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EXPERIMENTAL RESULTS OF JAERI IN
THE CANADIAN HT FIELD RELEASE
STUDY OF JUNE 10, 1987

November 1988

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Experimental Results of JAERI in the Canadian HT
Field Release Study of June 10, 1987

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(Received October 26, 1988)

A tritium gas (HT) release study was performed in Chalk River Nuclear Laboratories, Ontario, Canada, on June 10, 1987. About 3.5×10^{12} Bq (96 Ci) of HT gas was released to an experimental field over 30 minutes from an outlet placed at 1 m height from the ground surface. Scientists from six countries (Canada, France, Germany F. R., Japan, Sweden, U.S.A.) participated in the study.

From measurements of air, soil and pine needle samples collected during the extended period of 5 days after initiation of the HT release, the following findings were obtained.

The observed HT concentrations in the air during the release period along the field centerline agreed well with those predicted by the Gaussian Plume Dispersion Model.

HT gas was deposited in the soil through diffusion into the soil and conversion to HTO by microbial activity therein.

Rapid conversion of HT to HTO in the atmosphere was not found.

After the HT release, the HTO concentration in the atmosphere remained elevated for a long time due to HTO resuspended from the soil and

+ Department of Environmental Safety Research

vegetation.

The concentration ratio of HTO to HT in the air during the release period tended to increase with downwind distance and was 4.1×10^{-4} at 400 m.

Exposure doses from the time-integrated HT and HTO air concentrations at 100 m downwind were equal each other about 10 minutes after the end of the HT release.

An HTO diffusion passive sampler using 20 ml ethylene glycol was shown to be a useful tool to measure the time-integrated HTO air concentration within a sampling period of six hours.

Soil measurements showed that HT gas was deposited in the soils as HTO, mostly in the top 5 cm soils and its deposition velocities to the soils ranged from 1.6×10^{-4} to 3.0×10^{-4} m/s. A low deposition velocity of $<1.0 \times 10^{-5}$ m/s was measured for the silty loam with low microbial activity. The deposition velocities for the coarse sands were comparable to those for the very fine sandy loam. The deposition velocities for resuspended HTO to the silty loam, ethylene glycol and water were 2.4×10^{-2} , 1.5×10^{-2} and 2.3×10^{-2} m/s, respectively. These values are quite similar each other although the materials were different. The precipitation of 11 mm remarkably lowered the tritium deposit in the top 5 cm soils, especially in the coarse sands, and HTO concentrations in the air by more than one order of magnitude. The top 5 cm of the very fine sandy loam still contained 71 % of the total deposit after the rain. The HTO in the soils disappeared at the loss rates of 1.3 - 4.7 %/h (0 to 49 hours) and 0.47 - 2.1 %/h (0 to 116 hours) for the 0 - 10 cm soil and 2.1 - 7.2 %/h (0 to 49 hours) and 0.55 - 2.5 %/h (0 to 116 hours) for the 0 - 5 cm soil. The 0 - 10 cm loss rates for the loam and sand did not differ significantly, but the 0 - 5 cm ones for the sand were about two times higher than those for the loam.

Pine needle measurement showed that HT deposition was negligible as compared with HTO deposition. Due to deposition of air HTO, the tissue-free-water-tritium concentration increased with time and reached a peak concentration in 5 hours. This fact suggested that vapor exchange between air and vegetation was an important process. Uptake of HTO by roots was seen from about 50 hours after the end of the HT release. The HTO concentrations in the tissue-free-water of pine needles and air moisture tracked those in the soil water and at all times were lower than HTO concentrations in the soil water. The deposition velocity for HTO to

the pine needles was 2.4×10^{-4} m/s.

Keywords: HT, HTO, Behavior, Field Experiment, Deposition, Conversion,
Resuspension, Dispersion

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カナダにおけるトリチウムガス野外環境
放出実験（1987年6月）（原研の成果）

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（1988年10月26日受理）

1987年6月1日から約3週間にわたって、カナダ・チョークリバー原子力研究所（CRNL）敷地においてトリチウムガス野外環境放出実験が6カ国（Canada, France, Germany F.R., Japan, Sweden, U.S.A.）の協力のもとに行われた。

6月10日の15時20分から30分間にわたって 3.5×10^{12} Bq（約96 Ci）のトリチウムガス（HT）が高さ1 mの放出口から実験場に向けて放出された。HTガスの放出後、5日間にわたって採取した空気、土壌、松葉、雨水サンプル中のトリチウム濃度の測定から、トリチウムの環境中移行を解明するうえで重要な以下の事柄が明らかになった。

HTガスの風下主軸方向の濃度拡散は、従来から濃度計算に用いられているガウスプルームモデルによって十分に予測できることが確認された。HTが空気中を通過している間におけるHTOへの転換は認められなかった。HTガスはプルームの通過中に土壌に拡散し、微生物の作用によってHTOに転換し土壌中に沈着した。HTプルームの通過後においても、土壌からおよび植物を通じて大気中に放散されるHTOによって、空気中のHTO濃度が長期間にわたり上昇した状態に保たれることが分かった。HTプルーム中のHTO/HT濃度比は風下距離とともに増加する傾向があり、400 m地点では 4.1×10^{-4} であった。風下100 m地点におけるHTとHTOの積算濃度の被曝線量への寄与は、放出終了10分後には同程度となった。このことから、土壌への沈着とそれに続く放散が重要な被曝源となることがわかった。雨（11 mm）は、空気中のHTO濃度を1桁以上にわたって低下させた。

土壌に沈着したHTOの大部分は初期には表層5 cmの土壌中に留まっていた。土壌への沈着速度は 1.6×10^{-4} から 3.0×10^{-4} m/s の間にあり、シルト質ロームと砂の間で沈着速度の有意な差は認められなかった。雨は、砂層表面（5 cm）におけるHTOを下層に向けて

大きく移動させたが、細砂ローム土壌では雨後にも71%がなお表層5cmに残留していた。土壌からのHTOは時間に関して指数関数的に消失し、消失率は0-10 cm層で見ると、1.3-4.7%/h(0-49時間の平均)、0.47-2.1%/h(0-116時間の平均)、また、0-5 cm層で見ると、2.1-7.2%/h(0-49時間の平均)、0.55-2.5%/h(0-116時間の平均)であった。この場合、砂の消失率のほうが約2倍程度大きかった。また、土壌から空気中に放散したHTOの土壌、エチレングリコールおよび水への再沈着を調べた結果、沈着速度は物質の違いにもかかわらず、それぞれ 2.4×10^{-2} 、 1.5×10^{-2} 、 2.3×10^{-2} m/sと極めて近い値であった。

HTガスが環境モニタリングの指標物質である松葉に直接沈着する現象は認められなかった。松葉組織自由水中のHTO濃度は5時間程度まで急速な増加が見られた。このことは、空気中のHTOが水蒸気交換等によって植物に取り込まれる過程が重要であることを示していた。根からの吸収と思われる濃度上昇は50時間後から認められた。松葉自由水中および空気中湿分中のHTO濃度は、土壌水中のHTO濃度の変化傾向に追従し、全期間を通して、土壌水中の濃度を越えることはなかった。HTOの松葉への沈着速度は 2.4×10^{-4} m/sであった。

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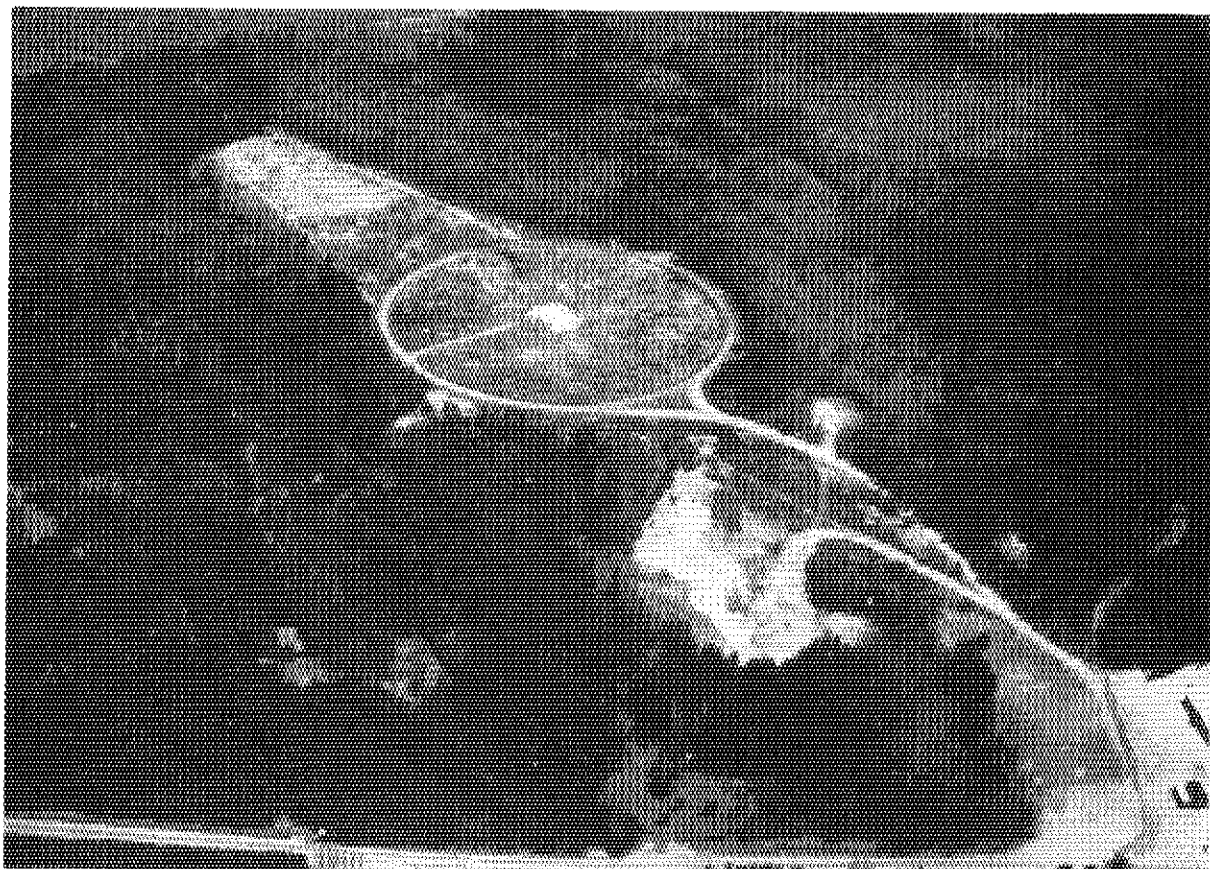
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実験場全景写真



Aerial view of experimental field at CRNL

I. INTRODUCTION

Atmospheric dispersion and dose calculations for acute releases of tritium oxide and tritium gas present two problems not normally encountered with similar calculations for other radioisotopes. Airborne tritium oxide (HTO) deposits on soil and vegetation and may resuspend into the air later resulting in increased air concentrations. Tritium gas (HT) deposits on to the soil, is converted into the oxide form by enzymes therein and may resuspend into the air. The HTO dose factor is approximately 10^4 times greater than that for HT on a per becquerel inhaled basis. Therefore, the radiological consequences of conversion and resuspension are significant and must be included in any calculational model used for acute tritium dispersion /1/.

To construct and validate models for the assessment of the impact of tritium gas (HT) releases, it is essential to investigate the fate of HT after release to the environment. Field chamber experiments /2/ and the Chalk River pilot experiment in August 1986 /3/ revealed that direct atmospheric conversion of HT to tritiated water (HTO) is slow and that the dominant process for formation of atmospheric HTO is the conversion of HT to HTO by microbes in surface soil, followed by HTO reemission. A key conclusion from the Chalk River pilot study was that future effort should be directed towards quantifying these processes and establishing their dependence on environmental factors.

On the basis of discussion at the planning meeting held at Chalk River Nuclear Laboratories (CRNL) in October 1986 for the present HT release experiment in the environment at Chalk River, the following objectives of this experiment were proposed:

- to establish a firm international consensus on rate of appearance of atmospheric HTO from a release of HT,
- to enable more extensive studies of the deposition, reemission and dispersal processes by scientist with a wide range of expertise,
- to obtain a common data base for validation of models describing the environmental transport of tritium, and
- to test and inter-compare sampling and analysis equipment and techniques.

Scientists from six countries (Canada, France, Germany F.R., Japan, Sweden and U.S.A.) participated in the field experiment at Chalk River. The participants are listed in Table I .1. The study was organized by Dr. C. D. Burnham, Canadian Fusion Fuels Technology Project (CFFTP), and Dr. R. M.

Brown, CRNL, took the lead in arrangement of the experiment.

Japan Atomic Energy Research Institute (JAERI) participated in the Canadian HT release study of June, 1987. JAERI participation focused on (1) HT and HTO deposition velocities to soil and reemission of HTO from soil, (2) evaporation rates of soil water, (3) HT and HTO deposition velocities to pine needles, and (4) the comparison of measured HT concentrations in air with those predicted by the Gaussian Plume Dispersion Model.

This report describes the detailed experimental methods and the results of JAERI. The experimental methods and the results of the dispersion of HT and formation of HTO in the atmosphere, soil and pine needles are described in section II, and of the transfer of tritium in soil in section III.

A summary report of the experimental results of JAERI will be published in Fusion Technology /4/. A summary report of the whole results obtained by all the participant countries in the Canadian HT field release study will be issued both as an individual document and as an introduction to a data report which will include all the participant reports.

Table I.1 List of Participants in the Canadian HT field experiment

Name	Country	Organization
C. Burnham	Canada	Canadian Fusion Fuels Technology Project (CFFTP)
M. Wong	"	"
G. Ogram	Canada	Ontario Hydro Research Division (OHRD)
F. Spencer	"	"
C. Donovan	"	"
L. Sheehan	"	"
R. Brown	Canada	Atomic Energy of Canada Limited Chalk River Nuclear Laboratories (CRNL)
P. Barry	"	"
B. Robertson	"	"
R. Gentner	"	"
D. Wildsmith	"	"
W. Workman	"	"
Z. Franic	"	(attached) "
C. Ohno	"	(summer student) "
M. Yoshida	"	(attached) "
H. Djerassi	France	Commissariat a l'Energie Atomique
J. Guenot	"	"
A. Beneito	"	"
M. Brossard	"	"
P. Paillard	"	"
B. Wiener	Germany F.R.	Niedersachsisches Institute fur Radio - Okologie an der Universitat Hannover
M. Taschner	"	"
H. Forstel	"	Institute fur Radioagronomie Kernforschungsanlage GmbH
H. Hutzen	"	"
W. Gulden	"	Max - Planck - Institute fur Plasmaphysik
M. Murata	Japan	Japan Atomic Energy Research Institute
H. Noguchi	"	"
T. Matsui	"	"
O. Edlund	Sweden	Studsvik Energiteknik AB
A. Kronberg	"	"
R. Jalbert	U.S.A.	Los Alamos National Laboratory
C. Murphy	"	E. I Dupont de Nemours Company Savannah River Laboratory
O. Griesbach	"	Princeton Plasma Physics Laboratory

II. Dispersion of HT and Formation of HTO in the Atmosphere, Soil and Pine Needles

Mikio MURATA, Hiroshi NOGUCHI, Tomoaki MATSUI,
Tsutomu OHHATA, Minoru OHKOSHI, Kazunari SEKI
and Jun AKAISHI

1. Experimental Method

1.1 Experimental field

The experimental field, as shown in Fig. II .1, is located in a forest about 6 km from the Chalk River Plant /5/. The field layout is shown in Fig. II .2 The field consisted of a grassy circular field of 183 m diameter and a sparsely vegetated field of 226 m long.

The soil texture of the JAERI core sampling sites was sand-fine sand* (Silty loam**) at site B (X = 100 m, Y = -10 m), and sand-fine soil with gravel* (sand**) at site E (X = 394 m, Y = 0 m). For 0 to 20 cm soil core, the water contents ranged from 22 to 24 % at site B, and 2.3 to 3.3 % at site E. The soil properties measured by JAERI is shown in Table II .1.

The soil texture is also examined extensively by Canada team /8/. The soil texture of the field ranged from a very fine sandy loam to silty loam between 5 m and 183 m from the release point, a coarse sandy loam to coarse sand from 183 to 409 m, and a fine sandy loam at 426 m in the forest, Table II .2. The absence of topsoil was reflected in the very low organic content of 0.2 % at 400 m compared to a normal range, 2.1 to 3.0 %, for 0 to 22 cm depth cores at other distances. For 0 to 22 cm soil cores the water content ranged from 11.2 % to 29.4 %, except at 400 m where the water content was 1.6 % due to low organic content and coarse texture. The top 0 to 2 cm soil layer at 43 m was high in organic matter, 7.9 %. Soil pH was acidic at all sites ranging from 4.8 to 5.7 /8/.

As shown in Table II .3 on June 8, 1987 the dominant vegetation cover of this central field area included common grasses (Danthonia spicata L. and Poa compressa L.), the herbs orange hawkweed (Hieracium aurantiacum L.) and strawberry (Fragaria sp), moss (Polytrichum sp) and large-toothed aspen

* Classified according to Japanese Standard JSF M1-1973 (79), (1979).

** Classified according to American Standard ASTM D-3282-73 (1979).

(Populus grandidentata Michx.) saplings. Beyond 200 m and out to 400 m the open field consisted of a coarse sandy soil (top soil removed) sparsely covered (> 75 % bareground) with large-toothed poplar saplings, sweet fern (Myrica asplenifolia L.) and a few herbs and grasses. The field was bordered by coniferous and deciduous forest with red maple (Acer rubrum, L.), large-toothed aspen, jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.) and white pine (Pinus strobus L.) as the major species /8/.

1.2 Sampling items and locations

JAERI's samplers for HT and HTO in air were located at distances of about 50, 100 and 400 m from the HT release point along the field centerline; hereafter these sites are referred to as AS(1), AS(2) and AS(3), respectively. Soil cores were taken at distances about 50, 100, 200, 300 and 400 m; hereafter these sites are referred to as A, B, C, D and E. Diffusion passive samplers for HT and HTO were located at 29 and 30 points in the field, respectively. Evaporation rates of soil water were measured at distance of 100 m. At the coniferous forest located at the end of the field (409 m), pine needles were taken from red pines.

Figure II.2 shows locations of tritium air samplers, HT and HTO diffusion passive samplers, an evaporation measuring apparatus, and soil core and pine needle sampling. Table II.4 summarizes sampling items and time. The time elapsed is expressed by "H + hh" hours in tables, figures and a text. H refers to the time at which the HT release began: 1520 (EDT), June 10, 1987. The coordinates of sampling and measuring points are shown in Table II.5.

1.3 Air HT and HTO measurement with air samplers and diffusion passive samplers

Two different types of air samplers were used to collect HT and HTO in air: low volume air samplers mainly for HT measurement and high volume ones mainly for HTO measurement.

1.3.1 Low volume air sampler

Four low volume air samplers were used in the field. Figure II.3 is a schematic of the sampler. It consisted of an adsorbent column, a pump, batteries and a wet rotary gas meter. A small electrolysis cell containing about 200 ml of 13 % NaOH solution was mounted at an inlet of air. This cell released H₂ to give a concentration of 0.4 % in the air to ensure the oxidation of HT. The adsorbent column was sectioned into four small traps

with glass wool separators. The first two traps respectively contained 40 and 10 g of Molecular Sieve 4A (MS trap) to collect HTO in air. The second two traps respectively contained 40 and 10 g of PdCl₂-loaded Molecular Sieve 4A (Pd-MS trap) to oxidize HT and H₂ and then collect resulting water.

At sites AS(1), AS(2) and AS(3), sample air was pumped at a rate of 1 ℓ/min at a height of 1 m for the first sampling period from H-0.4 to H + 0.7 hours including the HT release duration. The same procedure was carried out with fresh columns at sites AS(2) and AS(3) for the second sampling period from H + 0.7 to H + 1.8 hours.

For tritium measurement, the contents (40 and 10 g) of each trap were soaked in 40 and 20 ml of low-tritium water in bottles, respectively. The bottles were shaken and allowed to stand one week. The supernatant water of 1 ml was taken for counting.

1.3.2 High volume air sampler

Two high volume air samplers operated by 110 volt AC were used to collect air HT and HTO, and were intended mainly to collect a sufficiently large water sample even at low relative humidity conditions. Figure II .4 is a schematic of the high volume air sampler. The air sample was drawn through a MS trap (500 g), a Pd-MS trap (470 g) and a MS trap in series during the release period. For the second sampling, two MS traps were placed before a Pd-MS trap because a high concentration of HTO was expected. For the subsequent sampling, one or two MS traps were used for HTO collection from the air sample. The electrolysis cell was not used in this sampler.

A flow rate of the sampler was chosen between 2 and 30 ℓ/min depending on sampling duration.

For tritium measurement, all the water collected on the MS and Pd-MS traps was recovered by heating the traps at 450 °C, sweeping the water vapor with dry nitrogen gas at a rate of 0.8 ℓ/min, and then collecting the water in a cold trap. To ensure complete recovery of the HTO, 10 ml of low-tritium water were added to the MS and Pd-MS traps when the amount of water trapped was less than 5 g.

1.3.3 Diffusion passive samplers

In order to estimate time-integrated HTO air concentrations over the experimental field, diffusion passive samplers using ethylene glycol were placed at 30 locations on the ground surface. As shown in Fig. II .5(a), a small plastic container (6 cm diameter) containing 20 ml ethylene glycol was

placed in a large plastic container (13 cm diameter) to exclude rain. The wall of large container was perforated to permit air to diffuse into ethylene glycol. Twenty eight samplers were placed on the ground surface and two samplers at two different heights, 0.5 and 2 m from the ground surface (see Fig. II .2).

Pd-MS diffusion passive samplers were on trial used to observe distribution of time-integrated HT air concentration in the field during the release period. Figure II .5(b) is a schematic of the sampler. Pd-MS (26 g) was packed in a thin cylinder (10 cm diameter) both sides of which were covered with 40 mesh wire gauzes. Twenty nine samplers were placed close to the locations of the ethylene glycol passive samplers at a height of 40 cm from the ground surface.

To extract tritium, the Pd-MS from the diffusion passive sampler was soaked in 50 mℓ of low-tritium water in a bottle. The bottle was shaken and allowed to stand one week to allow complete exchange.

Pd-MS was prepared as follows in JAERI:

A solution in a 100 mℓ beaker was made of 1.50 g of dry PdCl₂ in 16.8 mℓ of 1N HCl. Distilled water of 10 mℓ was added while stirring and warming on a magnetic stirrer until a clear, reddish-brown solution was obtained. The solution was cooled to room temperature and transferred to a 50 mℓ measuring cylinder to adjust the volume to 40 mℓ. The entire solution was quickly poured onto 120 g of Molecular Sieve 4A in a 500 mℓ separatory funnel. Vigorous shaking was begun immediately by hand. Shaking was continued without interruption while part of the water boiled off. The freshly prepared catalyst was predried in a muffle furnace heated at 350 °C for three hours. The catalyst filled in the glass tube was dried by heating at 500 °C for four hours. To activate the catalyst, hydrogen gas was passed through the tube at a flow rate of 0.3ℓ/min under heating at 500 °C for eight hours and then the catalyst was dried by heating at 500 °C for one hour.

1.4 Pine needle measurement

To measure the direct deposition of air HT to pine needles, bare pine needle samples were harvested from red pines standing in the forest near site E. In order to observe only uptake of HTO, the samples were taken from branches which were covered with plastic bags during the release period to avoid HT deposition and then uncovered to allow exposure to air HTO. In addition, to observe uptake of HTO by roots, the samples were also taken from branches which were covered to avoid HT and HTO deposition until immediately

before sampling.

Tissue-free-water of pine needles was extracted from about 50 g of pine needles by azeotropic distillation with toluene in the laboratory of CRNL on the day following the sampling.

1.5 Evaporation measurement of soil water

Evaporation rates of soil water were measured near site B by energy budget with Bowen's ratio method /7/. The apparatus, as shown in Fig. II .6, was composed of two hygrometers which were set in screens at height of 0.75 and 2.1 m, a soil heat flux plate buried at 2 cm underground and a net radiometer at 1.5 cm height. The evaporation rate was estimated as follows.

The energy balance equation at the surface can be written as

$$R - G = LE + H \quad (1)$$

where R is the net radiation, G the soil heat flux, L the latent heat for vaporization (=2417 J/g), E the evaporation rate, LE the latent heat flux, and H the sensible heat flux.

The ratio of H to LE called Bowen's ratio (β) was used for the determination of H. The ratio is described by

$$\beta = H/LE = \gamma (K_H \partial T / \partial Z) / (K_E \partial e / \partial Z) \quad (2)$$

where γ is the psychrometric constant (=0.509 mmHg/°C), K_H the turbulent diffusivity for heat, K_E the turbulent diffusivity for water vapor, and Z the height. Since K_H approximately equals K_E , equation (2) is reduced to

$$\beta = \gamma (T_1 - T_2) / (e_1 - e_2) \quad (3)$$

where subscripts, 1 and 2, refer to lower and higher levels of temperature and vapor pressure measurements, respectively. Temperature and relative humidity which were measured at two different heights (0.75 and 2.1 m) at site B were used to calculate Bowen's ratio. The following equation obtained from equations (1) to (3) was used to calculate the evaporation rate.

$$E = (R - G) / \{L(1 + \beta)\} \quad (4)$$

1.6 Liquid scintillation counting

Air, soil and vegetation HTO were measured in the JAERI laboratory by liquid scintillation counting. When the volume of recovered water was over 8 ml, 8 ml of the sample water were counted in 12 ml of Aquasol-2. A low level counter having a background of 5.8 counts/min was used. The counting time was usually 60 minutes, giving a lower measurement limit (2 sigma) of 2.0 counts/min. Ethylene glycol of 1 ml taken from the HTO diffusion passive sampler was counted with 1 ml of ethanol in 15 ml of Aquasol-2.

2. Results

2.1 Release of HT gas and meteorological conditions

About 3.5×10^{12} Bq (96 Ci) of tritium as HT was released at 1 m height for 30 minutes using a HT release system (Appendix II -1) /8/. The release started at 1520 hours on June 10, 1987. Details of the meteorological conditions during the release period measured by the CRNL team are given in Table II .6 /6/. The mean wind speed was 2.3 m/s at 1 m height and the mean wind direction was about 20° off the field centerline towards north (264° to 301°, mean 281°). During the evening and through most of the following day when additional air and vegetation measurements were made, the wind direction did not markedly change, remaining within 240° and 340°. The wind speed maintained 2 - 3 m/s except at night (2130, 10 June, to 0800, 11 June) when it dropped to < 1 m/s. During the HT release, the temperature and relative humidity measured at site B (100 m from the release point) were about 21°C and 34%. Diurnal variations of temperature and relative humidity from 1200 hours on June 10 to 0600 hours on June 12 measured at site B are presented in Appendix II .2. Light rain began to fall at about 1500 hours of the second day (June 11) continued intermittently to at about 1400 hours on June 12 with a precipitation of 11 mm. Tritium concentrations in rain water are shown in Table II .7.

2.2 Dispersion of HT in the atmosphere

Figure II .7 shows the air HT concentration variation with time during the plume passage measured by an ionization chamber placed 6 m downwind of the release point and 1 m above the ground surface /6/.

Instantaneous concentration fluctuated widely due to change of wind direction. In spite of those fluctuations, samples integrated over the release period indicated that good coverage of the experimental sites on the field was achieved.

Air samplers were manually started at $H - 0.4$ hour and stopped 6 to 10 minutes after the end of the release ($H + 0.60$ to $H + 0.67$) for the first air sampling. In Table II .8, values are given of the time-averaged air concentration of HT and HTO during the release period measured at sites AS(1), AS(2) and AS(3) at 1 m height. The air concentrations of HT for the second sampling ($H + 0.63$ to $H + 1.75$ hours) are shown in Table II.9. The HT still remained in the atmosphere in the field after the end of the release. However the concentrations were two orders of magnitude less than those

measured during the release period. The results of air sampling are presented in Appendix II .3.

In Fig. II .8, The observed HT air concentrations at 1 m height along the field centerline are plotted against distance from the release point together with the CRNL's data /6/ and the concentrations predicted by the Gaussian Plume Dispersion Model. A following fundamental equation was used for concentration calculation /9/.

$$\chi(x, y, z) = \frac{Q}{2\pi \cdot \sigma_y \cdot \sigma_z \cdot U} \cdot \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \cdot \left[\exp\left\{-\frac{(z-H)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(z+H)^2}{2\sigma_z^2}\right\}\right] \quad (5)$$

χ : concentration (Bq/m^3)

Q : release rate (Bq/s)

U : average wind speed (m/s)

σ_y, σ_z : standard deviation of cloud width in horizontal y-direction and vertical z-direction (m)

H : height of emission (m)

In this calculation the atmospheric stability of class B was assumed and the five-minutes average wind speeds at 1 m height and directions shown in Table II .6 were used. The observed concentrations of JAERI were in good agreement with CRNL's ones and also the predicted ones. Details of concentration calculation is described in Appendix II .4

2.3 Atmospheric HTO resuspended from soil and vegetation

From the air measurements, it appeared that after the HT release, the HTO concentration in the atmosphere remained elevated for a long time. Figure II .9 shows the time variations of the time-averaged HTO air concentrations measured at sites AS(1), AS(2) and AS(3) until H + 115 hours. At site AS(2), the concentrations rapidly increased with time until 1300 hours on June 11 (H + 22 hours). At site AS(3), however, the concentration was almost constant during the period of 22 hours. When the rain started at 1500 hours on June 11, the HTO air concentrations markedly decreased by more than one order of magnitude. After stop of the rain, the concentrations gradually increased again. Time-integrated HTO air concentrations are summarized in Table II .10.

2.4 Ratios of HTO/HT in the air

The ratios of HTO to HT in the air during the release period are shown in Table II .8. The ratio tends to increase with distance as shown in Fig. II .10. The results had the same tendency as those of the previous experiment /3/. The oxidation rate in the atmosphere of 0.85 %/h may be calculated from the measured HTO/HT ratio at AS(3) and the mean wind speed (2.3 m/s), assuming that HTO is produced by oxidation of HT only in the atmosphere. The second air sample at AS(3) taken after the end of the release (H + 0.7 to H + 2.5 hours), however, showed the same level of HTO concentration as that measured during the release period (see Fig. II .9). This fact suggests that most of the HTO in the air during the release period originated from the soil and vegetation HTO. Therefore it is considered that the oxidation rate in the atmosphere is far smaller than 0.85 %/h.

The ratios of the accumulated HTO air concentration (in Table II .10) to the HT air concentration integrated during the HT release period are plotted against time after the HT release in Fig. II .11. The ratio at H + 0.62 hour at 100 m is about 6×10^{-5} , meaning that contributions to doses of HT and HTO almost equal each other because a ratio of derived air concentration (DAC) of HTO to that of HT is 4×10^{-5} according to ICRP 30. In the figure, the ratios at 400 m are large compared with those at 100 m. In addition, both the ratios at 100 and 400 m increased with time. These results indicate that the dose from resuspended HTO become dominant for long term inhalation than the dose from the original HT plume. For instance, if person is exposed to HT and HTO at 100 or 400 m during 24 hours after the HT release, the dose from HTO will be more than two orders of magnitude higher than that from HT.

