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DOSE-Analyzer: A Computer Program with Graphical User Interface to Analyze Absorbed Dose inside a Body of Mouse and Human upon External Neutron Exposure

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DOSE-Analyzer is a computer program to retrieve the dose information from a database and generate a graph through a graphical user interface (GUI). The database is constructed for absorbed dose, fluence, and energy distribution inside a body of mouse and human exposed upon external neutrons, which is calculated by our developed Monte-Carlo simulation method using voxel-based phantom and particle transport code PHITS. The input configurations of irradiation geometry, subject, and energy are set by GUI. The results are tabulated at particle types, *i.e.* electron, proton, deuteron, triton, and alpha particle, and target organs on a data sheet of Microsoft Office Excel™. Simple analysis to compare the output values for two subjects is also performed on DOSE-Analyzer. This report is a user manual of DOSE-Analyzer.

Keywords: DOSE-Analyzer, Neutron Exposure, Absorbed Dose, Fluence, Energy Distribution, Mouse, Human, Monte Carlo Simulation, Voxel Phantom, PHITS

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DOSE-Analyzer: 外部中性子被ばくにおけるマウスとヒトの臓器線量解析のための グラフィカル・ユーザー・インターフェースを備えたコンピュータプログラム

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（2010 年 2 月 22 日受理）

DOSE-Analyzer は、グラフィカル・ユーザー・インターフェース（GUI）を通してデータベースより線量情報を収集し、表とグラフを生成するコンピュータプログラムである。照射体系、対象および中性子エネルギーは GUI 上で設定され、その結果は粒子種（電子、陽子、重陽子、三重陽子、アルファ粒子）および標的臓器毎にまとめられ、Microsoft Office Excel™のデータシートとして出力される。また、二つの照射対象に対して出力された結果は、DOSE-Analyzer 上で比較解析することができる。本レポートは、コンピュータプログラム DOSE-Analyzer のユーザーマニュアルである。

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Contents

目　次

1. Introduction

In general, neutrons are more effective than X-rays and gamma rays for induction of tumors, and for most other late somatic effects of radiation, even if same radiation dose is delivered to a subject.[1] In the 1990 Recommendations of the International Commission on Radiological Protection (ICRP),[2] the radiation weighting factor w_R was introduced into dosimetry for radiological protection to take into account the biological effects of different types of radiation. The values of w_R have been evaluated by reflecting latest knowledge of epidemiology, biophysics, and radiobiology studies with regard to relative biological effectiveness (RBE) that is defined as the ratio of doses of two types of radiation producing the same specified effect. In the 2007 Recommendations of ICRP, the w_R values for neutron below 1 MeV were decreased by considering the effect of neutron-produced secondary particles in a body.[3]

Epidemiological data of large irradiated human populations are significant resources in the evaluation of the w_R values. Among epidemiological studies, a joint working group of Japan and USA researchers developed a dosimetry system for Japanese survivors of the atomic bomb explosions.[4,5] The dosimetry system concluded that the contribution of neutrons is considerably lower than that of gamma rays to the total absorbed dose, and that dose-response relationship of neutrons cannot be determined from the data of the atomic bomb survivors. Thereby, there is no large scale epidemiological data by which to evaluate the neutron RBE in human carcinogenesis, and the evaluation must rely on the experimental data of small animals such as mice and rats.

Many radiobiological experiments have been performed for various endpoints. The National Institute of Radiological Sciences (NIRS, Japan) has carried out the experiments by using mice to analyze the biological effects of fast neutrons for carcinogenesis (murine myeloid and leukemia) and for development of nervous system.[6,7] Although the experimental data are useful to investigate the biological effects of neutrons needed for evaluating the RBE value, some difficulties remain to adopt the RBE data from the nonhuman experimental systems to humans; namely, variations in radiation response among species and in energy-deposition process depending on physical interactions of radiations inside bodies. The National Council on Radiation Protection and Measurements (NCRP) has reviewed this issue from the viewpoint of radiobiology.[8] A precise analysis for RBE from the experimental data requires also a complementary study considering the physical property of the energy deposition upon neutron exposure.

Neutrons going through a body produce various secondary particles by nuclear reactions, and those secondary particles impart energies to the body. Protons, deuterons, tritons, and alpha particles are ejectiles of the neutron-induced reactions with a nucleus. The neutrons moderated down to the thermal energy region (about 0.025 eV) are mainly

captured by a hydrogen nucleus in the body as a result of their interactions, which produce a secondary photon of 2.2 MeV via the $^{1}H(n, \gamma)^{2}D$ reaction. These secondary photons produce electrons through Compton scattering, photoelectric effect and pair production. Thus, the internal radiation fields with the primary neutrons and secondary particles depend on the incident neutron energy and body size, and they are quite different between a mouse and human, even exposed with an identical external neutron field.[9] In order to determine the neutron RBE for humans, it is important to understand the difference of internal radiation fields between animals used in radiological experiments and humans.

Computational simulation with a Monte-Carlo technique is useful to clarify the contributions of the particle types and their energy distributions to organ doses inside a body, which is impossible to determine by experimental investigations. For reliable simulation, it is indispensable to use a numerical phantom reflecting precise information about both the shape of the body and anatomical structure including the internal organs, and a particle transport code that can treat interaction, transport, and energy deposition of not only primary neutrons but also secondary particles in wide energy ranges.

We have developed a simulation method[10,11] to treat the whole range of particle behavior inside a mouse and human by incorporating the numerical phantoms[12-16] into the particle transport code PHITS[17]. The simulations were performed for neutron irradiation to a mouse and human with various neutron-irradiation geometries in the energy region from 10^{-9} to 150 MeV. The models of the mouse and human were developed in the volume-pixel (voxel) based phantom. Although the simulation method is very powerful to analyze the physical processes of secondary particle production and their energy deposition inside a body, it requires technical knowledge about Monte-Carlo simulations.

In order to disseminate the results obtained with our simulation method for the researchers who are not familiar with a Monte-Carlo computational simulation, we have developed a program, named DOSE-Analyzer, to access the simulation results easily through a user-friendly graphical interface. The program has a database of not only the results of our simulation for mouse and human, but the reference data in ICRP Publication 74[18] and the simulation results for simple spheres. By using DOSE-Analyzer, the users can obtain absorbed dose, fluence, energy distribution for each particle at specified organs in a mouse and human. In addition, the results are compared and graphed on the program.

This report is a user manual of DOSE-Analyzer. The overview of the program is described in Section 2. The detail of the simulation method used to prepare the database is explained in Section 3 together with some typical results of the simulation. The construction manner and data format of the database are also described in this section. The user guide is given in Section 4, where the users can find a description of the usage of DOSE-Analyzer. The summary of this report is given in Section 5.

2. Overview of DOSE-Analyzer

DOSE-Analyzer is a computer program to give the data of absorbed dose, fluence, and energy distribution in organs of mouse and human irradiated by external neutrons. The program is designed by Visual Basic for Application (VBA), which is executable on the Microsoft Office Excel™. Figure 1 depicts the flowchart of DOSE-Analyzer. The users can set their input configuration through a graphical user interface (GUI), and obtain numerical values and graphs for the designated physical quantity. The results are extracted from the database constructed by the Monte-Carlo simulations[10,11] with the voxel phantoms[12-16] and the particle transport code PHITS[17]. The comparison of the dose data calculated for the different irradiation subjects is also performed on DOSE-Analyzer. The results are saved as a file of Microsoft Office Excel 97-2007 binary file format (.xls). Appendix-A describes the essential environment of a computer system and the installation procedure of DOSE-Analyzer.

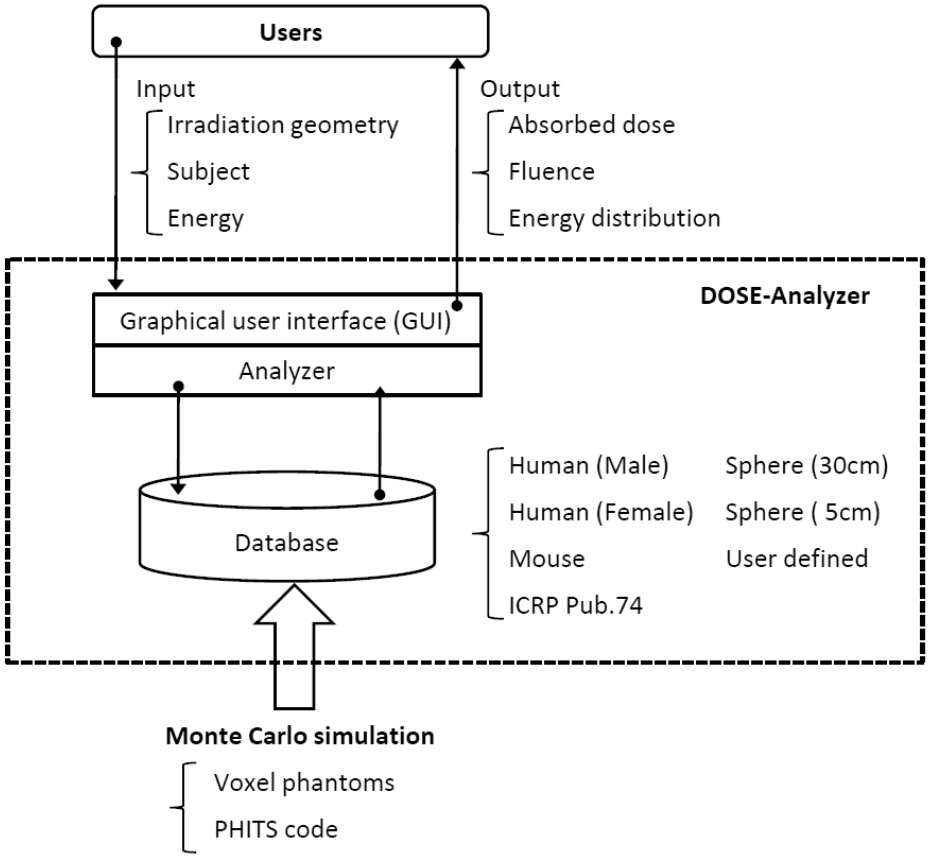


Figure 1. Flowchart of DOSE-Analyzer

3. Preparation of database

The database contained in DOSE-Analyzer has been prepared for absorbed dose, fluence, and energy distribution by means of the Monte-Carlo simulation method with the voxel phantoms and the particle transport code PHITS. The detail of the simulation method is described in the references 10 and 11). For the human models in Section 3.1.1, the results of organ doses showed reasonable agreements with the data in ICRP Publication 74[18], which involves reference data upon external neutron exposure. Here, we give a brief description about the simulation method.

3.1 Phantoms

The numerical phantoms of human (adult male and female), mouse, and sphere were incorporated into the PHITS code to analyze the particle-transport, interaction, and energy-deposition phenomena upon neutron exposure. For reliable simulation, it is indispensable to use a precise phantom reflecting information about both the shape of a body and anatomical structure including the internal organs. Thus, we employed the voxel phantoms in our Monte-Carlo simulation. The voxel phantom was constructed on the basis of tomographic images of a subject, and comprises a large number of voxels arranged like a lattice in the three-dimensional space with various elemental compositions corresponding to the physical properties of the real subject. The description about each phantom is given below.

3.1.1 Adult male and female

The adult male and female were simulated by the voxel phantoms designated as JM (height 171 cm, weight 65 kg) and JF (152 cm, 44 kg), respectively. These phantoms were developed at the Japan Atomic Energy Agency (JAEA) from CT images of healthy Japanese volunteers.[14-16] Figure 2 shows three-dimensional anterior views of the JM and JF. The skin, muscle, and adipose tissues were made transparent to exhibit the internal structure. The size of the unit voxel is $0.98 \times 0.98 \times 1.00$ mm^3. The elemental composition and density of the tissues are summarized in Table 1. These values were taken from the data reported by the ICRP[19] and the National Research Center for Environment and Health (GSF, Germany)[20]. The skeleton system was segmented into 7 subgroups according to the density of the bones determined by the CT values. The elemental compositions of each subgroup were assigned on the basis of the weight percentage of bone marrow.

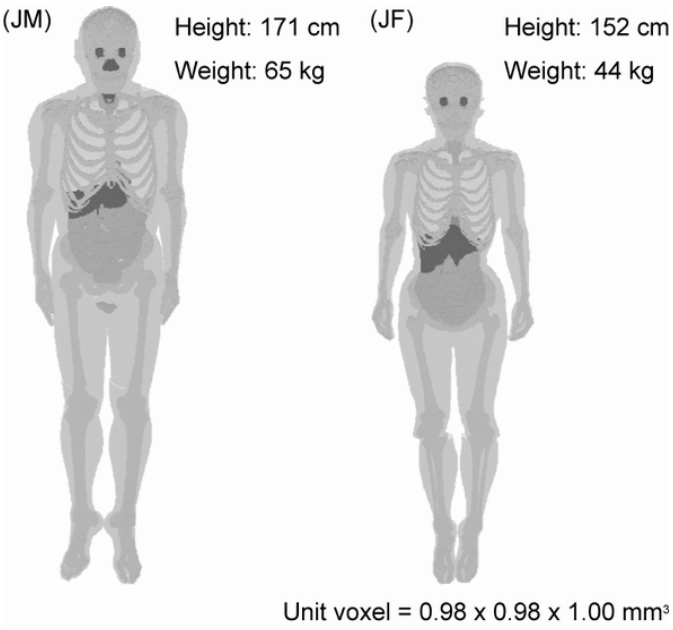


Figure 2. Three-dimensional views of JM and JF

Table 1. Elemental composition of body tissues assigned to JM and JF phantoms

Tissue	Elemental composition (wt%)												Dens. (g/cm^3)
	H	C	N	O	Na	Mg	P	S	Cl	K	Ca	Fe	
Teeth	2.2	9.5	2.9	42.1		0.7	13.7				28.9		2.75
Skin	10.0	20.4	4.2	64.5	0.2		0.1	0.2	0.3	0.1			1.09
Adipose	11.4	59.8	0.7	27.8	0.1		0.1	0.1					0.95
Muscle	10.2	14.3	3.4	71.0	0.1		0.2	0.3	0.1	0.4			1.05
Lung tissue	10.3	10.5	3.1	74.9	0.2		0.2	0.3	0.3	0.2			0.38
Soft tissue 1[a)]	10.5	13.9	2.7	71.8	0.17		0.27	0.17	0.23	0.27	0.03		1.05
Soft tissue 2[b)]	10.2	18.3	3.6	67.0	0.17		0.17	0.23	0.17	0.17			1.05
Soft tissue 3[c)]	10.5	10.8	2.4	75.4	0.15		0.15	0.15	0.21	0.18			1.04
Soft tissue 4[d)]	10.5	26.2	2.7	59.7	0.10		0.20	0.29	0.19	0.20			1.03
Bone 1[e)]	9.04	40.97	2.77	37.41	0.14	0.07	3.19	0.11			6.3	0.001	1.155
Bone 2[f)]	8.05	34.9	3.1	39.06	0.11	0.10	4.86	0.16			9.66	0.001	1.254
Bone 3[g)]	7.5	31.49	3.28	39.98	0.09	0.12	5.8	0.18			11.55	0.001	1.318
Bone 4[h)]	6.94	28.08	3.47	40.91	0.07	0.14	6.74	0.21			13.44		1.388
Bone 5[i)]	6.2	23.53	3.71	42.15	0.05	0.17	8.0	0.24			15.96		1.494
Bone 6[j)]	5.34	18.22	4.0	43.59	0.02	0.2	9.46	0.28			18.9		1.641
Bone 7[k)]	4.72	14.43	4.2	44.62		0.22	10.5	0.31			21.0		1.765

[a)] Brain, heart, kidney [b)] Eyes, liver, pancreas
[c)] Stomach, intestine, ovaries, spleen, testes, thyroid, urinary bladder
[d)] Adrenals, gall bladder, esophagus, thymus, trachea, uterus
[e)] Content of bone marrow is 70wt% [f)] Content of bone marrow is 54wt%
[g)] Content of bone marrow is 45wt% [h)] Content of bone marrow is 36wt%
[i)] Content of bone marrow is 24wt% [j)] Content of bone marrow is 10wt%
[k)] Content of bone marrow is 0wt%

3.1.2 Mouse

The mouse was simulated by the voxel phantom named Digimouse,[12] which was generated on the basis of a three-dimensional whole body atlas of a normal nude male mouse (28 g) taking with two imaging modalities, X-ray microCT and color cryosection images, at the University of Southern California. The mouse phantom was assigned materials according to the elemental compositions of ICRP Publication 89,[19] and voxelized with 0.1 × 0.1 × 0.1 mm^3 of a unit voxel.[13] Figure 3 gives views of the mouse phantom and its internal structure. The elemental compositions are listed in Table 2.

