new building

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Contents

Summary

This report describes a tracer study of the ventilation system in NILU's new building. The project is part of a larger study of the indoor air quality at the new location in Kjeller. The tracer SF_6 was used to measure the air exchange in selected rooms and in two of the five ventilation subsystems. To measure the ventilation rate in a single room, a known quantity of SF_6 was instantaneously released into the room and the tracer concentration decrease versus time was subsequently measured. For the ventilation subsystem tests, SF_6 was released at a constant rate into the appropriate air intake vent on the roof until a constant SF_6 concentration was observed in the area under investigation. The release was then shut off and the tracer concentration decay rate measured. Air exchange rates calculated from the tracer data are in reasonable agreement with values reported by the ventilation contractor except in areas containing fume hoods, where the numbers reported by the contractor are significantly higher. Finally, tracer was released directly into one of the laboratory fume hoods to check if exhaust flow might be recirculated into the building. No SF_6 was detected anywhere in the building, including the room where the tracer was released.

A tracer study of the ventilation system in NILU's new building

1. A tracer study of the ventilation system at NILUs new building

A common measure of how well a room or building is ventilated is the infiltration rate, which is defined as the number of air exchanges per unit time (usually an hour), where one air exchange is an amount of fresh air equal to the volume of the room or building. The infiltration rate is often presented as the time, τ, necessary for one air exchange, given simply as the volume divided by the flow rate of air into the room or building. τ can be determined by observing the concentration decay versus time of a tracer released into a room. A simple mass balance consideration yields the desired relationship. For a well-mixed room of volume = V, with flow rate of air into (or out of) the room given by Q, and concentration of some tracer = C(t), then the instantaneous change of mass of tracer in the room with time is:

$$dm/dt = Q * C(t)$$

but,

$$m = C * V$$

substituting and integrating yields:

$$C(t) = C_0 * e^{-Qt/V} = C_0 * e^{-t/\tau}$$

Therefore, τ is just the time required for the tracer concentration to decrease by 1/e.

The ventilation system in NILU's new building consists of five essentially separate intake/exhaust subsystems. The first two are housed on the roof of the north wing and handle the airflow for the auditorium and for the first and second floor of the north wing. The remaining three are housed on the roof above the south wing, with individual intake and exhaust ports for the cafeteria, the first floor and the second floor of the south wing. All five intake vents are located at roof level. The auditorium intake is on the east side of the north wing ventilation housing, and the intake for the first and second floors of the north wing is on the west side of this structure. The three intake vents for the south wing are located adjacent to each other on the east side of the south wing ventilation housing. Exhaust flow is discharged from five stacks (two on the north wing and three on the south wing) at approximately four meters above the tops of the ventilation housing structures. A schematic of the building is shown in Figure 1.

In this study the ventilation system of NILU's new building has been characterized by measuring the infiltration rate for representative rooms in the five different ventilation subsystems, and also for one of the larger ventilation subsystems as a whole. Two different methodologies were used. For all but the largest of the single rooms (the cafeteria) and the second floor, south wing ventilation test, a known quantity of SF_6 was instantaneously released and the tracer concentration decrease versus time subsequently measured in the room. For the cafeteria and the second floor, south wing subsystem, SF_6 was released at a constant rate into the appropriate air intake vent on the roof until a constant SF_6 concentration was observed in the area under investigation. The release was then shut off and the tracer concentration decay rate measured. Finally, tracer was released directly into one of the laboratory fume hoods to check if exhaust flow might be recirculated into the building.

2. Measurement of air exchange rates in single rooms

The procedure used to measure the infiltration rates in single rooms in the building was as follows: a small quanitity of pure SF_6 (or 1% SF_6 in air) was released in a designated room by walking around the room for about 10 seconds while expelling the tracer at a constant rate from a 20 ml syringe. A small fan was then run for two minutes to ensure adequate mixing of the tracer. Ten to fifteen minutes later, after it was determined from grab samples that the tracer concentration in the room had fallen into the linear range of the SF_6 gas chromatograph, approximately 15 grab samples were taken at several minute intervals to determine the air exchange rate. For the first few tests (which involved the largest rooms) samples were taken at various locations simultaneously to check that the tracer was well mixed.

The seven rooms tested using the above method included the auditorium (K-001), the library (K-006), the smoking room (K-019), two offices (K-113, L-210), the dioxin lab (L-235), and a printing room (L-157). The room locations are shown in Figure 2. Thus, a representative cross section of the rooms in NILU's new building was tested, with at least one from each of the five ventilation subsystems (The cafeteria was not tested with this method because it was thought to be too large to achieve adequate mixing with an instantaneous tracer release). Grab sample locations for the library (K-006), the auditorium (K-001), and later the cafeteria (L-001), are shown in Figure 3. For the remaining rooms, samples were taken at one location in the middle of the room, typically at a height of 1.5 meters above the floor.

Plots of concentration decay versus time for these rooms are shown in Figures 4-10, and the results are summarized in Table 1. For the library (K-006) and the auditorium (K-001), two sets of simultaneous grab samples during the tests at locations 1 through 6 in Figure 3 yielded concentrations of 230 parts-per-trillion-volume (pptv), 153 pptv, and 281 pptv, and 372 pptv, 460 pptv, and 463 pptv respectively, demonstrating that mixing was good in the auditorium and reasonable in the library, considering its layout. The full concentration versus time series from the auditorium was taken at location 5 and for the library at location 3 in Figure 3. From the figures and the table it is clear that all of the rooms tested are very well ventilated, with the worst case exchange rate of 4 per hour in K-113 and the best case rate of 12 per hour in the auditorium. Rooms tested at NILU's previous location in 1978 yielded a range of 0.25-4 exchanges per hour[1]. Thus, of the rooms tested, the location with the worst ventilation in the new building has an exchange rate comparable to the best ventilated room in the old building.