2.5 Spatial distributions of HT and HTO measured with diffusion passive samplers

2.5.1 HTO distribution

The tritium concentrations in ethylene glycol (E.G.) are shown in Fig. II .12 for 1 and 6 hour exposures and in Fig. II .13 for two day exposure. HT absorption in E.G. was very small judging from 1 hour exposure data. Therefore the tritium in E.G. could be attributed to absorption of HTO. The samplers absorbed water of 4.1 ± 0.4 g from the atmosphere during two day exposure. The small standard deviation suggests that the environmental conditions such as relative humidity, temperature, etc., which influenced the

diffusion sampling during the exposure period, were fairly uniform in the field. The HTO passive sampling data are presented in Appendix II .5.

The tritium concentrations in E.G. on the field centerline are plotted against distance from the release point in Fig. II .14. The HTO air concentrations integrated for 6 hours (from H to H + 6 hours) and 48 hours (from H to H + 48 hours) at sites AS(2) and AS(3) are also plotted in the figure. The curves have similar descending slopes, indicating that the time-integrated HTO air concentrations are reflected in the tritium concentrations in E.G.

The ratios of the time-integrated HTO air concentration at 1 m height to the absorbed HTO in E.G. at H + 5.2 hours were 518 (at 100 m) and 477 (at 400 m) $(\text{Bq}\cdot\text{s}/\text{m}^3)/(\text{Bq}/\ell\text{-E.G.})$. The average ratio was 497 $(\text{Bq}\cdot\text{s}/\text{m}^3)/(\text{Bq}/\ell\text{-E.G.})$. The average ratio at H + 48 hours was, in the same manner, 2242 $(\text{Bq}/\text{s}/\text{m}^3)/(\text{Bq}/\ell\text{-E.G.})$. Using these ratios, the time-integrated HTO air concentrations at 1 m height above each passive sampler at H + 5.2 and H + 48 hours were calculated and shown in columns 10 and 11, Appendix II .5.

As shown in Appendix II .6, a supplementary laboratory experiment showed that the HTO diffusion passive sampler absorbed air moisture with a fairly constant rate up to 6 hours at a relative humidity of 60-71 %, temperature of 20-22 °C, and that the desorption of water in E.G. was very slow in a desiccator. These results show that the HTO diffusion passive sampler is a useful tool to measure the time-integrated HTO air concentration within a sampling period of six hours.

2.5.2 HT distribution

HT diffusion passive samplers were exposed to the atmosphere at 0.4 m height from about H - 0.5 to H + 1 hours. Figure II .15 shows trapped tritium in the HT passive samplers which absorbed HT and probably HTO in a small portion. The longitudinal distributions of the trapped amount of tritium and the air HT concentrations along the field centerline are shown in Fig. II .16. The decreasing tendencies with distance for both the amounts agreed well with each other in the distance range shorter than about 100 m. However, in the distance range beyond 100 m, no agreement was obtained. A reason to explain this has not been found yet. The diffusion passive sampling data are presented in Appendix II .7.

2.6 HTO in pine needles

The time variations of the tissue-free-water tritium (TFWT) concen-

tration of pine needles are shown in Fig. II.17. The TFWT concentration was very low immediately following the release. Then, due to deposition of air HTO, TFWT concentration increased sharply and reached a peak in 5 hours, followed by a rapid decrease until 2 days. This fact suggested that vapor exchange between air and vegetation was an important process. The HTO concentration at peak was about one third of that in the air moisture. After stop of the rain, the TFWT concentration increased again gradually. The time variation of the TFWT concentration of pine needles exposed to both air HT and HTO was similar to that of pine needles exposed to only air HTO for the first 47 hours. This means that the HT deposition to the pine needles is very small compared with the HTO deposition. The TFWT concentration of pine needles exposed to neither air HT nor HTO began to increase from H + 50 hours with similar slope to those for the bare pine needles. This suggests that the HTO uptake of pine needles through the roots is slow. The TFWT concentrations of pine needles and leaf litters on the forest floor under the red pines are shown in Table II.11.

2.7 Comparison of air-soil-pine needle HTO concentrations

In Fig. II.18, the time variations of HTO concentration in the air moisture, in the soil water recovered from the top 5 cm layer of site E soil* and in the tissue-free-water recovered from the bare pine needles are shown. It appears that the tritium concentrations in the pine needle water and air moisture tracked tritium concentrations in the soil water*, and at all times were lower than the soil water concentrations.

2.8 Deposition velocities for HTO to soils, pine needles, ethylene glycol and water

The deposition velocity for HTO to site BB soil (silty loam) was 2.4×10^{-2} m/s, which was calculated from the ratio of the HTO deposit per unit area to the time-integrated HTO air concentration. This velocity is faster than the previous data which range from 5.9×10^{-3} to 1.4×10^{-2} m/s obtained by Garland in the laboratory experiment /10/.

The deposition velocity for HTO to the pine needles was calculated from the tritium deposit in the pine needles harvested at H + 2.7 hours, the sample weight and the surface area per unit weight (about $31 \text{ cm}^2/\text{g}$) and found to be 2.4×10^{-4} m/s expressed on a leaf area basis. Surface area of pine

* The results of soil measurement are described in section III.

needles was measured as described in Appendix II .8.

The average HTO deposition (or absorption) velocity to E.G. was 1.5×10^{-2} m/s which was calculated from the time-integrated HTO air concentration at 1 m height and trapped tritium in E.G. at H + 6 hours. The data used for calculation of the deposition velocities and the results are summarized in Table II .12.

At site B, 100 ml of low-tritium water in two plastic containers were exposed to air HTO on the ground for about 4 hours from the end of the release. The average HTO deposition velocity to the water was 2.3×10^{-2} m/s, which was comparable to that to the soil. Tritium concentrations in water are shown in Table II .13.

2.9 Evaporation of soil water

The evaporation rate of soil water was measured from 1100 on June 10 to 1700 on June 11. In Fig. II .19, the evaporation rates (averaged over 1 hour) measured near site B at 1100-1900 hours on June 10 are shown. The amounts of evaporation at site B were 0.7 mm from 1600 to 1900 hours on June 10 and 2.2 mm from 0700 to 1700 hours on June 11. The maximum evaporation rate of soil water measured at 1400 - 1500 on June 10 was 0.48 mm/h. Unfortunately, the correlation between these amounts and the HTO loss by evaporation at site B could not be obtained, because of the extremely low deposit of tritium at the site as described in section III. The results of the measurements are summarized in Appendix II .9. Soil temperatures were also measured at 0, 5, 10, 15, 20 and 30 cm underground in site B and site E soils. Soil temperature profiles are summarized in Appendix II .10.

Table II.1 Soil properties of JAERI core sampling sites

	Site					
	B			E		
	Soil depth (cm)			Soil depth (cm)		
	0 - 5	5 - 10	10 - 20	0 - 5	5 - 10	10 - 20
Gravel %	16.0	4.5	2.0	0.5	0.5	0.5
Sand %	77.5	86.5	87.5	43.0	39.5	36.0
Silt %	4.5	6.5	6.0	48.5	50.0	54.0
Clay %	2.0	2.5	4.5	8.0	10.0	9.5
Maximum grain diameter mm	19.1	9.5	4.8	4.8	4.8	4.8
Uniformity coefficient	6.7	7.3	10.3	13.0	15.1	12.0
Curvature Coefficient	1.8	1.6	2.1	0.98	1.3	1.3
Soil type	a*, d**	b*, d**	b*, d**	c*, e**	c*, e**	c*, e**

* Classified according to Japanese Standard

a* : sand - fine soil, b* : sand - fine soil with gravel, c* : fine - soil,

** Classified according to American Standard

d** : silty loam, e** : sand

Table II.2 Soil properties (measured by Canada team)/8/

Soil particle size is shown as a percent of total particle weight classified as follows: sand: 53 to 200 μm , silt: 2 to 53 μm and clay: less than 2 μm . Organic and water content are expressed on a dry weight basis. Samples were composed of five 1.9 cm diameter cores combined. Soils were taken on June 8, 1987 before the release.

LOCATION (X, Y)	SOIL DEPTH (cm)	SOIL TYPE	SAND (%)	SILT (%)	CLAY (%)	ORGANIC CONTENT (%)	WATER CONTENT (% of dry weight)	pH
5, 0	0-22	Fine sandy loam	60	36	3.5		22.3	4.8
43, 0	0- 2	Very fine sandy loam	63	30	6.7		12.6	5.2
43, 0	2- 7	Very fine sandy loam	60	36	4.3		24.0	4.8
43, 0	7-22	Very fine sandy loam	61	35	4.2		24.7	5.2
43, 0	0-22	Very fine sandy loam	60	36	3.9		22.5	5.2
183, 0	0-22	Silty loam	43	53	3.9		29.4	5.0
400, 0	0-22	Coarse sand	97	2	0.8		1.6	5.7
409, -8	0-22	Coarse sandy loam	74	23	3.8		11.2	5.0
435, 0	0-22	Coarse sandy loam	74	23	3.8		11.2	5.0
426, -35	0-22	Fine sandy loam	58	38	4.2		25.0	5.0

Table II.3 Vegetation composition and abundance /8/

Species	Site (X, Y)	Ground Cover (%)				
		5, 0	43, 0	183, 0	300, 0	400, 0
<u>Grasses and Legumes :</u>						
Poverty grass (<u>Danthonia spicata</u> (L) Beauv.)		30	15	35	1	1
Canada blue grass (<u>Poa Compressa</u> L.)		5	5	5		
Timothy (<u>Phleum pratense</u> L.)				5		
Cowvetch (<u>Vicia sp</u> L.)			1	1		
Red clover (<u>Trifolium pratense</u> L.)			1			
White clover (<u>Trifolium repens</u> L.)			1			
<u>Hervaceous Species :</u>						
Bristly blackberry (<u>Rubus setosus</u> Bigel.)		2				
Goldenrod (<u>Solidago sp</u>)		5				
Northern dewberry (<u>Rubus flagellaris</u> L.)				2		
Orange hawkweed (<u>Hieracium aurantiacum</u> L.)		15	35	20	1	1
Strawberry (<u>Fragaria sp</u> L.)		5	10	5		1
Yellow hawkweed (<u>Hieracium pratense</u>)					2	
Sheep sorvel (<u>Rumex acetosella</u> L.)					1	1
Curled dock (<u>Rumex crispus</u> L.)						1
<u>Trees :</u>						
Largetooth aspen (<u>Populus grandidentata</u> Michx.)			2	1	10	1
White pine (<u>Pinus Strobus</u> L.)						
Willow (<u>Salix sp.</u> L.)				1		
<u>Other Species :</u>						
Moss (<u>Polytrichum sp</u>)		35	30	20	5	5
Sweet fern (<u>Myrica asplenifolia</u> L.)		2			5	2
Sheep laurel (<u>Kalmia augustifolia</u> L.)				5		
<u>Bareground :</u>		0	0	0	75	86

Table II.4 Sampling items and time

Item	Location			Time in hours (0 is time at start of release)												
	X(m)	Y(m)	Z(m)	B.G.	0	0.5	1	2	2.5	3	4.5	6	24	48	70	115
HT in air AS(1) AS(2) AS(3)	50	3.5	1.0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	106	-10	1.0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	397	0	1.0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
HTO in air AS(1) AS(2) AS(3)	50	3.5	1.0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	106	-10	1.0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	397	0	1.0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
HT passive sampling	29 points			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
HTO passive sampling	30 points			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Soil site A site B site BB site C site D site E	50	0	0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	100	-10	0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	200	0	0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	300	0	0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	394	0	0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Pine needles	409	5	1.5to2	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Evaporation measurement	100	-16.8	0	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Soil temperature	100	-10	0to-0.3	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	394	0	0to-0.3	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲

Table II.5 Coordinates of sampling and measuring points (in meters)

Sampling or measurement	Location			Sampling or measurement	Location		
	X(m)	Y(m)	Z(m)		X(m)	Y(m)	Z(m)
HT/HTO air sampler				Pd-Molecular Sieve HT passive sampler			
AS(1) (low volume)	50	3.5	1.0	P _{HT} 1	26	7.1	0.4
AS(2) (low volume)	106	-10.0	1.0	P _{HT} 2	26	0	0.4
AS(3) (low volume)	397	0	1.0	P _{HT} 3	26	- 6.8	0.4
AS(2) (high volume)	106	-10.0	1.0	P _{HT} 4	50	17	0.4
AS(3) (high volume)	397	0	1.0	P _{HT} 5	50	9.4	0.4
Ethylene glycol HTO passive sampler				P _{HT} 6	50	0	0.4
P _{HTO} 1	26	7.1	0	P _{HT} 7	50	- 7.8	0.4
P _{HTO} 2	26	0	0	P _{HT} 8	50	-16.8	0.4
P _{HTO} 3	26	- 6.8	0	P _{HT} 9	96	30.6	0.4
P _{HTO} 4	50	17	0	P _{HT} 10	96	10.6	0.4
P _{HTO} 5	50	9.4	0	P _{HT} 11	100	0	0.4
P _{HTO} 6	50	0	0	P _{HT} 12	106	-10.0	0.4
P _{HTO} 7	50	- 7.8	0	P _{HT} 13	106	-10.0	1.0
P _{HTO} 8	50	-16.8	0	P _{HT} 14	100	-15.2	0.4
P _{HTO} 9	97	30.6	0	P _{HT} 15	100	-26.7	0.4
P _{HTO} 10	96	10.6	0	P _{HT} 16	164	55.7	0.4
P _{HTO} 11	100	0	0	P _{HT} 17	178	29.5	0.4
P _{HTO} 12	100	-16.8	2.0	P _{HT} 18	183	0	0.4
P _{HTO} 13	100	-16.8	0.5	P _{HT} 19	178	-29.5	0.4
P _{HTO} 14	100	-15.2	0	P _{HT} 20	164	-55.7	0.4
P _{HTO} 15	100	-26.7	0	P _{HT} 21	300	39.2	0.4
P _{HTO} 16	164	55.7	0	P _{HT} 22	300	18.5	0.4
P _{HTO} 17	178	29.5	0	P _{HT} 23	300	0	0.4
P _{HTO} 18	183	0	0	P _{HT} 24	300	-19.3	0.4
P _{HTO} 19	178	-29.5	0	P _{HT} 25	300	-38.6	0.4
P _{HTO} 20	164	-55.7	0	P _{HT} 26	400	33.5	0.4
P _{HTO} 21	300	39.2	0	P _{HT} 27	400	18.5	0.4
P _{HTO} 22	300	18.5	0	P _{HT} 28	400	0	0.4
P _{HTO} 23	300	0	0	P _{HT} 29	400	-16.5	0.4
P _{HTO} 24	300	-19.3	0	Soil*			
P _{HTO} 25	300	-38.6	0	site A	50	0	0
P _{HTO} 26	400	33.5	0	site B, BB	100	-10	0
P _{HTO} 27	400	18.5	0	site C	200	0	0
P _{HTO} 28	400	0	0	site D	300	0	0
P _{HTO} 29	400	-16.5	0	site E	394	0	0
P _{HTO} 30	400	-35.0	0	Soil temperature (1)			
Pine needles	409	5	1.5-2	(1)-1	100	-10	0
Leaf litters	409	5	0	(1)-2	100	-10	-0.05
Rain water	100	-16.8	0	(1)-3	100	-10	—
Evaporation	100	-16.8	0	(1)-4	100	-10	-0.15
temperature (1)	100	-16.8	0.75	(1)-5	100	-10	-0.20
& humidity (2)	100	-16.8	2.1	(1)-6	100	-10	-0.30
net radiation	100	-16.8	1.5	Soil temperature (2)			
soil heat flux	100	-16.8	-0.02	(2)-1	394	0	0
				(2)-2	394	0	-0.05
				(2)-3	394	0	-0.10
				(2)-4	394	0	-0.15
				(2)-5	394	0	-0.20
				(2)-6	394	0	-0.30

*Soil cores were taken down to a depth of 15 cm at sites A, C, and D, and 20 cm at sites B, BB and E.

Table II.6 Meteorological conditions during the HT release period /6/

Time	Direction (bearing from true north)	Wind speed (m/s)				
		Height (cm)				
		45	90	100*	135	185
1520 - 1525	301	1.8	2.3	2.4	2.6	2.7
1525 - 1530	264	1.4	1.7	1.7	1.8	2.0
1530 - 1535	285	2.3	2.8	2.9	3.1	3.4
1535 - 1540	289	2.1	2.7	2.8	3.0	3.3
1540 - 1545	280	1.8	2.2	2.3	2.5	2.6
1545 - 1550	268	1.5	1.9	2.0	2.2	2.3
Mean	281	1.8	2.3	2.3	2.5	2.7

* Interpolated value by a method of least squares (by present authors). Correlation between a mean wind speed V (m/s) and a height h (cm) is expressed by $V = -0.583 + 0.631 \ln h$ ($r^2 = 0.994$). An estimated mean wind speed at 1 m height is 2.3 m/s.

Table II.7 Tritium Concentration in rain water

Location X (m), Y (m), Z (m)	Sampling time mm/dd, hh:mm	Rainfall (mm)	[HTO] _{RAIN} (Bq/l)
Shed	06/08, 16:20	-	17.9
100, -16.8, 0	06/10, 14:24 - 06/12, 14:52	11.0	96.5

Table II.8 Atmospheric HT and HTO concentrations on release of 3.5×10^{12} Bq HT in 30 minutes

Site	Location			[HT] _{air} (Bq · m ⁻³)	[HTO] _{air} (Bq · m ⁻³)	$\frac{[HTO]_{air}}{[HT]_{air}}$
	X (m)	Y (m)	Z (m)			
AS(1)	50	3.5	1	1.3×10^6	78.4	6.0×10^{-5}
AS(2)	106	-10	1	2.9×10^5	17.5	6.0×10^{-5}
AS(3)	397	0	1	1.6×10^4	6.7	4.1×10^{-4}

Table II.9 Atmospheric HT concentrations on successive sampling

Site	Location			During release		40 min. after	
	X (m)	Y (m)	Z (m)	[HT] _{air}	(Bq · m ⁻³)	[HT] _{air}	(Bq · m ⁻³)
AS(2)	106	-10	1	2.9×10^5		7.3×10^2	
AS(3)	397	0	1	1.6×10^4		1.4×10^2	

Table II .10 Time-integrated HTO air concentrations

AS (2) X = 106m Y = -10m Z = 1m				
Sampling time		Time - averaged HTO air concentration (Bq/m ³)	Time - integrated HTO air concentration (Bq · h/m ³)	Accumulated HTO air concentration (Bq · h/m ³)
Span (h)	Total (h)			
H + 0 → H + 0.62	0.62	17.5	10.9	10.9
H + 0.63 → H + 2.50	1.87	41.2	77.0	87.9
H + 2.50 → H + 4.50	2.00	47.1	94.2	182.1
H + 4.50 → H + 22.4	17.9	74.3	1330.	1512
H + 22.4 → H + 47.4	25.0	3.99	99.8	1612
H + 47.4 → H + 70.9	23.5	6.48	153.	1765
H + 70.9 → H + 115	44.5	10.7	476.	2241

AS (3) X = 397m Y = 0m Z = 1m				
Sampling time		Time - averaged HTO air concentration (Bq/m ³)	Time - integrated HTO air concentration (Bq · h/m ³)	Accumulated HTO air concentration (Bq · h/m ³)
Span (h)	Total (h)			
H + 0 → H + 0.65	0.65	6.70	4.36	4.36
H + 0.7 → H + 2.50	1.80	6.46	11.6	16.0
H + 2.58 → H + 4.50	1.92	6.25	12.0	28.0
H + 4.52 → H + 24.6	20.1	9.13	184.	212.0
H + 22.7 → H + 46.6	21.9	0.60	13.1	225.1
H + 46.7 → H + 70.4	23.7	1.14	27.0	252.1
H + 70.4 → H + 114	43.8	1.68	73.6	325.7

Table II.11 Tissue-free-water-tritium concentrations of pine needles and leaf litters

No.	Sample	Date (mm/dd/yy)	Time (hh:mm)	Elapsed time (h)	Water content (% of wet weight)	[HTO] _{TFW} (Bq/l)
1	PN-BG	06/07/87	15:10	-72.17	47.7	197
2	PN-A	06/10/87	16:10	0.83	44.0	202
3	PN-A	06/10/87	18:00	2.67	43.8	261
4	PN-B	06/10/87	18:00	2.67	47.0	272
5	PN-A	06/10/87	20:05	4.75	46.1	333
6	PN-B	06/10/87	20:05	4.75	46.8	414
7	PN-A	06/11/87	16:05	24.75	48.0	257
8	PN-B	06/11/87	16:08	24.80	47.1	275
9	PN-C	06/11/87	16:16	24.93	51.4	113
10	PN-A	06/12/87	14:05	46.75	50.2	133
11	PN-B	06/12/87	14:10	46.83	51.9	167
12	PN-C	06/12/87	14:15	46.92	53.0	157
13	PN-A	06/15/87	10:00	114.67	43.6	253
14	PN-B	06/15/87	10:04	114.73	44.6	203
15	PN-C	06/15/87	10:02	114.70	50.2	276
16	LL-BG	06/10/87	10:05	-5.25	32.7	206
17	LL	06/10/87	18:10	2.83	8.49	2399
18	LL	06/10/87	20:09	4.82	9.31	3823
19	LL	06/12/87	14:20	47.00	53.1	512
20	LL	06/15/87	10:08	114.80	10.4	790
21	TW of No.9	06/11/87	16:16	24.93	-	153
22	TW of No.12	06/12/87	14:15	46.92	-	138
23	TW of No.15	06/15/87	10:02	114.70	-	67

PN-A: pine needles exposed to HT and HTO

PN-B: pine needles exposed to HTO

PN-C: pine needles exposed to neither HT nor HTO

LL: leaf litters

TW: transpiration water collected in a plastic bag

Table II.12 Deposition velocities for HTO to soil, pine needles, ethylene glycol and water

	Tritium deposit	Integration time		Time - averaged HTO air concentration ^a (Bq/m ³)	Deposition velocity (m/s)
		span (h)	total (sec)		
HTO → Soil ^b	gross	H + 0.67 → H + 2.55	6780	41.2	3.19×10^{-2} 2.42×10^{-2}
	net		6780		
HTO → Pine needle ^c	net ^c	H + 0.83 → H + 2.67	6600	6.46	2.01×10^{-4} 2.69×10^{-4} Av. 2.35×10^{-4}
	net ^d		6600		
HTO → Ethylene glycol No. 28 ^e No. 14 ^e	gross	H → H + 5.60	20160	6.94	1.49×10^{-2} 1.26×10^{-2}
	net		"		
	gross	H → H + 5.12	18420	40.6	1.49×10^{-2} 1.45×10^{-2}
	net		"		
HTO → Water B1 ^f B2 ^f	gross	H + 1.0 → H + 5.10 H + 1.0 → H + 5.17	14940	44.3	2.40×10^{-2} 2.12×10^{-2} Av. 2.26×10^{-2}
	gross		15000		

H refers to the time at which the HT release began.

a : see Table II.10

b : silty loam, X = 100m Y = - 10m

c : A sample weight is 53.9g. A specific area is 31 cm²/g (see Appendix II.8)

d : A sample weight is 42.8g.

e : Number of the HTO diffusion passive sampler (see Appendix II.5).

f : B1 : water basin No. 1, B2 : water basin No. 2.

Table II.13 Tritium concentration in water in basin

Location X(m), Y(m), Z(m)	Date and time (mm/dd, hh:mm)		Elapsed time (h)		[HTO] _w (Bq/l)
	Setting	Sampling	Setting	Sampling	
100, -16.8, 0	06/10, 16:20	06/10, 20:29	1.00	5.15	2.11×10^3
100, -16.8, 0	06/10, 16:20	06/11, 15:06	1.00	23.77	7.81×10^3
100, -16.8, 0	06/10, 16:20	06/10, 20:30	1.00	5.17	1.88×10^3
100, -16.8, 0	06/10, 16:20	06/11, 15:06	1.00	23.77	8.01×10^3

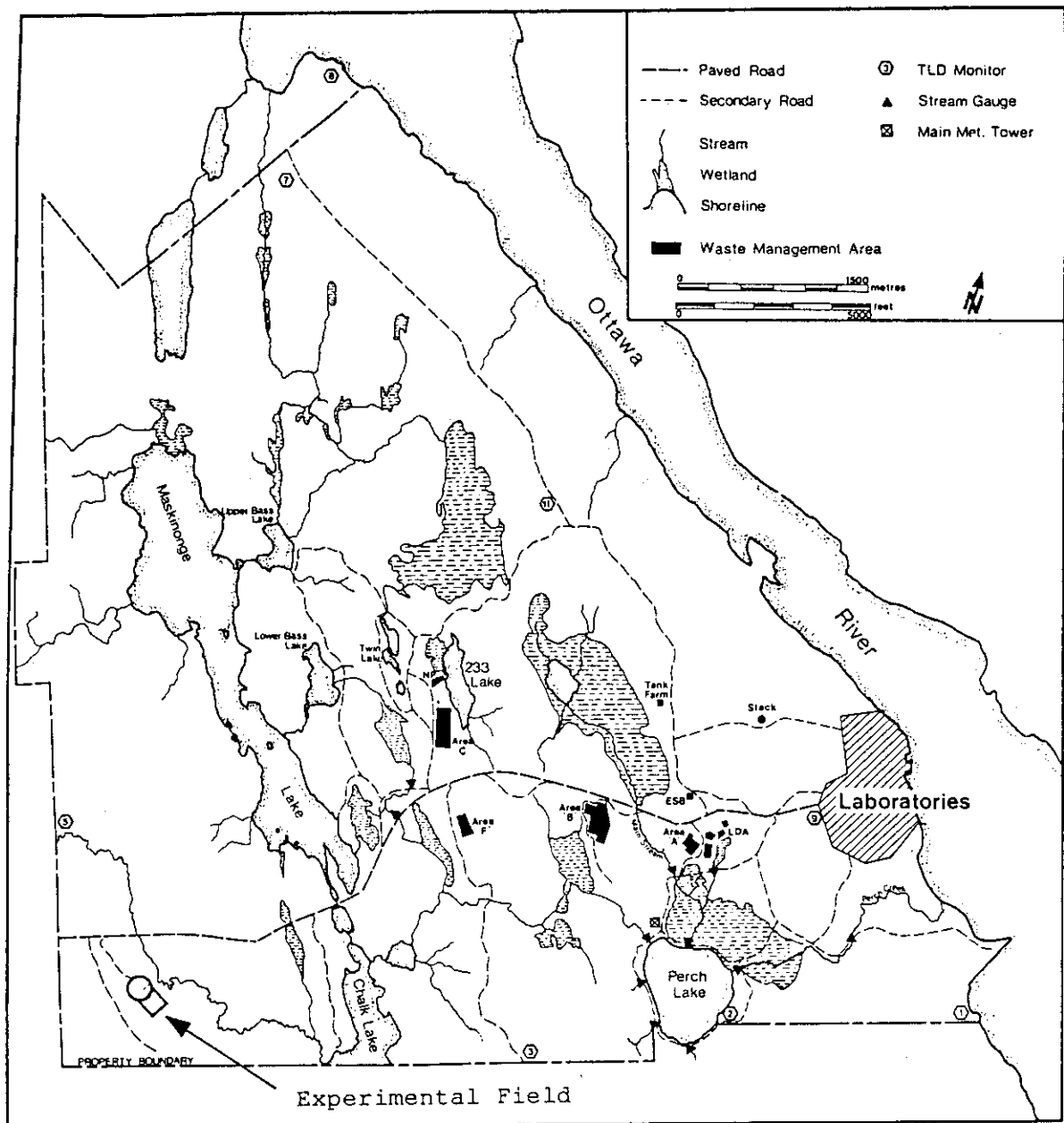


Fig. II.1 Location map. Chalk River Nuclear Laboratories Property

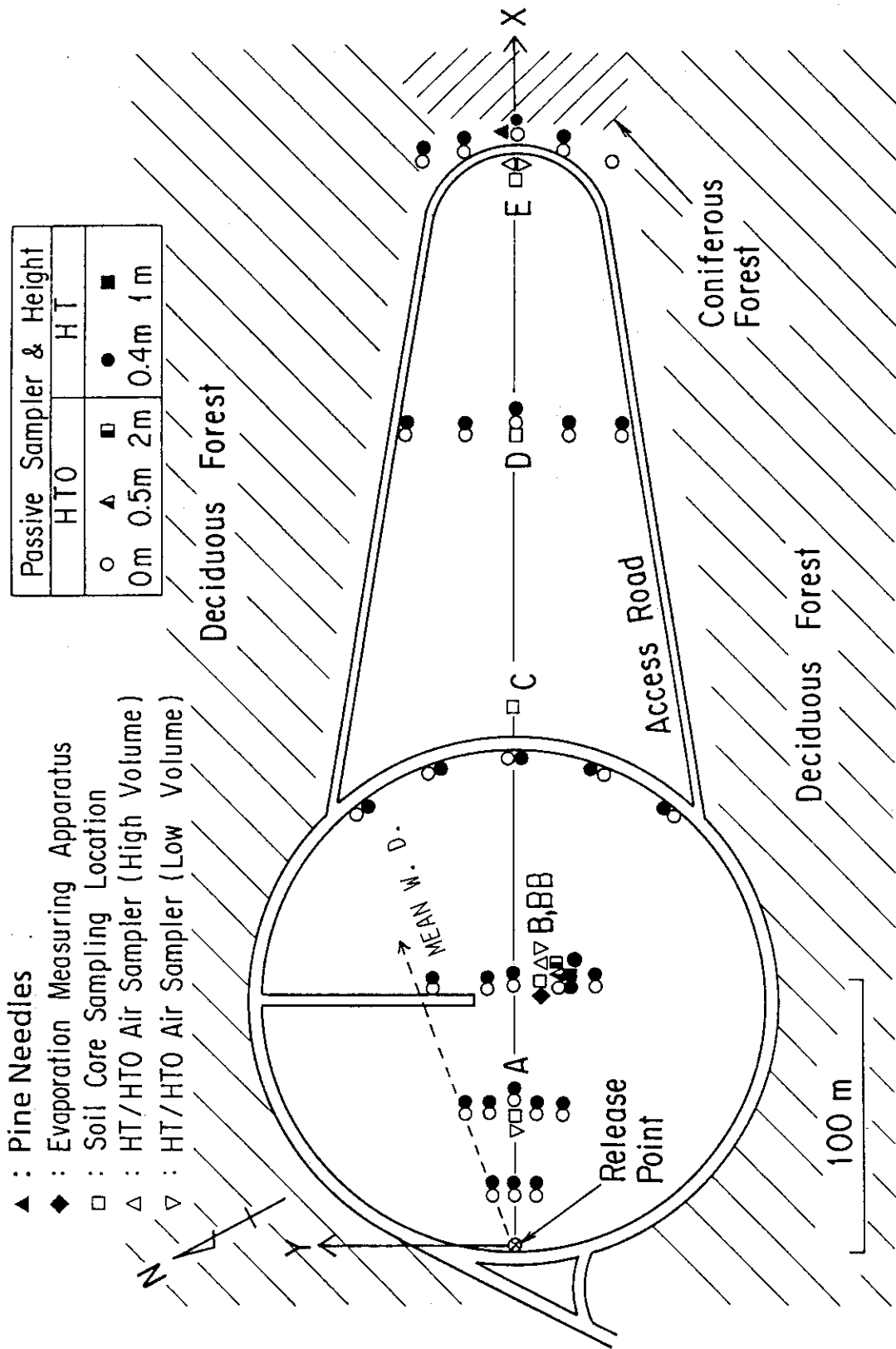


Fig. II.2 Locations of samplers and sampling points

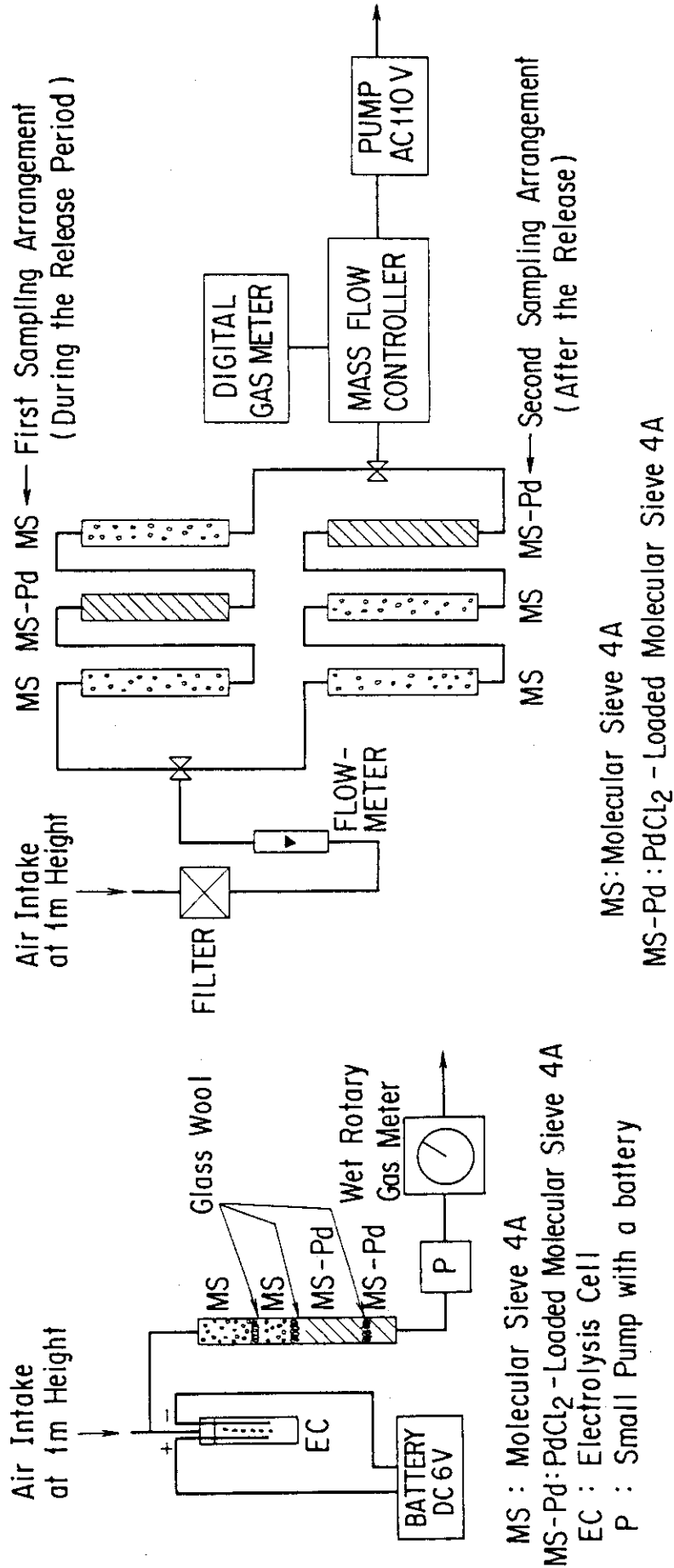
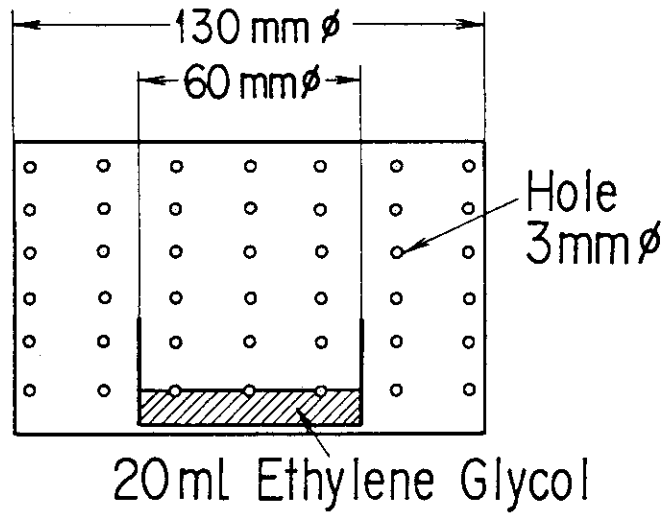


