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Intercomparison and biokinetic model validation of radionuclide intake assessment

Report of a co-ordinated research project 1996–1998

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FOREWORD

This TECDOC presents the results of a Co-ordinated Research Project (CRP) on Intercomparison and Biokinetic Model Validation of Radionuclide Intake Assessment, including the conclusions of a Research Co-ordination Meeting held from 6 to 8 July 1998.

The IAEA's research contract programme has the primary objectives of stimulating advances in scientific knowledge, assisting developing countries whenever possible to increase their participation in nuclear research, and co-ordinating research between the IAEA and national centres. In this context, several intercomparisons have been performed and are currently being carried out as CRPs, for example:

- Individual Monitoring International Intercomparison, 1988–1992;
- IAEA/RCA Personal Dosimeter Intercomparison, 1990–1992;
- Intercomparison for Individual Monitoring of External Exposure from Photon Radiation, 1996–1999.

The present CRP on Intercomparison and Biokinetic Model Validation of Radionuclide Intake Assessment is part of the activities of the IAEA's Occupational Protection programme. The objective of this programme is to promote an internationally harmonized approach for optimizing occupational radiation protection through:

- the development of guides, within the IAEA's activities for establishing standards for radiation protection, for restricting radiation exposures in the workplace and for applying current occupational radiation protection techniques; and
- the promotion of application of these guidelines.

While several similar intercomparisons have been organized in the past decades, either at the national or international level, notably in the framework of EURADOS (1992), only institutes in Europe or the United States of America participated in them. Australia and countries in Africa, Asia and Latin America were not represented. In addition, for many developing countries, the IAEA Technical Co-operation programme provides the only platform for them to gauge, through such intercomparison exercises, their capabilities in internal dosimetry.

The present intercomparison had a broader participation and the following objectives:

- to provide possibilities for the participating laboratories to check the quality of their methods;
- to compare different approaches in interpretation of internal contamination monitoring data;
- to quantify the differences in internal dose assessment based on various assumptions and approaches;
- to provide a forum for broad discussion of the results and methods which could help in more consistent interpretation of monitored data.

The CRP concluded with the Research Co-ordination Meeting held in Vienna, from 6 to 8 July 1998, whose results are presented here together with the results of the CRP.

The IAEA wishes to thank all the participants for their contributions to the intercomparison. Special thanks are due to A. Andrasi (Central Research Institute for Physics, Budapest, Hungary), H. Doerfel (Forschungszentrum Karlsruhe, Germany) and T.E. Hui (Profa Technologies C., Richland, Washington, USA) for providing excellent technical co-ordination and review of the CRP results. M. Gustafsson, of the IAEA's Division of Radiation and Waste Safety initiated the CRP and guided the programme until March 1997. R. Ouvrard, also of the Division of Radiation and Waste Safety, continued the work and was responsible for the final compilation of this TECDOC.

EDITORIAL NOTE

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CONTENTS

1. INTRODUCTION

The determination of internal doses is an essential component of individual monitoring programmes for workers who may have intakes of radionuclides in nuclear technology and nuclear medicine. Assessment of internal doses can be divided into two phases, namely

- determination of the amount of radioactive material in the human body, in body organs or in wounds by direct measurements and/or by indirect methods like excretion analysis or air monitoring;
- interpretation of the monitored data in terms of intake and/or internal dose considering many influencing factors and assumptions, like physical and chemical characteristics of the radioactive substances, the mode of intake, the biokinetic and energy absorption processes, the individual parameters, etc

The second phase is particularly important because of the number of variables and uncertainties involved. Although the ICRP and BSS have published extensive tables of dose per unit intake, these are default values based on assumptions about the intake parameters that may not be valid Determination of the intake and the resulting internal dose can, therefore, be approached in many different ways, depending on the amount and quality of the data, the skill of the dosimetrist, computational tools available, and the assumptions made. When a set of bioassay data is given to two different dosimetrists, it is likely that these data will be interpreted differently, that different methods and dosimetric models will be applied, and therefore different numerical solutions will be obtained. Thus, it is important for laboratories dealing with internal dosimetry to undergo performance testing procedures in both phases of internal dosimetry to demonstrate the correctness of methods applied and also the consistency of the results with those obtained by other laboratories.

Several intercomparison exercises have already been organized at national and international levels, usually separately for the two phases of internal dose assessment. In the United States of America, there were some intercomparison studies but these earlier ones focused more on a particular radionuclide or a particular issue. Among these were an intercomparison study on plutonium [Kathren et al 1987], one on UF_6 [NRC 1986], and another one on computer software used for intake and dose calculations [LaBone 1991]. In the plutonium intercomparison [Kathren et al 1987], six laboratories estimated systemic burdens of plutonium from urine data for 17 cases and reported relative standard deviations [RSD] ranging from 20–90%.

In the United Kingdom, the UK Internal Radiation Dosimetry Group reported in 1990 an interlaboratory comparison of methods used for estimates of systemic burdens of plutonium [Ramsden et al. 1990]. The results show that 90% of the values agreed within 40% of the mean of the six participating laboratories in an evaluation of four reference cases. Later studies include additional radionuclides such as tritium, uranium, cobalt [Ramsden et al. 1992] and reported similar variations in results.

The first major international intercomparison study was performed by the EURADOS Working Group Number 6 of the European Community [Gibson et al. 1992]. With the development of the European Union (EU) which leads to free movements of workers between member countries, reasonable consistency or compatibility of methods for assessment of internal dose from intakes is becoming more important. In this CEC/EURADOS intercomparison study, five test cases covering ^{137}Cs, ^{90}Sr, ^{32}P and various actinides were used, and nine institutes from six countries participated. Results showed that for most cases the RSD of the intake is about 30% and the RSD of the resulting dose is about 40%.

The second CEC/EURADOS study was recently completed. It covers intakes of uranium, plutonium, ^{241}Am, ^{60}Co and tritium. Fourteen laboratories, instead of nine in the first study, participated in the second study. Even though newer ICRP models, such as the new lung model [ICRP

1994], were available, it was agreed among the participants that a standardized approach, the ICRP 26 and 30 methodologies, were to be used in the assessments. Using this standardized approach, results of intakes and doses are reported to be similar to those of the first intercomparison. Subsequent analysis showed significant discrepancies will result if the new lung model was used. The third CEC/EURADOS intercomparison is currently in progress under the framework of the EULEP/EURADOS Action Group entitled Derivation of Parameter Values for Application to the New Model of New Respiratory Tract for Occupational Exposure.

Parallel to the intercomparisons performed under CEC/EURADOS, there are also other intercomparisons. These intercomparisons involve artificially created test cases and also involve a large number of participants (forty-four) from more countries (nineteen). Participants used different ICRP biokinetic models and reported RSD ranging from 20% to 138% In addition to the intercomparison of the calculational aspects of internal dosimetry, there are also intercomparisons on measurement techniques [M. THIEME et al.,in press]

The first major internal dosimetry intercomparison in the USA [Hui et al. 1994] was performed in 1992 by the Department of Energy (DOE) and Nuclear Regulatory Commission (NRC). The five test cases used in the DOE/NRC study are the ones previous used in the 1992 European intercomparison [Gibson et al 1992]. The philosophy behind the DOE/NRC intercomparison focuses more on assessing the inconsistencies of the results and is different from the CEC/EURADOS study which also focuses on the harmonization aspects. Therefore, there are several major differences in the DOE/NRC study compared to the CEC study in terms of the implementation of the study. For instance, to simulate a response in realistic situations, participants were only given 2–3 weeks, much shorter than that in the CEC study, to perform the intake and dose assessment. Once the results were submitted, no revisions were accepted. No formal discussions were held by participants to harmonize or revise the approaches or the results. Except for one test case, results show a slightly greater variation than that of the CEC/EURADOS study

In 1995, six institutes participated in another DOE intercomparison study [Hui et al 1997]. The main difference from the first one is that test cases are more related to work currently or previously performed at DOE facilities. A significant feature of this study is that some of the cases were generated artificially so the intakes and doses were known to the organizer. The focus of this study was not only on the different approaches used and variation of the results reported, but also to identify problem areas which may contribute to the discrepancies.

These previous intercomparison exercises revealed significant differences in the approaches, methods and assumptions, and consequently in the results. This underlined the importance of this kind of intercomparison programme as a key element of the harmonization process The previous studies, however, were only participated in by institutes from Europe or the United States of America Australia and other countries in Africa, Asia, and Latin America were not represented in these studies. Among these countries, some deal more with the possible incidences of intake of radiation than others.

2. OBJECTIVES

The main goals of the programme are

- to provide possibilities for the participating laboratories to check the quality of their internal dose assessment methods,
- to compare different approaches in interpretation of internal contamination monitoring data,
- to quantify the differences in internal dose assessment based on various assumptions and approaches,

- to provide a forum for broad discussion of the results and methods which could help in more consistent interpretation of monitored data.

3. ORGANIZATION

The IAEA recognises the importance of getting more Member States participate in intercomparisons, and this is particularly true for those who have not participated in intercomparisons before. The IAEA undertook the task of organizing a world-wide intercomparison exercise in the frame of a Co-ordinated Research Project, which was scheduled for the years 1997 and 1998.

To implement the project objectives the followings tasks were performed:

- Participants were selected and invited. Preference was given to those who are dealing with internal dosimetry but have never participated in one of the previous intercomparison exercises. In addition, some selected experienced laboratories were also invited. The number of participants from each country was limited to 2, and the total number of participants to about 30. Finally, 26 institutes from 22 countries plus the IAEA were invited, and 25 institutes actually participated. The final list of participants is shown in Annex I.

- Test scenarios were prepared for participants to evaluate. Nine realistic cases were prepared. A general structure for setting up the test scenarios was designed and shown in Annex II. The test scenarios designed were based either on real data or artificially generated data. The cases include different radionuclides and also range from simple straightforward cases to complicated cases with different exposure conditions. The following study cases were offered to the participants:

  Case 1: ^{3}H (HTO], single intake, pathway not specified

  Case 2: ^{45}Ca, time and duration of intake unknown, ingestion,

  Case 3: ^{60}Co, single intake, inhalation,

  Case 4: ^{90}Sr/Y, intake conditions completely unknown,

  Case 5: ^{125}I, multiple intakes, inhalation,

  Case 6: ^{192}Ir, single intake, inhalation,

  Case 7: $^{238/239}$Pu, multiple intakes, inhalation,

  Case 8: $^{239/239/240}$Pu and ^{241}Am, single intake, inhalation,

  Case 9: ^{241}Am, single intake, inhalation.

  Guidelines, shown in Annex III, were provided to the participants on the list of information to be included in the response. The actual test cases offered to the participants are shown in Annex IV.

- Case scenarios were distributed to the participants. The participants were given six months to evaluate the cases and to submit the results according to the guidelines.

- Data were compiled, analysed and discussed during a consultants meeting in October 1997. Results for each case and for each participant are presented in Annex V and Annex VI, respectively. If needed, participants were requested to comment and to clarify any ambiguities.

- After receiving corrections and comments from the participants, the summary report was drafted during a consultants meeting in May 1998. The draft of the summary report was distributed to the participants prior to the Research Co-ordination Meeting (RCM).

- In July 1998 a RCM was organized in Vienna to

  (i) discuss the results,

  (ii) draw conclusions on the intercomparison programme and

  (iii) give recommendations for future activities.

- The final report was prepared as an IAEA-TECDOC. In addition, a summary of the intercomparison will be prepared for publication in the open literature.

4. PROGRAMME SCHEDULE

Time	Programme point	Meeting	Responsibility
July/August 96	Preparing cases scenarios according to guidelines defined at first meeting		Consultants
31/08/96	Deadline for sending case scenarios		A Andrasi, T.E Hui
September 96	Distribution of collected case scenarios		H. Doerfel
September 96	Announcement and invitation for participation		IAEA
31/10/96	Deadline for sending comments on case scenarios to H Doerfel		A Andrasi, T E Hui
November 96	Finalizing the case scenarios		H Doerfel
31/12/96	Deadline for application of participants		Participants
January 97	Distribution of case scenarios to participants		IAEA
31/07/97	Deadline for submission of evaluation results to the organizer		Participants
20-24/10/97	Compilation of data, statistical evaluation, draft discussion of results, identification of lacking information from the participants	Consultants meeting	IAEA and consultants
October 97	Distribution of requests for further information to the participants		IAEA
31/01/98	Deadline for clarifying and commenting of the draft results by the participants		Participants
May 98	Completing the intercomparison and drafting the summary report	Consultants meeting	Consultants
May 98	Distribution of the draft of the summary report to the participants		IAEA
July 98	Final discussion of the results of the intercomparison, drawing of conclusions and definition of recommendations for the future (RCM); Preparing the final IAEA-TECDOC (consultants)	RCM and consultants meeting in Vienna	All
October 98	Distribution of the IAEA-TECDOC to the participants		IAEA
Nov/Dec 98	Preparing a summary paper for publication in the open literature		Consultants

5. RESULTS

5.1. General

Guidelines for presenting the results, as shown in Annex III, were provided along with the case scenarios to the participants. These guidelines serve three purposes First, participants were encouraged, not required, to evaluate as many case scenarios as possible. Second, if more than one approach were used, the participant should specify the preferred approach and answers Last, and the most important, participants were required to provide the key information as listed in Annex III to facilitate compilation and analysis of their response.

In terms of the participation rate for each case scenario, it apparently varies with the complexity of the exposure scenario. This may be due partly to the fact that some of the selected case scenarios may involve exposure to radionuclides considered rare in some participating countries. In addition, some of the cases scenarios may be complicated enough that efficient evaluation may require fairly sophisticated computations tools which may not be available to some participants However, this intercomparison represent an opportunity for many participants to gauge their performance against others and they are encouraged to do so Generally, the highest response rate is 24 out of 26 for Case 1 and the lowest is 11 for Case 7

It is obvious that most participants in most case scenarios attempted more than one approach to evaluate the test cases, even though many of them only include a single approach in their responses For those providing results for more than one approach, usually a preferred one was specified

In terms of the presentation of the results, the responses from participants varied greatly While some participants followed the guidelines and provided the key information to facilitate compilation and analysis, many others did not Some of the responses are extremely detailed and follow a clear format, probably dictated by the local requirements. Some others are too brief (some as short as a single page) and with insufficient data. Responses with insufficient data or ambiguous information not only increase the time and effort in compilation and analysis, they also increase the chance of error in these processes In these cases, clarifications are requested from participants and this increase the processing time and effort

During the compilation of the results, it was observed that there was some confusion of the older and most recent dosimetry concepts being used by the participants. The guidelines requested the resulting dose be reported in committed effective dose, E(50), as described in ICRP60. However, only a limited number of participants possess the more recently developed computation tools which allow such calculations If a particular participant is using the older ICRP30 approach, then the resulting doses are committed effective dose equivalent, CEDE. These two concepts are technically different However, for the purpose of this intercomparison, they are both considered the same, as E(50) The availability of more recently developed computational tools also affect the choice the biokinetic and lung models For the ICRP26 lung model, the clearance classes are D, W, and Y Whereas for the ICRP66 respiratory tract model, the clearance class are F, M and S. The clearance classes were listed as the participants described. It is expected that, only until the more recently developed computational tools which contain all the recent models are made available to all, these confusions will continue.

Similar to other prior intercomparisons, the mean, standard deviation, relative standard deviations (or the coefficient of variance) were compiled for each case and each exposure (if more than one) In addition, the geometric mean was also included as some suggested that it reflects better the statistical variation of the results

Finally, since anonymity is important to some participants, the identities of the participants are not shown in the compilation of the results. The order of the listing of participants in Annex I is not the same as the laboratory number used in Annex V.

5.2. Results on cases

5 2 1 Case 1 Intake of tritium

This scenario involves a single intake of tritium at a nuclear facility. Urinary data in activity concentration over a span of about 300 days were provided. This is an artificially generated case, with the urinary data generated using a three-term exponential retention function This retention function, however, is based on fitting a set of actual data belonging to a case used in a previous intercomparison [Hui et al. 1997]. Clear information on the nature of the intake (time, location, and the event) and the chemical form of the tritium (tritiated water assumed) was also provided.

For tritium exposure, intake assessment is particularly sensitive to data collected soon after the intake occurred. Therefore, values for activity concentrations in the urine was daily for the first 45 days and then more sparingly after that Information on the chemical form and nature of the intake is usually critical in short term post-exposure, during which the dose assessor needs to make a projection for long-term retention with limited data. However, for urinary data that span over several clearance half-times (about 300 days) with the activity concentration decreasing by five orders of magnitude, this information is usually less critical in terms of dose equivalent calculation. The variation of the numerical answer of the E(50) can be expected to be small. Therefore, the variation of the intake is higher than the variation of the dose because the intake estimates depends strongly on the model used or the curve fitting method. One should also realised that even though the test case requires an intake estimate, but the intake is not a pre-requisite for the calculation of the E(50).

This is a relatively simple case in terms of calculation As a result, this case receives the highest number of responses, 24 out of the 26 participants responded, compared to other test cases As shown in Annex V, the mean (±SD) of the intake is 5.99 ± 2.03 GBq and the mean E(50) is 84.46 ± 32 92 mSv The RSD for the intake and the E(50) are 34% and 39%, respectively. This is very good agreement compared to the result of other cases. The actual intake estimates range from 1.2 to 9 5 GBq, indicating that the minimum value is a factor of five less than the mean value, whereas the maximum is about 50% higher than the mean The E(50) estimates range from 21 to 140 mSv, indicating that the minimum value is a factor of four less than the mean value, whereas the maximum is about two thirds higher than the mean. It is unclear, however, why the variation of intake in this cases is less than the variation of the E(50) which was expected to be higher.

Although the participants used slightly different methods, a general approach to the assessment of the intake and dose is apparent. The general approach is that the total number of disintegrations was integrated and then a dose factor applied. The dose factor is either adopted directly from ICRP reports or may have been in-house derived. No correction for weight of the person is needed since he has approximately the weight of the standard reference man.

In terms of the retention, the urinary data are sufficient for the identification of a long-term slow component. Some participants applied multiple (two or three) exponential terms to fit the curve. Assuming the chemical form is tritiated water, some participants used a single exponential to fit the excretion data. In this case, one obviously does not need to derive the equation of the retention function to perform the integration. A simple spreadsheet program will also suffice, as the error due the remaining activity after 300 days is bound to be insignificant. As a result, some participants stated that no internal dosimetry code was used to solve this cases.

Among those who have used commercially or publicly available computer codes for the intake and dose assessments, the computer codes used include (in alphabetical order) AGEDOS, CINDY, DOSINT, DOSIS, GENMOD, IABM, IDSS, INDO, LUDEP, and MICROFIT. It is not possible in this case to consider the effect of the choice of the computer code on the final results because using the same code may select different biokinetic models.

It appears that the selection of the model used may have a significant influence on the final results. For example, two participants used the three-exponential terms retention function and came up with virtually identical intakes (7.7 and 7.8 GBq) and E(50) (75 and 78 mSv), even though one used INDO and the other stated that no (internal dose) code was used. Similarly, three of the four participants that used 2 two-exponential terms have yielded very similar E(50) results as a group (70, 75 and 76 mSv). It is not clear why another participant using the same two-exponential terms retention function (but used a different code) obtained a much lower E(50) (21 mSv). Among those who used the newer ICRP dose factors, good consistency was also observed as a group. The E(50)s reported are generally higher (130 and 138 mSv).

The participants are divided in the particle size used, reflecting the fact that they base their calculations on either the ICRP 30 methodology (1 mm AMAD) or the newer ICRP 66 (5 mm AMAD). Similar difference is seen on the selection of the clearance types (F, M, SR-2 for the newer ICRP 66, and D for ICRP 30). It must be pointed out that while these differences may affect much on the intake estimates, they should not have much effect on the E(50). In fact, calculation of the E(50) does not require these parameters to be known. However, the variation of the parameters make intercomparison difficult, if not impossible. For example, two participants both used the Johnson and Dunford model, but they used different computer codes and also different particle size. Just by looking at the results, one could not decided whether particle size have more influence than the choice of the computer code, which is probably the case.

5.2.2. Case 2: Intake of ^{45}Ca

This is a unique case because of its obvious criminal background. There is a lack of any information about the time and duration of intake. However, there is evidence of the probable pathway of intake, of the chemical form and of the maximum amount of the incorporated activity.

Eighteen participants provided results for this case, 14 of which being complete with respect to the required quantities. For the evaluation of the data most of the participants (6) used the systemic model of ICRP 71 or Johnson, respectively. Some participants (3) used the 7 compartment model of NUREG CR 4884 or Skrable, respectively, some others (3) used the systemic model of ICRP 30, two used ICRP 20 and one participant used ICRP 10. Two participants applied the tissue weighting factors of ICRP 60, the others use the factors of ICRP 26 or do not specify on this. Most participants adopted the f_l factor 0.3 and one participant 0.5.

According to the case description the intake could have occurred between 15.12.92 (delivery of the ^{45}Ca solution) and 10.03.93 (first detection of ^{45}Ca in urine). Most participants (9) found the time of intake to be close to the 26.01.93 within a standard deviation of 2.5 days. Four other participants found the intake to be around the 08.02.93 within a standard deviation of 2.6 days. One participant identified the 07.03.93 as time of intake which is very close to the end of the possible period of time. Two participants assumed conservatively the very first day to be the day of intake.

The average of the estimated intakes is 28.7 MBq with a standard deviation of 8.7 MBq (29.50%). Two participants using the same 7 compartment model of NUREG CR 4884 found almost the same time of intake (25.01.93 and 27.01.93, respectively) but rather different intakes (33.1 MBq and 50 MBq, respectively). This underlines the importance of the computer codes used for evaluation.

Most participants found the dose of the bone surface to be between 50% and 100% higher than the dose of the bone marrow. Two participants, however, derived bone surface doses which are by a factor of 12 higher than the bone marrow dose. This results in a rather high standard deviation of the bone surface dose (123%) as compared to the standard deviation of the bone marrow dose (27%). The average of the effective committed dose is 21.81 mSv with a standard deviation of 8.77 mSv (40.21%). The average dose factor is 0.77 mSv/MBq. The standard deviation of the dose factor is 0.24 mSv/MBq (31%). When neglecting 3 outlyers, the standard deviation is reduced to 0.056 mSv/MBq

(7 2%) So, with respect to the dose factor, most of the participants are in excellent agreement with each other. Thus, the different models are equivalent with respect to the dose factor. Nevertheless there is a relative high variation of the intake. When neglecting the outlyers with respect to the dose factors, however, the standard deviation of the intake for the other 14 participants increases to 37%.

5 2 3 Case 3 Single intake of ^{60}Co

This accidental case is relatively simple since in its description, the time of the intake is well known, and the intake pathway can obviously be considered as inhalation The radionuclide involved is also known, only the physical and chemical parameters are not. It seems, however, reasonable to assume a metallic form or oxide as the chemical compound The data set measured on the exposed worker by whole body counting covers a four-year time period, which allows to fit retention functions either considering recommended standard functions (ICRP 54, ICRP 67) with given parameters, or just fitting exponential functions to the measured values and the parameters determined by the fitting procedure For this purpose, all the measured data could be used; however, due to the imprecise time given between the intake and the first measurement, this monitoring result caused some problems.

Twenty-four participants submitted results for this ^{60}Co case. As for the intake, 6.58 kBq was calculated as arithmetic mean with a standard deviation of 44.8%. Disregarding one outlyer the obtained intake values range from 3.1 to 14 5 kBq, which means that the individual results varied within a factor of about 4

As far as the committed effective dose values (E(50)) are concerned, the obtained arithmetic mean is 142.4 mSv with a relative standard deviation of ±52.3%, which is slightly higher than that calculated for the intakes It is interesting that for the effective dose ($E_{88}(1)$) received in the calendar year 1988, the results showed even less spread around the arithmetic mean than that for the intake, namely ±42 4% relative standard deviation was found while for the mean 67.6 mSv was obtained.

Most of the participants used all the 8 measured data for intake and dose calculation, but there were some who used only less measured points for fitting a retention function. In this latter case, the main reason was to obtain the best initial value extrapolated to the time of intake. In this respect it has to be mentioned, that in the case description unprecisely given times for intake and for the first measurement were the main reason of ignoring measured values. In most cases, retention functions and parameters were taken from ICRP recommendations A great variety of assumptions could be observed in the use of AMAD values and for f_1 gut uptake factors. For AMAD, most participants accepted either 1 mm or 5 mm standard values, recommended as default values by the ICRP in its previous and recent recommendations respectively; but 0.5 mm and in one case also 0.003 mm extreme low value were also assumed. For f_1 factor, depending on the source of ICRP publication, values from 0.01 to 1 were applied but in majority a value of 0.05 was used. Since in the case description, metallic cobalt or cobalt oxide was given as the possible chemical compound, inhalation class of W or Y and alternatively M or S as absorption type have been used. It is interesting to note that 7 participants assumed a mixture of materials belonging to W and Y classes and 6 of them found 80% W and 20% Y as providing the best fit. In general, most of the participants using appropriate computer codes tried to give as input parameter different values for particle size, inhalation class or clearance type, and for f_1 factor in order to find the best fit to the measured data. The most frequently applied computer codes were CINDY and LUDEP; however, several other commercially available and self-developed codes like INDOS, INDO, DOSIS, GENMOD-PC, DOSINT, IABM, IDSS2, IMIE-2 were also used.

A broad variety in using the older and more recently published ICRP recommendations could be observed in the answers. The participants mostly combined the terms, models and parameter values recommended by ICRP based either on the previous or on the newer concepts depending on the computer code and individual approach applied. This inconsequent use of the older and newer

ICRP recommendations leads to conceptional inconsistencies and can be regarded as incorrect approach, however in the present transition period this is quite frequently followed procedure.

As far as the submitted results are concerned one source of differences in intake estimates is due to the unprecisely given time of intake and of the initial measurement. When looking at the numerical results and the corresponding figure, large differences in the conversion from intake to committed effective dose can be observed. The large spread of calculated E(50) values (ranging from 40 to 320 μSv) can be attributed to the different dose factors applied depending on assumptions made for AMAD and clearance type as well as on the ICRP recommendation used

5 2 4 Case 4 Intake of ^{90}Sr and ^{90}Y

This test case is based on a real exposure scenario In evaluating this test case, some participants expressed concerns about the data provided and the results requested In the case description, there were several typographical errors showing the wrong dates of measurement and a units conversion error (from Ci to Bq) These errors, however, are obvious and easily discovered by many participants, others were alerted and allowed to revised their results In terms of the results requested, participants were asked to calculate the 'skeletal dose' instead of the doses to the bone marrow and bone surfaces This incorrect use of terms is unfortunate and confusing. It is because the concept of the skeletal dose became outdated since the publication of ICRP 30 (1979), which leads to the use of the revised and more specific concepts of the doses to the bone surface and to the bone marrow As a result of this mix up, some of the participants provided their results in terms of total skeleton dose, while others provided doses to the bone surface and the red bone marrow. Thus, the participants giving the total skeleton dose were asked to specify their results in terms of doses to the bone surface and the bone marrow These errors were corrected in the case description in this document

Twenty-one participants responded to this case In this case there is no information on the intake pathway, hence the participants are required to make the intake assumptions Fortunately, for this particular case, assumptions on either inhalation or ingestion both yield relatively good fitting of the data to biokinetic models and lead to similar results in terms of both the intake and the committed effected dose It appears that the assumptions of intake via inhalation leads to slightly higher dose estimates and thus some participants assumed this pathway as a conservative assessment. As shown in the following table, the assumption among the participants on intake pathway varies from 100% inhalation to 100% ingestion with some in between The overall average is approximately half on inhalation and the other half on ingestion. There is also no information on the exact date and time of the intake Most of the participants assumed single intake on 24.11.90. Some participants assumed single intakes on 26.11 90 and on 27.11.90, respectively, and 3 participants assumed chronic intake by ingestion from 24.11 90 until 27 11 90 or 28 11.90, respectively

In addition to using different assumptions on the route and time of intake, participants used different combination of biokinetic models for the evaluation of the data For modelling of the systematic kinetics ICRP 30, 54, 67, 71, and the functions of Johnson and Meyers have been used in different combinations Most of the participants used the urine data and the whole body counting data. The whole body counting data have been evaluated under the assumption that all the activity is deposited in soft tissues In reality, especially at longer times after intake, most of the activity is deposited in the skeleton, where the production of bremsstrahlung is higher than in soft tissues Thus, the whole body counting data are giving conservative estimates

The average intake is 3.0 ± 0.8 MBq ^{90}Sr for the estimates based on ingestion (N = 10), 4.2 ± 3 0 MBq ^{90}Sr for the estimates based on inhalation (N = 8) and 3.2 ± 1.3 MBq ^{90}Sr for the estimates based on a mixture of inhalation and ingestion (N = 3). The relative large scatter of the inhalation values is mainly due to the assumed lung retention class and to some extend due to the assumed AMAD values as can be seen from the table below

Participant	Inhalation (percentage, mode, time)	Ingestion (percentage, mode, time)
1		100% single 24.11.90
3	100% single 24.11.90	
4	100% single 24.11.90	
6	92% single 24.11.90	8% chronic 24–28.11.90
8		100% chronic 24–27.11.90
9		100% single 24.11.90
10	70% single 26.11.90	30% single 26.11.90
11		100% single 24.11.90
12	100% single 24.11.90	
13		100% single 24.11.90
14	n.s.	n.s.
16		100% single 24.11.90
17	100% single 27.11.90	
18	100% single 24.11.90	
19		100% single (date n.s.)
21	50% single 24.11.90	50% single 24.11.90
22	100% single 26.11.90	
23		100% single 26.11.90
24	100% single 24.11.90	
25		100% chronic 24. – 27.11.90
26		100% single 24.11.90
	Average percentage: 46%	Average percentage: 54%

Number of estimates		Intake of ^{90}Sr (MBq)	
	AMAD (μm)	Class D or F	Class W or M
2	1	1.9 ± 0.3	
3	5	2.2 ± 0.3	7.3
1	10		10

The average effective dose in 1990 is 7.9 ± 4.4 mSv for the estimates based on ingestion (N = 10) and 19.6 ± 27.4 mSv for the estimates based on inhalation (N = 8). The relative large scatter of the inhalation values is due the assumed retention class. When specifying the inhalation values for the assumed retention class, the average effective dose in 1990 is 3.7 ± 3.3 mSv for class D/F and 52 ± 26 mSv for class M.

What the committed effective dose is concerned, the scatter of the results is much smaller than that of the annual doses for the first year: The average committed effective dose is 104 ± 56 mSv for the estimates based on ingestion (N = 10) and 130 ± 45 mSv for the estimates based on inhalation (N = 8). Thus, there is no significant difference between the inhalation values and the ingestion values. There is also no significant dependence of the inhalation values on the assumed retention class. Similar findings may be derived for the committed equivalent dose to the red bone marrow and to the bone surface, respectively. As can be seen from the table below there is no significant difference of the average values due to the assumed intake pathway.

Assumed	$H_{BM}(50)$		$E_{BS}(50)$	
Intake pathway	Average (Sv)	RSD (%)	Average (Sv)	RSD (%)
Ingestion	0.50	24	1.42	58
Inhalation	0.54	41	1.36	40

In conclusion, in this case the different assumptions with respect to the intake pathway are of minor importance for the results in terms of committed dose.

5.2.5. Case 5: Repeated intake of ^{125}I

These ^{125}I contamination cases are characterizing a very frequently occurring situation when routine monitoring results have to be evaluated and interpreted in terms of intake and dose. Since a series of iodine compounds are volatile, there is a high probability of intakes by inhalation during the work with radioiodines. In the given two cases, the workers handled high level of activities when preparing ^{125}I labelled compounds, and since the procedure was repeated many times in a year, routine monitoring of the workers was reasonable. There were some differences in the working activities of the two persons involved, namely beside the slightly different nature of their work. V.A. was working in this field also during the year of 1994 while P.L. started to work only sometime at the beginning of February 1995. As far as the chemical and physical characteristics of the inhaled radioiodine are concerned, a great variety of assumptions could be made since there were no information available.

Altogether, 22 participants submitted results for this case scenario. It turned out, from the answers, that the information provided in the case description about the time periods prior to the dates of monitoring given in the table of measurements was not sufficient to interpret the situation in this time period unambiguously. Consequently, there were different assumptions made by the participants. These differences however could not influence considerably the final spread of the results. As it was expected, there were two basic approaches followed by the participants when calculating the intake and received doses. The majority of the participants assumed multiple single intakes occurring at the midpoints of the monitoring periods (except one participant assuming the time of intake just after the previous thyroid measurement). There were 8 participants who assumed fully or partly continuous exposure during the monitoring periods. Within this group, the approaches were different with respect to the time period for which continuous intake was assumed. It can be stated that no significant systematic difference could be observed between the results of these two kinds of approaches.

As far as the arithmetic mean values are concerned for intakes 0.25 MBq and 0.13 MBq activities could be calculated with relative standard deviations of 60.6% and 65.8% in the cases of V.A and P.L respectively. Much smaller spread of results were observed for the thyroid equivalent doses received by the workers in the year of 1995, namely 19.0% for V.A. and 24.4% for P.L. standard deviations were calculated. For the committed effective dose values, the arithmetic means for the two workers show the values of 2.47 mSv and 1.29 mSv with the relative standard deviations of 55 5% and 62.8% in the case of V.A. and P.L. respectively. When looking at these figures of standard deviations as it was expected the spread of data for both the intake and committed dose, a significantly larger number can be observed compared to those obtained for simpler cases of single intakes (like the ^{60}Co case).

Like in other cases, wide variety of commercialized and home-made computer codes were used for the evaluation of this case (CINDY, LUDEP, REMEDY, GENMOD-PC, DOSINT, INDO, etc) Most of the participants used the multiple single intake approach indicating in their answer that when calculating the intake values they always took into account the remaining activities in the thyroid from the intake that occurred in the previous monitoring period. This has to be mentioned because most of the computer codes cannot handle easily this situation For inhalation class or absorption type, D or F categories were used and for particle size 1 mm or 5 mm AMAD values were given, if at all As for the different AMAD values used, no significant influence could be observed with regard to the results, which seems to be obvious in the case of radioiodine and considering the large spread of data Most of the participants used for intake calculation the biokinetic model for iodine given in the older ICRP recommendations [ICRP 30, 54]; however, a few of them calculated mainly on the basis of the recent recommendations [ICRP 66, 67].

As far as the intake to dose conversion is concerned, it turned out from the given results that mostly the new ICRP recommendations were considered in dose estimations because the ratio of mean values of the committed effective dose and the corresponding thyroid equivalent dose lead to a value of 0.045 which is very close to the new tissue weighting factor for the thyroid (w_T = 0 05).

5 2 6 Case 6 Single intake of ^{192}Ir

This case represents a relatively simple internal contamination event when the time of the intake is very well defined and the measurements started a few hours after the intake. The way of intake seemed to be obviously inhalation. Like in most of the cases, no information was available concerning the physical characteristics of the inhaled aerosol and its chemical form. As for the chemical form, it is reasonable to assume either metallic iridium or its oxide. What is not common in this case is the radionuclide itself which is usually the source of external exposure but rarely causes internal contamination.

Despite of the relative simplicity of the case, only 20 participants out of 24 submitted results. It has to be mentioned that unfortunately, the last date of measurement had to be corrected after the case scenarios have been distributed It may have cause inconveniences and additional work to the participants, but the influence of this mistake on the final results would not cause essential differences all the more because this value seemed to be outlying from the retention curve and therefore 6 participants ignored this measured point anyway. Almost half of the participants disregarded one or more measured data to obtain a better fit when calculating the expected intake. From this point of view, the first monitoring result was not considered by more participants because they assumed that external body surface contamination probably also contributed to the measured results. The majority of the participants found better fit to the measured data when they assumed higher than 1 mm AMAD (3–10 mm) which assumption seems to be quite reasonable considering the kind of work which caused the ^{192}Ir intake. It is interesting to mention that there were a few participants who assumed partly also ingestion beside inhalation.

As far as the chemical form is concerned, the majority of the participants assumed Y inhalation class or S absorption type, partly because they obtained a better fit to the monitored data and partly

because it provided a more conservative estimate with respect to the committed effective dose. As mean values, 37.9 kBq intake and 170 mSv committed effective dose were calculated with relative standard deviation of 52.6% and 72.0% respectively (the outlying data of one participant were ignored) The spread of data seems to be quite high compared to the outcome of similar exercises. One reason of this large scatter of results can be attributed to the strong influence of the first measurement to the calculated intake and so the results depended very much on whether this measured value has or has not been considered. Investigating this aspect it turned out, that the intake average calculated from the results of those participants they ignored the first measured values was found to be (19.7 ± 6 9) kBq whereas of those they didn't (51.0 ± 14.2) kBq was obtained. The ratios between the maximum and minimum values were found to be about 5 for the intake and more than 7 for the committed effective dose The larger spread of dose data can be attributed mostly to the differences in the values of the dose factors taken from different ICRP recommendations, considering also various AMAD values and different clearance types It is interesting to mention, that three laboratories (Code No. 3, 16 and 18) obtained exactly the same value for the intake assuming same conditions and using the ICRP 30 model, however they applied three different computer codes On the other hand four laboratories from the five (Code No 4, 12, 24, 25 and 26) using the same computer code and ICRP 66 lung model, calculated very similar values for the intake in spite of the fact, that they assumed different conditions and influencing parameters.

As far as the applied models are concerned, there were participants who used exclusively the previous ICRP recommendations [ICRP 30, 54]; however, the majority of participants indicated also the use of the more recent publications [ICRP 66, 68, 72]. As it is seen in the table of results, the applied computer codes were practically the same as already listed previously.

5 2 7 Case 7 Multiple intakes of $^{238/239}Pu$

This plutonium case is designed to test the ability to detect multiple intakes and to distinguish class W and Y behaviour. The data are generated (courtesy G. Miller of Los Alamos National Laboratory, New Mexico, USA) using the Jones excretion model. A random component of 30% of the true excretion value was added to represent uncertainty due to measurement and error due to biological/urine collection variability. Dates of the two possible intakes are given The intakes and the E(50) for both events are known. The first intake involved 370 Bq of ^{239}Pu of class W, and the second intake involved 370 kBq of ^{238}Pu of class Y and 1.11 kBq of ^{239}Pu of class Y. The resulting E(50) for the first intake is 43 mSv and for the second intake, 119 mSv (29 mSv from ^{238}Pu and 90 mSv from ^{239}Pu). It was somewhat surprising that the first intake did not produce positive nose swipes (and hence no additional bioassay was taken), however nose swipes are not completely reliable as indicators of intakes. In addition, any data (zero and negatives) below the least positive value (0.07 mBq/d in this case) of the measurements are only presented as "<0.07 mBq/d" to participants.

This is a fairly complicated case and was attempted by only 11 participants For the first intake, it is obvious from the exposure scenario that only ^{239}Pu was involved, it is therefore unclear why two participants reported intakes for ^{238}Pu. For ^{239}Pu, the reported results show excellent agreement in the intake estimate All except one participants assumes a class W (or M) if using the new lung model clearance, which also determines the value of f_1 used. The one exception used 50% class W and 50% class Y seems to obtain excellent results for both the first and second events. Two participants used the new lung model even though only one of them reported the dose estimates. For the biokinetic model, the common plutonium models are all used, including ICRP 30, ICRP 54, ICRP 67, Durbin model, and Jones excretion function. For those who used the ICRP 30 approach, the 1 mm AMAD was used as particle size, for those who used the new lung model, 5 μm. It is not clear why one participant used an AMAD of 0.5 mm All except one (who assumes chronic inhalation) correctly assume the event as a single inhalation. Participants also treat the data with values less than the least positive value (0 07 mBq/d), which was treated by participants as the detection limit. Some did not used these data, some assume they are zero, some assume they are zero until the first positive result and assume they are 0.06 after that, and, finally, some assume that they are the same as the least

positive number. Since we have few participants for this case and no two participants used the identical set of models, input parameters and data handling techniques, it is not possible to isolate the influence of the individual factors on the results

Nevertheless, the results for the first intake show remarkable agreement. The mean and the SD is 384 ± 109 Bq, with a RSD of only 28.45%. The mean intake of 384 Bq compared well with the true value of 370 Bq used to generate the data. The bone surface dose is 687 ± 297 mSv with an RSD of 43%. The E(50) is 34.12 ± 21.7 mSv, with an RSD of 63%. Both the bone surface dose and E(50) show good agreements among the participants. The E(50) also agree reasonably well with the true value of 43 mSv. One participant incidentally used the same models [ICRP 30 and Jones excretion model) and parameters (AMAD, class W) and obtained an intake of 400 Bq and a E(50) of 44 mSv. This is virtually identical to the true values (370 Bq and 43 mSv), considering a random element was added to the data This indicates that if models and input parameters are similar, it is possible to have good agreement of the results

For the second intake, the averages of intake estimate are 391 ± 523 Bq and 1116 ± 1950 Bq for ^{238}Pu and ^{239}Pu, respectively. While the mean values for the intake estimates are virtually identical to the true values (370 Bq and 1110 Bq for ^{238}Pu and ^{239}Pu, respectively), significant variations were observed among the participants. This can be attributed to more varying input parameters used. For instance, several participants correctly interpret the clearance class as Y/S but some remain with W/M. In addition to the different models and input parameters used, an additional factor is the mode of intake selected Among the participants, most assumed the intake as single inhalation for both ^{238}Pu and ^{239}Pu at the same time, but several other did not. Some assumed single and chronic inhalation for both ^{238}Pu and ^{239}Pu, some assumed single for one but chronic for the other, and one assume single inhalation for both but they occurred at slightly different dates (the doses for this case were added as if they occurred on the same date for comparison). These additional variations of input adds to the variation of results from event A and hence we got a much greater variation.

It appears that these cases show some merits of an artificially generated case. While it was not surprising that good results (in terms of agreement with the true value and agreement among participants) were obtained for the first intake, the agreement of the mean values with the true values for the second intake should not be interpreted as good results were obtained. The wide variations of the intake estimates and the resulting doses (both in the range of values and the RSD) show some of the inherent difficulty in getting good agreement for an exposure scenario involving multiple intakes

5 2 8 Case 8 Single intake of $^{238\ 239/240}$Pu and ^{241}Am

This is one of the best documented cases of a single intake of Transuranium elements world-wide There is a set of excretion and organ burden data from the first day after intake over a time period of almost ten years available. The data are good for fitting to biokinetic models because

(1) the values are relative high and thus the statistical errors are relative small and

(2) the data were not affected by any chelation therapy. In addition, there is quite a lot of additional information, such as the chemical form, the original nuclide composition and the particle size.

12 participants provided results for this case, all of them being complete with respect to required information Some participants provided results for ^{239}Pu and ^{240}Pu together. For those participants the required ^{239}Pu data were calculated from the ^{239}Pu/^{240}Pu data using the known ^{239}Pu/^{240}Pu activity ratio.

Seven participants used the models of ICRP 30, five of them in connection with ICRP 54 or the systemic functions of Jones and/or Durbin, respectively. Two participants applied the more recent models of ICRP 66 and ICRP 67, and two other participants used a combination of the old and the new models. Most of the participants applied the lung retention parameters for heavy soluble compounds (Class Y/S), some of them being modified according to the measured data. Three participants used the parameters for medium soluble compounds (Class W/M) and two applied a mixture of 90–95% Class Y/S and 5–10% Class W/M. The f_1 factors were assumed to be 0.00001 (4 participants) or 0.0005 (5 participants), however, there is no correlation between the assumed f_1 factors and the applied lung absorption parameters.

The averages of the estimated intake values are 3.08 ± 1.46 kBq ^{238}Pu, 18.7 ± 11.84 kBq ^{239}Pu and 3.37 ±1.68 kBq ^{241}Am. The percentages of the different isotopes are very close to the percentages given in the case description. However, five participants did not use the given percentages as a boundary condition for their estimates and derived significant different percentages. The relative standard deviations of the intake estimates are 49% for ^{238}Pu and ^{241}Am, respectively, and 33% for ^{239}Pu. As can be seen from the following table, the spread of the intake estimates is to some extend due to the assumed AMAD values. According to the case description the AMAD is supposed to be between 3 and 40 µm. Three participants, however, used AMAD values of 1 and 2 µm, respectively. As can be seen from the table there is a good correlation between the assumed AMAD value and the estimated intake.

Number of estimates	AMAD (mm)	Intake of ^{239}Pu (kBq)
2	1	5.90 ± 3.95
1	2	13,1
2	3	15.3 ± 2.23
6	5	28.9 ± 18.1
1	30	27

The averages of the effective committed dose values E(50) are 0.13 ± 0.08 Sv for ^{238}Pu, 0.88 ± 0.68 Sv for ^{239}Pu and 0.21 ±0.21 Sv for ^{241}Am. Contrary to intake, the wide spread of the dose values cannot be correlated with some input parameters. The dose factors of ^{239}Pu are ranging from 0.008 Sv/kBq up to 0.145 Sv/kBq, and the lowest values of 0.008 Sv/kBq are found both for 1 mm AMAD and 30 mm AMAD. There is also a very wide spread of the ratio of the committed bone surface dose and the committed effective dose. The ratio $H_{BS}(50)/E(50)$ varies over one order of magnitude from 3.3 up to 33.5, this indicating that the bone surface contribution to the total effective dose is ranging from 3.3% up to 33.5%. Also the ratio of the effective dose in 1983 and the committed effective dose shows a very wide spread, which cannot be correlated to any parameter. So the ratio $H_{83}(1)/H(50)$ varies from 0.0014 up to 0.33, this indicating that the contribution of the first year to the total committed dose is ranging from 0.14% up to 33%.

For conclusion, in this case there is no evidence of any systematic correlation of the dose values with some input parameter. However, there is limited evidence that the results of the participants using ICRP 30 and ICRP 54 are more consistent with each other than the results of the participants using more recent models. This is illustrated by the following table, which shows some averages for ^{239}Pu according to the models used. The old models, however, show the tendency to underestimate the intake and to overestimate the committed doses as compared to the more recent models.

Models used	Intake of ^{239}Pu		$H_{BS}(50)$		E(50)	
	Average (kBq)	RSD (%)	Average (Sv)	RSD (%)	Average (Sv)	RSD (%)
ICRP 30/ICRP 54	14,0	34	10,7	71	1,38	41
ICRP 66/ICRP 67	31 5 22.3*	60 23*	4,4	67	0,31	52
Other Combinations	16 3	95	18.1	122	0 70	86

*) Without laboratory No 13

5 2 9 Case 9 Single intake of ^{241}Am

This is a special case with a very untypical behaviour of inhaled ^{241}Am. According to the common models, the initial urinary excretion rate would indicate an intake of some hundred ALIs The faecal excretion and the lung counting data, however, revealed a much lower intake. Thus, the ^{241}Am shows in this case an untypical high solubility. Because of this high solubility the effect of the chelation therapy was not that high as compared to other cases. So the urinary excretion enhancement due to the DTPA treatment was not more than a factor of about 2 at the beginning and it increased up to a factor of about 10 by the end of the monitoring period.

Thirteen participants provided answers for this case. Six participants applied ICRP 30 models, some of them in connection with the systemic functions of Durbin or Jones. Four participants used the new lung model of ICRP 66 in connection with the systemic model of ICRP67 or Durbin's function of ICRP 54. Most participants (12) applied Class W/M parameters and one participant assumed a mixture of 85% Class W and 15% Class Y. Although the participants assumed similar lung retention, they used quite different f_1 factors ranging over two order of magnitudes from 0.00005 up to 0.005.