Table 1

Rom	Number	τ (minutes)	Air exchanges/hour
auditorium	K-001	5	12
library	K-006	7	8.6
smoking room	K-019	6	10
office	K-113	15	4
office	L-210	12	5
dioxin lab	L-235	6	10
printing room	L-157	7	8.6
cafeteria	L-001	12	5

With knowledge of room volumes, we can use the τ values listed above to calculate the actual air inflow rates for comparison with the values provided by the system designer. In Table 2 we have listed room number, approximate room volume, inflow rate (Q) as calculated from τ, and inflow and outflow rates as measured from the room vents by the ventilation subcontractor, Gunnar Karlsen a/s. (Theoretically, for a room at constant pressure, the inflow and outflow rates should be equal.) With the exception of L-235 (the dioxin lab), there is reasonable agreement between our calculated Q values and the inflow and outflow rates from the subcontractor. For 6 of the 7 rooms tested, the tracer derived ventilation is within 30-40% of at least one of the corresponding inflow/outflow numbers from Gunnar Karlsen a/s. For L-235, however, there is a large discrepancy both between our Q value and their inflow value and also between their measured inflow and outflow values. Some of this difference may be accounted for by the presence of fume hoods in the dioxin lab. Perhaps a large percentage of the airflow is 'short-circuited' directly from the fresh air vents into the fume hood and therefore does not contribute substantially to the ventilation of the entire room. Considering the factor of two difference between the Gunnar Karlsen inflow and outflow rates for L-235, it is difficult to further discuss the discrepancies without an accurate knowledge of their measurement methodology.

Table 2

Room	Volume (m^3)	Q (m^3/hr)	G.K. inflow (m^3/hr)	G.K. outflow (m^3/hr)
K-001	251	3012	4537	4097
K-006	304	2606	1948	
K-019	59	590	663	548
K-113	28	112	104	110
L-210	28	140	129	86
L-235	94	940	3420	7500
L-157	40	343	490	

3. Measurement of air exchange in ventilation subsystems

While measurement in a single room yields the ventilation rate for that room, no information is obtained about where the air is exchanged from. For example, is the exchanged air actually fresh air or is it just recirculated air from another area in the building? If the exchange time is found to be substantially longer in a room when tracer is released into the entire ventilation subsystem than when it is released in the room only, recirculation between rooms or from the building exterior is probably occurring.

For this test, tracer was released at the rate of 60 ml/min from a 1% SF_6-in-air bottle at the air intake vent on the roof for the second floor, south wing of the building, which comprises the organic and inorganic laboratories and offices. (We chose not to attempt a building wide tracer release because the air intake vents for the five ventilation subsystems are so widely separated.) During the release, grab samples were taken at three locations (L-235, L-210, and in the middle of the inorganic laboratory (L-249) (see Figure 2)) and at 10 minute intervals to assure that the tracer was well mixed and the concentration was steady. The concentration levelled off at approximately 1000 pptv. Grab samples were also taken at other locations in the building to check for possible recirculation of air between the building ventilation subsystems. No tracer was detected anywhere else in the building except the cafeteria, which exhibited 30-40 pptv SF_6 during the release. This suggests that the separate ventilation subsystems are almost totally uncoupled.

The release was then turned off and the tracer concentration decay rate was measured in L-235 and L-210. The results are shown in Figure 11. With time constants of 10 minutes and 8 minutes for the office and the dioxin lab, respectively, the ventilation rates are nearly the same as determined from the single room tests. This gives further evidence that the air exchanged into rooms in the building is fresh air.

The continuous release method was also used to measure the infiltration rate in the cafeteria, which is a single room but also comprises one of the ventilation subsystems in the building. The test proceeded in the manner described above except that the 1% SF_6-in-air tracer was released at 30 ml/min into the cafeteria intake vent. Sampling locations were at points 7,8 and 9 in Figure 3. The results are shown in Figure 12 and also included in Table 1. Throughout the test the tracer was well mixed and the decay was uniform, exhibiting an air exchange rate of 5 per hour.

The continuous release measurement method also yields the fresh air inflow rate (Q) directly as the ratio of the tracer release rate to the steady state concentration of tracer in the volume tested. The 0.3 ml/min pure SF_6 released into the cafeteria resulted in an average steady state concentration of 2700 pptv, yielding a fresh air inflow of 6600 m^3 /hr. This compares well with the inflow of 6400 m^3 /hr and outflow of 9300 m^3 /hr measured by Gunnar Karlsen a/s. The 0.6 ml/min pure SF_6 released into the second floor, south wing ventilation system yielded an average steady state concentration of 1230 pptv, corresponding to an air inflow rate of 29,000 m^3 /hr. This is considerably less than the 44,000 m^3 /hr inflow and

55,000 m^3 /hr outflow rates (obtained by summing the numbers from all of the separate rooms in the system) measured by the ventilation subcontractor. The difference is consistent with the above results for the dioxin lab, as there are numerous laboratory areas with fume hood ventilation in this area of the building.

4. Fume hood release

Tracer was released at the rate of 60 ml/min of 1% SF_6-in-air directly into a fumehood in L-231 (a laboratory used for aldehydes analysis in air). Grab samples were taken at various locations around the building during two hours of tracer release. No SF_6 was detected in any of the samples, including several taken in the aldehyde laboratory during the release in the fume hood. This suggests that the fumehood functions very well and there is no gross recirculation problem with the second floor laboratory exhaust. However, possible recirculation between exterior exhaust and input vents will be dependent on meteorological conditions. The fumehood release was carried out on a partly cloudy afternoon in August with a breeze from the SSW, and thus represents a minimum likelihood for a recirculation event. It would be more useful, for example, to conduct such a test under inversion conditions in February.

5. References

Lamb, B. (1978) A tracer investigation of a laboratory ventilation system. Kjeller (NILU TN 8/78).