Fig. II.3

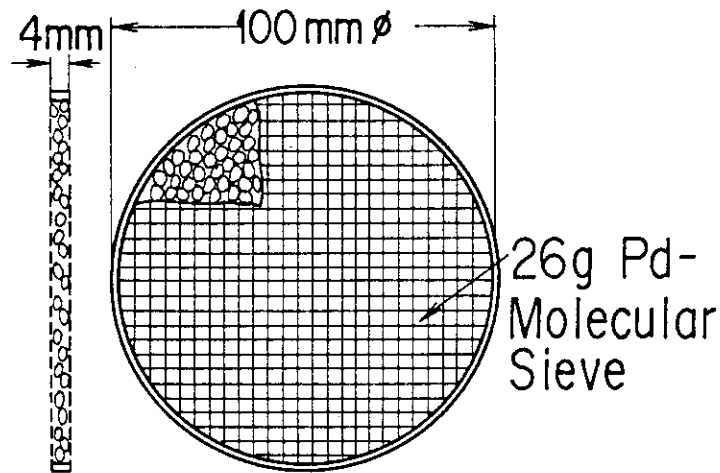
Low volume HT and HTO air sampler

Fig. II.4

High volume HT and HTO air sampler



HTO Diffusion Passive Sampler



HT Diffusion Passive Sampler

Fig. II.5 Diffusion passive sampler

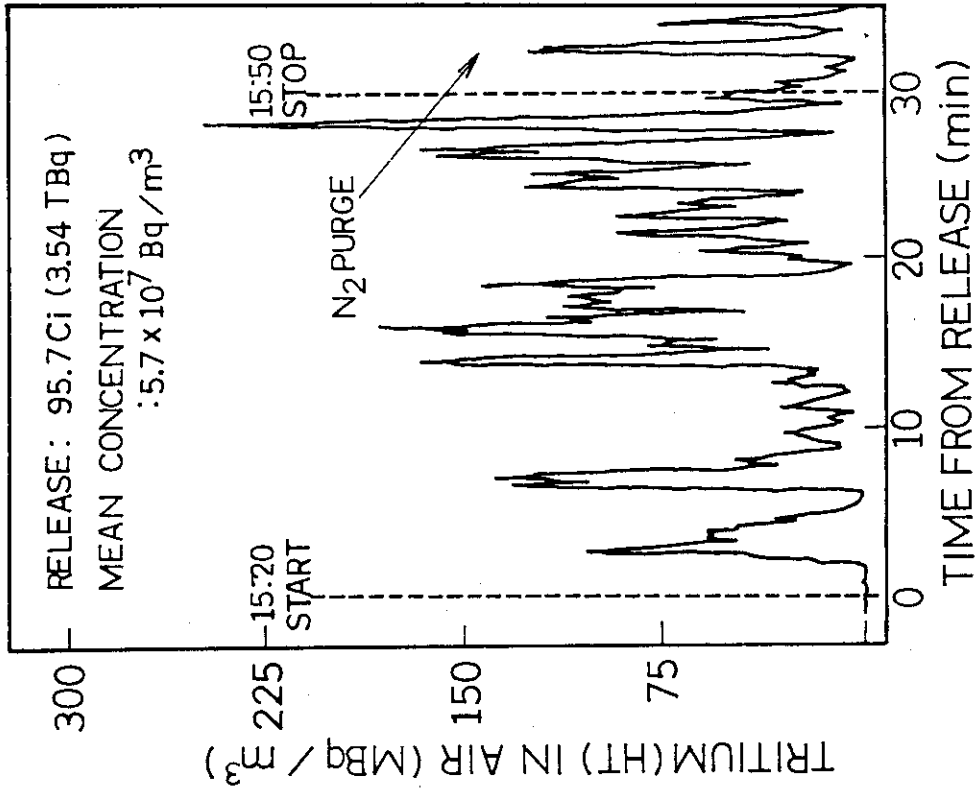


Fig. II.7 Tritium concentrations recorded during plume passage by an ion chamber placed 6 m downwind of the release point /6/

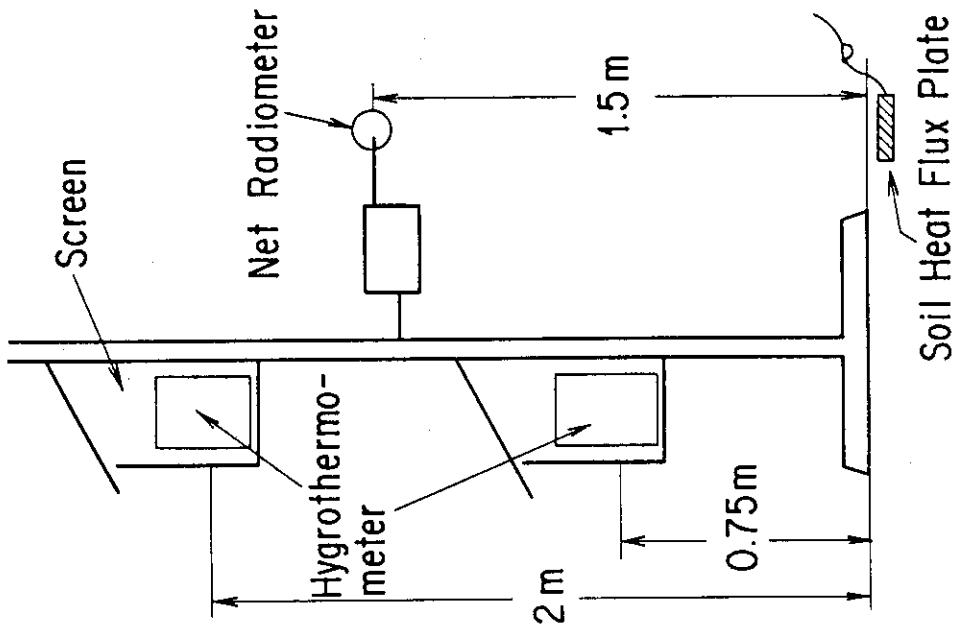


Fig. II.6 Evaporation measuring apparatus

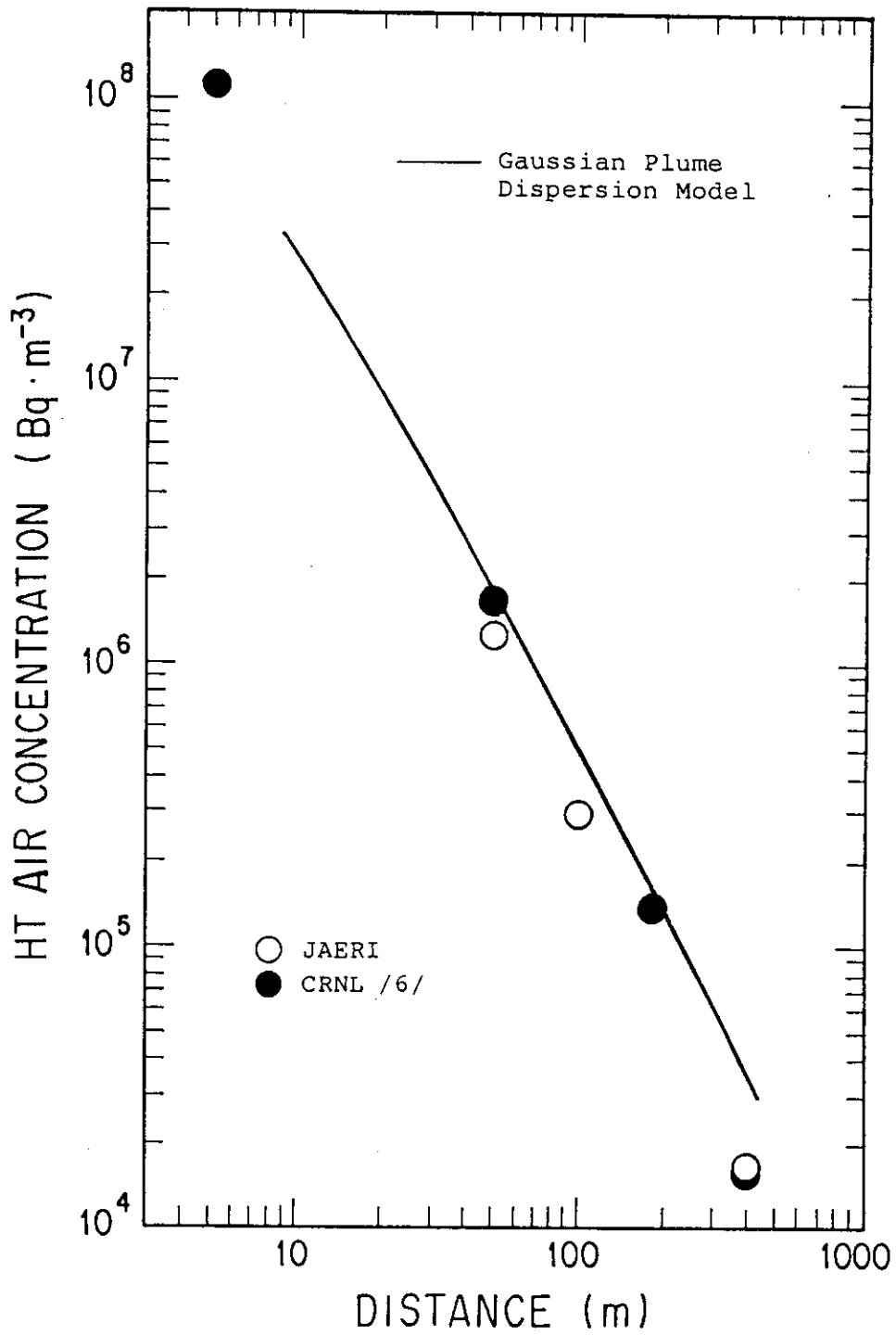


Fig. II.8 Observed and predicted HT air concentrations along the field centerline at 1 m height

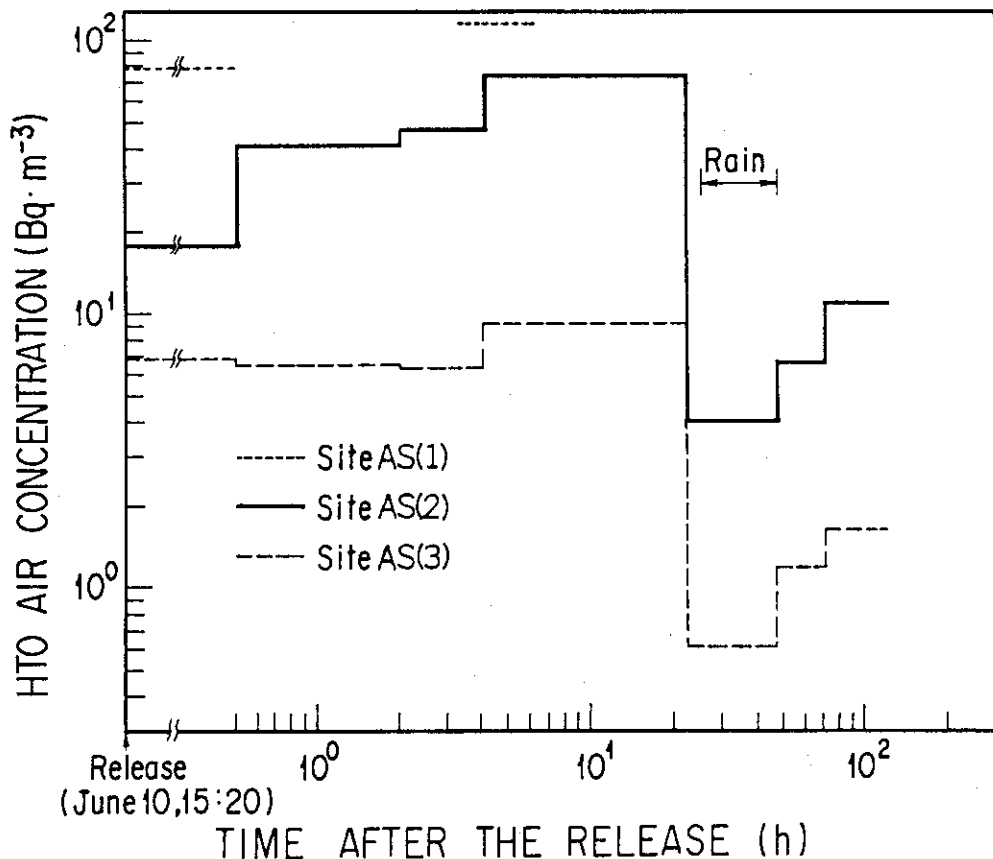


Fig. II.9 Variations of HTO air concentration with time at sites AS(1), AS(2) and AS(3)

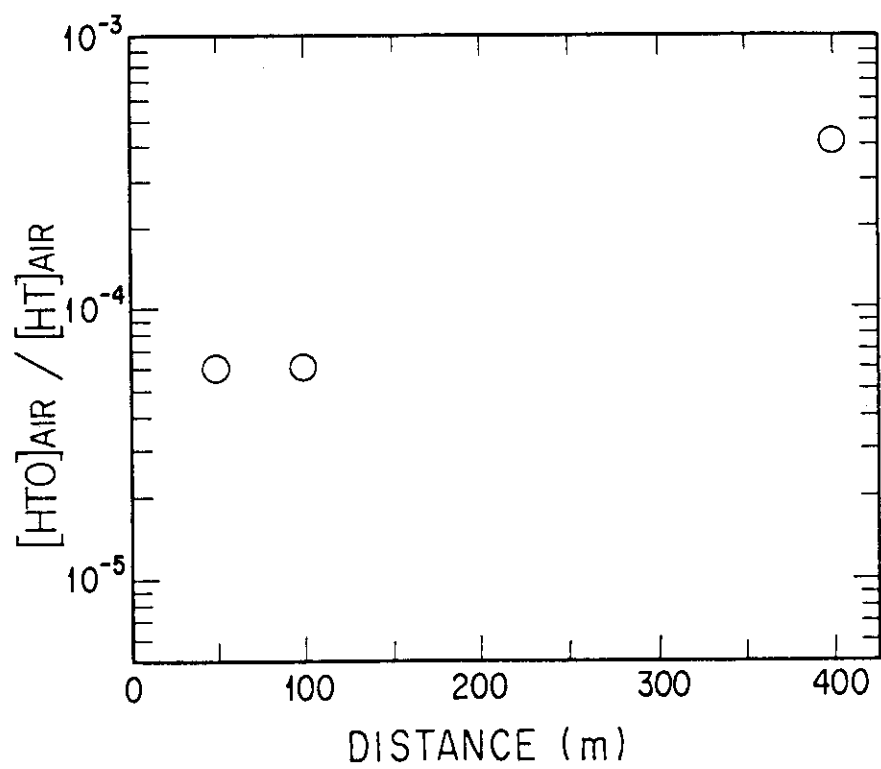


Fig. II.10 Variation of air concentration ratio of HTO to HT with distance during the release period

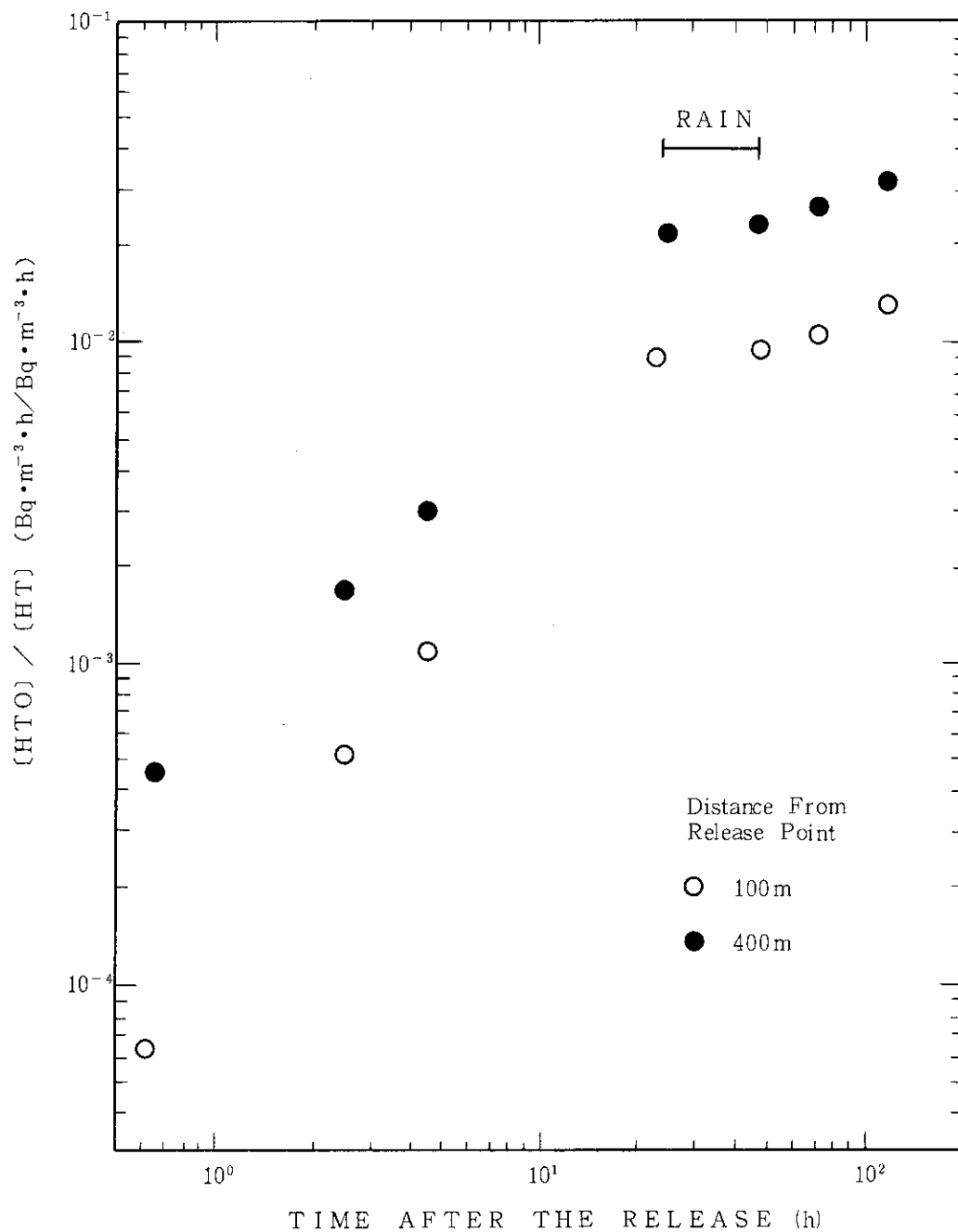


Fig. II.11 Ratios of accumulated air concentration of HTO to that of HT as a function of time

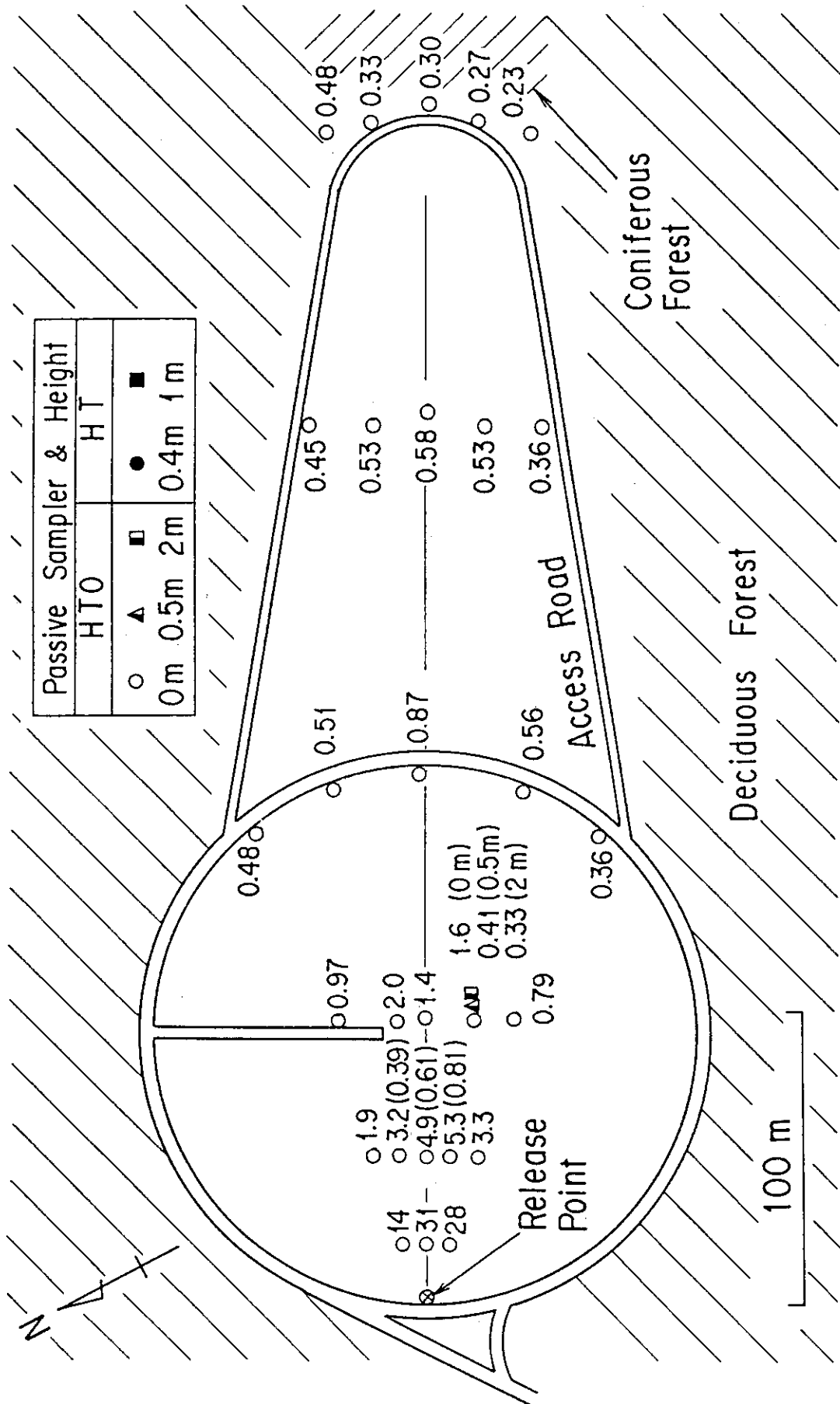


Fig. II.12 Tritium concentrations in HTO diffusion passive samplers (kBq/l) about 1 hour (in parentheses) and 5-6 hours after the release

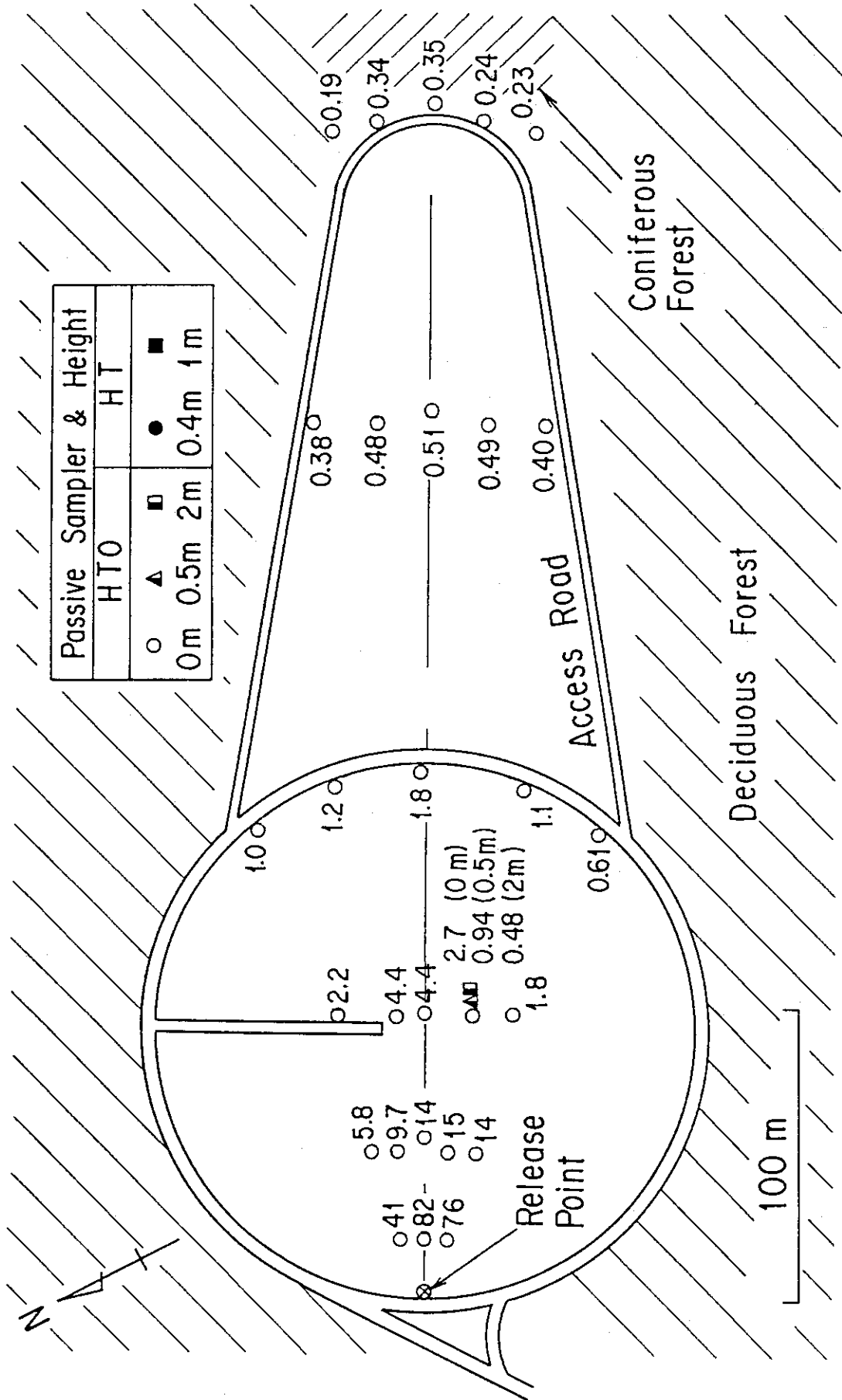


Fig. II.13 Tritium concentrations in HTO diffusion passive samplers (kBq/
 λ-ethylene glycol) about 48 hours after the release