The average of the estimated intake values is 4.14 ± 3.12 kBq ^{241}Am. The relative standard deviation is 75% and, as in case 8, the spread of the intake estimates is to some extend due to the assumed AMAD values.

Number of estimates	AMAD (μm)	Intake of ^{241}Am (kBq)
1	0.2	1.18
1	0.3	2.5
1	0.4	1.46
3	1	2.00 ± 0.53
4	5	7.22 ± 1.69
1	10	9.6

The averages of the committed dose to the bone surface and of the effective committed dose are 6.73 ± 11.84 Sv and 0.29 ± 0.38 Sv, respectively. Thus, the relative standard deviation of the dose estimates is very high (178% for the bone surface and 131% for the effective dose, respectively). This is mainly due to Laboratory No. 1 which used only the lung counting data for evaluation. When neglecting the results of Laboratory No. 1, the relative standard deviation of the dose estimates comes down to 64% and 61%, respectively. As can be seen from the table below, there is also a systematic

dependence of the dose estimate on the assumed AMAD value This dependence, however, is not that strong as that of the intake estimates

Number of estimates	AMAD (μm)	Committed effective dose E(50) (Sv)
1	0.2	0 12
1	0.3	0 082
1	0.4	0 13
3	1	0.21 ± 0 11
3 (without Lab No 1)	5	0.18 ± 0 11
1	10	0 26

Two participants applied Hall's model for interpretation of the DTPA chelation therapy However, they found rather different figures of the dose reduction due to DTPA (50% and 3%, respectively). The other participants found the dose reduction to be 30% (for 6 participants) and 50% (for 2 participants) and 93.3% (for 1 participant), but they did not specify how they calculated these percentages

6. DISCUSSIONS AND CONCLUSION

The schematics of organising and implementing an international internal dose intercomparison, involve selecting or designing the test scenarios, selecting and inviting willing participants, distributing and collecting the responses, compiling and analysing the responses, summarising and presenting the findings Each of these steps taken should be reviewed for improvement for similar intercomparisons in the future

6.1. Design of test cases

The nine test cases used in this intercomparison cover a wide range of exposure scenarios In terms of time and duration of the intake, the test cases cover single, multiple, and chronic intakes In some cases (particular the cases based on real exposure scenarios in the past) not all the necessary information are known, and the participants have made different assumptions in the time and duration of intake The test cases also cover many common radionuclides for occupation exposures· ^{3}H, ^{45}Ca, ^{60}Co, $^{90}Sr/Y$, ^{125}I, ^{192}Ir, $^{238/239}Pu$, $^{238/239/240}Pu$ and ^{241}Am. There is some interests in other radionuclides, such as those involved in the nuclear fuel cycle, those used in nuclear medicine or biomedical research (e g ^{32}P, ^{131}I), or those that are naturally occurring (e.g thorium). Cases involving these radionuclides could be considered in future intercomparisons.

In terms of the routes of intake, both inhalation and ingestion are covered In some cases, particular those based on real exposure scenarios and do not have all the needed information, participants have to make assumption to which route of intake to consider. There is no test case in this intercomparison, however, for direct skin/wound absorption This route is not that uncommon in accidents and should be considered in selecting test scenarios for future intercomparisons. In addition, cases involving different intake routes simultaneously should also be considered.

For the modes of intake, both single and multiple intakes but not chronic intakes are covered when designing the test cases. The participants, however, have made intake assumptions including all these situations. The participants have suggested that, in the future intercomparisons, different modes including single, multiple, chronic and their combinations should be covered

Uncertainties of the retention or excretion data was provided to participants for Cases 2, 5, 6 and 7. In Case 7, uncertainty in the activity measurement was provided, but it is unclear if any participants had included the uncertainty in their intake and dose assessment. For Case 7, some of the data are actually zero or negative, but presented as "less then the least positive value" since activity do not have negative values. This is due to the fact that in actual measurements, the net count rate of the sample could be zero or negative. The internal dosimetrist has to decide the approach of data handling. In Case 7, all different approaches were used by different participants some assumed these data as zero, some did not use these data, some used all data, and some used part of the data An improvement over this may be providing the net count rates and calibration factor and let the dosimetrist decide on the assumptions.

A unique feature of this intercomparison is that some of the test cases are artificially generated instead of based on actual exposure scenarios. Artificially generated data provide advantages such as better control of the amount of information available to the participants. All necessary information such as time and duration of intake, rout of intake, amounts of intake, biokinetics, uncertainty in measurements, and the resulting doses are known to the organiser. The organiser could provide all or part of the information to the participants, depending on the goal of the intercomparison. This would avoid a major shortcoming of real cases (and a major complaint from participants), that in these real cases many necessary information are unknown or not provide to them. Another advantage is that the reference values of the intake and dose are known, as in Case 7, and this could provide insight on the agreements of the participants' results with the reference values and with each other. In real cases, even if the results are consistent with one another, it is not certain that the results are correct since the reference value is not known. Therefore, artificially generated cases are valuable and should be included along with the real case in future intercomparisons.

In setting up the test cases, it was assumed that the participants have all the necessary training and tools to solve the case. To solve exposure scenarios, the necessary tools include the assess to the relevant information such as reports (examples are as the BSS or ICRP reports), scientific papers, and computational tools (both hardware and software). A lower response rate for more complicated cases may be attributed to the fact that some tools are not available to some participants. This is also a concern that some participants are using the newer ICRP dose factors with the older biokinetic models. This may be due to a national requirement or a desire to use the combination of the latest available information to solve the cases. However, the use of the dose factors should be consistent with the choice of the biokinetic models. It is important to point out that computation tools for applying the more recent models are not widely available yet. As a result, the mixed use of different models and dose factors can lead to results which are not scientifically based and also lead to wider inconsistencies as shown in Case 8. This issue is viewed as a temporary phenomenon because it is expected that computational tool for implementing the more recent biokinetic models will be more readily available in the near future.

There is also a problem of shortage of suitable test scenarios. It is recommended that parallel to the intercomparison effort, a pool of suitable test scenarios should be collected for future intercomparisons. For the used test cases, results from past attempts to solve the cases should also be documented for anyone who may wish to try the test case and compare the results to past trials. These test cases may also serve well in providing training in actual practice of case solving for internal dosimetrists

6.2. Participants

Twenty-five institutes from twenty-four countries participated in this international internal dose intercomparison. For Australia, countries from South America and Asia, and some countries from Europe and North America, this intercomparison provides them the first opportunity to gauge their capability and performance with others. Most participants have clearly indicated that this intercomparison of internal dose assessment is important to them, have served them well, like to see that this intercomparison be repeated and expanded, and would like to be invited again to participate in the future. Most have indicated that internal dosimetry intercomparison should be held bi-annually.

Tremendous amount of time and effort are required to compile, interpret, and analyse the responses on nine test cases from twenty-five participants. There is a concern whether the total number of participants should be limited to twenty for manageability. However, as indicated by the participants, this intercomparison has been an importance service of the IAEA to them, and as such, no countries should be excluded If a much larger number of countries would like to participate, it may require the organiser to prioritize the selection criteria. In future, countries that have never participant in such intercomparison should be given preference. Another solution to this is to held regional such as Asian intercomparisons. In some region such as Europe, such intercomparisons have been organised more frequently in the past. Another solution is to reduce the number of test cases.

6.3. Distributing the test cases and receiving the responses

The participants were given six months to complete the test cases. Solving all the nine cases involved substantial efforts. Some participants have indicated that their management have not allocated adequate resources for them to solve the test cases. This additional work-load may partly explain why some participants asked to be invited but did not actually participated by not responding. For those responded, some of the responses are about three months late. One recommendation to this problem may be to reduce the number of test cases. Another approach is require the participant to obtain their management support prior to participation.

Late responses present a problem that the analysis of the responses need to be revised continuously. As a result, interpretation, statistically analysis and conclusions for each test cases must also be revised. It is therefore recommended that the organiser should make it clear that, if a response is received after the deadline, there is no guarantee that it would be included in the compilation of the results. One suggestion to speed up the distribution of the test cases and collection of response is via electronic means. Providing an electronic file, via the Internet or with a diskette, of data may also minimise the chance of error in entering the data for analysis.

6.4. Compilation, interpretation and analysis of responses

Participants were given clear instructions on the list of the information requested. Most of the information requested, such as the computer code, intake assumptions, biokinetic models, and the data handling approach, are important for the interpretation of the results. Some other requested information, such as the national guidelines, are however not important for this intercomparison exercise

In many cases, we have not receive sufficient information from the participants to allow the interpretation and comparison of the final answers In fact, if critical information such as the intake assumptions or biokinetic model is not given, it is impossible to identify the factors which are critical in accounting for the variation of the answer. In these cases, the organiser needs to decide if such a result should be included in the intercomparison. A suggestion to improve this is to provide the participants with a summary table for each test cases. This summary table would requested all the important information, such as intake assumptions, input parameters, and biokinetic models used, which would essentially allow one to reproduce the results If any of requested information is not provided by the participants, an explanation must be provided. The information supplied by the participants must be sufficient for others to follow their approach and reproduce the result. Otherwise, there is no guarantee the participants have correctly obtained the results using the stated variables.

There also appears to be a negative correlation on the rate of response with the complexity of the test case The more complicated a test case, the lower the response rate. Non-response may be attributed to the test case may be too complicated, test case may not related to their work condition, test case may require tools that participants do not possess, or management of individual participants may not have allocated sufficient resource for participants to solve the test cases.

The response are compiled by categorising the critical factors such as intake assumptions, input parameter, and biokinetic model used. The mean, SD and RSD (in %) were also calculated for analysis The maximum and minimum values are also presented to show the range of the variation In addition to the use of arithmetic mean, the use of geometric mean appears to better represent the results There is a suggestion to model the distribution of the results in either normal or log-normal distributions However, the use of these statistical concepts are questioned since this intercomparison is not for the random sampling of the results. The results from the participants are based on specific assumptions and models should not be considered as random (even though it appears to be that way) As aforementioned, many of the critical factors were not provided by some participants, making interpretation extremely difficult.

It appears that participants based their assumptions on the goodness of fit to the data and subsequently selected input parameters for assessments. The scientific basis for this approach seems reasonable but should be further investigated The list of factors which can contribute to the variation in answers include·

- intake assumptions (time and duration of intake, route of intake)
- input parameters (AMAD, f1)
- biokinetic models used
- computer code used.

It appears that the selection of the biokinetic model is the critical factor in determining the final results As indicated in the analysis of Case 8, the use of the older and newer models leads to two clusters of results There seems to be come correlation with the AMAD and the results in some cases The selection of the computer code used, however, requires further elaboration. Many commercially available internal dose computer code have gone through a quality assurance process. So, the variation may due more to the way the computer code is used, rather than the code itself This may explain why two difference participants using the same input parameters and models may get different answers

There seems to have a positive correlation of the complexity of the case and the variation of the results. More events or more radionuclides or more complex models require more variables and hence a greater difference in the results. One approach to resolve this is to limit the number of variables to be selected by the participants. This would allow the intercomparison to identify a critical factor to see its influence on the results. This would slightly change the focus of the intercomparison which the current goal is to look at the whole internal dosimetry process. It should, however, be considered in the future for more in depth analysis of particular cases. It would also be informative if uncertainty of the results can be provide by the participants in their response.

There is also the issue of the confusion of the concepts. While the IAEA and organisations such as the ICRP are using the concept of effective dose, many participants are not. This may be due to the fact that computational tools for the newer model may not be readily available to all yet Therefore, many reported the resulting dose as the E(50) while some are reporting the dose as the effective dose Technically they are different concepts and cannot be compared with each other. However, this issue is beyond the scope of this intercomparison. For the purpose of intercomparison they are treated as the same physical quantity. As aforementioned in Section 6 1, there is also the issue of the consistencies of using the dose factors with he corresponding biokinetic models

6.5. Harmonisation of results

One of the purpose for this intercomparison is to evaluate and illustrate the variation of results for the whole internal dosimetry process from the participants. Therefore, this intercomparison does not allow the participant to revise their answer once they were submitted. Some participants have shown concern when their results differ much from the mean, and have requested a revised answer be accepted. It should be pointed out that this intercomparison is not a contest and should never be considered that way. Each answer from participants, if evaluated properly using the assumptions and models correctly, has some scientific basis even though it still requires the subjective judgement of the participant. An answer closer to the mean value is not necessary more correct. The meaning of harmonisation for this intercomparison study is to make sure the various approaches used by the participants are clearly stated and understood so the discrepancies of the results can be explained. The reduction of the discrepancies of the answers is not a goal for this particular intercomparison.

There are some suggestions to have more in depth analysis for exposure scenarios which may be of particular interest to some participants. In this case, limiting the number of variables by suggesting the use of some common factors may be acceptable. If the purpose of the intercomparison is to reduce the variation of the results, it may be considered to allow a revision of approach after the forum of discussion. In this case, both the original and revised result should be documented to serve both purposed. This does not, however, applied to the situation when a participant make an obvious/trivial mistake. In this case, clarification should be requested. These mistakes usually would be caught be quality assurance procedures, if it existed in the participating institute.

6.6. Conclusion

Programme objectives have been accomplished in this intercomparison. This intercomparison is a very valuable exercise in which many countries are participating the first time in such intercomparison. It is recommended that the IAEA should continue to perform and expand such intercomparisons

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ANNEXES I–VI

Annex I

PARTICIPATING INSTITUTES

Scientific co-ordination of the intercomparison will be done by KFKI Atomic Energy Research Institute Budapest, Hungary (A Andrasi), Battelle Pacific Northwest National Laboratory Richland, USA (T.E. Hui) and Research Centre Karlsruhe, Germany (H. Doerfel).

The following institutes were invited to participate

Country	Institute (contact person)
Argentina	CAE, Buenos Aires (I. Gomez Parada)
Australia	Australian Radiation Laboratory, Yallambie (S Solomon)
Austria	Austrian Research Centre, Seibersdorf (F. Steger)
Belgium	AIB Vincotte Nucléaire, Bruxelles (J -P Culot)
Canada	Rad Protection Bureau, Ottawa (G. Kramer)
China	China Institute for Radiation Protection (J. Yueru)
Cuba	CPHR Habana (G. Lopez Bejerano)
Czech Republic	National Radiation Protection Institute, Prague (I. Malatova)
Finland	Finnish Centre for Radiation and Nucl Safety, Helsinki (T Rahola)
Germany	Federal Office for Radiation Protection, Berlin (R Scheler)
Hungary	Nat Res. Inst for Radiobiology & Radiohygiene, Budapest (A Kerekes)
Italy	ENEA, Bologna (G Tarroni)
Japan	National Inst of Radiological Sciences, Chiba (N. Ishigure)
Mexico	CNSNS, Mexico City (J.E. Garcia-Ramirez)
Netherlands	Energieonderzoek Centrum Nederland, Petten (A.S. Keverling Brisman)
Romania	Natk Ubst, "Horia Hulubei", Bucharest (M A. Puscalau, N.M Mocanu)
Russian Federation	Institute of Radiation Hygiene, St. Petersburg (M. Balonov)
Spain	CIEMAT, Madrid (T Navarro)
Sweden	Institute for Radiation Protection, Stockholm (R Falk)
Switzerland	Paul Scherrer Institute, Villigen (M. Boschung)
Ukraine	Ukrainian Rad. Prot. Inst., Kiev (V. Berkovski)
United States of America	Battelle Pacific Northwest Natl. Laboratory, Richland (D. Bihl)
United Kingdom	AEA Technology, Harwell (D. Spencer)
United Kingdom	NRPB, Chilton Didcot (A. Birchall)
IAEA	Radiation Safety Services Section, IAEA, Vienna (R Cruz Suarez)

Annex II

STRUCTURE OF CASES (GENERAL FORM)

1. THE EVENT

1.1. Description of the working area

1.2. Characteristics of work

1.3. Reasons for monitoring; initiating event

1.4. Actions taken

2. ADDITIONAL INFORMATION

2.1. Air monitoring

2.2. Chemical form

2.3. Physical characteristics, particle size

2.4. Nose swab, bronchial slime or similar

2.5. Non removable skin contamination

2.6. Wound site activity

2.7. Any intervention used (blocking, chelating, etc.)

3. BODY MONITORING DATA

3.1. Organ activity measurement

	Organ content			
Date	Organ	Nuclide	Activity	Uncertainty

3.2. Whole body activity measurement

Date	Whole body content		
	Nuclide	Activity	Uncertainty

3.3. Excretion monitoring data

3.3.1. Urine activity measurement

Sample				Daily excretion rate	
Date	Volume	Activity	Remarks	Activity	Uncertainty

3.3.2. Faeces activity measurement

Sample				Daily excretion rate	
Date	Volume	Activity	Remarks	Activity	Uncertainty

3.4. Personal data

3.4.1. Sex

3.4.2. Age

3.4.3. Weight

4. OTHER COMMENTS RELEVANT FOR INTAKE AND DOSE ESTIMATION

Annex III

GUIDELINES FOR PRESENTING THE RESULTS BY THE PARTICIPANTS

The participant should provide answers for as many case scenarios as the participant prefers to handle For a particular case scenario, if a participant obtains more than one answer using different approaches, all answers should be provided The participant should also determine the best answer from all possible answers and indicate the basis for such determination. The answers should be given according to the following scheme

1 GENERAL INFORMATION ABOUT THE METHODS APPLIED

1.1. National guidelines (are there any, and if so, are they applied or not)

1.2. Computer codes

2 INTAKE ASSUMPTIONS

2.1. Mode of intake (single, multiple or chronic)

2.2. Time of intake(s)

2.3. Pathway of intake(s)

3 MODEL(S) APPLIED

3.1. Standard ICRP models

3.2. Type of model(s)

3.3. Model parameters (inhalation class or clearance type, particle size, f_1-value)

3.4. Other models

3 4 1 Reason for applying other models

3 4 2 Type of model(s)

3 4 3 Characteristic parameters

4 DATA HANDLING

4.1. Data used for calculation (all or selected data)

4.2. Method for handling of measurements below detection limit

4.3. Method for assessment of uncertainty

5 RESULTS (SI UNITS)

5.1. Intake(s)

5.2. Dose (committed dose and, if relevant, also annual dose)

5.3. Effective dose

5.4. Organ dose(s) (for limiting organs only)

6 ADDITIONAL INFORMATION

Annex IV

STUDY CASES

1 CASE 1 SINGLE INTAKE OF ^{3}H

1.1. The event

1 1 1 Description of the working area

The overall radiation safety record was good Large amount of tritium in many different chemical forms are being processed

1 1 2 Characteristics of work

When the incident occurred, the worker was performing flame sealing of ampoules The glass broke and released an unknown amount of tritium into the atmosphere

1 1 3 Reasons for monitoring, initiating event

There was a tritium monitor (set up at the ceiling) whose alarm went off on 23 June, 1991

1 1 4 Actions taken

Urinary samples were taken daily for 45 days, then twice weekly until three months post incident, and then more sparingly until 6 months post incident

1.2. Additional information

1 2 1 Air monitoring

There were several tritium monitors set up in the work area

1 2 2 Chemical form

Many chemical forms exist in this facility However, for dose assessment purposes, one may assume it is mainly tritiated water There may also be an organically bound tritium (OBT) component, but it should not be significant

1 2 3 Physical characteristics, particle size

No data

1 2 4 Nose swab, bronchial slime or similar

Not applicable

1 2 5 Non removable skin contamination

None

1 2 6 Wound site activity

None

1.2.7. Any intervention used (blocking, chelating, etc.)

None

1.3. Body monitoring data

Not relevant

1.4. Excretion monitoring data

1.4.1. Urine activity measurement

Sample		
Date (dd.mm.aa)	Days Post Intake	Activity concentration[1)] ($MBq.l^{-1}$)
25.06.91	2	136.0
26.06.91	3	119.6
27.06.91	4	104.5
28.06.91	5	91.79
29.06.91	6	81.04
30.06.91	7	71.42
01.07.91	8	62.76
02.07.91	9	55.41
03.07.91	10	48.65
04.07.91	11	43.29
05.07.91	12	38.28
06.07.91	13	33.82
07.07.91	14	30.28
08.07.91	15	26.79
09.07.91	16	23.96
10.07.91	17	21.35
11.07.91	18	19.06
12.07.91	19	17.19
13.07.91	20	15.32
14.07.91	21	13.78
15.07.91	22	12.39
16.07.91	23	11.17
17.07.91	24	10.13
18.07.91	25	9.15
19.07.91	26	8.29
20.07.91	27	7.51

21.07.91	28	6.80
22.07.91	29	6.20
23.07.91	30	5.62
24.07.91	31	5.15
25.07.91	32	4.69
26.07.91	33	4.28
27.07.91	34	3.92
28.07.91	35	3.60
29.07.91	36	3.31
30.07.91	37	3.05
31.07.91	38	2.79
01.08.91	39	2.57
02.08.91	40	2.36
03.08.91	41	2.18
04.08.91	42	2.01
05.08.91	43	1.86
06.08.91	44	1.73
07.08.91	45	1.59
10.08.91	48	1.27
14.08.91	52	0.92
17.08.91	55	0.76
21.08.91	59	0.58
24.08.91	62	0.47
28.08.91	66	0.36
31.08.91	69	0.30
04.09.91	73	0.24
07.09.91	76	0.20
11.09.91	80	0.16
14.09.91	83	0.13
18.09.91	87	0.11
21.09.91	90	0.094
28.09.91	97	0.069
05.10.91	104	0.053
12.10.91	111	0.043
19.10.91	118	0.036
26.10.91	125	0.031
02.11.91	132	0.027

16.11.91	146	0.022
30.11.91	160	0.018
28.12.91	188	0.013
11.01.92	202	0.011
18.01.92	209	0.011
29.02.92	251	0.007
04.04.92	286	0.005

1) These values are based on single or multiple sampling per day; for evaluation they should be considered to be daily averages.

1.5. Personal data

1.5.1. Sex

Male

1.5.2. Age

The subject was 31 during the exposure incident.

1.5.3. Weight

The subject weighs about 73 kg.

1.6. Other comments relevant for intake and dose estimation

The following quantities have to be calculated:

Intake of ^{3}H

Committed effective dose (E(50))

2. CASE 2: INTAKE OF ^{45}Ca

2.1. The event

2.1.1. Description of the working area

Research laboratory in the pharmacological institute of a university

2.1.2. Characteristics of work

In the laboratory pharmacological research studies have been performed. There is no evidence for any connection between the work and the intake.

2 1 3 Reasons for monitoring, initiating event

There was no routine incorporation monitoring in the laboratory. On 10.03.93 a missing amount of 76 µL was assessed in a vial containing originally 37 MBq ^{45}Ca (reference date 08.01.93) dissolved in 100 µL water. A scientist suspected a colleague to have mixed the missing activity in her tea The colleague, being mentally disturbed, committed suicide after being confronted to the suspicion

2 1 4 Actions taken

After discovering the activity deficit urine samples have been taken from the scientist over a period of about seven weeks. In addition, on 13.04.93 a whole body measurement has been performed

2.2. Additional information

2 2 1 Air monitoring

None

2 2 2 Chemical form

$CaCl_2$

2 2 3 Physical characteristics, particle size

Water solution

2 2 4 Nose swab, bronchial slime or similar

None

2 2 5 Non removable skin contamination

None

2 2 6 Wound site activity

None

2 2 7 Any intervention used (blocking, chelating, etc)

None

2.3. Body monitoring data

2 3 1 Whole body activity measurement

Whole body activity has been measured on 13.04 93 using a NaI(Tl) detector scanning device The device has been calibrated with ^{45}Ca sources in a press wood phantom resulting in a calibration error of about 50%. The scan showed well defined count rate maxima at the height of shoulder, pelvis and knees, respectively, thus indicating that the activity mainly was distributed in the skeleton The measurement resulted in a whole body activity of 4.5 ± 2.5 MBq ^{45}Ca

2.4. Excretion monitoring data

2 4 1 Urine activity measurement (^{45}CA)

Sample	Daily excretion rate		
Date (dd mm aa)	Volume (mL)	Activity (Bq d $^{-1}$)	Uncertainty (Bq d $^{-1}$)
11 03 93	1100	5170	259
12 03 93	1720	5332	267
13 03 93	1420	5396	270
14 03 93	1650	6765	338
22 03 93	1500	4650	233
25 03 93	2100	3360	168
27 03 93	1610	3864	193
28 03 93	1390	4031	202
29 03 93	1670	4342	217
30 03 93	2050	3895	195
31 03 93	2040	2856	143
01 04 93	2120	3816	191
02 04 93	1970	3152	158
03 04 93	1130	3842	192
04 04 93	1940	4074	204
11 04 93	2360	2690	n a
18 04 93	1590	2067	n a
25 04 93	1720	2064	n a
02 05 93	1230	1353	n a

2 4 2 Faeces activity measurement

None

2.5. Personal data

2 5 1 Sex

Female

2 5 2 Age

33 years

2 5 3 Weight

70 kg

2.6. Other comments relevant for intake and dose estimation

The intake could have been occurred by single or multiple ingestion in the time period between 15.12.92 (delivery of the ^{45}Ca solution) and 10.03.93 (first detection of 45Ca in the urine).

The following quantities have to be estimated:

Time and activity of intake(s) of ^{45}Ca

Skeleton equivalent dose (H_{sk}) received in 1993;

Effective dose (E) received in 1993;

Committed equivalent dose of the skeleton (H_{sk} (50))

Committed effective dose (E (50))

3. CASE 3: SINGLE INTAKE OF ^{60}Co

3.1. The event

3.1.1. Description of the working area

Isotope production laboratory for handling unsealed radioisotopes in hot cells in high levels of activity

3.1.2. Characteristics of work

Cobalt wires irradiated by neutrons in a nuclear reactor facility was used for the preparation of sealed ^{60}Co sources. An irradiated capsule containing 740 TBq of ^{60}Co wire was opened in a hot cell and after 10 minutes the dose rate alarms sounded in the room.

3.1.3. Reasons for monitoring; initiating event

The operators hearing the alarm signal closed immediately the ^{60}Co source tightly in the capsule and left the working area. After putting on protective clothing and respirators the operators returned to the laboratory, stopped the leakage on the hot cell and decontaminated the workplace. (Date of event: 24.02.88)

3.1.4. Actions taken

After shower-bathing no body surface contamination could be detected. The next day in vivo monitoring was instituted.

3.2. Additional information

3.2.1. Air monitoring

None

3 2 2 Chemical form

Cobalt metal and/or oxide (temperature during irradiation was around 300°- 400°C)

3 2 3 Physical characteristics, particle size

No data

3 2 4 Nose swab, bronchial slime or similar

None

3 2 5 Non removable skin contamination

None

3 2 6 Wound site activity

None

3 2 7 Any intervention used (blocking, chelating, etc)

None

3.3. Body monitoring data

3 3 1 Organ activity measurement

Profile scanning indicated dominant lung deposition

3 3 2 Whole body activity measurements

The first whole-body activity monitoring was performed one day after the event and was repeated several times for a long period of time as given in the attached table

Date (dd.mm.aa)	Whole body content Activity [Bq]
25.02.88	2720
01.03.88	1150
11 03.88	1010
28.03.88	790
16.05.88	482
11.08.88	358
29.11.90	78
19.02.92	35

3.4. Excretion monitoring data

3.4.1. Urine activity measurement

None

3.4.2. Faeces activity measurement

None

3.5. Personal data

3.5.1. Sex

Male

3.5.2. Age

34 years

3.5.3. Weight

79 kg

3.6. Other comments relevant for intake and dose estimation

The following quantities have to be estimated:

Intake of ^{60}Co

Effective dose (E) received in 1988;

Committed effective dose (E (50))

4. CASE 4: INTAKE OF ^{90}Sr AND ^{90}Y

4.1. The event

4.1.1. Description of the place

Abandoned sand mine, used in late fiftieth as low-activity waste. The galleries are now closed by heavy iron doors and brick walls. Penetrating into the area of low-activity waste became time to time rather popular, at 1990 among green activists.

4.1.2. Characteristics of intake circumstances

It is not exactly known. Partly it was described by the internally contaminated person, partly it was reconstructed.

The person entered the area through the hole in the wall from bricks (if he dug the hole or if somebody else has done it is not quite clear) He found barrel with marker for radioactive substances, took out tin labelled as ISOMET ^{90}Sr, opened the tin and found white powder

4 1 3 Reasons for monitoring, initiating event

The person started to worry few days after entering area of low activity waste He found a possibility to be measured with a dose-rate meter As a positive response was found and serious surface contamination was supposed, the authorities were informed

4 1 4 Actions taken

Measurement with dose rate meter was repeated, again with positive response As the person already repeatedly took shower, suspicion that he is internally contaminated arose and he was sent for whole body counting Also his apartment and his belongings were measured and action for removing surface contamination was undertaken The surface contamination was found at his home on the bed sheets, carpet, TV set, etc Also, his sport wear and backpack and its content were contaminated Quite a lot of activity was found on play-cards and on microtene bag used for sandwiches

4.2. Additional information

It was later found that ISOMET was used in the late fiftieth for the measurement of thickness of paper o contaminated the rolling mill

4 2 1 Air monitoring

None

4 2 2 Chemical form

No data

4 2 3 Physical characteristics, particle size

White powder, particle size not measured

4 2 4 Nose swab, bronchial slime or similar

None

4 2 5 Non removable skin contamination

Not found, person measured probably 5 days after the major part of intake

4 2 6 Wound site activity

None

4 2 7 Any intervention used (blocking, chelating, etc)

None

4.3. Body monitoring data

4.3.1. Organ activity measurement

None

4.3.2. Whole body activity measurement

Date	Whole body burden	
(dd.mm.aa)	Nuclide	Activity(kBq)[1)]
29.11.1990	$^{90}Sr/^{90}Y$	692
30.11.1990	$^{90}Sr/^{90}Y$	400.5
03.12.1990	$^{90}Sr/^{90}Y$	292
04.12.1990	$^{90}Sr/^{90}Y$	272
05.12.1990	$^{90}Sr/^{90}Y$	256.5
06.12.1990	$^{90}Sr/^{90}Y$	261.5
07.12.1990	$^{90}Sr/^{90}Y$	248
10.12.1991	$^{90}Sr/^{90}Y$	218
12.12.1991	$^{90}Sr/^{90}Y$	215
27.05.1991	$^{90}Sr/^{90}Y$	118.5
05.06.1991	$^{90}Sr/^{90}Y$	135
04.07.1991	$^{90}Sr/^{90}Y$	110.5
08.08.1991	$^{90}Sr/^{90}Y$	102.5
02.06.1992	Sr-90/Y-90	96
11.08.1992	Sr-90/Y-90	79

1) 50% of the activity is supposed to be deposited in the soft tissues and 50% in the bones.

4.4. Excretion monitoring data

4 4 1 Urine activity measurement (^{90}Sr)

			Daily excretion rate	
Date (dd.mm.aa)	Volume (l)	Activity (kBq.l^{-1})	Sampling time (h)	Activity (kBq.d^{-1})
29 11.1990	0.70	44.81	19	56.60
01 12 1990	0.80	27.80	-	55.28[1)]
03 12 1990	1.00	11.83	19	14 46[1)]
14 12 1990	0.65	10.64	19	10.81[1)]
06 12.1990	0.85	8.68	18	9.80[1)]
09 12.1990	0.50	6.36	19	5.91[1)]
11.12.1990	1.00	4.44	24	4.44[1)]
03.07.1991	-	0.47	24	0.47
07 08 1991	-	0.20	24	0.20

1) Normalisation according to creatinin content

4 4 2 Faeces activity measurement

Date (dd.mm.aa)	Daily excretion rate (kBq.d^{-1})
01.12.1990	8.54
03.12.1990	2.56
04 12 1990	10 52
06.12.1990	0.36
09.12.1990	0.12
11.12.1990	2.3

4.5. Personal data

4 5 1 Sex

Male

4 5 2 Age

20 years

4 5 3 Weight

70 kg

4.6. Other comments relevant for intake and dose estimation

The co-operation of P.R. with people from radiation protection was rather poor. In spite of instruction ho journalists about danger from low activity waste. In TV, he mentioned also some health problems.

The following quantities have to be estimated:

Intake of ^{90}Sr and ^{90}Y

Skeleton equivalent dose (H_{sk}) received in 1990;

Effective dose (E) received in 1990;

Committed equivalent dose of the skeleton ($H_{sk}(50)$)

Committed effective dose (E (50))

5. CASE 5: REPEATED INTAKE OF ^{125}I

5.1. The event

5.1.1. Description of the working area

Isotope laboratory specially equipped for handling radioiodines in high levels of activity.

5.1.2. Characteristics of work

In this laboratory the most characteristic work is labelling different organic compounds by ^{125}I. The chemical preparations are done in ventilated hood. The ^{125}I isotope is dominantly in iodine form in the starting aqueous solution containing sodium thiosulfate. This kind of work is repeated several times in a month but not in regular time periods. Decontamination of the devices and working surfaces belong also to the task of the workers involved. The level of activity handled at the same time is around 1 GBq.

5.1.3. Reasons for monitoring; initiating event

Monitoring of workers was performed only on routine basis and was not connected to any working phase or event.

5.1.4. Actions taken

None

5.2. Additional information

5.2.1. Air monitoring

None

5.2.2 Chemical form

Mostly iodide and organically bound iodine

5 2 3 Physical characteristics, particle size

No data

5.2 4 Nose swab, bronchial slime or similar

None

5 2 5 Non removable skin contamination

None

5 2 6 Wound site activity

None

5 2 7 Any intervention used (blocking, chelating, etc.)

None

5.3. Body monitoring data

5.3 1 Organ activity measurement

Thyroid activity has been measured by collimated scintillation counter calibrated for ^{125}I. The attached table show the routine monitoring results together with their uncertainties due to counting statistics (1 σ) in the time period from the end of 1994 to the beginning of 1996.

	Thyroid ^{125}I activity			
Date (dd.mm.aa)	V.A.		P.L.	
	Activity (kBq)	Uncertainty (kBq)	Activity (kBq)	Uncertainty (kBq)
16.11.94	6.70	0.59	n.a.	n.a.
23.01 95	14.55	0.86	n.a.	n.a.
08.02 95	17.71	0.95	1.59	0.30
08.03.95	9 78	0.71	3.57	0.43
22 03.95	9.99	0.71	4 93	0.51
20.04.95	4.66	0.49	2.32	0.35
22.05.95	2 42	0.36	1.41	0.28
23 06.95	2 71	0.38	1.17	0.26
29 08.95	3.51	0 43	1 74	0.31
26.09.95	4.05	0.46	2.29	0.35
25.10.95	3.69	0.44	5.52	0.53
23.11.95	3.00	0.40	5.44	0.53
24.01.96	2.50	0.37	5.88	0.55

5.4. Excretion monitoring data

5.4.1. Urine activity measurement

None

5.4.2. Faeces activity measurement

None

5.5. Personal data

5.5.1. Sex

Males

5.5.2. Age

V.A.	P.L.
50 a	37 a

5.5.3. Weight

V.A.	P.L.
85 kg	100 kg

5.6. Other comments relevant for intake and dose estimation

The worker V.A. was continuously involved in the work described above in the years of 1994, 1995 and 1996, but P.L. started to work on 1 February 1995 only.

The following quantities have to be calculated:

Total Intake of ^{125}I

Thyroid equivalent dose (H_{th}) received in 1995;

Effective dose (E) received in 1995;

Committed equivalent dose of the thyroid ($H_{th}(50)$)

Committed effective dose (E (50))

6 CASE 6 SINGLE INTAKE OF ^{192}Ir

6.1. The event

6 1 1 Description of the working area

Laboratory properly prepared for encapsulation of radioactive sources

6 1 2 Characteristics of work

^{192}Ir sources for industrial radiography were manufactured in the last phase by sealing the sources by electro-welding The worker involved sharpened the wolfram electrode by grinding without checking its possible contamination due to a previous use for sealing The time of event 21/05/1980 at 1

6 1 3 Reasons for monitoring, initiating event

After the work had been finished the worker, before leaving the laboratory, checked himself by a contamination monitor which showed high level of surface contamination

6 1 4 Actions taken

After discovering the contamination the worker was sent for whole body measurements The body surface contamination could be removed by careful shower bathing

6.2. Additional information

6 2 1 Air monitoring

None

6 2 2 Chemical form

Elemental or oxide

6 2 3 Physical characteristics, particle size

No data

6 2 4 Nose swab, bronchial slime or similar

None

6 2 5 Non removable skin contamination

None

6 2 6 Wound site activity

None

6 2 7 Any intervention used (blocking, chelating, etc)

None

6.3. Body monitoring data

6.3.1. Organ activity measurement

Partial body monitoring showed the highest count rate above the chest

6.3.2. Whole body activity measurement

The first whole body measurement was performed on the day of the event at 2 PM. The uncertainty of measurements given in the table below refers to 1s of the counting statistics.

Date	Whole body burden		
(dd.mm.aa)	Nuclide	Activity (kBq)	Uncertainty (kBq)
21.05.80	^{192}Ir	41.7	0.3
22.05.80	^{192}Ir	14.5	0.2
23.05.80	^{192}Ir	5.03	0.12
26.05.80	^{192}Ir	2.26	0.09
03.06.80	^{192}Ir	1.80	0.08
06.06.80	^{192}Ir	1.79	0.09
17.06.80	^{192}Ir	1.37	0.06
29.07.80	^{192}Ir	0.93	0.05
09.09.80	^{192}Ir	0.56	0.04
01.10.80	^{192}Ir	0.11	0.02

6.4. Excretion monitoring data

6.4.1. Urine activity measurement)

None

6.4.2. Faeces activity measurement

None

6.5. Personal data

6.5.1. Sex

Male

6.5.2. Age

30 years

6.5.3. Weight

73 kg

6.6. Other comments relevant for intake and dose estimation

The following quantities have to be estimated:

Intake of ^{192}Ir

Committed effective dose (E (50))

7 CASE 7: MULTIPLE INTAKES OF $^{238/239}Pu$

This case is about a male worker who began plutonium work in January 1983 doing glove box work in a laboratory processing ^{239}Pu, primarily in nitrate form. In April 1988, the individual transferred to another multipurpose research lab, working mostly with ^{239}Pu. There are possibly 2 (and maybe more) events during his entire time of employment, one occurred on March 21 1985, the second possible one happened around March 5 1990. Both events would be described separately before the presentation of monitoring data.

7.1. Event A

7 1 1 The event

7 1 1.1. Description of the working area

The overall radiation safety record was good, with few measurable intakes.

7 1 1.2 Characteristics of work

The working area is a ^{239}Pu processing facility.

7 1.1.3. Reasons for monitoring; initiating event

The subject submitted urine samples twice yearly during his entire time of employment. There was a Continuous Air Monitor (CAM) alarm incident on March 21, 1985.

7 1.1 4 Actions taken

The subject did not have positive nose swabs, so additional bioassay data was not obtained.

7 1 2 Additional information

7 1.2.1. Air monitoring

There were several CAMs set up in the work area

7.1 2 2 Chemical form

It is safe to assume the chemical form is plutonium nitrate, mainly ^{239}Pu.

7.1.2.3. Physical characteristics, particle size

No data

7 1.2 4. Nose swab, bronchial slime or similar

Nose swabs were taken, but the result is not positive.

7 1.2.5 Non removable skin contamination

None

7 1.2.6. Wound site activity

Not applicable

7.1 2.7 Any intervention used (blocking, chelating, etc.)

None

7.2. Event B

7 2 1 The event

7.2.1.1. Description of the working area

The overall radiation safety record was good, with few measurable intakes.

7.2.1.2. Characteristics of work

This is a multipurpose research laboratory. The subject works mainly with ^{239}Pu in a glove box. However, some ^{239}Pu processing was also done in the same work area.

7.2.1.3. Reasons for monitoring; initiating event

The subject submitted urine samples twice yearly during his entire time of employment. There was significant skin contamination (working with Pu-238 during that time) on another worker on March 5, 1990. But again, the subject did not have positive nose swabs, and no skin contamination was found on the subject, so additional bioassay data was not obtained.

7 2.1.4. Actions taken

Nothing in particular

7 2.2 Additional information

7.2.2.1. Air monitoring

There were several CAMs set up in the work area, but no alarm was sounded.

7.2.2.2. Chemical form

No data

7 2.2 3 Physical characteristics, particle size

No data

7.2.2.4 Nose swab, bronchial slime or similar

Nose swabs were taken, but the result is not positive.

7.2 2.5 Non removable skin contamination

None

7.2.2.6 Wound site activity

Not applicable

7 2.2 7 Any intervention used (blocking, chelating, etc.)

None

7.3. Body monitoring data

None available

7.4. Excretion monitoring data

The subject submitted urine samples twice yearly during his entire time of employment. A simulated 24h sample collection protocol was used with collection on two successive evenings and mornings, using a specific gravity correction. This collection protocol was known to have an coefficient of variation of 30%. During this time period the analysis laboratory (the second facility the subject works in) had a history of doing high quality work with measurement uncertainties (standard deviation) for uncontaminated samples of 0.148 mBq/24h and 0.222 mBq/24h for ^{239}Pu- and ^{238} Pu- respectively

7 4 1 Urine activity measurement

Sample	Daily excretion rate	
Date (dd mm.aa)	Activity ^{238}Pu (mBq.d ^{1})	^{239}Activity Pu (mBq.d^{-1})
15.01.1983	<0 07	<0.07
17.07.1983	0.35	<0.07
16 01.1984	<0.07	<0.07
17 07.1984	0.28	<0.07
16 01 1985	0.28	0 19
18 07 1985	<0.07	2.49
17.01.1986	<0.07	2.67
19.07.1986	<0 07	1.22
18 01.1987	0.07	0 99
20.07 1987	<0.07	1 50

19.01.1988	<0.07	0.62
20.07.1988	0.21	0.91
19.01.1989	<0.07	0.43
21.07.1989.	<0.07	0.73
20.01.1990	<0.07	0.67
22.07.1990	0.18	1.27
21.01.1991	0.88	0.94
23.07.1991	0.39	1.21
22.01.1992		2.34
23.07.1992	0.65	1.35
22.01.1993	0.63	2.37
24.07.1993	0.21	1.75
23.01.1994	0.69	1.89
25.07.1994	0.28	2.18
24.01.1995	0.12	0.65
26.07.1995	0.65	2.12
25.01.1996	0.30	1.28
26.07.1996	0.08	1.14

7.5. Personal data

7.5.1. Sex

Male

7.5.2. Age

39 years

7.5.3. Weight

70 kg

7.6. Other comments relevant for intake and dose estimation

The following quantities have to be estimated for event A and B, respectively:

Intake of ^{238}Pu and ^{239}Pu

Committed bone surface equivalent dose (H_{bs})

Committed effective dose (E (50))

8 CASE 8. SINGLE INTAKE OF $^{238/239/240}$Pu AND ^{241}Am

8.1. The event

8 1.1 Description of the working area

Radiochemical laboratory for the development of advanced nuclear fuels in a nuclear research centre

8 1 2 Characteristics of work

In the laboratory nuclear fuel microspheres had been produced in a glove box using a special gelling technique. The waste water resulting from this technique was routinely collected and evaporated in the box. The residual waste was transferred into a second glove box for further evaporation and disposal.

8 1 3 Reasons for monitoring, initiating event

On 24.05.83 at 4.15 p.m. there was an explosion in the second glove box during evaporation of 3 l waste as a consequence of an unexpected exothermic reaction. The pressure of the explosion opened the sluice of the box and destroyed the gloves. Two persons working at the first box left the laboratory immediately after the explosion. However, they were strongly contaminated at face, hairs and clothes.

8 1 4 Actions taken

The two directly involved persons were decontaminated in the radiation protection unit of the research centre Nose swabs and also bronchial slime samples were taken from both persons. In addition. the two persons were measured in the lung counter of the research centre at the same day.

8.2. Additional information

8 2 1 Air monitoring

There were stationary room air samplers.

8 2 2 Chemical form

Uranium/plutonium hydroxide gel in washing water containing about 10% ammonium nitrate and about 3.5% hexamethylentetramine

8 2 3 Physical characteristics particle size

The α activity composition of the inhaled substance was 9% ^{238}Pu, 55% ^{239}Pu, 26% ^{240}Pu and 10 ^{241}Am. The ^{241}Pu activity was 750% of the total α activity. The diameter of the plutonium containing particles is supposed to be between 3 and 40 µm according to REM exposures and qualitative X-ray analyses of dust samples from the laboratory.

8 2 4 Nose swab bronchial slime or similar

The nose swab contained 5.5 kBq α activity (^{239}Pu and ^{240}Pu) and the bronchial slime 1.4 kBq.

8.2.5. Non removable skin contamination

No data

8.2.6. Wound site activity

None

8.2.7. Any intervention used (blocking. chelating. etc.)

None

8.3. Body monitoring data

8.3.1. Organ activity measurement

The first lung counter measurement was performed in the research institute at the day of the event and was repeated several times until 1991 as given in the following table. The indicated uncertainties of measurements refer to 1 σ of the counting statistics

Date (dd.mm.aa)	Lung burden		
	Nuclide	Activity (Bq)	Uncertainty
24.05.83	^{241}Am	390	25%
25.05.83	^{241}Am	310	25%
27.05.83	^{241}Am	230	25%
^{241}Am	^{241}Am	240	25%
08.06.83	^{241}Am	230	25%
27.06.83	^{241}Am	230	25%
01.07.83	^{241}Am	260	25%
07.07.83	^{241}Am	230	25%
31.10.83	^{241}Am	220	25%
04.11.83	^{241}Am	230	25%
15.05.84	^{241}Am	220	25%
05.05.86	^{241}Am	240	25%
27.05.91	^{241}Am	180	25%

On 03.08.93 and on 15.11.93 more detailed organ activity measurements have been performed in two other institutions (Lab. A and Lab. B). The results of these measurements are given in the following table.