6. Figures

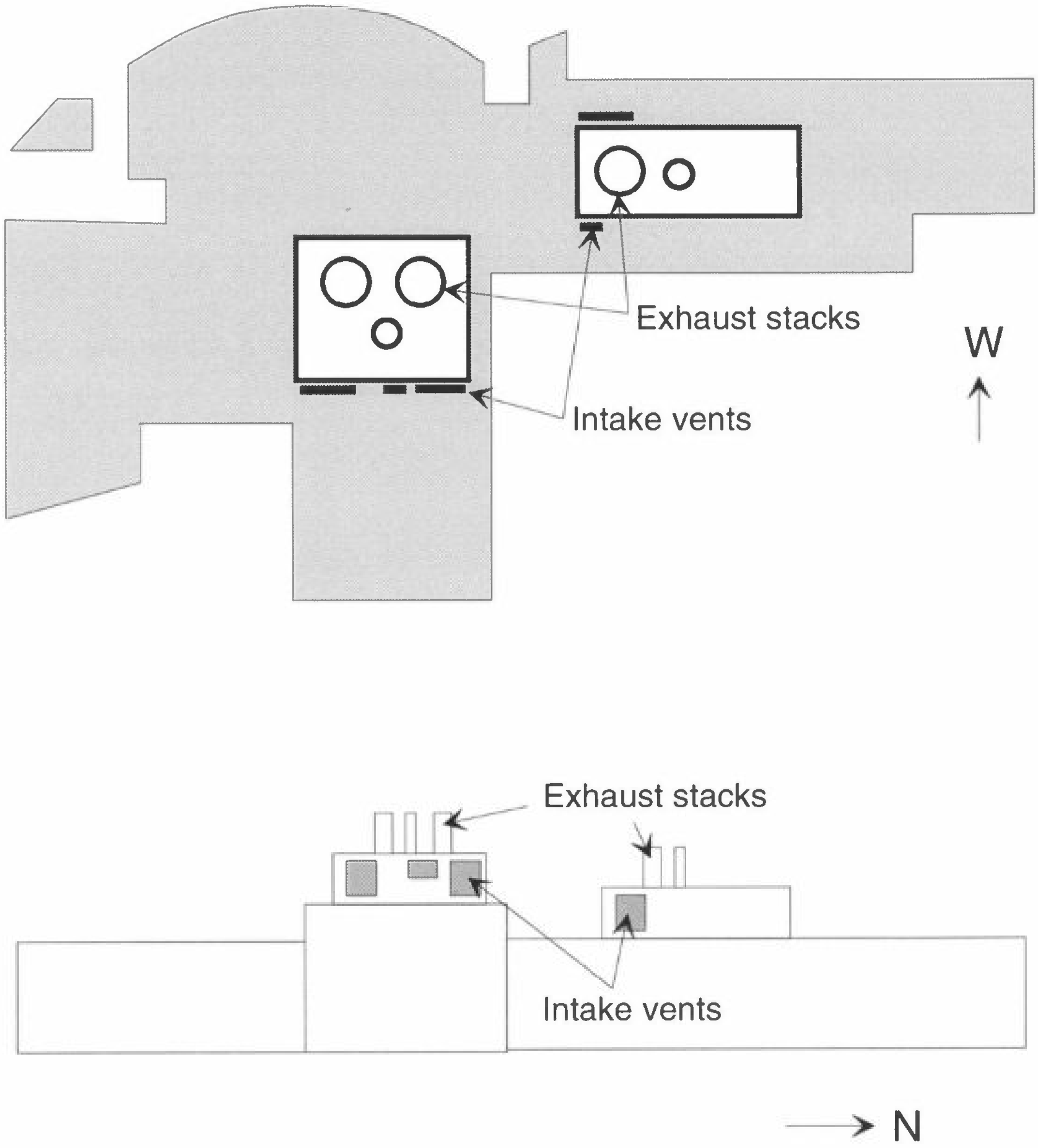

Figure 1: Exhaust stacks and intake vents in NILU's new building.

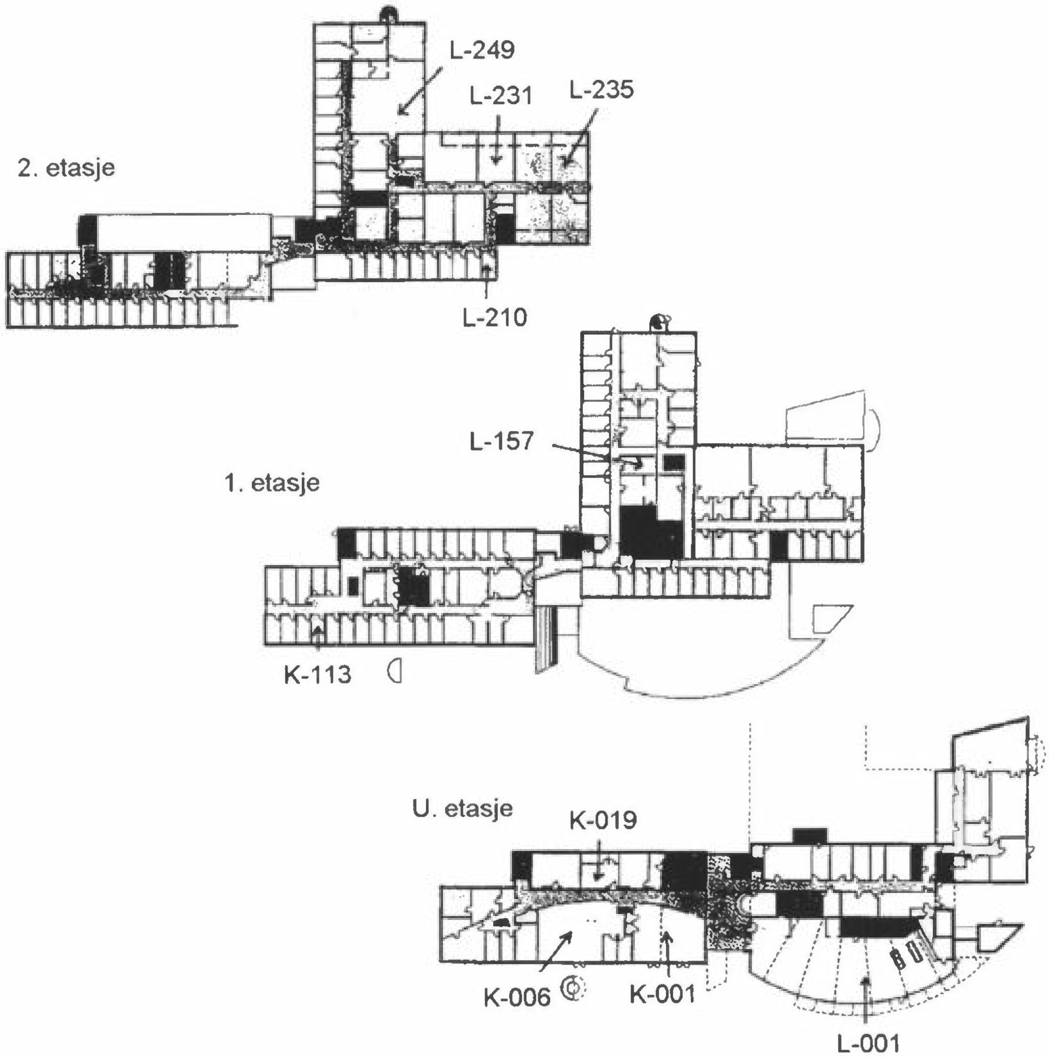

Figure 2: Rooms used in ventilation study.