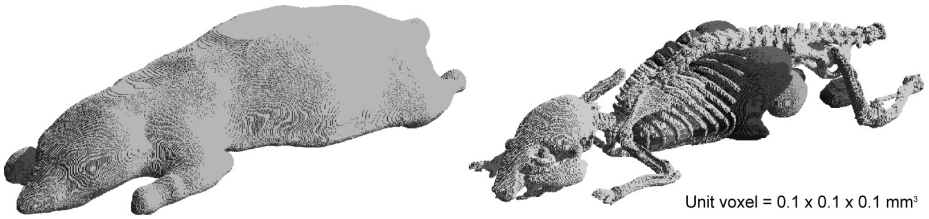


Figure 3. Three-dimensional views of Digimouse and its internal structure

Table 2. Elemental composition of body tissues assigned to Digimouse phantom

Tissue	Elemental composition (wt%)											Dens. (g/cm^3)
	H	C	N	O	Na	Mg	P	S	Cl	K	Ca	
Skin	10.0	20.4	4.2	64.5	0.2		0.1	0.2	0.3	0.1		1.09
Adipose	11.4	59.8	0.7	27.8	0.1		0.1	0.1				0.95
Muscle	10.2	14.3	3.4	71.0	0.1		0.2	0.3	0.1	0.4		1.05
Lung tissue	10.3	10.5	3.1	74.9	0.2		0.2	0.3	0.3	0.2		0.38
Soft tissue 1[a)]	10.5	13.9	2.7	71.8	0.17		0.27	0.17	0.23	0.27	0.03	1.05
Soft tissue 2[b)]	10.2	18.3	3.6	67.0	0.17		0.17	0.23	0.17	0.17		1.05
Soft tissue 3[c)]	10.5	10.8	2.4	75.4	0.15		0.15	0.15	0.21	0.18		1.04
Soft tissue 4[d)]	10.5	26.2	2.7	59.7	0.10		0.20	0.29	0.19	0.20		1.03
Bone	3.40	15.5	4.20	43.5	0.10	0.20	10.30	0.30			22.50	1.920

[a)] Medulla, striatum, external cerebrum, cerebellum, rest of the brain, heart, kidney [b)] Eyes, liver, pancreas
[c)] Stomach, spleen, testes, bladder [d)] Lachrymal glands, adrenals

3.1.3 Spheres

In order to investigate the effect of a subject size on interactions for neutron exposure, we prepared two sizes of simple spherical phantom depicted in Fig. 4. The phantoms consist of ICRU tissue, [21] and the diameters are set at 30 cm and 5 cm, which roughly represent the size of human and mouse bodies. Target regions for calculation of physical quantities were defined at the center of the spheres, and the sizes of the region

were 3.0 cm and 0.5 cm in diameter for 30-cm-diameter and 5-cm-diameter phantoms, respectively.

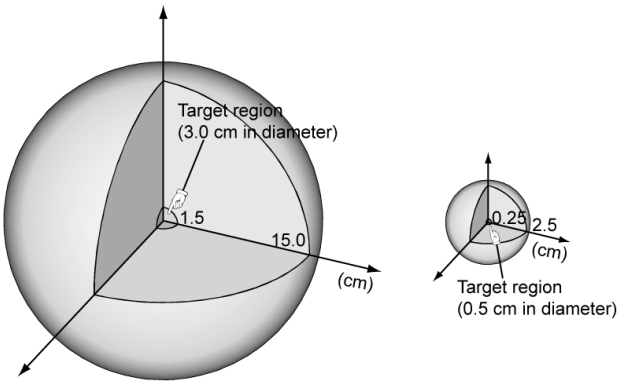


Figure 4. Schematic of spherical phantoms

3.2 Dose calculation in PHITS

3.2.1 Physical quantities

Three kinds of physical quantity, *i.e.* absorbed dose, fluence, and energy distribution were calculated in the Monte-Carlo simulation by PHITS. The each quantity can give useful information as follows;

- **Absorbed dose (pGy cm²)**: In the system of DOSE-Analyzer, the data of absorbed dose are normalized to the fluence of source neutron, and expressed with the unit of pGy cm². Absorbed dose per unit neutron fluence denoted as D, is the quotient of $d\bar{\varepsilon}$ by dm and Φ, where $d\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass dm, and Φ is the neutron fluence, thus:

$$D = \frac{d\bar{\varepsilon}}{dm}\frac{1}{\Phi} \quad \text{(pGy cm}^2\text{)}$$

- **Fluence (1/cm²/source)**: Fluence can present characteristics of radiation field inside the subject. The fluence per source neutron denoted as Φ, is the quotient of dN by da, where dN is the number of particles across a cross-section area da, thus:

$$\Phi = \frac{dN}{da} \quad \text{(1/cm}^2\text{/source)}$$

- **Energy distribution (1/source)**: Distribution of the energies deposited by charged particles at a target organ or tissue. The energy deposition is calculated on basis of the stopping power for the charged particle in the matter. The number of particle is scored at intervals of deposit energy and normalized to the number of source neutron.

3.2.2 Irradiation conditions

In the simulation for neutron transport, each subject was irradiated by mono-energetic neutrons in the energy region between 10^{-9} MeV and 150 MeV with the idealized irradiation geometry, *i.e.* AP, PA, LLAT, RLAT, ROT, and ISO. The schematic of the irradiation geometries is depicted in Fig. 5, and the explanation is given below:

- **AP**: Antero-posterior geometry. Neutrons are incident on the whole body in a direction orthogonal to the long axis of the body from the front to back.
- **PA**: Postero-anterior geometry. Neutrons are incident on the whole body in a direction orthogonal to the long axis of the body from the back to front.
- **LLAT**: Left lateral geometry. Neutrons are incident on the whole body from the left of the body.
- **RLAT**: Right lateral geometry. Neutrons are incident on the whole body from the right of the body.
- **ROT**: Rotational geometry. Irradiation by a parallel beam rotating at a uniform rate around the long axis of the body.
- **ISO**: Isotropic geometry. Neutrons are incident on the whole body isotropically for three dimensions.

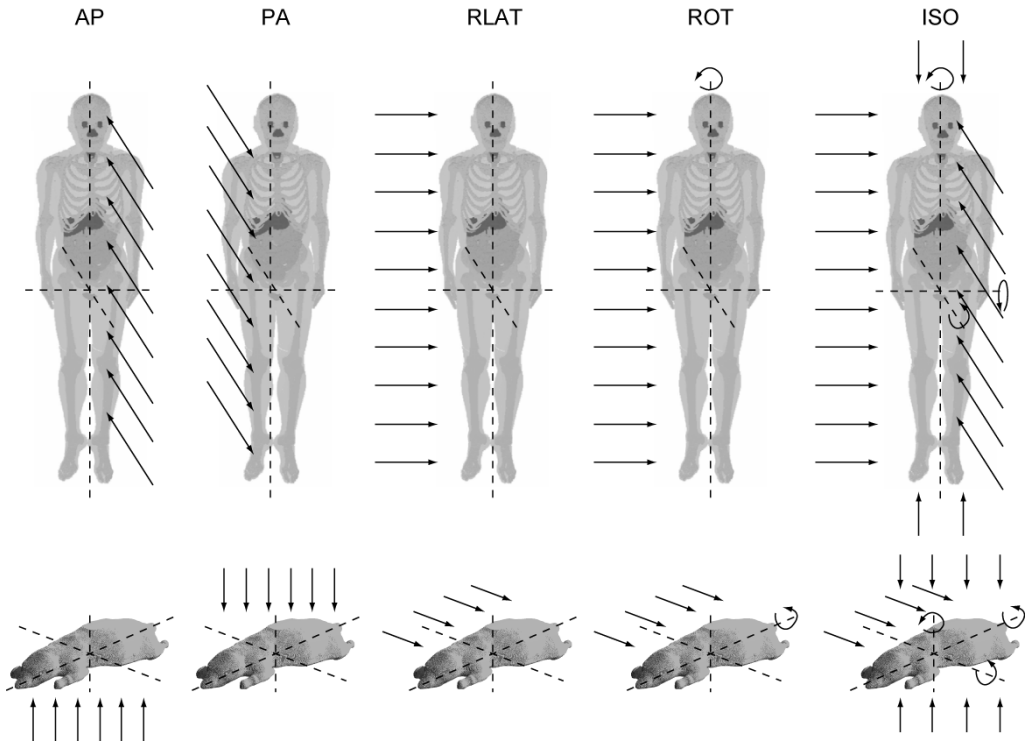


Figure 5. Schematic of irradiation geometries.

3.2.3 Particle transport conditions

The incident neutrons and the secondary particles produced in the phantoms were tracked until their kinetic energies fall below the cutoff energies, or the particles escape outside the computational geometry. The cutoff energies were set at 1.0×10^{-10} MeV for neutrons and 1.0×10^{-3} MeV for photons, electrons and the other charged particles. The particle transport above 20 MeV was calculated with the theoretical models Jet AA Microscopic[22] (JAM), Quantum Molecular Dynamics[23] (QMD), and Generalized Evaporation Model[24] (GEM). Below 20 MeV, the transport was processed with continuous-energy nuclear-data libraries, in which evaluated cross sections and angular distributions of the nuclear reactions caused by a specific particle incidence are compiled. The U.S. Evaluated Nuclear Data Files, ENDF/B-VII.0,[25] were applied for neutron and photon transport. The thermal neutron scattering sub-library, S(α, β) data, for hydrogen in light water was also utilized to take into account the effect of molecular binding that is important in thermal neutron scattering.

The absorbed dose, fluence, and energy distribution for each particle were calculated by event generator (EG) mode[26] of PHITS. This mode makes it possible to treat the particle behavior considering all significant correlations between the incident neutron and the ejectiles event by event. In the EG mode, an interaction point and a reaction type are sampled using random numbers and probability densities that are tabulated in the nuclear-data library. If the reaction type demands ejection of one or more neutrons, the nuclear data are used again to determine the kinetic energy and the direction vector of the first outgoing neutron. Then, the emissions of the remnants including charged particles are processed by a special statistical decay model restricted to be consistent with the reaction type and the energy balance. Through the above procedure, an event is generated which observes energy and momentum conservation and preserves the accuracy of the transport calculation made using the nuclear-data library.

The estimated relative errors in the Monte Carlo dose calculation, defined as one estimated standard deviation of the mean (SDOM) divided by the estimated mean, were set below 0.10.

3.2.4 Typical results

We show some typical results obtained from the Monte-Carlo simulation using the voxel phantom and PHITS. Figure 6 depicts the calculation results of absorbed dose at the stomach in the ISO irradiation geometry together with the contribution of electrons and protons. The upper and lower figures indicate the results for the adult male and mouse, respectively. It is obvious that the energy dependence and particle type contributing to the

absorbed dose are different in human and mouse even at the same organ for the identical external neutron field.

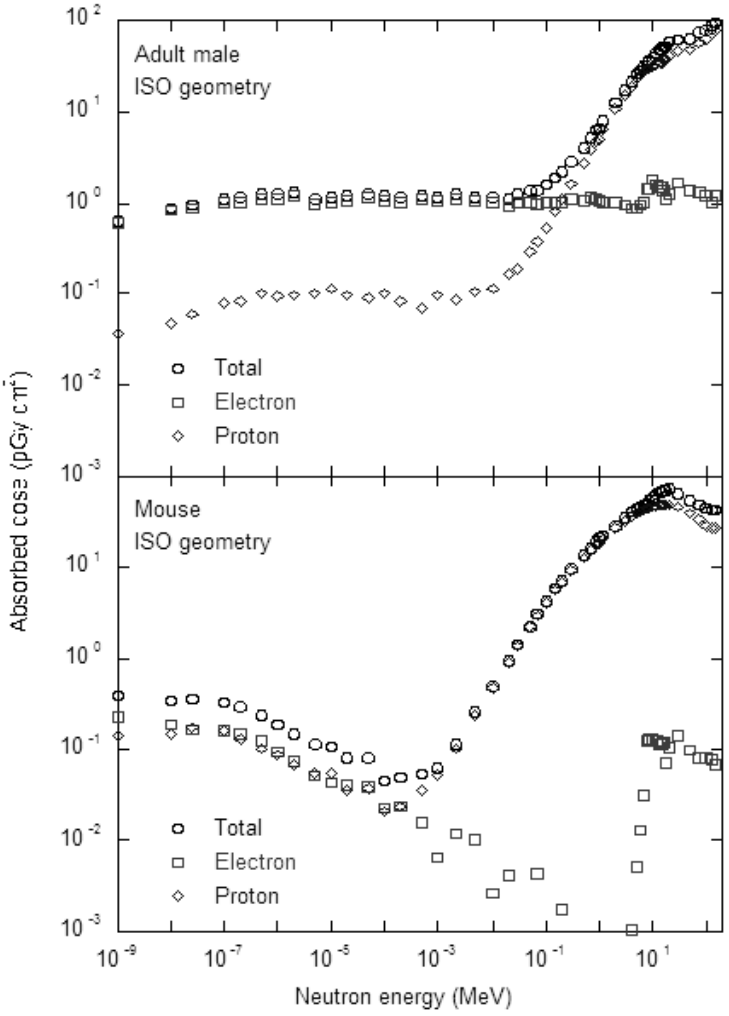


Figure 6. Absorbed dose per unit neutron fluence for stomach in ISO geometry.

In the results for the adult male, the contribution of proton is dominant above about 10^{-1} MeV, and the electrons play an important role below 10^{-1} MeV. This can be explained as follows. The neutrons which have higher incident energy collide with hydrogen nuclei (protons), and kick out them. Then the scattered protons impart their energies to the target organ. As decreasing the incident energy, the neutrons passing through the body are slowed down and thermalized by nuclear reaction and multiple scattering. The thermalized neutron, whose kinetic energy is about 0.025 eV, is captured by hydrogen nucleus, and the nucleus releases a 2.2-MeV photon via $^{1}H(n, \gamma)^{2}D$ reaction. The secondary photon transfers the energy to the electron by Compton scattering, and the electron deposits the energy at the target organ.

On the other hand, for the mouse, the neutrons are not significantly moderated

because the body size of the mouse is smaller than the one of the human. Therefore, the contribution of the scattered protons is dominant in the incident energies above about 10^{-3} MeV, which is two order lower than the energy in the human case. The electron component observed above 10 MeV originates from the photons emitted from the residual nuclei excited by the fast neutron collisions.

Figure 7 shows the distribution of energies deposited at the stomach in a human body upon irradiation with neutrons of 10 and 10^{-3} MeV in the ISO geometry. The energy spectra of electron are limited to below a few mega-electron volts, because almost all electrons are created from the interactions with secondary photons with energies of 2.2 MeV. A peak of deuterons observed around 10^{-3} MeV in deposit energy is composed of the remnant of $^{1}H(n, \gamma)^{2}D$ reaction.