Date (dd.mm.aa)	Organ burden			
	Organ	Nuclide	Activity (Bq)	Uncertainty
3.8.93 (Lab. A)	Lymph	^{241}Am	26	14%
3.8.93 (Lab. A)	Lung	^{241}Am	120	13%
3.8.93 (Lab. A)	Bone	^{241}Am	69	12%
3.8.93 (Lab. A)	Liver	^{241}Am	57	16%
15.11.93 (Lab. B)	Lymph	^{241}Am	72	29%
15.11.93 (Lab. B)	Lung	^{241}Am	120	21%
15.11.93 (Lab. B)	Bone	^{241}Am	65	12%
15.11.93 (Lab. B)	Liver	^{241}Am	24	33%

8.3.2. Whole body activity measurements

See table above

8.4. Excretion monitoring data

8.4.1. Urine activity measurement

Sample	Daily excretion rate	
Date (dd.mm.aa)	Activity (mBq.d^{-1}) ^{239}Pu + ^{240}Pu	Activity (mBq.d^{-1}) ^{241}Am + ^{238}Pu
25.05.83	11	110
26.05.83	41	100
07.06.83	4.7	16
14.06.83	3.7	11
24.06.83	3.7	5.6
30.06.83	5.6	5.6
06.07.83	3.7	5.2
21.11.83	3.7	4.6
26.05.84	3.5	4.0
20.01.85	2.9	3.4
03.05.86	3.7	2.7
27.08.88	5.9	4.7
11.02.89	6.2	3.8
28.01.94	3.4	2.6
	Activity (mBq.d^{-1}) ^{238}Pu + ^{239}Pu + ^{240}Pu	Activity (mBq.d^{-1}) ^{241}Am
25.04.90	6.7	4.3
25.05.91	4.6	2.3

8.4.2. Faeces activity measurement

Sample	Daily excretion rate	
Date (dd.mm.aa)	Activity ($Bq.d^{-1}$) $^{239}Pu + ^{240}Pu$	Activity ($Bq.d^{-1}$) $^{241}Am + ^{238}Pu$
25.05.83	5.2E+03	1.5E+03
26.05.83	3.0E+03	7.4E+02
27.05.83	4.4E+02	7.4E+01
06.06.83	6.7E-01	1.6E-01
14.06.83	7.2E-01	1.5E-01
23.06.83	6.7E-01	1.2E-01
30.06.83	2.5E-01	7.8E-02
07.07.83	2.1E-01	5.9E-02
21.11.83	4.2E-01	9.4E-02
27.05.84	2.6E-01	5.9E-02
20.01.85	2.6E-01	7.5E-02
	Activity ($Bq.d^{-1}$) $^{238}Pu + ^{239}Pu + ^{240}Pu$	Activity ($Bq.d^{-1}$) ^{241}Am
03.05.86	7.0E-02	1.8E-02
27.08.88	9.5E-02	2.5E-02
24.04.90	3.4E-02	1.2E-02
25.05.91	1.3E-02	5.6E-03

8.5. Personal data

8.5.1. Sex:

Male

8.5.2. Age:

26 years (at year of intake)

8.5.3. Weight:

80 kg

8.6. Other comments relevant for intake and dose estimation

The following quantities have to be estimated for ^{238}Pu, ^{239}Pu and ^{241}Am, respectively

Intake

Bone surface equivalent dose (H_{bs}) received in 1995;

Effective dose (E) received in 1995;

Committed bone surface equivalent dose (H_{bs} (50))

Committed effective dose (E (50))

9 CASE 9 SINGLE INTAKE OF ^{241}Am

9.1. The event

9 1 1 Description of the working area

Producer of detectors systems for radiation measurement in nuclear technology and nuclear medicine

9 1 2 Characteristics of work

The person was in charge with disposing an industrial source containing 3.7 GBq (100 mCi) ^{241}Am which formerly had been used for density measurements. The work had been performed in a normal laboratory without any measures for preventing external or internal contamination.

9 1 3 Reasons for monitoring, initiating event

On 29.06.95 at 10.30 a.m. the person tried to dismantle the source and destroyed unintentional the capsule. He realized some powder coming out of the capsule.

9 1 4 Actions taken

First measurements revealed a large contamination of the person and the whole laboratory. The person removed his contaminated clothes and took a shower. He also blew his nose to remove some internal contamination. Further measurements with a hand-foot-clothing monitor show still a significant contamination and thus the person was sent to a special radiological protection centre for further treatment. There extensive decontamination procedures were performed and a nose-throat swab was taken. The direct measurement of the swab revealed a significant α-activity in the ET2 compartment and thus immediately an infusion therapy with 1 g Ca-DTPA diluted in 250 mL NaCl was applied. In addition the collection of excretion samples was initiated and direct in-vivo measurements were performed at the same day.

9.2. Additional information

9.2.1. Air monitoring

None

9.2.2. chemical form

Oxide

9.2.3. Physical characteristics. particle size

Powder

9.2.4. Nose swab. bronchial slime or similar

Nose swab taken about four hours after the intake contained 59 Bq ^{241}Am.

Non removable skin contamination.

About 3 mBq.cm^{-2} at the right side of the face; this value had been derived by direct α-measurement and might underestimate the real skin contamination because the non removable activity is supposed to be in the deep pores.

9.2.5. Wound site activity

None

9.2.6. Any intervention used (blocking. chelating. etc.)

DTPA infusions (see Table below)

9.3. Body monitoring data

9.3.1. Organ activity measurement

Date	Organ content			
(dd.mm.aa)	Organ	Nuclide	Activity (Bq)	Uncertainty (Bq)
29.06.95	Resp. tract	^{241}Am	533	53
29.06.95	Liver	^{241}Am	<27	
30.06.95	Resp. tract	^{241}Am	435	44
30.06.95	Liver	^{241}Am	<22	
03.07.95	Resp. tract	^{241}Am	376	38
03.07.95	Liver	^{241}Am	<19	
03.07.95	Skeleton	^{241}Am	26	11
20.07.95	Resp. tract	^{241}Am	313	31
20.07.95	Liver	^{241}Am	<16	
20.07.95	Skeleton	^{241}Am	<22	

27 07 95	Resp tract	^{241}Am	312	31
27 07 95	Liver	^{241}Am	<16	
21 08 95	Resp tract	^{241}Am	211	21
21 08 95	Liver	^{241}Am	<11	
21 08 95	Skeleton	^{241}Am	<28	
28 09 95	Resp tract	^{241}Am	130	13
28 09 95	Liver	^{241}Am	9	4
28 09 95	Skeleton	^{241}Am	30	11
22 01 96	Resp tract	^{241}Am	47	5
22 01 96	Liver	^{241}Am	<6	
22 01 96	Skeleton	^{241}Am	36	11
02 04 96	Resp tract	^{241}Am	43	4
02 04 96	Liver	^{241}Am	<6	
02 04 96	Skeleton	^{241}Am	46	11

9.4. Excretion monitoring data

9 4 1 Urine activity measurement

Sample				
Date (dd mm aa)	Volume (mL)	Activity of ^{241}Am (Bq)	Uncertainty (Bq)	Remarks
30 06 95	2100	8 65	1 1	1g Ca-DTPA[1)]
01 07 95	1150	2 92	0 48	
02 07 95	2650	2 66	0 58	
03 07 95	2850	1 68	0 3	1g Ca-DTPA
04 07 95	1850	3 24	0 43	
05 07 95	1750	1 28	0 28	1g Ca-DTPA
06 07 95	2150	2 49	0 18	
07 07 95	1850	2 05	0 15	
08 07 95	1000	2 14	0 18	
09 07 95	1270	1 63	0 13	
10 07 95	2830	2 3	0 20	
11 07 95	2750	1 66	0 12	
12 07 95	1200	1 43	0 10	
13 07 95	2000	1 89	0 15	
14 07 95	2700	2 75	0 26	1g Ca-DTPA
15 07 95	1050	2 65	0 19	

16.07.95	1800	2.02	0.16	
17.07.95	2000	1.87	0.13	1g Ca-DTPA
18.07.95	2000	2.57	0.19	
19.07.95	2850	2.65	0.21	
20.07.95	2000	1.43	0.12	1g Ca-DTPA
21.07.95	1200	2.7	0.21	
22.07.95	1800	2.09	0.16	
23.07.95	2800	2.44	0.22	
24.07.95	1550	1.98	0.14	1g Ca-DTPA
25.07.95	2000	2.4	0.18	
26.07.95	2850	2.24	0.17	
27.07.95	1750	2.01	0.16	1g Ca-DTPA
28.07.95	3500	3.26	0.21	
29.07.95	2000	1.41	0.11	
30.07.95	1700	2.3	0.20	
31.07.95	3000	1.49	0.10	
19.08.95	1980	1.23	0.066	
20.08.95	1960	1.43 ?	0.093	
21.08.95	2650	1.15	0.064	
30.08.95	2000	0.562	0.041	
31.08.95	4000	1.18	0.089	
01.09.95	2000	0.72	0.052	
13.09.95	2000	0.418	0.024	
14.09.95	2000	0.548	0.031	
15.09.95	2800	0.929	0.056	
26.09.95	2000	0.275	0.018	
27.09.95	2000	0.343	0.023	
28.09.95	3200	0.51	0.031	2g Zn-DTPA
29.09.95	2000	2.5	0.18	
30.09.95	2000	1.17	0.097	
01.10.95	2000	1.4	0.11	
02.10.95	2900	1.87	0.15	
17.10.95	2000	1.44	0.11	2g Ca-DTPA[1)]
18.10.95	2000	1.07	0.09	
19.10.95	2000	1.38	0.12	
20.10.95	3000	1.74	0.13	
01.11.95	2000	0.65	0.065	

02 11 95	2000	0 64	0 06	
17 11 95	2000	0 265	0 025	2g Zn-DTPA
18 11 95	2000	1 56	0 12	
19 11 95	3150	0 905	0 081	
15 12 95	n a	0 258	n a	2g Ca-DTPA
16 12 95	n a	1 41	n a	
17 12 95	n a	0 566	n a	
18 12 95	n a	0 953	n a	
22 01 96	n a	0 084	n a	2g Zn-DTPA
23 01 96	n a	0 733	n a	
24 01 96	n a	0 836	n a	
25 01 96	n a	0 291	n a	
05 02 96	n a	0 165	n a	
21 02 96	n a	0 081	n a	
22 02 96	n a	0 887	n a	
23 02 96	n a	0 288	n a	
24 02 96	n a	0 203	n a	
27 03 96	n a	0 0415	n a	2g Zn-DTPA
28 03 96	n a	0 733	n a	
30 03 96	n a	0 29	n a	
31 03 96	n a	0 328	n a	
01 04 96	n a	0 111	n a	
18 04 96	n a	0 0564	n a	

9.5. Faeces activity measurement

Sample				
Date (dd mm aa)	Volume (g)	Activity of ^{241}Am (Bq)	Uncertainty (Bq)	Remarks
30 06 95	228	215	13	1g Ca-DTPA[1)]
01 07 95	164	86 2	9 3	
02 07 95	108	8 01	1 5	
03 07 95	237	4 13	1 1	1g Ca-DTPA
04 07 95	369	3 91	0 34	
05 07 95	44	0 033	0 002	1g Ca-DTPA
06 07 95	115	0 199	0 018	

07.07.95	93	0.469	0.04	
08.07.95	142	1.51	0.11	
09.07.95	76	0.169	0.016	
10.07.95	209	0.295	0.026	
11.07.95	230	0.529	0.044	
13.07.95	167	0.41	0.053	
14.07.95	217	0.531	0.046	1g Ca-DTPA
16.07.95	122	0.529	0.045	
17.07.95	146	0.353	0.031	1g Ca-DTPA
19.07.95	152	0.8	0.066	
20.07.95	233	0.83	0.058	1g Ca-DTPA
22.07.95	286	0.9	0.073	
23.07.95	211	0.233	0.025	
24.07.95	329	0.366	0.032	1g Ca-DTPA
25.07.95	152	0.398	0.033	
27.07.95	310	0.566	0.046	1g Ca-DTPA
28.07.95	202	0.219	0.024	
29.07.95	166	0.253	0.021	
30.07.95	74	0.168	0.017	
31.07.95	163	0.653	0.056	
19.08.95	248	0.415	0.023	
21.08.95	268	0.746	0.04	
29.08.95	303	0.136	0.021	
30.08.95	184	0.103	0.023	
01.09.95	277	0.113	0.021	
13.09.95	187	0.138	0.0097	
15.09.95	243	0.365	0.021	
25.09.95	205	0.27	0.018	
26.09.95	221	0.387	0.028	
27.09.95	66	0.039	0.0036	
28.09.95	281	0.405	0.036	2g Zn-DTPA
30.09.95	148	0.369	0.041	
02.10.95	352	1.2	0.28	
17.10.95	212	0.224	0.021	2g Ca-DTPA[1)]
18.10.95	142	0.289	0.023	
19.10.95	250	1.18	0.011	
20.10.95	128	0.433	0.035	

18.11.95	155	0.049	0.0066	2g Ca-DTPA[1)]
19.11.95	124	0.33	0.029	
16.12.95	n.a.	0.06	n.a.	2g Ca-DTPA[1)]
17.12.95	n.a.	0.321	n.a.	
18.12.95	n.a.	0.396	n.a.	
23.01.96	n.a.	0.044	n.a.	2g Ca-DTPA[1)]
24.01.96	n.a.	0.0858	n.a.	
25.01.96	n.a.	0.309	n.a.	
23.02.96	n.a.	0.042	n.a.	
28.03.96	n.a.	0.0912	n.a.	2g Ca-DTPA[1)]
29.03.96	n.a.	0.131	n.a.	
01.04.96	n.a.	0.25	n.a.	

1) DTPA was administered one day before.

9.6. Personal data

9.6.1. Sex

Male

9.6.2. Age

39 years

9.6.3. Weight

76 kg

9.7. Other comments relevant for intake and dose estimation

The following quantities have to be estimated:

Intake of ^{241}Am

Bone surface equivalent dose (H_{bs}) received in 1983;

Effective dose (E) received in 1983;

Committed bone surface equivalent dose (H_{bs} (50))

Committed effective dose (E (50))

Optional: Reduction of committed effective dose due to DTPA

Annex V

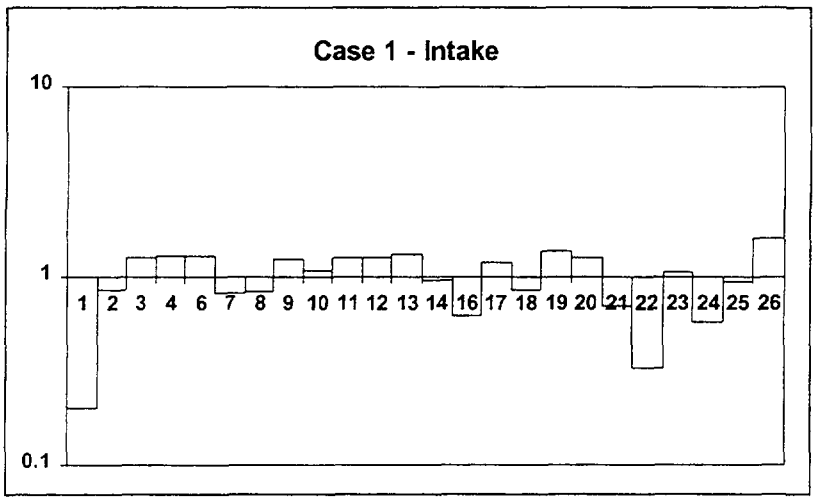
RESULTS CASE PER CASE

The histograms refer to the values related to the arithmetic means.

Case 1 - Single intake of ^{3}H

Lab. N°	Intake (GBq)	CEDE(50) (mSv)	Computer code	Model	Particle size (mm)	Clearance Type
1	1 2	21	NS	NS	NS	NS
2	5 11	134	LUDEP 2 04	ICRP 56	5	M, SR-2
3	7 5	75 6	MICROFIT	ICRP 30/54	NR	NR
4	7 674	138	None	ICRP 30 ICRP 68 (DF)	5 (default)	S-R 2 (default)
6	7 68	75	INDO	3 term exponential retention	NR	NR
7	4 89	41 35	DOSIS	ICRP 66 (lung) ICRP 30/54 (biokinetics)	5	F
8	5	90	CINDY	ICRP 30	NS	NR
9	7 3	130	NO CODE	ICRP 54 ICRP 68 (dose factors)	NS	SR-2
10	6 4	80	CINDY	Johnson & Dunford	5	NR
11	7 5	76	STATGRAPHICS	2 term exponential retention	NR	NR
12	7 52	70 1	LUDEP 2 04	2 term exponential retention	NR	NR
13	7 8	78	NO CODE	3 term exponential retention	NR	NR
14	5 72	97 2	DOSINT	ICRP 30	NR	NR
16	3 7	70 3	IABM	NUREG CR-4884	1	F
17	7 14	77	NO CODE	1 term exponential retention	NR	SR-2
18	5 08	100	GENMOD PC	JOHNSON & DUNFORD	1	D

Lab. N°	Intake (GBq)	CEDE(50) (mSv)	Computer code	Model	Particle size (mm)	Clearance Type
19	8	100	NS	Direct extrapolation for intake ICRP 71 (dose factors)	NR	NR
20	7 4	130	NS	ICRP 66 (lungs) ICRP 56 (biokinetics)	5	F
21	4 2	75	NS	ICRP 30 2 terms exponential	NR	NR
22	2	21	IDSS 2	2 term exponential retention	NR	Absorption V
23	6 3	63	NS	1 term exponential retention	NR	NR
24	3 5	63	None	ICRP 30 ICRP 68 (DF) ICRP 60 (w_T)	NR	NR
25	5 6	81 5	CINDY 1 4	ICRP 30	NR	NR
26	9 5	140	LUDEP 2 04	ICRP 66 (lungs) ICRP 30/54 (biokinetics) BSS 115 (DF) ICRP 60 (w_T)	5	F
Geo Mean	5 51	76 72				
Arith mean (X)	5 99	84 46				
SD (s)	2 03	32 92				
SD%	33 95	38 98				
(X+s)/X	1 34	1 39				
(X-s)/X	1 95	1 57				


Case 1 - Intake
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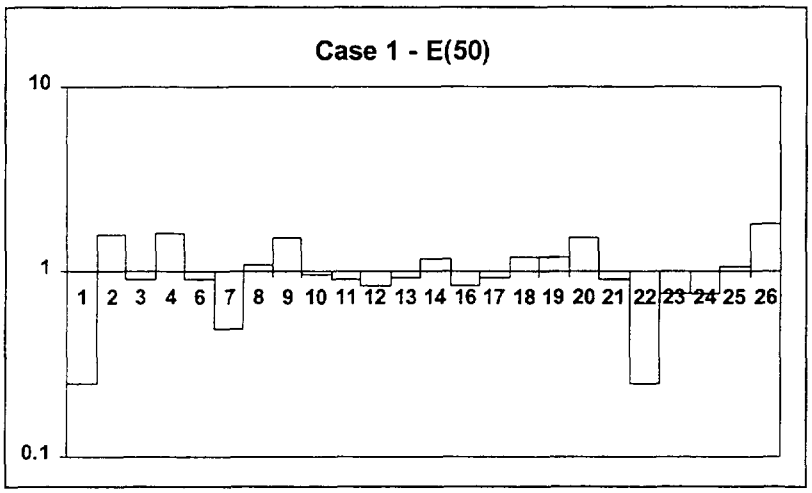
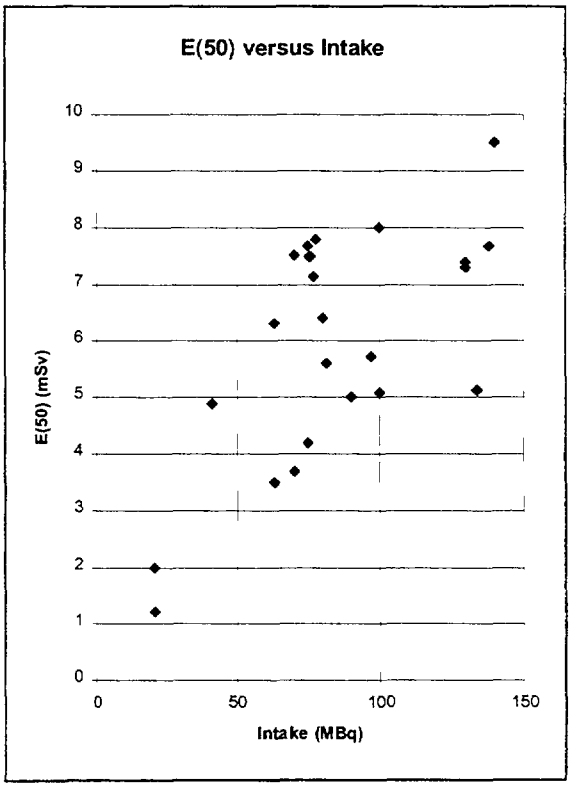
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26

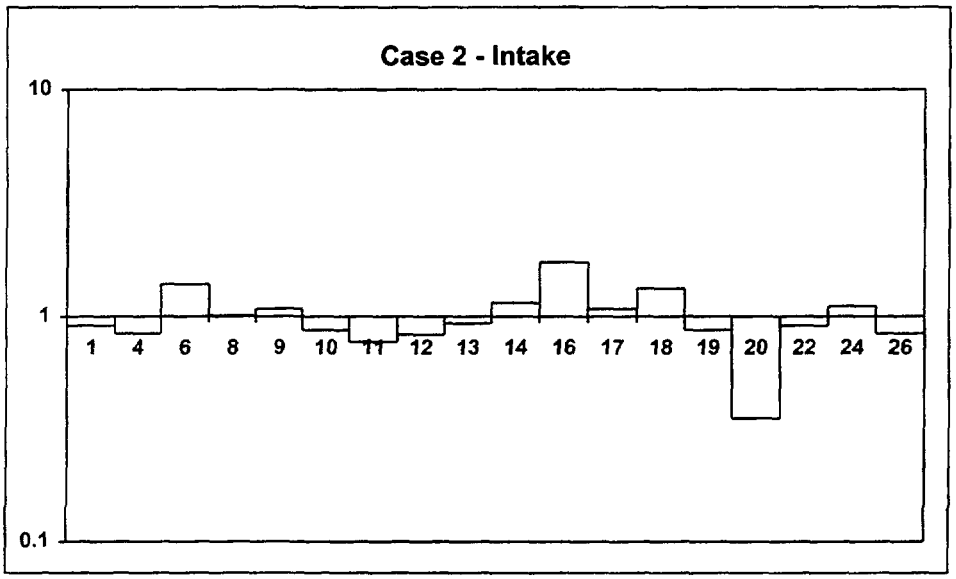

Case 1 - E(50)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26


E(50) versus Intake
E(50) (mSv)
10
9
8
7
6
5
4
3
2
1
0
0
50
100
150
Intake (MBq)

Case 2 - Intake of ^{45}Ca

Lab.N°	Time of intake	Intake (MBq)	$H_{BS,93}$ (1) (mSv)	$H_{BM,93}$ (1) (mSv)	$H_{SK,93}$ (1) (mSv)	E_{93}(1) (mSv)	H_{BS} (50) mSv)	H_{BM} (50) (mSv)	H_{SK} (50) (mSv)	E(50) (mSv)	Computer code	Model	f1
1		26			40	5			120	15			
4	2/12/93	24 23			97.8	15 36			128	18 04	LUDEP	7 compartments (Skrabble)	NS
6	01/25/93	39 9	180	120		29	210	140		32	INDO	ICRP 30	0 3
8		29	120	82		21	150	100		25	CINDY	ICRP 30 Johnson (Alkaline earth)	0.3
9	12/15/92	31	600	50		18	700	60		22	NRPB R 245	NS	NS
10	01/29/93	25	100	71		18	130	90		22	CINDY	Johnson AE	0.3
11	03/07/93	22	190	110		16	190	130		18	AGEDOS	ICRP 20 (biokinetics) ICRP 30 (DF)	0 5
12	02/06/93	23.7	98.2	66 8		15.3	125 6	84.6		17 7	LUDEP 2.04	ICRP 20 ICRP 30 (GI)	0 3
13	01/20/93	26.7				8 6				8 7	NO CODE	ICRP 71	0.3
14	01/25/93	33.1	140	94.2		22	172	116		26.8	DOSINT	7 compartments (NUREG CR 4884)	0.3
16	01/27/93	50	183.3	124 7		33 8	231 7	155 9		38	NS	7 compartments (NUREG CR 4884)	0 3
17	12/16/92	31	140	70		11	170	84		14	NO CODE	ICRP 10	0.3

Lab.N°	Time of intake	Intake (MBq)	$H_{BS,93}$ (1) (mSv)	$H_{BM\ 93}$ (1) (mSv)	$H_{SK,93}$ (1) (mSv)	E_{93}(1) (mSv)	H_{BS} (50) mSv)	H_{BM} (50) (mSv)	H_{SK} (50) (mSv)	E(50) (mSv)	Computer code	Model	f1
18	12/16/92	38 3	211	142		31	199	134		31	REMEDY	ICRP 10 (intake) ICRP 30 (biokinetics)	0 3
19	02/08/93	25	1290	99		31	1700	130		38	LUDEP 2 0	ICRP 30 (biokinetics) ICRP 60 (w_T)	NS
20	12/15/92	10								7 6	NS	ICRP 71	NS
22	01/28/93	26	140	65		16	160	80		18	IDSS 2	ICRP 71	0 3
24	01/26/93	32	170	80		20	200	99		23	LUDEP 2 66	ICRP 71 (biokinetics) ICRP 30 (GI)	0 3
26	02/07/93	24	98	67		15 3	125	85		17 7	LUDEP 2 04		
Geom Mean		27 43	185 04	85 04	62 55	17 40	220 12	102 85	123 94	20 04			
Arith Mean(X)		28 72	261 46	88 69	68 90	19 20	318 81	106 32	124 00	21 81			
SD (s)		8 47	321 65	27 03	40 87	8 10	422 94	28 01	5 66	8 77			
SD%		29 50	123 02	30 48	59 32	42 18	132 66	26 34	4 56	40 21			
(X+s)/X		1 29	2 23	1 30	1 59	1 42	2 33	1 26	1 05	1 40			
(X-s)/X		2 39		2 28	0 69	1 37		2 80	20 92	1 49			


Case 2 - Intake
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0.1
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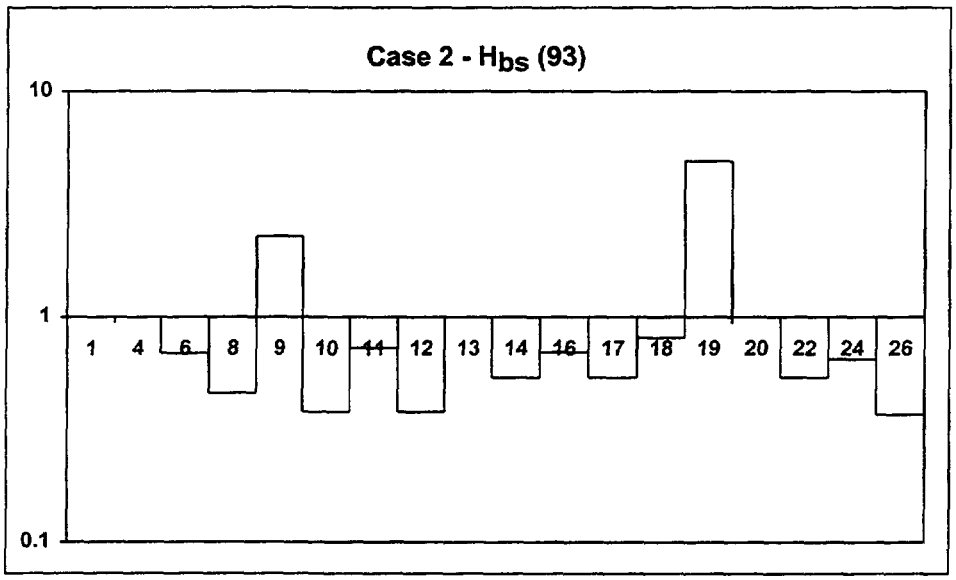
Case 2 - Hbs (93)
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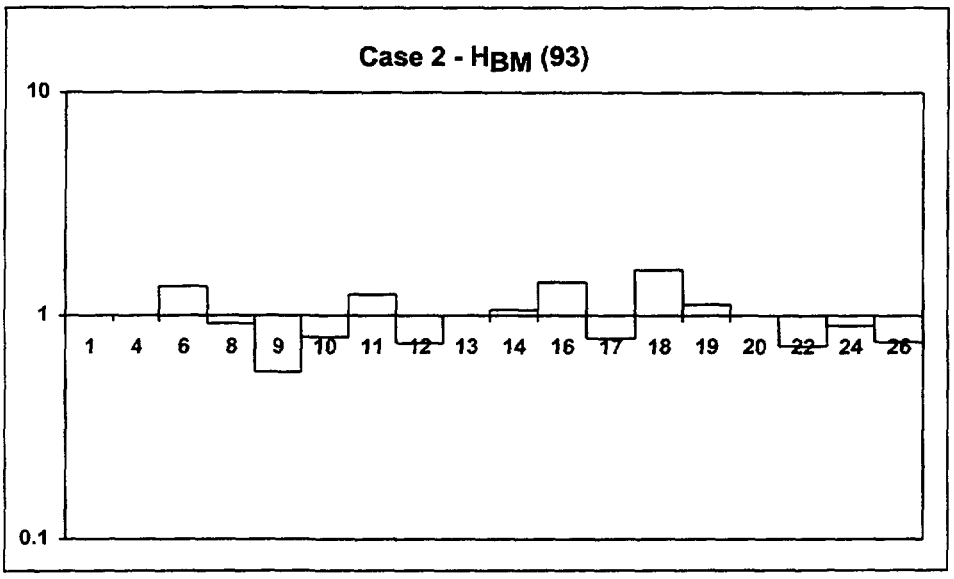
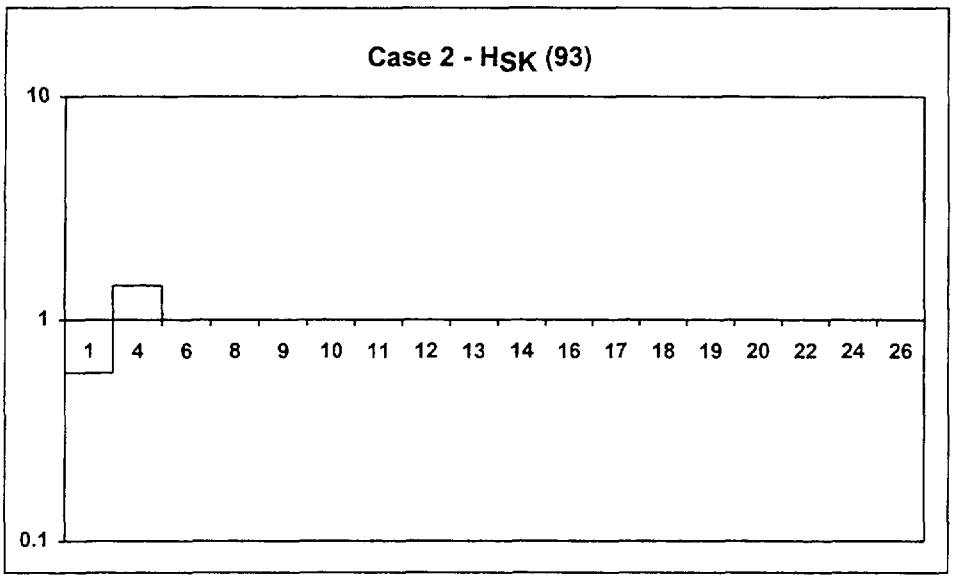
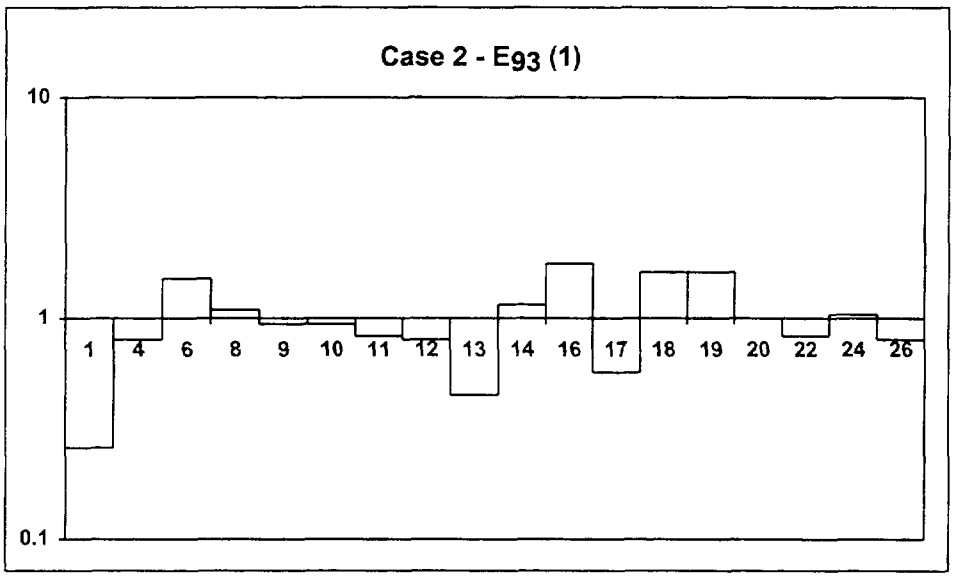
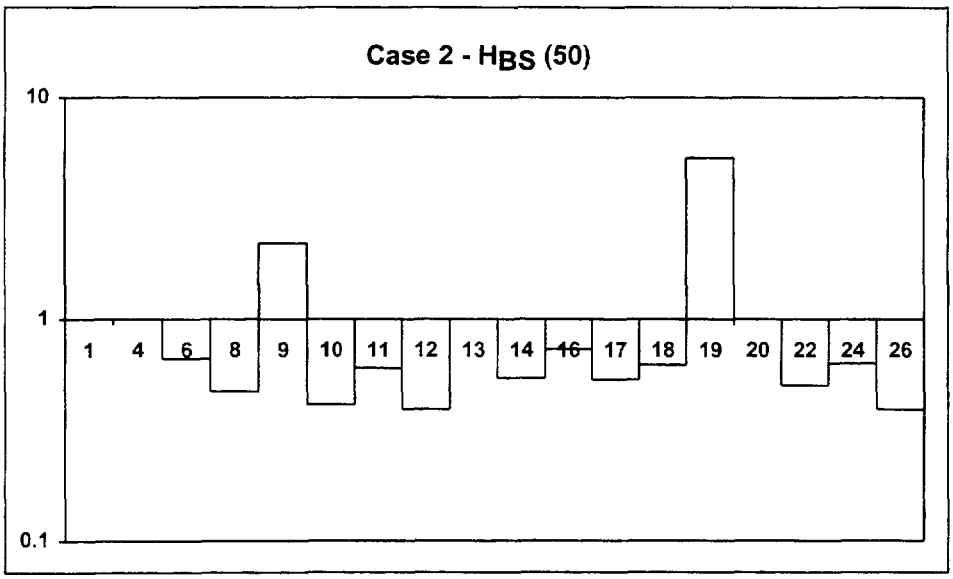
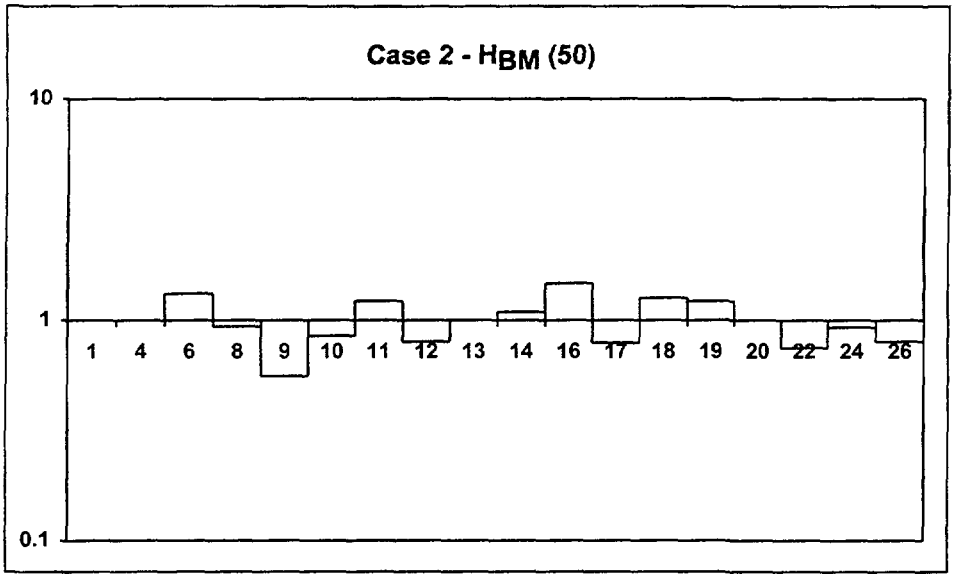
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26

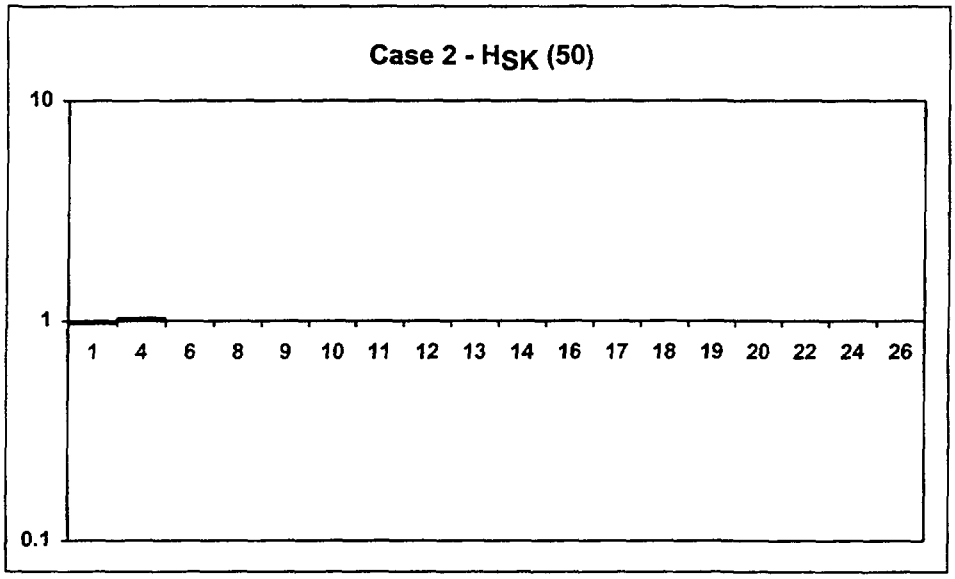

Case 2 - HBM (93)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26

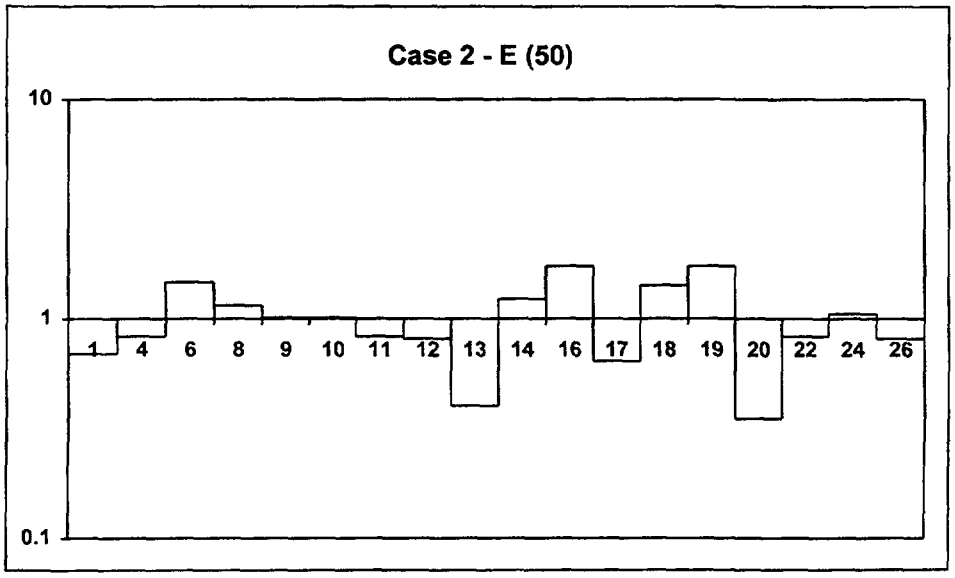

Case 2 - H_{SK} (93)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26

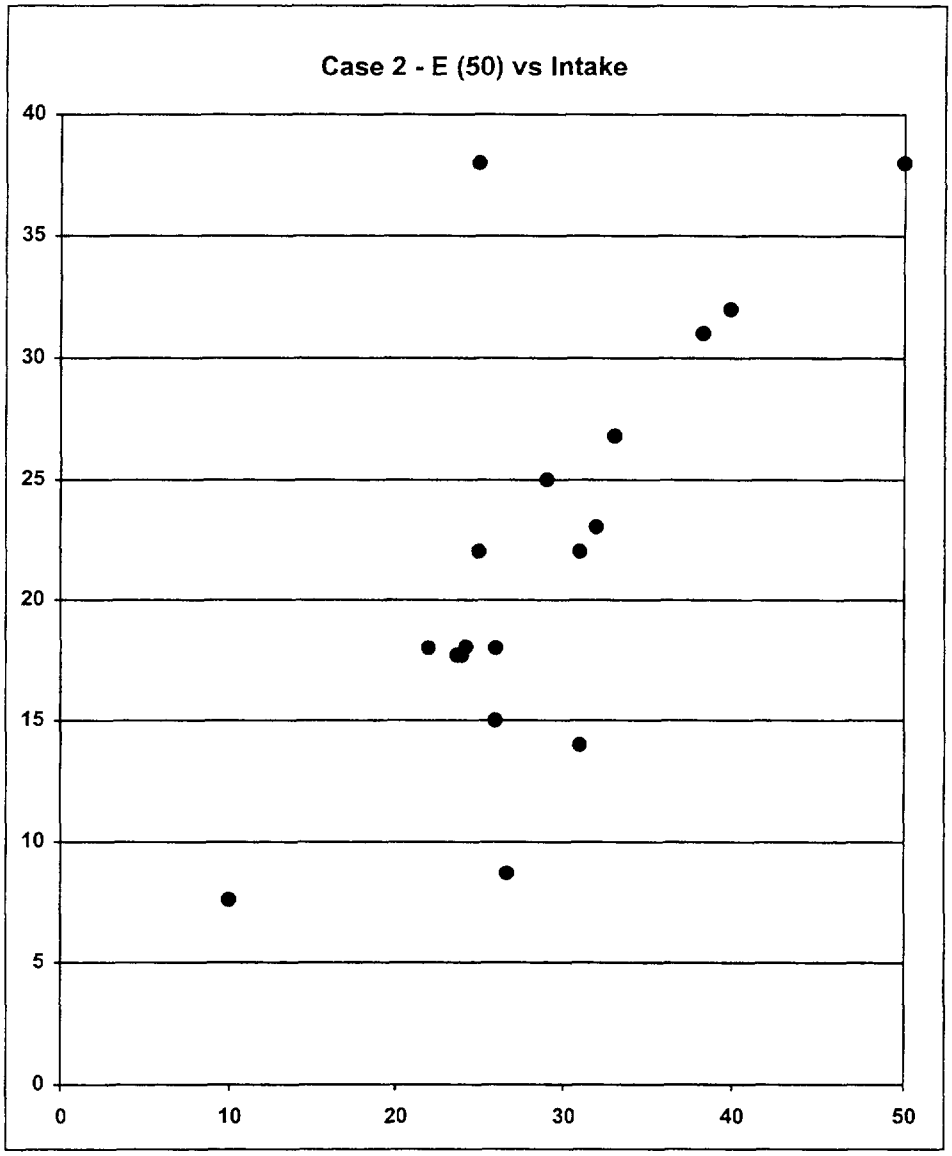

Case 2 - E_{93} (1)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26


Case 2 - H_{BS} (50)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26


Case 2 - H_{BM} (50)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26


Case 2 - H_{SK} (50)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26


Case 2 - E (50)
10
1
0.1
1 4 6 8 9 10 11 12 13 14 16 17 18 19 20 22 24 26

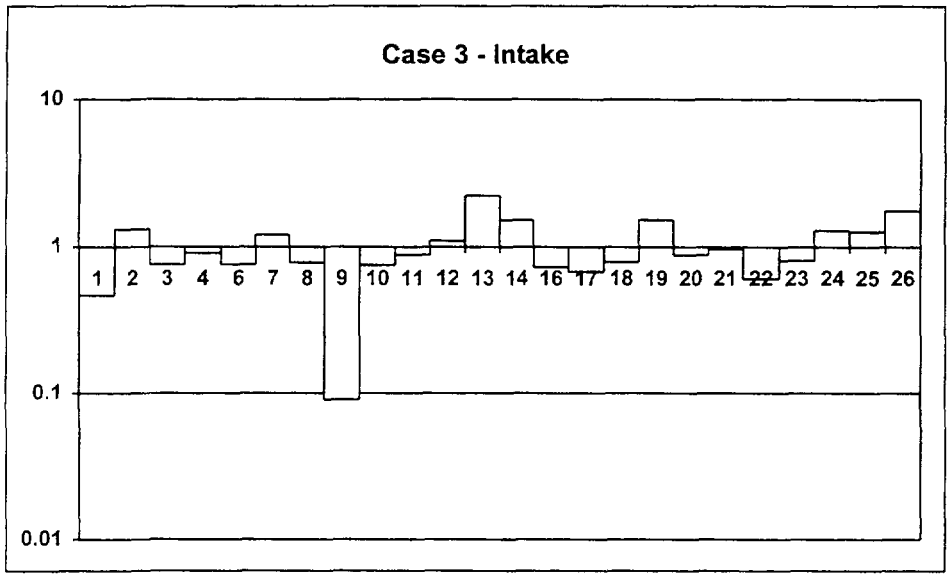

Case 2 - E (50) vs Intake
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50