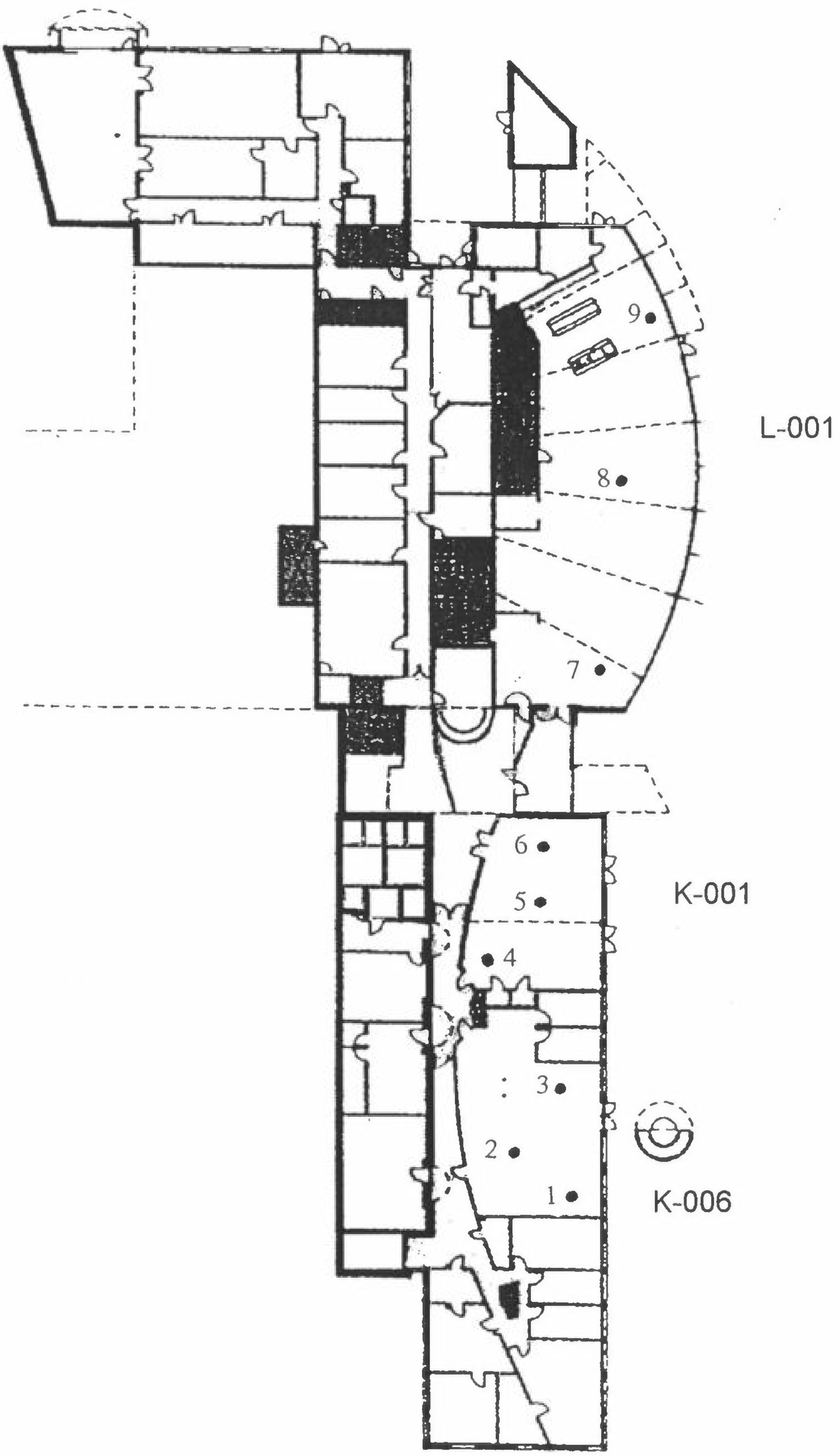

Figure 3: Sampling locations in the Auditorium (K-001), library (K-006) and cafeteria (L-001).

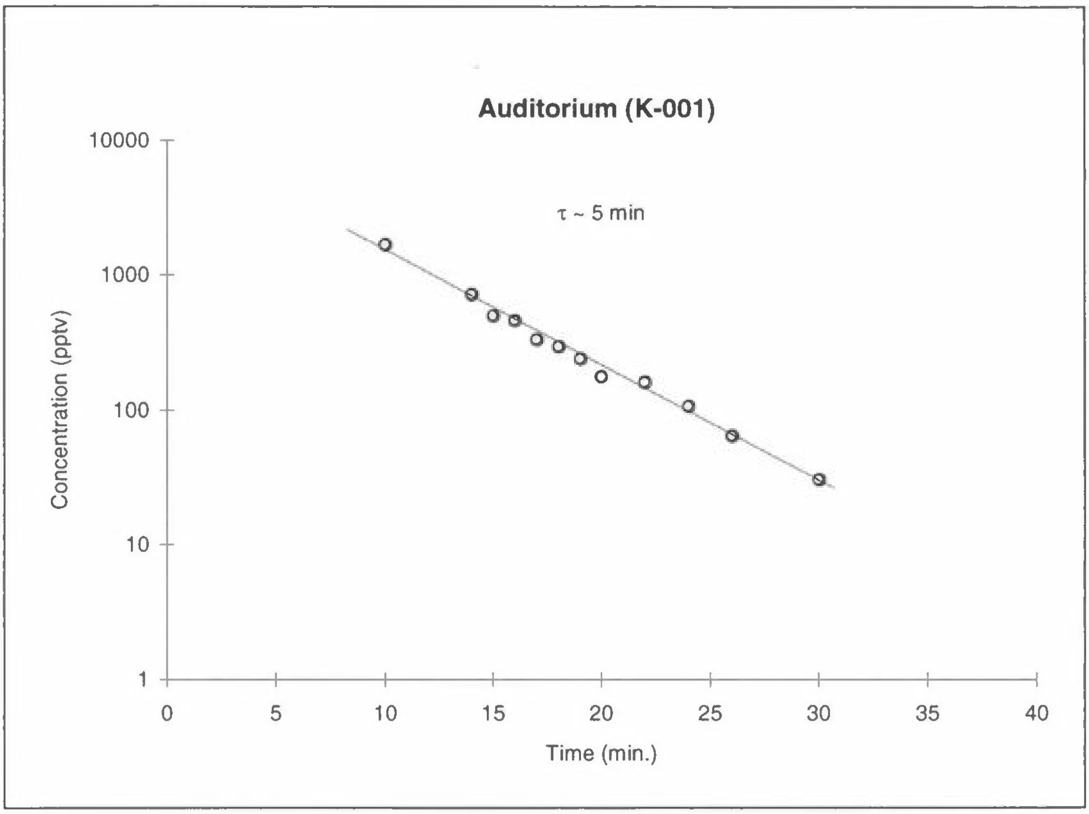

Figure 4: Concentration decay versus time for the auditorium.