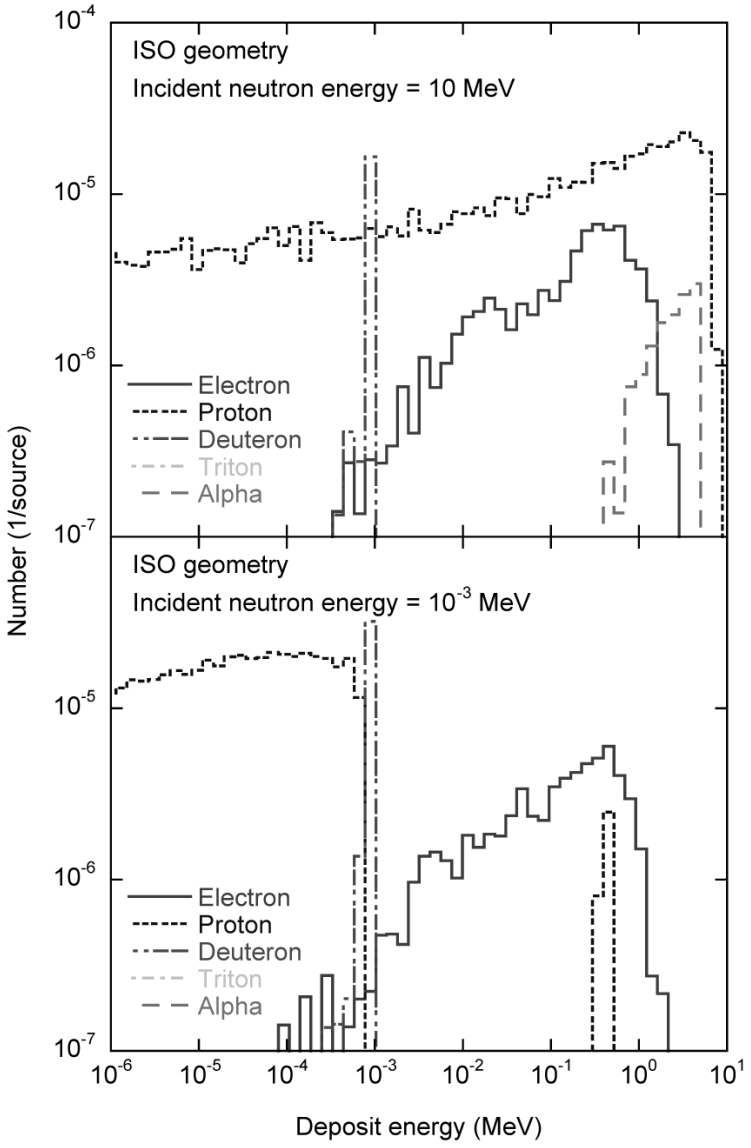


Figure 7. Distribution of deposit energy in human stomach.

The deposit energies by proton are distributed below the incident energy, because the protons are transferred the energy from the incident neutrons through the elastic scattering. One can see a sharp peak of protons in the lower figure. The peak is constructed by 0.62 MeV protons emitted from the neutron capture reaction of a nitrogen nucleus, *i.e.* $^{14}N(n, p)^{14}C$. The component of alpha particle is appeared in 10 MeV neutron irradiations. This comes from the non-elastic reactions of neutrons with nuclei, such as $^{16}O(n, \alpha)^{13}C$ and $^{12}C(n, \alpha)^{9}Be$.

The Monte-Carlo simulation with precise phantoms gives significant information about the particle behavior inside the body of the irradiated subject. By utilizing DOSE-Analyzer, the users can retrieve the information easily from the database constructed with the simulations.

3.3 Construction manner of database in DOSE-Analyzer

We explain here the construction manner of the database adopted in DOSE-Analyzer. The data were saved in a file for each particle and each irradiation condition. For example, the data of absorbed dose at AP geometry were saved in the file named “AP_dose.txt”. For electron, proton, deuteron, triton, and alpha particle, the file name was appended the following characters; “_e”, “_p”, “_d”, “_t”, and “_a”, respectively, *e.g.* the fluence of electrons at ISO irradiation is named as “ISO_fluence_e.txt”.

The database was constructed by columns of text data whose width is 10 characters and delimited by a single space. The detailed format for the data of absorbed dose, fluence, and energy distribution are given below.

3.3.1 Data format for absorbed dose

Figure 8 shows an example of the database for absorbed dose. The first line is dedicated to the titles of each column. These titles are exhibited in the data sheets of the DOSE-Analyzer output. The numerical values of absorbed dose are given from the second line. The first column indicates the kinetic energy of irradiation neutrons in the unit of MeV. The following columns are the data of absorbed dose of target organs in the irradiation energy. The doses are normalized to the fluence of the source neutron, and given in the unit of pGy cm^2. The users can change the number of column according to the number of interesting organs.

ISO_dose.txt

	Energy	Brain	Eyes	Heart	Kidney	Liver	Lung	Pancreas	Skin	Spleen	Stomac
2	1.5000E+02	9.4013E+01	7.1912E+01	9.6075E+01	1.0119E+02	1.0141E+02	9.2631E+01	1.0164E+02	6.4287E+01	9.3673E+01	9.7824E+0
3	1.3000E+02	8.9744E+01	8.6259E+01	9.4465E+01	9.2728E+01	9.5855E+01	9.0801E+01	9.2842E+01	6.2177E+01	9.7168E+01	9.3636E+0
4	1.0000E+02	8.2615E+01	7.8145E+01	8.3521E+01	8.2439E+01	8.2984E+01	8.1107E+01	7.9842E+01	5.5949E+01	7.6849E+01	7.8384E+0
5	7.5000E+01	7.2403E+01	6.3458E+01	7.2481E+01	7.3808E+01	7.3938E+01	7.1219E+01	7.8845E+01	5.2594E+01	6.8995E+01	6.9769E+0
6	5.0000E+01	6.6780E+01	6.0993E+01	6.5717E+01	6.5633E+01	6.7155E+01	6.5824E+01	6.6000E+01	5.0477E+01	6.6916E+01	6.4232E+0
7	3.0000E+01	6.5313E+01	5.2677E+01	6.2452E+01	5.9845E+01	6.0501E+01	6.1489E+01	5.9225E+01	5.0392E+01	6.3235E+01	5.7400E+0
8	2.0000E+01	6.2917E+01	6.5429E+01	5.7572E+01	5.5311E+01	5.6321E+01	6.0621E+01	5.4907E+01	5.4655E+01	5.7309E+01	5.6843E+0
9	1.8000E+01	6.0154E+01	6.0034E+01	5.4773E+01	5.0770E+01	5.2908E+01	5.7141E+01	5.6534E+01	5.2451E+01	5.3686E+01	5.5548E+0
10	1.6000E+01	5.8213E+01	5.7677E+01	5.4039E+01	4.7419E+01	5.1187E+01	5.5015E+01	4.7419E+01	5.2176E+01	5.4992E+01	5.1942E+0
11	1.5000E+01	5.6098E+01	5.5071E+01	5.0482E+01	4.6874E+01	4.9284E+01	5.3560E+01	4.7633E+01	5.0928E+01	4.9892E+01	4.9806E+0
12	1.4000E+01	5.3891E+01	4.8363E+01	4.9931E+01	4.2332E+01	4.6805E+01	5.1465E+01	4.5437E+01	4.8954E+01	4.7855E+01	4.7145E+0
13	1.2000E+01	5.0111E+01	4.6430E+01	4.7326E+01	4.0904E+01	4.3120E+01	4.7757E+01	4.2100E+01	4.7923E+01	4.5639E+01	4.2977E+0
14	1.0000E+01	4.5954E+01	4.7093E+01	4.1894E+01	3.5909E+01	3.8209E+01	4.3169E+01	3.3824E+01	4.3682E+01	3.6068E+01	3.9641E+0
15	9.0000E+00	4.3148E+01	4.7168E+01	3.8333E+01	3.3466E+01	3.6342E+01	4.1215E+01	3.4448E+01	4.1225E+01	3.8132E+01	3.6364E+0
16	8.0000E+00	4.0169E+01	4.1258E+01	3.6068E+01	3.0720E+01	3.2860E+01	3.7333E+01	3.0593E+01	3.8711E+01	3.2897E+01	3.3141E+0
17	7.0000E+00	3.8062E+01	3.7104E+01	3.3842E+01	2.9452E+01	3.1184E+01	3.5338E+01	3.0739E+01	3.6967E+01	3.2962E+01	3.3161E+0
18	6.0000E+00	3.5272E+01	3.6000E+01	3.0369E+01	2.5676E+01	2.7994E+01	3.2768E+01	2.6608E+01	3.5570E+01	2.8093E+01	2.9786E+0
19	5.0000E+00	3.1226E+01	3.2032E+01	2.7824E+01	2.4054E+01	2.5178E+01	2.9704E+01	2.4233E+01	3.2740E+01	2.7001E+01	2.5587E+0
20	4.0000E+00	2.7584E+01	2.4855E+01	2.2702E+01	1.8627E+01	2.0878E+01	2.4760E+01	1.9792E+01	2.9718E+01	2.1447E+01	2.1247E+0
21	3.0000E+00	2.2313E+01	2.0142E+01	1.8348E+01	1.4682E+01	1.6929E+01	2.0377E+01	1.5030E+01	2.4919E+01	1.6861E+01	1.8046E+0
22	2.0000E+00	1.6127E+01	1.6769E+01	1.2738E+01	1.0141E+01	1.1937E+01	1.4832E+01	1.0173E+01	2.0265E+01	1.2057E+01	1.3101E+0
23	1.2000E+00	1.0256E+01	1.2356E+01	7.4408E+00	5.8128E+00	7.2673E+00	9.2108E+00	6.6383E+00	1.5534E+01	8.8250E+00	8.2455E+0
24	1.0000E+00	7.6774E+00	1.0770E+01	5.4126E+00	4.0249E+00	5.3359E+00	6.7964E+00	4.4960E+00	1.4929E+01	5.8696E+00	6.5410E+0
25	9.0000E-01	7.8226E+00	9.4294E+00	5.7788E+00	4.3657E+00	5.4734E+00	6.9379E+00	5.0431E+00	1.3062E+01	6.0481E+00	6.4818E+0
26	7.0000E-01	6.3396E+00	8.3027E+00	4.5225E+00	3.4930E+00	4.5091E+00	5.6441E+00	3.7347E+00	1.1117E+01	5.0196E+00	5.4238E+0
27	5.0000E-01	4.6140E+00	6.7537E+00	3.4611E+00	2.8537E+00	3.4855E+00	4.0597E+00	2.9155E+00	9.1626E+00	3.4070E+00	4.1356E+0
28	3.0000E-01	2.9150E+00	3.7614E+00	2.3021E+00	1.9165E+00	2.3887E+00	2.5396E+00	2.1320E+00	6.8042E+00	2.3932E+00	2.9142E+0
29	2.0000E-01	2.1701E+00	3.0949E+00	1.7259E+00	1.7510E+00	1.9133E+00	1.9685E+00	1.8055E+00	5.3434E+00	2.2845E+00	2.2527E+0
30	1.5000E-01	1.8137E+00	2.4461E+00	1.5471E+00	1.5933E+00	1.6844E+00	1.6563E+00	1.4877E+00	4.4793E+00	1.4115E+00	1.8281E+0
31	1.0000E-01	1.4536E+00	2.3471E+00	1.3893E+00	1.5272E+00	1.5081E+00	1.3400E+00	1.3825E+00	3.4475E+00	1.4616E+00	1.5673E+0
32	7.0000E-02	1.2532E+00	1.4007E+00	1.2943E+00	1.3005E+00	1.3729E+00	1.2705E+00	1.1434E+00	2.7630E+00	1.8702E+00	1.4575E+0
33	5.0000E-02	1.2037E+00	8.9514E-01	1.3367E+00	1.3695E+00	1.2813E+00	1.1612E+00	1.1138E+00	2.2473E+00	1.3338E+00	1.2720E+0
34	3.0000E-02	1.0767E+00	1.0933E+00	1.2014E+00	1.3028E+00	1.2777E+00	1.0683E+00	1.3335E+00	1.6227E+00	1.0294E+00	1.1021E+0
35	2.0000E-02	1.0302E+00	8.3888E-01	1.2557E+00	1.4693E+00	1.2001E+00	1.0840E+00	1.1754E+00	1.2667E+00	9.9970E-01	1.1719E+0
36	1.0000E-02	1.0268E+00	1.1860E+00	1.1953E+00	1.3131E+00	1.2083E+00	1.0556E+00	1.3136E+00	9.4964E-01	9.9148E-01	1.1381E+0
37	5.0000E-03	1.0519E+00	1.0255E+00	1.0805E+00	1.2881E+00	1.2035E+00	1.0152E+00	1.1991E+00	7.3588E-01	1.4536E+00	1.2697E+0
38	2.0000E-03	1.0897E+00	7.7378E-01	1.1552E+00	1.2569E+00	1.1973E+00	1.0468E+00	1.2162E+00	6.4807E-01	1.0787E+00	1.1646E+0
39	1.0000E-03	1.0610E+00	6.7212E-01	1.2681E+00	1.2429E+00	1.2752E+00	1.0691E+00	1.2534E+00	6.1860E-01	1.5392E+00	1.1543E+0

Figure 8. Example of database for absorbed dose

3.3.2 Data format for fluence

An example is depicted in Fig. 9. The first line of the file is the titles of the data column. The irradiation energy is indicated in the first column with MeV, and the fluence at the target organs are given in the following columns expressed in the unit of 1/cm²/source. The number of the columns is changeable on the user's demand.