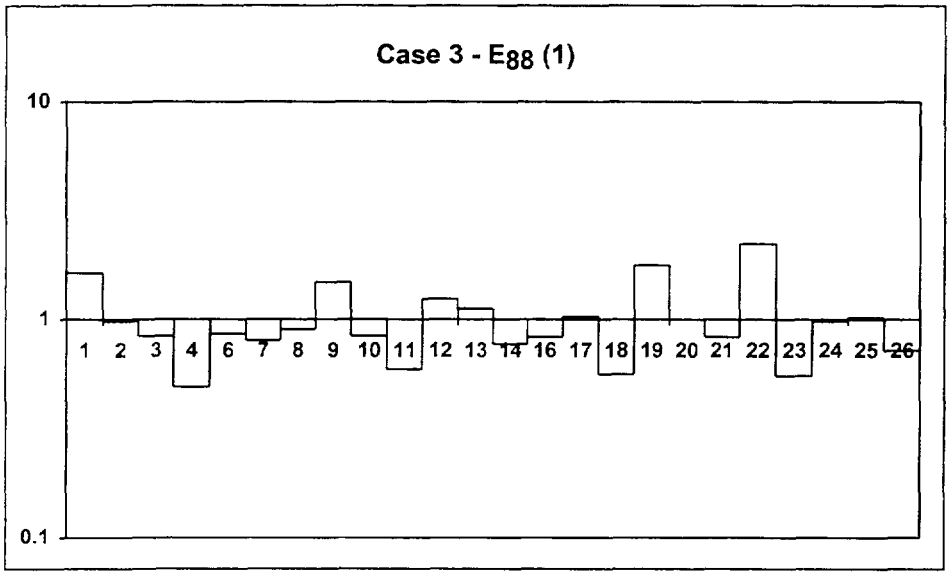
Case 3 - Single intake of ^{60}Co

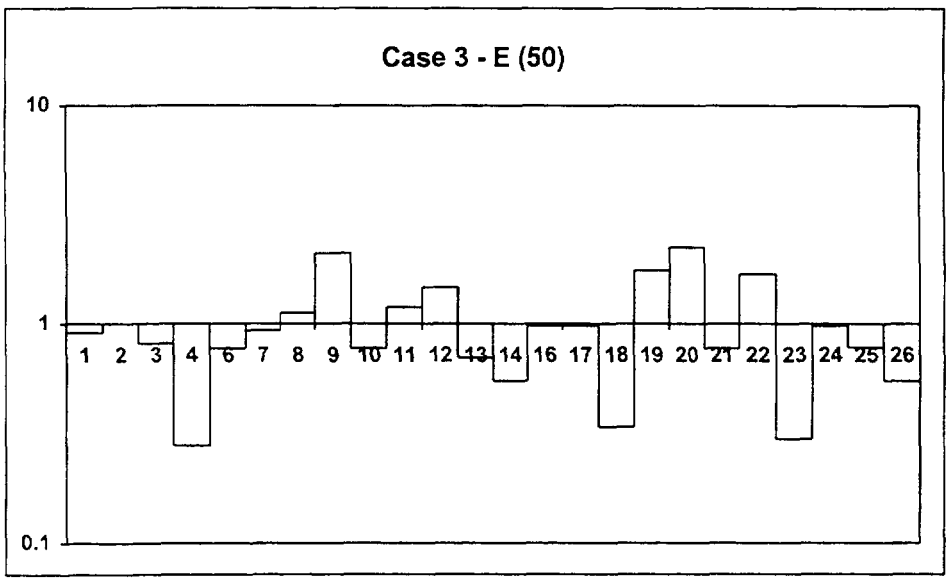
Lab.N°	Intake (kBq)	E88(1) (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type	f1
1	3 1	110	130	NS	NS	1	Y	NS
2	8 625	66 5	142 3	LUDEP 2 04	ICRP 30 (intake) ICRP 54 (retention)	5	Y/S	0 05
3	4 976	56 6	115	INDOS	ICRP 30 / ICRP 54	0 5	80% W 20%Y	0 05
4	6 01	33	40	LUDEP	ICRP 66 (lung) ICRP 30 (intake)	5	M	0 05
6	4 97	58	110	INDO (in-house)	ICRP 30	0 5	83% W 17% Y	1
7	7 864	54	133	DOSIS (in-house)	ICRP 66 (lung) ICRP 30/54 (bio-kinetics)	5	S	0 05
8	5 1	61	160	CINDY	ICRP 30	1	50% W 50% Y	0 05
9	0 6	100	300	NS	ICRP 30	1	Y	0 05
10	4 9	57	110	CINDY	ICRP 30	0 5	80% W 20% Y	0 05
11	5 8	40	170	NS	ICRP 54 (bio-kinetics) ICRP 68 (dose factors)	1	Y	NS
12	7 24	84	210	LUDEP 2 04	ICRP 30 (systemic) ICRP 54 (whole body) ICRP66 (lung)	1	S	0 05
13	14 5	76	99	NO CODE	ICRP 66 (lung) ICRP 67 (bio-kinetics)	5	M	0 1

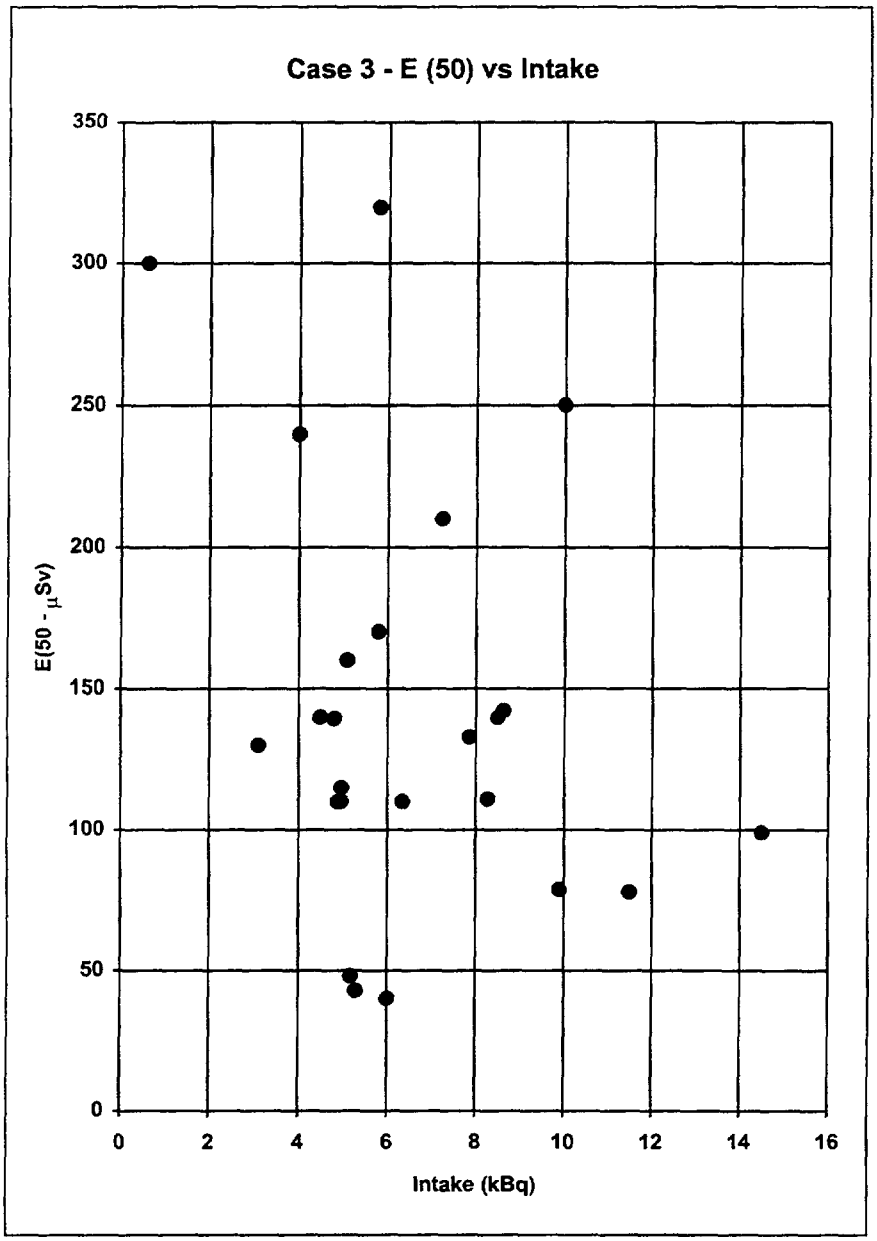
Lab.N°	Intake (kBq)	E88(1) (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type	f1
14	9 9	52 4	78 7	DOSIN I	ICRP 30 modified	1	Y	0 05
16	4 81	56 1	139 5	LUDEP in-house (IABM)	ICRP 30 NUREG	1	Y	0 05
17	4 5	70	140	NS	ICRP 66 (deposition) ICRP 72 (dose factors) 3 term exponential retention function	1 (50%) 5 (50%)	S or M	01 or 1
18	5 19	38	48	GENMOD PC	ICRP 66 (lung) ICRP 30 (biokinetics)	1	W	0 05
19	10	120	250	LUDEP 2 0	ICRP 30	NS	NS	NS
20	5 8		320	NS	ICRP 67	5	S	0 05
21	6 35	56	110	CINDY	ICRP 30	1	80% W 20% Y	0 05
22	4	150	240	IDSS2 - IMIE-2	ICRP 66 (lung) ICRP 67 (metabolic)	0 003	S	0 01
23	5 3	37	43	NS	ICRP 30	1	W	0 05
24	8 5	66	140	LUDEP 2 66	ICRP 67 (bio-kinetics) ICRP 66 (lung) ICRP 30 (GI) ICRP 60 (wR)	5	S	0 05

Lab.N°	Intake (kBq)	E88(1) (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type	f1
25	8.28	69.1	110.9	LUDEP 2.02	ICRP 66 (lung) ICRP 30 (systemic)	1	20% S 80% M	M: .1 S: .05
26	11.5	45	78	LUDEP 2.04	ICRP 66 (lung) ICRP 30 (bio-kinetics)	0.25	80% M	NS
Geom. Mean	5.79	62.82	124.40					
Arith. Mean(X)	6.58	67.64	142.39					
SD (s)	2.95	28.66	74.50					
SD%	44.83	42.37	52.32					
(X+s)/X	1.45	1.42	1.52					
(X-s)/X	0.55	0.58	0.48					


Case 3 - Intake
10
1
0.1
0.01
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26


Case 3 - E88 (1)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26


Case 3 - E (50)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26

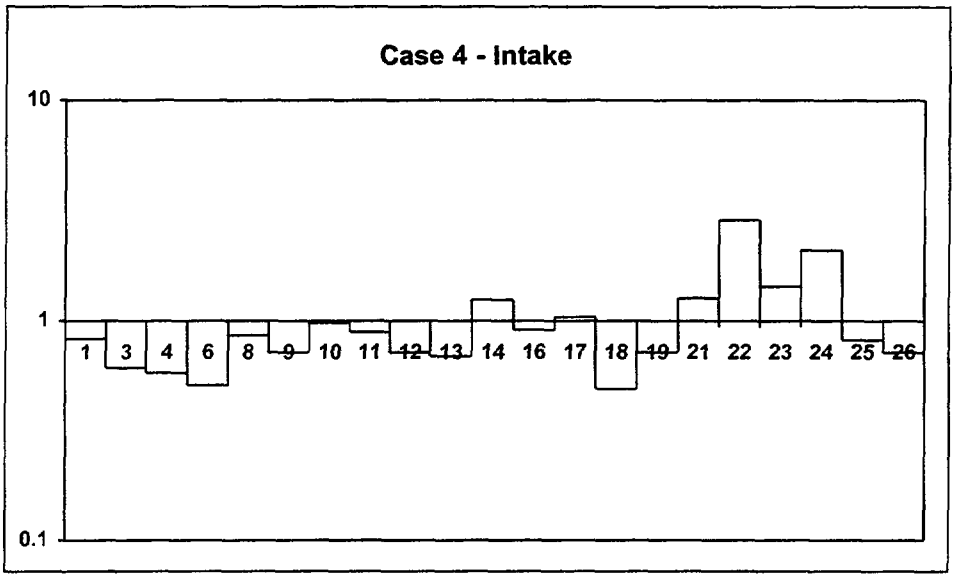

Case 3 - E (50) vs Intake
E(50 - μSv)
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
Intake (kBq)

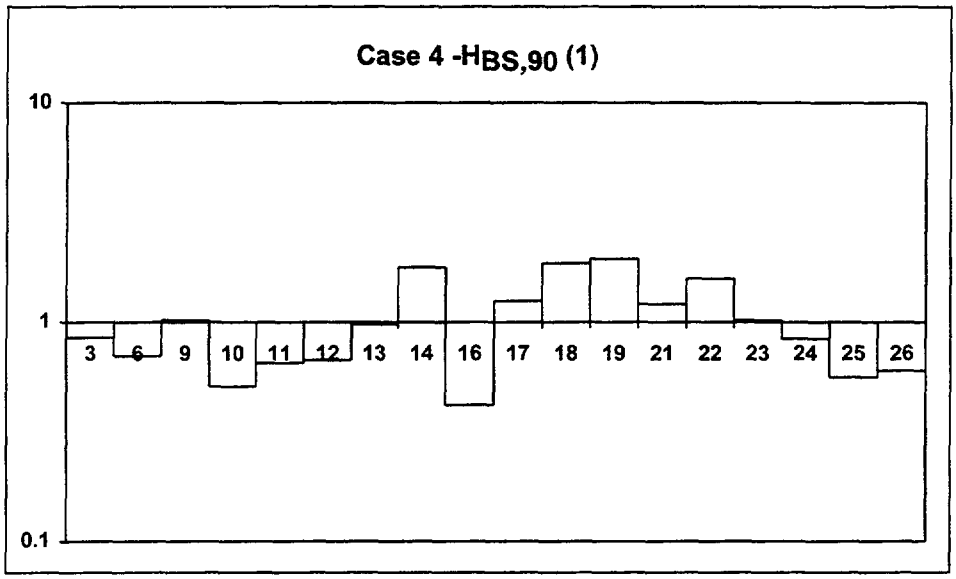
Case 4 - Intale of ^{90}Sr and ^{90}Y

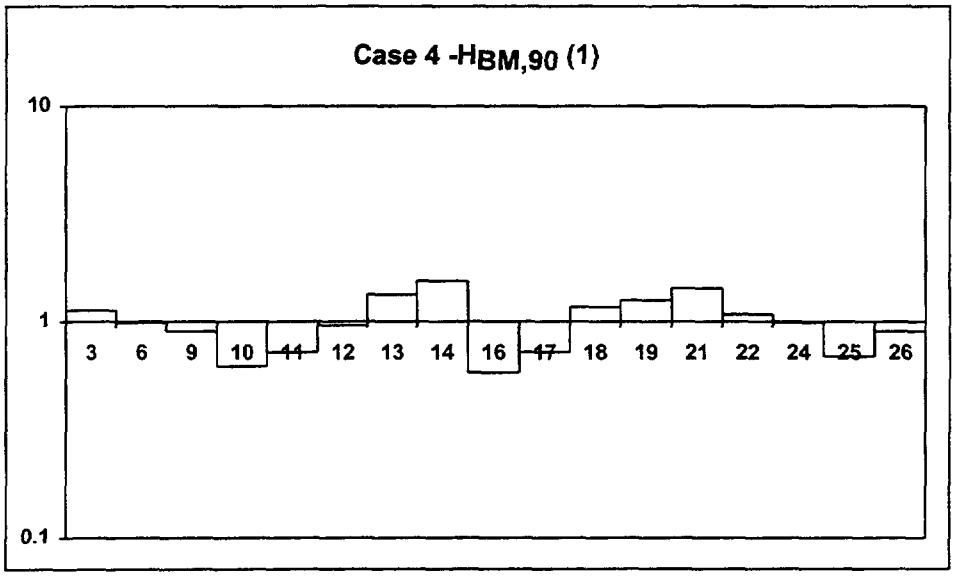
ab.N°	Intake (MBq)	$H_{BS\ 90}$ (1) (mSv)	$H_{BM\ 90}$ (1) (mSv)	$H_{SK\ 90}$ (1) (mSv)	E_{90}(1) (mSv)	H_{BS} (50) (mSv)	H_{BM} (50) (mSv)	H_{SK} (50) (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type	f1
1	2 9			215	12			1800	105	NS	NS	NR	NR	NS
3	2 11	18 2	12 6		2 33	1540	696		131	RBD	ICRP 30 ICRP 54	1	D	0 3
4	2	12			0 33	890			61		ICRP 66 (lung) ICRP 30 7 compart (Skrabble)	5	F	0 3
6	1 77	15	11		1 8	1200	560		110	INDO	ICRP 30 (GI) Johnson & Meyers (systemic)	1	D	0 3
8	3					1230	540		85	CINDY	ICRP 30 (systemic) Johnson (alkaline earth)	NR	NR	0 3
9	2 5	22	10		1 5	580	260		40	NS	ICRP 54 ICRP 56	NR	NR	NS
10	3 4	11	6 9		2 7	970	430		87	CINDY	Johnson (alkaline earth)	1	D	0 3
11	3 1	14	8		1	1300	600		95	AGEDOS	3 term exponential ICRP 30 (SEE) ICRP 68 (ingestion, RF)	NR	NR	NS

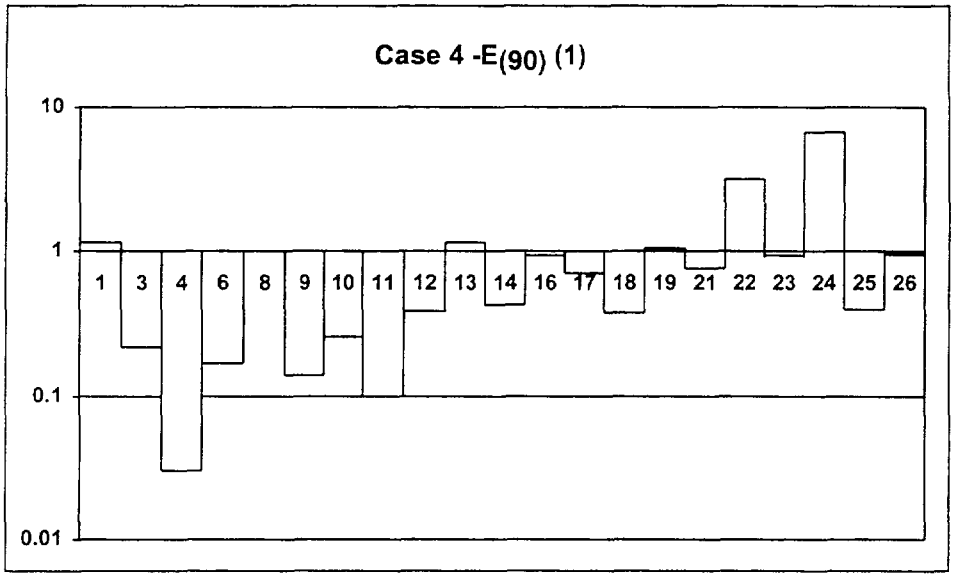
Lab.N°	Intake (MBq)	$H_{BS,90}$ (1) (mSv)	$H_{BM\ 90}$ (1) (mSv)	$H_{SK\ 90}$ (1) (mSv)	E_{90}(1) (mSv)	H_{BS} (50) (mSv)	H_{BM} (50) (mSv)	H_{SK} (50) (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type	f1
12	2 49	14 5	10 7		4 1	1100	520		76	LUDEP 2 04	ICRP 30 (systemic) ICRP 54 (excretion) ICRP 66 (lung)	5	NR	0 3
13	2 4	21	15		12	920	530		82	NO CODE	ICRP 67	NR	NR	0 3
14	4 35	38 4	17 3		4 48	1830	827		156	DOSINT	ICRP 30	NS	NS	NS
16	3 18	8 94	6 42		9 84	1100	500		89	SS115 SR245 LUDEP IABM	ICRP 30 7 term exponential	NR	NR	0 3
17	3 6	27	8		7 4	600	200		160		ICRP 67 (DF) ICRP 54/71 (biokinetics)	NR	M	0 1
18	1 7	40	13		4	1240	572		110	REMEDY	ICRP 30	1	D	0 3
19	2 5	42	14		11	3100	650		120	NS	ICRP 30 (biokinetics) ICRP 60 (w_T)	NR	NR	0 3
21	4 4	26	16		8	2100	920		190	CINDY	ICRP 30 (lung - GI) ICRP 54 (systemic-excretion)	1	D	0 3
22	10	34	12		33	2200	570		160	IDSS2 - IMIE2	ICRP 66 (lung) ICRP 67 (biokinetics)	10	M	0 1

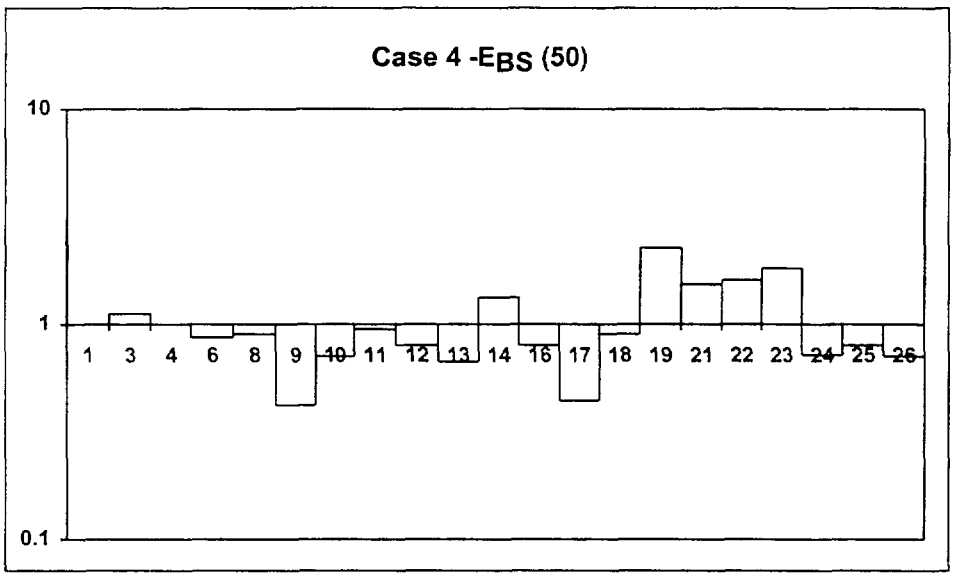
Lab.N°	Intake (MBq)	$H_{BS\ 90}$ (1) (mSv)	$H_{BM\ 90}$ (1) (mSv)	$H_{SK\ 90}$ (1) (mSv)	E_{90}(1) (mSv)	H_{BS} (50) (mSv)	H_{BM} (50) (mSv)	H_{SK} (50) (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type	f1
23	5	22			9 9	2500			250	NS	ICRP 30	NR	NR	0 3
24	7 3	18	11		70	990	450		190	LUDEP 2 66	ICRP 66 (lung) ICRP 67 (Sr) ICRP 30 (Y) ICRP 30 (GI) ICRP 66 (w_1)	5	M	0 1
25	2 84	12	7 7		4 2	1100	470		97	CINDY	ICRP 30 (GI) Johnson alkaline earth (systemic)	NR	NR	0 4
26	2 5	13	10		10	970	440		74	LUDEP 2 04	ICRP 66 ICRP 30	NR	NR	0 3
Geom Mean	3 13	19 38	10 71	215 00	5 35	1248 60	511 96	1800 00	107 87					
Arith Mean(X)	3 48	21 53	11 15	215 00	10 48	1373 00	540 83	1800 00	117 52					
SD (s)	1 97	10 40	3 22		15 74	654 35	171 55		50 70					
SD%	56 57	48 31	28 84		150 17	47 66	31 72		43 14					
(X+s)/X	1 57	1 48	1 29		2 50	1 48	1 32		1 43					
(X-s)/X	0 43	0 52	0 71			0 52	0 68		0 57					

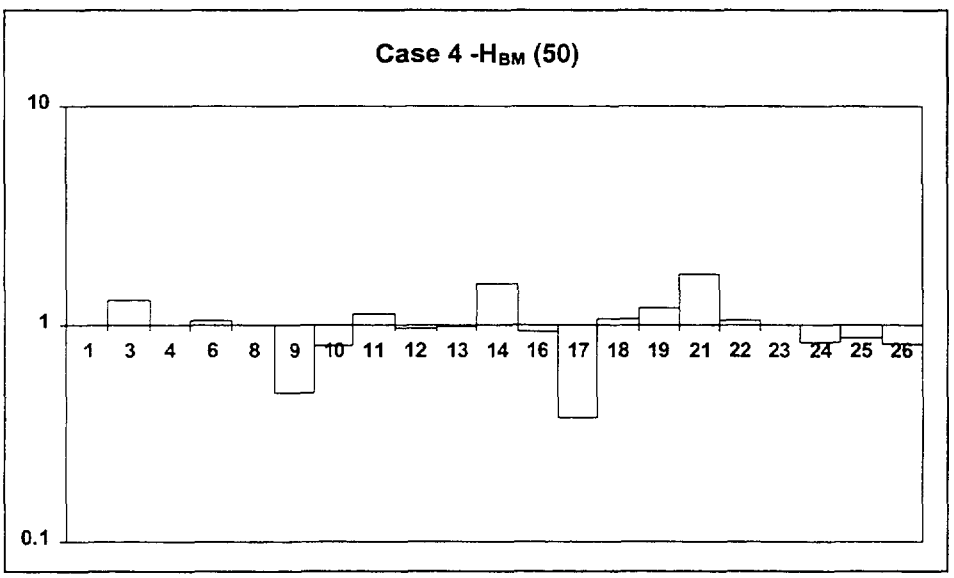

Case 4 - Intake
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26

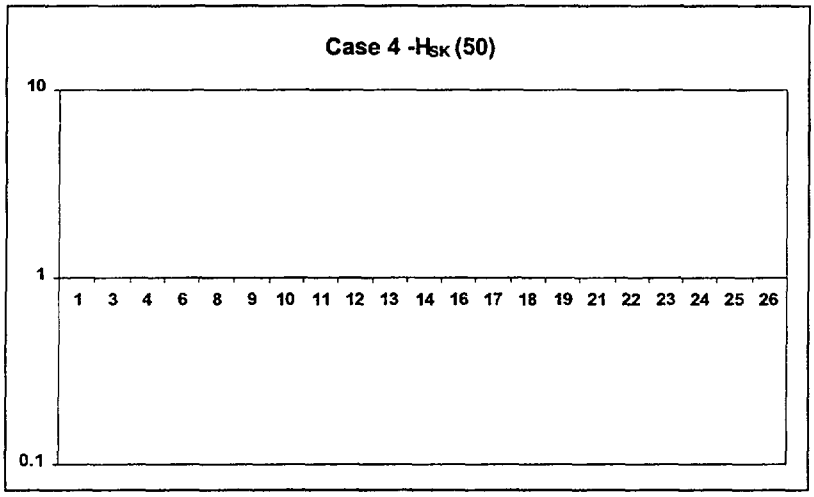

Case 4 -HBS,90 (1)
10
1
0.1
3 6 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26

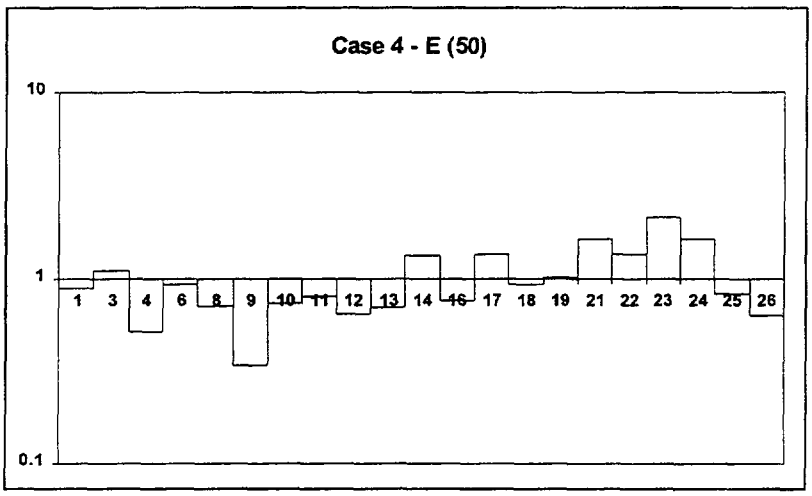

Case 4 -HBM,90 (1)
10
1
0.1
3 6 9 10 11 12 13 14 16 17 18 19 21 22 24 25 26

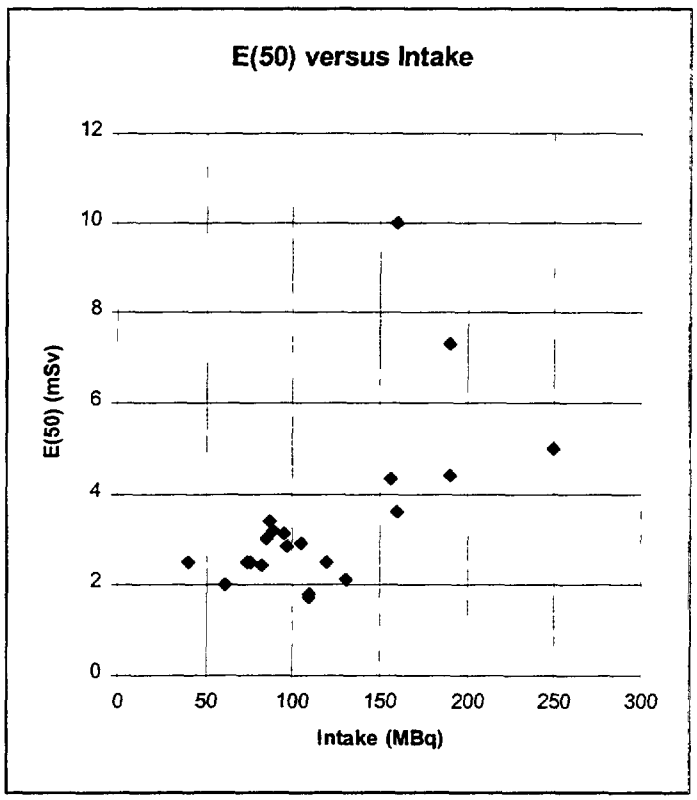

Case 4 -E(90) (1)
10
1
0.1
0.01
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26


Case 4 -EBS (50)
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26


Case 4 -HBM (50)
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26


Case 4 -H_{SK} (50)
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26

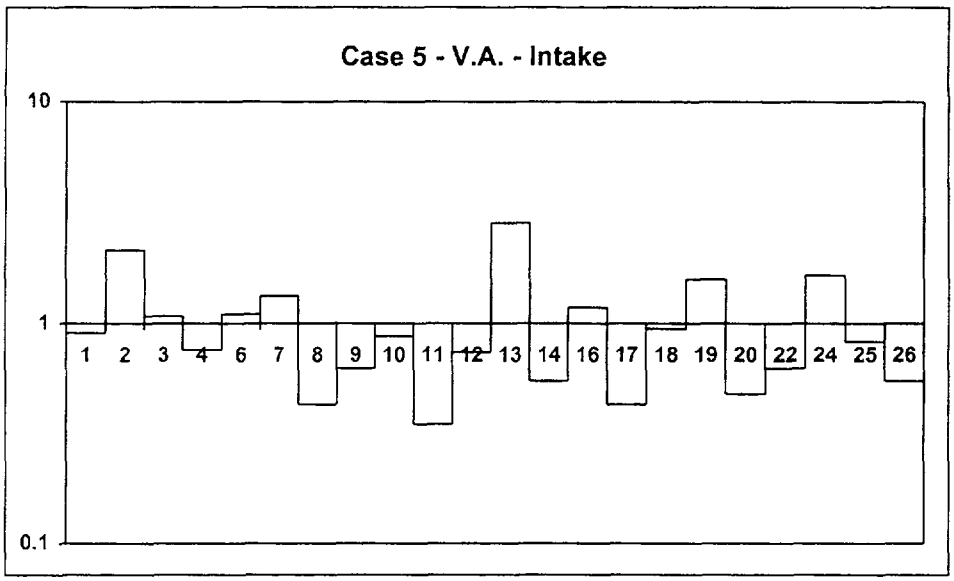

Case 4 - E (50)
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 21 22 23 24 25 26

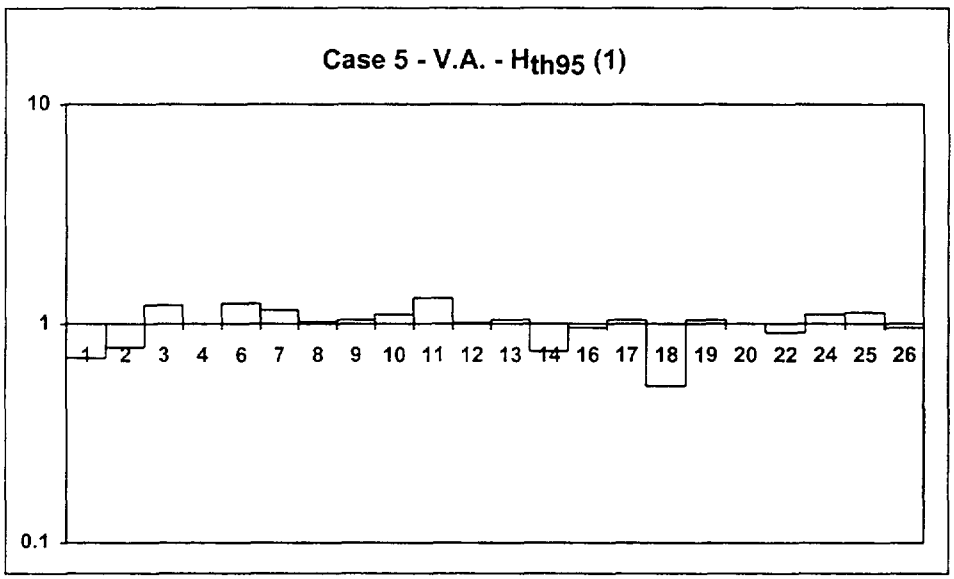

E(50) versus Intake
E(50) (mSv)
12
10
8
6
4
2
0
0 50 100 150 200 250 300
Intake (MBq)

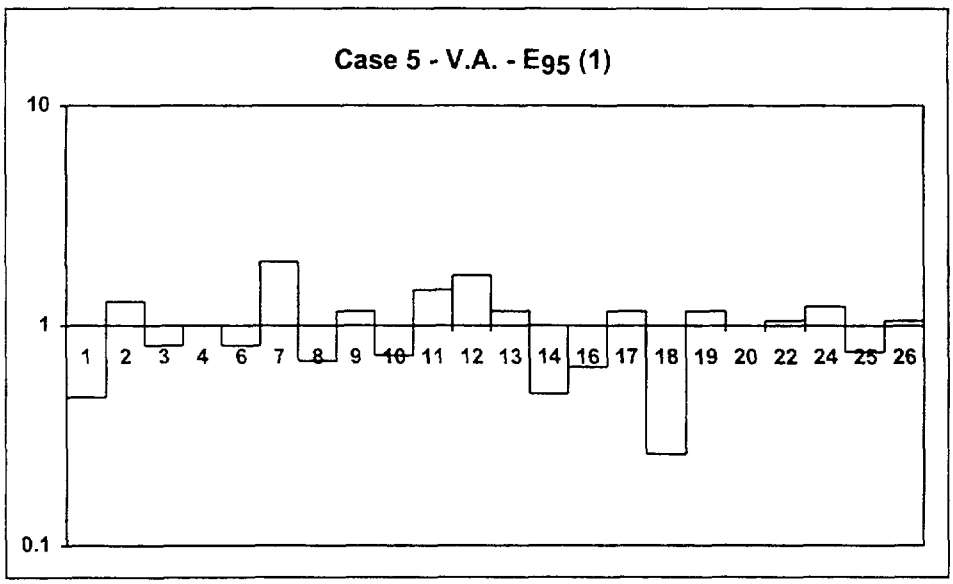
Case 5 - Repeated intake of ^{125}I - V A

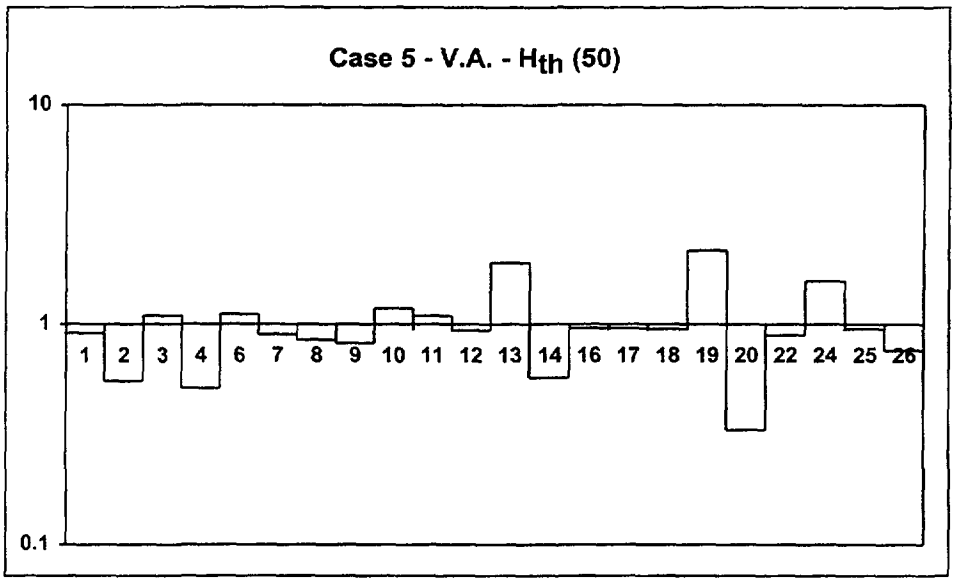
Lab.N°	^{125}I Intake (MBq)	$H_{th,95}(1)$ (mSv)	$E_{95}(1)$ (mSv)	$H_{th}(50)$ (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type
1	0 23	27	0 8	50	1 5	NS	NS	1	D
2	0 54	30 1	2 2	30 1	2 2	LUDEP 2 04	ICRP 30 (biokinetics) ICRP 54 (retention)	5	D (f1=1)
3	0 273	46 3	1 39	60	1 8	Multiple codes	ICRP 30/54	1	*D (f1=1)*
4	0 192			28	1 4			5	
6	0 279	47	1 4	61	1 8	INDO	ICRP 30 - 3 compartment	1	D (f1=1)
7	0 338	44 22	3 34	49 57	3 75	DOSIS	ICRP 66 (lungs) ICRP 30/54 (biokinetics)	5	D (f1=1)
8	0 11	39	1 18	47	1 41	CINDY	ICRP 30	1	D (f1=1)
9	0 16	40	2	45	2 2	NS	ICRP 68	NS	NS
10	0 223	42	1 26	65	1 96	CINDY	ICRP 54	5	D (f1=1)
11	0 09	50	2 5	60	3	In-house	ICRP 30 (DF) ICRP 60 (w_T)	1	NS
12	0 188	38 8	2 9	51 7	3 9	LUDEP 2 04	ICRP 30 (systemic) ICRP 54 (thyroid) ICRP 66 (lung)	V	F (f1=1)
13	0 718	40	2	105	5 2	No code	ICRP 66 (lung) ICRP 56 (biokinetics)	5	F (f1=1)
14	0 14	28 7	0 85	31 6	0 93	DOSIN I	ICRP 54	NS	NS
16	0 3	36 89	1 11	52 65	1 59	IABM - LUDEP	ICRP 54 (biokinetics) SS115 (DF)	5	F (f1=1)
17	0 11	40	2	53	2 7	NS	ICRP 66 (lungs)	NS	F SR1 (f1=1)

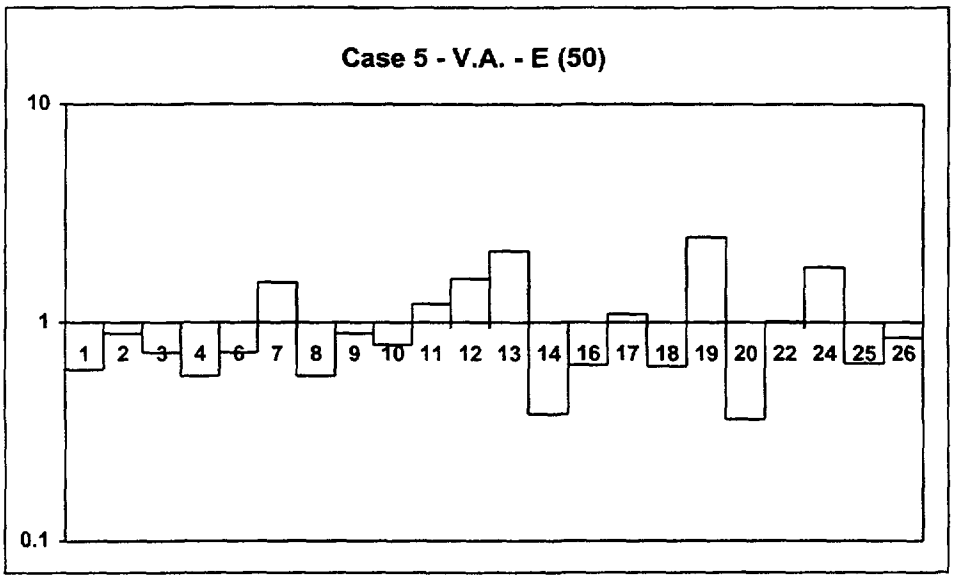
Lab.N°	^{125}I Intake (MBq)	$H_{th,95}(1)$ (mSv)	$E_{95}(1)$ (mSv)	$H_{th}(50)$ (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type
18	0 241	20	0 45	52	1 56	REMEDY GENMOD PC	Johnson iodine model ICRP 30	1	D (f1=1)
19	0 4	40	2	120	6	NS	NS	NS	NS
20	0 123			18	0 9	NS	ICRP 66 (lung) ICRP 67 (biokinetics)	5	F (f1=1)
22	0 16	35	1 8	49	2 5	IDSS2	ICRP 66 (lung) ICRP 56/67 (biokinetics)	5	F (f1=1)
24	0 417	42	2 1	87	4 4	LUDEP 2 04	ICRP 66 (lungs) ICRP 30 (iodine) ICRP 66 (w_T)	50% V 50% 5	F (f1= 99)
25	0 21	43	1 3	52 2	1 6	CINDY 1 4	ICRP 54	1	D
26	0 14	37	1 8	42	2 1	LUDEP 2 04	ICRP 66 (lungs) ICRP 30 (biokinetics)	NR	F (f1=1)
Geom Mean	0 22	37 58	1 56	50 65	2 17				
Arith Mean(X)	0 25	38 35	1 72	54 99	2 47				
SD (s)	0 15	7 29	0 72	23 56	1 37				
SD%	60 58	19 01	41 79	42 85	55 47				
(X+s)/X	1 61	1 19	1 42	1 43	1 55				
(X-s)/X	0 39	0 81	0 58	0 57	0 45				

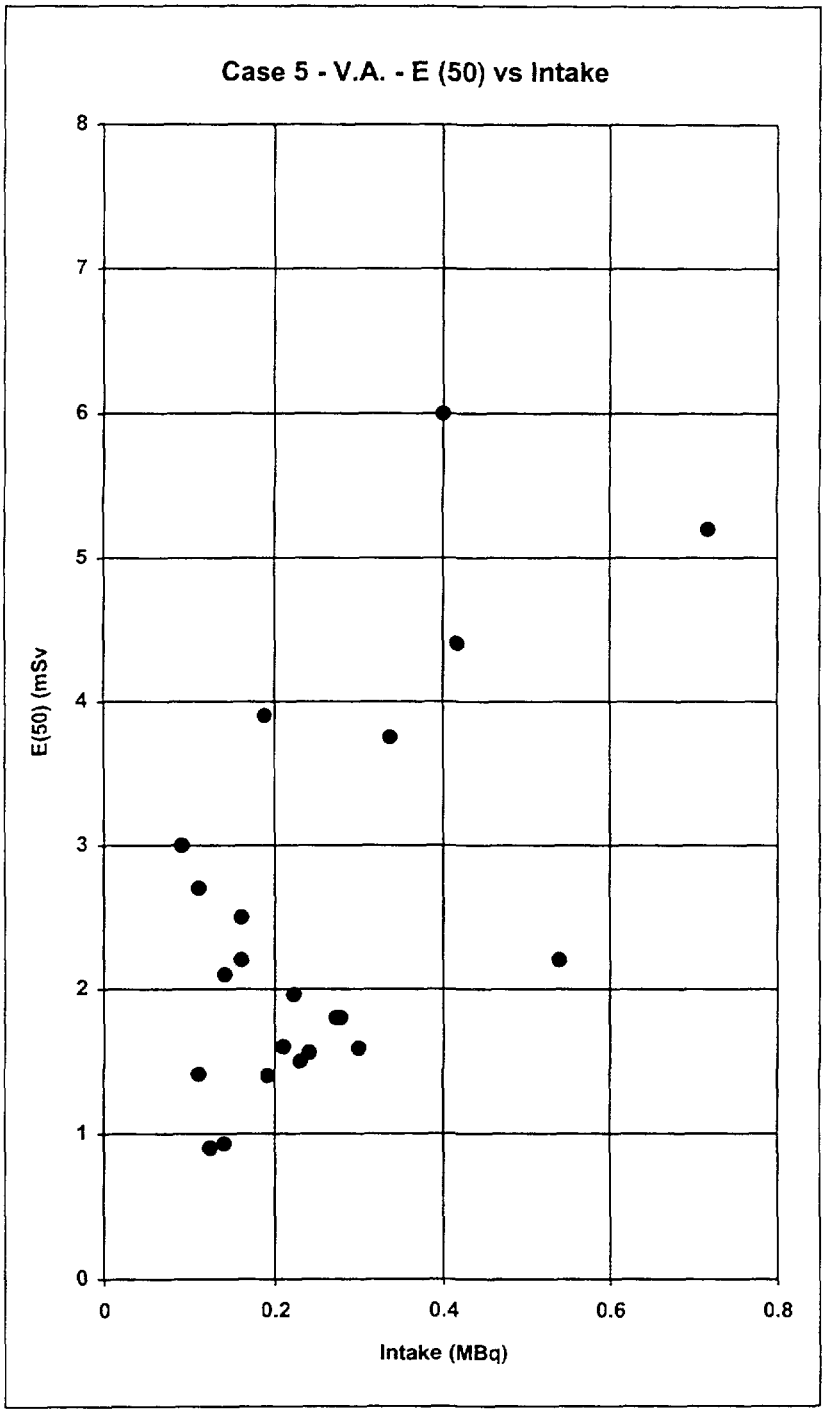

Case 5 - V.A. - Intake
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26


Case 5 - V.A. - Hth95 (1)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26


Case 5 - V.A. - E95 (1)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26


Case 5 - V.A. - H_{th} (50)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26

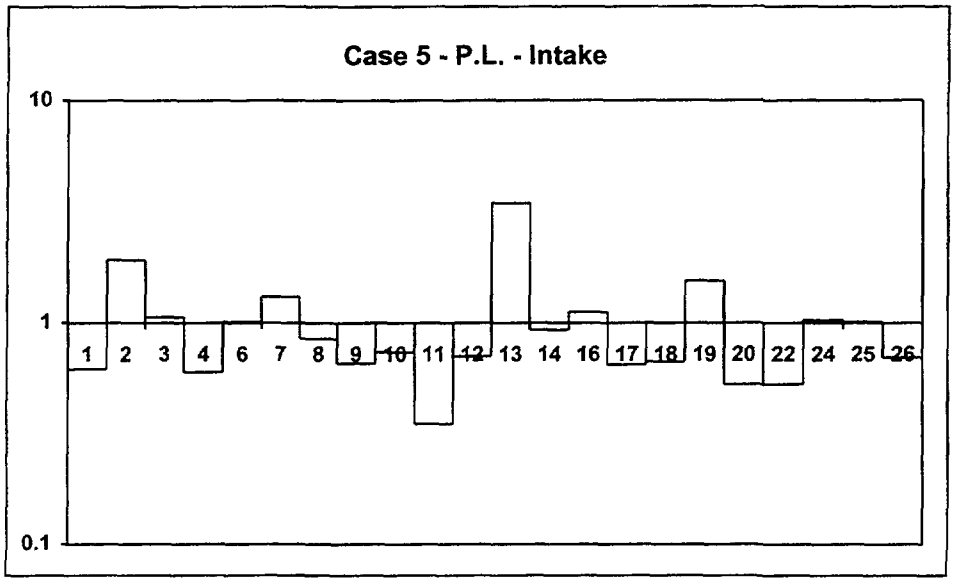

Case 5 - V.A. - E (50)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26

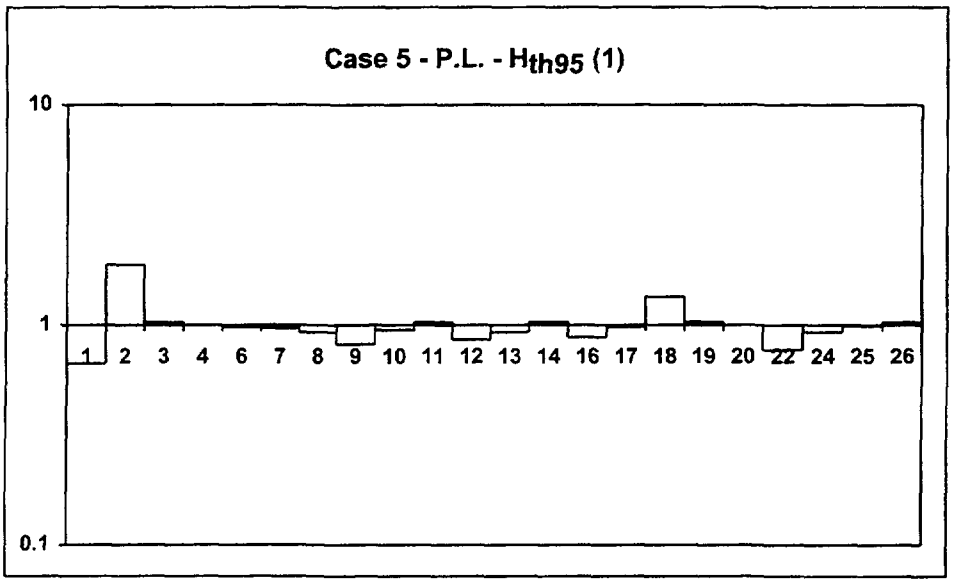

Case 5 - V.A. - E (50) vs Intake
E(50) (mSv)
Intake (MBq)
0
1
2
3
4
5
6
7
8
0
0.2
0.4
0.6
0.8

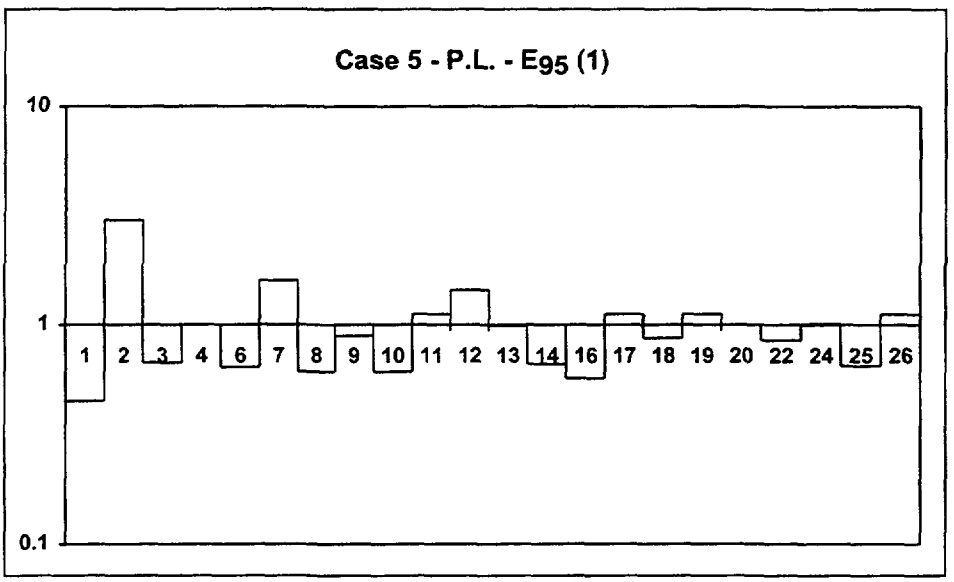
Case 5 - Repeated intake of ^{125}I - P.L.