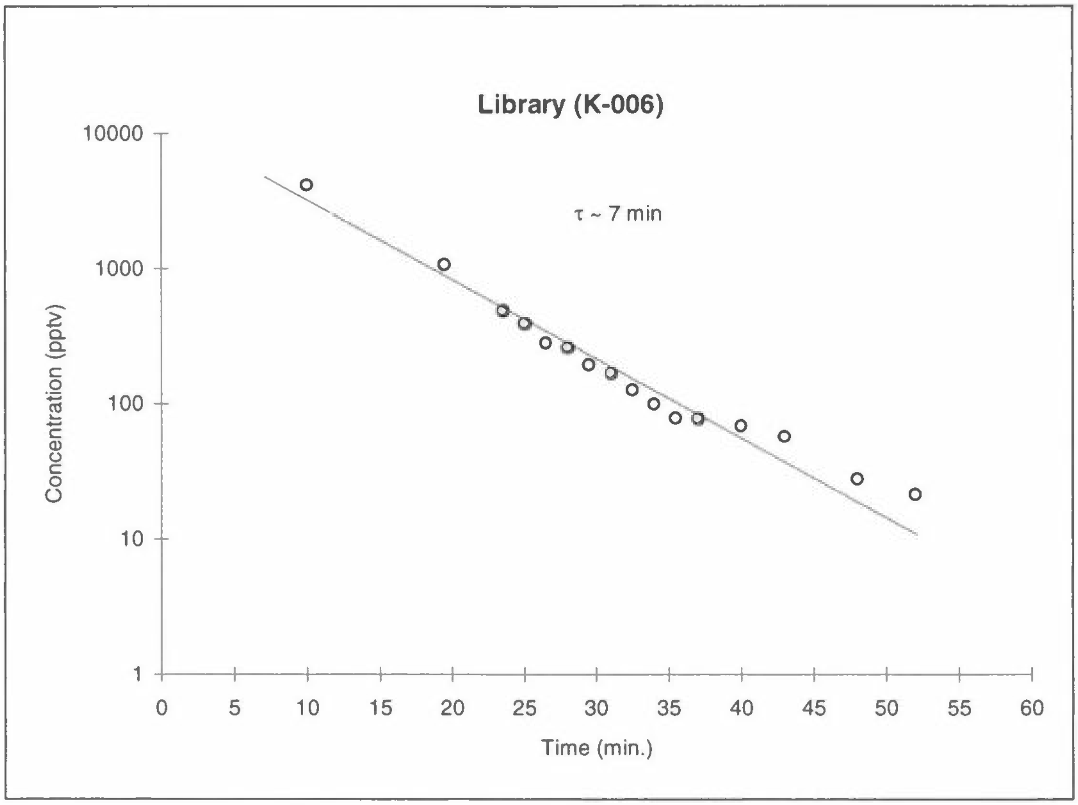

Figure 5: Concentration decay versus time for the library.

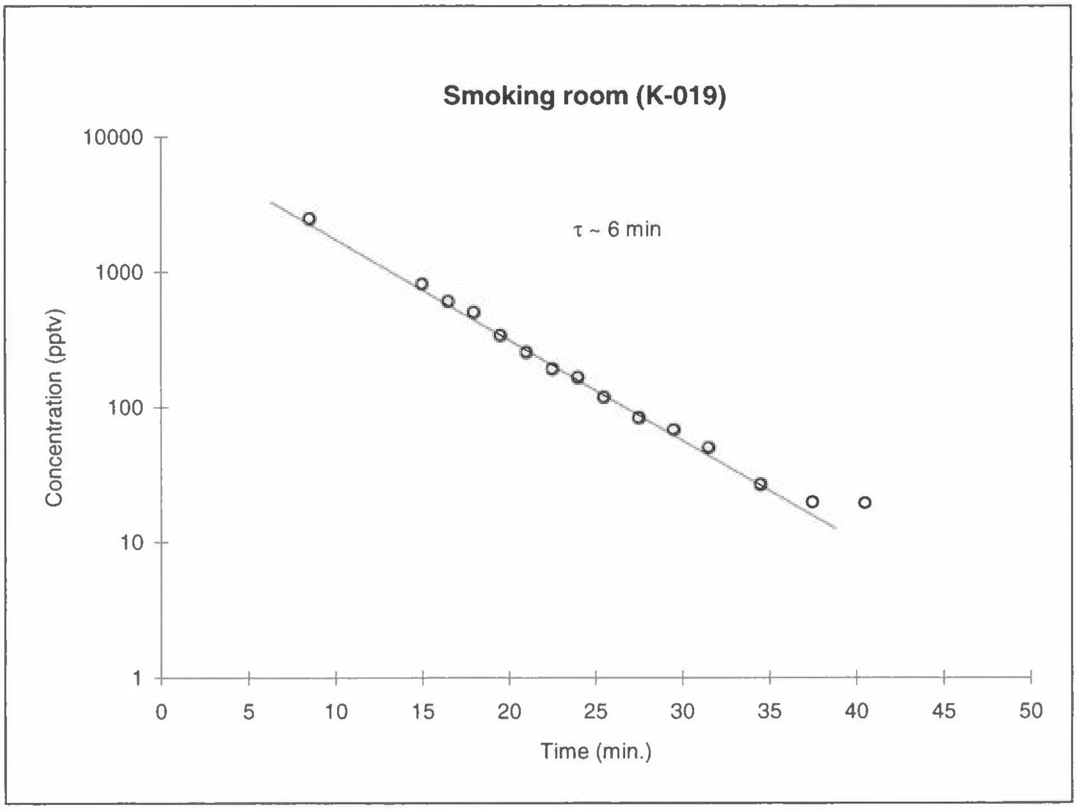

Figure 6: Concentration decay versus time for the smoking room.