ISO_fluence.txt

	Energy	Brain	Eyes	Heart	Kidney	Liver	Lung	Pancreas	Skin	Spleen	Stomac
2	1.5000E+02	4.0276E-05	3.8317E-05	4.2322E-05	4.5532E-05	4.3711E-05	4.0968E-05	4.5523E-05	3.6583E-05	4.2762E-05	4.3214E-0
3	1.3000E+02	3.9613E-05	3.7761E-05	4.2131E-05	4.5232E-05	4.3449E-05	4.0568E-05	4.5399E-05	3.6401E-05	4.2861E-05	4.2949E-0
4	1.0000E+02	3.9662E-05	3.7926E-05	4.1769E-05	4.5376E-05	4.2904E-05	4.0460E-05	4.4780E-05	3.6223E-05	4.2263E-05	4.2916E-0
5	7.5000E+01	3.9577E-05	3.8383E-05	4.1787E-05	4.5497E-05	4.3410E-05	4.0522E-05	4.5298E-05	3.5948E-05	4.2588E-05	4.3007E-0
6	5.0000E+01	3.9772E-05	3.6936E-05	4.1944E-05	4.6231E-05	4.3634E-05	4.0809E-05	4.5260E-05	3.5771E-05	4.2351E-05	4.3031E-0
7	3.0000E+01	4.0173E-05	3.9282E-05	4.2867E-05	4.6817E-05	4.4725E-05	4.1622E-05	4.6880E-05	3.5650E-05	4.2483E-05	4.3840E-0
8	2.0000E+01	3.7598E-05	3.5264E-05	3.9906E-05	4.3294E-05	4.0800E-05	3.8902E-05	4.2912E-05	3.3030E-05	3.8423E-05	4.0334E-0
9	1.8000E+01	3.7846E-05	3.4748E-05	4.1046E-05	4.4699E-05	4.1675E-05	3.9640E-05	4.3678E-05	3.3115E-05	4.0508E-05	4.0603E-0
10	1.6000E+01	3.8990E-05	3.5747E-05	4.1673E-05	4.5311E-05	4.2425E-05	4.0054E-05	4.4918E-05	3.3186E-05	4.1552E-05	4.1483E-0
11	1.5000E+01	3.8908E-05	3.5592E-05	4.1871E-05	4.5547E-05	4.2939E-05	4.0266E-05	4.5512E-05	3.3186E-05	4.1110E-05	4.1923E-0
12	1.4000E+01	3.8679E-05	3.4928E-05	4.1750E-05	4.5809E-05	4.3247E-05	4.0388E-05	4.5724E-05	3.3195E-05	4.1230E-05	4.2028E-0
13	1.2000E+01	3.9223E-05	3.7436E-05	4.2675E-05	4.5890E-05	4.3227E-05	4.1054E-05	4.5882E-05	3.3335E-05	4.2124E-05	4.2470E-0
14	1.0000E+01	4.0938E-05	3.6778E-05	4.4460E-05	4.8620E-05	4.4935E-05	4.2571E-05	4.7665E-05	3.3601E-05	4.2976E-05	4.3777E-0
15	9.0000E+00	4.1515E-05	3.7375E-05	4.5285E-05	4.8677E-05	4.5842E-05	4.3147E-05	4.8749E-05	3.3430E-05	4.3479E-05	4.4116E-0
16	8.0000E+00	4.2526E-05	3.6805E-05	4.6010E-05	4.9540E-05	4.6457E-05	4.3879E-05	4.9779E-05	3.3457E-05	4.3131E-05	4.4681E-0
17	7.0000E+00	4.2264E-05	3.7310E-05	4.6399E-05	5.0564E-05	4.6962E-05	4.4093E-05	4.9723E-05	3.2899E-05	4.4812E-05	4.4771E-0
18	6.0000E+00	4.2792E-05	3.7389E-05	4.7187E-05	5.0502E-05	4.6457E-05	4.4427E-05	4.9922E-05	3.2914E-05	4.4508E-05	4.4544E-0
19	5.0000E+00	4.3671E-05	3.5825E-05	4.7819E-05	5.1450E-05	4.7747E-05	4.5507E-05	5.0381E-05	3.2420E-05	4.4668E-05	4.5484E-0
20	4.0000E+00	4.4864E-05	3.8602E-05	4.8635E-05	5.2116E-05	4.8396E-05	4.6530E-05	5.1114E-05	3.2521E-05	4.4734E-05	4.6083E-0
21	3.0000E+00	4.7772E-05	4.0258E-05	5.2437E-05	5.4936E-05	5.1207E-05	4.9209E-05	5.3516E-05	3.2779E-05	4.7444E-05	4.7131E-0
22	2.0000E+00	4.9598E-05	4.0651E-05	5.3109E-05	5.4407E-05	5.0384E-05	5.0222E-05	5.1628E-05	3.2812E-05	4.6993E-05	4.6894E-0
23	1.2000E+00	4.8492E-05	4.0937E-05	5.0621E-05	5.0255E-05	4.7670E-05	4.8386E-05	4.7297E-05	3.2732E-05	4.6565E-05	4.4736E-0
24	1.0000E+00	4.3602E-05	3.8689E-05	4.4442E-05	4.3463E-05	4.2428E-05	4.3044E-05	4.1658E-05	3.2259E-05	4.0338E-05	3.9702E-0
25	9.0000E-01	4.8535E-05	4.0815E-05	4.9804E-05	4.7484E-05	4.6832E-05	4.7545E-05	4.6269E-05	3.2608E-05	4.3548E-05	4.3333E-0
26	7.0000E-01	4.9022E-05	3.9110E-05	4.8935E-05	4.5933E-05	4.5637E-05	4.7227E-05	4.4523E-05	3.2627E-05	4.4563E-05	4.2396E-0
27	5.0000E-01	4.7455E-05	4.0490E-05	4.6171E-05	4.3486E-05	4.3009E-05	4.5304E-05	4.2516E-05	3.2548E-05	4.2338E-05	4.0799E-0
28	3.0000E-01	4.4192E-05	3.8298E-05	4.2851E-05	3.8918E-05	3.9446E-05	4.1884E-05	3.7857E-05	3.2414E-05	3.9484E-05	3.8121E-0
29	2.0000E-01	4.2260E-05	3.7885E-05	4.1061E-05	3.7432E-05	3.7979E-05	4.0699E-05	3.6701E-05	3.2328E-05	3.8566E-05	3.6934E-0
30	1.5000E-01	4.1274E-05	3.7132E-05	3.9527E-05	3.5459E-05	3.6376E-05	3.9115E-05	3.4045E-05	3.2224E-05	3.7220E-05	3.5515E-0
31	1.0000E-01	3.9523E-05	3.4981E-05	3.7352E-05	3.3743E-05	3.5165E-05	3.7487E-05	3.2952E-05	3.2176E-05	3.5717E-05	3.4083E-0
32	7.0000E-02	3.8231E-05	3.5904E-05	3.5774E-05	3.2217E-05	3.3754E-05	3.6187E-05	3.1708E-05	3.2128E-05	3.4657E-05	3.3403E-0
33	5.0000E-02	3.7074E-05	3.5797E-05	3.5050E-05	3.1078E-05	3.2982E-05	3.5410E-05	3.1153E-05	3.2083E-05	3.4886E-05	3.2650E-0
34	3.0000E-02	3.6259E-05	3.3596E-05	3.4010E-05	3.0221E-05	3.1924E-05	3.4305E-05	2.9722E-05	3.2033E-05	3.2856E-05	3.1594E-0
35	2.0000E-02	3.6478E-05	3.2365E-05	3.3929E-05	2.9670E-05	3.1518E-05	3.4162E-05	2.9497E-05	3.1973E-05	3.2946E-05	3.1760E-0
36	1.0000E-02	3.5106E-05	3.5085E-05	3.2774E-05	2.8215E-05	3.1143E-05	3.3568E-05	2.8584E-05	3.2004E-05	3.1276E-05	3.0838E-0
37	5.0000E-03	3.4963E-05	3.5080E-05	3.2350E-05	2.8454E-05	3.1082E-05	3.2954E-05	2.8583E-05	3.1991E-05	3.2854E-05	3.0575E-0
38	2.0000E-03	3.5008E-05	3.4982E-05	3.1883E-05	2.7940E-05	3.0249E-05	3.2799E-05	2.7463E-05	3.1989E-05	3.2436E-05	3.1047E-0
39	1.0000E-03	3.4774E-05	3.5798E-05	3.1587E-05	2.8349E-05	3.0732E-05	3.2713E-05	2.8062E-05	3.1977E-05	3.2617E-05	3.0650E-0
40	5.0000E-04	3.4543E-05	3.3759E-05	3.1534E-05	2.7428E-05	2.9780E-05	3.2325E-05	2.7484E-05	3.2078E-05	3.0561E-05	3.0648E-0

Figure 9. Example of database for fluence

3.3.3 Data format for energy distribution

Figure 10 depicts an example of the database. A single file contains the data of distribution for several incident energies. The first column indicates the incident neutron energy in MeV. The second and third columns mean respectively the lower and upper bin of deposit energy in MeV at the incident neutron energy. The following columns give the number of particle deposited the energy within the interval in the unit of 1/source. For example, the second line of the file depicted in Fig. 10 means that the number of particles per source neutron that deposit their energies at brain within the interval from 1.0000E-10 to 1.3274E-10 MeV at 150 MeV neutron incidences is 3.5036E-02 (particles/source). The change of the value in the first column causes the change of the irradiation energy.

ISO_deposit.txt

	Irrad.Ene	Elow	Eupp	Brain	Eyes	Heart	Kidney	Liver	Lung	Pancreas	Ski
2	1.5000E+02	1.0000E-10	1.3274E-10	3.5036E-02	0.0000E+00	0.0000E+00	2.2728E-01	3.3878E-01	4.7178E-01	0.0000E+00	0.0000E+0
3	1.5000E+02	1.3274E-10	1.7621E-10	2.2912E-01	0.0000E+00	0.0000E+00	4.8116E+00	3.8090E-01	1.0887E-01	0.0000E+00	0.0000E+0
4	1.5000E+02	1.7621E-10	2.3390E-10	8.1278E-01	0.0000E+00	3.1055E-01	0.0000E+00	5.2910E-01	1.0197E+00	0.0000E+00	0.0000E+0
5	1.5000E+02	2.3390E-10	3.1049E-10	4.8676E-01	0.0000E+00	1.9923E-01	1.4357E+00	5.7358E-01	6.3598E-01	1.6860E+00	2.7194E-0
6	1.5000E+02	3.1049E-10	4.1215E-10	4.2458E-01	0.0000E+00	1.6609E+00	0.0000E+00	1.9776E+00	1.0313E+00	1.2876E-01	4.1126E-0
7	1.5000E+02	4.1215E-10	5.4709E-10	1.3937E+00	0.0000E+00	1.9718E+00	4.9795E+00	1.6804E+00	2.0915E+00	3.2419E+00	5.3277E-0
8	1.5000E+02	5.4709E-10	7.2623E-10	9.7511E-01	0.0000E+00	2.8165E+00	8.4075E+00	2.8118E+00	2.3004E+00	4.9071E+00	1.3495E+0
9	1.5000E+02	7.2623E-10	9.6401E-10	1.7853E+00	0.0000E+00	1.4354E+00	4.6148E+00	2.2590E+00	2.8546E+00	5.2359E-01	9.3938E-0
10	1.5000E+02	9.6401E-10	1.2797E-09	1.9381E+00	0.0000E+00	2.6610E+00	1.0719E+01	3.6897E+00	3.8360E+00	1.4191E+00	1.0233E+0
11	1.5000E+02	1.2797E-09	1.6986E-09	2.4086E+00	2.1769E+01	2.5206E+00	1.3635E+01	4.4137E+00	6.0080E+00	8.1687E+00	1.7005E+0
12	1.5000E+02	1.6986E-09	2.2548E-09	2.9180E+00	0.0000E+00	2.5890E+00	1.8243E+01	4.9340E+00	6.5191E+00	1.1701E+01	3.2998E+0
13	1.5000E+02	2.2548E-09	2.9931E-09	4.0558E+00	0.0000E+00	8.3216E+00	2.4970E+01	8.4348E+00	1.0055E+01	9.9333E+00	3.2369E+0
14	1.5000E+02	2.9931E-09	3.9731E-09	5.7620E+00	9.0867E+00	6.5500E+00	3.2581E+01	9.7915E+00	1.1602E+01	1.7630E+01	5.8921E+0
15	1.5000E+02	3.9731E-09	5.2740E-09	7.9676E+00	1.6308E+00	9.9194E+00	3.2653E+01	1.3679E+01	1.5335E+01	1.7573E+01	7.6070E+0
16	1.5000E+02	5.2740E-09	7.0009E-09	9.1268E+00	5.5906E+00	1.5353E+01	4.5699E+01	1.5117E+01	2.0563E+01	1.9608E+01	8.7545E+0
17	1.5000E+02	7.0009E-09	9.2932E-09	1.0922E+01	6.5514E+00	1.3437E+01	5.2698E+01	1.8735E+01	2.2411E+01	2.6502E+01	1.0630E+0
18	1.5000E+02	9.2932E-09	1.2336E-08	1.2516E+01	8.3655E+00	1.6981E+01	5.8945E+01	2.2701E+01	2.8580E+01	3.1064E+01	1.3258E+0
19	1.5000E+02	1.2336E-08	1.6375E-08	1.6450E+01	4.2262E+00	1.9655E+01	7.6250E+01	2.6863E+01	3.2723E+01	4.0937E+01	1.4029E+0
20	1.5000E+02	1.6375E-08	2.1737E-08	1.5852E+01	4.7188E+00	2.3996E+01	8.1510E+01	2.8427E+01	3.6441E+01	4.3722E+01	1.4990E+0
21	1.5000E+02	2.1737E-08	2.8854E-08	1.6277E+01	9.5312E+00	2.1256E+01	8.1027E+01	2.9969E+01	3.6064E+01	4.4127E+01	1.7934E+0
22	1.5000E+02	2.8854E-08	3.8302E-08	1.5605E+01	1.0242E+01	2.0344E+01	7.9329E+01	3.0158E+01	3.5915E+01	3.7364E+01	1.7037E+0
23	1.5000E+02	3.8302E-08	5.0842E-08	1.3122E+01	8.1835E+00	1.9963E+01	7.1529E+01	2.4897E+01	3.0861E+01	3.5870E+01	1.5368E+0
24	1.5000E+02	5.0842E-08	6.7490E-08	1.0074E+01	8.8470E+00	1.4539E+01	5.5181E+01	1.9408E+01	2.2813E+01	2.6754E+01	1.1922E+0
25	1.5000E+02	6.7490E-08	8.9587E-08	6.8391E+00	4.2564E+00	9.3931E+00	3.3589E+01	1.2616E+01	1.5148E+01	1.8327E+01	8.0593E+0
26	1.5000E+02	8.9587E-08	1.1892E-07	3.3921E+00	2.5885E+00	4.4906E+00	1.7891E+01	6.1399E+00	7.5914E+00	9.2414E+00	4.2248E+0
27	1.5000E+02	1.1892E-07	1.5786E-07	1.4321E+00	5.5428E-01	1.9382E+00	7.7983E+00	2.4047E+00	2.9969E+00	3.4701E+00	1.9433E+0
28	1.5000E+02	1.5786E-07	2.0955E-07	4.1961E-01	7.3557E-01	6.2798E-01	2.0098E+00	9.0561E-01	1.1850E+00	1.2099E+00	8.0258E-0
29	1.5000E+02	2.0955E-07	2.7816E-07	1.9172E-01	5.6229E-01	2.2452E-01	6.9733E-01	3.4202E-01	5.2665E-01	4.8136E-01	3.7089E-0
30	1.5000E+02	2.7816E-07	3.6923E-07	1.5039E-01	6.5873E-02	1.5247E-01	6.3400E-01	2.0539E-01	3.6003E-01	4.6058E-01	2.6006E-0
31	1.5000E+02	3.6923E-07	4.9013E-07	1.2152E-01	2.3411E-01	1.5715E-01	3.9719E-01	1.4607E-01	2.5233E-01	2.3632E-01	1.8559E-0
32	1.5000E+02	4.9013E-07	6.5061E-07	8.5713E-02	1.0758E-01	1.0045E-01	2.3798E-01	1.1801E-01	1.8582E-01	1.8101E-01	1.4049E-0
33	1.5000E+02	6.5061E-07	8.6363E-07	5.2868E-02	6.0619E-02	6.1257E-02	1.9268E-01	7.8551E-02	1.2036E-01	1.3718E-01	1.0967E-0
34	1.5000E+02	8.6363E-07	1.1464E-06	4.6213E-02	5.1032E-02	4.7458E-02	1.6178E-01	6.9978E-02	9.5522E-02	9.0064E-02	9.1701E-0
35	1.5000E+02	1.1464E-06	1.5218E-06	3.9828E-02	4.9041E-02	5.2437E-02	1.2709E-01	5.7248E-02	6.9308E-02	8.3987E-02	5.9503E-0
36	1.5000E+02	1.5218E-06	2.0200E-06	2.1603E-02	1.0961E-02	2.9505E-02	9.4657E-02	4.2536E-02	6.9329E-02	4.0004E-02	4.8510E-0
37	1.5000E+02	2.0200E-06	2.6815E-06	2.0551E-02	2.1966E-02	3.4463E-02	5.7483E-02	2.4868E-02	4.2489E-02	3.6401E-02	3.3743E-0
38	1.5000E+02	2.6815E-06	3.5594E-06	1.4634E-02	4.3395E-03	1.7957E-02	5.2238E-02	2.2131E-02	3.1918E-02	3.4082E-02	2.8885E-0
39	1.5000E+02	3.5594E-06	4.7249E-06	1.1332E-02	5.4415E-03	1.5096E-02	4.6405E-02	1.6406E-02	2.3634E-02	1.7194E-02	2.5142E-0

Figure 10. Example of database for energy distribution

4. User guide for DOSE-Analyzer

DOSE-Analyzer has many functions to retrieve the dose information from the database, and analyze the particle behavior in subjects exposed by external neutrons. All the function is invoked through a GUI. In this section, we give a user guide how to use DOSE-Analyzer.