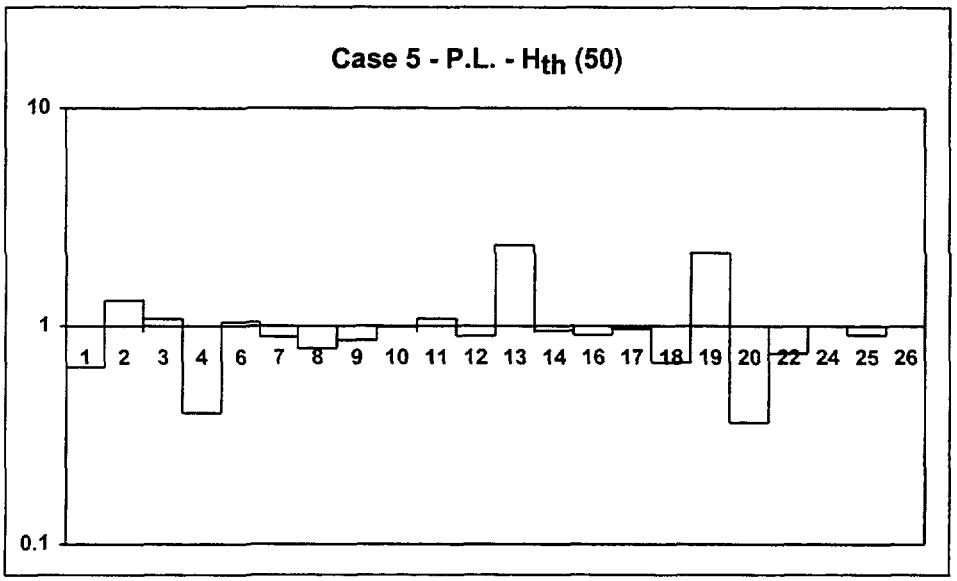
Lab.N°	^{125}I Intake (MBq)	$H_{th,95}(1)$ (mSv)	$E_{95}(1)$ (mSv)	$H_{th}(50)$ (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type
1	0.08	13	0.4	18	0.5	NS	NS	1	D
2	0.248	36.4	2.7	36.4	2.7	LUDEP 2.04	ICRP 30 (biokinetics) ICRP 54 (retention)	5	D (f1=1)
3	0.137	20.1	0.6	30.2	0.91	Multiple codes	ICRP 30/54	1	D
4	0.077			11.2	0.56			5	
6	0.131	19	0.57	29	0.85	INDO	ICRP 30 3 compartments	1	D (f1=1)
7	0.169	18.89	1.43	24.78	1.87	DOSIS	ICRP 66 (lungs) ICRP 30/54 (biokinetics)	5	D (f1=1)
8	0.11	18	0.55	22	0.66	CINDY	ICRP 30	1	D (f1=1)
9	0.085	16	0.8	24	1.2	NS	ICRP 68	NS	NS
10	0.096	18.5	0.55	27.5	0.84	CINDY	ICRP 54	5	D (f1=1)
11	0.045	20	1	30	1.5	In-house	ICRP 30 (DF) ICRP 60 (w_T)	1	NS
12	0.091	16.8	1.3	25.1	1.9	LUDEP 2.04	ICRP 30 (systemic) ICRP 54 (thyroid) ICRP 66 (lung)	V	F (f1=1)
13	0.446	18	0.89	65	3.3	NO CODE	ICRP 66 (lung) ICRP 56 (biokinetics)	5	F (f1=1)
14	0.12	20.1	0.59	26.4	0.78	DOSINT	ICRP 54	NS	NS
16	0.145	17.02	0.51	25.45	0.77	IABM - LUDEP	ICRP 54 (biokinetics) SS115 (DF)	5	F (f1=1)

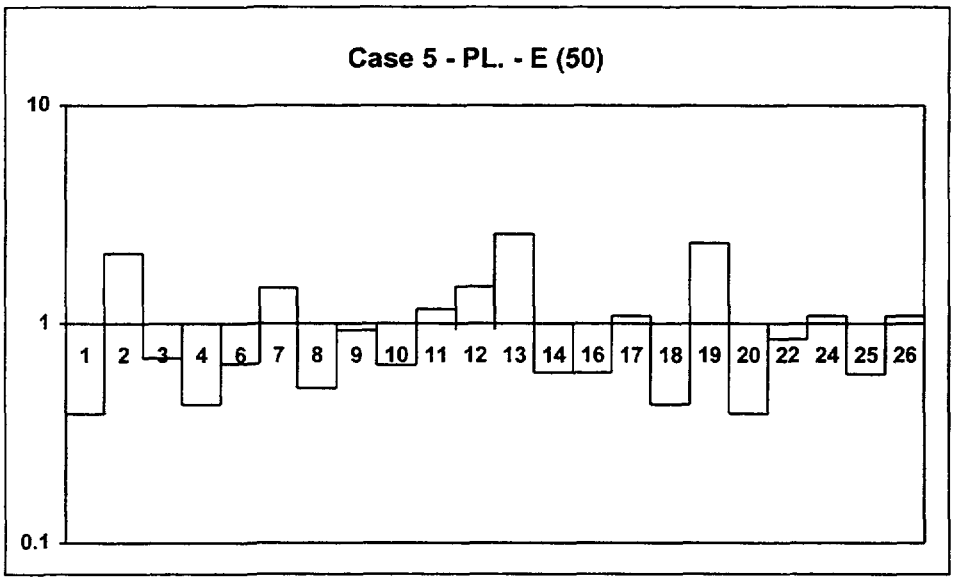
Lab.N°	^{125}I Intake (MBq)	$H_{th,95}(1)$ (mSv)	$E_{95}(1)$ (mSv)	$H_{th}(50)$ (mSv)	E(50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type
17	0 084	19	1	27	1 4	NS	ICRP 66 (lungs)	NS	F SR1 (f1=1)
18	0 0865	26	0 78	19	0 55	REMEDY - GENMOD PC	Johnson iodine model ICRP 30	1	D (f1=1)
19	0 2	20	1	60	3	NS	NS	NS	NS
20	0 068			10	0 5	NS	ICRP 66 (lung) ICRP 67 (biokinetics)	5	F (f1=1)
22	0 068	15	0 76	21	1 1	IDSS2	ICRP 66 (lung) ICRP 56/67 (biokinetics)	5	F (f1=1)
24	0 133	18	0 9	28	1 4	LUDEP 2 04	ICRP 66 (lungs) ICRP 30 (iodine) ICRP 66 (w_T)	50% V 50% 5	F (f1= 99)
25	0 13	19 2	0 58	25 3	0 759	CINDY 1 4	ICRP 54	1	D
26	0 09	20	1	28	1 4	LUDEP 2 04	ICRP 66 (lungs) ICRP 30 (biokinetics)	NR	F (f1=1)
Geom Mean	0 11	19.02	0 81	25 62	1 10				
Arith Mean(X)	0 13	19 45	0 90	27 88	1 29				
SD (s)	0 08	4 74	0 50	12 72	0 81				
SD%	65 81	24 35	56 18	45 63	62 83				
(X+s)/X	1 66	1 24	1 56	1 46	1 63				
(X-s)/X	0 34	0 76	0 44	0 54	0 37				

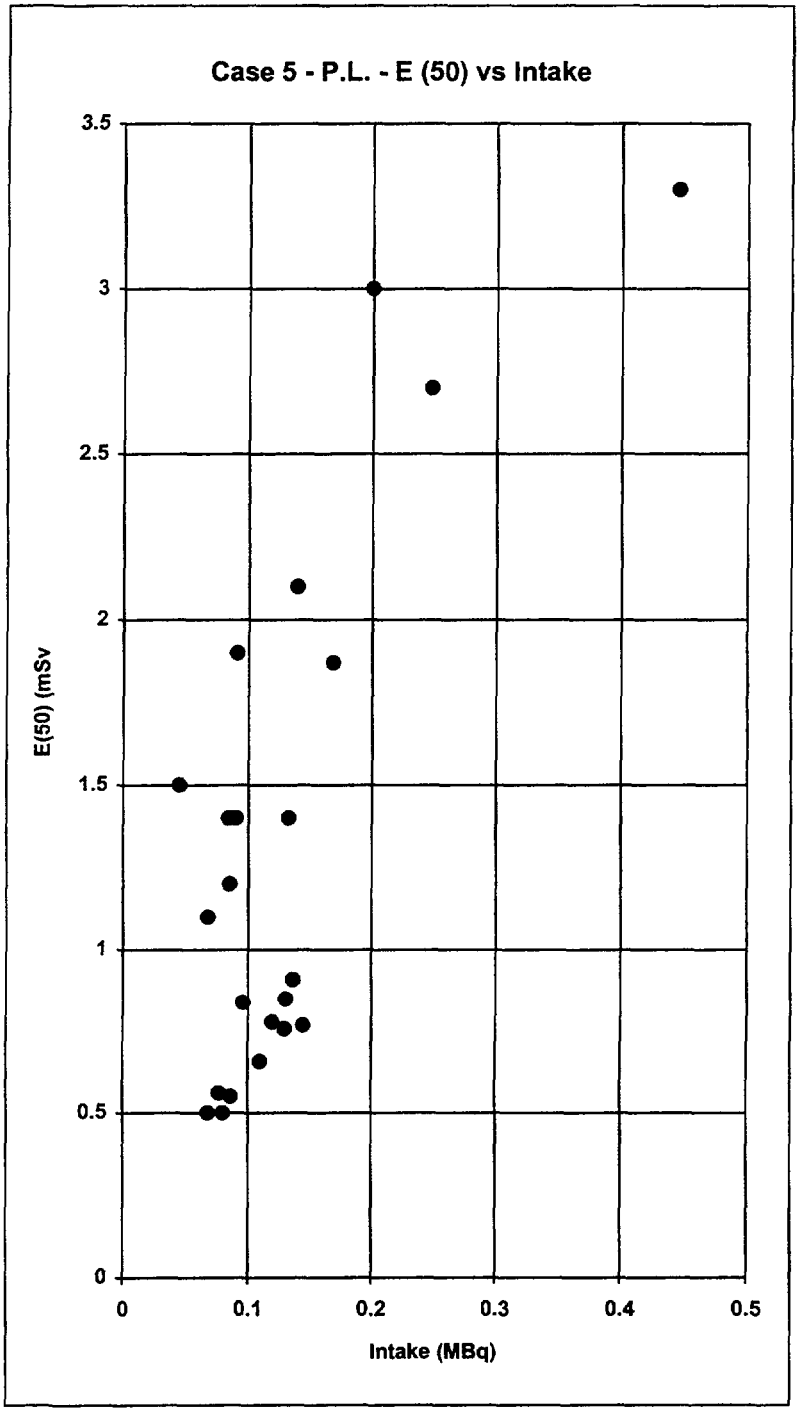

Case 5 - P.L. - Intake
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26


Case 5 - P.L. - Hth95 (1)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26


Case 5 - P.L. - E95 (1)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26


Case 5 - P.L. - H_{th} (50)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26

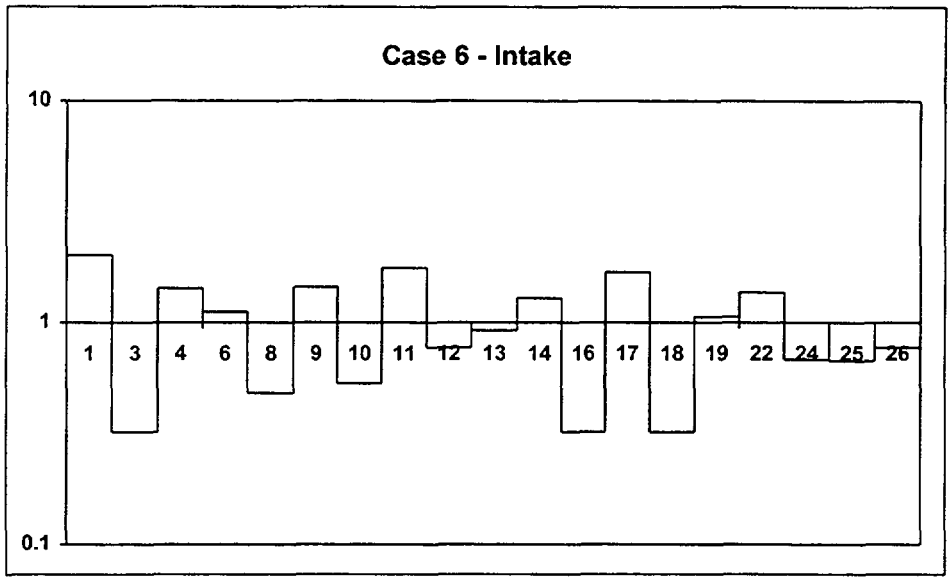

Case 5 - PL. - E (50)
10
1
0.1
1 2 3 4 6 7 8 9 10 11 12 13 14 16 17 18 19 20 22 24 25 26

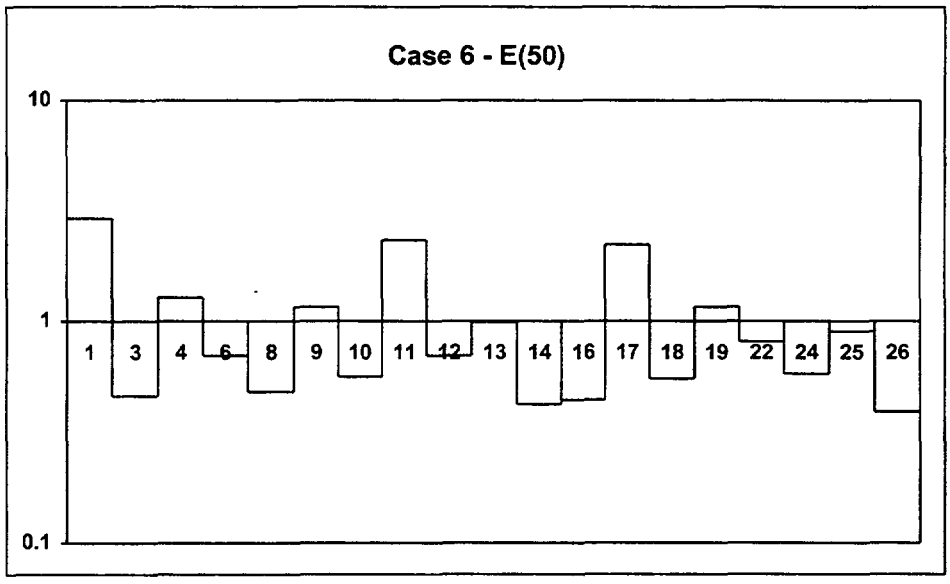

Case 5 - P.L. - E (50) vs Intake
E(50) (mSv
3.5
3
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
0.5
Intake (MBq)

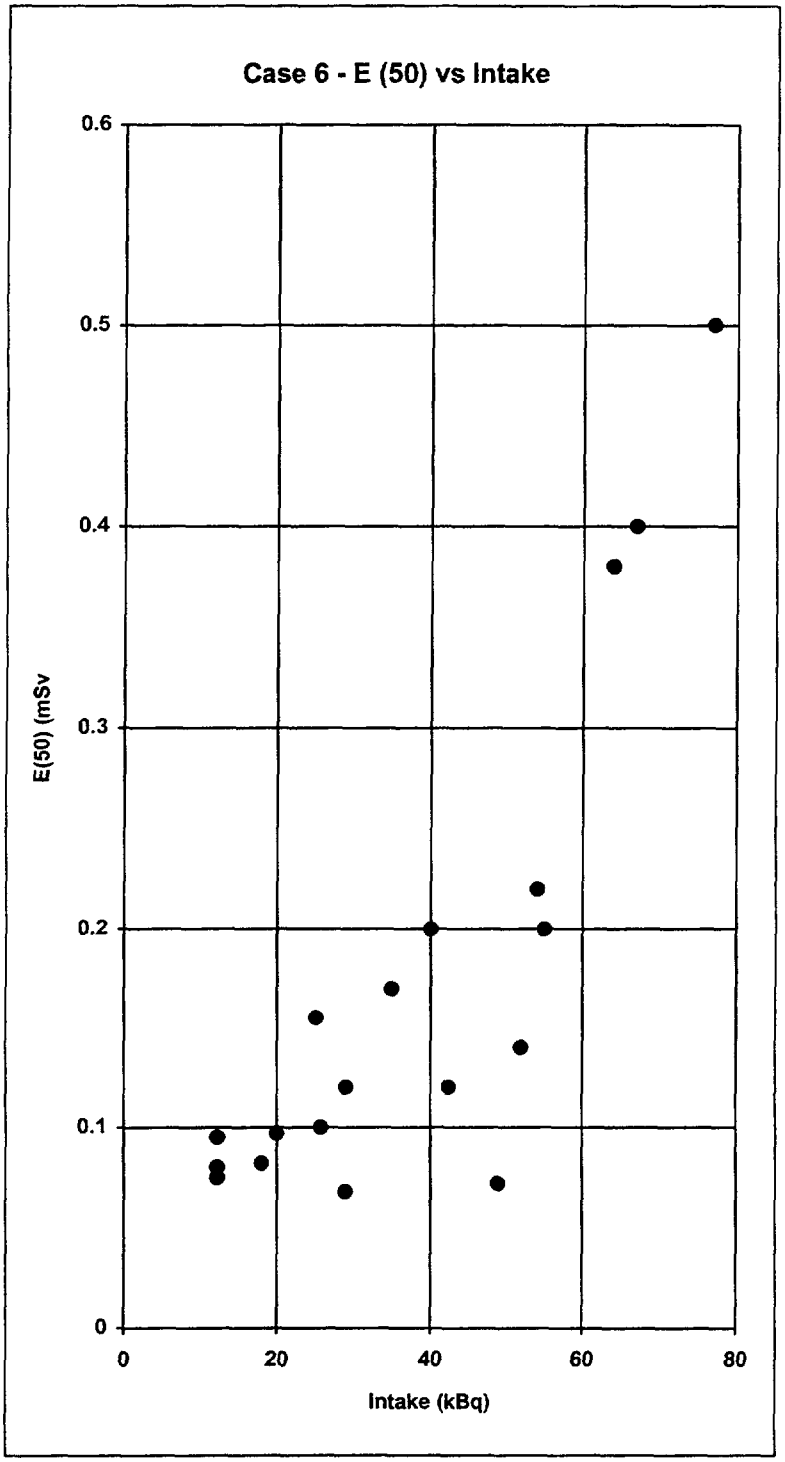
Case 6 - Single intake of ^{192}Sr

Lab.N°	Intake (kBq)	E (50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type
1	77	0.5	NS	NS (ICRP 30)	1	Y
3	12.2	0.08	BAP	ICRP 30/54	1	Y (f1=0.01)
4	54.1	0.22	LUDEP 2.04	ICRP 66 (lung) ICRP 30 (metabolic)	5	M
6	42.4	0.12	INDO	ICRP 30	10	Y
8	18	0.082	CINDY	ICRP 30	3	Y
9	55	0.2	NS	ICRP 68	5	(f1=0.01)
10	20	0.097	CINDY	ICRP 30	1	Y (90%) W (10%) f1=0.01
11	67	0.4	Empirical fit	ICRP 30 ICRP 68 (DF)	1	S
12	29.1	0.12	LUDEP 2.04	ICRP 66 ICRP 30	5	M
13	35	0.17	none	ICRP 66 ICRP 30	5	S (f=0.01)
14	48.97	0.072	ns	Empirical fit	NS	Modified Y
16	12.2	0.075	IABM	NUREG ICRP 30	1	Y
17	64	0.38	NS	ICRP 66	50%:1 50%:5	S or M

Lab.N°	Intake (kBq)	E (50) (mSv)	Computer code	Model	AMAD (mm)	Clear. Type
18	12 2	0 095	GENMOD-PC	ICRP 30	1	Y (fl=0 01)
19	40	0 2	NS	ICRP 66 ICRP 30	5	Y (fl=0 01)
20	(240)	(1)	NS	ICRP 30 ICRP 66	5	M (f=0 01)
22	52	0 14	IDSS v 2 IMIE v 2	ICRP 30 ICRP 66	10	M
24	25 8	0 1	LUDEP 2 0	ICRP 66 ICRP 30 ICRP 68	5	M
25	25 2	0 155	LUDEP 2 0	ICRP 66 ICRP 30	3	S
26	29	0 068	LUDEP 2 04	ICRP 66 ICRP 30	10	M
Geom Mean	31 72	0 13				
Arith Mean(X)	37 85	0 17				
SD (s)	19 90	0 12				
SD%	52 57	71 99				
(X+s)/X	1 53	1 72				
(X-s)/X	0 47	0 28				


Case 6 - Intake
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 22 24 25 26

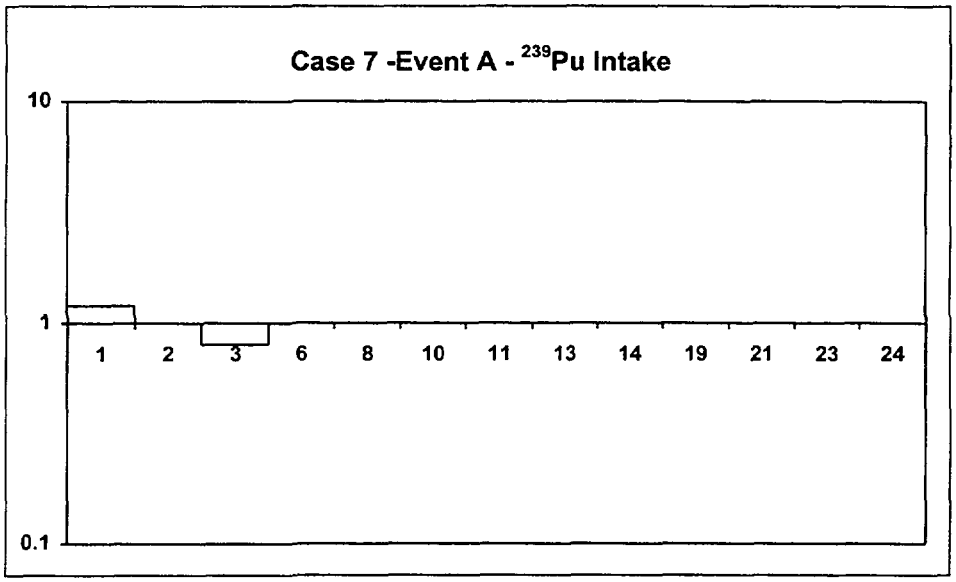

Case 6 - E(50)
10
1
0.1
1 3 4 6 8 9 10 11 12 13 14 16 17 18 19 22 24 25 26

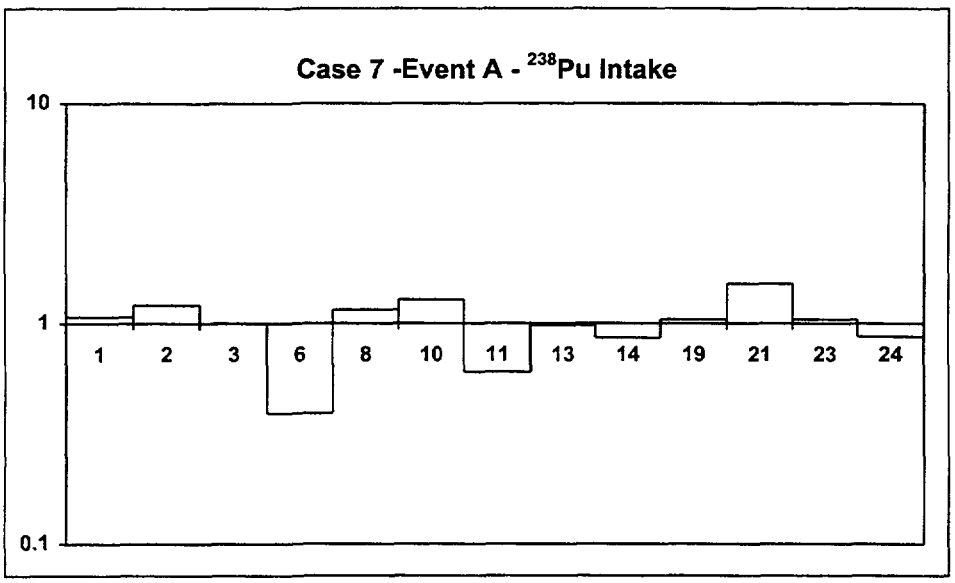

Case 6 - E (50) vs Intake
0.6
0.5
0.4
0.3
0.2
0.1
0
E(50) (mSv
0
20
40
60
80
Intake (kBq)

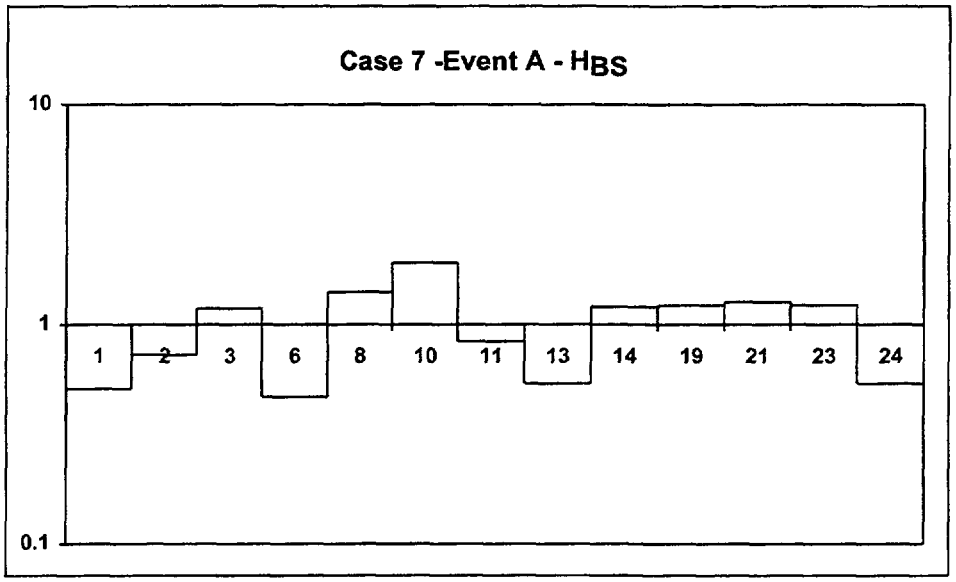
Case 7 - Multiple intakes of ^{238} ^{239}Pu - Event A

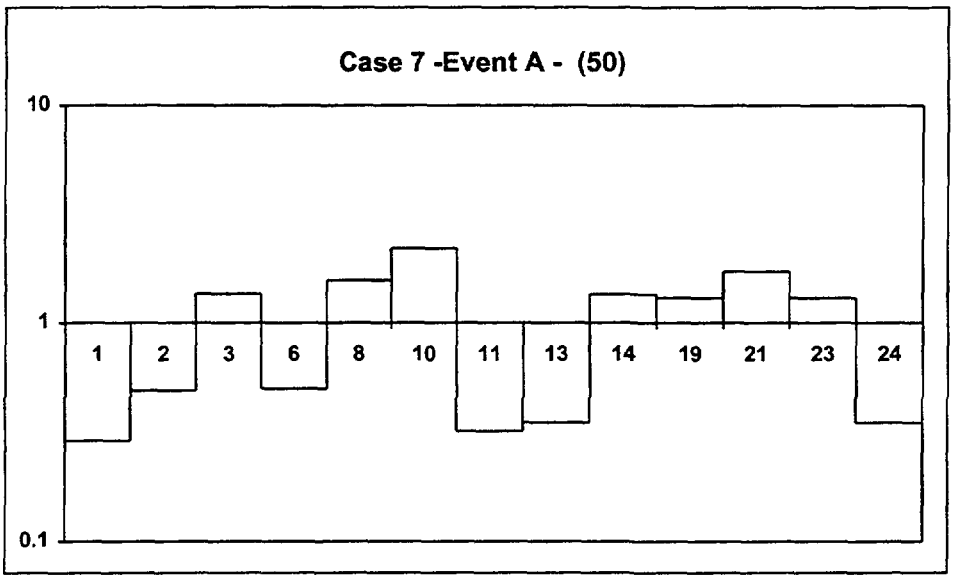
Lab.N°	Intake of ^{238}Pu (Bq)	Intake of ^{239}Pu Bq)	Hbs (mSv)	E(50) (mSv)	Computer code	Model	Data handling	AMAD (mm)	Clear. Type	f1
1	75	410	350	10	NS	NS	NS	1	W	NS
2		466 3	504 1	16 8	LUDEP 2 04	ICRP 54 (excretion & retention) ICRP 30 (biokinetics)	Assume value of DL	5	W/M	5 0E-04
3	50 5	385	810	46	In house	ICRP 30 ICRP 54		1	W	1 0E-04
6		151	320	17	INDO	ICRP 30	Zero before any value exceeding Dlimit 0 06	1	W	5 0E-04
8		440	960	53	CINDY	Durbin model	Not used	1	W	1 0E-03
10		490	1300	74	NS	ICRP 30	All data above LLD	0 5	W	1 0E-04
11		230	580	11		ICRP 30 ICRP 54 ICRP 68	NS	1	W	1 0E-04
13		376	370	12	In house	ICRP 66 ICRP 67	Zero assumed before the first positive result, 06 after that	5	M	5 0E-04
14		330 78	827	45 7	DOSINT	ICRP 30	NS	NS	NS	NS
19		400	840	44		ICRP 54	NS	NS	W	NS

Lab.N°	Intake of ^{238}Pu (Bq)	Intake of ^{239}Pu (Bq)	Hbs (mSv)	E(50) (mSv)	Computer code	Model	Data handling	AMAD (mm)	Clear. Type	f1
21		578	870	58	PUCALC CINDY	ICRP 30 ICRP 54	All data	1		Y (50%) W (50%)
23		400	841	44	NS	ICRP30 Jones excretion function	Zero	1	W	1.0E-05
24		335	370	12	LUDEP 2.66	ICRP 66 (modified) ICRP 67 (plutonium) ICRP 66 (w_T)	Not used	5	M (modified)	5.0E-04
Geom. Mean	61.54	366.12	626.77	27.07						
Arith. Mean(X)	62.75	384.01	687.85	34.12						
SD (s)	17.32	109.27	297.18	21.75						
SD%	27.61	28.45	43.20	63.75						
(X+s)/X	1.28	1.28	1.43	1.64						
(X-s)/X	0.72	0.72	0.57	0.36						


Case 7 -Event A - 239Pu Intake
10
1
0.1
1
2
3
6
8
10
11
13
14
19
21
23
24

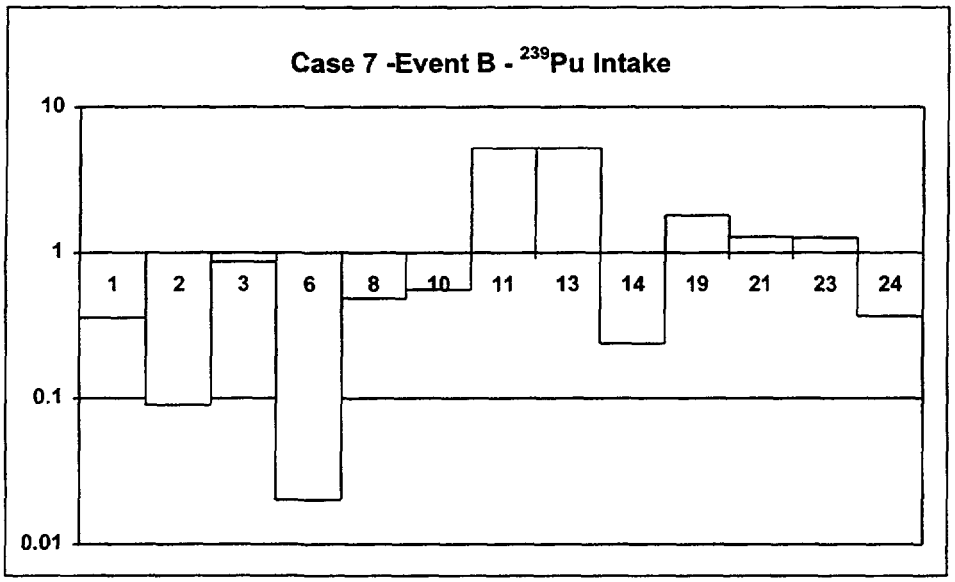

Case 7 -Event A - 238Pu Intake
10
1
0.1
1
2
3
6
8
10
11
13
14
19
21
23
24

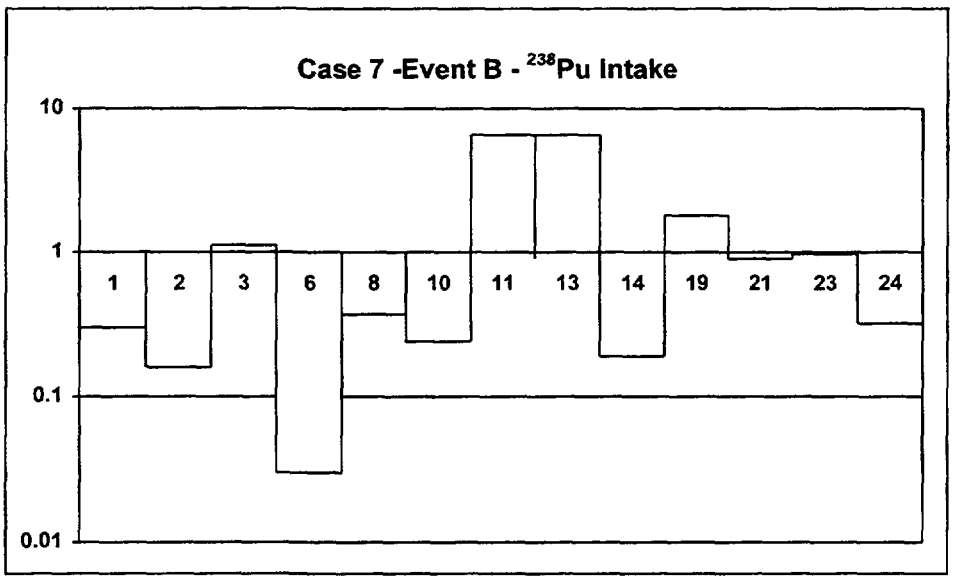

Case 7 -Event A - H_{BS}
10
1
0.1
1
2
3
6
8
10
11
13
14
19
21
23
24

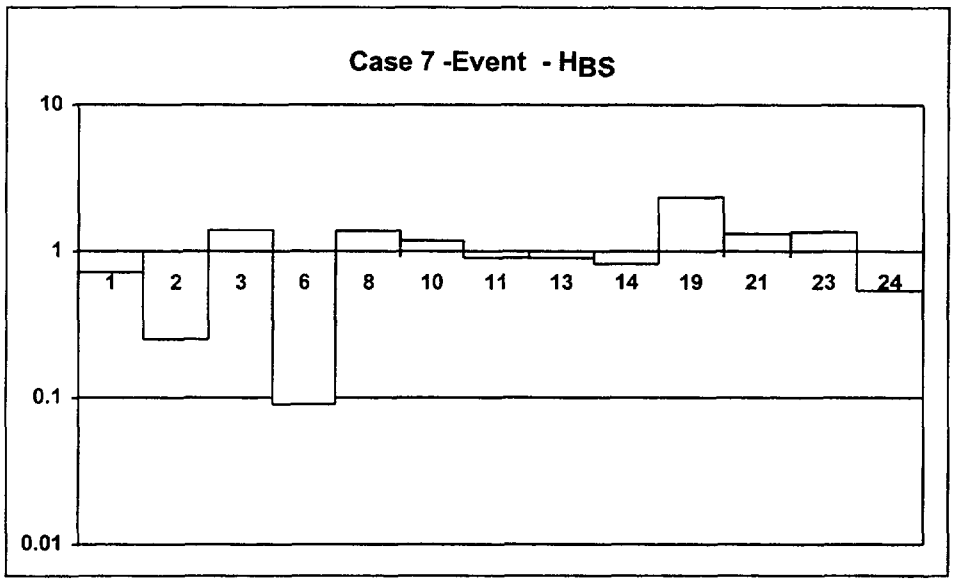

Case 7 -Event A - (50)
10
1
0.1
1
2
3
6
8
10
11
13
14
19
21
23
24

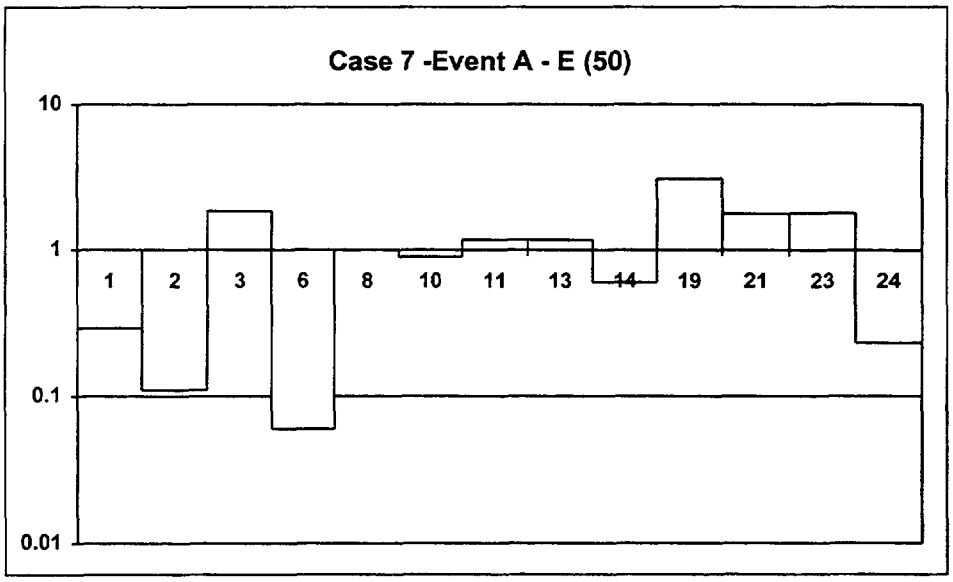
Case 7 - Multiple intakes of $^{238-239}Pu$ - Event B

Lab.N°	Intake of ^{238}Pu (Bq)	Intake of ^{239}Pu (Bq)	Hbs (mSv)	E(50) (mSv)	Computer code	Model	AMAD	Clearance Type	f1
1	140	330	650	20					
2	34.8	176.3	223.9	7.53					
3	341	1248	1270	127					
6	6.76	34.3	85	4.4					
8	190	410	1250	69					
10	220	270	1070	62				W	1.0E-04
11	200	70	620	12					
13	2020	7320	817	81				S	5.0E-05
14	95.04	214.09	744	41.2					
19	700	2000	2140	212				Y	NS
21	500	1000	1200	122					
23	491	1079	1237	124				Y	1.0E-05
24	145	360	490	16				M	5.0E-04
Geom. Mean	190.96	440.48	713.08	40.30					
Arith. Mean(X)	391.05	1116.28	907.45	69.09					
SD (s)	529.56	1950.80	539.31	62.60					
SD%	135.42	174.76	59.43	90.61					
(X+s)/X	2.35	2.75	1.59	1.91					
(X-s)/X			0.41	0.09					


Case 7 -Event B - 239Pu Intake
10
1
0.1
0.01
1
2
3
6
8
10
11
13
14
19
21
23
24


Case 7 -Event B - 238Pu Intake
10
1
0.1
0.01
1
2
3
6
8
10
11
13
14
19
21
23
24

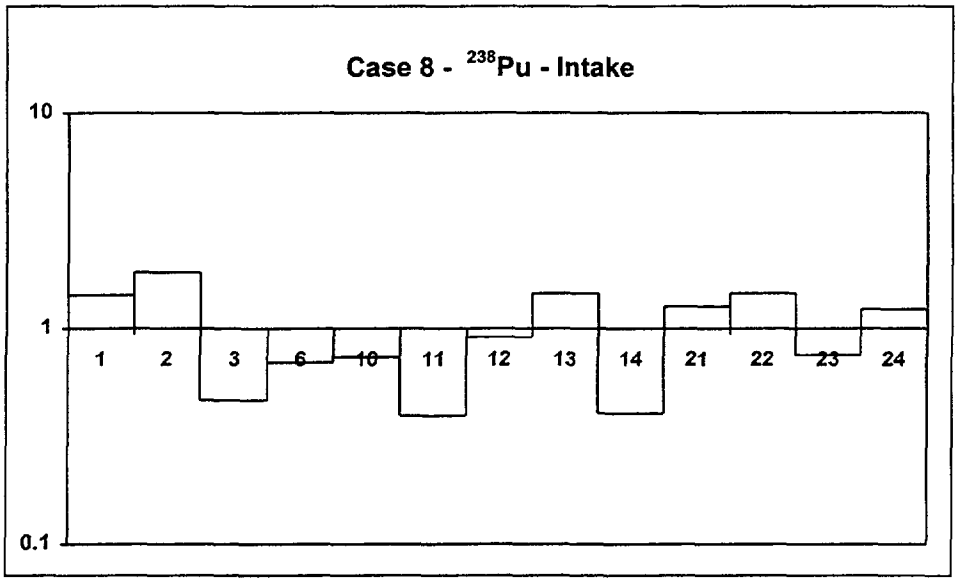

Case 7 -Event - HBS
10
1
0.1
0.01
1
2
3
6
8
10
11
13
14
19
21
23
24

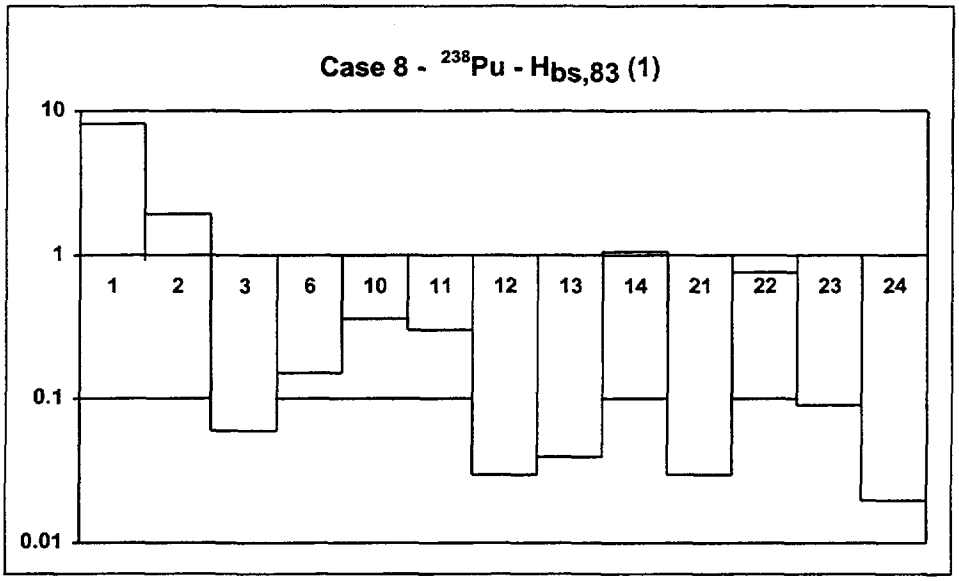

Case 7 -Event A - E (50)
10
1
0.1
0.01
1
2
3
6
8
10
11
13
14
19
21
23
24

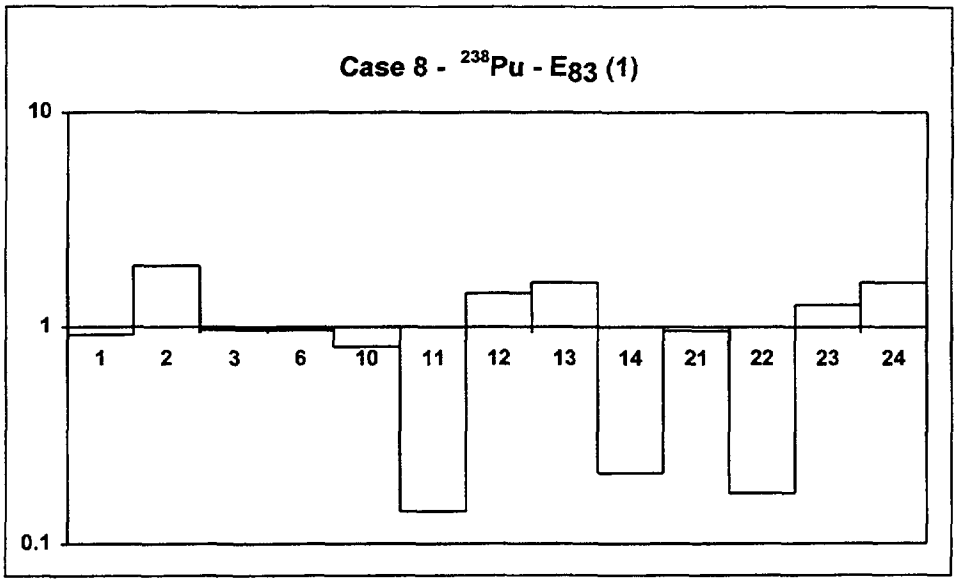
Case 8 - Single intake of $^{238\ 239\ 240}$Pu and ^{241}Am - ^{238}Pu