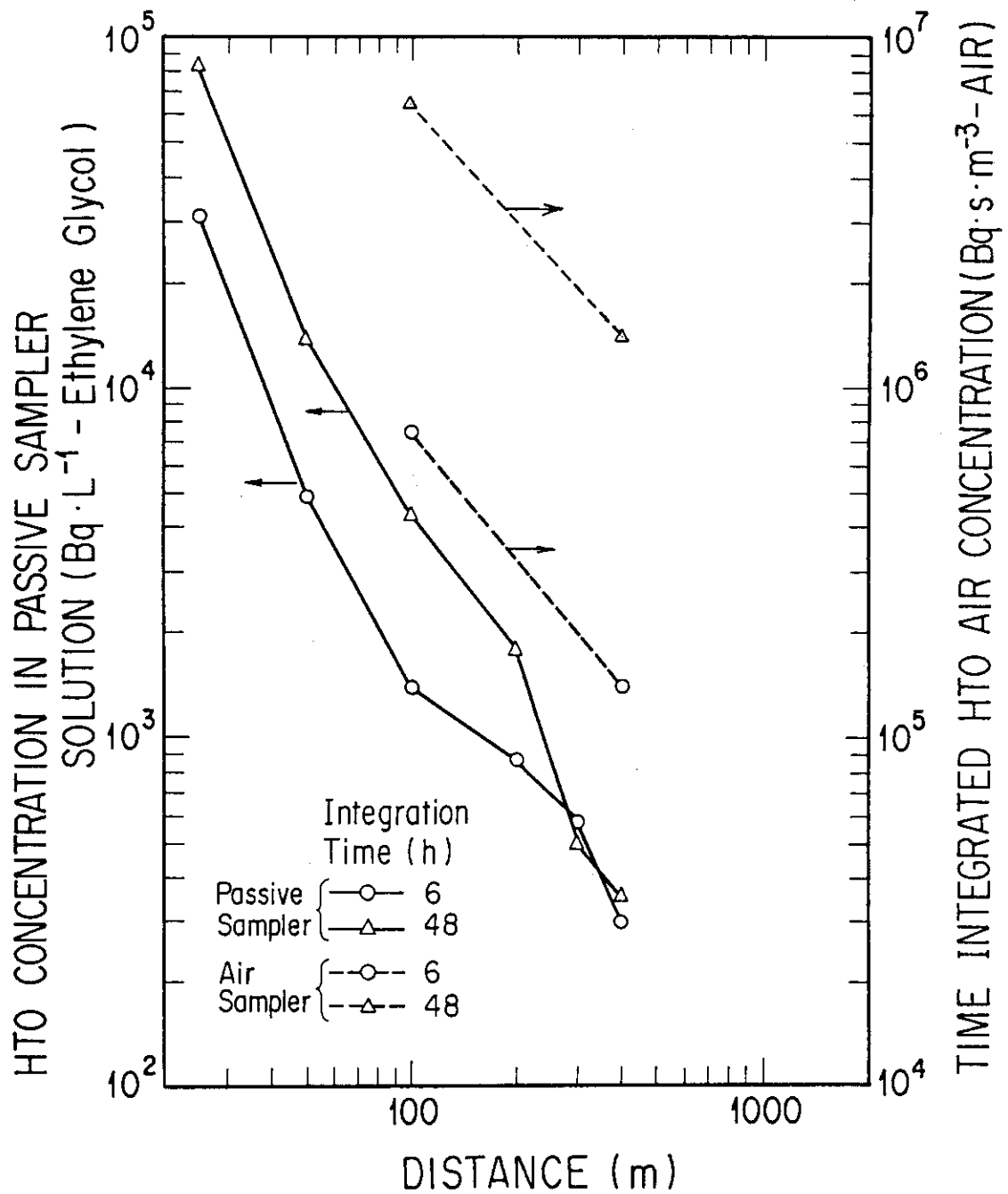


Fig. II.14 Comparison between time-integrated HTO air concentrations and tritium concentrations in HTO diffusion passive samplers

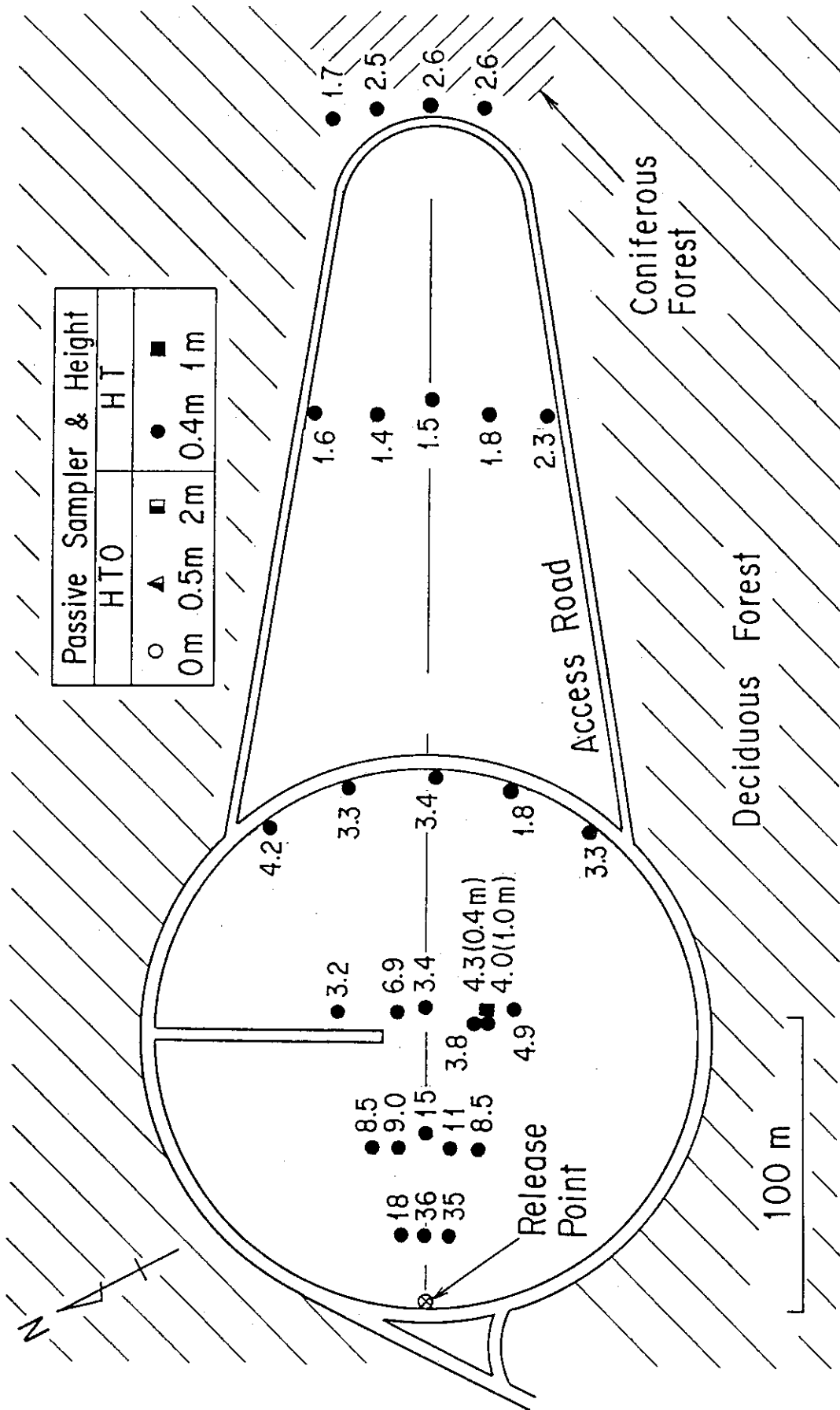


Fig. II.15 Tritium trapped by HT diffusion passive samplers (kBq/26g-PdCl₂ Molecular Sieves)

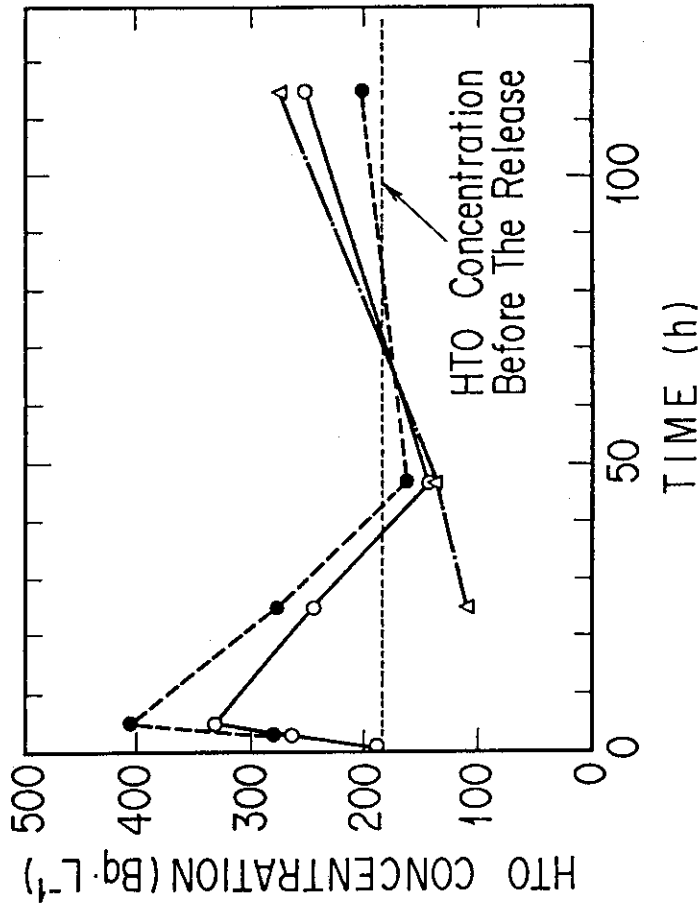


Fig. II.17

Variations of tissue-free-water-tritium concentration with time in pine needles

- :exposed to HT and HTO in air, ●:exposed to HTO in air, and
- △ :exposed to neither HT nor HTO in air

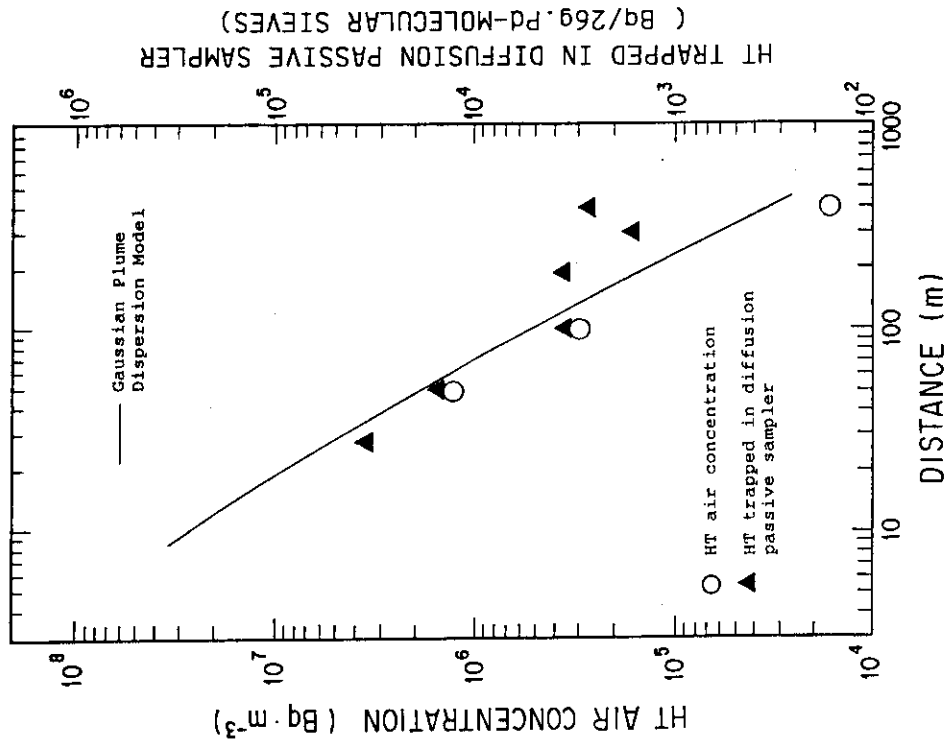


Fig. II.16 Comparison between longitudinal distributions of trapped amount of HT in diffusion passive samplers and HT air concentrations along the field centerline.

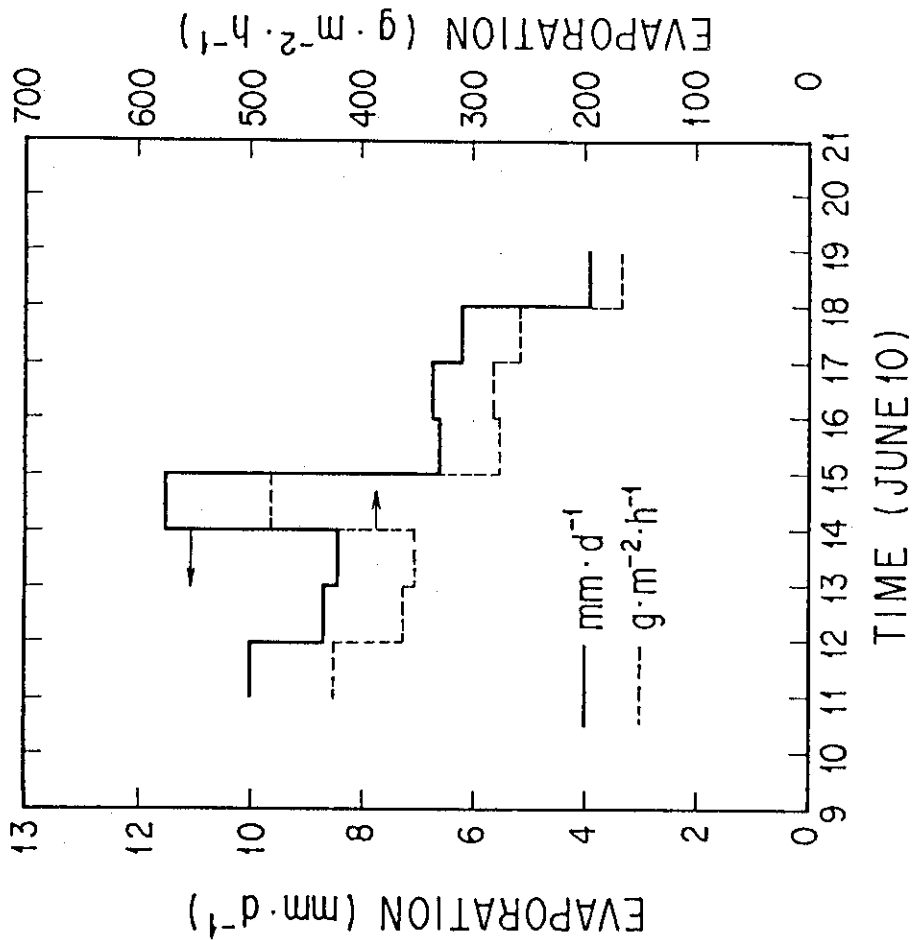


Fig. II.19
Evaporation rates of soil water at site B on June 10

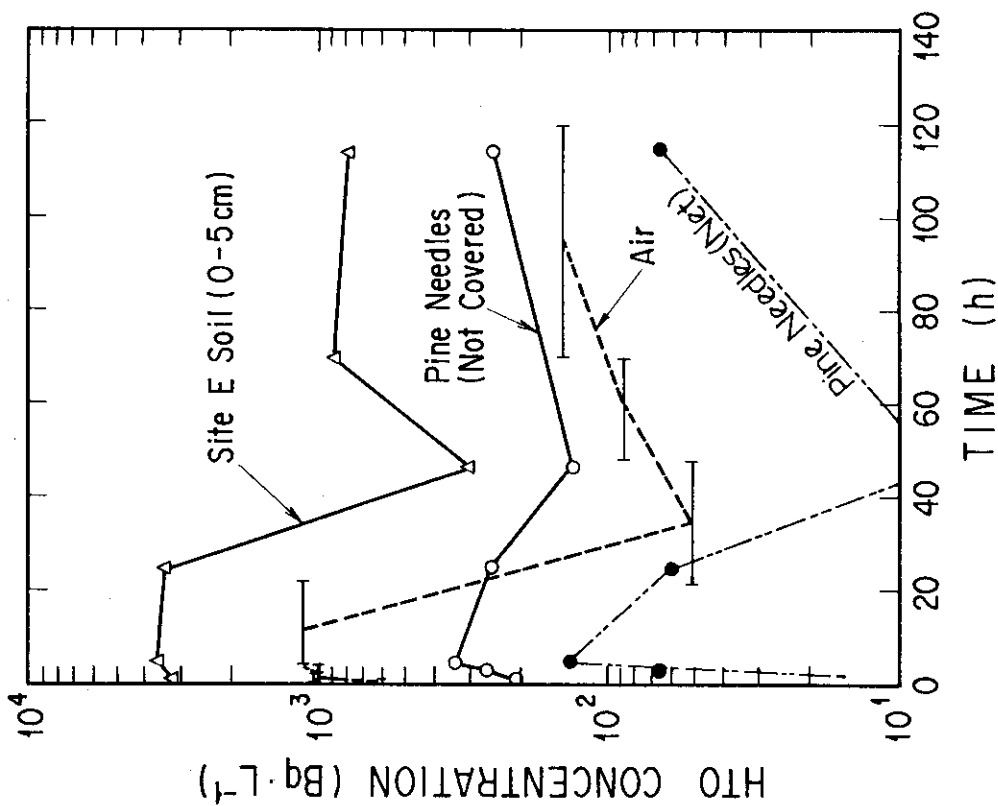


Fig. II.18
Comparison of HTO concentrations in air moisture, soil water and tissue-free-water of pine needles

III. Transfer of Tritium in Soil

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Hikaru AMANO, Takashi UENO and Atsushi KASAI

1. Soil Measurement

Soil cores (5 cm diameter) were taken down to a depth of 15 cm at sites A, C and D, and to 20 cm at sites B and E using a soil core sampler. Figure III .1 is a schematic of the soil core sampler. The cores taken at sites B and E were segmented into either eight sections of 2.5 cm each or three sections of 0 - 5, 5 - 10 and 10 - 20 cm in order to obtain the tritium depth profile. The cores taken at sites A, C and D were segmented into three sections of 5 cm each.

Duplicate or triplicate soil samples were taken in the case of 2.5 cm segmentation and then combined together for analysis. In the case of 5 cm or 10 cm segmentation, single or duplicate soil samples were taken. By using the inner cylinders, it was possible to take intact cores of soil, even from the coarse sand at sites C, D and E.

The soil types in the field were very fine sandy loam /8/ at site A (0.5 × 0.5 m) with water contents of 20 - 24 % of wet weight, silty loam at site B (4 × 4 m) with water contents of 17 - 26 %, coarse sand at sites C, D (0.5 × 0.5 m) and E(4 × 4 m) with water contents of 3.2 - 8.1, 2.7 - 5.7 and 0.93 - 3.9 %, respectively. At site A, all ground cover such as grass and moss were removed and the bare soil was exposed to the released HT gas. At site B, there was no vegetation but fine sand on the ground surface. Five days before the release, the fine sand on the ground was removed to allow to expose the bare silty loam to HT gas. At sites C, D and E, small stones in the sampling region were removed seven days before the release. A part (1.5 × 1 m) of site B was covered with a double plastic sheet during the release period and uncovered about five minutes after the end of the release. This site is referred to as site BB hereafter. This procedure allowed to expose site BB soil only to HTO so as to observe the HTO deposition.

Soil samples were put in bottles with toluene and sent back to JAERI. Soil water was extracted by two methods. The first method was the azeotropic distillation with toluene sample ratio 2 : 1. The other method was as follows. The soil was soaked in 130 ml of low-tritium water in a bottle. The bottle was shaken and allow to stand 3 hours. It was shaken again and

centrifuged 10 min at 2000 r.p.m.. The supernatant water was filtered with a membrane filter (pore size 1 μm) for counting.

2. Results

2.1 HT deposition to soil

The first soil cores were taken during the period from H + 0.7 to H + 1.1 hours at sites B and E, at H + 2.6 hours at site BB and during the period from H + 5.9 to H + 6.1 hours at sites A, C and D.

The soil deposit at site E was calculated from the total activity in the 0 - 20 cm layer and at sites A, C and D from the activity in the 0 - 15 cm layer. The soil cores down to a depth of 20 cm were taken at sites B and BB. The 10 - 20 cm layers contained higher activities than those estimated from the extrapolation of the activities of 0 - 5 cm and 5 - 10 cm layers (shown later in profiles of deposited tritium in Fig. III.3). These high activities in the 10 - 20 cm layers were not considered to be the results of HT deposition in this experiment. Therefore the tritium deposits in the 0 - 10 cm layer at sites B and BB were regarded as the total deposits.

The soil HTO deposits per unit area as a function of distance from the release point are shown in Fig. III.2 together with the air concentrations of HT during the release period. In the first sampling (from H + 0.7 to H + 1.1 hours), the HT deposit to site B soil was less than that to the site E soil, in spite of the higher HT air concentration at site B. Moreover, the soil HTO deposit to site B soil at about H + 3 hours was almost the same as that to site BB soil. These results suggest that the microbial activity in site B soil was extremely low. This may be caused by the removal of the surface fine sand together with the microbes at site B before the release. The soil water contents, soil water HTO concentrations and HTO deposits in soils are summarized in Appendices III.1 and III.2.

2.2 Deposition velocity for HT to soil

The deposition velocity for HT to soil was calculated at each site from the ratio of the tritium deposit per unit area to time-integrated HT air concentration at 1 m height during the release period. The HT air concentrations at sites C and D were derived by interpolation based on the data in Fig. II.8. It was assumed that loss of HTO from the soil during the period of time between the release initiation and the first soil sampling was negligible. Table III.1 shows that the calculated deposition velocities are

centrifuged 10 min at 2000 r.p.m.. The supernatant water was filtered with a membrane filter (pore size 1 μm) for counting.

2. Results

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The first soil cores were taken during the period from H + 0.7 to H + 1.1 hours at sites B and E, at H + 2.6 hours at site BB and during the period from H + 5.9 to H + 6.1 hours at sites A, C and D.

The soil deposit at site E was calculated from the total activity in the 0 - 20 cm layer and at sites A, C and D from the activity in the 0 - 15 cm layer. The soil cores down to a depth of 20 cm were taken at sites B and BB. The 10 - 20 cm layers contained higher activities than those estimated from the extrapolation of the activities of 0 - 5 cm and 5 - 10 cm layers (shown later in profiles of deposited tritium in Fig. III.3). These high activities in the 10 - 20 cm layers were not considered to be the results of HT deposition in this experiment. Therefore the tritium deposits in the 0 - 10 cm layer at sites B and BB were regarded as the total deposits.

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in a range between $<1.0 \times 10^{-5}$ to 3.0×10^{-4} m/s. The lowest value was measured for site B soil because of the low HT deposition. The deposition velocities for the sandy soils at sites C, D and E were comparable to that for the very fine sandy loam at site A. These deposition velocities, except that for site B soil, are slightly smaller than the values (4.0×10^{-4} to 1.3×10^{-3} m/s) measured in the pilot experiment /3/, but are within a range between 7×10^{-5} and 7×10^{-3} m/s of the velocities obtained from the field chamber experiment /2/.

2.3 Profiles of deposited tritium in soil

Profiles of deposited tritium and their time evolution are shown in Fig. III.3(a) and III.3(b). The profiles measured during the period from H + 0.5 to H + 1.1 hour showed that most of the tritium was deposited in the top 5 cm layer. This results also agreed with the previous experiment /3/. The top 5 cm soils taken at the first soil sampling contained 85, 80, 73 and 83 % of the total deposits for sites A, C, D and E, respectively.

The rain starting around H + 24 hours markedly changed the profiles for the sandy soils as shown in Fig. III.3(b). The tritium deposit in the upper soil layer moved into the deeper soil layer and some reached below 20 cm deep. This is because the HTO concentration of the rain water (e.g. 97 Bq/l at site B, see Table II.7) was considerably lower than that of the soil water (e.g. 3840 Bq/l for the top 2.5 cm soil water at H + 25 hours at site E) and the soil water was diluted and pushed down with the rain water. After stop of the rain, the percentages of tritium deposits in the top 5 cm layers at sites C, D and E were 19, 18 and 12 % of the total deposits, respectively. On the other hand, at site A, 71 % of the total deposit still remained in the top soil. This means that the precipitation of 11 mm did not significantly influence the movement of HTO in the very fine sandy loam.

Figure III.4 shows that the tritium deposit in the top 2.5 cm layer at site E soil decreased from 5440 Bq/m^2 to 1320 Bq/m^2 in 20 hours (H + 5 to H + 25 hours) with the difference of 4120 Bq/m^2 , while a tritium deposit in the 2.5 - 20 cm layer slightly increased from 5370 Bq/m^2 to 5930 Bq/m^2 with the difference of 560 Bq/m^2 . This result suggests that the dominant mechanism of loss of HTO in the sandy soil on a fine day is evaporation of HTO from the surface soil layer to the atmosphere rather than diffusion or mass transfer of HTO from surface to deeper soil layer.

2.4 Time histories of deposited tritium

The time histories of the total tritium deposit are shown in Figs. III .5 and III .6 respectively. There was a tendency for the rate of loss of soil HTO for sites A, C, D and E to decrease with time. The time histories for sites B and BB soils were markedly different from others due to extremely low HT deposit. The tritium deposits at sites B and BB rapidly increased from H + 5 hours due to redeposition of HTO emitted from the soil and vegetation.

The time histories for sites A, B and BB in Fig. III .5 show the same tendency as those in Fig. III .6. However, the tritium deposits in the 0 - 5 cm layer of coarse sand decreased more rapidly than the total deposits. This results indicate that the tritium deposited in the surface layer of coarse sand is lost faster than that of loam due to evaporation and infiltration.

2.5 Loss rate of soil tritium

Loss rate of HTO in soil was calculated from an exponential fit of relationship between the time elapsed and the tritium deposit in 0 - 10 cm and 0 - 5 cm soil layer. The results are shown in Table III .2. The HTO loss rates for stated time periods ranged from 1.3 to 4.7 %/h (H to H + 49 hours) and 0.47 to 2.1 %/h (H to H + 116 hours) for the 0 - 10 cm soil and from 2.1 to 7.2 %/h (H to H + 49 hours) and 0.55 to 2.5 %/h (0 to 116 hours) for the 0 - 5 cm soil. The 0 - 10 cm loss rates for the loam and sand did not differ significantly, but the 0 - 5 cm ones for the sand were about two times higher than those for the loam.

Table III.1 HT deposition velocity to soil

Site	Location			HT Deposition Velocity (m/s)	Sampling Time (H + hr) ^a
	X (m)	Y (m)	Z (m)		
A	50	0	0	1.7×10^{-4}	H + 6.1
B	100	-10	0	$< 1.0 \times 10^{-5}$ ^b	H + 0.68
BB ^c	100	-10	0	-	-
C	200	0	0	1.6×10^{-4}	H + 5.9
D	300	0	0	3.0×10^{-4}	H + 5.9
E	394	0	0	2.7×10^{-4}	H + 1.1

a : H refers to time HT release began.

b : calculated based on the deposited tritium, a portion of which might be caused by deposition of air HTO.

c : site BB was covered with a plastic sheet during the release period.

Table III.2 Loss rate of HTO from soil

Site	HTO loss rate from soil ^a (%/h)			
	0 - 5 cm soil		0 - 10 cm soil	
	< 49h	< 116h	< 49h	< 116h
A	3.3	0.65	2.8	0.50
B	2.1	1.8	1.3	1.3
BB ^b	2.8	0.55	1.8	0.47
C	7.2	2.5	4.7	2.1
D	6.2	2.3	4.7	1.8
E	5.3	2.0	2.8	1.2

a : calculated from an exponential fit for tritium deposit in 0 - 5 cm and 0 - 10 cm soil layers.

b : Site BB was covered with a plastic sheet during the release period.