4.1 Input and output parameters on GUI window

Figure 11 shows the GUI window of DOSE-Analyzer, with which the users should determine the input configurations. Description about each input parameter is given below.

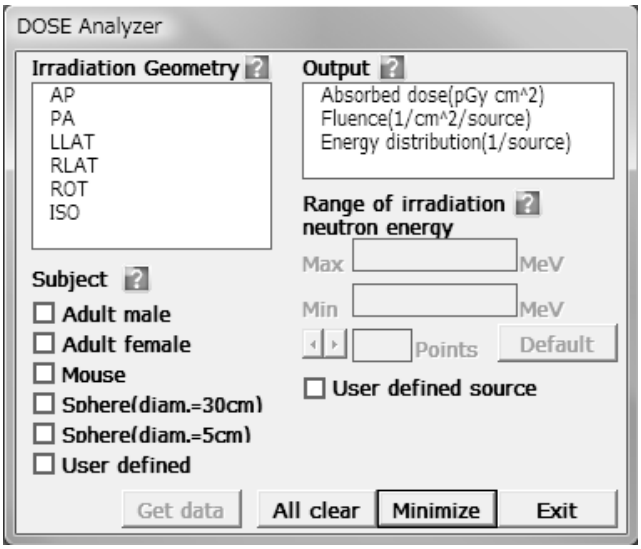


Figure 11. GUI window of DOSE-Analyzer

4.1.1 Irradiation geometry

This parameter chooses the irradiation geometry from **AP**, **PA**, **LLAT**, **RLAT**, **ROT**, and **ISO**, which is explained in Section 3.2.2.

4.1.2 Subject

This parameter determines the subject to be irradiated by neutrons. Each subject corresponds to the numerical phantoms used in the Monte Carlo simulation discussed in Section 3. The users can choose the one or more subjects from the following with single click on the check boxes:

- **Adult male:** Voxel phantom of an adult male, named JM-phantom.[16] The detail of the JM-phantom is described in Section 3.1.1.
- **Adult female:** Voxel phantom of an adult female, name JF-phantom.[16] The detail of the JF-phantom is described in Section 3.1.1.
- **Mouse:** Voxel phantom of a mouse, named Digimouse.[12,13] The detail of the Digimouse is described in Section 3.1.2.
- **Sphere(diam.=30)**: Spherical phantom whose diameter is 30 cm. The detail is described in Section 3.1.3.
- **Sphere(diam.=5cm)**: Spherical phantom whose diameter is 5 cm. The detail is described in Section 3.1.3.
- **User defined**: The subject defined by the users. The original database can be prepared, and used on DOSE-Analyzer. The user defined database should be located at the folder

named “UserDefined” in “DATABASE” folder. The manner constructing the database is described in Section 3.3. The users can define an arbitrary dataset in accordance with a preinstalled template with the data in ICRP74[18].

4.1.3 Output

This parameter determines the output quantity on the current session of DOSE-Analyzer from **Absorbed dose**, **Fluence**, and **Energy distribution**. The detail of each physical quantity is given in Section 3.2.1

4.1.4 Range of irradiation neutron energy

The energy mesh for the output is defined here by giving maximum energy, minimum energy, and number of points indicated by **Max**, **Min**, and **Points**, respectively. The mesh is divided equally by the number of points in linear scale. When “Energy distribution (1/source)” is chosen as the output, DOSE-Analyzer returns the distributions of the deposit energy for single irradiation energy. Therefore, the users cannot define the plural points of irradiation energy, and must indicate single energy through **Max** or **User defined source**.

- **Max**: Maximum energy given in MeV. The value must be greater than that of **Min**, and less than 150 MeV.
- **Min**: Minimum energy given in MeV. The value must be greater than 10^{-9} MeV, and less than that of **Max**.
- **Points**: Number of points in the energy range from **Min** to **Max**. The value is acceptable in integer from 2 to 99.
- **Default**: By clicking on “Default”, the maximum energy (**Max**), minimum energy (**Min**), and number of points (**Points**) are set to 150 MeV, 10^{-9} MeV, and 53 points, respectively.
- **User defined source**: By use of this option, **Max**, **Min** and **Points** are inactivated, and the *user defined source* is used as an input neutron source. The users can define not only monoenergetic but also continuous energy source by describing spectrum information with energy and weight in a text file named “User_defined_source.txt”, which should be located in the folder “DATABASE”. The spectrum data are read from the second line of the file, since the first line is a header. The first and second columns indicate the energy in MeV and the corresponding weight, respectively, which are delimited with a single space. Processing the data on DOSE-Analyzer, the weights are normalized to the total weight.

4.1.5 Buttons on GUI window

The GUI window has the following buttons:

- **Get data**: By clicking on this button, the output data requested by the input parameters are acquired from the database, and opened in Excel data sheets for each subject. The structure of the data sheet is described in Section 4.3. This buttons is activated after all the input parameters are given.
- **All clear**: Clearing and initializing the all input parameters.
- **Minimize**: Minimization of the GUI window. Figure 12 shows an example of the minimized window. The users can expand the window again by clicking on "Back to GUI".
- **Exit**: With this button, the users can close the GUI window. If the users want to display the GUI window again, restart the software.

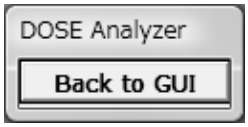


Figure 12. Minimized window of DOSE-Analyzer

4.1.6 Help window

DOSE-Analyzer contains help messages for each input parameter. Figure 13 shows an example of the help. By clicking on the help icon, the message is appeared in a separate window.

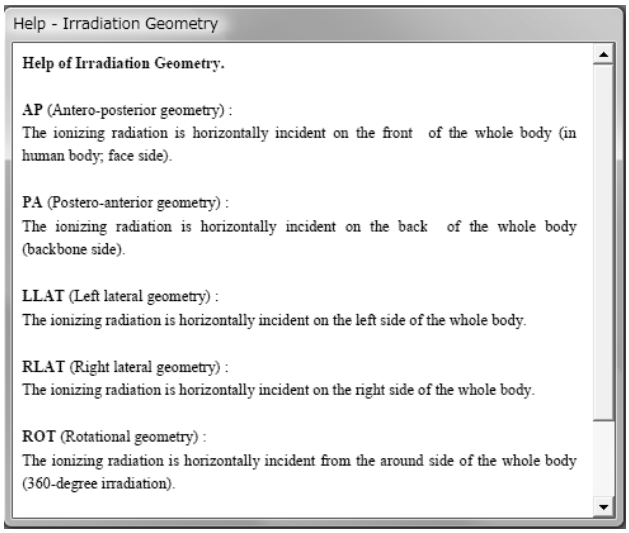


Figure 13. Example of help window

4.2 Output data sheet

The outputs of DOSE-Analyzer are exhibited by using data sheets of Microsoft Office Excel™. If the users choose irradiation subjects more than one, the data corresponding to a subject are opened in a separate sheet. The data sheet for absorbed dose, fluence, and energy distribution are introduced below.

4.2.1 Absorbed dose

Figure 14 shows an example of the sheet for absorbed dose. The input configuration is summarized in the top of the sheet, *e.g.* output quantity, irradiation geometry, and subject. The energy mesh is indicated in the left side of the sheet with the number of meshing points. The numerical values of absorbed dose are tabulated in each target organ, and given for total, electron, proton, deuteron, triton, and alpha particle. The labels of the targets and particles are given in the top of the data block.

C21 35.2719993591308

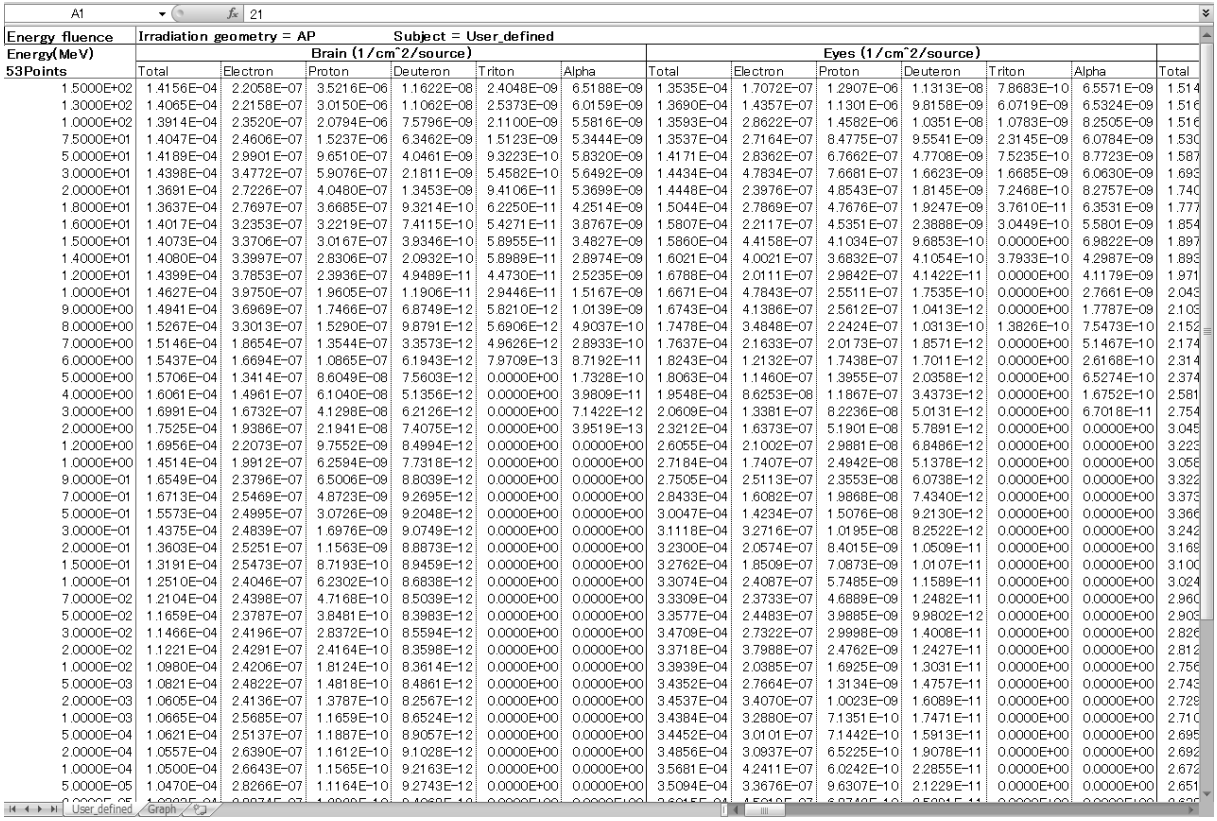
Absorbed dose	Irradiation geometry = ISO						Subject = Adult_male						
Energy(MeV)	Brain (pGy cm^2)						Eyes (pGy cm^2)						
53Points	Total	Electron	Proton	Deuteron	Triton	Alpha	Total	Electron	Proton	Deuteron	Triton	Alpha	Total
1.5000E+02	9.4013E+01	7.2713E-01	7.6425E+01	2.0076E+00	6.8682E-01	8.6598E+00	7.1912E+01	6.6328E-01	5.1214E+01	4.1705E+00	1.7940E+00	9.1852E+00	9.607
1.3000E+02	8.9744E+01	7.4213E-01	7.2882E+01	2.0185E+00	5.2686E-01	8.2736E+00	8.6259E+01	5.9766E-01	6.8327E+01	5.1552E-01	1.0139E+00	6.9164E+00	9.446
1.0000E+02	8.2615E+01	8.1541E-01	6.6842E+01	1.4588E+00	4.8654E-01	7.4378E+00	7.8145E+01	1.5618E-01	6.4644E+01	1.3353E+00	4.0267E-01	5.6482E+00	8.352
7.5000E+01	7.2403E+01	8.3767E-01	5.6069E+01	1.4157E+00	4.8916E-01	7.6643E+00	6.3458E+01	9.2530E-01	4.5135E+01	1.5633E+00	0.0000E+00	9.8875E+00	7.248
5.0000E+01	6.6780E+01	9.8911E-01	5.0363E+01	9.7294E-01	3.2060E-01	8.2485E+00	6.0993E+01	1.1828E+00	4.6741E+01	1.5624E-01	3.0176E-02	8.0285E+00	6.571
3.0000E+01	6.5313E+01	1.2377E+00	4.7965E+01	5.1176E-01	1.8471E-01	9.5025E+00	5.2677E+01	1.0057E+00	3.3759E+01	1.4778E+00	3.9068E-01	1.0008E+01	6.245
2.0000E+01	6.2917E+01	8.4803E-01	4.3984E+01	3.8615E-01	6.2767E-02	9.6525E+00	6.5429E+01	5.2775E-01	4.4775E+01	0.0000E+00	0.0000E+00	1.1311E+01	5.757
1.8000E+01	6.0154E+01	9.6825E-01	4.4056E+01	2.1754E-01	2.2181E-02	7.8453E+00	6.0034E+01	4.1020E-01	4.5248E+01	2.1941E-04	0.0000E+00	8.3324E+00	5.477
1.6000E+01	5.8213E+01	1.0318E+00	4.1943E+01	1.5711E-01	1.2018E-02	7.8172E+00	5.7677E+01	6.2301E-01	4.4145E+01	3.8594E-04	0.0000E+00	5.9592E+00	5.403
1.5000E+01	5.6098E+01	1.1460E+00	4.0670E+01	1.7709E-01	1.5210E-02	6.9388E+00	5.5071E+01	5.6807E-01	3.6295E+01	3.0787E-01	0.0000E+00	1.0421E+01	5.046
1.4000E+01	5.3891E+01	1.0505E+00	4.0412E+01	6.7917E-02	3.2098E-02	5.8692E+00	4.8363E+01	3.6690E-01	3.1883E+01	1.7582E-01	0.0000E+00	8.0802E+00	4.993
1.2000E+01	5.0111E+01	1.1648E+00	3.8267E+01	1.3870E-02	9.5799E-03	4.6548E+00	4.6430E+01	9.8560E-01	3.3028E+01	9.5239E-02	0.0000E+00	5.6233E+00	4.732
1.0000E+01	4.5954E+01	1.3736E+00	3.6952E+01	9.7386E-03	6.9248E-03	3.0039E+00	4.7093E+01	1.1019E+00	3.8866E+01	3.0451E-04	0.0000E+00	2.6401E+00	4.189
9.0000E+00	4.3148E+01	1.2032E+00	3.5902E+01	5.2792E-03	2.5421E-03	2.0550E+00	4.7168E+01	1.0443E+00	3.8350E+01	4.8424E-04	0.0000E+00	2.5340E+00	3.833
8.0000E+00	4.0169E+01	1.0672E+00	3.4617E+01	7.0042E-03	2.0784E-03	1.0984E+00	4.1258E+01	9.8899E-01	3.4544E+01	4.4051E-04	0.0000E+00	1.2670E+00	3.606
7.0000E+00	3.8062E+01	6.1378E-01	3.3819E+01	8.6565E-04	2.8837E-03	7.3033E-01	3.7104E+01	3.4347E-01	3.2873E+01	2.3387E-04	0.0000E+00	7.5082E-01	3.384
6.0000E+00	3.5272E+01	5.6103E-01	3.1387E+01	1.0514E-03	1.2546E-03	2.3260E-01	3.6000E+01	6.4601E-01	3.0804E+01	4.8687E-04	0.0000E+00	1.9212E-01	3.036
5.0000E+00	3.1226E+01	4.6109E-01	2.7947E+01	1.1169E-03	0.0000E+00	4.7957E-01	3.2032E+01	4.8960E-01	2.8380E+01	8.4138E-04	0.0000E+00	6.7753E-01	2.782
4.0000E+00	2.7584E+01	4.5983E-01	2.4694E+01	1.3480E-03	0.0000E+00	1.2220E-01	2.4855E+01	2.9736E-01	2.2149E+01	7.4579E-04	0.0000E+00	5.1063E-02	2.270
3.0000E+00	2.2313E+01	5.6795E-01	2.0330E+01	1.6920E-03	0.0000E+00	2.7471E-02	2.0142E+01	3.1025E-01	1.8180E+01	4.6386E-04	0.0000E+00	0.0000E+00	1.834
2.0000E+00	1.6127E+01	6.2612E-01	1.4428E+01	1.9507E-03	0.0000E+00	1.3580E-03	1.6769E+01	3.9800E-01	1.4930E+01	7.4179E-04	0.0000E+00	0.0000E+00	1.273
1.2000E+00	1.0256E+01	7.7296E-01	8.7291E+00	2.2768E-03	0.0000E+00	0.0000E+00	1.2356E+01	7.0632E-01	1.0620E+01	1.0767E-03	0.0000E+00	0.0000E+00	7.440
1.0000E+00	7.6774E+00	7.4881E-01	6.2337E+00	2.1349E-03	0.0000E+00	0.0000E+00	1.0770E+01	5.4092E-01	8.9975E+00	1.3987E-03	0.0000E+00	0.0000E+00	5.412
9.0000E-01	7.8226E+00	8.3365E-01	6.5124E+00	2.9235E-03	0.0000E+00	0.0000E+00	9.4294E+00	4.3978E-01	8.1687E+00	1.1258E-03	0.0000E+00	0.0000E+00	5.778
7.0000E-01	6.3396E+00	8.1667E-01	5.1752E+00	2.8216E-03	0.0000E+00	0.0000E+00	8.3027E+00	4.9624E-01	7.2485E+00	9.4684E-04	0.0000E+00	0.0000E+00	4.522
5.0000E-01	4.6140E+00	8.5877E-01	3.5123E+00	2.6492E-03	0.0000E+00	0.0000E+00	6.7537E+00	8.4307E-01	5.3914E+00	1.2178E-03	0.0000E+00	0.0000E+00	3.461
3.0000E-01	2.9150E+00	9.1462E-01	1.8859E+00	2.6909E-03	0.0000E+00	0.0000E+00	3.7614E+00	5.4558E-01	2.9874E+00	1.6446E-03	0.0000E+00	0.0000E+00	2.302
2.0000E-01	2.1701E+00	8.9207E-01	1.2007E+00	2.6796E-03	0.0000E+00	0.0000E+00	3.0949E+00	7.6743E-01	2.1109E+00	1.8252E-03	0.0000E+00	0.0000E+00	1.725
1.5000E-01	1.8137E+00	8.8389E-01	8.6990E-01	2.6281E-03	0.0000E+00	0.0000E+00	2.4461E+00	5.1468E-01	1.8206E+00	1.9996E-03	0.0000E+00	0.0000E+00	1.547
1.0000E-01	1.4536E+00	8.6724E-01	5.4966E-01	2.5813E-03	0.0000E+00	0.0000E+00	2.3471E+00	9.0243E-01	1.3834E+00	1.6543E-03	0.0000E+00	0.0000E+00	1.389
7.0000E-02	1.2532E+00	8.2882E-01	3.9020E-01	2.6791E-03	0.0000E+00	0.0000E+00	1.4007E+00	4.6148E-01	8.9543E-01	1.7575E-03	0.0000E+00	0.0000E+00	1.294
5.0000E-02	1.2037E+00	8.8868E-01	2.9293E-01	2.5447E-03	0.0000E+00	0.0000E+00	8.9514E-01	3.0932E-01	5.5626E-01	1.6605E-03	0.0000E+00	0.0000E+00	1.336
3.0000E-02	1.0767E+00	8.5355E-01	1.9858E-01	2.6710E-03	0.0000E+00	0.0000E+00	1.0933E+00	4.4494E-01	5.8397E-01	1.3756E-03	0.0000E+00	0.0000E+00	1.201
2.0000E-02	1.0302E+00	8.5209E-01	1.5688E-01	2.5933E-03	0.0000E+00	0.0000E+00	8.3888E-01	4.6987E-01	3.5202E-01	1.3544E-03	0.0000E+00	0.0000E+00	1.255
1.0000E-02	1.0268E+00	8.5776E-01	1.3657E-01	2.6304E-03	0.0000E+00	0.0000E+00	1.1860E+00	7.9814E-01	3.6406E-01	1.2941E-03	0.0000E+00	0.0000E+00	1.195
5.0000E-03	1.0519E+00	9.1259E-01	1.1697E-01	2.5998E-03	0.0000E+00	0.0000E+00	1.0255E+00	6.1732E-01	3.3970E-01	1.6105E-03	0.0000E+00	0.0000E+00	1.080
2.0000E-03	1.0897E+00	9.5523E-01	1.0919E-01	2.7174E-03	0.0000E+00	0.0000E+00	7.7378E-01	5.7691E-01	1.8262E-01	1.6724E-03	0.0000E+00	0.0000E+00	1.155
1.0000E-03	1.0610E+00	9.2580E-01	1.1430E-01	2.7824E-03	0.0000E+00	0.0000E+00	6.7212E-01	5.8345E-01	8.1320E-02	1.8034E-03	0.0000E+00	0.0000E+00	1.268
5.0000E-04	1.0781E+00	9.4507E-01	1.0602E-01	2.8415E-03	0.0000E+00	0.0000E+00	5.9592E-01	3.9397E-01	1.8667E-01	2.0180E-03	0.0000E+00	0.0000E+00	1.146
2.0000E-04	1.1077E+00	9.7619E-01	1.1195E-01	2.9429E-03	0.0000E+00	0.0000E+00	1.3422E+00	1.0805E+00	2.4122E-01	3.0511E-03	0.0000E+00	0.0000E+00	1.285
1.0000E-04	1.1544E+00	1.0061E+00	1.1574E-01	2.8715E-03	0.0000E+00	0.0000E+00	9.7413E-01	6.8421E-01	2.6820E-01	2.3689E-03	0.0000E+00	0.0000E+00	1.223
5.0000E-05	1.1193E+00	9.6956E-01	1.2187E-01	2.8937E-03	0.0000E+00	0.0000E+00	1.0592E+00	7.3144E-01	3.0308E-01	2.8165E-03	0.0000E+00	0.0000E+00	1.414