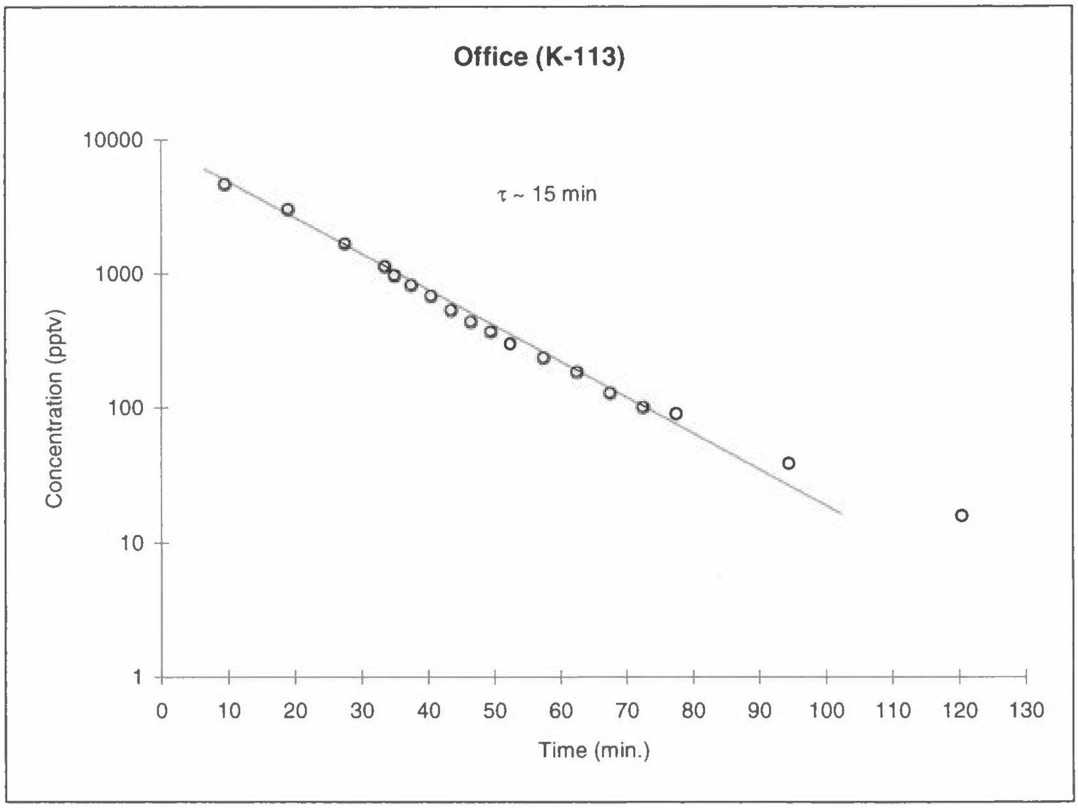

Figure 7: Concentration decay versus time for an office (K-113).

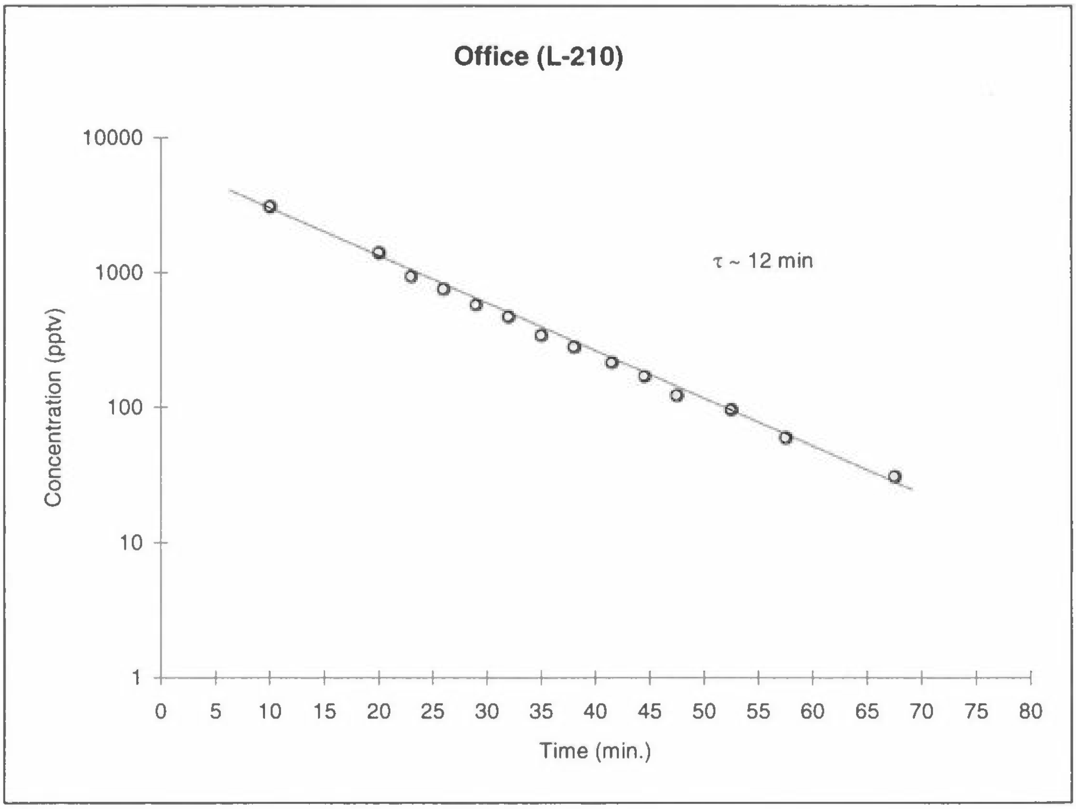

Figure 8: Concentration decay versus time for an office (L-210).