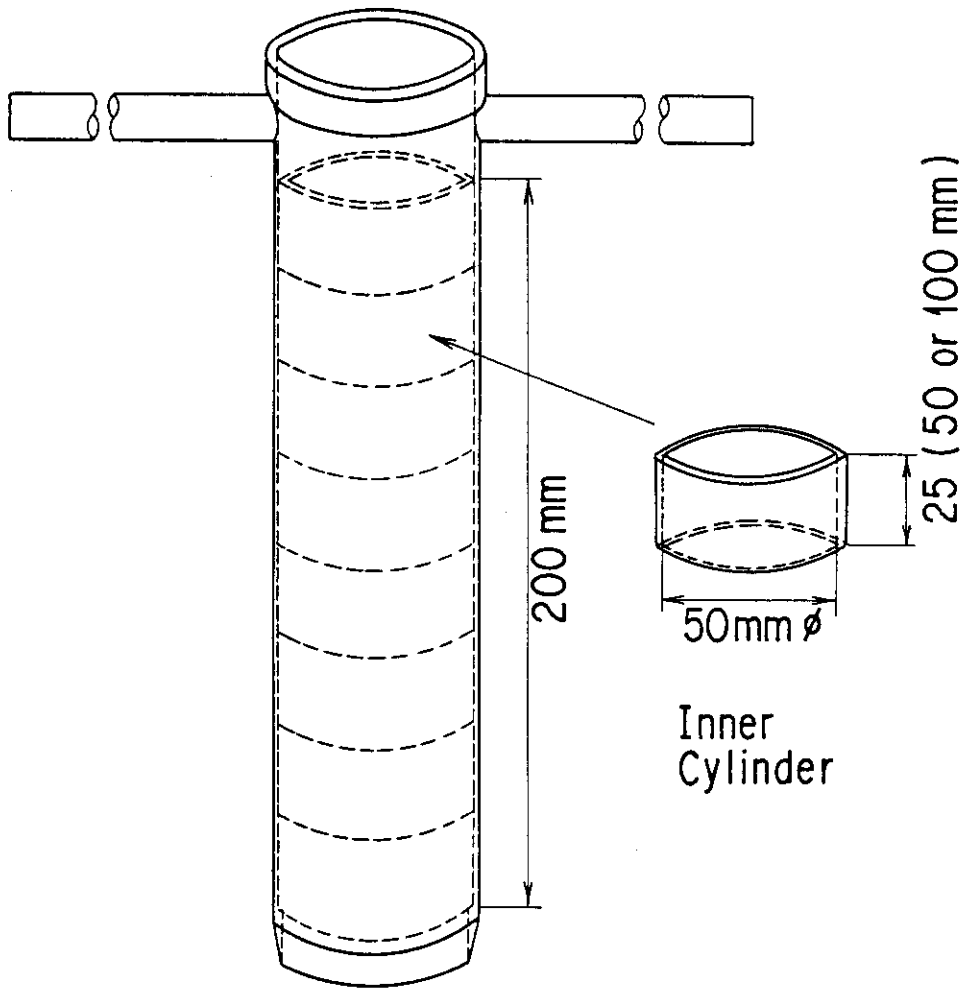


Fig. III.1 Soil core sampler

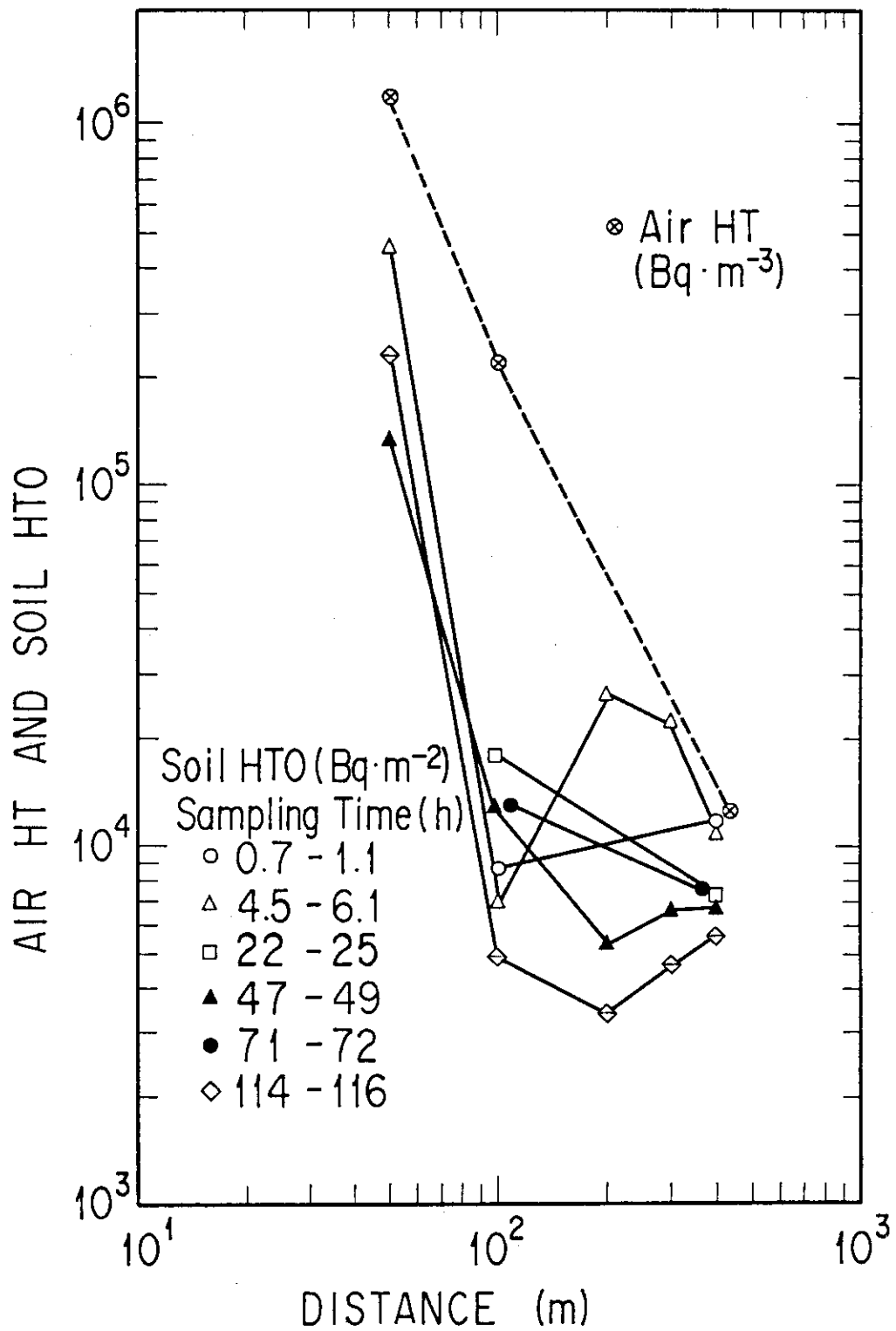


Fig. III.2 Tritium deposits to soil at various times and HT air concentrations as a function of distance from the release point

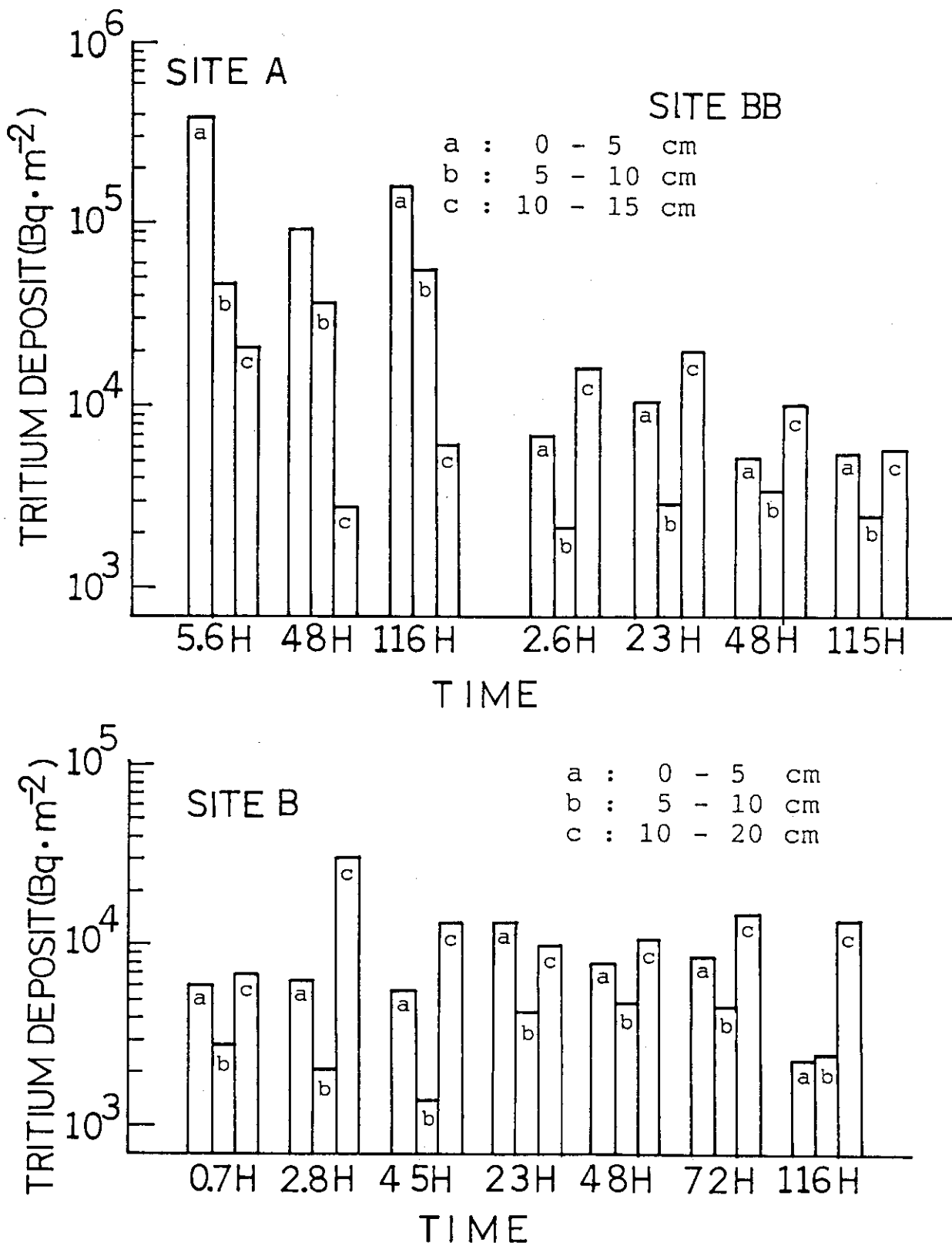


Fig. III.3(a) Profiles of tritium deposit in soils at sites A, B and BB

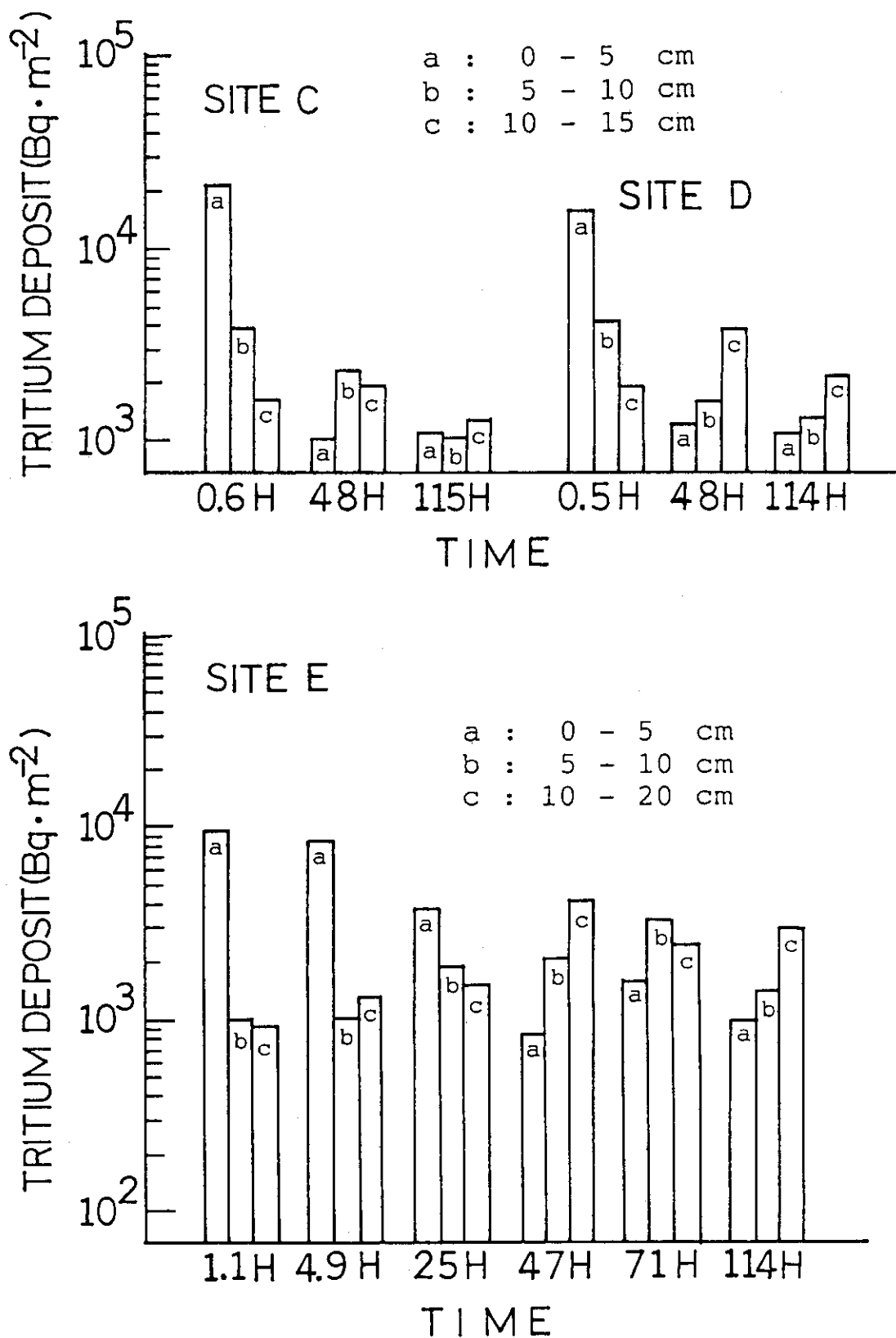


Fig. III.3(b) Profiles of tritium deposit in soils at sites C, D and E

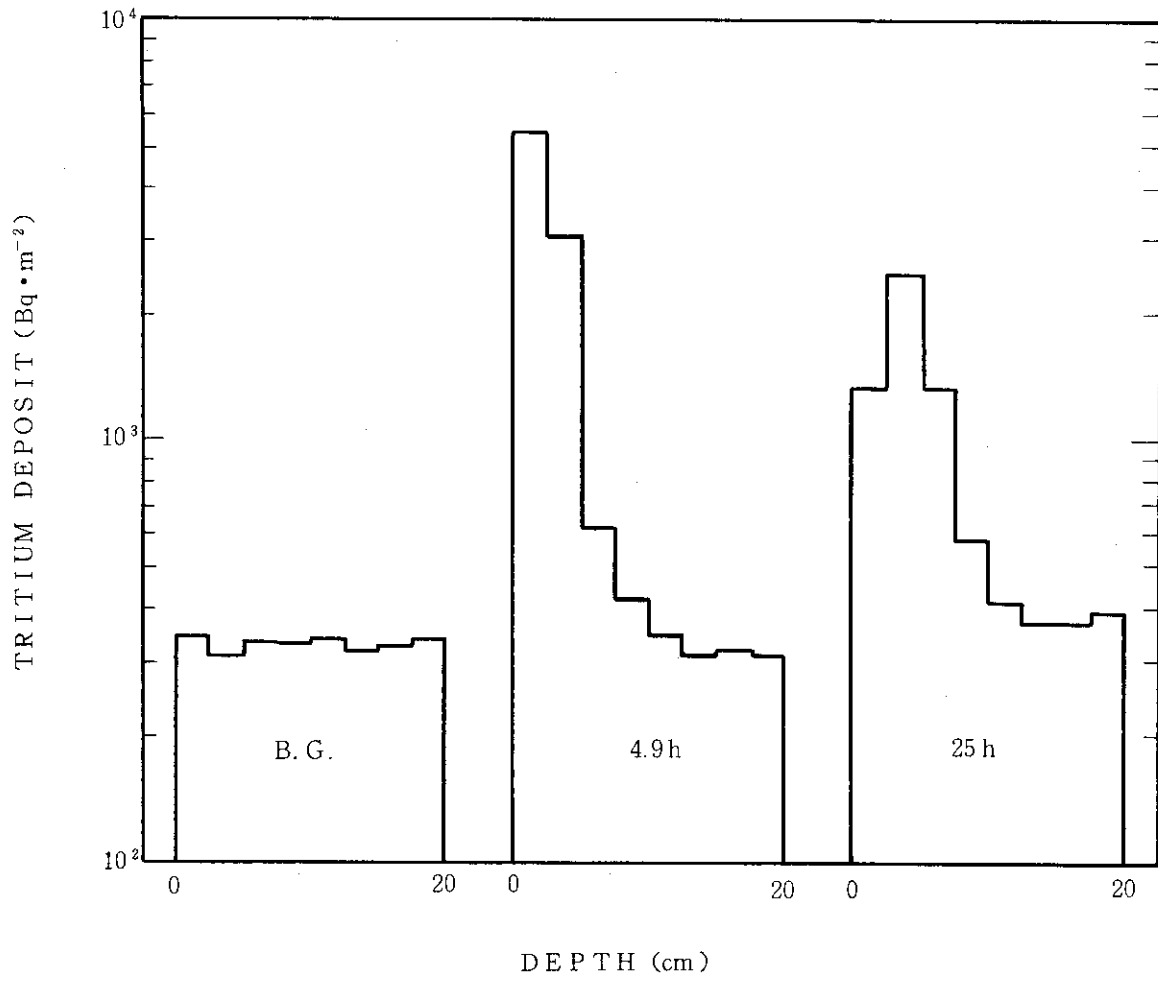


Fig. III.4 Detailed profiles of tritium deposit at site E

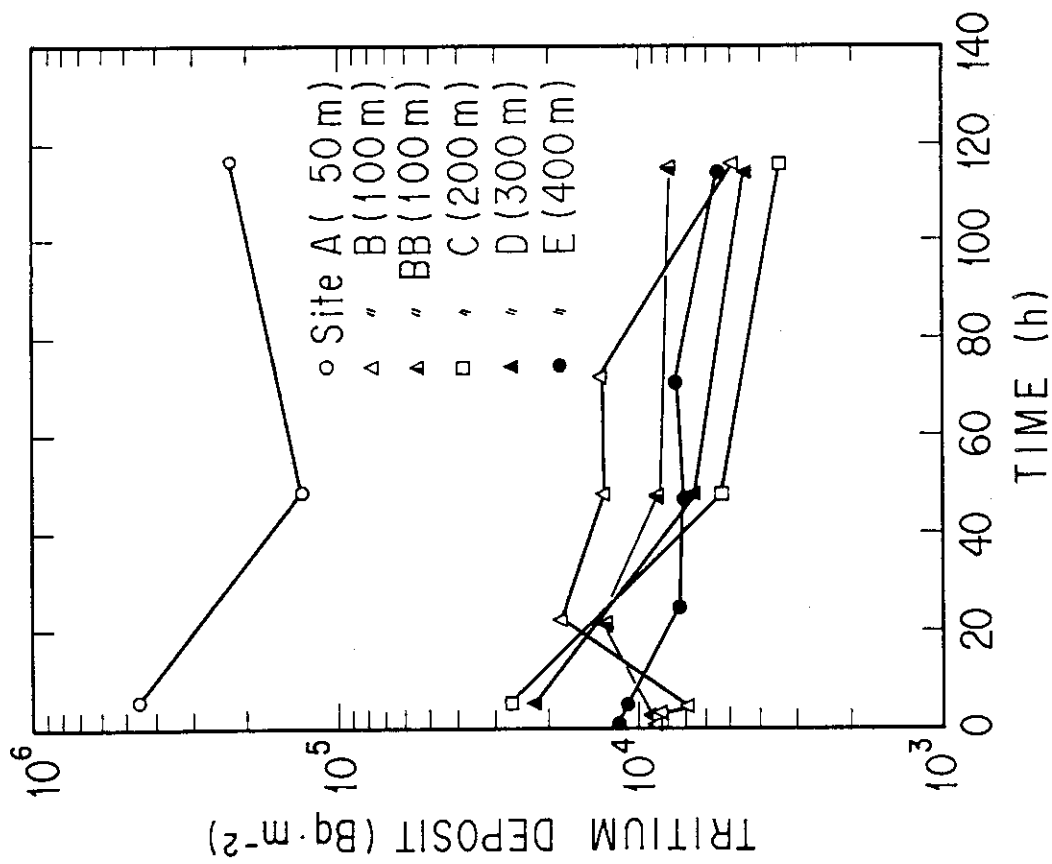


Fig. III.5 Time histories of total tritium deposit in soils at sites A, B, BB, C, D and E

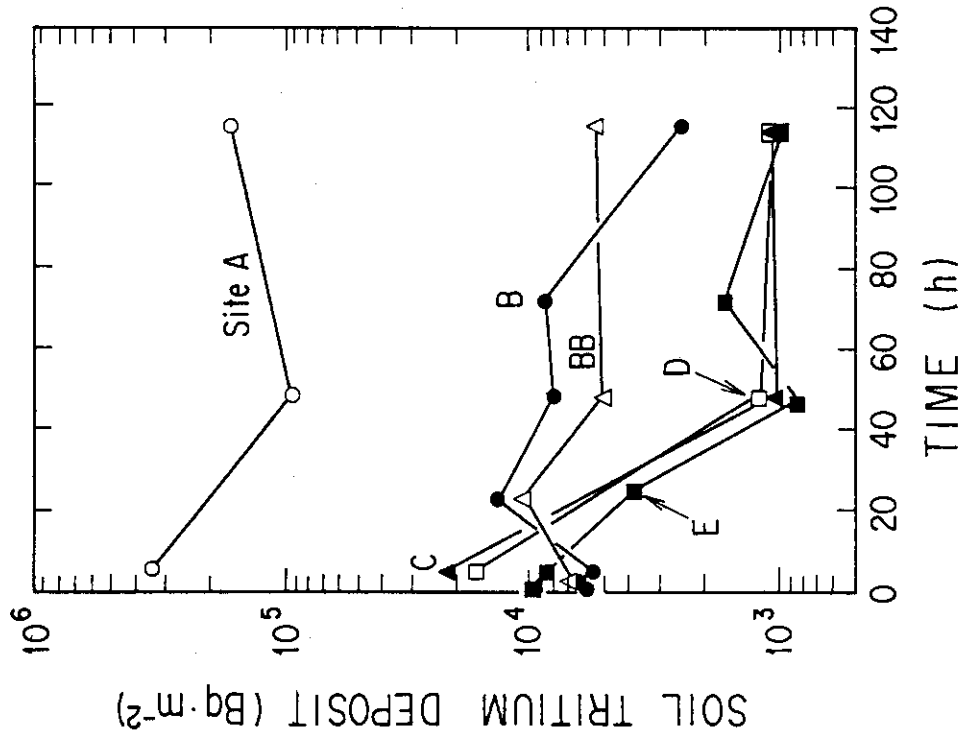


Fig. III.6 Time histories of tritium deposit in 0-5 cm soils at sites A, B, BB, C, D and E

IV. Conclusions

The following results were obtained on dispersion of HT and formation of HTO in the Canadian HT Release Study at Chalk River in June, 1987.

- (1) It was shown that the Gaussian Plume Dispersion Model was an appropriate tool to predict the atmospheric HT concentration downwind of the release, when dispersion parameters were properly chosen.
- (2) HT gas was deposited in the soil through diffusion into the soil and conversion to HTO by microbial activity.
- (3) The HTO concentration in the atmosphere remained elevated for a long time after the HT release due to resuspended HTO from the soil and vegetation.
- (4) During the HT release period, the concentration ratio of HTO to HT in the air tended to increase with downwind distance and was 4.1×10^{-4} at 400 m, corresponding to a conversion rate of 0.85 %/h assuming no resuspension of HTO from the soil and vegetation.
- (5) The HTO air concentrations at 400 m downwind during and immediately after the end of the HT release were similar. This indicated that the conversion rate in the atmosphere was far smaller than 0.85 %/h.
- (6) Exposure doses from the time-integrated HT and HTO air concentrations at 100 m downwind were equal each other 10 minutes after the end of the release.
- (7) It was found that the HTO passive sampler using ethylene glycol was a useful tool to measure the time-integrated HTO air concentration within a sampling period of six hours.
- (8) The time variations of the tissue-free-water-tritium (TFWT) concentration in pine needles showed that HT deposition was negligible compared to HTO deposition. Due to deposition of the air HTO, the concentration reached a peak in 5 hours after the HT release and then decreased until 2 days. This fact suggested that vapor exchange between air and vegetation was an important process. The HTO deposition velocity to pine needles was 2.4×10^{-4} m/s expressed on a leaf area basis.
- (9) It was seen that the HTO concentrations in the pine needle water and air moisture tracked the soil water HTO concentration and were at all times lower than the soil water concentration.
- (10) The deposition velocities for HTO to the silty loam, ethylene glycol and water were 2.4×10^{-2} , 1.5×10^{-2} and 2.3×10^{-2} m/s, respectively.

These values are, contrary to expectation, quite similar each other although the materials were different.

- (11) A maximum evaporation rate of 0.48 mm/h for soil water of the silty loam was measured at 1400-1500 on June 10.

The following results were also obtained on transfer of tritium in soil.

- (12) The deposition velocities for HT to the soils ranged from $<1.0 \times 10^{-5}$ to 3.0×10^{-4} m/s. The lowest value was measured for the silty loam with low microbial activity. The deposition velocities for the coarse sands were comparable to those for the very fine sandy loam.
- (13) Deposited soil HTO became an important source of the air HTO for a long time after the release of HT gas.
- (14) The first soil measurement showed that HT was mostly deposited in the top 5 cm soils: 85, 80, 73 and 83 % of the total tritium deposits for sites A (very fine sandy loam), C, D and E (coarse sand) soils, respectively.
- (15) The precipitation of 11 mm remarkably lowered the tritium deposits in the top 5 cm soil layer, especially in the coarse sands, and HTO concentrations in the air by more than one order of magnitude. After stop of the rain, the percentages of tritium deposits in the top 5 cm layers at sites C, D and E were 19, 18 and 12 % of the total deposits, respectively. On the other hand, at site A, 71 % of the total deposit still remained in the top soil.
- (16) The HTO in the soils disappeared at the loss rates of 1.3 - 4.7 %/h (0 to 49 hours) and 0.47 - 2.1 %/h (0 to 116 hours) for the 0 - 10 cm soil and 2.1 - 7.2 %/h (0 to 49 hours) and 0.55 - 2.5 %/h (0 to 116 hours) for the 0 - 5 cm soil. The 0 - 10 cm loss rates for the loam and sand did not differ significantly, but the 0 - 5 cm ones for the sand were about two times higher than those for the loam.

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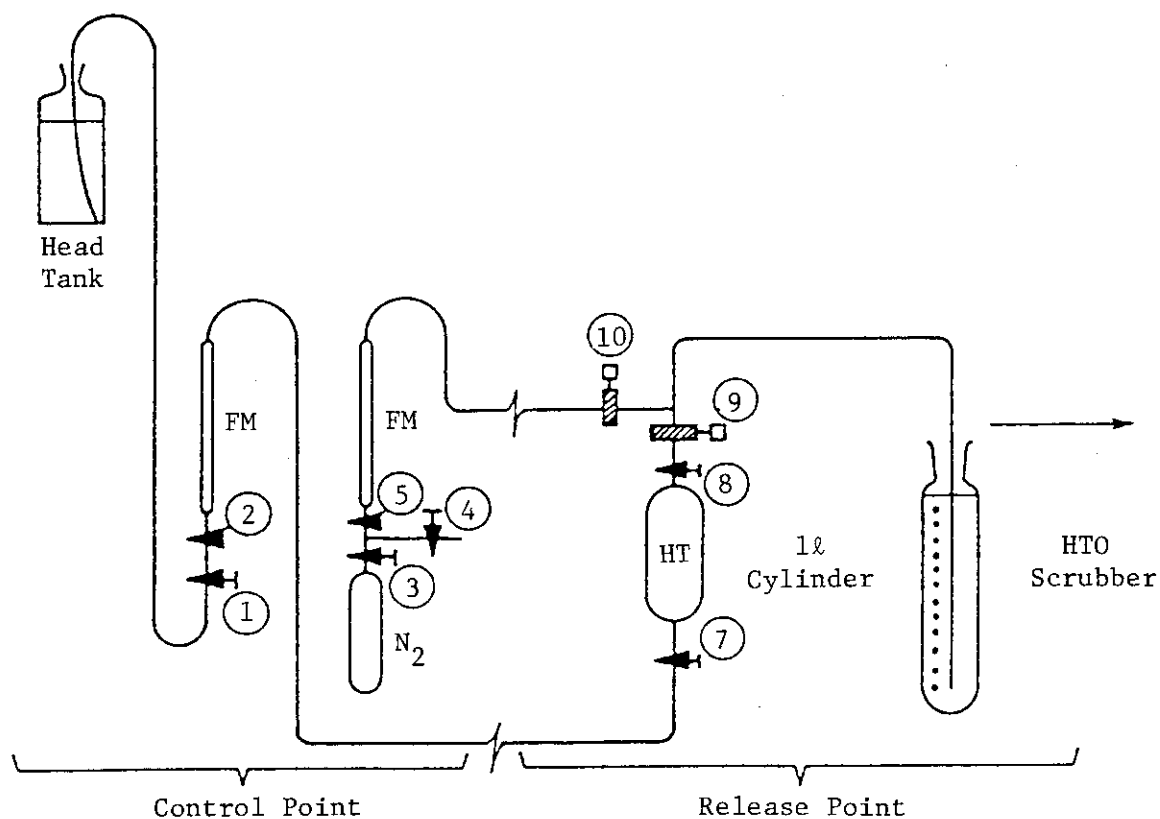
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Appendices

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Appendix II.1 HT release system /8/



Head Tank - 1 Litre Plastic Bottle

FM - Rotameter

HT - Tritiated Hydrogen Contained in 1l
Steel Cylinder

N₂ - Lecture Cylinder of N₂ Purge Gas

Head tank and N₂ purge systems at distance of 50 m
from the release site. Interconnecting N₂ and water
lines are plastic tubing.

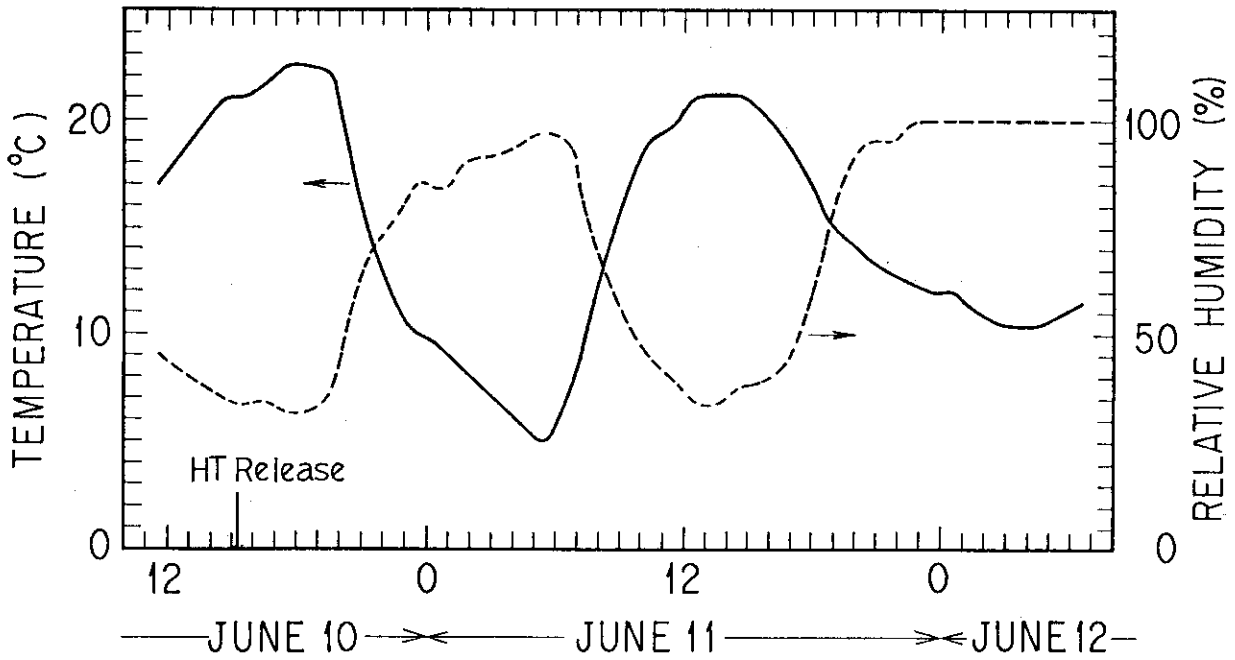
1, 4 - Needle Valves

3, 7, 8 - Manual Shutoff Valves

2, 5 - Toggle Valves

9, 10 - Solenoid Valves Operated From the
Control Point

Appendix II.2 Diurnal variations of temperature and relative humidity measured at 2 m height at site B



Appendix II.3 Results of air sampling

Number	Date and Time		Location			[HTO] _{air} [HTO] _{water} (Bq/L)	[HT] _{air} (Bq/m ³)	[HTO] _{air} (Bq/m ³)
	mm/dd, hh:mm (start)	mm/dd, hh:mm (stop)	X(m)	Y(m)	Z(m)			
AL-1	06/10 14:59	06/10 15:56	50	3.5	1		1.26E+06*	7.84E+01*
	H-0.35	H+0.60						
AH-1	06/10 18:40	06/10 21:32	50	3.5	1	8.71E+03		1.15E+02
	H+3.33	H+6.20						
AL-2	06/10 14:57	06/10 15:57	106	-10	1		2.93E+05*	
	H-0.38	H+0.62						
AL-3	06/10 15:58	06/10 16:50	106	-10	1		7.31E+02	4.78E+01*
	H+0.63	H+1.50						
AH-2	06/10 14:56	06/10 15:57	106	-10	1	2.09E+03	1.73E+05*	1.75E+01*
	H-0.40	H+0.62						
AH-3	06/10 15:58	06/10 17:50	106	-10	1	6.49E+03	3.44E+02	4.12E+01
	H+0.63	H+2.50						
AH-4	06/10 17:50	06/10 19:50	106	-10	1	7.59E+03		4.71E+01
	H+2.50	H+4.50						
AH-5	06/10 19:50	06/11 13:45	106	-10	1	9.76E+03		7.43E+01
	H+4.50	H+22.4						
AH-6	06/11 13:45	06/12 14:45	106	-10	1	3.72E+02		3.99E+00
	H+22.4	H+47.4						
AH-7	06/12 14:45	06/13 14:15	106	-10	1	5.00E+02		6.48E+00
	H+47.4	H+70.9						
AH-8	06/13 14:15	06/15 10:43	106	-10	1	8.04E+02		1.07E+01
	H+70.9	H+115.4						
AL-4	06/10 14:54	06/10 16:00	397	0	1		1.64E+04	
	H-0.43	H+0.67						
AL-5	06/10 16:05	06/10 17:05	397	0	1		1.41E+02	
	H+0.75	H+1.75						
AH-9	06/10 14:53	06/10 15:59	397	0	1	5.96E+02	9.37E+03*	6.70E+00*
	H-0.45	H+0.65						
AH-10	06/10 16:02	06/10 17:50	397	0	1	1.02E+03	8.54E+01	6.46E+00
	H+0.70	H+2.50						
AH-11	06/10 17:55	06/10 19:50	397	0	1	1.01E+03		6.25E+00
	H+2.58	H+4.50						
AH-12	06/10 19:51	06/11 15:58	397	0	1	1.12E+03		9.13E+00
	H+4.52	H+24.6						
AH-13	06/11 16:02	06/12 13:55	397	0	1	5.06E+01		6.02E-01
	H+24.7	H+46.6						
AH-14	06/12 14:01	06/13 13:43	397	0	1	8.71E+01		1.14E+00
	H+46.7	H+70.4						
AH-15	06/13 13:45	06/15 9:31	397	0	1	1.43E+02		1.68E+00
	H+70.4	H+114.2						

AL: Low volume air sampler

AH: High volume air sampler

H refers to time HT release began: 15:20 (EDT), 10 June 1987.