Adult_male / Adult_female / User_defined / Comparison / Graph

Figure 14. Data sheet for absorbed dose

4.2.2 Fluence

The data sheet of fluence uses the same format as absorbed dose. An example is shown in Fig. 15.



A1 21

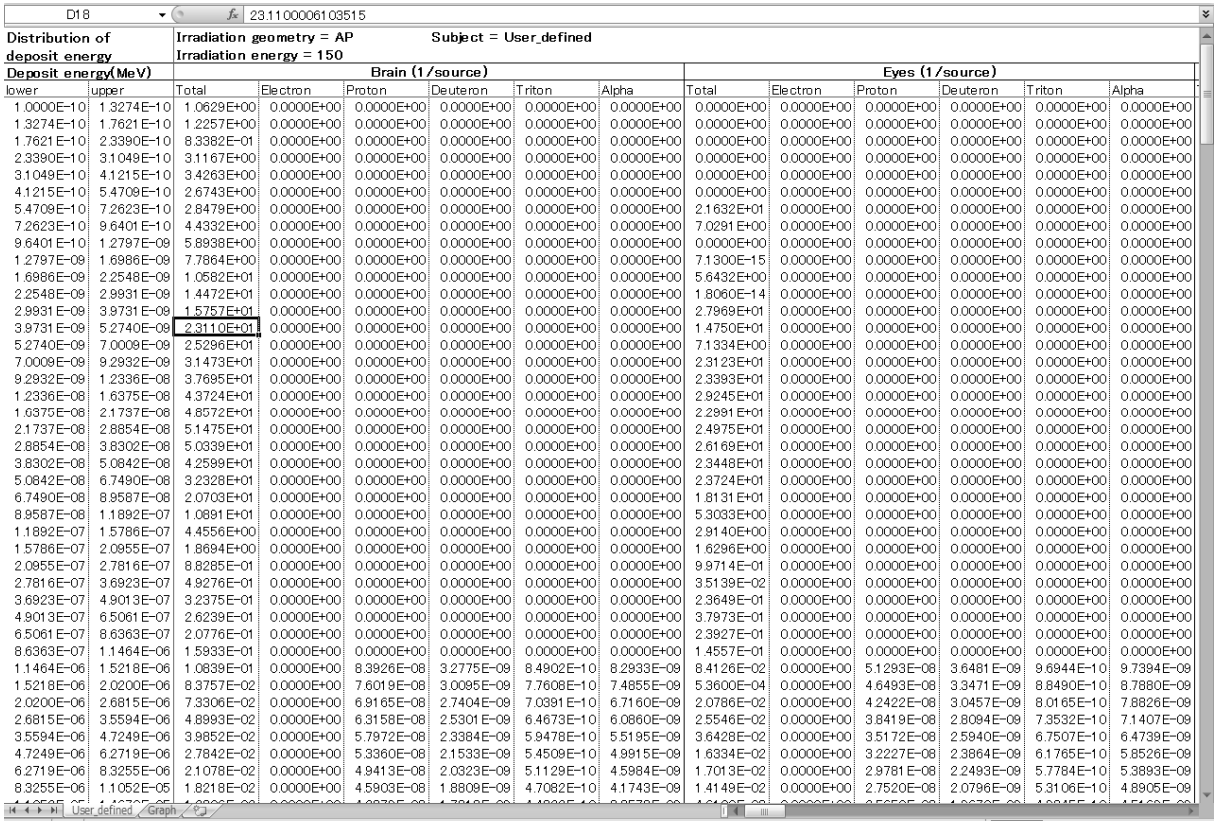
Energy fluence	Irradiation geometry = AP				Subject = User_defined											
Energy(MeV)	Brain (1/cm^2/source)						Eyes (1/cm^2/source)									
53Points	Total	Electron	Proton	Deuteron	Triton	Alpha	Total	Electron	Proton	Deuteron	Triton	Alpha	Total			
1.5000E+02	1.4156E-04	2.2058E-07	3.5216E-06	1.1622E-08	2.4048E-09	6.5188E-09	1.3535E-04	1.7072E-07	1.2907E-06	1.1313E-08	7.8683E-10	6.5571E-09	1.514			
1.3000E+02	1.4065E-04	2.2158E-07	3.0150E-06	1.1062E-08	2.5373E-09	6.0159E-09	1.3690E-04	1.4357E-07	1.1301E-06	9.8158E-09	6.0719E-09	6.5324E-09	1.516			
1.0000E+02	1.3914E-04	2.3520E-07	2.0794E-06	7.5796E-09	2.1100E-09	5.5816E-09	1.3593E-04	2.8622E-07	1.4582E-06	1.0351E-08	1.0783E-09	8.2505E-09	1.516			
7.5000E+01	1.4047E-04	2.4606E-07	1.5237E-06	6.3462E-09	1.5123E-09	5.3444E-09	1.3537E-04	2.7164E-07	8.4775E-07	9.5541E-09	2.3145E-09	6.0784E-09	1.530			
5.0000E+01	1.4189E-04	2.9901E-07	9.6510E-07	4.0461E-09	9.3223E-10	5.8320E-09	1.4171E-04	2.8362E-07	6.7662E-07	4.7708E-09	7.5235E-10	8.7723E-09	1.587			
3.0000E+01	1.4398E-04	3.4772E-07	5.9076E-07	2.1811E-09	5.4582E-10	5.6492E-09	1.4434E-04	4.7834E-07	7.6681E-07	1.6623E-09	1.6685E-09	6.0630E-09	1.693			
2.0000E+01	1.3691E-04	2.7226E-07	4.0480E-07	1.3453E-09	9.4106E-11	5.3699E-09	1.4448E-04	2.3976E-07	4.8543E-07	1.8145E-09	7.2468E-10	8.2757E-09	1.740			
1.8000E+01	1.3637E-04	2.7697E-07	3.6685E-07	9.3214E-10	6.2250E-11	4.2514E-09	1.5044E-04	2.7869E-07	4.7676E-07	1.9247E-09	3.7610E-11	6.3531E-09	1.777			
1.6000E+01	1.4017E-04	3.2353E-07	3.2219E-07	7.4115E-10	5.4271E-11	3.8767E-09	1.5807E-04	2.2117E-07	4.5351E-07	2.3888E-09	3.0449E-10	5.5801E-09	1.854			
1.5000E+01	1.4073E-04	3.3706E-07	3.0167E-07	3.9346E-10	5.8955E-11	3.4827E-09	1.5860E-04	4.4158E-07	4.1034E-07	9.6853E-10	0.0000E+00	6.9822E-09	1.897			
1.4000E+01	1.4080E-04	3.3997E-07	2.8306E-07	2.0932E-10	5.8989E-11	2.8974E-09	1.6021E-04	4.0021E-07	3.6832E-07	4.1054E-10	3.7933E-10	4.2987E-09	1.893			
1.2000E+01	1.4399E-04	3.7853E-07	2.3936E-07	4.9489E-11	4.4730E-11	2.5235E-09	1.6788E-04	2.0111E-07	2.9842E-07	4.1422E-11	0.0000E+00	4.1179E-09	1.971			
1.0000E+01	1.4627E-04	3.9750E-07	1.9605E-07	1.1906E-11	2.9446E-11	1.5167E-09	1.6671E-04	4.7843E-07	2.5511E-07	1.7535E-10	0.0000E+00	2.7661E-09	2.043			
9.0000E+00	1.4941E-04	3.6969E-07	1.7466E-07	6.8749E-12	5.8210E-12	1.0139E-09	1.6743E-04	4.1386E-07	2.5612E-07	1.0413E-12	0.0000E+00	1.7787E-09	2.103			
8.0000E+00	1.5267E-04	3.3013E-07	1.5290E-07	9.8791E-12	5.6906E-12	4.9037E-10	1.7478E-04	3.4848E-07	2.2424E-07	1.0313E-10	1.3826E-10	7.5473E-10	2.152			
7.0000E+00	1.5146E-04	1.8654E-07	1.3544E-07	3.3573E-12	4.9626E-12	2.8933E-10	1.7637E-04	2.1633E-07	2.0173E-07	1.8571E-12	0.0000E+00	5.1467E-10	2.174			
6.0000E+00	1.5437E-04	1.6694E-07	1.0865E-07	6.1943E-12	7.9709E-13	8.7192E-11	1.8243E-04	1.2132E-07	1.7438E-07	1.7011E-12	0.0000E+00	2.6168E-10	2.314			
5.0000E+00	1.5706E-04	1.3414E-07	8.6049E-08	7.5603E-12	0.0000E+00	1.7328E-10	1.8063E-04	1.1460E-07	1.3955E-07	2.0358E-12	0.0000E+00	6.5274E-10	2.374			
4.0000E+00	1.6061E-04	1.4961E-07	6.1040E-08	5.1356E-12	0.0000E+00	3.9809E-11	1.9548E-04	8.6253E-08	1.1867E-07	3.4373E-12	0.0000E+00	1.6752E-10	2.581			
3.0000E+00	1.6991E-04	1.6732E-07	4.1298E-08	6.2126E-12	0.0000E+00	7.1422E-12	2.0609E-04	1.3381E-07	8.2236E-08	5.0131E-12	0.0000E+00	6.7018E-11	2.754			
2.0000E+00	1.7525E-04	1.9386E-07	2.1941E-08	7.4075E-12	0.0000E+00	3.9519E-13	2.3212E-04	1.6373E-07	5.1901E-08	5.7891E-12	0.0000E+00	0.0000E+00	3.045			
1.2000E+00	1.6956E-04	2.2073E-07	9.7552E-09	8.4994E-12	0.0000E+00	0.0000E+00	2.6055E-04	2.1002E-07	2.9881E-08	6.8486E-12	0.0000E+00	0.0000E+00	3.223			
1.0000E+00	1.4514E-04	1.9912E-07	6.2594E-09	7.7318E-12	0.0000E+00	0.0000E+00	2.7184E-04	1.7407E-07	2.4942E-08	5.1378E-12	0.0000E+00	0.0000E+00	3.056			
9.0000E-01	1.6549E-04	2.3796E-07	6.5006E-09	8.8039E-12	0.0000E+00	0.0000E+00	2.7505E-04	2.5113E-07	2.3553E-08	6.0738E-12	0.0000E+00	0.0000E+00	3.322			
7.0000E-01	1.6713E-04	2.5469E-07	4.8723E-09	9.2695E-12	0.0000E+00	0.0000E+00	2.8433E-04	1.6082E-07	1.9868E-08	7.4340E-12	0.0000E+00	0.0000E+00	3.373			
5.0000E-01	1.5573E-04	2.4995E-07	3.0726E-09	9.2048E-12	0.0000E+00	0.0000E+00	3.0047E-04	1.4234E-07	1.5076E-08	9.2130E-12	0.0000E+00	0.0000E+00	3.366			
3.0000E-01	1.4375E-04	2.4839E-07	1.6976E-09	9.0749E-12	0.0000E+00	0.0000E+00	3.1118E-04	3.2716E-07	1.0195E-08	8.2522E-12	0.0000E+00	0.0000E+00	3.242			
2.0000E-01	1.3603E-04	2.5251E-07	1.1563E-09	8.8873E-12	0.0000E+00	0.0000E+00	3.2300E-04	2.0574E-07	8.4015E-09	1.0509E-11	0.0000E+00	0.0000E+00	3.169			
1.5000E-01	1.3191E-04	2.5473E-07	8.7193E-10	8.9459E-12	0.0000E+00	0.0000E+00	3.2762E-04	1.8509E-07	7.0873E-09	1.0107E-11	0.0000E+00	0.0000E+00	3.100			
1.0000E-01	1.2510E-04	2.4046E-07	6.2302E-10	8.6838E-12	0.0000E+00	0.0000E+00	3.3074E-04	2.4087E-07	5.7485E-09	1.1589E-11	0.0000E+00	0.0000E+00	3.024			
7.0000E-02	1.2104E-04	2.4398E-07	4.7168E-10	8.5039E-12	0.0000E+00	0.0000E+00	3.3309E-04	2.3733E-07	4.6889E-09	1.2482E-11	0.0000E+00	0.0000E+00	2.960			
5.0000E-02	1.1659E-04	2.3787E-07	3.8481E-10	8.3983E-12	0.0000E+00	0.0000E+00	3.3577E-04	2.4483E-07	3.9885E-09	9.9802E-12	0.0000E+00	0.0000E+00	2.903			
3.0000E-02	1.1466E-04	2.4196E-07	2.8372E-10	8.5594E-12	0.0000E+00	0.0000E+00	3.4709E-04	2.7322E-07	2.9998E-09	1.4008E-11	0.0000E+00	0.0000E+00	2.826			
2.0000E-02	1.1221E-04	2.4291E-07	2.4164E-10	8.3598E-12	0.0000E+00	0.0000E+00	3.3718E-04	3.7988E-07	2.4762E-09	1.2427E-11	0.0000E+00	0.0000E+00	2.812			
1.0000E-02	1.0980E-04	2.4206E-07	1.8124E-10	8.3614E-12	0.0000E+00	0.0000E+00	3.3939E-04	2.0385E-07	1.6925E-09	1.3031E-11	0.0000E+00	0.0000E+00	2.756			
5.0000E-03	1.0821E-04	2.4822E-07	1.4818E-10	8.4861E-12	0.0000E+00	0.0000E+00	3.4352E-04	2.7664E-07	1.3134E-09	1.4757E-11	0.0000E+00	0.0000E+00	2.743			
2.0000E-03	1.0605E-04	2.4136E-07	1.3787E-10	8.2567E-12	0.0000E+00	0.0000E+00	3.4537E-04	3.4070E-07	1.0023E-09	1.6089E-11	0.0000E+00	0.0000E+00	2.729			
1.0000E-03	1.0665E-04	2.5685E-07	1.1659E-10	8.6524E-12	0.0000E+00	0.0000E+00	3.4384E-04	3.2880E-07	7.1351E-10	1.7471E-11	0.0000E+00	0.0000E+00	2.710			
5.0000E-04	1.0621E-04	2.5137E-07	1.1887E-10	8.9057E-12	0.0000E+00	0.0000E+00	3.4452E-04	3.0101E-07	7.1442E-10	1.5913E-11	0.0000E+00	0.0000E+00	2.695			
2.0000E-04	1.0557E-04	2.6390E-07	1.1612E-10	9.1028E-12	0.0000E+00	0.0000E+00	3.4856E-04	3.0937E-07	6.5225E-10	1.9078E-11	0.0000E+00	0.0000E+00	2.692			
1.0000E-04	1.0500E-04	2.6643E-07	1.1565E-10	9.2163E-12	0.0000E+00	0.0000E+00	3.5681E-04	4.2411E-07	6.0242E-10	2.2855E-11	0.0000E+00	0.0000E+00	2.672			
5.0000E-05	1.0470E-04	2.8266E-07	1.1164E-10	9.2743E-12	0.0000E+00	0.0000E+00	3.5094E-04	3.3676E-07	9.6307E-10	2.1229E-11	0.0000E+00	0.0000E+00	2.651			