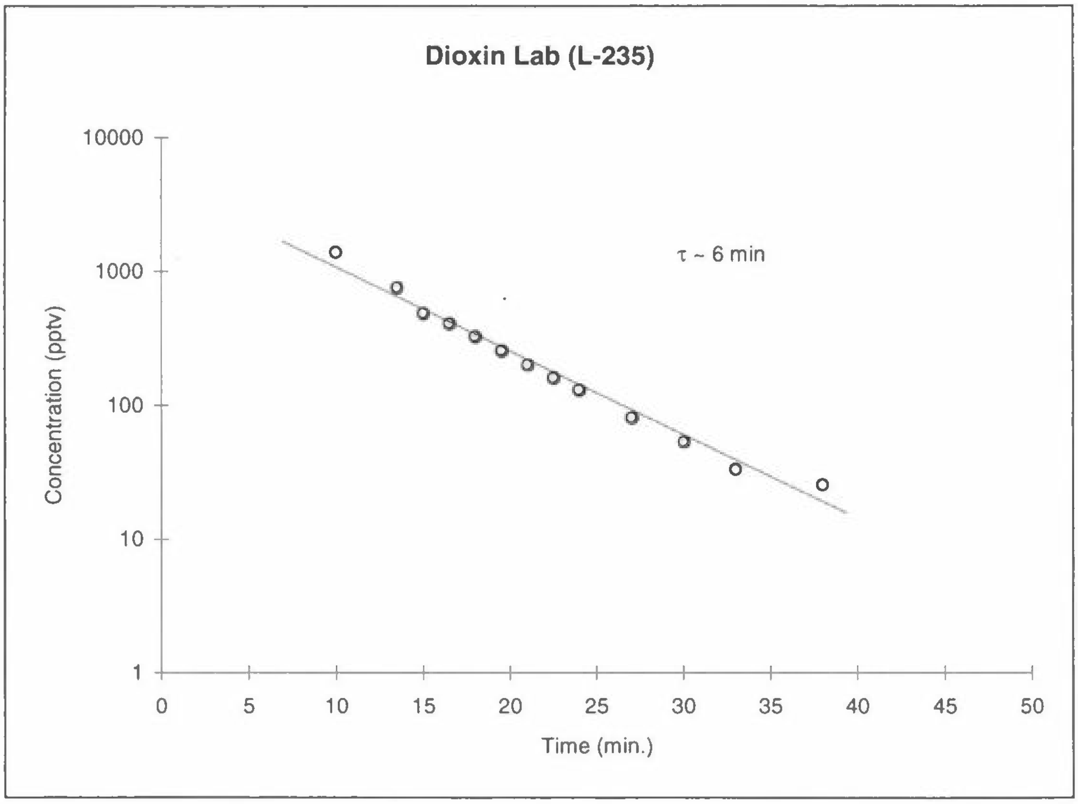

Figure 9: Concentration decay versus time for the Dioxin Laboratory.

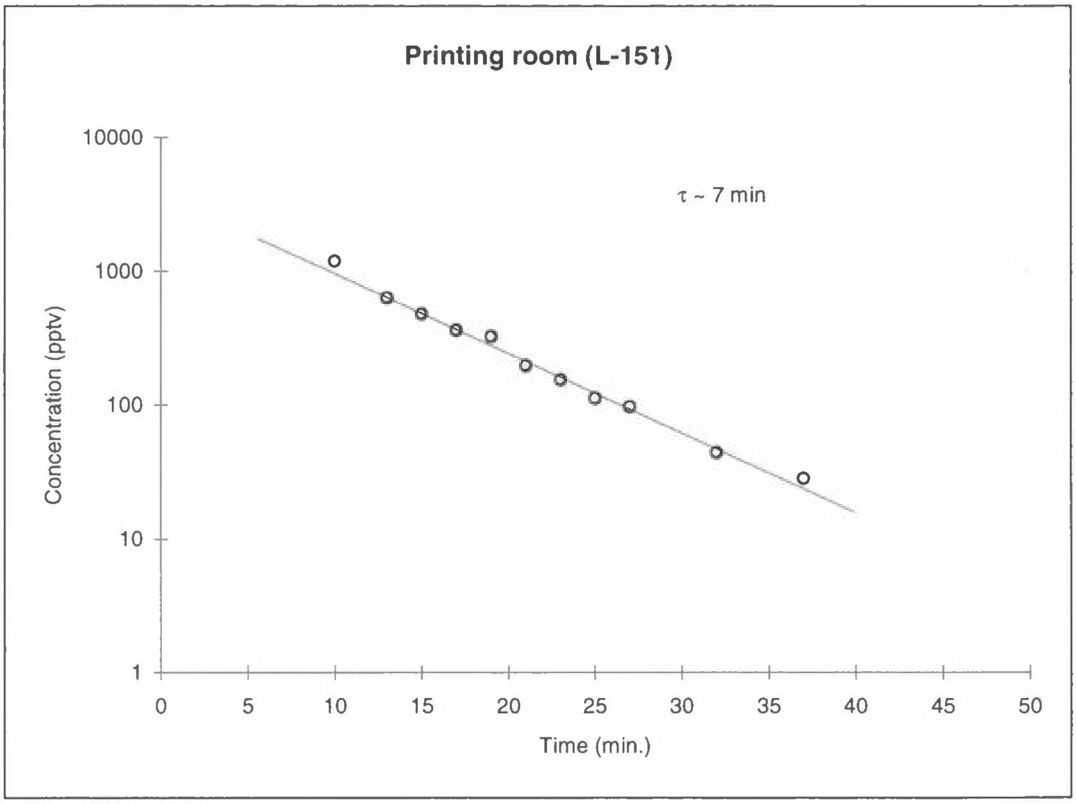

Figure 10: Concentration decay versus time for a printing room.