* : Shown as time-averaged concentration from 15:20 to 15:55

Appendix II.4 Prediction of HT air concentration by the Gaussian Plume Dispersion Model

HT concentration in air was predicted by the Gaussian Plume Dispersion Model.

The air concentration downwind was calculated according to the following formulae /7/.

$$\chi(x, y, z) = \frac{Q}{2\pi\sigma_y\sigma_z U} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left[\exp\left\{-\frac{(z-H)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(z+H)^2}{2\sigma_z^2}\right\} \right]$$

where χ : Average air concentration (Bq/m³)

Q: Release rate (Bq/s)

U: Wind speed (m/s)

σ_y, σ_z : Standard deviation of cloud width in horizontal y-direction and vertical z-direction (m)

x: Downwind distance from the source.

H: Height of emission (m)

Where, wind velocity U is assumed constant, and σ_y and σ_z are the function of down wind distance x and stability only.

Parameters σ_y and σ_z are statistically given so as to coincide the calculated one with the observed.

$$\sigma_y = 0.67775 \theta_{0.1} \cdot (5 - \log x) \cdot x$$

x is measured in km unit,

where $\theta_{0.1}$ (deg) is shown in the following table.

Stability	A	B	C	D	E	F
$\theta_{0.1}$	50	40	30	20	15	10

σ_z is expressed approximately by a quadratic expression on the logarithmic diagram as,

$$\sigma_z = \sigma_1 x^{a_1} + a_2 \log x + a_3 (\log x)^2$$

where σ_z is assumed to be 1,000 m which is to be calculated over 1,000 m.

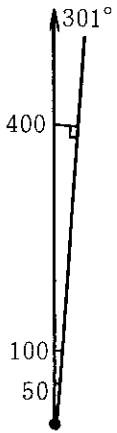
(x > 0.2km)

Stability	σ_1	a_1	a_2	a_3
A	768.1	3.9077	3.898	1.7330
B	122.0	1.4132	0.49523	0.12772
C	58.1	0.8916	-0.001649	0.0
D	31.7	0.7626	-0.095108	0.0
E	22.2	0.7117	-0.12697	0.0
F	13.8	0.6582	-0.1227	0.0

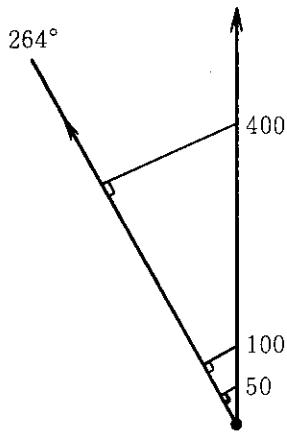
(x < 0.2km)

Stability	σ_1	a_1
A	165	1.07
B	83.7	0.894
C	58.0	0.891
D	33.0	0.854
E	24.4	0.854
F	15.5	0.822

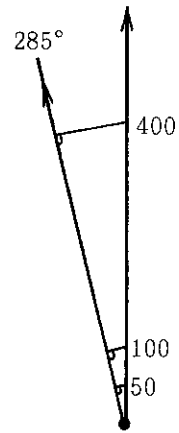
where, $a_2 = a_3 = 0$



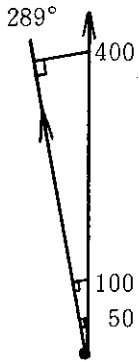
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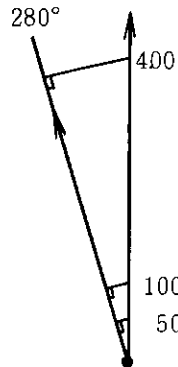
(15:25-15:30, 1.7 m/s)



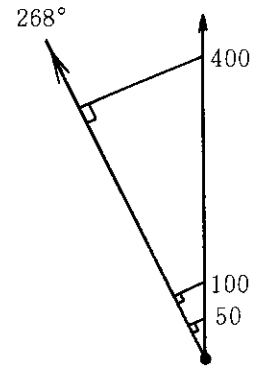
(15:30-15:35, 2.9 m/s)



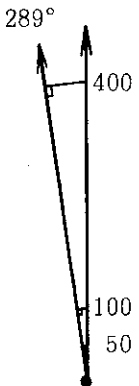
(15:35-15:40, 2.8 m/s)



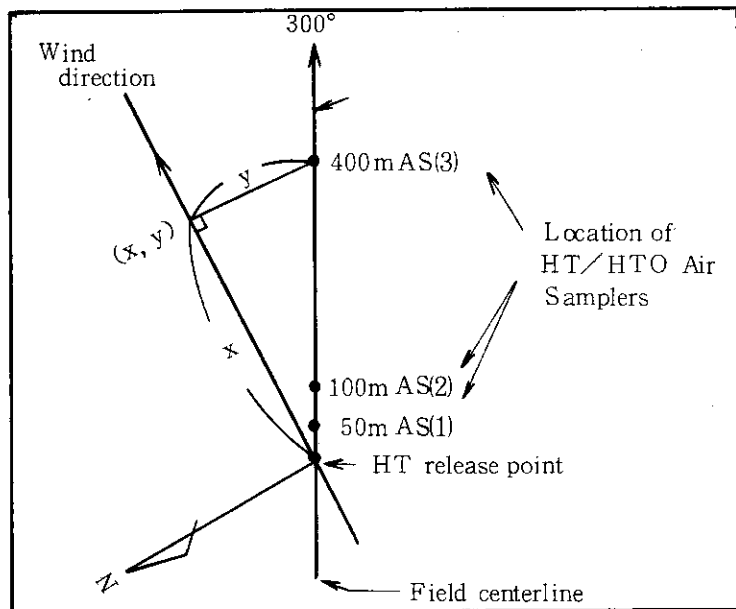
(15:40-15:45, 2.3 m/s)



(15:45-15:50, 2.0 m/s)



(15:50-15:55, 1.2 m/s)



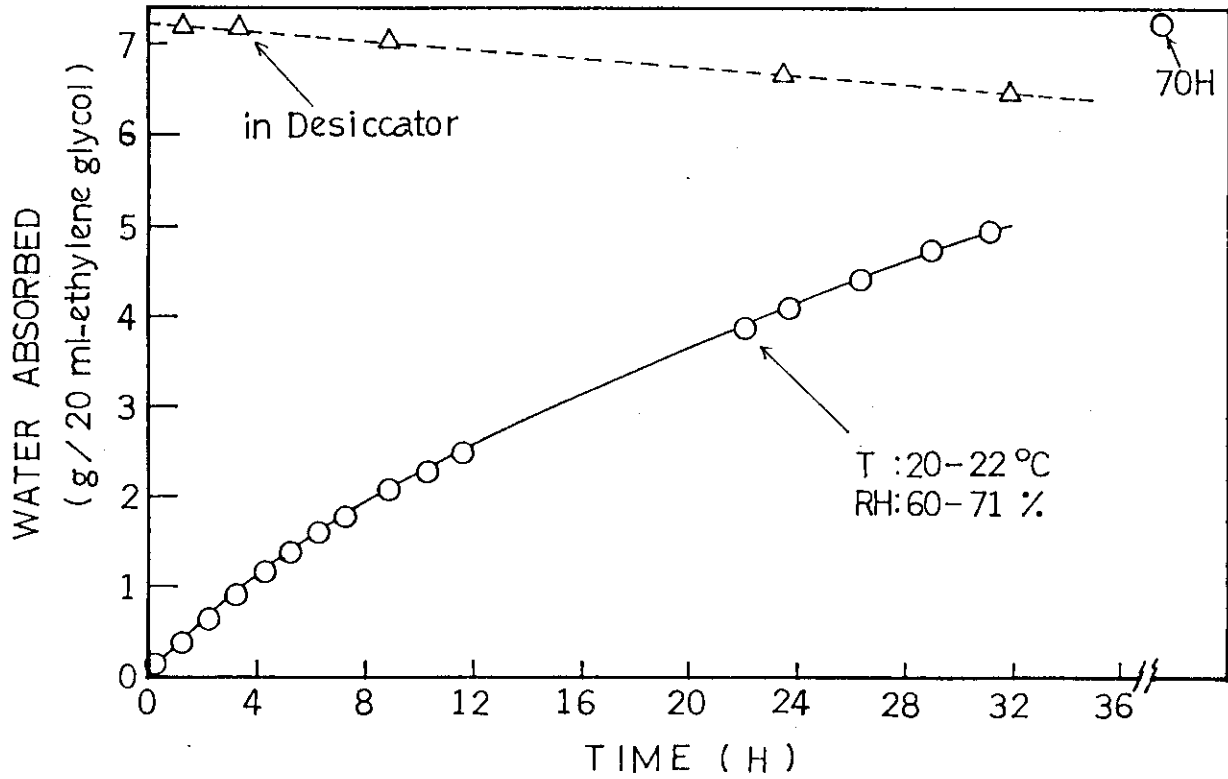
(Appendix II .4 Prediction of HT air concentration by the Gaussian Plume Dispersion Model)

Appendix II.5 Tritium trapped in ethylene glycol in HTO diffusion passive samplers

Number	X (m)	Location Y (m)	Z (m)	Time H + hh	Concentration (Bq/L-EG)	Time H + hh	Concentration (Bq/L-EG)	Time H + hh	Concentration (Bq/L-EG)	Trapped water (g)	Estimated [HTO] _{air} conc. (Bq·s/m ³) at H+5.2 hr at H+48 hr	Conc. (Bq·s/m ³) at H+48 hr
P _{HTO} 1	26.3	7.1	0			H+ 5.38	1.44E+04	H+ 47.8	4.10E+04	4.07	7.2E06	9.2E07
P _{HTO} 2	26.3	0	0			H+ 5.42	3.13E+04	H+ 47.8	8.21E+04	4.15	1.6E07	1.8E08
P _{HTO} 3	26.3	-6.8	0			H+ 5.43	2.77E+04	H+ 47.8	7.58E+04	3.55	1.4E07	1.7E08
P _{HTO} 4	50	17	0			H+ 5.35	1.92E+03	H+ 47.8	5.77E+04	3.81	9.5E05	1.3E07
P _{HTO} 5	50	9.4	0	H+ 1.10	3.93E+02	H+ 5.32	3.19E+03	H+ 47.7	9.72E+03	3.63	1.6E06	2.2E07
P _{HTO} 6	50	0	0	H+ 1.13	6.15E+02	H+ 5.28	4.91E+03	H+ 47.8	1.40E+04	3.73	2.4E06	3.1E07
P _{HTO} 7	50	-7.8	0	H+ 1.18	8.10E+02	H+ 5.27	5.32E+03	H+ 47.7	1.48E+04	3.72	2.6E06	3.3E07
P _{HTO} 8	50	-16.8	0			H+ 5.23	3.30E+03	H+ 47.7	1.35E+04	4.28	1.6E06	3.0E07
P _{HTO} 9	96.8	30.6	0			H+ 5.00	9.67E+02	H+ 47.7	2.24E+03	3.90	4.8E05	5.0E06
P _{HTO} 10	96.4	10.6	0			H+ 5.02	1.97E+03	H+ 47.6	4.41E+03	4.20	9.8E05	9.9E06
P _{HTO} 11	100	0	0			H+ 5.05	1.37E+03	H+ 47.7	4.38E+03	3.84	6.8E05	9.8E06
P _{HTO} 12	100	-16.8	2.0			H+ 5.07	3.25E+02	H+ 47.6	4.78E+02	4.35	1.6E05	1.1E06
P _{HTO} 13	100	-16.8	0.5			H+ 5.12	4.08E+02	H+ 47.6	9.35E+02	4.19	2.0E05	2.1E06
P _{HTO} 14	100	-15.2	0			H+ 5.12	1.59E+03	H+ 47.5	2.67E+03	5.53	7.9E05	6.0E06
P _{HTO} 15	100	-26.7	0			H+ 5.20	7.85E+02	H+ 47.5	1.79E+03	4.40	3.9E05	4.0E06
P _{HTO} 16	163.8	55.7	0			H+ 4.97	4.76E+02	H+ 47.4	1.03E+03	3.78	2.4E05	2.3E06
P _{HTO} 17	177.9	29.5	0			H+ 4.93	5.08E+02	H+ 47.4	1.24E+03	4.24	2.5E05	2.8E06
P _{HTO} 18	182.7	0	0			H+ 4.90	8.65E+02	H+ 47.4	1.81E+03	4.11	4.3E05	4.1E06
P _{HTO} 19	177.9	-29.5	0			H+ 4.87	5.61E+02	H+ 47.4	1.11E+03	3.58	2.8E05	2.5E06
P _{HTO} 20	163.8	-55.7	0			H+ 4.83	3.62E+02	H+ 47.5	6.14E+02	-	1.8E05	1.4E06
P _{HTO} 21	300	39.2	0			H+ 5.50	4.50E+02	H+ 47.1	3.78E+02	4.24	2.2E05	8.5E05
P _{HTO} 22	300	18.5	0			H+ 5.52	5.73E+02	H+ 47.2	4.76E+02	-	2.9E05	1.1E06
P _{HTO} 23	300	0	0			H+ 5.53	5.75E+02	H+ 47.2	5.12E+02	4.33	2.9E05	1.2E06
P _{HTO} 24	300	-19.3	0			H+ 5.55	5.34E+02	H+ 47.2	4.91E+02	4.34	2.7E05	1.1E06
P _{HTO} 25	300	-38.6	0			H+ 5.57	3.62E+02	H+ 47.3	4.04E+02	4.47	1.8E05	9.1E05
P _{HTO} 26	400	33.5	0			H+ 5.58	4.83E+02	H+ 47.1	1.89E+02	3.68	2.4E05	4.2E05
P _{HTO} 27	400	18.5	0			H+ 5.60	3.34E+02	H+ 47.1	3.42E+02	3.76	1.7E05	7.7E05
P _{HTO} 28	400	0	0			H+ 5.60	2.96E+02	H+ 47.1	3.52E+02	4.01	1.5E05	7.9E05
P _{HTO} 29	400	-16.5	0			H+ 5.62	2.67E+02	H+ 47.0	2.38E+02	4.13	1.3E05	5.3E05
P _{HTO} 30	400	-35.0	0			H+ 5.63	2.29E+02	H+ 47.0	2.27E+02	4.56	1.1E05	5.1E05

EG: ethylene glycol
H refers to time release began: 15:20 (EDT), 10 June 1987.

Appendix II.6 Absorption-desorption characteristics of HTO diffusion passive sampler (20 ml ethylene glycol) for air moisture



Appendix II.7 Tritium trapped in Pd-Molecular Sieve in HT diffusion passive samplers

Number	Location			Time H + hh	Trapped tritium (Bq/26g-MS)
	X (m)	Y (m)	Z (m)		
P _{HT} 1	26.3	7.1	0.4	H+ 1.05	1.78E+04
P _{HT} 2	26.3	0	0.4	H+ 1.05	3.63E+04
P _{HT} 3	26.3	- 6.8	0.4	H+ 1.05	3.49E+04
P _{HT} 4	50	17	0.4	H+ 1.07	8.51E+03
P _{HT} 5	50	9.4	0.4	H+ 1.07	8.95E+03
P _{HT} 6	50	0	0.4	H+ 1.17	1.54E+04
P _{HT} 7	50	- 7.8	0.4	H+ 1.15	1.12E+04
P _{HT} 8	50	-16.8	0.4	H+ 1.20	8.51E+03
P _{HT} 9	96.8	30.6	0.4	H+ 1.20	3.22E+03
P _{HT} 10	96.4	10.6	0.4	H+ 1.22	6.92E+03
P _{HT} 11	100	0	0.4	H+ 1.22	3.35E+03
P _{HT} 12	106	-10.0	0.4	H+ 1.23	4.26E+03
P _{HT} 13	106	-10.0	1.0	H+ 1.23	4.03E+03
P _{HT} 14	100	-15.2	0.4	H+ 1.25	3.81E+03
P _{HT} 15	100	-26.7	0.4	H+ 1.25	4.92E+03
P _{HT} 16	163.8	55.7	0.4	H+ 1.18	4.22E+03
P _{HT} 17	177.9	29.5	0.4	H+ 1.17	3.25E+03
P _{HT} 18	182.7	0	0.4	H+ 1.15	3.37E+03
P _{HT} 19	177.9	-29.5	0.4	H+ 1.13	1.78E+03
P _{HT} 20	163.8	-55.7	0.4	H+ 1.13	3.25E+03
P _{HT} 21	300	39.2	0.4	H+ 0.90	1.60E+03
P _{HT} 22	300	18.5	0.4	H+ 0.90	1.41E+03
P _{HT} 23	300	0	0.4	H+ 0.91	1.52E+03
P _{HT} 24	300	-19.3	0.4	H+ 0.92	1.76E+03
P _{HT} 25	300	-38.6	0.4	H+ 0.92	2.28E+03
P _{HT} 26	400	33.5	0.4	H+ 0.85	1.65E+03
P _{HT} 27	400	18.5	0.4	H+ 0.85	2.51E+03
P _{HT} 28	400	0	0.4	H+ 0.83	2.64E+03
P _{HT} 29	400	-16.5	0.4	H+ 0.83	2.58E+03

MS: PdCl₂-impregnated Molecular Sieve 4A
H refers to time release began: 15:20 (EDT), 10 June 1987.
Samplers were placed at each location about 30 minutes
before the release initiation.

Appendix II .8 Measurement of surface area of pine needles

A specific surface area S of pine needles was calculated as follows, assuming a hemi-ellipse in cross sectional shape of pine needle.

$$S = \ell \times p \times n \quad (\text{cm}^2/\text{g})$$

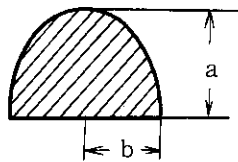
where, ℓ : mean longitudinal length of pine needles (cm)

n : the number of pine needles per unit gram

p : mean periphery length of a hemi-ellipse

$$= \pi \{1.5 (a+b) - \sqrt{ab}\}/2 + 2b \quad (\text{cm})$$

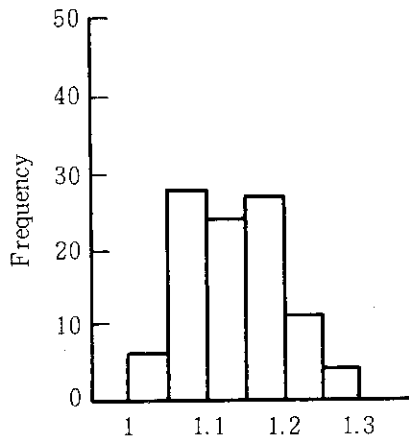
$2a, 2b$: mean lengths of axes



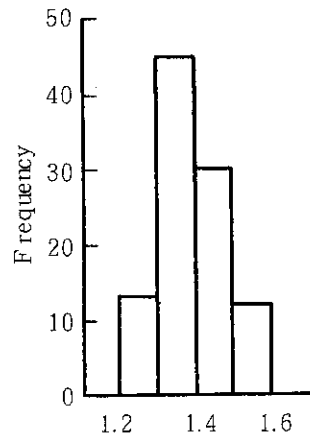
sectional view of
a pine needle

50 gram of pine needles were counted for n and 100 pine needles were measured for a and b . 449 needles were measured for ℓ . The resulting values are: $n = 8.98$, $a = 0.0743$ cm, $2b = 0.116$ cm, $\ell = 10.6$ cm, $p = 0.324$ cm and $S = 30.8$ cm²/g.

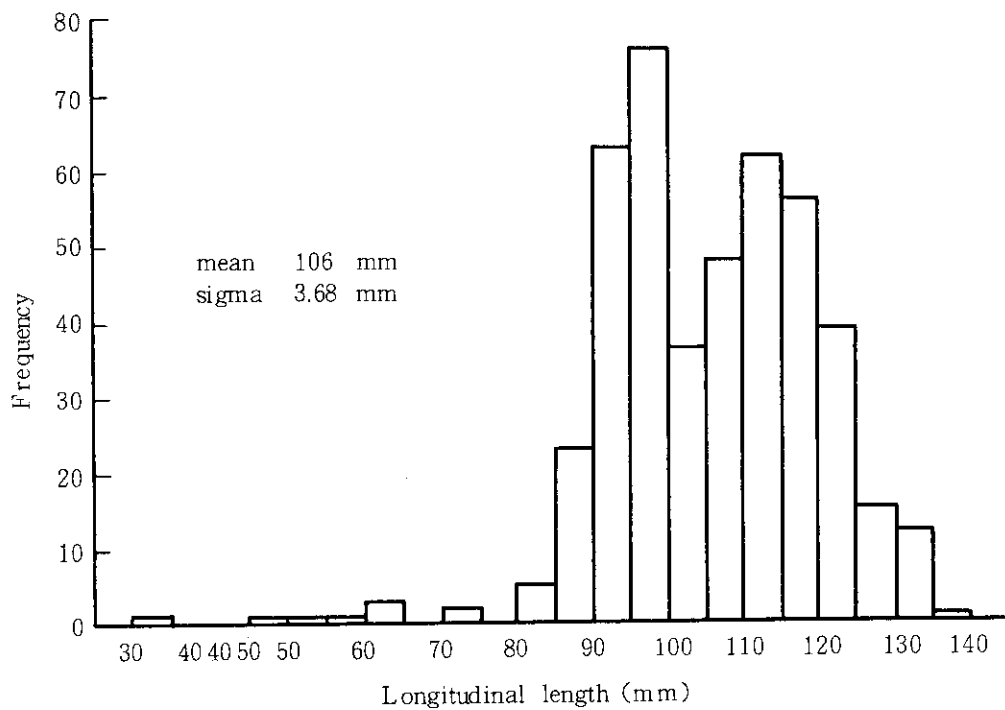
Histograms of the distributions of major axis lengths, minor axis lengths and longitudinal lengths of pine needles are shown in the following figures.



Minor axis length (mm)
 mean 1.16 mm
 sigma 0.064 mm



Major axis length (mm)
 mean 1.49 mm
 sigma 0.082 mm



(Appendix II .8 Measurement of surface area of pine needles)

Histograms of the distributions of major axis lengths minor axis lengths and longitudinal lengths of pine needles.

Appendix II.9 Evaporation from the ground at site B

Date (mm/dd/yy)	Time (h)	210 cm height		75 cm height		Bowen's ratio	Net radiation (W/m ²)	Soil heat flux (W/m ²)	Evaporation	
		Temp. (°C)	RH (%)	Temp. (°C)	RH (%)				(g/m ² h)	(mm/h)
06/10/87	11-12	16.97	45.91	17.43	47.08	0.629	616	152	424	0.424
06/10/87	12-13	18.14	42.14	18.73	42.66	0.907	645	152	362	0.362
06/10/87	13-14	19.51	39.28	20.16	40.32	0.721	520	113	352	0.352
06/10/87	14-15	21.00	35.25	21.59	35.51	1.025	571	123	480	0.480
06/10/87	15-16	21.00	33.69	21.59	34.86	0.656	376	70.6	275	0.275
06/10/87	16-17	21.65	33.95	21.91	34.47	0.636	361	54.6	279	0.279
06/10/87	17-18	22.44	31.47	22.57	31.73	0.636	330	46.4	258	0.258
06/10/87	18-19	22.37	31.60	22.50	31.99	0.505	172	6.70	164	0.164
06/11/87	7-8	11.25	77.26	11.38	80.12	0.186	87.5	52.0	44.6	0.045
06/11/87	8-9	14.57	60.48	14.76	61.52	0.434	271	90.2	188	0.188
06/11/87	9-10	17.49	52.54	17.62	53.19	0.403	396	128	285	0.285
06/11/87	10-11	19.25	43.44	19.51	43.70	0.817	400	127	224	0.224
06/11/87	11-12	19.83	39.41	20.16	39.80	0.800	487	123	301	0.301
06/11/87	12-13	21.13	34.08	21.59	34.08	1.280	557	143	271	0.271
06/11/87	13-14	21.85	33.82	22.30	33.82	1.245	568	115	301	0.301
06/11/87	14-15	21.72	37.46	22.37	37.33	1.235	464	95.8	245	0.245
06/11/87	15-16	20.55	38.63	20.68	39.41	0.333	230	21.6	233	0.233
06/11/87	16-17	19.38	42.01	19.44	42.27	0.430	131	-7.73	144	0.144

Appendix II.10 Soil temperature profile

Site	Date (mm/dd/yy)	Time (hh:mm)	Elapsed time (h)	Temperature profile (°C)					
				0 cm	5 cm	10 cm	15 cm	20 cm	30 cm
B	06/08/87	13:54	-49.43	19.5	18.2	-	17.0	16.5	16.2
B	06/09/87	17:22	-21.97	13.9	14.0	-	14.7	15.0	15.2
B	06/10/87	16:01	0.683	19.1	18.1	-	15.6	14.5	14.0
B	06/10/87	17:53	2.55	19.6	18.3	-	16.2	15.1	14.3
B	06/10/87	19:52	4.53	16.1	17.2	-	16.5	15.5	14.5
B	06/11/87	13:49	22.48	21.3	18.4	-	15.6	15.0	14.5
B	06/11/87	14:25	23.08	21.4	13.8	-	16.0	15.1	14.6
B	06/12/87	15:13	47.88	17.6	16.1	-	15.5	15.2	15.0
B	06/13/87	14:19	71.98	25.1	21.2	-	17.5	16.2	15.2
B	06/15/87	10:49	115.48	22.6	20.0	-	19.0	18.6	18.1
E	06/09/87	16:40	-22.67	14.0	14.6	14.7	14.7	14.6	15.5
E	06/09/87	18:00	-21.33	13.2	14.7	15.0	15.0	14.8	16.0
E	06/10/87	16:25	1.08	24.4	23.0	20.5	18.1	16.2	14.5
E	06/10/87	20:30	5.17	19.0	20.7	20.7	19.5	18.4	16.5
E	06/11/87	16:20	25.00	21.5	22.4	21.6	19.8	18.4	16.5
E	06/12/87	14:05	46.75	16.5	16.6	16.5	16.0	15.6	16.0
E	06/13/87	13:49	70.48	26.5	25.4	21.0	18.6	17.2	16.1
E	06/15/87	9:39	114.32	18.7	18.2	19.0	19.2	19.7	20.2

Appendix III.1(a) Soil water contents, soil water HTO concentrations and HTO deposits in soils (sites A and BB)

Date mm/dd/yy	Time hh:mm:ss (H+ hh)	Location X(m) Y(m) Z(m)			Site	Depth (cm)	Water Content (% of wet weight)	[HTO] _{soil water} (Bq/L)	[HTO] _{soil} (Bq/m ²)	[HTO] _{soil} (Bq/m ³)
06/09/87	19:21: (H -20.0)	50	0	0	A	0-5	20.3	9.54E+01	1.78E+03	3.56E+04
						5-10	20.2	1.28E+02	2.36E+03	4.72E+04
						10-15	20.4	7.48E+01	1.54E+03	1.54E+04
						Total		5.68E+03	2.84E+04	
06/10/87	21:28:20 (H+ 6.13)	50	0	0	A	0-5	20.1	2.27E+04	3.88E+05	7.76E+06
						5-10	20.6	2.53E+03	4.74E+04	9.48E+05
						10-15	22.1	1.09E+03	2.10E+04	2.10E+05
						Total		4.56E+05	2.28E+06	
06/12/87	16:18: (H+ 49.0)	50	0	0	A	0-5	20.3	5.36E+03	9.39E+04	1.88E+06
						5-10	23.7	1.72E+03	3.68E+04	7.36E+05
						10-15	22.4	1.48E+02	2.80E+03	2.80E+04
						Total		1.33E+05	6.65E+05	
06/15/87	11:35: (H+ 116.)	50	0	0	A	0-5	20.5	9.39E+03	1.63E+05	3.26E+06
						5-10	19.8	3.02E+03	5.64E+04	1.13E+06
						10-15	21.0	3.24E+02	6.11E+03	6.11E+04
						Total		2.25E+05	1.13E+06	
06/09/87	17:43: (H -21.6)	100	-10	0	BB	0-2.5	26.4	8.29E+01	6.96E+02	2.78E+04
						2.5-5	21.3	6.47E+01	5.49E+02	2.19E+04
						5-7.5	21.5	5.17E+01	4.84E+02	1.94E+04
						7.5-10	22.3	5.39E+01	5.48E+02	2.19E+04
						10-12.5	22.8	5.52E+01	5.69E+02	2.28E+04
						12.5-15	22.5	6.59E+01	6.87E+02	2.75E+04
						15-17.5	20.4	6.04E+01	5.66E+02	2.26E+04
						17.5-20	16.8	6.95E+01	5.77E+02	2.31E+04
						Total		4.67E+03	2.34E+04	
						06/10/87	17:53: (H+ 2.55)	100	-10	0
5-10	18.0	1.23E+02	2.16E+03	4.32E+04						
10-20	22.0	4.01E+02	1.57E+04	1.57E+05						
Total		2.46E+04	1.23E+05							
06/11/87	14:25: (H+ 23.1)	100	-10	0	BB	0-5	18.5	6.52E+02	1.04E+04	2.08E+05
						5-10	20.6	1.55E+02	2.86E+03	5.72E+04
						10-20	23.7	4.71E+02	1.97E+04	1.97E+05
						Total		3.30E+04	1.65E+05	
06/12/87	15:13: (H+ 47.9)	100	-10	0	BB	0-5	17.9	3.41E+02	5.18E+03	1.04E+05
						5-10	19.6	1.81E+02	3.39E+03	6.78E+04
						10-20	21.6	2.49E+02	1.01E+04	1.01E+05
						Total		1.87E+04	9.35E+04	
06/15/87	10:49: (H+ 116.)	100	-10	0	BB	0-5	16.2	3.83E+02	5.41E+03	1.08E+05
						5-10	16.7	1.51E+02	2.49E+03	4.98E+04
						10-20	19.2	1.64E+02	5.84E+03	5.84E+04
						Total		1.37E+04	6.85E+04	

H refers to time release began: 15:20 (EDT), 10 June 1987.

BB: Area covered with a plastic sheet during the release period.