User_defined Graph

Figure 15. Data sheet for fluence

4.2.3 Energy distribution

The data sheet of energy distribution is shown in Fig. 16. The summary of the input configuration is appeared in the top of the sheet. The intervals of deposit energy are given at the left side of the sheet by using lower and upper energies. The numerical values are tabulated for total, electron, proton, deuteron, triton, and alpha particle at each target organ.



Distribution of deposit energy		Irradiation geometry = AP Irradiation energy = 150						Subject = User_defined					
Deposit energy(MeV)		Brain (1/source)						Eyes (1/source)					
lower	upper	Total	Electron	Proton	Deuteron	Triton	Alpha	Total	Electron	Proton	Deuteron	Triton	Alpha
1.0000E-10	1.3274E-10	1.0629E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3274E-10	1.7621E-10	1.2257E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.7621E-10	2.3390E-10	8.3382E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.3390E-10	3.1049E-10	3.1167E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3.1049E-10	4.1215E-10	3.4263E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4.1215E-10	5.4709E-10	2.6743E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5.4709E-10	7.2623E-10	2.8479E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.1632E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7.2623E-10	9.6401E-10	4.4332E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.0291E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.6401E-10	1.2797E-09	5.8938E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2797E-09	1.6986E-09	7.7864E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.1300E-15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6986E-09	2.2548E-09	1.0582E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.6432E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2548E-09	2.9931E-09	1.4472E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8060E-14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.9931E-09	3.9731E-09	1.5757E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.7969E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3.9731E-09	5.2740E-09	2.3110E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4750E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5.2740E-09	7.0009E-09	2.5296E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.1334E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7.0009E-09	9.2932E-09	3.1473E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3123E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.2932E-09	1.2336E-08	3.7695E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3393E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2336E-08	1.6375E-08	4.3724E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9245E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6375E-08	2.1737E-08	4.8572E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2891E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.1737E-08	2.8854E-08	5.1475E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.4975E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8854E-08	3.8302E-08	5.0339E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.6169E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3.8302E-08	5.0842E-08	4.2599E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3448E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5.0842E-08	6.7490E-08	3.2328E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3724E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6.7490E-08	8.9587E-08	2.0703E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8131E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8.9587E-08	1.1892E-07	1.0891E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.3033E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.1892E-07	1.5786E-07	4.4556E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9140E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5786E-07	2.0955E-07	1.8694E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6296E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0955E-07	2.7816E-07	8.8285E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.9714E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.7816E-07	3.6923E-07	4.9276E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.5139E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3.6923E-07	4.9013E-07	3.2375E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3649E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4.9013E-07	6.5061E-07	2.6239E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.7973E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6.5061E-07	8.6363E-07	2.0776E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3927E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8.6363E-07	1.1464E-06	1.5933E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4557E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.1464E-06	1.5218E-06	1.0839E-01	0.0000E+00	8.3926E-08	3.2775E-09	8.4902E-10	8.2933E-09	8.4126E-02	0.0000E+00	5.1293E-08	3.6481E-09	9.6944E-10	9.7394E-09
1.5218E-06	2.0200E-06	8.3757E-02	0.0000E+00	7.6019E-08	3.0095E-09	7.7608E-10	7.4855E-09	5.3600E-04	0.0000E+00	4.6493E-08	3.3471E-09	8.8490E-10	8.7880E-09
2.0200E-06	2.6815E-06	7.3306E-02	0.0000E+00	6.9165E-08	2.7404E-09	7.0391E-10	6.7160E-09	2.0786E-02	0.0000E+00	4.2422E-08	3.0457E-09	8.0165E-10	7.8826E-09
2.6815E-06	3.5594E-06	4.8993E-02	0.0000E+00	6.3158E-08	2.5301E-09	6.4673E-10	6.0860E-09	2.5546E-02	0.0000E+00	3.8419E-08	2.8094E-09	7.3532E-10	7.1407E-09
3.5594E-06	4.7249E-06	3.9852E-02	0.0000E+00	5.7972E-08	2.3384E-09	5.9478E-10	5.5195E-09	3.6428E-02	0.0000E+00	3.5172E-08	2.5940E-09	6.7507E-10	6.4739E-09
4.7249E-06	6.2719E-06	2.7842E-02	0.0000E+00	5.3360E-08	2.1533E-09	5.4509E-10	4.9915E-09	1.6334E-02	0.0000E+00	3.2227E-08	2.3864E-09	6.1765E-10	5.8526E-09
6.2719E-06	8.3255E-06	2.1078E-02	0.0000E+00	4.9413E-08	2.0323E-09	5.1129E-10	4.5984E-09	1.7013E-02	0.0000E+00	2.9781E-08	2.2493E-09	5.7784E-10	5.3893E-09
8.3255E-06	1.1052E-05	1.8218E-02	0.0000E+00	4.5903E-08	1.8809E-09	4.7082E-10	4.1743E-09	1.4149E-02	0.0000E+00	2.7520E-08	2.0796E-09	5.3106E-10	4.8905E-09

Figure 16. Data sheet for energy distribution

4.2.4 Comparison

DOSE-Analyzer has a function to analyze the physical quantities effectively under certain conditions, which are set up with the GUI in Fig. 11. If the two or more subjects are selected in the input configurations, the "Comparison" sheet is appeared, and the results for each subject are compared on the sheet. Figure 17 shows an example of the sheet. The users can determine the subject to be compared by a pull-down menu located under the message of "**Select the subjects to be compared**". By clicking on the "**Compare**" button, and the ratio of the output quantity at a same organ is given for each particle. All the data are cleared by the "**Clear**" button.

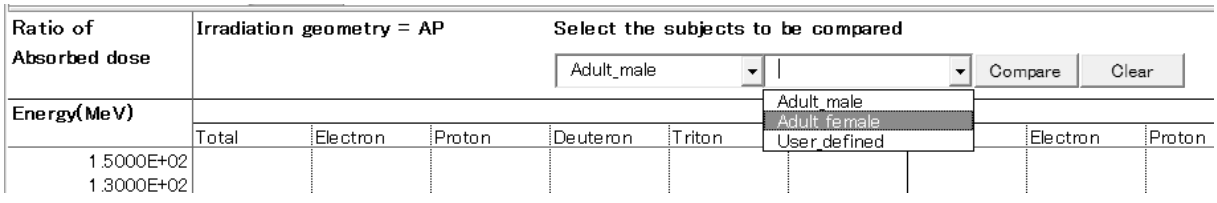


Figure 17. Example of comparison sheet

4.2.5 Graph

This sheet generates the graph for the obtained data. Figure 18 depicts an example of the "Graph" sheet for absorbed dose of an adult male. The marks colored for the particle type are plotted on the graph for a target organ chosen by a pull-down menu shown in Fig. 19. The color of the marks is determined by clicking on the color icons arranged next to the label of the particle on a color palette depicted in Fig. 20. The selection of the color is canceled by clicking the "**Clear**" icon on the palette. After the set of the target organ and the color of the marks, the users can view the graph with the "**Display**" button. The "**Clear**" button erases the graph and the color setting.