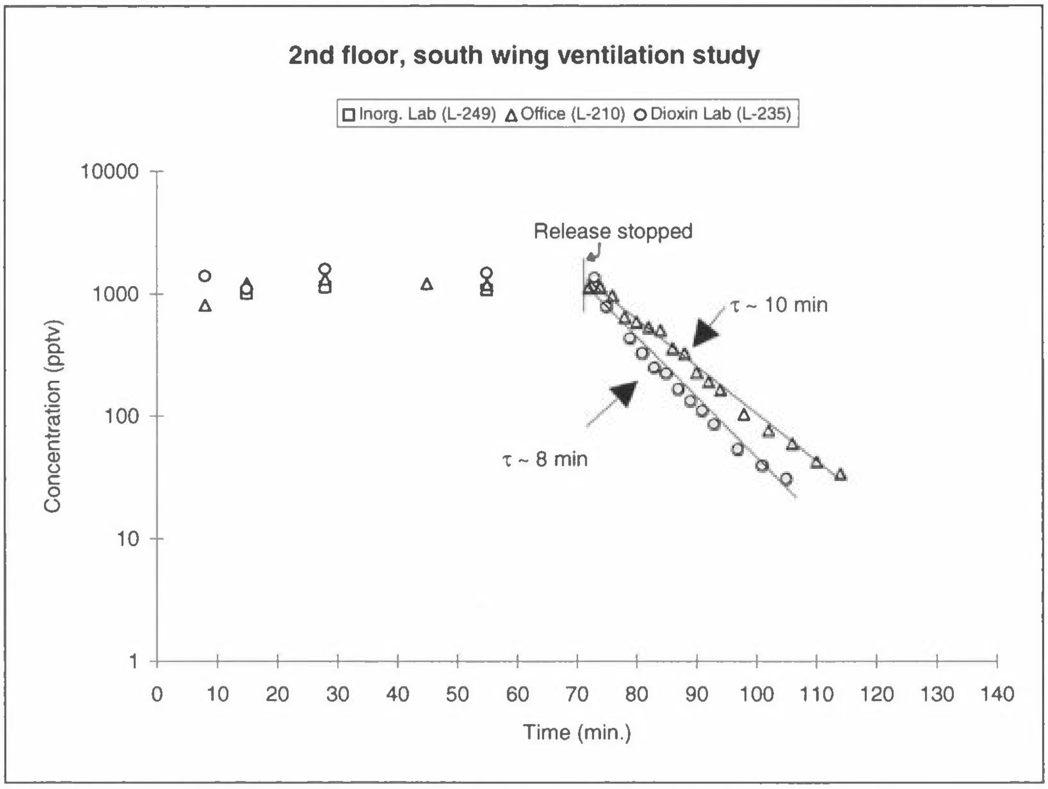

Figure 11: Concentration decay versus time for the 2nd floor, south wing ventilation study.

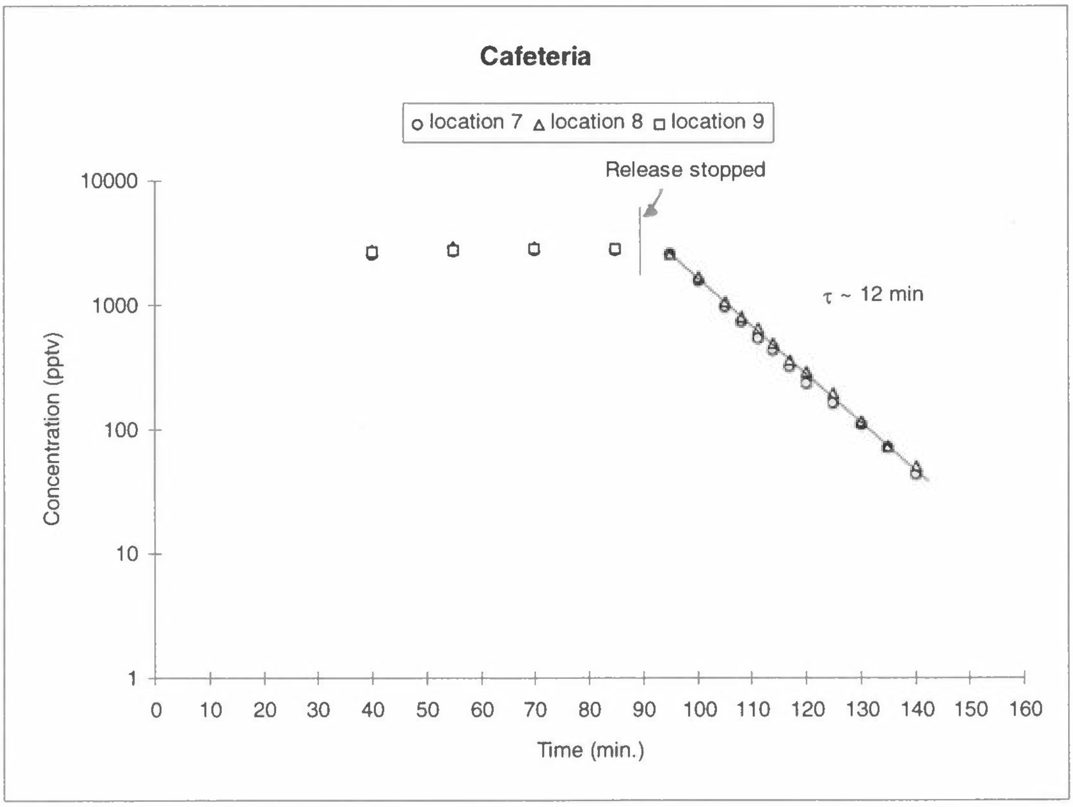

Figure 12: Concentration decay versus time for the cafeteria.

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REPORT SERIES	REPORT NO. TR 15/94	ISBN-82-425-0613-2	
TECHNICAL REPORT			
DATE 12.11.94	SIGN. [signature]	NO. OF PAGES 15	PRICE NOK 30.-

TITLE

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PROJECT LEADER

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NILU PROJECT NO.

E-94050

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CLASSIFICATION *

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CLIENT'S REF.

CLIENT

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ABSTRACT

This report describes a tracer study of the ventilation system in NILU's new building. The tracer SF_6 is used to measure the air exchange in selected rooms and in two of the five ventilation subsystems in the building. Air exchange rates calculated from the tracer data are compared with values reported by the ventilation contractor.

NORWEGIAN TITLE

Sporstoffundersøkelse av ventilasjonsanlegget i NILUs nybygg.

DESCRIPTORS

ABSTRACT (in norwegian)

Rapporten beskriver en sporstoffundersøkelse av ventilasjonsanlegget i NILU's nybygg. Ved hjelp av sporgassen SF_6, ble luftutskiftningen målt i utvalgte rom og i to av fem undersystemer av ventilasjonsanlegget. Hastigheten av luftutskiftningen beregnet fra sporstoffdata ble sammenlignet med verdier fra ventilasjonsfirmaet.

** Classification* | |
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| *A* | *Unclassified (can be ordered from NILU)*
| *B* | *Restricted distribution*
| *C* | *Classified (not to be distributed)*