Appendix III.1(b) Soil water contents, soil water HTO concentrations and HTO deposits in soils (site B)

Date mm/dd/yy	Time hh:mm:ss (H + hh)	Location X(m) Y(m) Z(m)			Site	Depth (cm)	Water Content (% of wet weight)	[HTO] _{soil water} (Bq/L)	[HTO] _{soil} (Bq/m ²)	[HTO] _{soil} (Bq/m ³)
06/09/87	17:43: (H -21.6)	100	-10	0	B	0-2.5	26.4	8.29E+01	6.96E+02	2.78E+04
						2.5-5	21.3	6.47E+01	5.49E+02	2.20E+04
						5-7.5	21.5	5.17E+01	4.84E+02	1.94E+04
						(BG) 7.5-10	22.3	5.39E+01	5.48E+02	2.19E+04
						10-12.5	22.8	5.52E+01	5.69E+02	2.28E+04
						12.5-15	22.5	6.59E+01	6.87E+02	2.75E+04
						15-17.5	20.4	6.04E+01	5.66E+02	2.26E+04
						17.5-20	16.8	6.95E+01	5.77E+02	2.31E+04
Total								4.67E+03	2.34E+04	
06/10/87	16:01: (H+ 0.68)	100	-10	0	B	0-2.5	23.7	4.94E+02	4.77E+03	1.91E+05
						2.5-5	24.6	1.16E+02	1.22E+03	4.88E+04
						5-7.5	23.7	1.30E+02	1.33E+03	5.32E+04
						7.5-10	22.6	1.42E+02	1.45E+03	5.80E+04
						10-12.5	23.8	1.44E+02	1.50E+03	6.00E+04
						12.5-15	24.0	1.58E+02	1.73E+03	6.92E+04
						15-17.5	21.3	2.14E+02	2.14E+03	8.56E+04
						17.5-20	20.8	1.75E+02	1.73E+03	6.92E+04
Total								1.59E+04	7.95E+04	
06/10/87	18:06: (H+ 2.8)	100	-10	0	B	0-5	22.4	3.15E+02	6.37E+03	1.27E+05
						5-10	22.6	1.02E+02	2.05E+03	4.10E+04
						10-20	21.5	7.81E+02	3.13E+04	3.13E+05
Total								3.97E+04	1.99E+05	
06/10/87	19:52: (H+ 4.5)	100	-10	0	B	0-5	22.7	2.94E+02	5.56E+03	1.11E+05
						5-10	21.1	6.88E+01	1.35E+03	2.70E+04
						10-20	21.9	3.37E+02	1.26E+04	1.26E+05
Total								1.95E+04	9.75E+04	
06/11/87	13:49: (H+ 22.5)	100	-10	0	B	0-2.5	21.7	1.39E+03	1.16E+04	4.64E+05
						2.5-5	21.1	1.90E+02	1.82E+03	7.28E+04
						5-7.5	21.6	2.11E+02	1.92E+03	7.68E+04
						7.5-10	23.7	2.26E+02	2.31E+03	9.24E+04
						10-12.5	23.0	2.34E+02	2.44E+03	9.76E+04
						12.5-15	23.0	2.37E+02	2.50E+03	1.00E+05
						15-17.5	21.1	2.55E+02	2.48E+03	9.92E+04
						17.5-20	19.8	2.52E+02	2.49E+03	9.96E+04
Total								2.76E+04	1.38E+05	
06/12/87	15:23: (H+ 48.1)	100	-10	0	B	0-5	19.7	4.41E+02	7.93E+03	1.59E+05
						5-10	21.6	2.33E+02	4.76E+03	9.52E+04
						10-20	22.0	3.02E+02	1.10E+04	1.10E+05
Total								2.37E+04	1.19E+05	
06/13/87	14:19: (H+ 72.0)	100	-10	0	B	0-5	22.2	4.58E+02	8.55E+03	1.71E+05
						5-10	23.9	1.94E+02	4.60E+03	9.20E+04
						10-20	22.4	3.55E+02	1.50E+04	1.50E+05
Total								2.82E+04	1.41E+05	
06/15/87	10:57: (H+ 116.)	100	-10	0	B	0-0.5	19.0	1.43E+02	1.21E+03	4.84E+04
						2.5-5	19.9	1.24E+02	1.15E+03	4.60E+04
						5-7.5	21.6	1.16E+02	1.16E+03	4.64E+04
						7.5-10	21.9	1.33E+02	1.35E+03	5.40E+04
						10-12.5	22.3	1.58E+02	1.50E+03	6.00E+04
						12.5-15	22.2	1.99E+02	2.07E+03	8.28E+04
						15-17.5	21.5	4.22E+02	3.91E+03	1.56E+05
						17.5-20	22.3	8.11E+02	6.58E+03	2.63E+05
Total								1.89E+04	9.45E+04	

H refers to time release began: 15:20 (EDT), 10 June 1987.

Appendix III.1(c) Soil water contents, soil water HTO concentrations and HTO deposits in soils (sites C and D)

Date mm/dd/yy	Time hh:mm:ss (H + hh)	Location X(m) Y(m) Z(m)			Site	Depth (cm)	Water Content (% of wet weight)	[HTO] _{soil water} (Bq/L)	[HTO] _{soil} (Bq/m ²)	[HTO] _{soil} (Bq/m ³)
06/09/87	19:32:— (H -19.8)	200	0	0	C	0-5	8.03	1.48E+02	1.03E+03	2.06E+04
						5-10	5.71	1.98E+02	9.33E+02	1.87E+04
						(BG) 10-15	3.80	2.06E+02	6.29E+02	1.26E+04
						Total		2.59E+03	1.73E+04	
06/10/87	21:16:45 (H+ 5.93)	200	0	0	C	0-5	6.80	3.91E+03	2.12E+04	4.24E+05
						5-10	3.23	1.37E+03	3.75E+03	7.50E+04
						10-15	3.34	5.55E+02	1.58E+03	3.16E+04
						Total		2.65E+04	1.77E+05	
06/12/87	15:56:00 (H+ 48.6)	200	0	0	C	0-5	7.19	1.73E+02	1.00E+03	2.00E+04
						5-10	6.74	4.42E+02	2.34E+03	4.68E+04
						10-15	8.08	2.52E+02	1.92E+03	3.84E+04
						Total		5.25E+03	3.50E+04	
06/15/87	10:33:— (H+ 115.)	200	0	0	C	0-5	4.13	3.51E+02	1.08E+03	2.16E+04
						5-10	4.28	2.70E+02	1.03E+03	2.06E+04
						10-15	4.93	3.11E+02	1.26E+03	2.52E+04
						Total		3.37E+03	2.25E+04	
06/09/87	19:36:— (H -19.7)	300	0	0	D	0-5	3.57	2.54E+02	6.93E+02	1.39E+04
						5-10	4.31	2.15E+02	7.58E+02	1.52E+04
						(BG) 10-15	4.62	2.11E+02	8.55E+02	1.71E+04
						Total		2.30E+03	1.53E+04	
06/10/87	21:12:40 (H+ 5.88)	300	0	0	D	0-5	2.96	7.10E+03	1.64E+04	3.28E+05
						5-10	4.16	1.26E+03	4.21E+03	8.42E+04
						10-15	5.19	4.36E+02	1.88E+03	3.76E+04
						Total		2.25E+04	1.50E+05	
06/12/87	15:40:— (H+ 48.3)	300	0	0	D	0-5	4.33	3.44E+02	1.19E+03	2.38E+04
						5-10	5.44	3.97E+02	1.58E+03	3.16E+04
						10-15	5.66	8.47E+02	3.90E+03	7.80E+04
						Total		6.66E+03	4.44E+04	
06/15/87	10:14:— (H+ 115.)	300	0	0	D	0-5	2.68	5.07E+02	1.08E+03	2.16E+04
						5-10	3.74	4.58E+02	1.30E+03	2.60E+04
						10-15	3.67	7.36E+02	2.23E+03	4.46E+04
						Total		4.61E+03	3.07E+04	

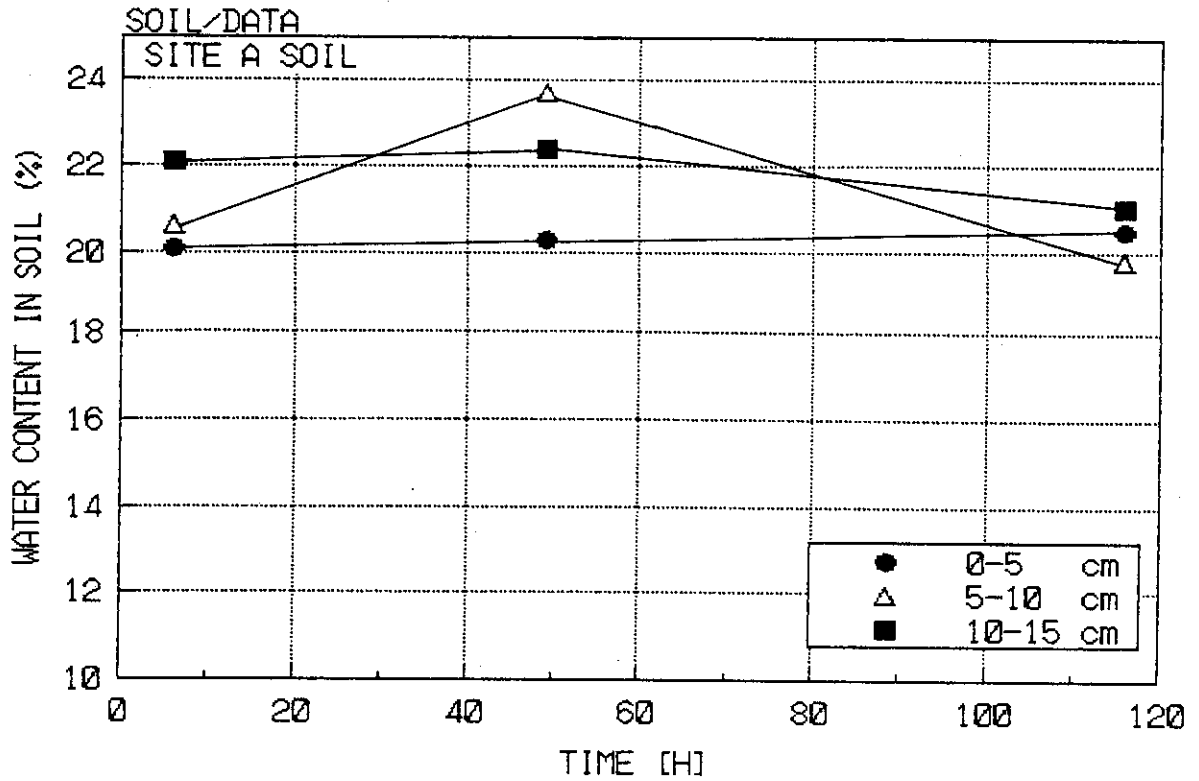
H refers to time release began: 15:20 (EDT), 10 June 1987.

Appendix III.1(d) Soil water contents, soil water HTO concentrations and HTO deposits in soils (site E)

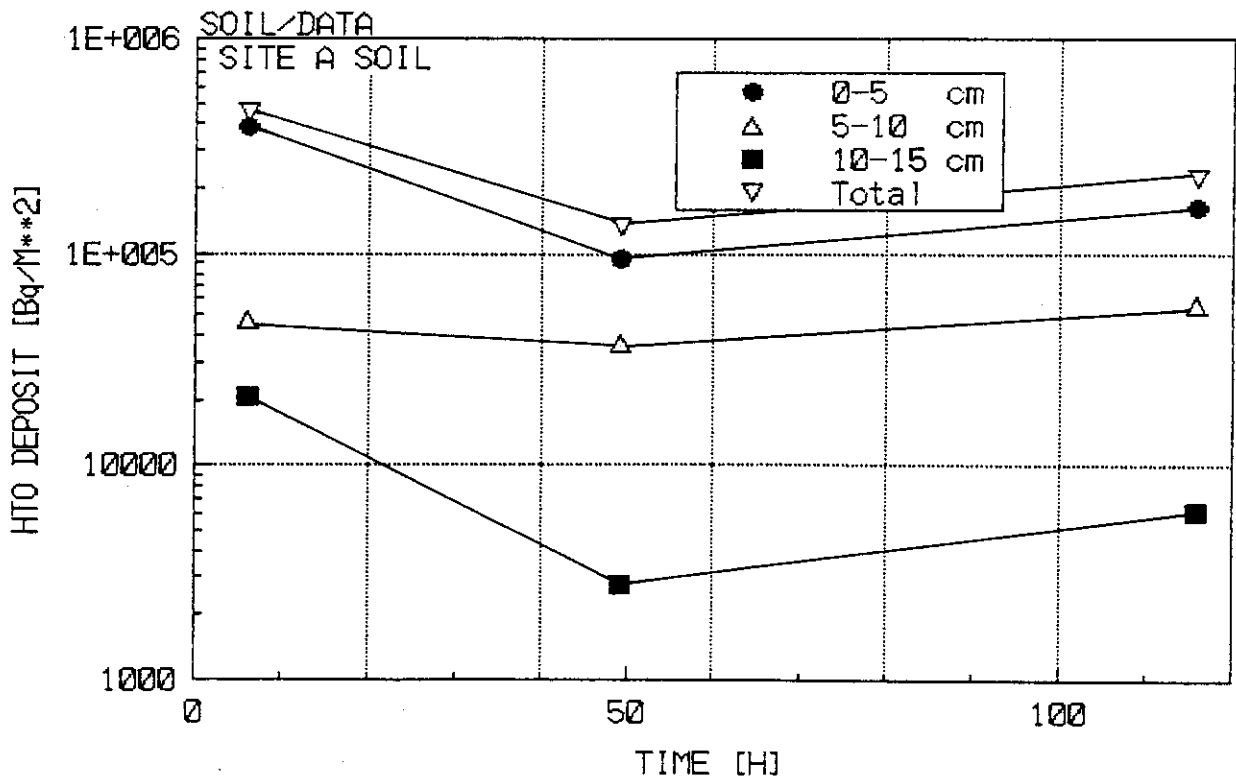
Date mm/dd/yy	Time hh:mm:ss (H + hh)	Location X(m) Y(m) Z(m)			Site	Depth (cm)	Water Content (% of wet weight)	[HTO] _{soil} water (Bq/L)	[HTO] _{soil} (Bq/m ²)	[HTO] _{soil} (Bq/m ³)
06/09/87	16:40: (H -22.7)	394	0	0	E	0-2.5	3.24	2.83E+02	3.45E+02	1.38E+04
						2.5-5	3.21	2.53E+02	3.05E+02	1.22E+04
						5-7.5	3.50	2.38E+02	3.32E+02	1.33E+04
						(BG) 7.5-10	3.48	2.25E+02	3.26E+02	1.30E+04
						10-12.5	3.65	2.17E+02	3.36E+02	1.34E+04
						12.5-15	3.53	2.02E+02	3.15E+02	1.26E+04
						15-17.5	3.62	2.04E+02	3.26E+02	1.30E+04
						17.5-20	3.67	2.02E+02	3.36E+02	1.34E+04
							Total	2.62E+03	1.31E+04	
06/10/87	16:25: (H+ 1.08)	394	0	0	E	0-5	3.91	3.20E+03	9.63E+03	1.93E+05
						5-10	3.88	3.16E+02	1.02E+03	2.04E+04
						10-20	3.32	1.63E+02	9.39E+02	9.39E+03
							Total	1.16E+04	5.80E+04	
06/10/87	20:15: (H+ 4.92)	394	0	0	E	0-2.5	2.13	6.59E+03	5.44E+03	2.18E+05
						2.5-5	3.58	1.98E+03	3.06E+03	1.22E+05
						5-7.5	2.56	5.59E+02	6.16E+02	2.46E+04
						7.5-10	2.34	4.31E+02	4.21E+02	1.68E+04
						10-12.5	2.46	3.44E+02	3.46E+02	1.38E+04
						12.5-15	2.81	2.69E+02	3.10E+02	1.24E+04
						15-17.5	2.54	2.94E+02	3.14E+02	1.26E+04
						17.5-20	2.77	2.48E+02	3.08E+02	1.23E+04
							Total	1.08E+04	5.40E+04	
06/11/87	16:20: (H+ 25.0)	394	0	0	E	0-2.5	0.93	3.84E+03	1.32E+03	5.28E+04
						2.5-5	1.89	3.28E+03	2.50E+03	1.00E+05
						5-7.5	2.04	1.56E+03	1.33E+03	5.32E+04
						7.5-10	2.53	5.52E+02	5.76E+02	2.30E+04
						10-12.5	2.69	3.87E+02	4.07E+02	1.63E+04
						12.5-15	2.78	3.03E+02	3.66E+02	1.46E+04
						15-17.5	3.15	2.83E+02	3.64E+02	1.46E+04
						17.5-20	3.43	2.73E+02	3.90E+02	1.56E+04
							Total	7.25E+03	3.63E+04	
06/12/87	14:05: (H+ 46.8)	394	0	0	E	0-5	3.49	3.12E+02	8.45E+02	1.69E+04
						5-10	3.71	7.24E+02	2.11E+03	4.22E+04
						10-20	3.76	6.45E+02	4.08E+03	4.08E+04
							Total	7.04E+03	3.52E+04	
06/13/87	13:49: (H+ 70.5)	394	0	0	E	0-5	2.26	8.96E+02	1.64E+03	3.28E+04
						5-10	2.85	1.32E+03	3.31E+03	6.62E+04
						10-20	3.25	0.47E+02	2.52E+03	2.52E+04
							Total	7.47E+03	3.74E+04	
06/15/87	9:39: (H+ 114.)	394	0	0	E	0-5	1.62	8.00E+02	1.02E+03	2.04E+04
						5-10	1.71	1.05E+03	1.41E+03	2.82E+04
						10-20	2.55	7.26E+02	3.05E+03	3.05E+04
							Total	5.48E+03	2.74E+04	

H refers to time release began: 15:20 (EDT), 10 June 1987.

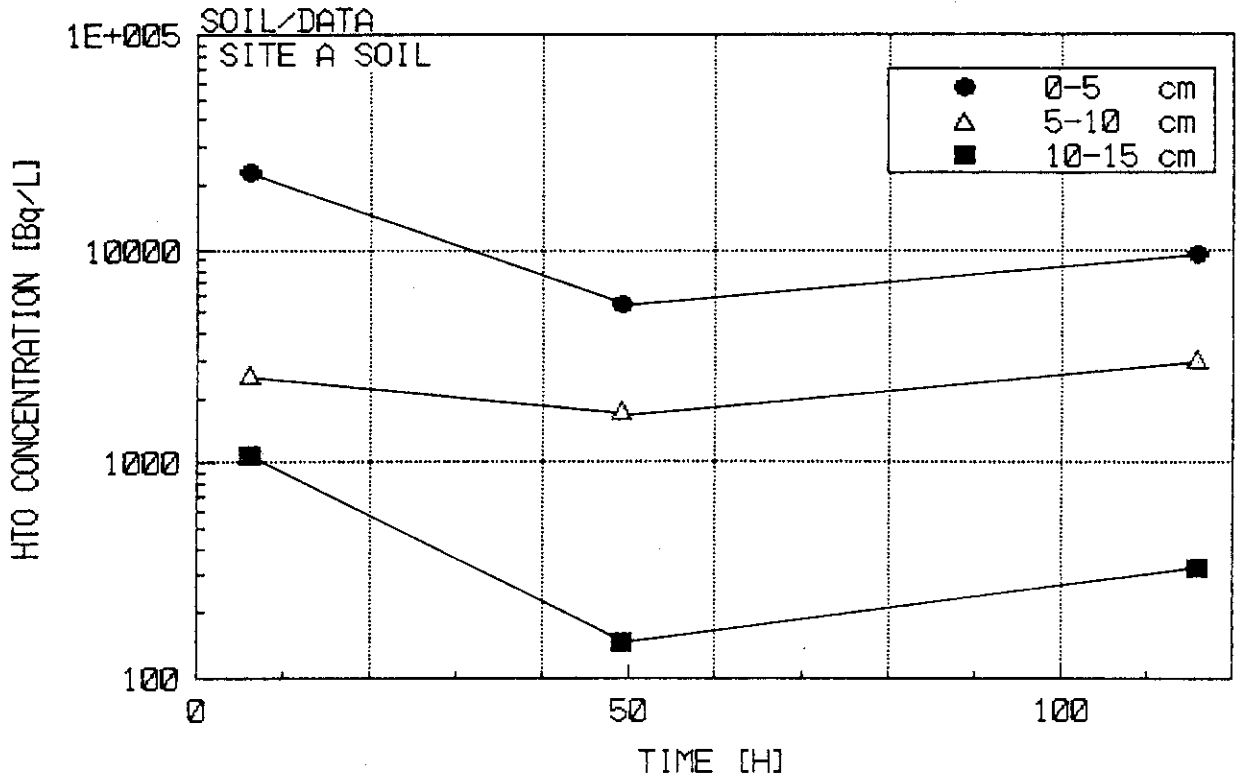
Appendix III.2(a) Time histories of soil water contents (site A)



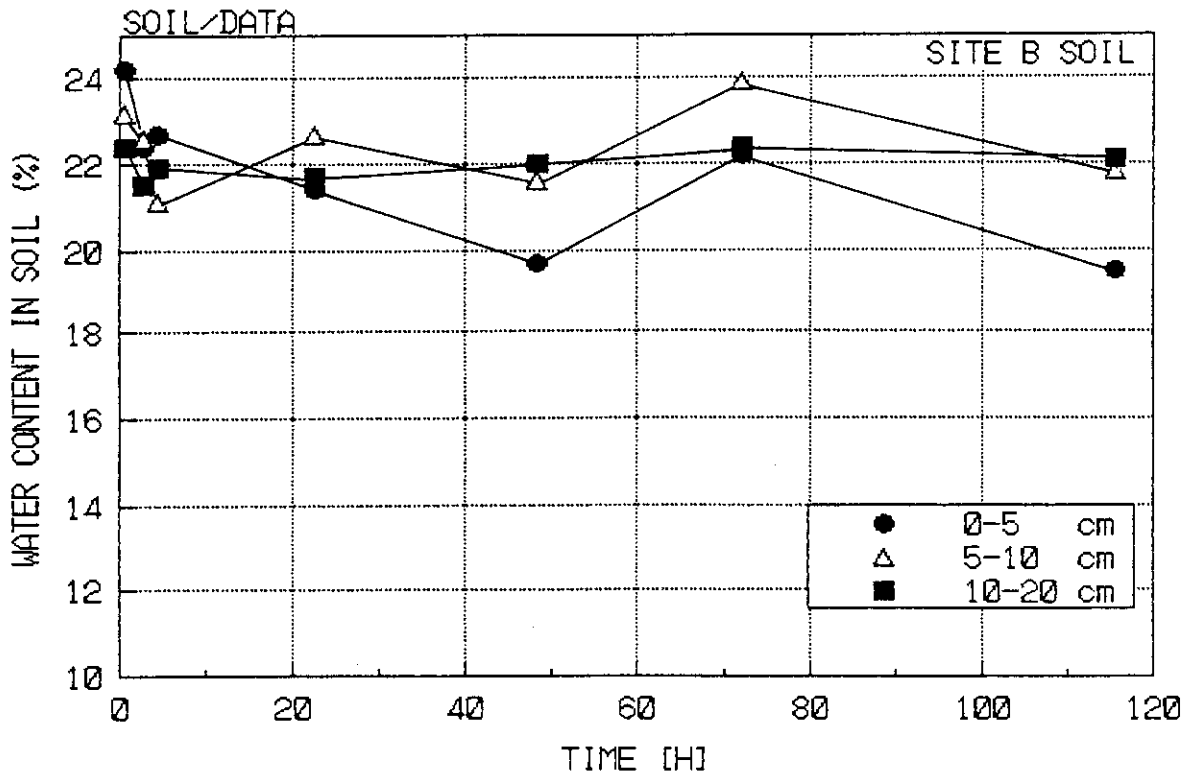
Appendix III.2(b) Time histories of HTO deposits in soils (site A)



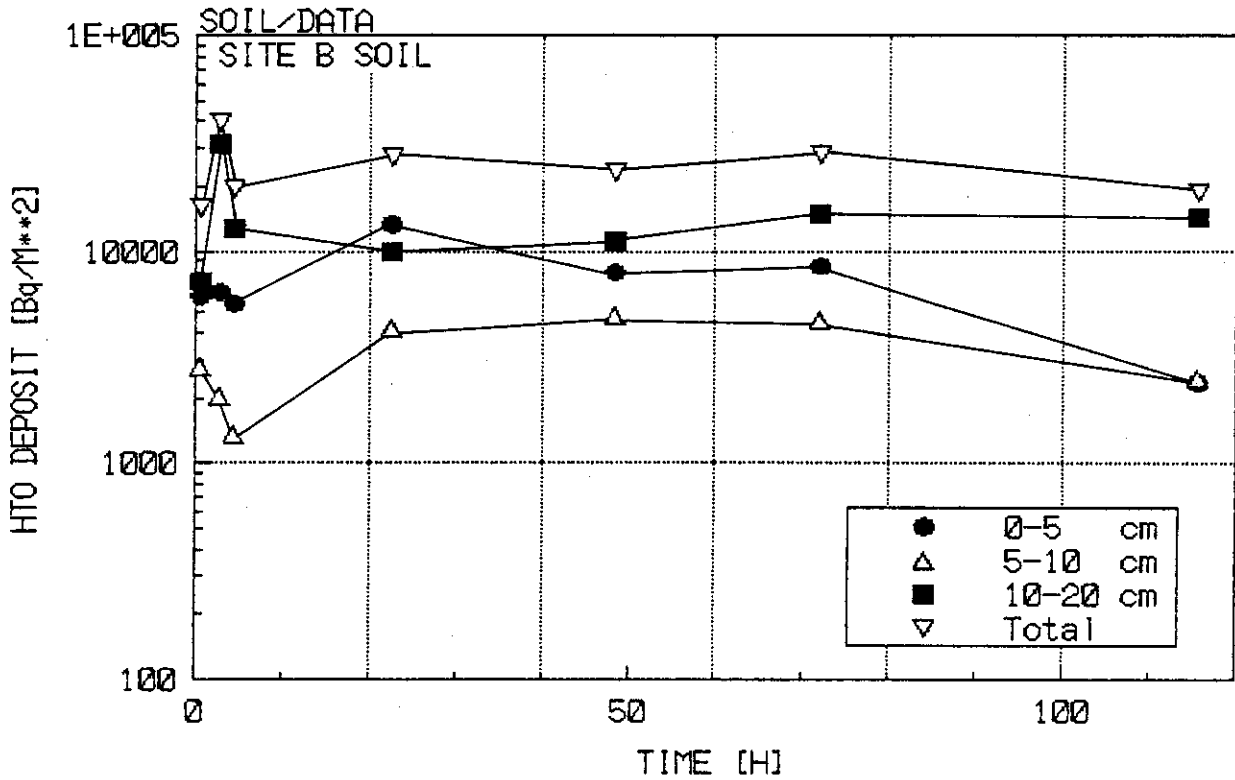
Appendix III.2(c) Time histories of soil water HTO concentrations
(site A)



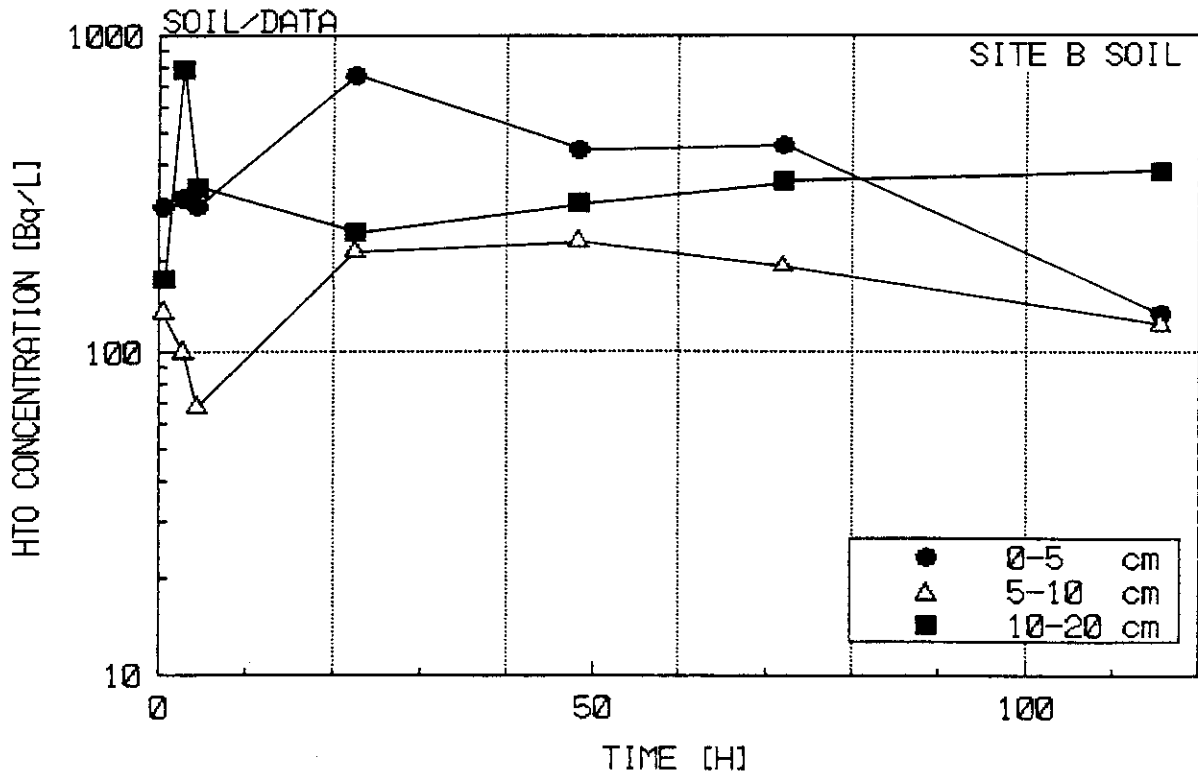
Appendix III.2(d) Time histories of soil water contents (site B)



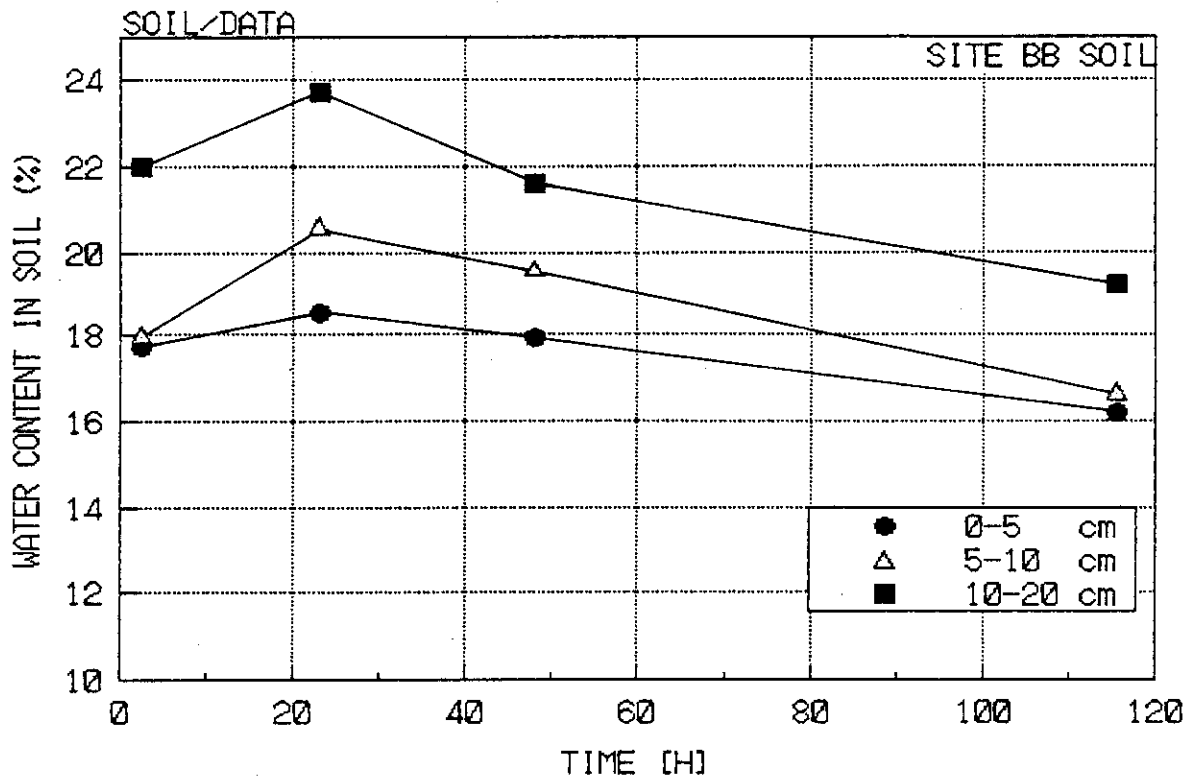
Appendix III.2(e) Time histories of HTO deposits in soils (site B)