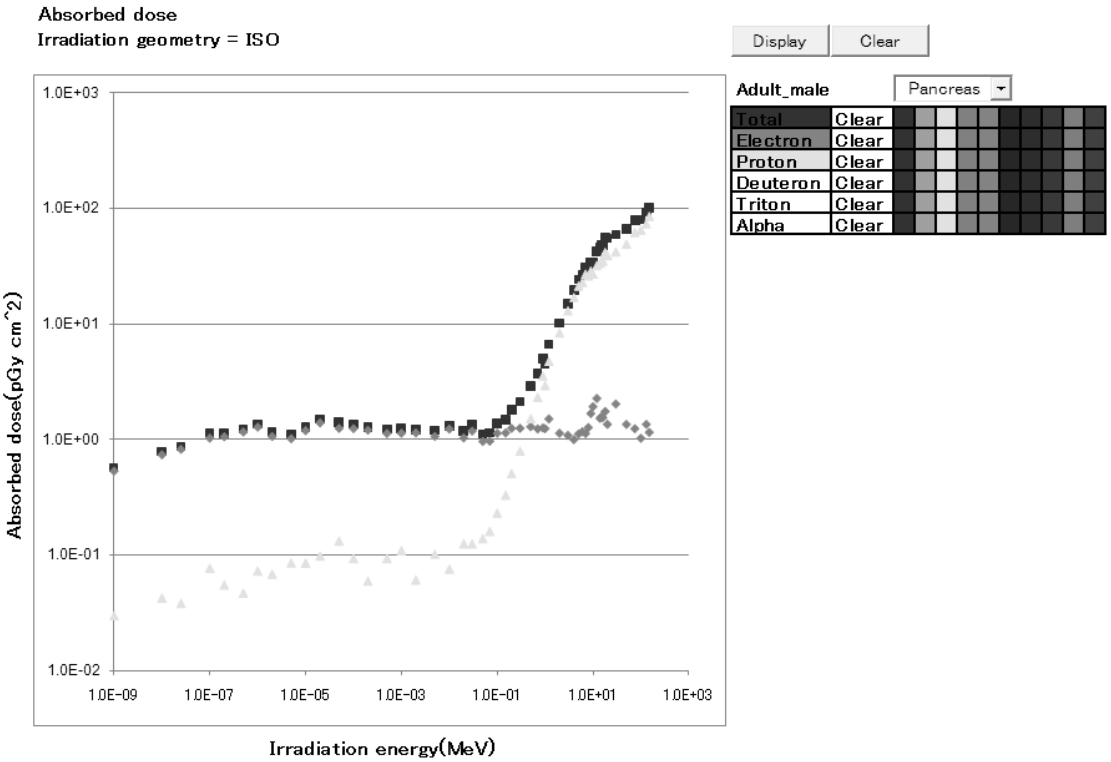


Figure 18. Example of graph sheet

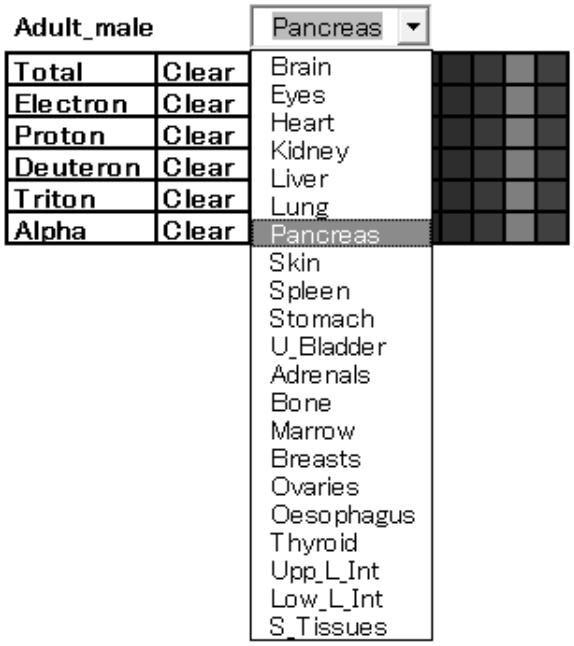


Figure 19. Pull-down menu for target selection on graph sheet

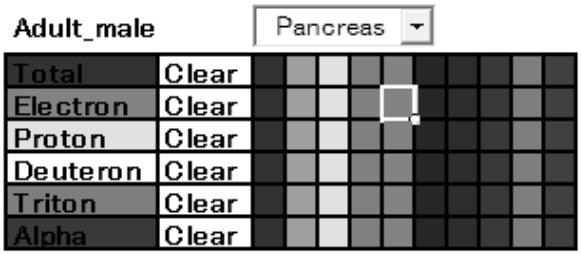


Figure 20. Color palette on graph sheet

5. Summary

We have developed a computer program named DOSE-Analyzer, which has a user-friendly GUI utilizing the Microsoft Office Excel™. DOSE-Analyzer can retrieve the data for absorbed dose, fluence, and energy distribution inside bodies of a mouse and human upon external neutron exposure, and make a graph through the GUI. The database installed in DOSE-Analyzer is composed of the calculated results by the Monte-Carlo simulation using the voxel phantoms and particle transport code PHITS.[10,11] Without technical knowledge about the Monte-Carlo simulation, the users can access the result of the simulation by using DOSE-Analyzer. The information about the contribution of particle type and their energy distribution to organ dose of a mouse and human is quite important in the research to adopt the experimental data obtained from mice to the radiological protection system for humans. This program will be opened for public under the agreement with the Center for Computational Science & e-System (CCSE) of JAEA.

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Appendix-A How to set up DOSE-Analyzer

A-1 Contents of the software

The software includes the executable binary file, dose database, and manual. It has the following structure:

- Folder “DATABASE” contains the relational database. The detailed description about the database structure is given in Section 3.
- File “DOSE-Analyzer.xls” contains the VBA code to launch DOSE-Analyzer.
- File “UserGuide.pdf” is this report as a user guide.

A-2 System Requirements

DOSE-Analyzer requires the following minimum system configuration:

- Microsoft Windows 2000, XP, or Vista operating system. Others are not supported.
- Microsoft Office Excel 97™ or latter.
- Intel Pentium II 350 MHz or higher processor.
- 256 MB physical memory (RAM).
- 300 MB of available disk space for software installation on system drive.
- CD-ROM drive for software installation.

A-3 Installation

To obtain optimal performances from DOSE-Analyzer, the software and the database should be installed on the local hard drive. Simply copy the whole CD-ROM content to the local hard drive in a folder of user’s convenience, *e.g.* D:¥DOSEAnalyzer.

The users can also run DOSE-Analyzer directly from the CD-ROM drive and access the packaged database on the CD-ROM, while the performances will not be optimal.

A-4 Uninstall

If the software installed on the local hard drive, just remove the whole files and folders copied in the installation process.

A-5 Starting DOSE-Analyzer

To start DOSE-Analyzer, double click on the "DOSEAnalyzer.xlm" file. When the macro security level in Excel is set to **Low**, DOSE-Analyzer can be run without prompting. When the macro security is set to **Medium**, a security dialog is appeared. Figure A-1 shows an example of the dialog. In this case, the users must click on "Enable Macros" to start up the software. When macro security is set to **High**, Excel allows to run only those macros that are digitally signed or stored in a trusted location. In this case, we recommend that the users change the macro security level to **Medium** or lower temporarily. The macro security setting is different in the versions of Excel. Therefore, if you have a trouble in starting DOSE-Analyzer, refer the Microsoft Office Excel help for the version used.

Figure A-1. Example of security dialog in Microsoft Office Excel

国際単位系（SI）

表１．SI 基本単位

基本量	SI 基本単位	
	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd

表２．基本単位を用いて表されるSI組立単位の例

組立量	SI 基本単位	
	名称	記号
面積	平方メートル	m^2
体積	立法メートル	m^3
速さ，速度	メートル毎秒	m/s
加速度	メートル毎秒毎秒	m/s^2
波数	毎メートル	m^{-1}
密度，質量密度	キログラム毎立方メートル	kg/m^3
面積密度	キログラム毎平方メートル	kg/m^2
比体積	立方メートル毎キログラム	m^3/kg
電流密度	アンペア毎平方メートル	A/m^2
磁界の強さ	アンペア毎メートル	A/m
量濃度(a)，濃度	モル毎立方メートル	mol/m^3
質量濃度	キログラム毎立法メートル	kg/m^3
輝度	カンデラ毎平方メートル	cd/m^2
屈折率(b)	（数字の） 1	1
比透磁率(b)	（数字の） 1	1

(a) 量濃度（amount concentration）は臨床化学の分野では物質濃度（substance concentration）ともよばれる。
(b) これらは無次元量あるいは次元１をもつ量であるが、そのことを表す単位記号である数字の１は通常は表記しない。

表３．固有の名称と記号で表されるSI組立単位

組立量	SI 組立単位			
	名称	記号	他のSI単位による表し方	SI基本単位による表し方
平面角	ラジアン(b)	rad	1 (b)	m/m
立体角	ステラジアン(b)	sr(c)	1 (b)	m^2/m^2
周波数	ヘルツ(d)	Hz		s^{-1}
力	ニュートン	N		m kg s^{-2}
圧力，応力	パスカル	Pa	N/m^2	m^{-1} kg s^{-2}
エネルギー，仕事，熱量	ジュール	J	N m	m^2 kg s^{-2}
仕事率，工率，放射束	ワット	W	J/s	m^2 kg s^{-3}
電荷，電気量	クーロン	C		s A
電位差（電圧），起電力	ボルト	V	W/A	m^2 kg s^{-3} A^{-1}
静電容量	ファラド	F	C/V	m^{-2} kg^{-1} s^4 A^2
電気抵抗	オーム	Ω	V/A	m^2 kg s^{-3} A^{-2}
コンダクタンス	ジーメンス	S	A/V	m^{-2} kg^{-1} s^3 A^2
磁束	ウエーバ	Wb	Vs	m^2 kg s^{-2} A^{-1}
磁束密度	テスラ	T	Wb/m^2	kg s^{-2} A^{-1}
インダクタンス	ヘンリー	H	Wb/A	m^2 kg s^{-2} A^{-2}
セルシウス温度	セルシウス度(e)	℃		K
光束	ルーメン	lm	cd sr(c)	cd
照度	ルクス	lx	lm/m^2	m^{-2} cd
放射性核種の放射能(f)	ベクレル(d)	Bq		s^{-1}
吸収線量，比エネルギー分与，カーマ	グレイ	Gy	J/kg	m^2 s^{-2}
線量当量，周辺線量当量，方向性線量当量，個人線量当量	シーベルト(g)	Sv	J/kg	m^2 s^{-2}
酸素活性	カタール	kat		s^{-1} mol

(a)SI接頭語は固有の名称と記号を持つ組立単位と組み合わせても使用できる。しかし接頭語を付した単位はもはやコヒーレントではない。
(b)ラジアンとステラジアンは数字の１に対する単位の特別な名称で、量についての情報をつたえるために使われる。実際には、使用する時には記号rad及びsrが用いられるが、習慣として組立単位としての記号である数字の１は明示されない。
(c)測光学ではステラジアンという名称と記号srを単位の表し方の中に、そのまま維持している。
(d)ヘルツは周期現象についてのみ、ベクレルは放射性核種の統計的過程についてのみ使用される。
(e)セルシウス度はケルビンの特別な名称で、セルシウス温度を表すために使用される。セルシウス度とケルビンの単位の大きさは同一である。したがって、温度差や温度間隔を表す数値はどちらの単位で表しても同じである。
(f)放射性核種の放射能（activity referred to a radionuclide）は、しばしば誤った用語で"radioactivity"と記される。
(g)単位シーベルト（PV,2002,70,205）についてはCIPM勧告2（CI-2002）を参照。

表４．単位の中に固有の名称と記号を含むSI組立単位の例

組立量	SI 組立単位		
	名称	記号	SI 基本単位による表し方
粘度	パスカル秒	Pa s	m^{-1} kg s^{-1}
力のモーメント	ニュートンメートル	N m	m^2 kg s^{-2}
表面張力	ニュートン毎メートル	N/m	kg s^{-2}
角速度	ラジアン毎秒	rad/s	m m^{-1} s^{-1}=s^{-1}
角加速度	ラジアン毎秒毎秒	rad/s^2	m m^{-1} s^{-2}=s^{-2}
熱流密度，放射照度	ワット毎平方メートル	W/m^2	kg s^{-3}
熱容量，エントロピー	ジュール毎ケルビン	J/K	m^2 kg s^{-2} K^{-1}
比熱容量，比エントロピー	ジュール毎キログラム毎ケルビン	J/(kg K)	m^2 s^{-2} K^{-1}
比エネルギー	ジュール毎キログラム	J/kg	m^2 s^{-2}
熱伝導率	ワット毎メートル毎ケルビン	W/(m K)	m kg s^{-3} K^{-1}
体積エネルギー	ジュール毎立方メートル	J/m^3	m^{-1} kg s^{-2}
電界の強さ	ボルト毎メートル	V/m	m kg s^{-3} A^{-1}
電荷密度	クーロン毎立方メートル	C/m^3	m^{-3} sA
表面電荷	クーロン毎平方メートル	C/m^2	m^{-2} sA
電束密度，電気変位	クーロン毎平方メートル	C/m^2	m^{-2} sA
誘電率	ファラド毎メートル	F/m	m^{-3} kg^{-1} s^4 A^2
透磁率	ヘンリー毎メートル	H/m	m kg s^{-2} A^{-2}
モルエネルギー	ジュール毎モル	J/mol	m^2 kg s^{-2} mol^{-1}
モルエントロピー，モル熱容量	ジュール毎モル毎ケルビン	J/(mol K)	m^2 kg s^{-2} K^{-1} mol^{-1}
照射線量（X線及びγ線）	クーロン毎キログラム	C/kg	kg^{-1} sA
吸収線量率	グレイ毎秒	Gy/s	m^2 s^{-3}
放射強度	ワット毎ステラジアン	W/sr	m^4 m^{-2} kg s^{-3}=m^2 kg s^{-3}
放射輝度	ワット毎平方メートル毎ステラジアン	$W/(m^2$ sr)	m^2 m^{-2} kg s^{-3}=kg s^{-3}
酵素活性濃度	カタール毎立方メートル	kat/m^3	m^{-3} s^{-1} mol

表５．SI 接頭語

乗数	接頭語	記号	乗数	接頭語	記号
10^{24}	ヨタ	Y	10^{-1}	デシ	d
10^{21}	ゼタ	Z	10^{-2}	センチ	c
10^{18}	エクサ	E	10^{-3}	ミリ	m
10^{15}	ペタ	P	10^{-6}	マイクロ	μ
10^{12}	テラ	T	10^{-9}	ナノ	n
10^9	ギガ	G	10^{-12}	ピコ	p
10^6	メガ	M	10^{-15}	フェムト	f
10^3	キロ	k	10^{-18}	アト	a
10^2	ヘクト	h	10^{-21}	ゼプト	z
10^1	デカ	da	10^{-24}	ヨクト	y

表６．SIに属さないが、SIと併用される単位

名称	記号	SI 単位による値
分	min	1 min=60s
時	h	1h =60 min=3600 s
日	d	1 d=24 h=86 400 s
度	°	1°=(π/180) rad
分	’	1’=(1/60)°=(π/10800) rad
秒	”	1”=(1/60)’=(π/648000) rad
ヘクタール	ha	$1ha=1hm^2=10^4m^2$
リットル	L, l	$1L=11=1dm^3=10^3cm^3=10^{-3}m^3$
トン	t	$1t=10^3$ kg

表７．SIに属さないが、SIと併用される単位で、SI単位で表される数値が実験的に得られるもの

名称	記号	SI 単位で表される数値
電子ボルト	eV	$1eV=1.602\ 176\ 53(14)\times10^{-19}J$
ダルトン	Da	$1Da=1.660\ 538\ 86(28)\times10^{-27}kg$
統一原子質量単位	u	1u=1 Da
天文単位	ua	$1ua=1.495\ 978\ 706\ 91(6)\times10^{11}m$

表８．SIに属さないが、SIと併用されるその他の単位

名称	記号	SI 単位で表される数値
バール	bar	$1\ bar=0.1MPa=100kPa=10^5Pa$
水銀柱ミリメートル	mmHg	1mmHg=133.322Pa
オングストローム	Å	$1\ Å=0.1nm=100pm=10^{-10}m$
海里	M	1 M=1852m
バーン	b	$1\ b=100fm^2=(10^{-12}cm)2=10^{-28}m^2$
ノット	kn	1 kn=(1852/3600)m/s
ネーパ	Np	SI単位との数値的な関係は、対数量の定義に依存。
ベル	B	
デジベル	dB	

表９．固有の名称をもつCGS組立単位

名称	記号	SI 単位で表される数値
エルグ	erg	$1\ erg=10^{-7}$ J
ダイン	dyn	$1\ dyn=10^{-5}$N
ポアズ	P	1 P=1 dyn s cm^{-2}=0.1Pa s
ストークス	St	1 St =$1cm^2$ s^{-1}=$10^{-4}m^2$ s^{-1}
スチルブ	sb	1 sb =1cd cm^{-2}=10^4cd m^{-2}
フォト	ph	1 ph=1cd sr cm^{-2} 10^4lx
ガル	Gal	1 Gal =1cm s^{-2}=$10^{-2}ms^{-2}$
マクスウェル	Mx	1 Mx = 1G cm^2=10^{-8}Wb
ガウス	G	1 G =1Mx cm^{-2} =10^{-4}T
エルステッド(c)	Oe	1 Oe ≙ $(10^3/4\pi)$A m^{-1}

(c) ３元系のCGS単位系とSIでは直接比較できないため、等号「 ≙ 」は対応関係を示すものである。

表10．SIに属さないその他の単位の例

名称	記号	SI 単位で表される数値
キュリー	Ci	$1\ Ci=3.7\times10^{10}Bq$
レントゲン	R	$1\ R=2.58\times10^{-4}C/kg$
ラド	rad	$1\ rad=1cGy=10^{-2}Gy$
レム	rem	$1\ rem=1\ cSv=10^{-2}Sv$
ガンマ	γ	1γ=1 nT=10-9T
フェルミ		1フェルミ=1 fm=10-15m
メートル系カラット		1メートル系カラット = 200 mg = 2×10-4kg
トル	Torr	1 Torr = (101 325/760) Pa
標準大気圧	atm	1 atm = 101 325 Pa
カロリー	cal	1cal=4.1858J（「15℃」カロリー），4.1868J（「IT」カロリー）4.184J（「熱化学」カロリー）
ミクロン	μ	1 μ =1μm=10^{-6}m

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