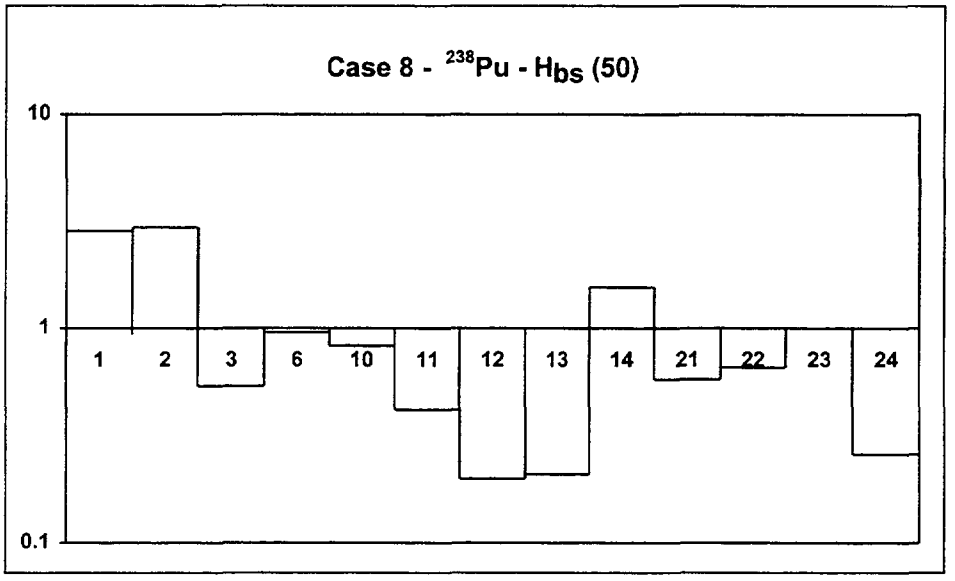
Lab.N°	Intake (kBq)	$H_{bs\ 83}$ (1) (mSv)	E_{83} (1) (mSv)	H_{bs}(50) (Sv)	E(50) (Sv)	Computer code	Model	Data handling	AMAD (mm)	Clear. Type	f1
1	4 4	270	8	4 7	0 14	NS	NS		5	Y	NS
2	5 631	63 97	16 81	4 88	0 169	LUDEP 2 04	ICRP 30/54	Actual values	5	W/M	0 0005
3	1 41	1 9	8 44	0 9	0 174	RBD	ICRP 30/54	Data < DL not considered	1	Y modified	0 00001
6	2 14	4 8	8 4	1 6	0 21	INDO	ICRP 30		2	Y modified	0 0005
10	2 25	12	7	1 375	0 295	NS	ICRP 30	All actual values	3	90% Y (modified) 10% W	0 0005
11	1 2	10	1 2	0 7	0 04	NS	ICRP 54(SYSTEMIC) ICRP 68 (dose factors)	Lung data Initial faeces	5	M	NS
12	2 8	1	12 5	0 33	0 036	LUDEP	ICRP 66 (LUNG) ICRP 30 (systemic) ICRP 54 (Pu)	All actual values	3	M	0 00001
13	4 5	1 2	14	0 35	0 046	In house	ICRP 66 (lung) ICRP 67 (biokinetics)	All actual values	5	S	0 00001
14	1 227	34 9	1 83	2 57	0 135	DOSINT	ICRP 30		NS	NS	NS
21	3 9	1 1	8 3	0 97	0 2	CINDY	ICRP 30 Durbin (Am) Jones (Pu)		5	95% Y (modified) 5% W	00001 (Y) 001 (W)

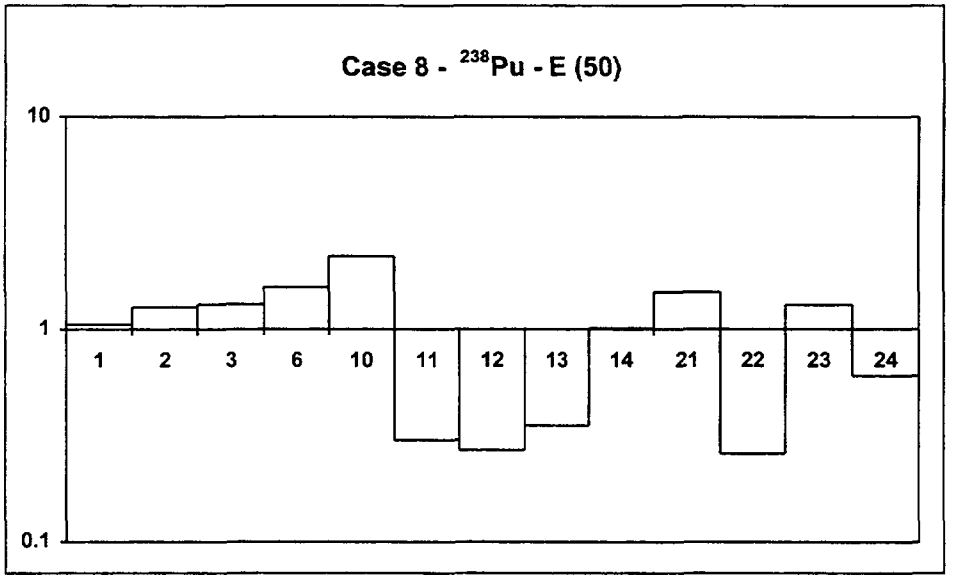
Lab.N°	Intake (kBq)	$H_{bs,83}$ (1) (mSv)	E_{83} (1) (mSv)	H_{bs}(50) (Sv)	E(50) (Sv)	Computer code	Model	Data handling	AMAD (mm)	Clear. Type	f1
22	4 5	25	1 5	1 1	0 035	IDSS 2 IMIE 2	ICRP 66 (lungs) ICRP 67 (Pu-Am)		30	M	0 0005
23	2 312	3 1	11	1 665	0 173		ICRP 30 Jones (Pu)		1	Y	0 00001
24	3 8	0 78	14	0 43	0 08	LUDEP 2 66	ICRP 67 (Am-Pu) ICRP 66 (lungs) ICRP 30 (systemic)		5	S (modified)	0 0005
Geom Mean	2 74	6 68	6 64	1 16	0 11						
Arith Mean(X)	3 08	33 06	8 69	1 66	0 13						
SD (s)	1 46	73 55	5 01	1 52	0 08						
SD%	47 27	222 49	57 60	91 75	60 99						
(X+s)/X	1 47	3 22	1 58	1 92	1 61						
(X-s)/X	0 53										

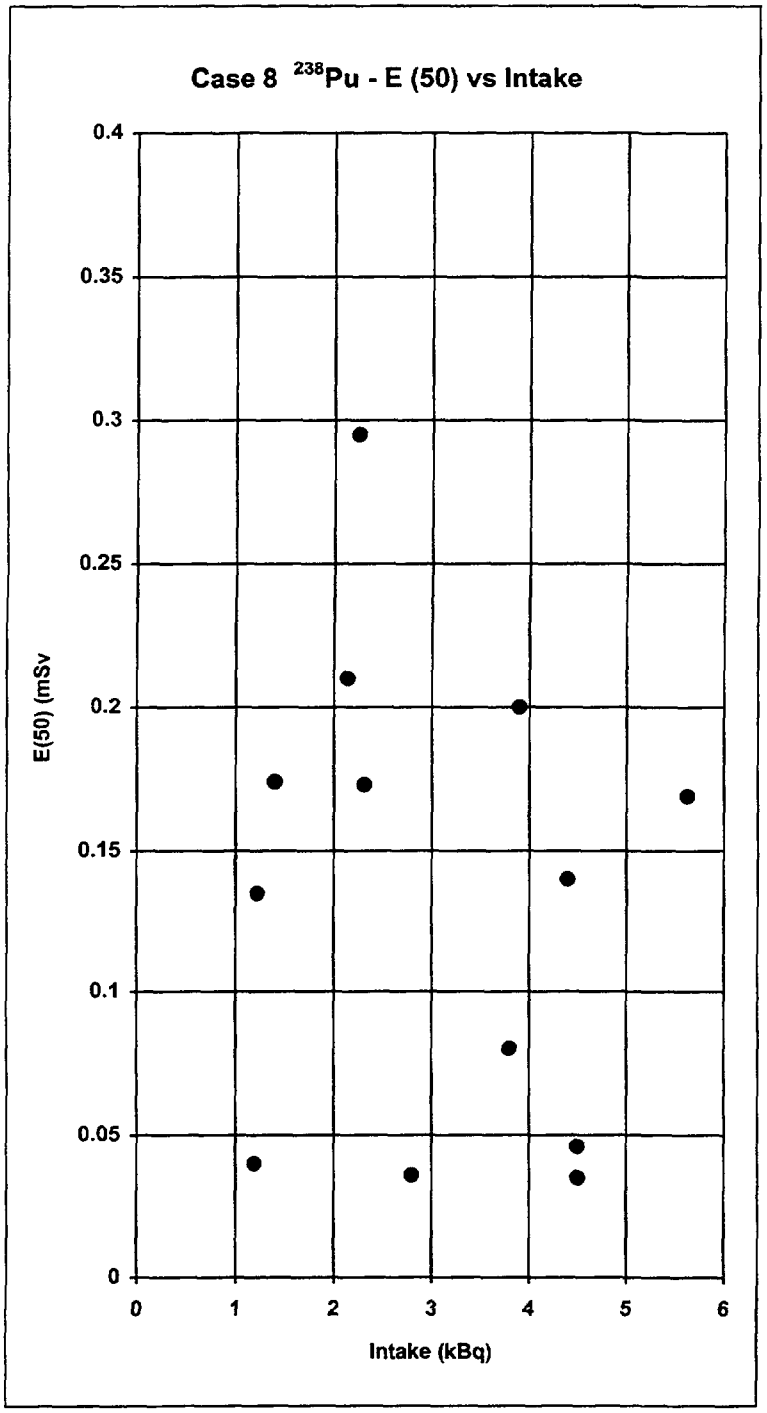

Case 8 - ^{238}Pu - Intake
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{238}Pu - $H_{bs,83}$ (1)
10
1
0.1
0.01
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{238}Pu - E_{83} (1)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{238}Pu - H_{bs} (50)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24

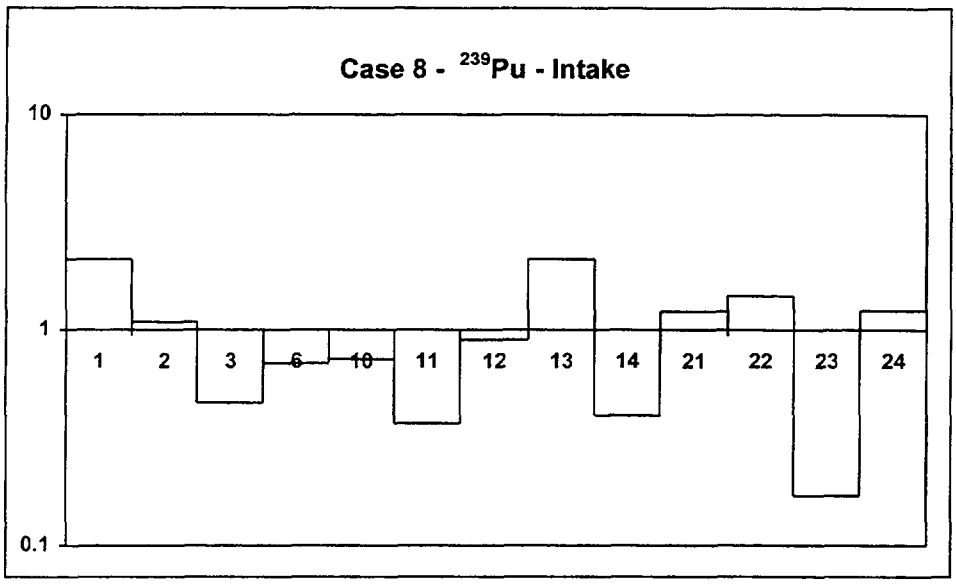

Case 8 - ^{238}Pu - E (50)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24

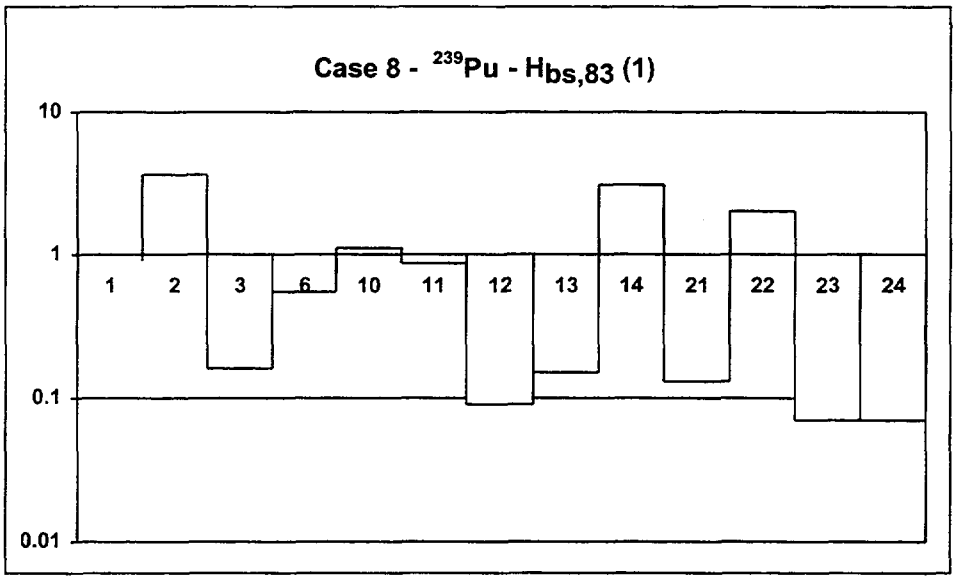

Case 8 ^{238}Pu - E (50) vs Intake
E(50) (mSv
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
Intake (kBq)

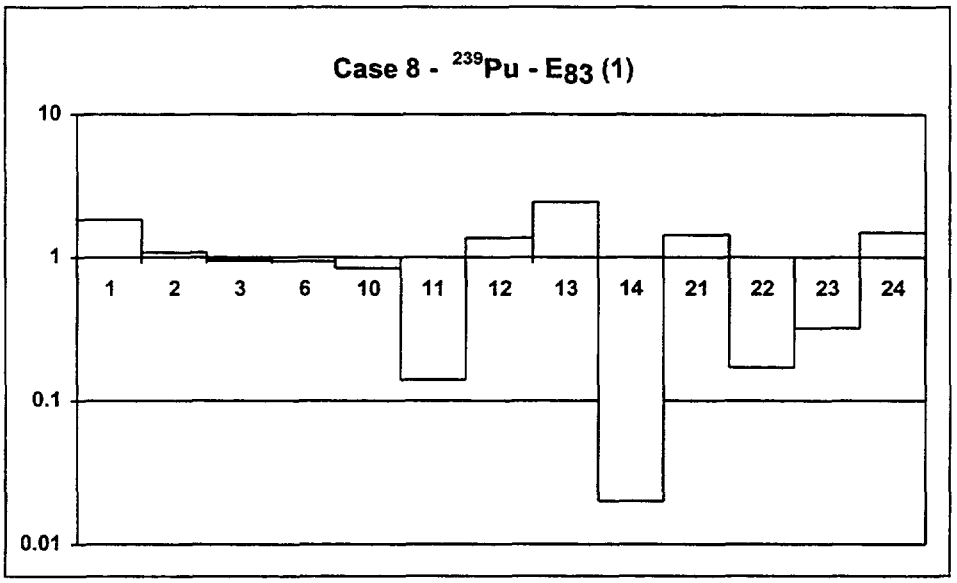
Case 8 - Single intake of $^{238\ 239\ 240}$Pu and ^{241}Am - ^{239}Pu

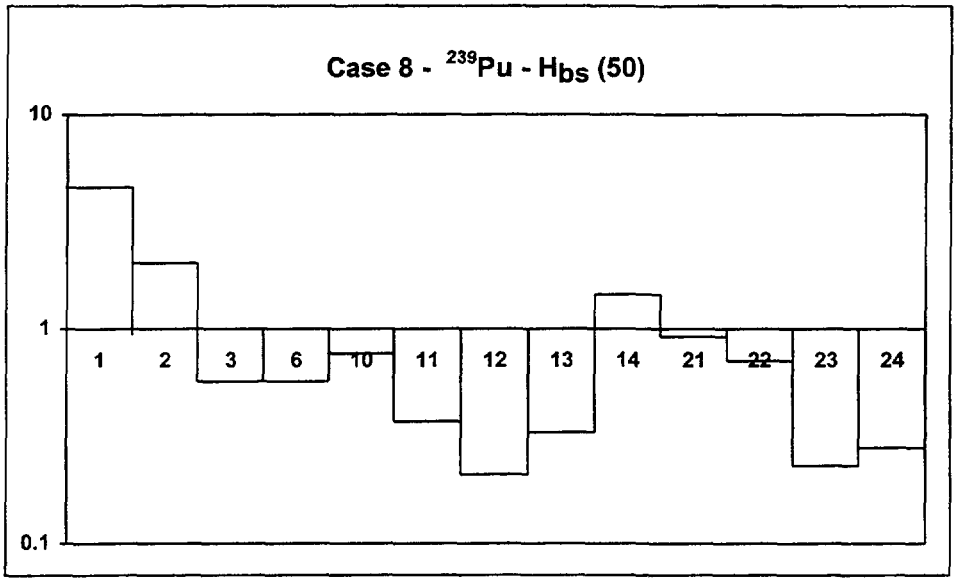
Lab. Number	Intake (kBq)	$H_{bs\ 83}$ (1) (mSv)	E_{83} (1) (mSv)	H_{bs}(50) (Sv)	E(50) (Sv)	Computer code	Model	f1
1	40	(3000)	90	50	1 5	NS	NS	
2	20 356	251 1	53	22	0 736	LUDEP 2 04	ICRP 30/54	
3	8 69	10 7	46 4	6 27	1 09	In house RBD	ICRP 30/54	
6	13 1	38	46	6 2	1 9	INDO	ICRP 30	1 00E-05
10	13 75	76	41	8 4	1 8	NS	ICRP 30	
11	7	60	7	4	0 22	NS	ICRP 54 ICRP 68	
12	16 9	6	66 7	2 32	0 202	LUDEP	ICRP 66 (LUNG) ICRP 30 (systemic) ICRP 54 (Pu)	1 00E-05
13	*40*	*10*	*120*	*3 6*	*0 33*	In house	ICRP 66 (lung) ICRP 67 (biokinetics)	1 00E-05
14	7 5	213	1 12	15 75	0 825	DOSINT	ICRP 30	
21	22 9	9 1	70	10	1 9	CINDY	ICRP 30 Durbin (Am) Jones (Pu	
22	27	140	8 3	7 7	0 23	IDSS 2 IMIE 2	ICRP 66 (lungs) ICRP 67 (Pu-Am)	

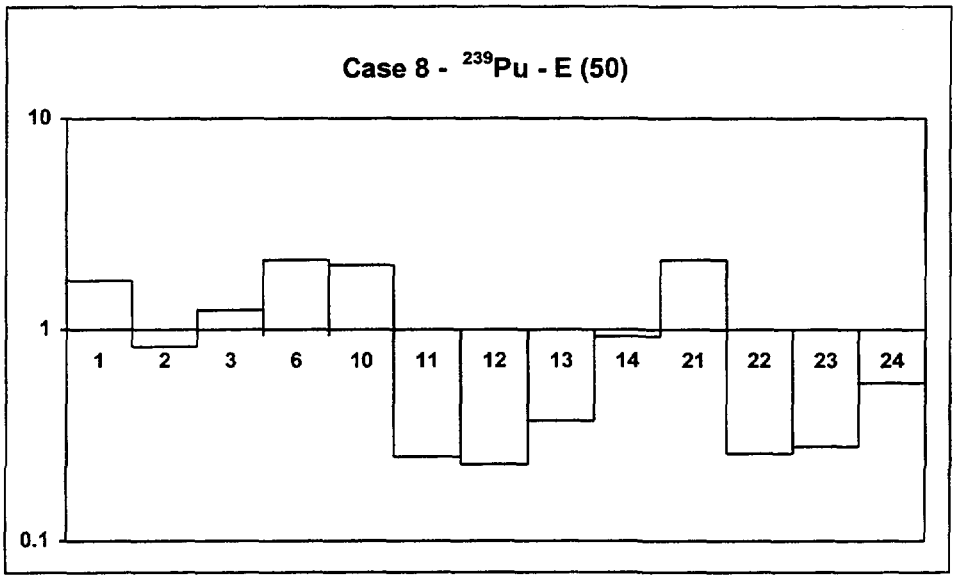
Lab. Number	Intake (kBq)	$H_{bs,83}$ (1) (mSv)	E_{83} (1) (mSv)	H_{bs}(50) (Sv)	E(50) (Sv)	Computer code	Model	f1
23	3 105	4 753	15 6	2 546	0 251	NS	ICRP 30 Jones (Pu)	
24	23 1	4 5	73	3 07	0 49	LUDEP 2 66	ICRP 67 (Am-Pu) ICRP 66 (lungs) ICRP 30 (systemic	
Geom Mean	15 03	27 17	30 19	7 09	0 63			
Arith Mean(X)	18 72	68 60	49 09	10 91	0 88			
SD (s)	11 84	86 73	35 33	13 04	0 68			
SD%	63 21	126 44	71 97	119 54	77 03			
(X+s)/X	1 63	2 26	1 72	2 20	1 77			
(X-s)/X	0 37		0 28		0 23			

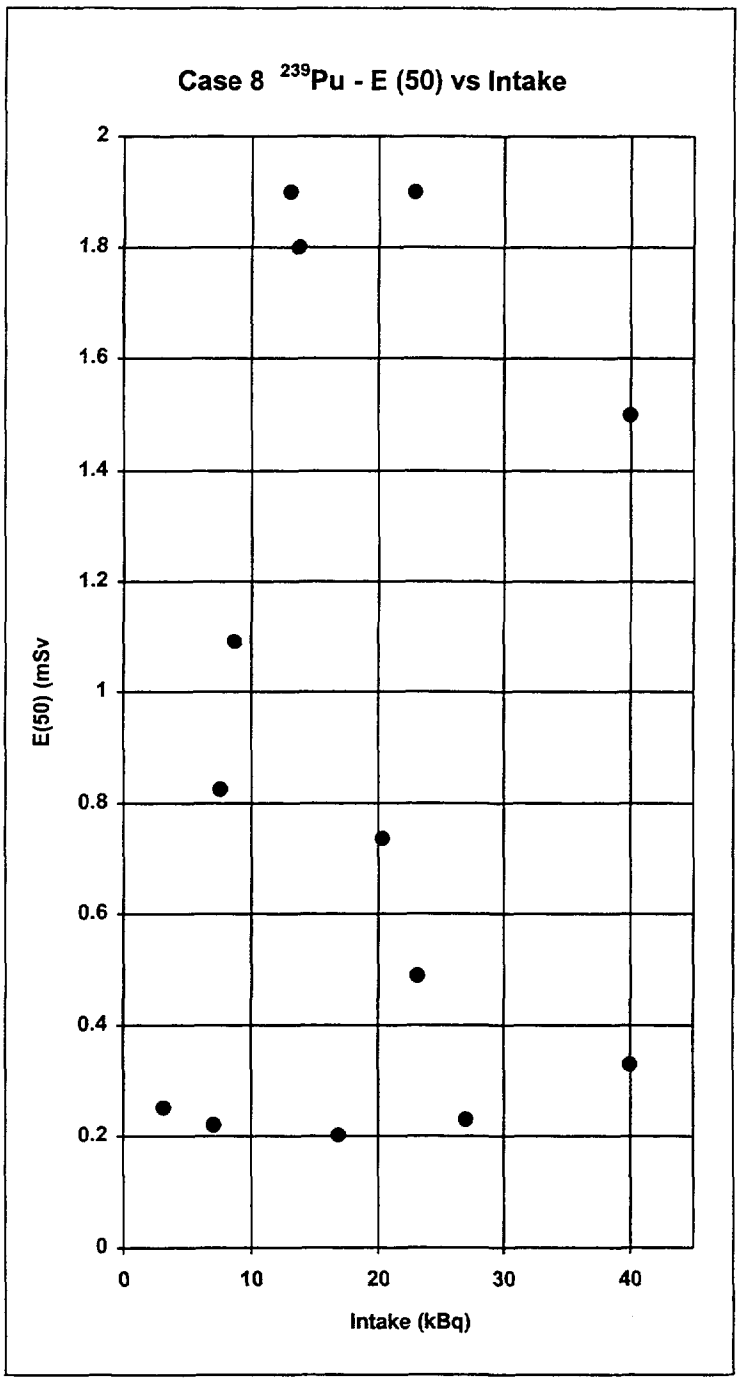

Case 8 - 239Pu - Intake
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - 239Pu - Hbs,83 (1)
10
1
0.1
0.01
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - 239Pu - E83 (1)
10
1
0.1
0.01
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{239}Pu - H_{bs} (50)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24

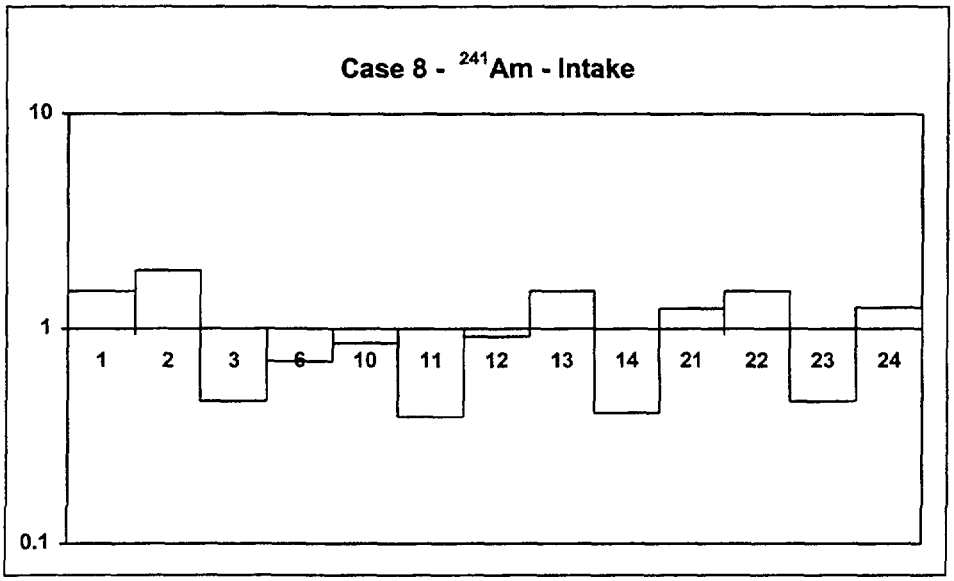

Case 8 - ^{239}Pu - E (50)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24

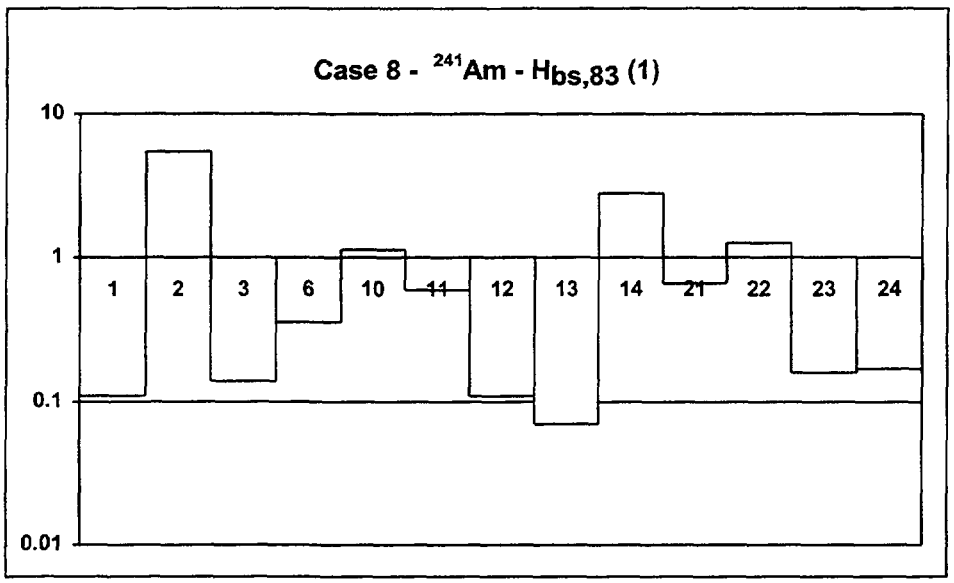

Case 8 239Pu - E (50) vs Intake
E(50) (mSv)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
Intake (kBq)

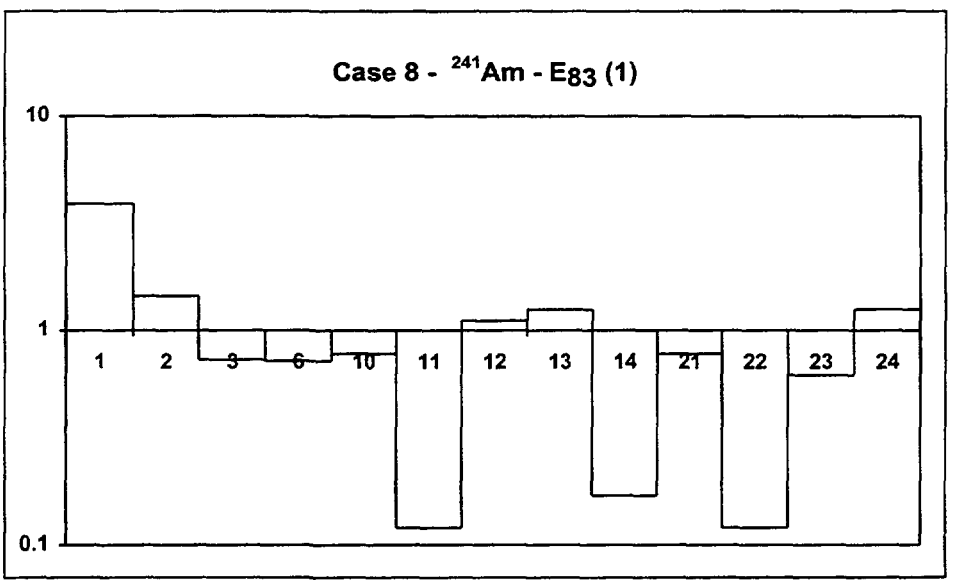
Case 8 - Single intake of $^{238\ 239\ 240}$Pu and ^{241}Am - ^{241}Am

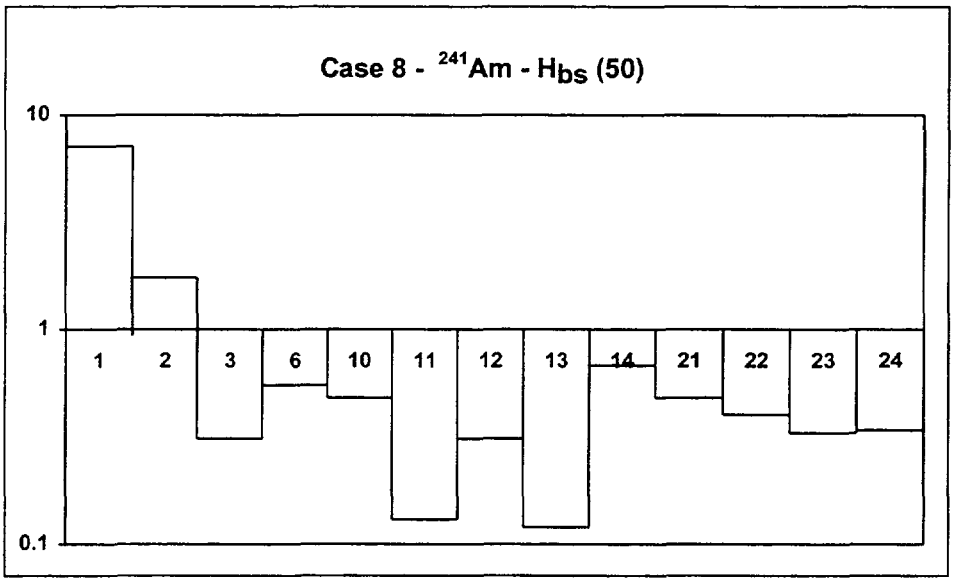
Lab. N°	Intake (kBq)	$H_{bs,83}$ (1) (mSv)	E_{83} (1) (mSv)	H_{bs}(50) (Sv)	E(50) (Sv)	Computer code	Model
1	5	1 6	50	27	0 8	NS	NS
2	6 253	82 3	18 6	6 6	0 234	LUDEP 2 04	ICRP 30/54
3	1 56	2 11	9 38	1 19	0 213	In house RBD	ICRP 30/54
6	2 38	5 4	9 3	2 1	0 27	INDO	ICRP 30
10	2 9	17	10	1 8	0 4	NS	ICRP 30
11	1 3	9	1 6	0 5	0 04	NS	ICRP 54 ICRP 68
12	3 1	1 7	14 3	1 16	0 07	LUDEP	ICRP 66 (Lung) ICRP 30 (systemic) ICRP 54 (Pu)
13	*5*	*1*	*16*	*0 47*	*0 04*	In house	ICRP 66 (lung) ICRP 67 (biokinetics)
14	1 364	41 8	2 2	2 59	0 136	DOSINT	ICRP 30
21	4 17	10	10	1 8	0 27	CINDY	ICRP 30 Durbin (Am) Jones (Pu)

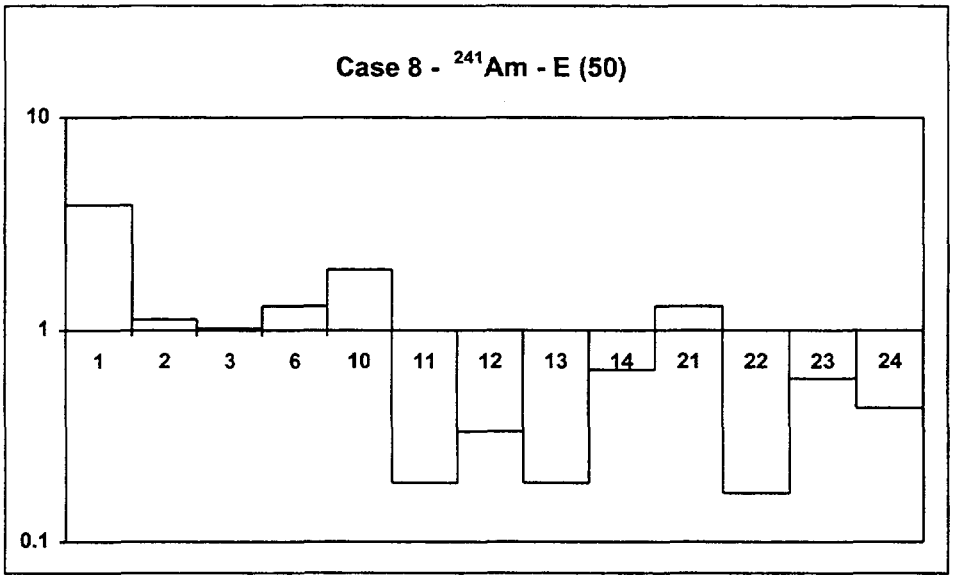
Lab. N°	Intake (kBq)	$H_{bs,83}$ (1) (mSv)	E_{83} (1) (mSv)	H_{bs}(50) (Sv)	E(50) (Sv)	Computer code	Model
22	5	19	1 6	1 5	0 035	IDSS 2 IMIE 2	ICRP 66 (lungs) ICRP 67 (Pu-Am)
23	1 535	2 4	8	1 259	0 124	NS	ICRP 30 Jones (Pu)
24	4 2	2 5	16	1 28	0 09	LUDEP 2 66	ICRP 67 (Am-Pu) ICRP 66 (lungs) ICRP 30 (systemic)
Geom Mean	2 94	6 17	8 57	1 82	0 14		
Arith Mean(X)	3 37	15 06	12 84	3 79	0 21		
SD (s)	1 68	23 19	12 47	7 14	0 21		
SD%	49 88	153 97	97 09	188 55	100 11		
(X+s)/X	1 50	2 54	1 97	2 89	2 00		
(X-s)/X	0 50		0 03		0 00		

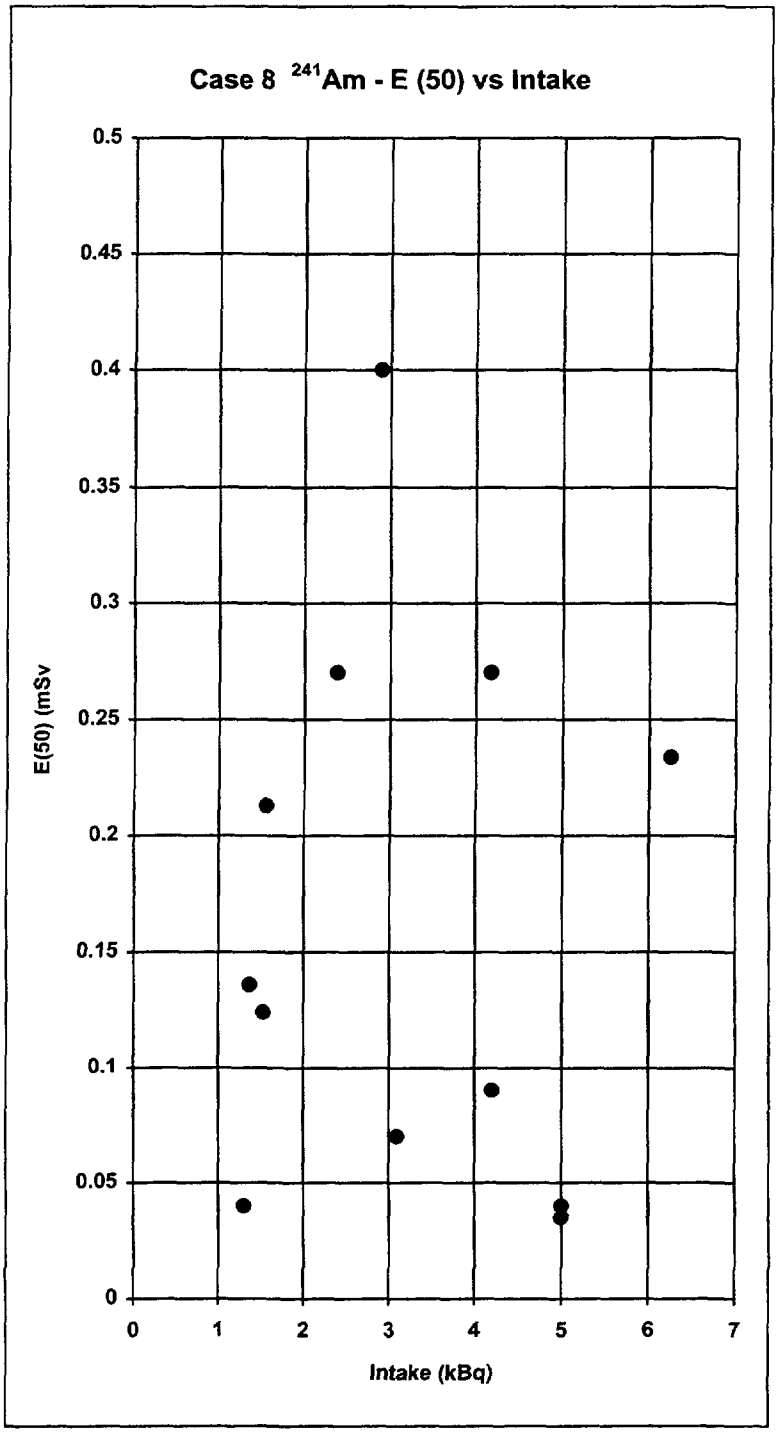

Case 8 - ^{241}Am - Intake
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{241}Am - $H_{bs,83}$ (1)
10
1
0.1
0.01
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{241}Am - E_{83} (1)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24


Case 8 - ^{241}Am - H_{bs} (50)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24

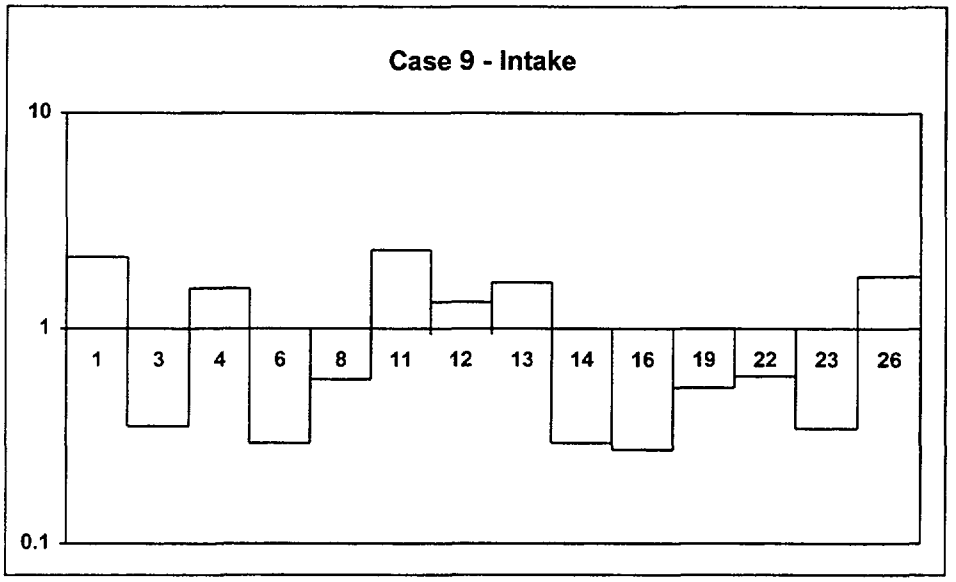

Case 8 - ^{241}Am - E (50)
10
1
0.1
1
2
3
6
10
11
12
13
14
21
22
23
24

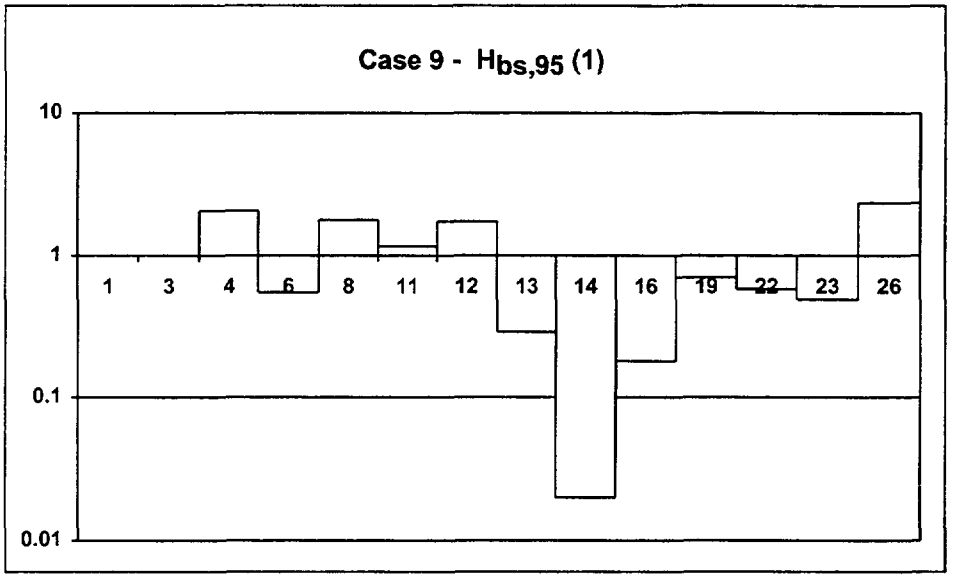

Case 8 241Am - E (50) vs Intake
E(50) (mSv)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
Intake (kBq)

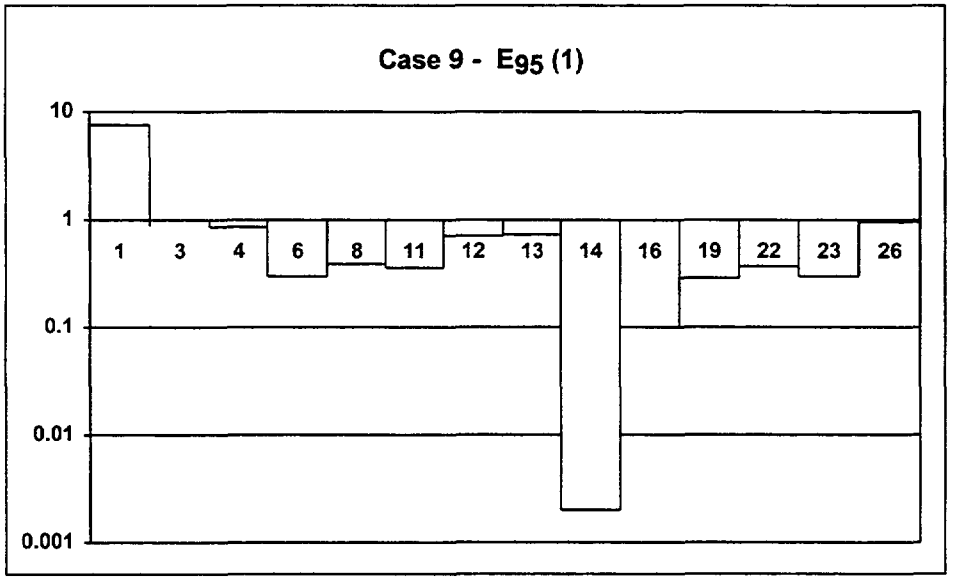
Case 9 - Single intake of ^{241}Am

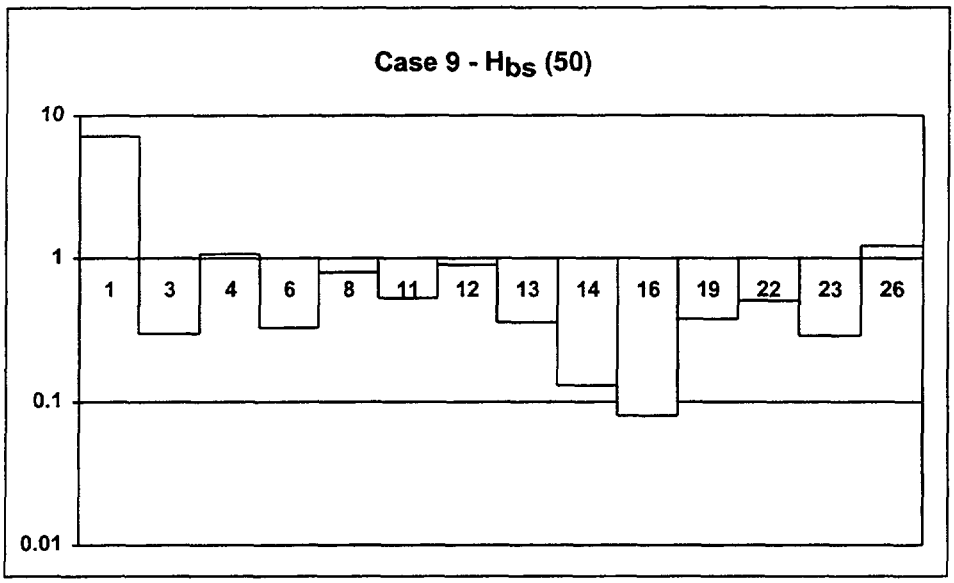
Lab Number	Intake (kBq)	$H_{bs\,95}$ (1) (mSv)	E_{95} (1) (mSv)	H_{bs} (50) (Sv)	E(50) (Sv)	Reduction of dose (%)	Computer code	Model	AMAD	Clearance Type	f1
1	8 9		168	47	1 4	50	NS	NS	5	W	NS
3	1 463			1 97	0 13	50	*In house*	ICRP 30 Hall's Model (chelation)	0 4	W	1E-03
4	6 38	72	19	7 1	0 24	Not done	LUDEP 2 04	ICRP 66 (lung) Durbin	5	M	1E-03
6	1 18	19	6 5	2 2	0 12	30	INDO	ICRP 30	0 2	W (85%) Y (15%)	1E-03
8	2 4	62	8 5	5 3	0 29		CINDY	ICRP 30 Durbin (Am)	1	W	1E-03
11	9 6	40	8	3 5	0 26	18	AGEDOS	ICRP 54 ICRP 68 (5um)DF	10	W	NS
12	5 51	60 7	15 5	5 98	0 2	3	LUDEP 2 04	ICRP 66 (lung) ICRP 54 Durbin ICRP 30 (systemic) Hall's (reduction)	5	M	1E-03
13	6 8	10	16	2 4	0 061	66	In house	ICRP 66 (lung) ICRP 67 (biokinetics)	5	M	5E-04