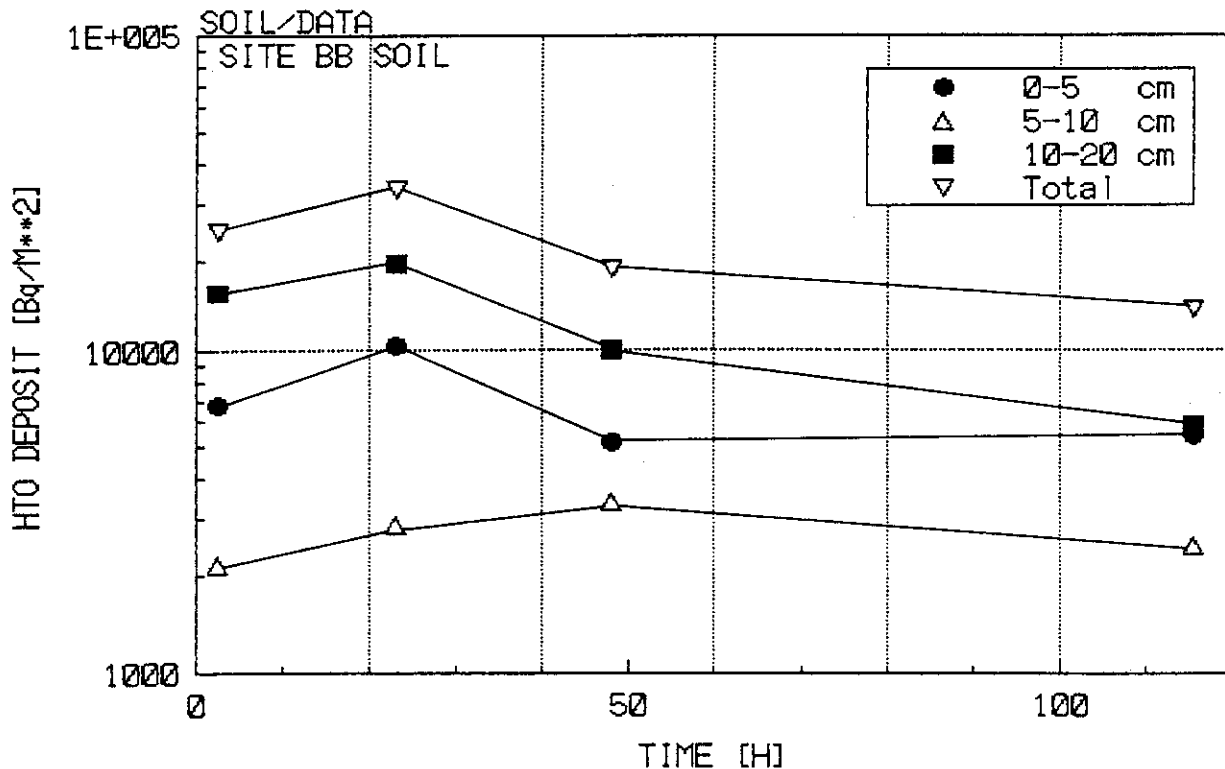
Appendix III.2(f) Time histories of soil water HTO concentrations (site B)



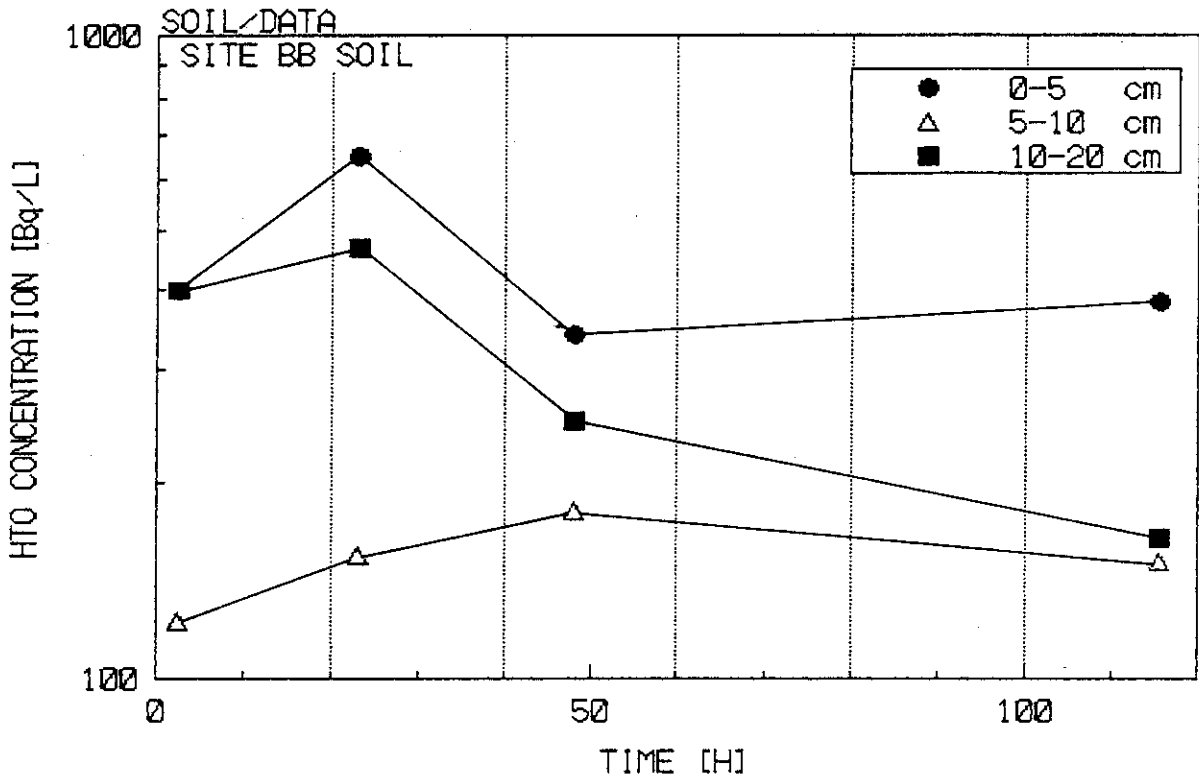
Appendix III.2(g) Time histories of soil water contents (site BB)



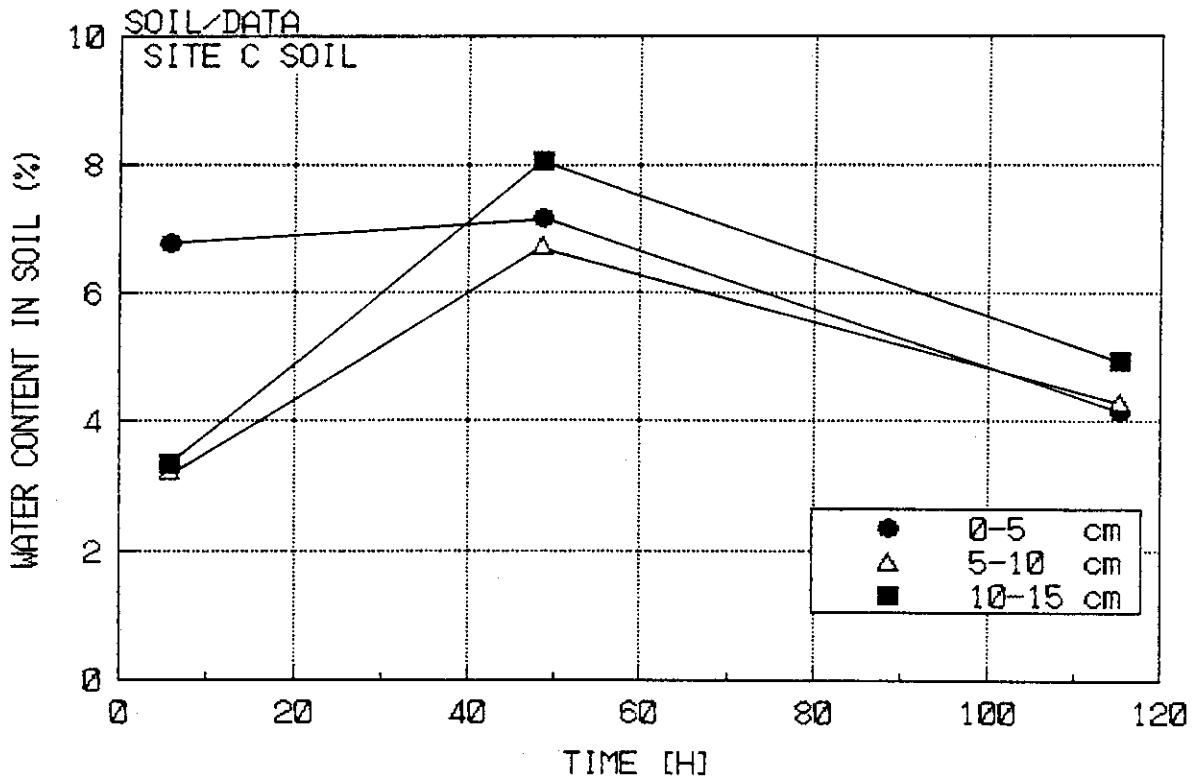
Appendix III.2(h) Time histories of HTO deposits in soils (site BB)



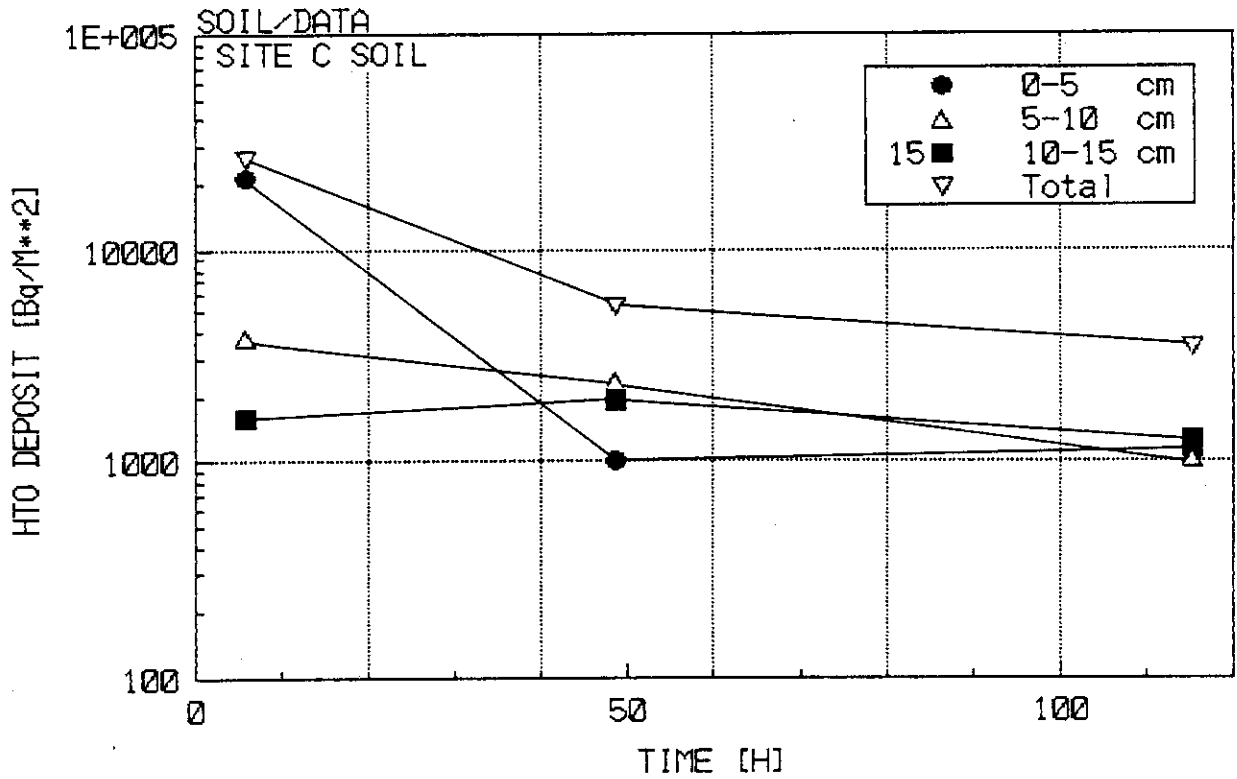
Appendix III.2(i) Time histories of soil water HTO concentrations (site BB)



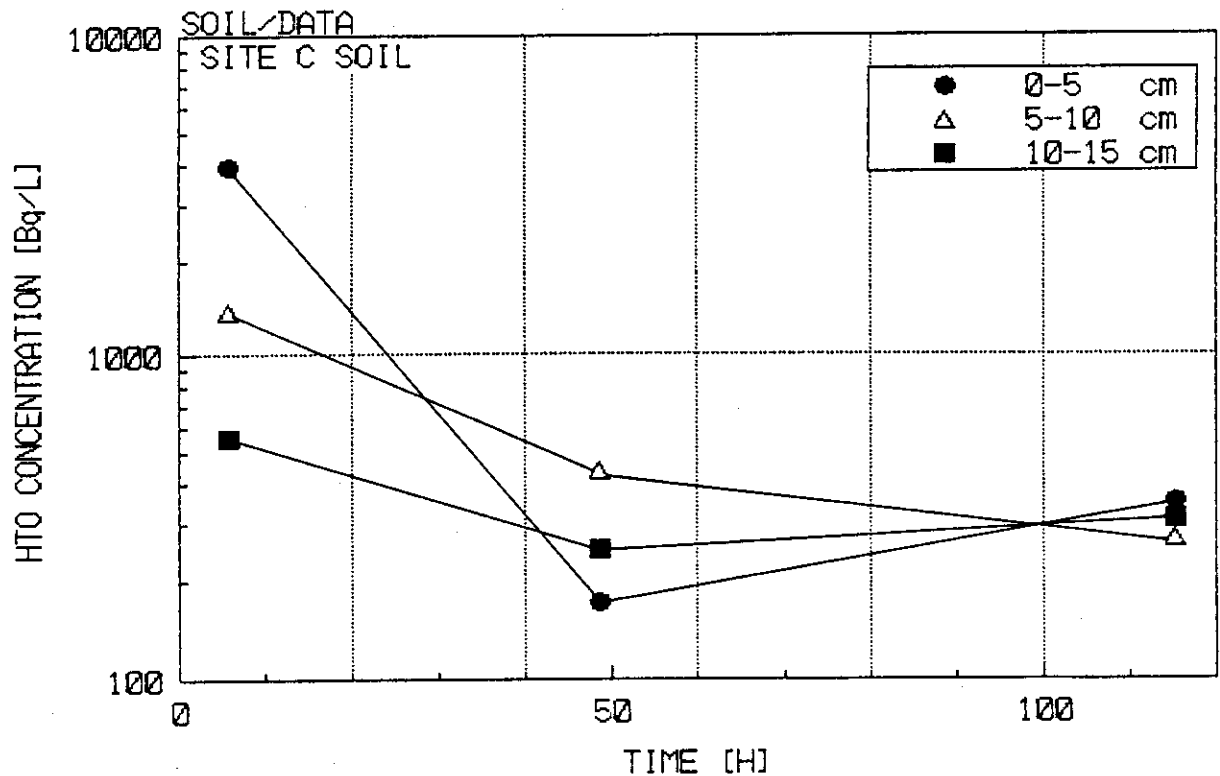
Appendix III.2(j) Time histories of soil water contents (site C)



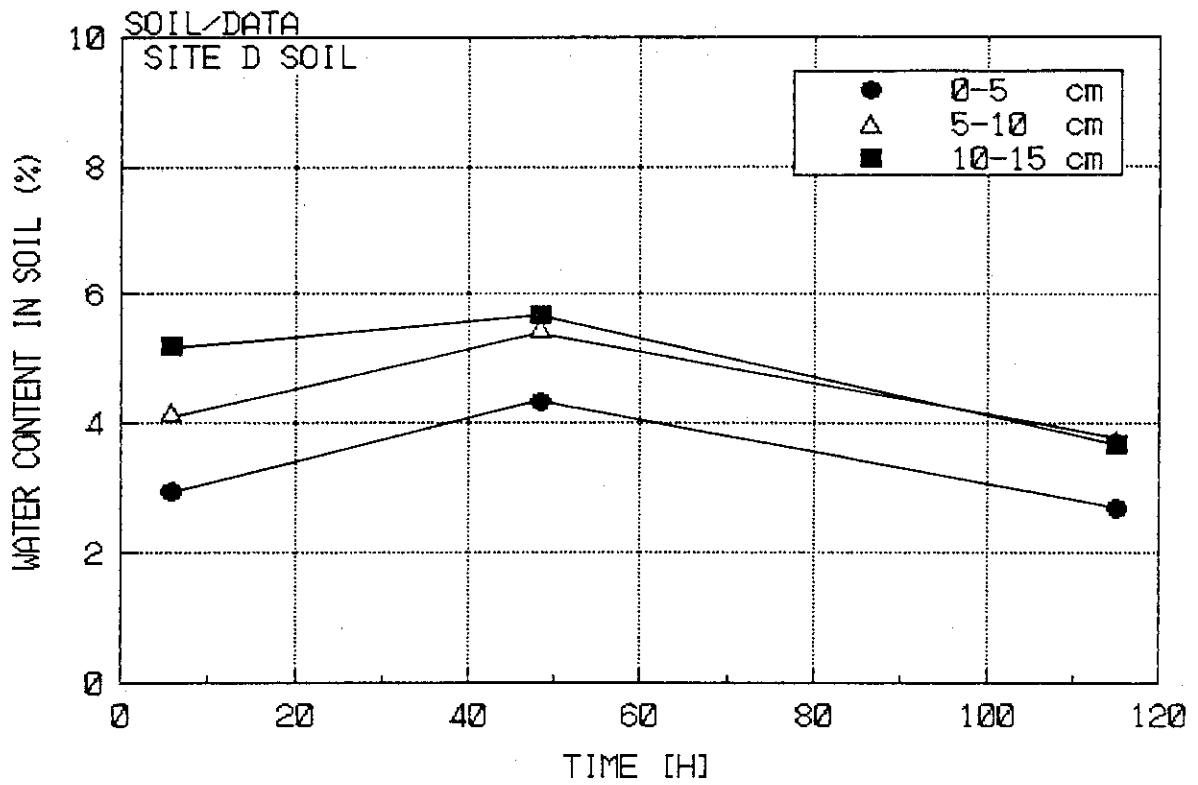
Appendix III.2(k) Time histories of HTO deposits in soils (site C)



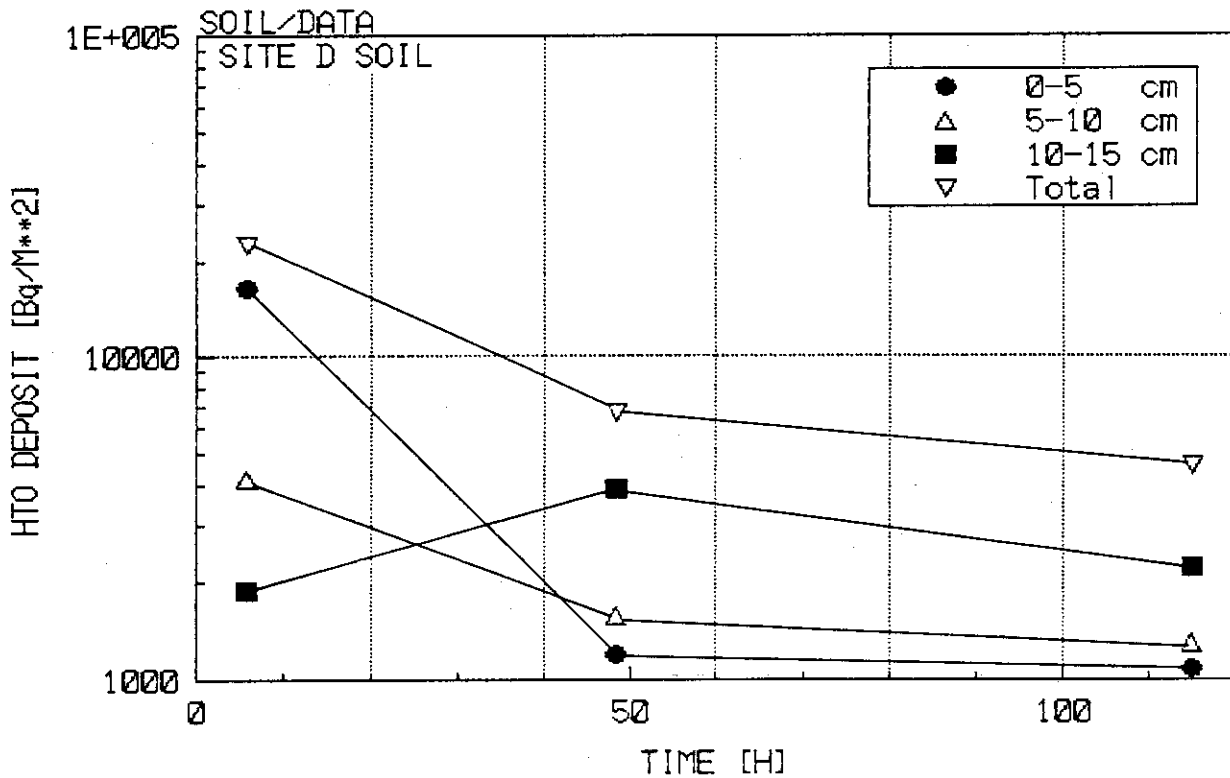
Appendix III.2(l) Time histories of soil water HTO concentrations (site C)



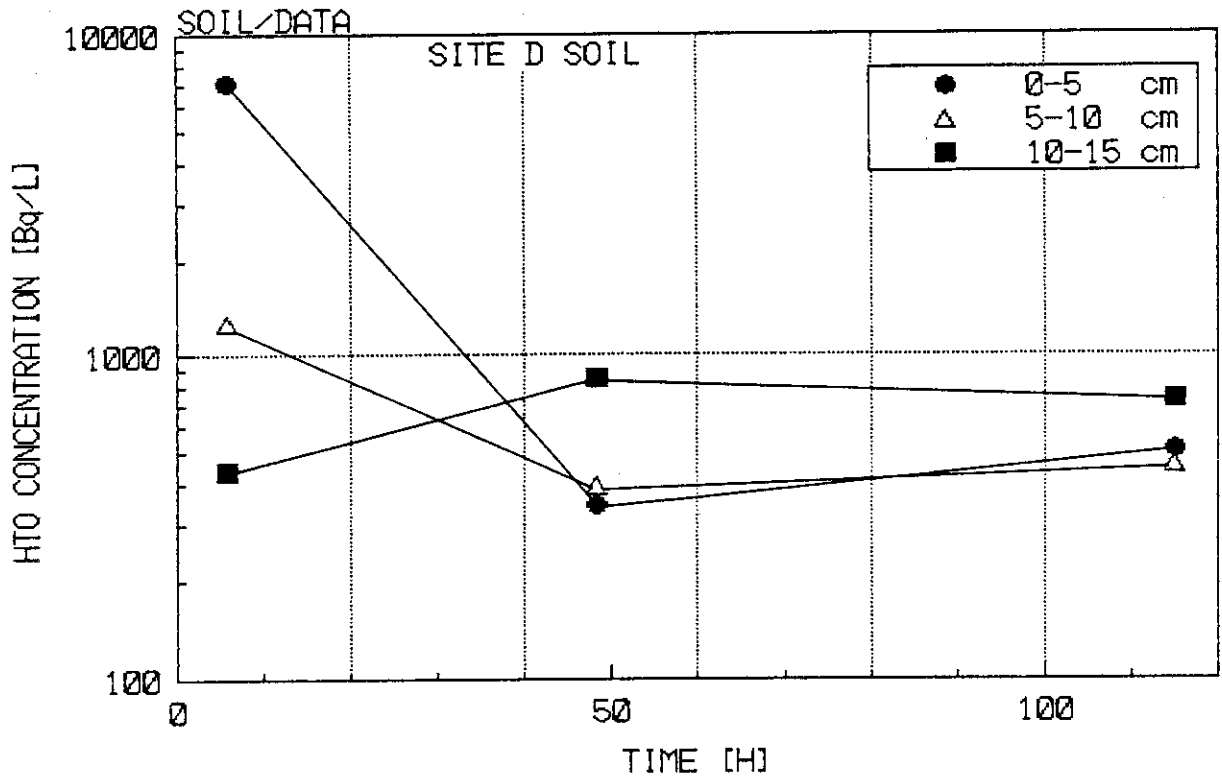
Appendix III.2(m) Time histories of soil water contents (site D)



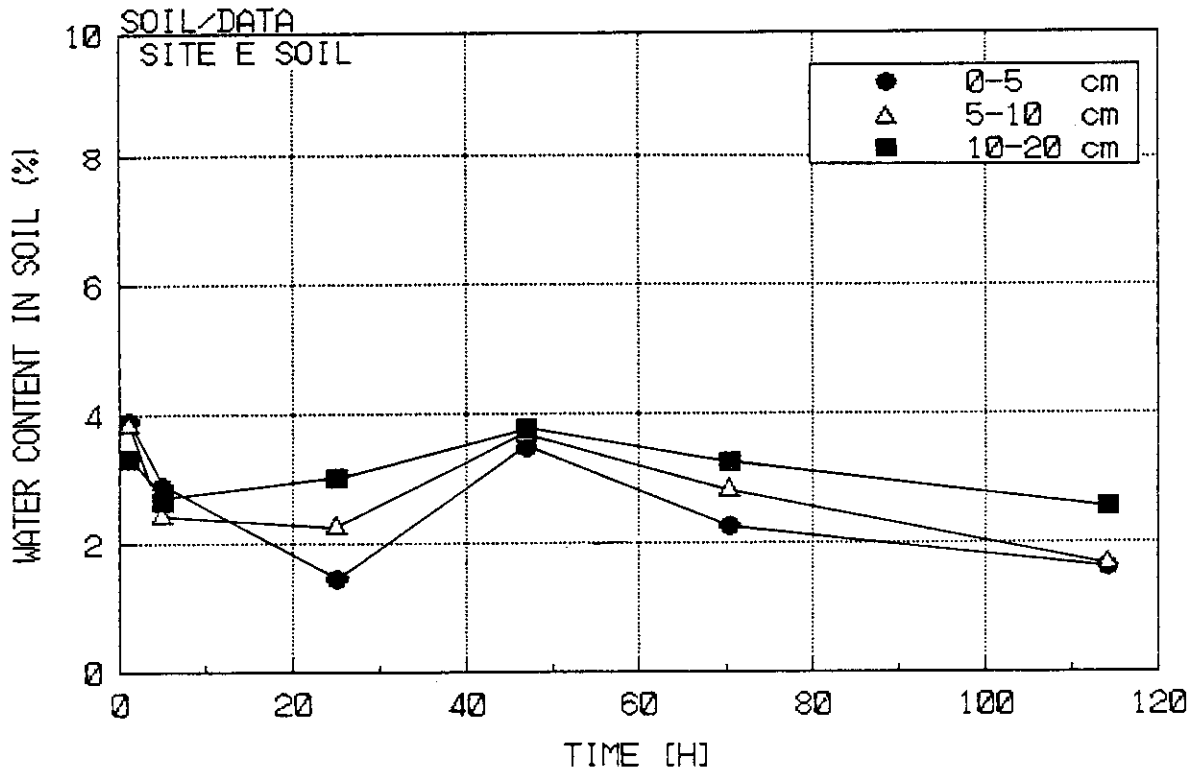
Appendix III.2(n) Time histories of HTO deposits in soils (site D)



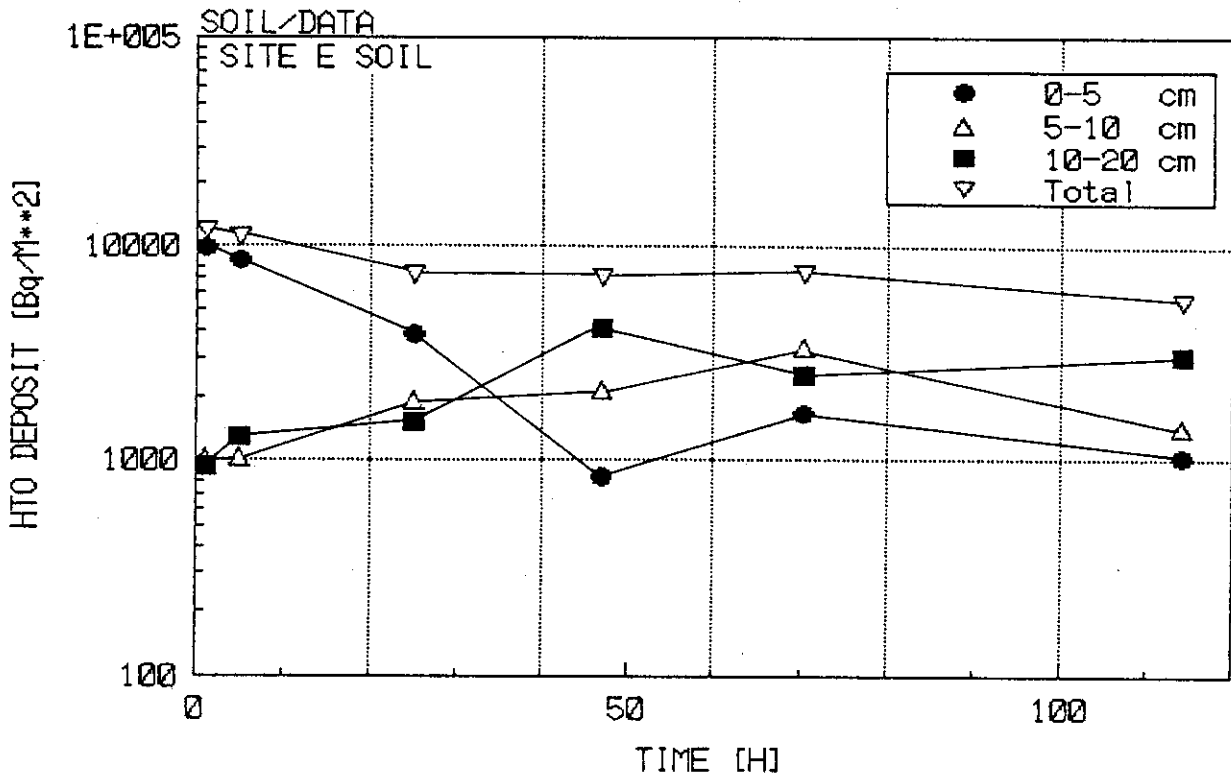
Appendix III.2(o) Time histories of soil water HTO concentrations (site D)



Appendix III.2(p) Time histories of soil water contents (site E)



Appendix III.2(q) Time histories of HTO deposits in soils (site E)



Appendix III.2(r) Time histories of soil water HTO concentrations (site E)