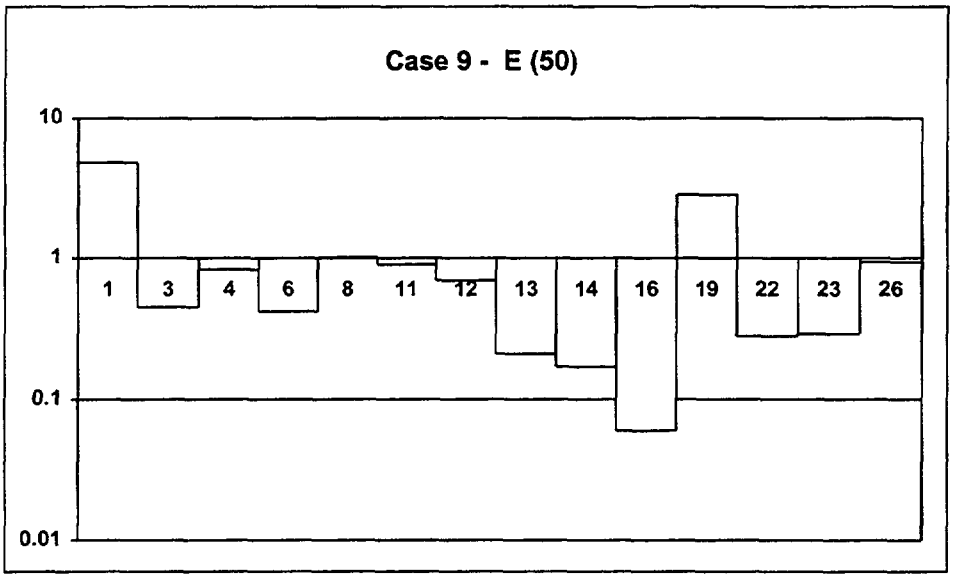
Lab. Number	Intake (kBq)	$H_{bs,95}$ (1) (mSv)	E_{95} (1) (mSv)	H_{bs} (50) (Sv)	E(50) (Sv)	Reduction of dose (%)	Computer code	Model	AMAD	Clearance Type	f1
14	1.2	0.68	0.037	0.89	0.048	93.3	NS	Empirical fit	NS	NS	
16	1.134	6.3	2.1	0.519	0.0183	30	Several codes	NS	NS	W	5E-04
19	2.2	24	6.3	2.5	0.83	30	LUDEP	ICRP 30 ICRP 54	5	W/M	
22	2.5	20	8.1	3.4	0.082	NS	IRSS 2 IMIE 2	ICRP 66 (lung) ICRP 67 (Am)	0.3	M	5E-03
23	1.4	17	6.6	1.93	0.085	50	NS	ICRP 30 Jones	1	W	5E-05
26	7.26	82	21	8.1	0.27	NS	LUDEP 2.04	ICRP 66 (lungs) ICRP 56 (Am) ICRP 30 (GI)	5	M	1E-03
Geom. Mean	3.06	20.62	7.38	3.36	0.16						
Arith. Mean(X)	4.14	34.47	21.97	6.63	0.29						
SD (s)	3.12	27.87	44.33	11.84	0.38						
SD%	75.47	80.83	201.74	178.68	131.27						
(X+s)/X	1.75	1.81	3.02	2.79	2.31						
(X-s)/X	0.25	0.19									

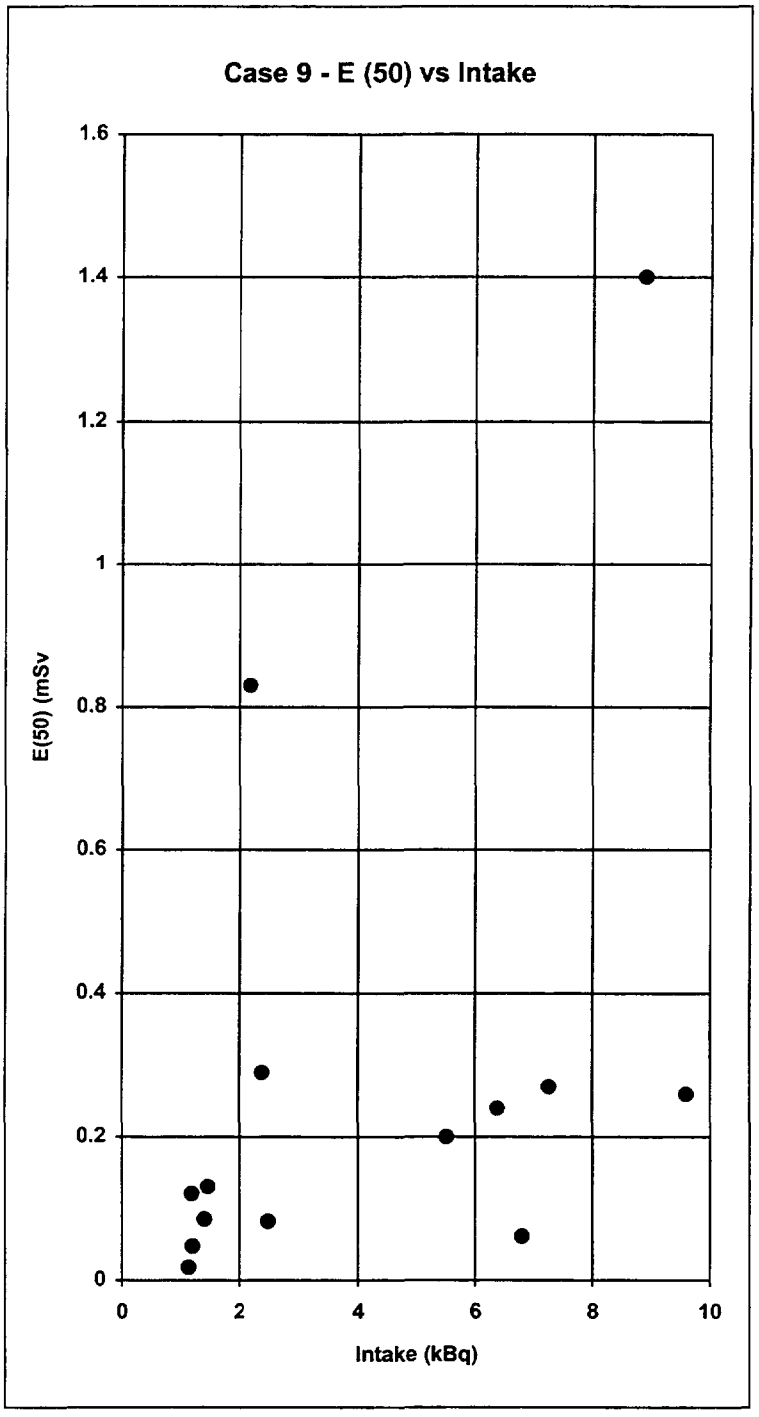

Case 9 - Intake
10
1
0.1
1 3 4 6 8 11 12 13 14 16 19 22 23 26


Case 9 - Hbs,95 (1)
10
1
0.1
0.01
1 3 4 6 8 11 12 13 14 16 19 22 23 26


Case 9 - E95 (1)
10
1
0.1
0.01
0.001
1 3 4 6 8 11 12 13 14 16 19 22 23 26


Case 9 - H_{bs} (50)
10
1
0.1
0.01
1
3
4
6
8
11
12
13
14
16
19
22
23
26


Case 9 - E (50)
10
1
0.1
0.01
1
3
4
6
8
11
12
13
14
16
19
22
23
26


Case 9 - E (50) vs Intake
E(50) (mSv
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
Intake (kBq)

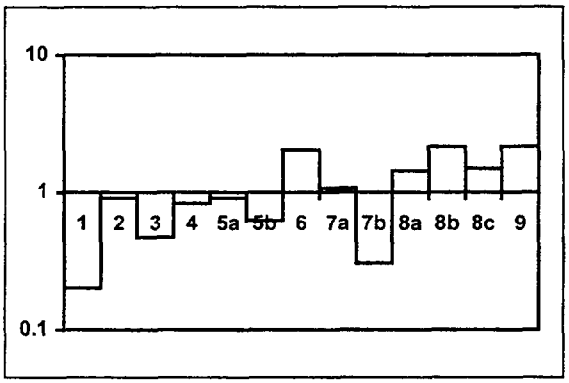
Annex VI

RESULTS PER LABORATORY

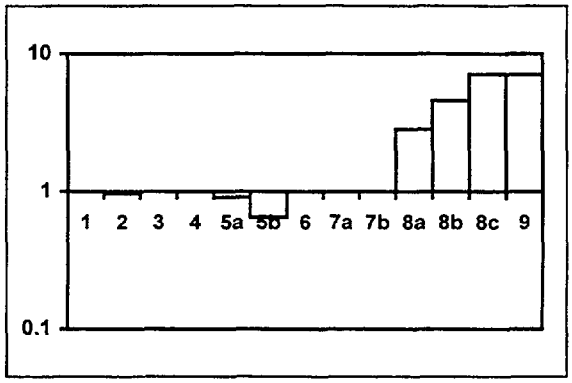
The histograms refers to the values related to the *arithmetic* means

Laboratory 1

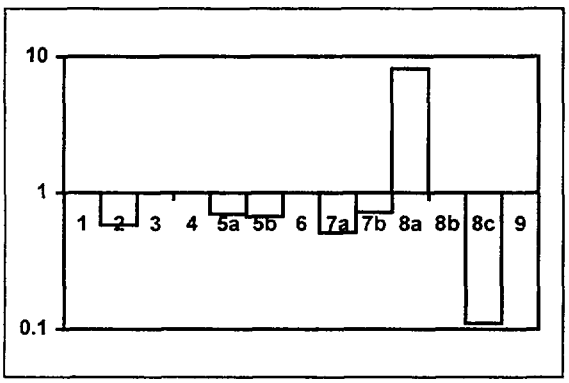
Intake



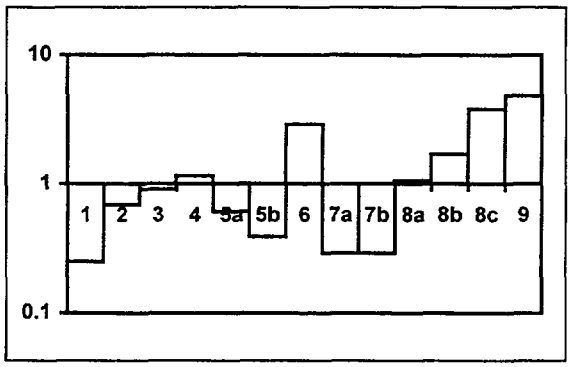
H(50)



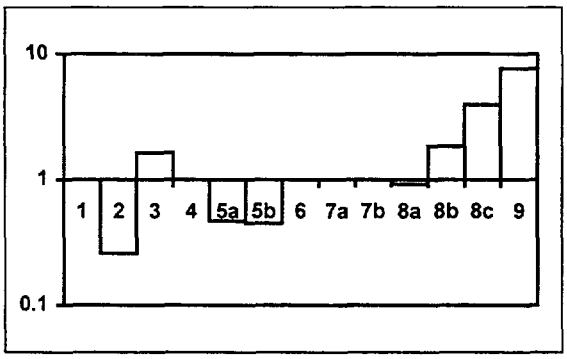
H(year)



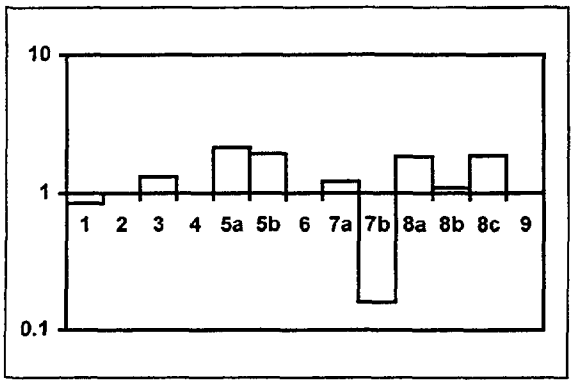
E(50)



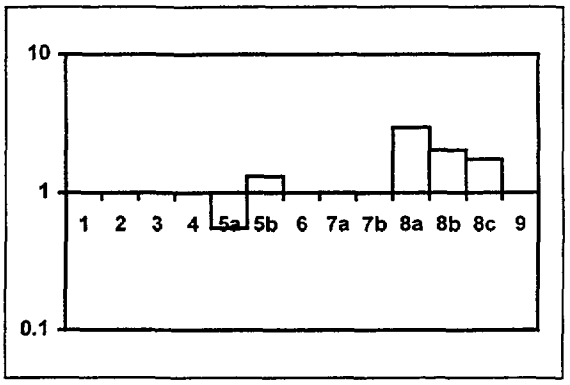
E(year)



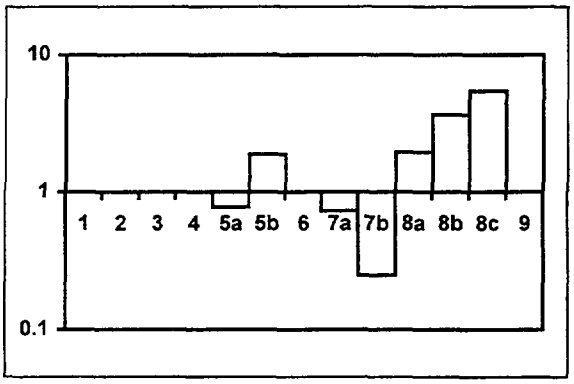
Intake



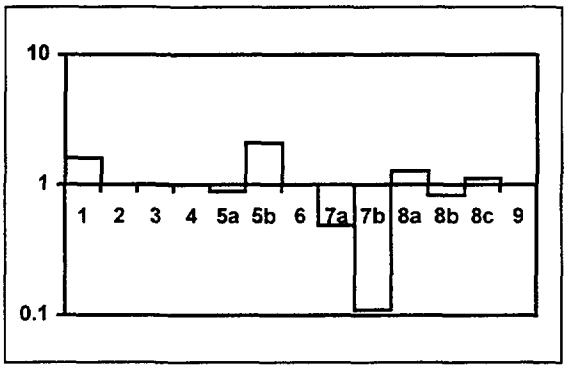
H(50)



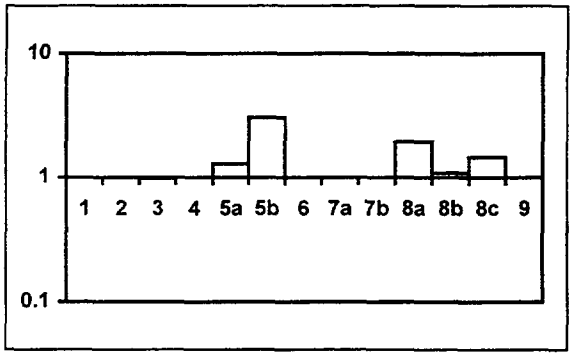
H(year)



E(50)

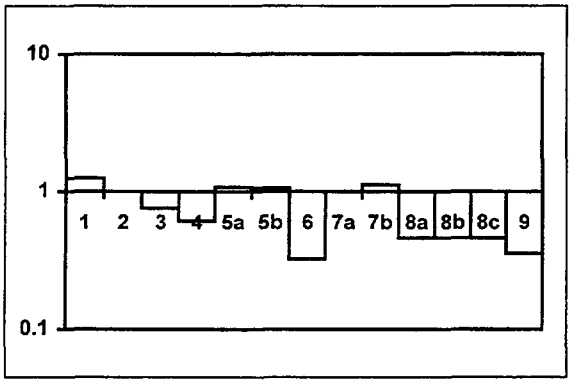


E(year)

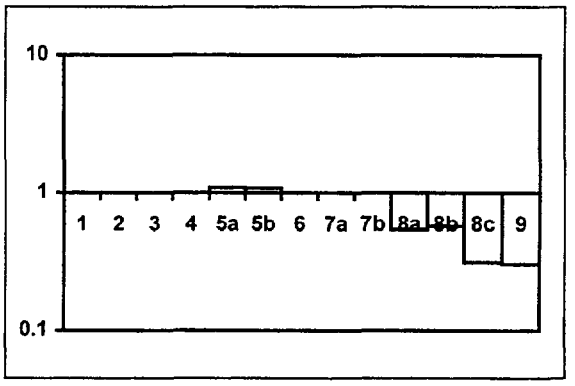


Laboratory 3

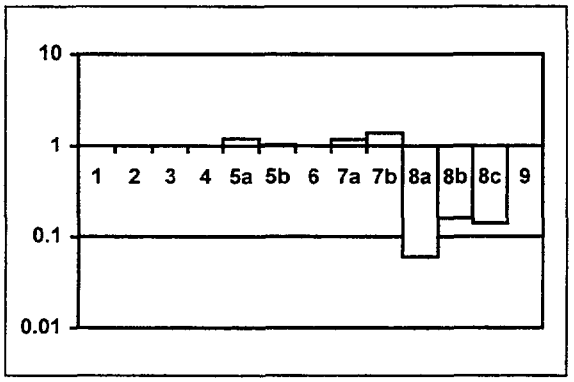
Intake



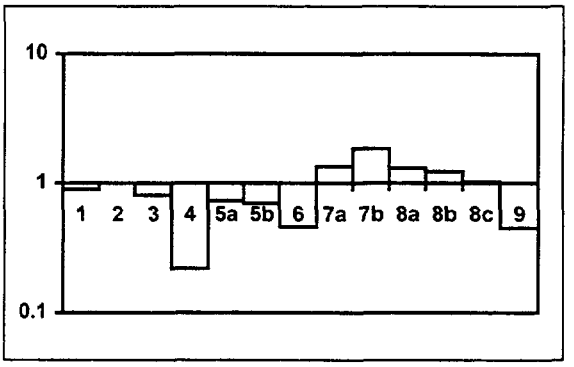
H(50)



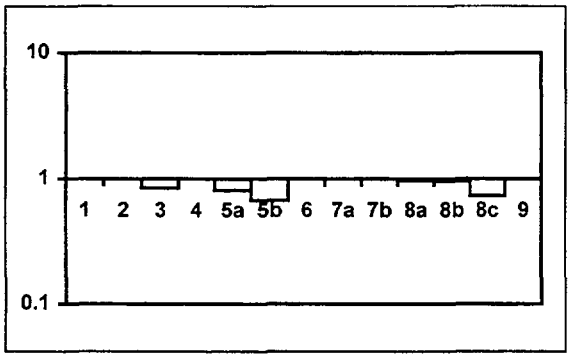
H(year)



E(50)

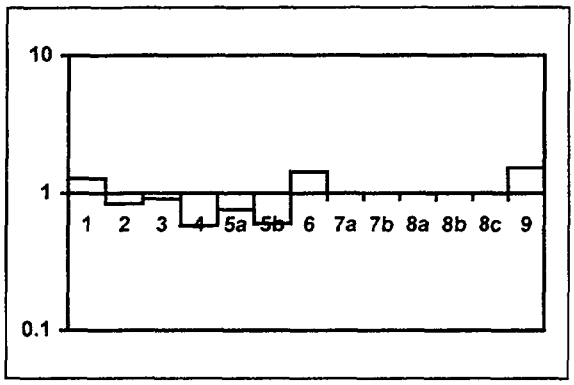


E(year)



Laboratory 4

Intake



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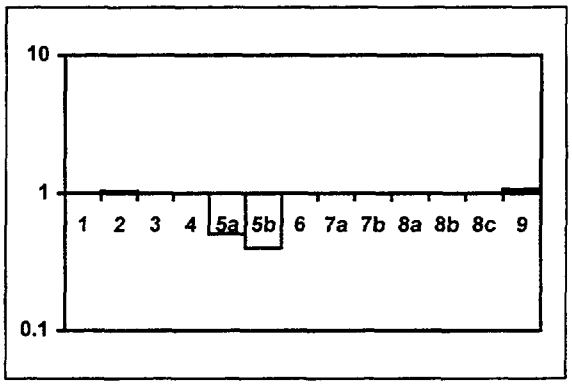

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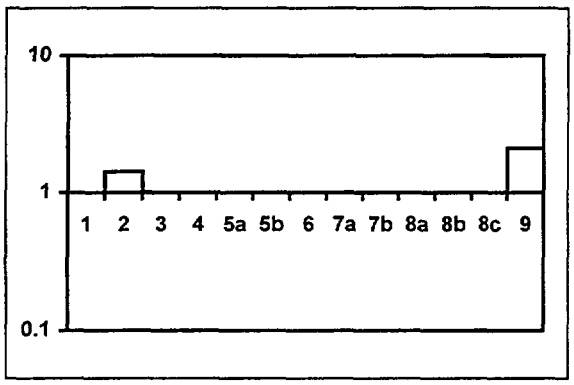

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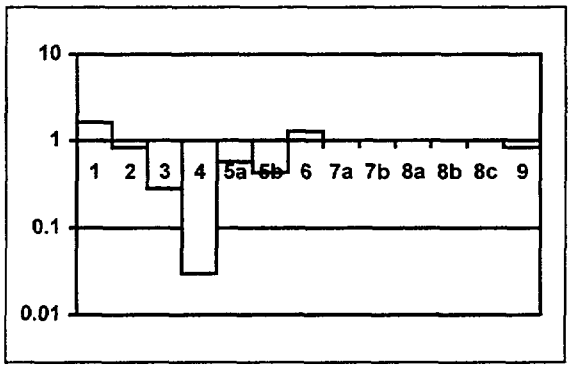

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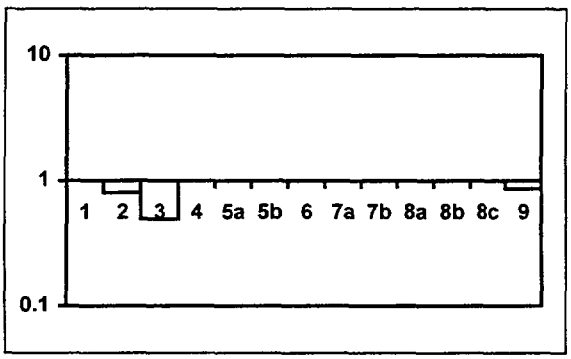

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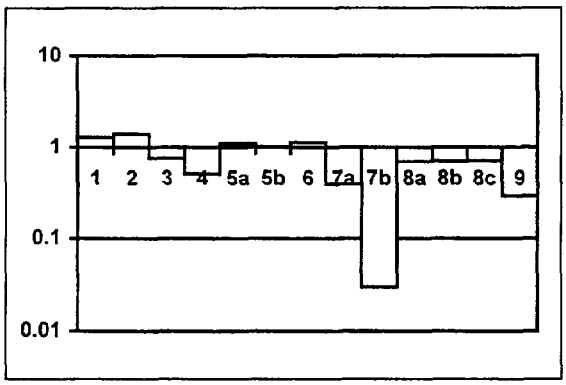

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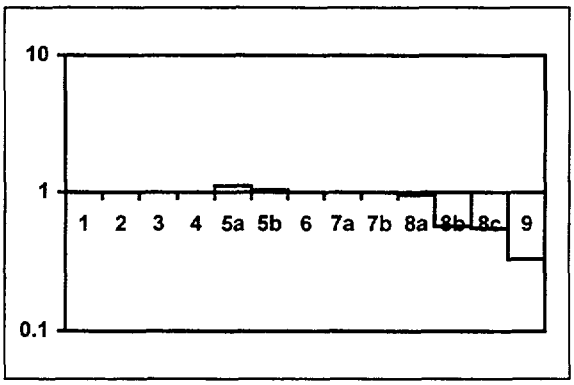

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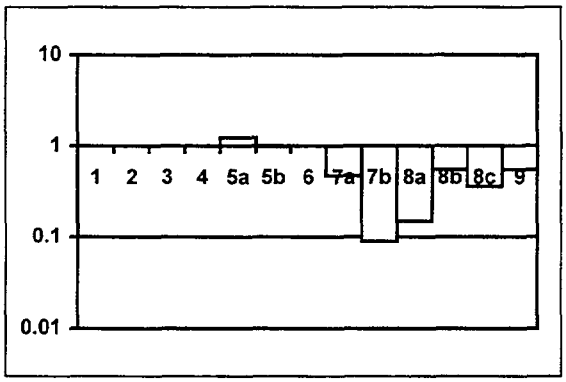

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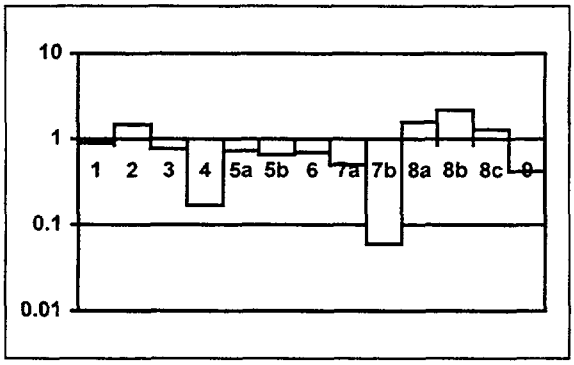

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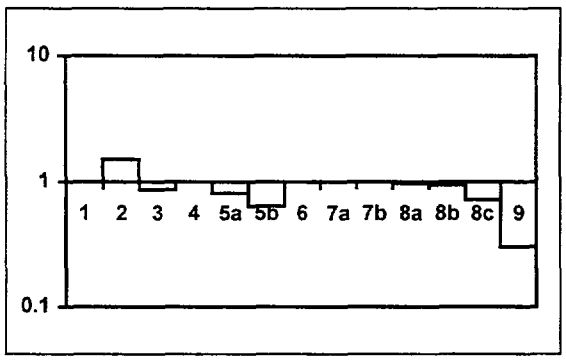

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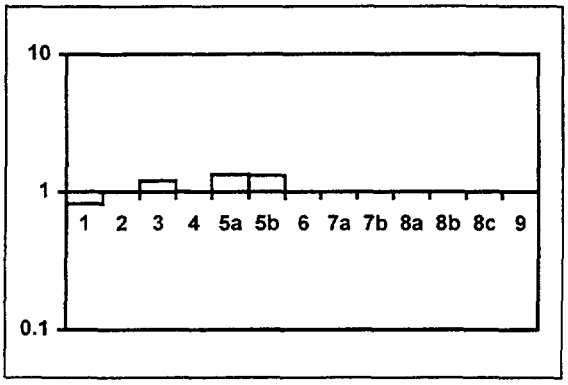

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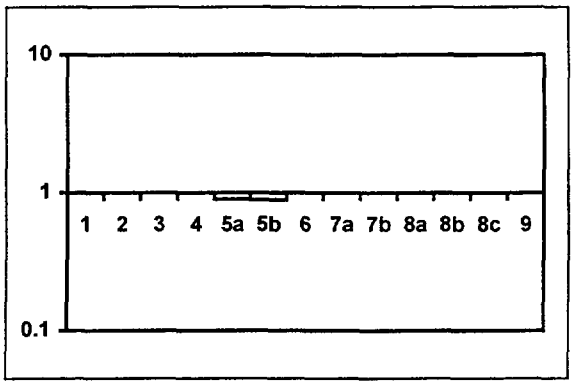

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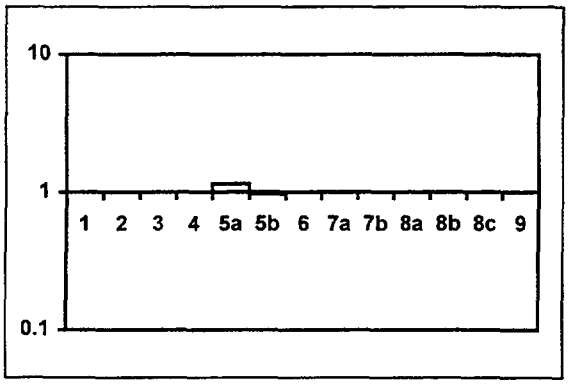

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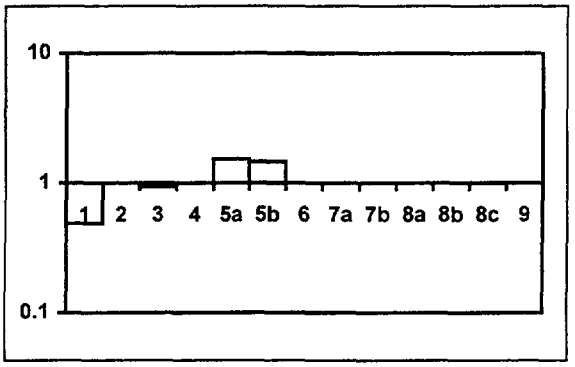

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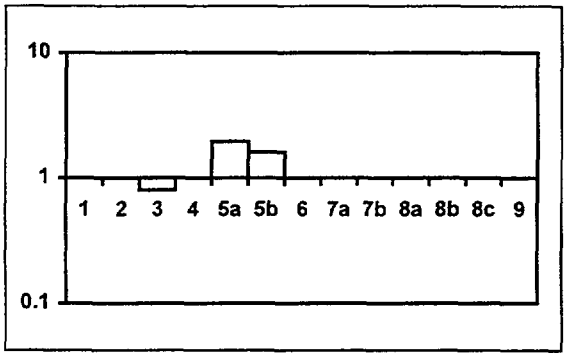

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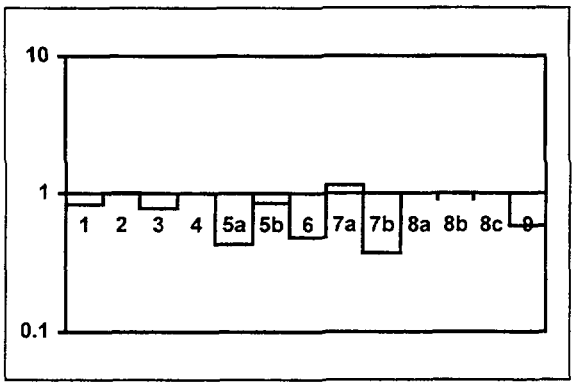

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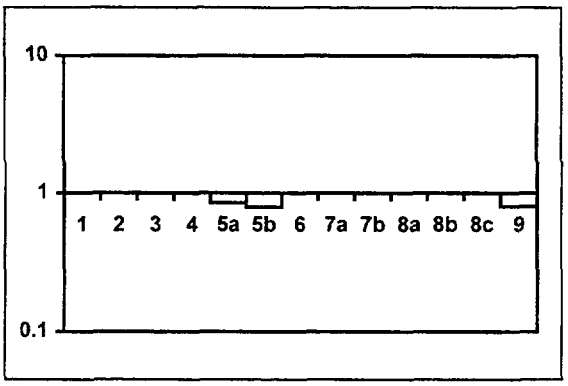

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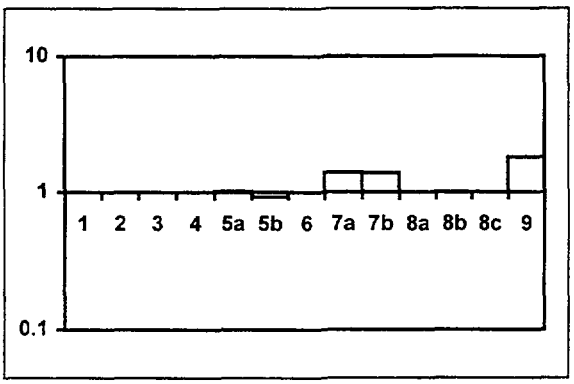

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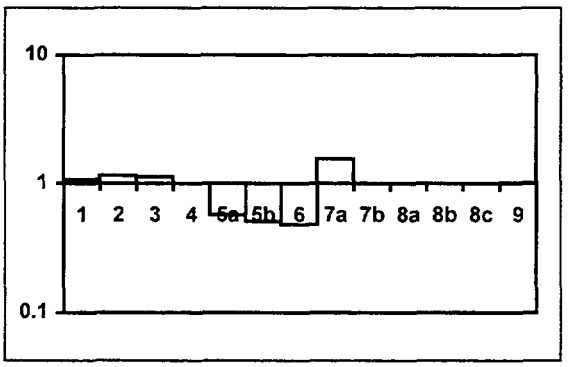

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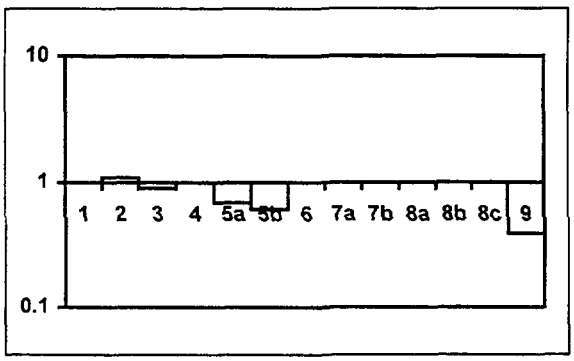

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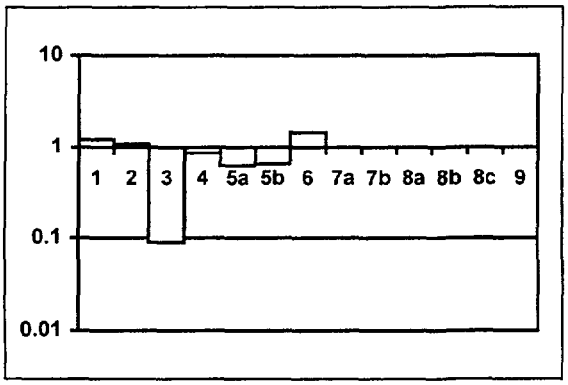

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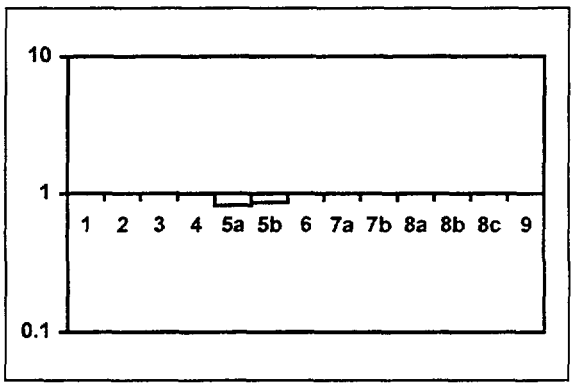

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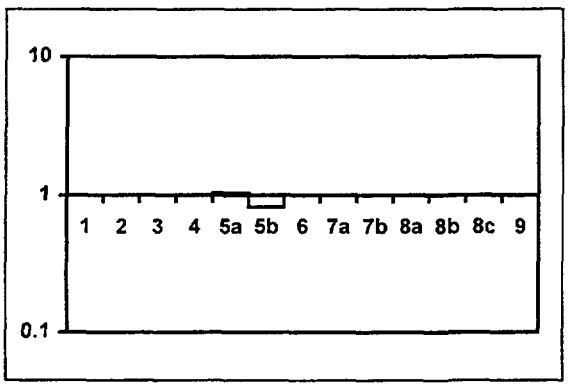

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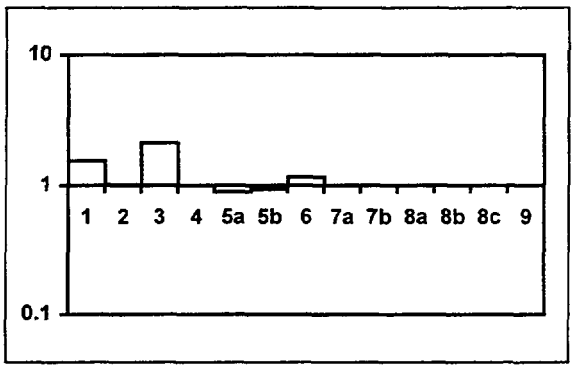

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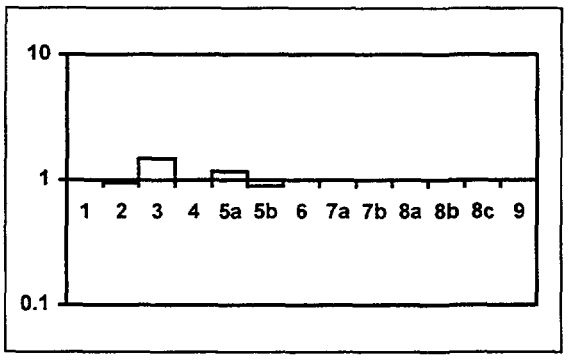

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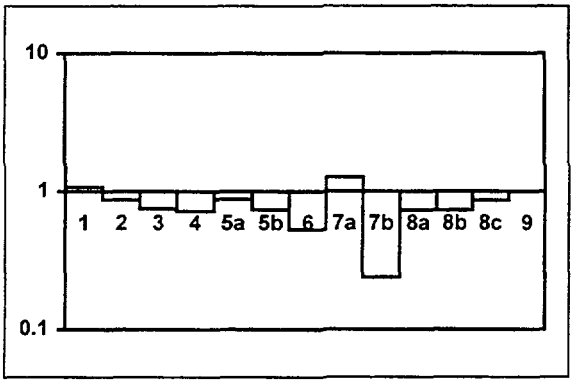

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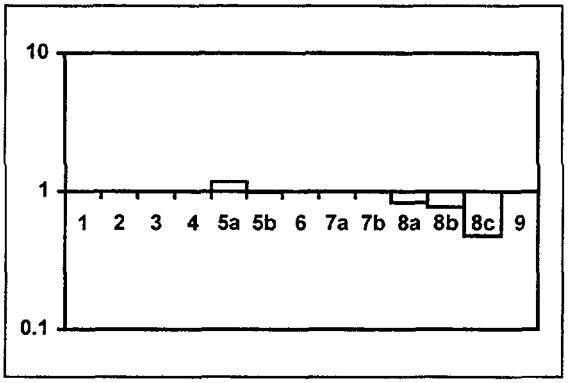

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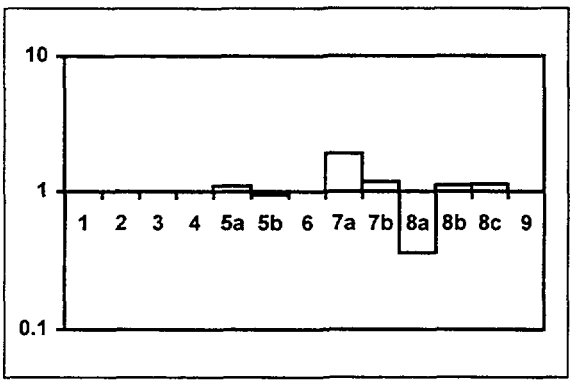

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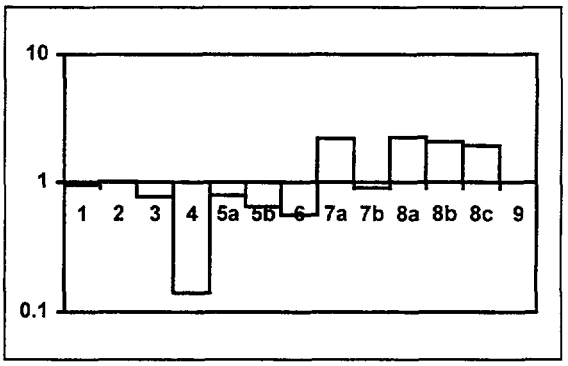

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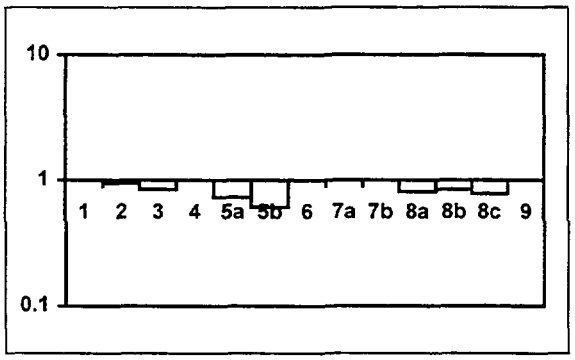

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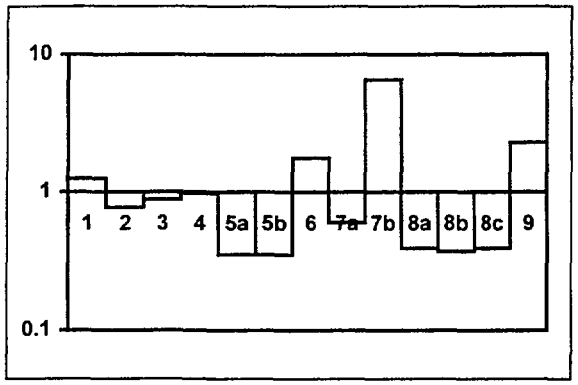

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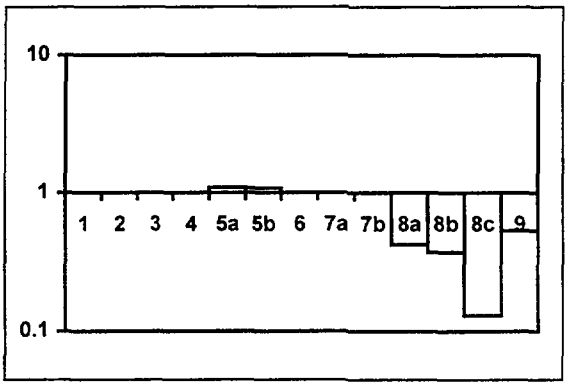

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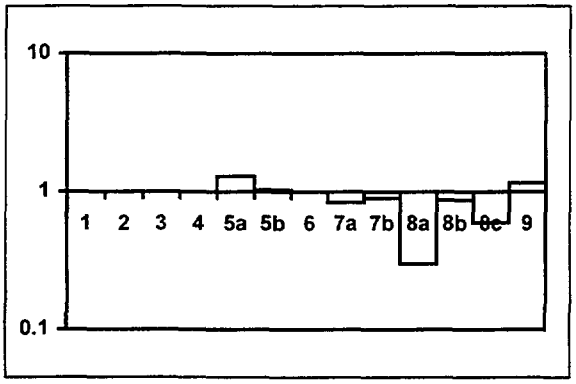

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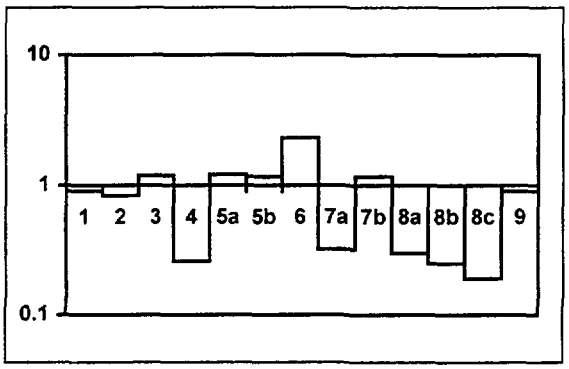

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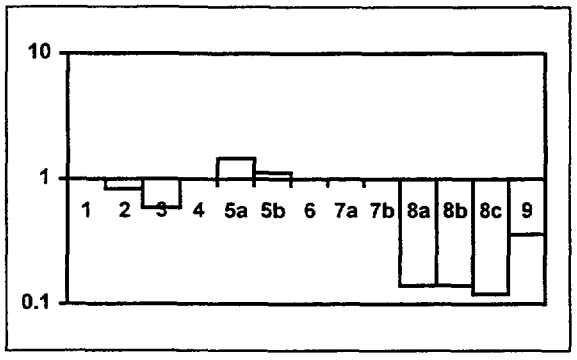

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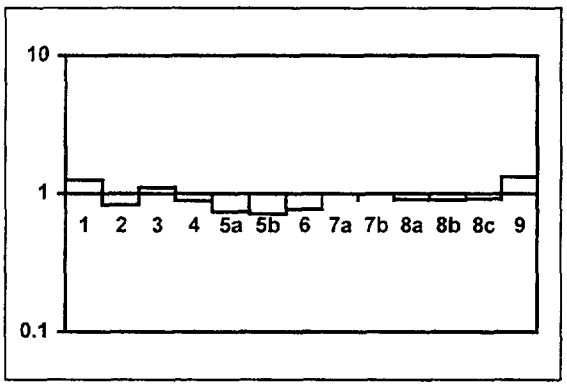

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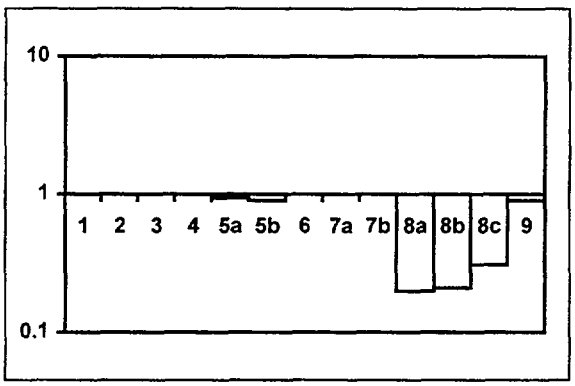

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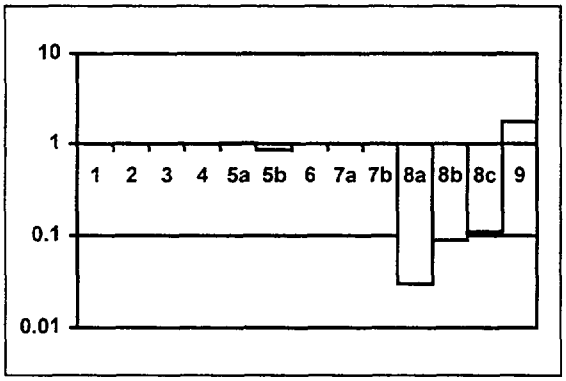

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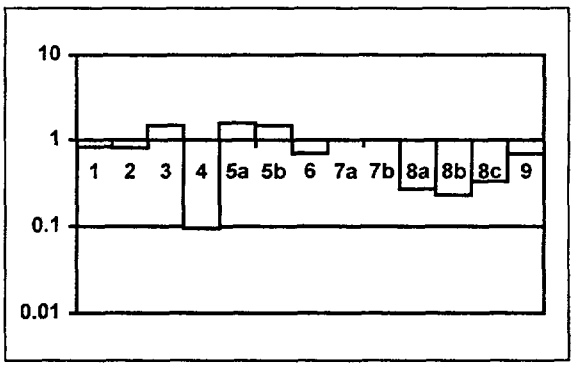

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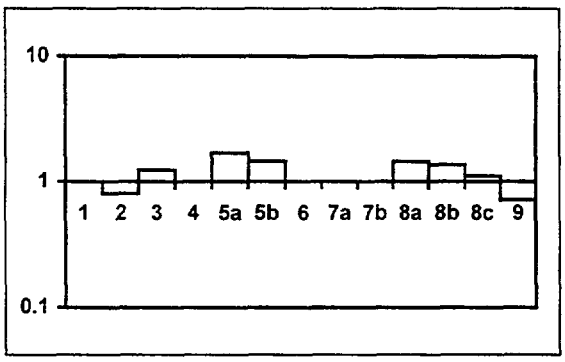

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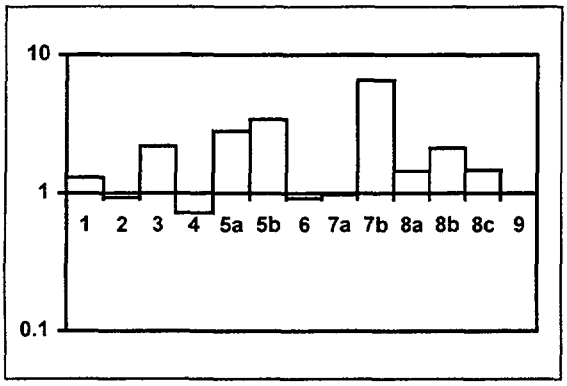

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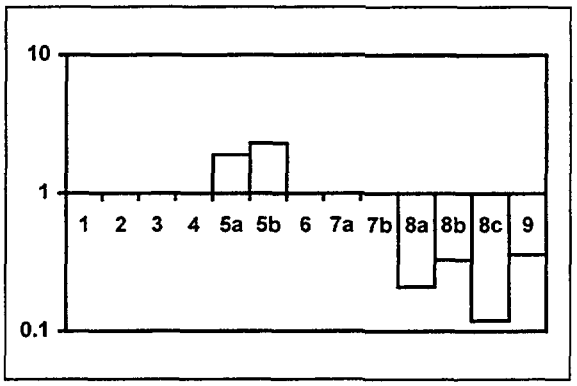

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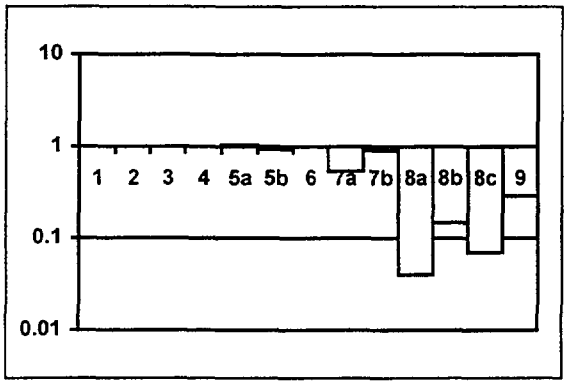

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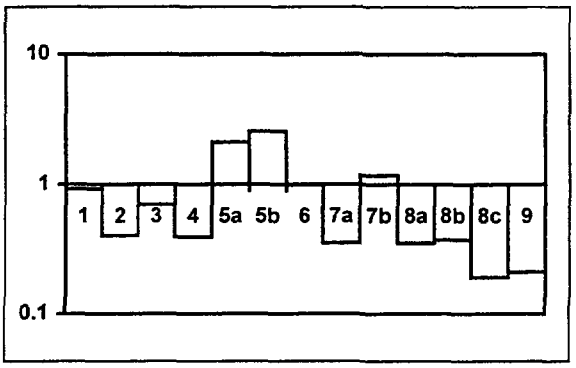

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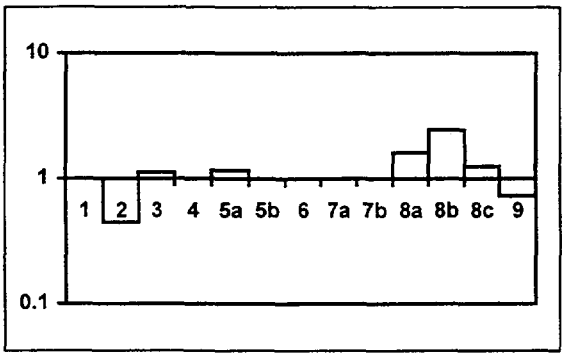

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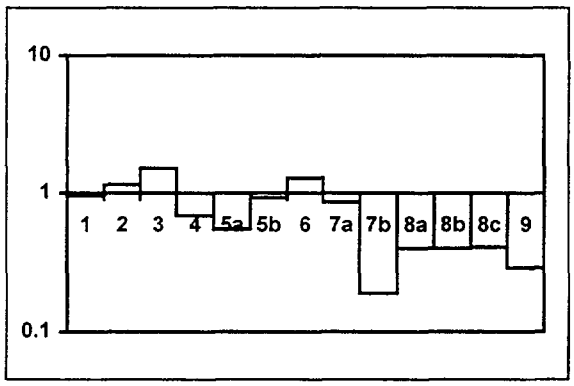

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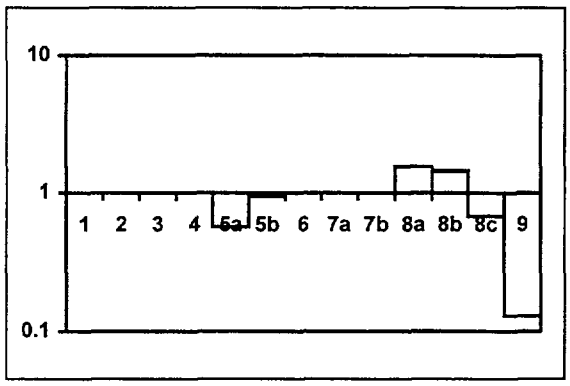

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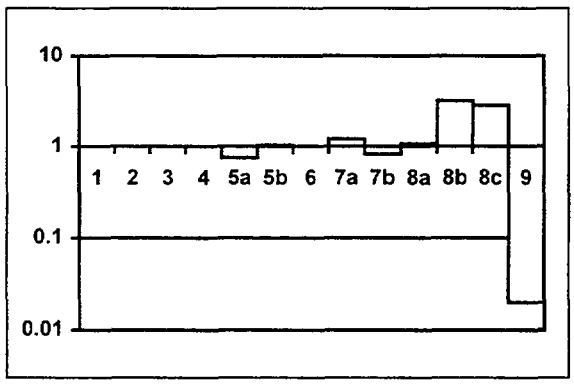

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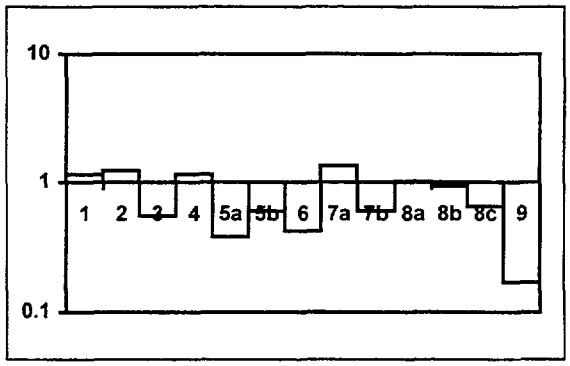

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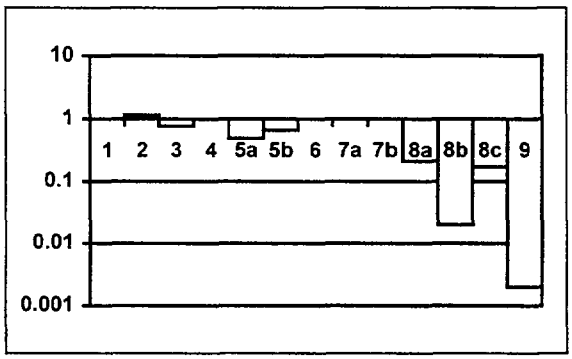

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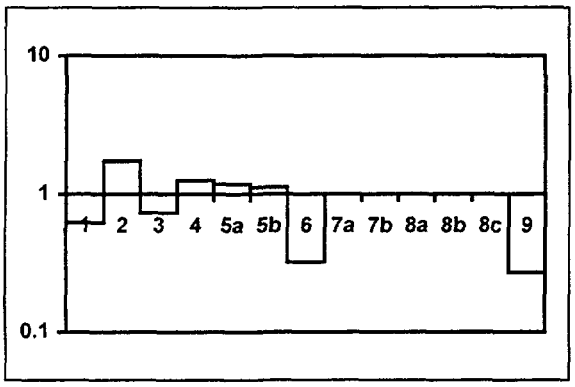

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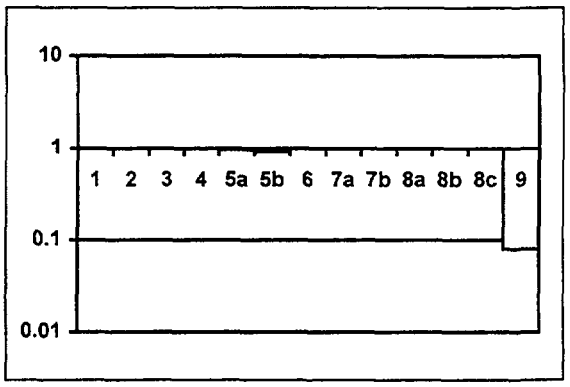

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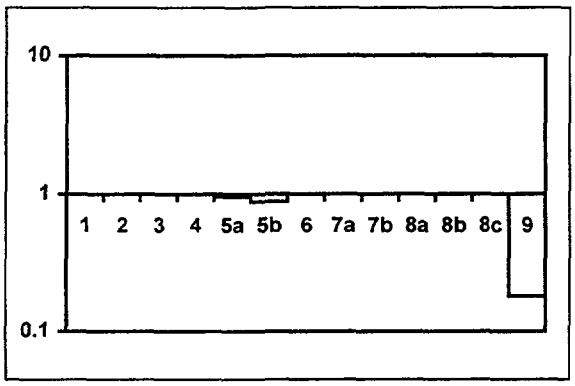

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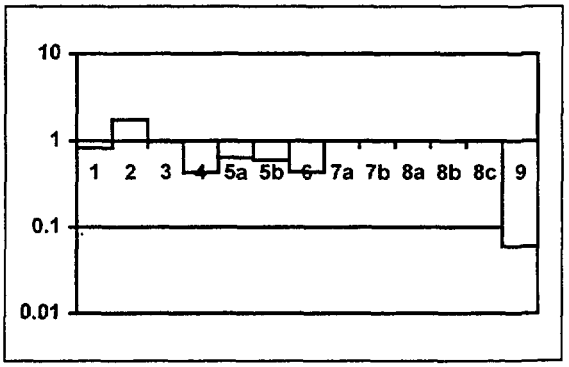

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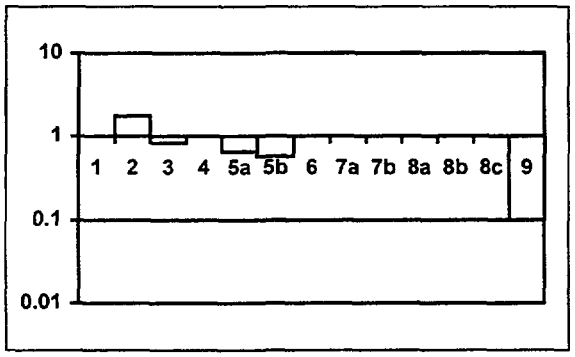

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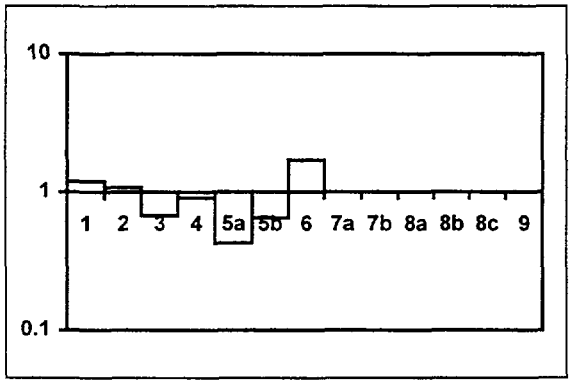

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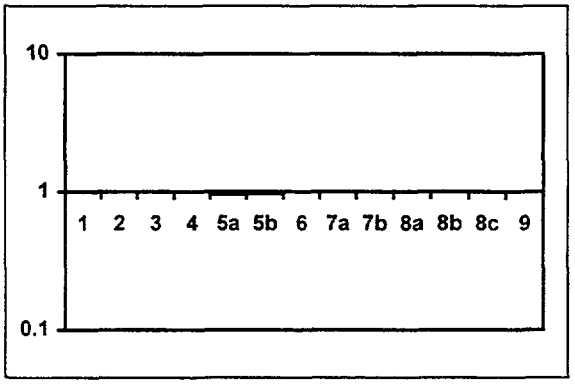

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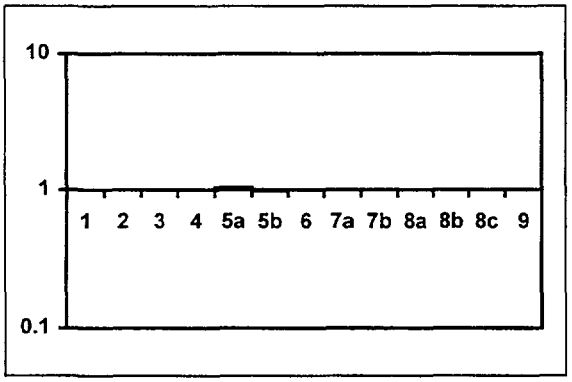

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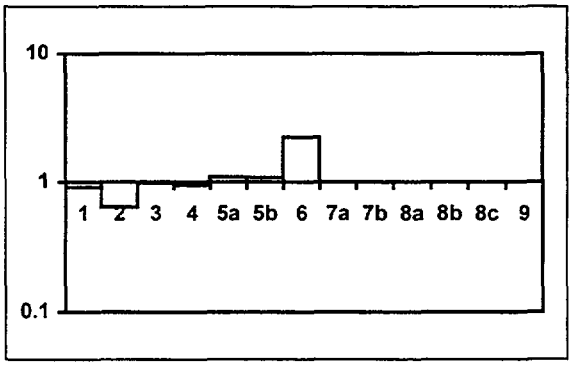

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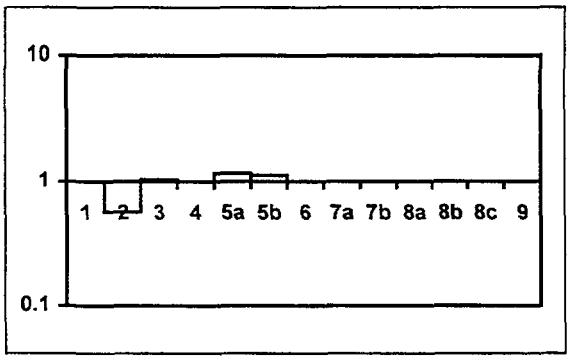

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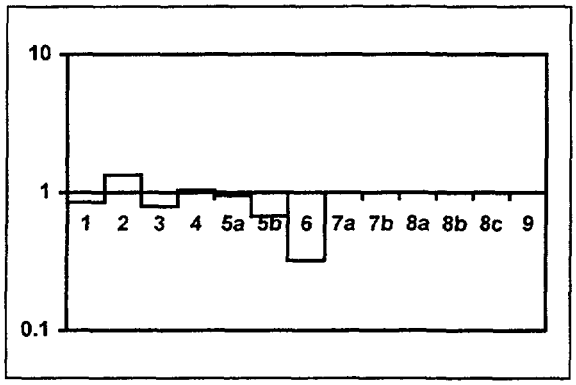

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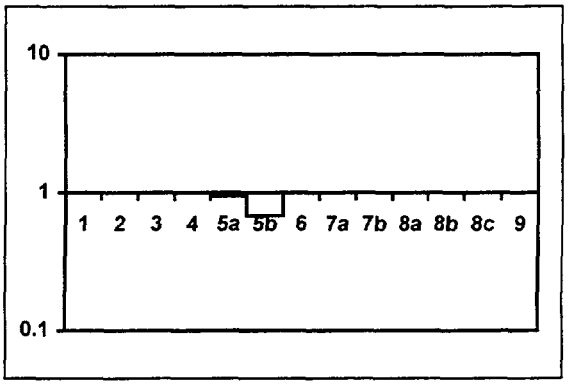

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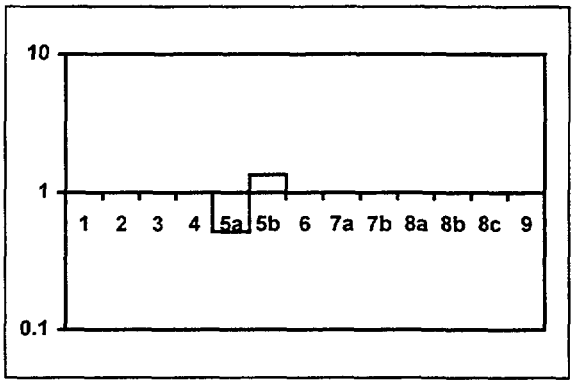

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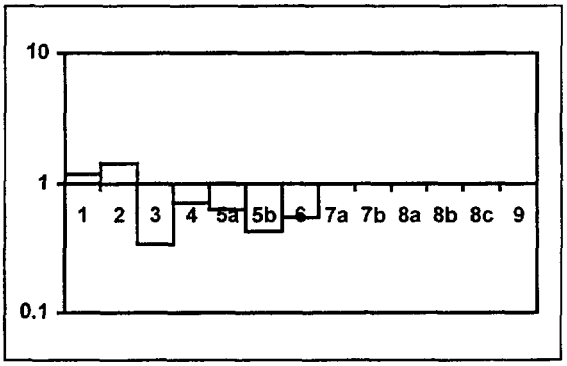

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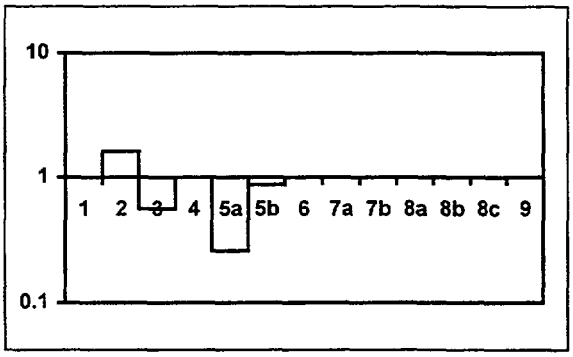

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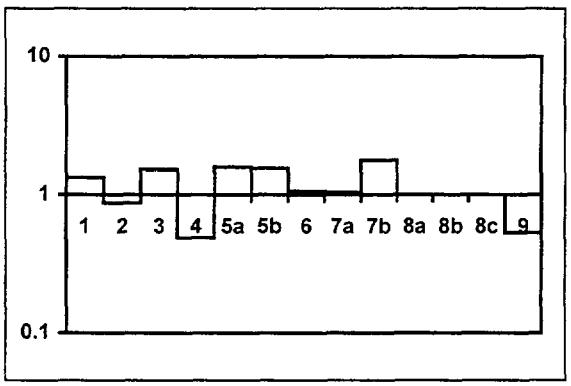

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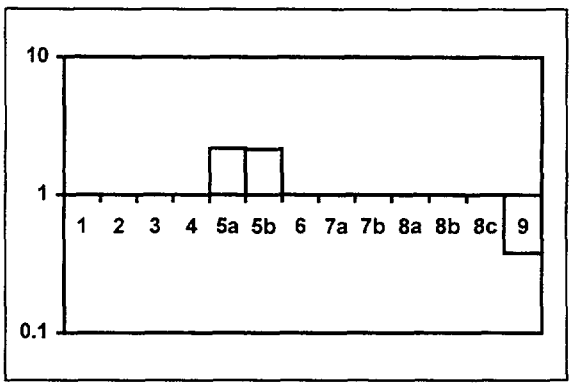

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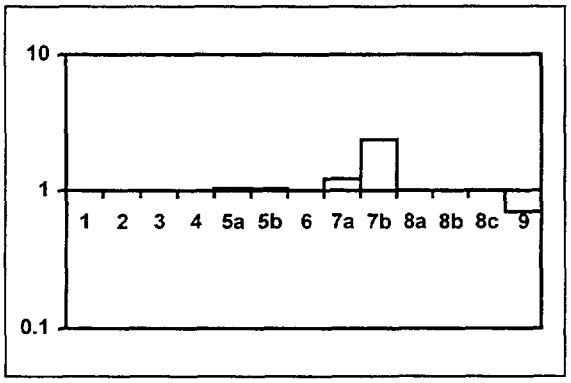

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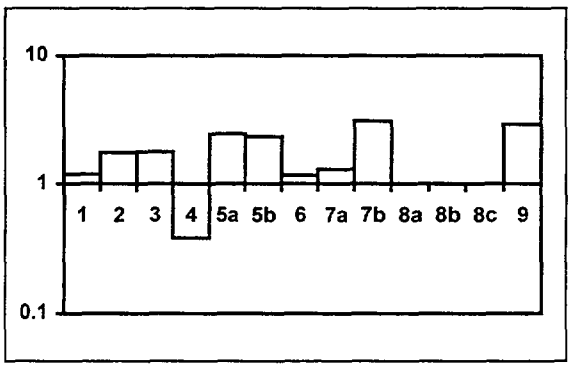

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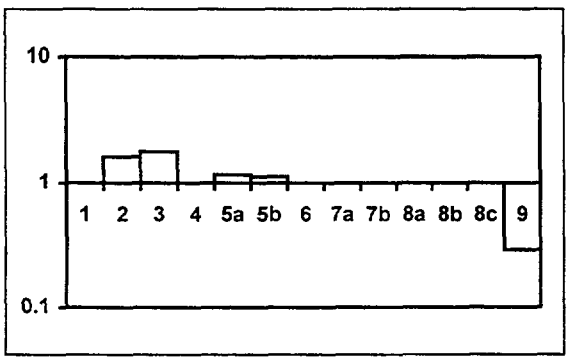

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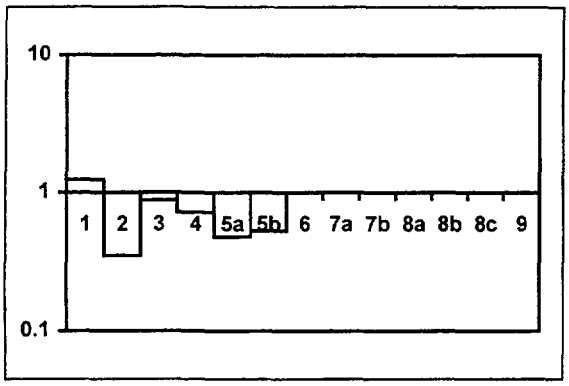

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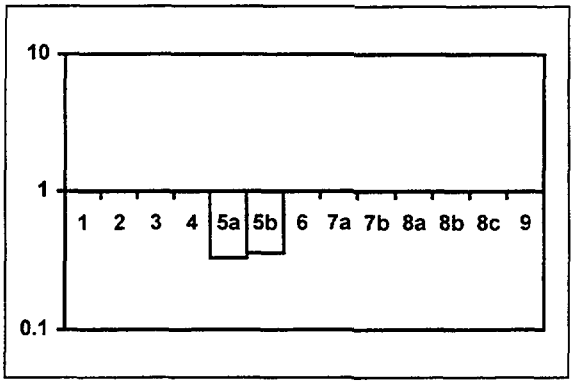

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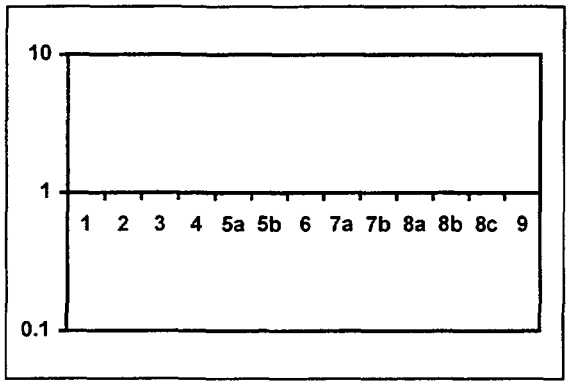

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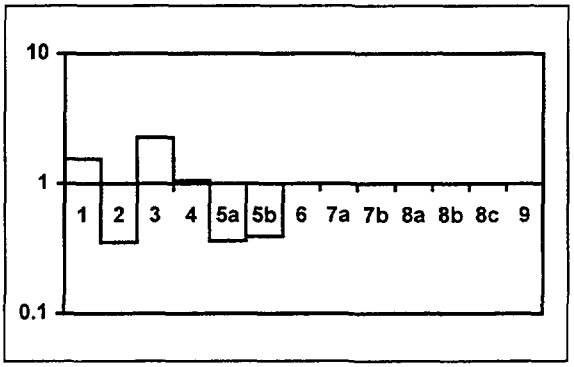

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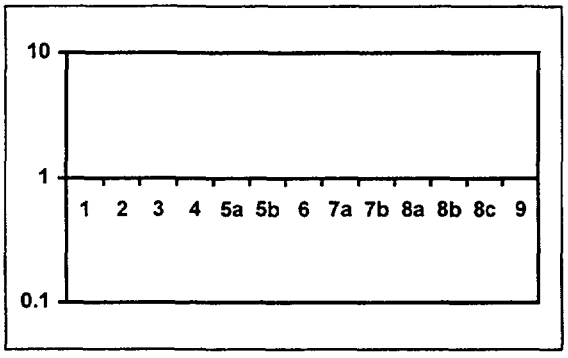

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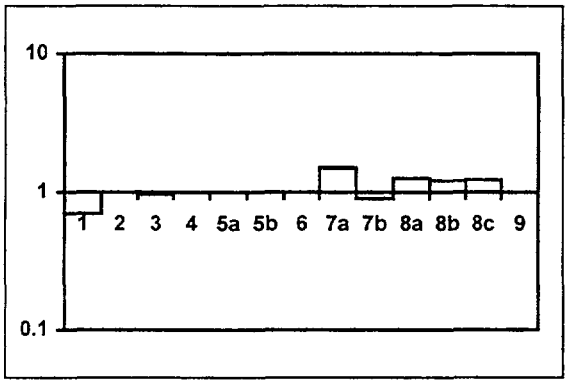

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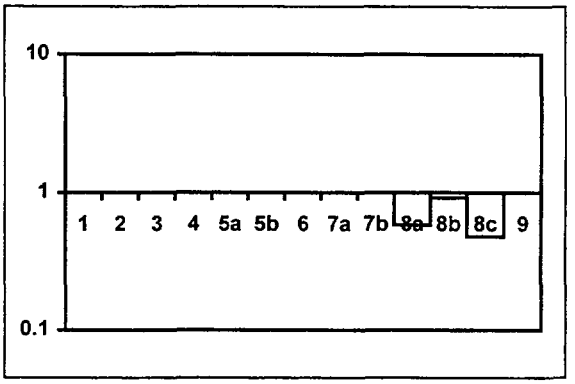

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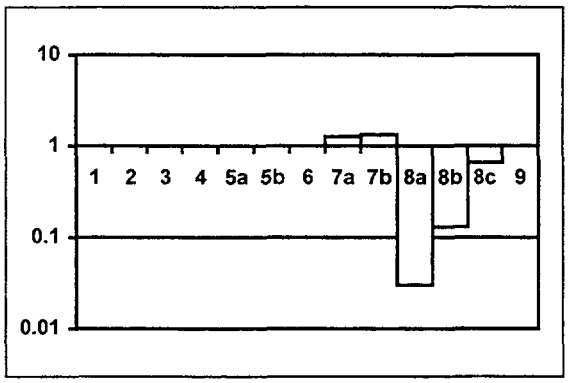

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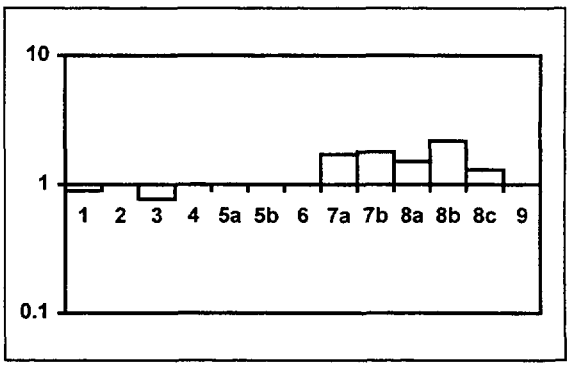

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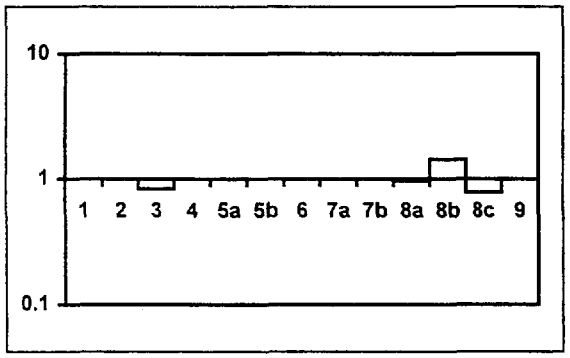

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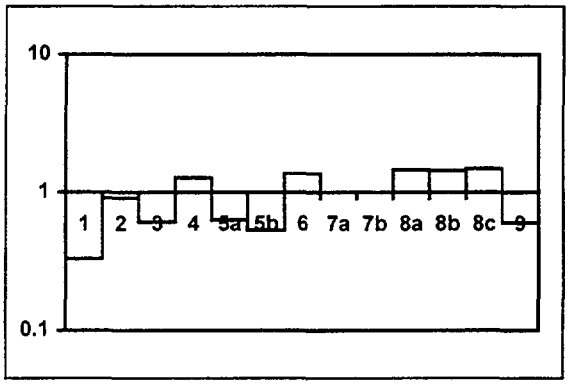

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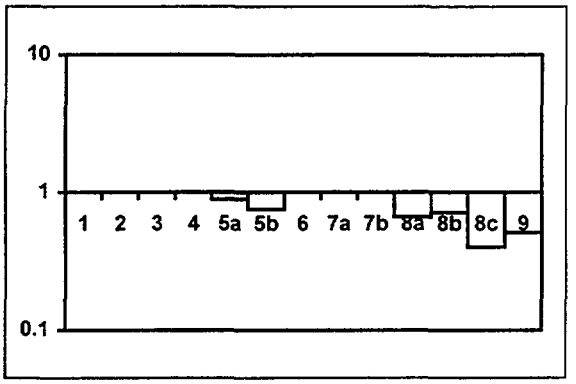

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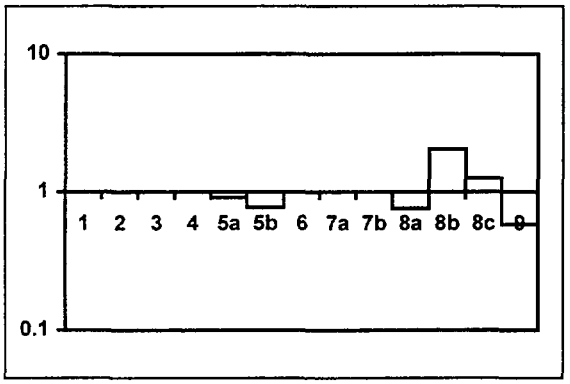

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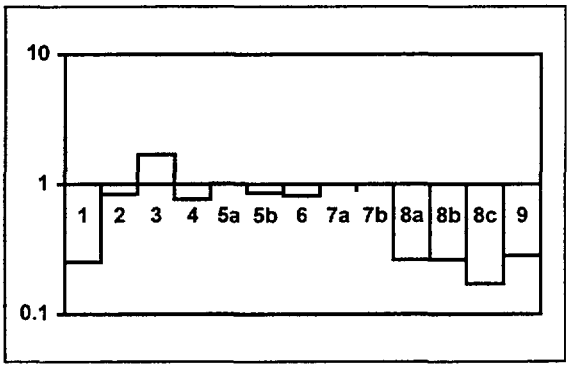

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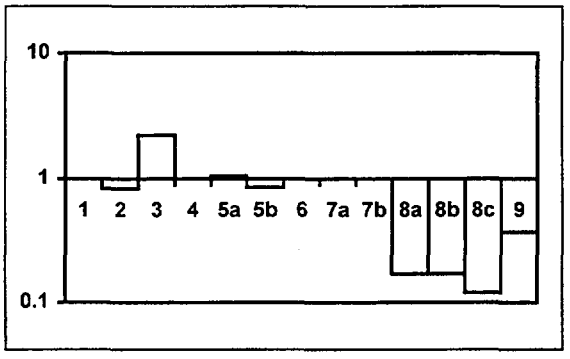

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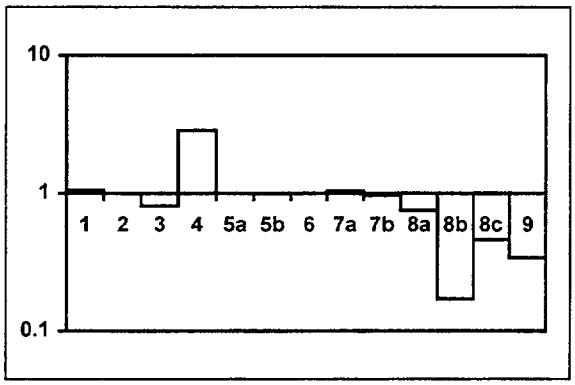

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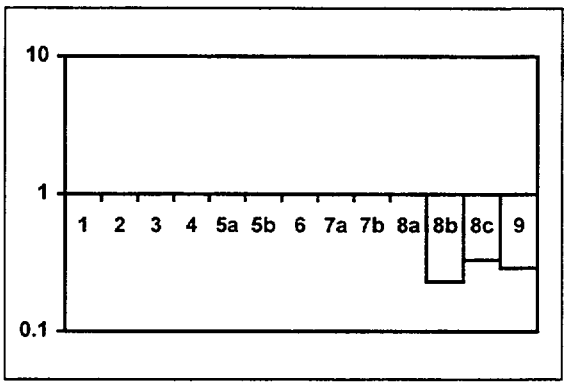

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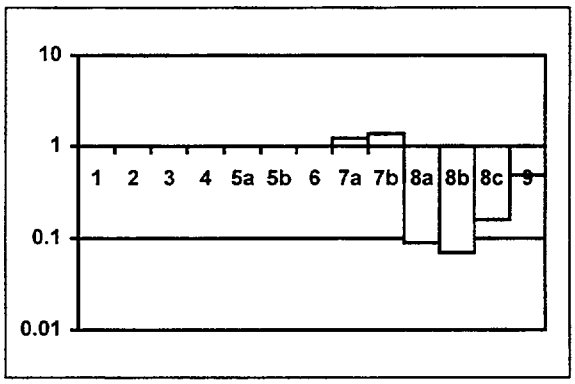

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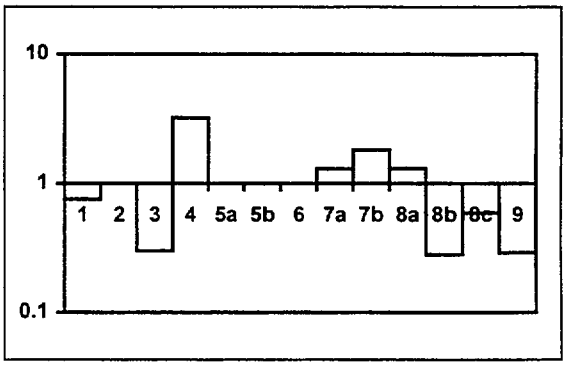

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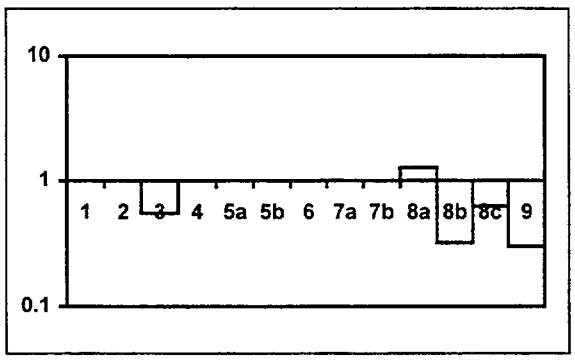

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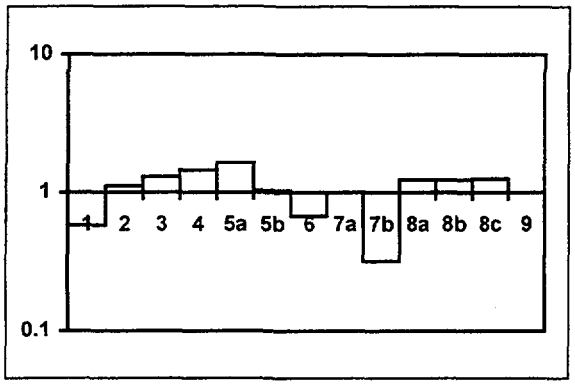

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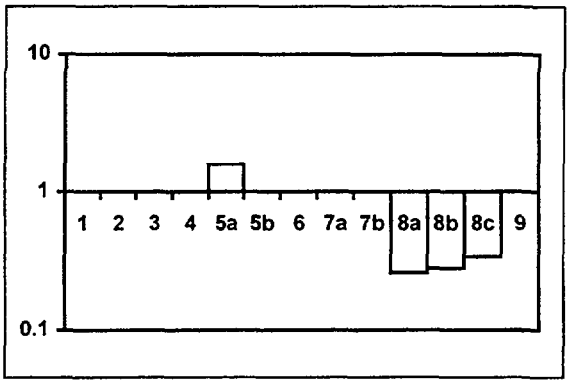

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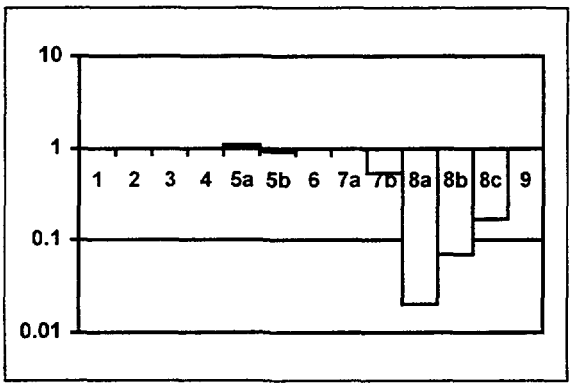

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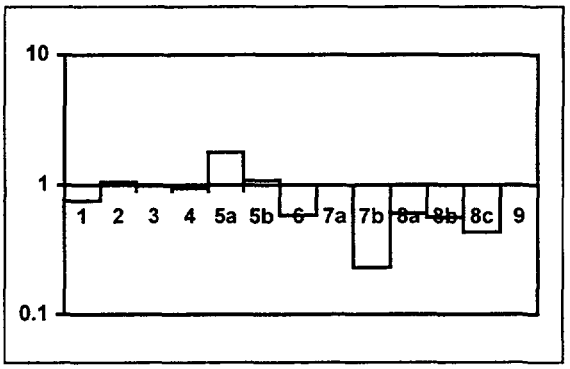

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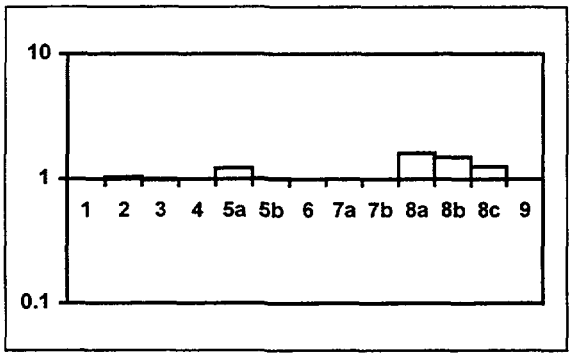

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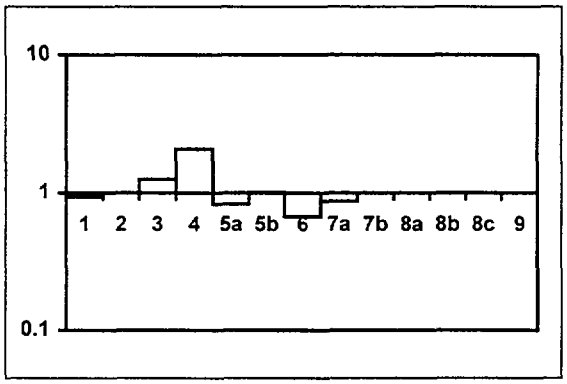

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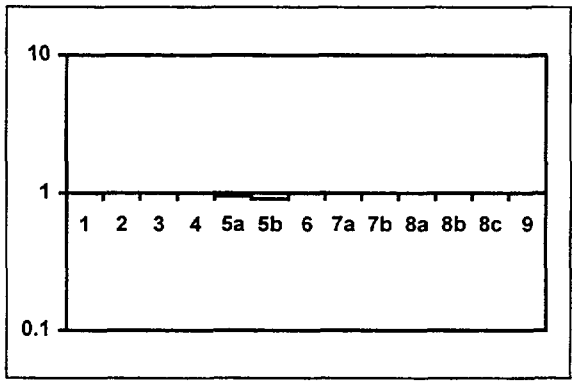

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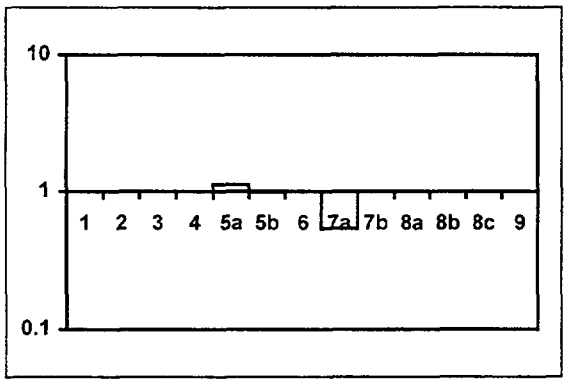

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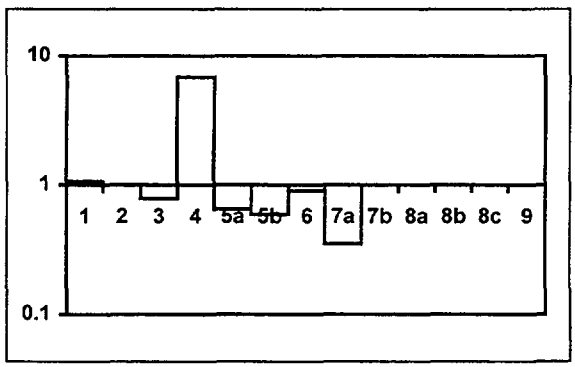

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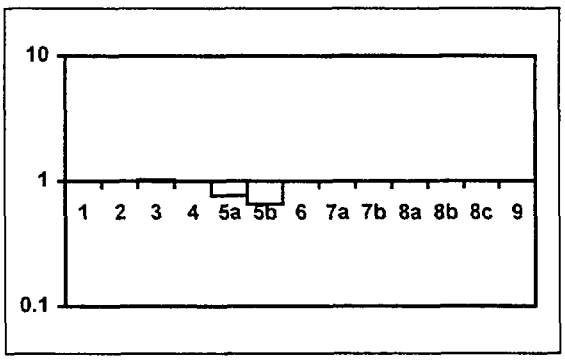

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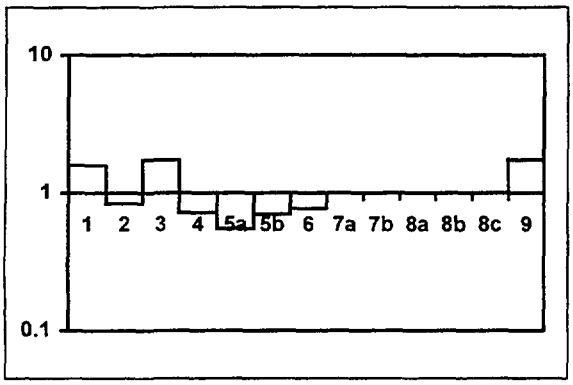

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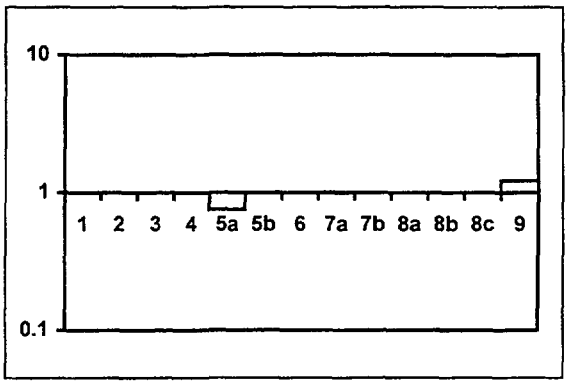

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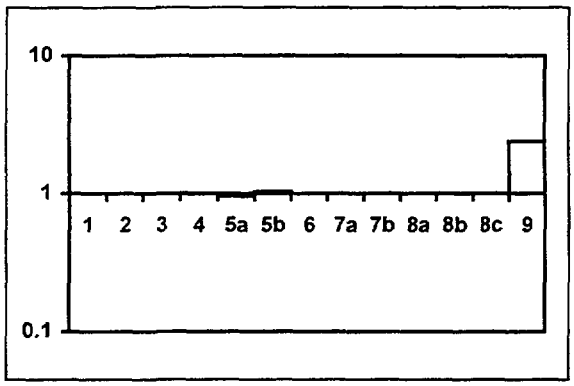

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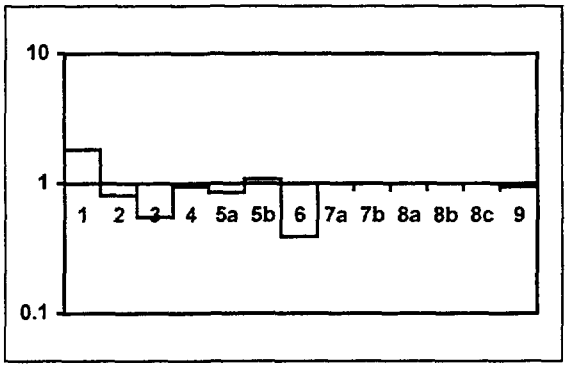

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