International Atomic Energy Agency

Guidance for Calculating the Indicator of Sustainable Development for Radioactive Waste Management

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1. BACKGROUND

As a follow up to the United Nation's (UN) Conference on Environment and Development in 1992 [1], the UN's Department of Economic and Social Affairs (DESA) invited the IAEA to develop one or more indicators of sustainable development (ISD) for the management of radioactive waste (RW). Responsibility for this task was given to the IAEA's Division of Nuclear Fuel Cycle and Waste Technology (NEFW) within the Department of Nuclear Energy.

Indicators were required to cover radioactive waste from both Nuclear Power and Nuclear Applications activities. Following guidance from UN-DESA on scope and methodology, a series of workshops and consultancies resulted in the development of a family of indicators. As of 1999, the IAEA had proposed a set of nine ISD-RW. However, in late 1999 DESA, the UN agency responsible for indicators, began a process to consolidate the various ISD that had been developed and, to varying degrees, subjected to country testing. The result was that experts chosen by DESA selected a single ISD-RW to remain in the DESA list of indicators ("*Indicators of Sustainable Development: Guidelines and Methodologie*s", UN, New York, 2001).

This selected ISD-RW was reviewed by the IAEA's experts in two consultants' meetings held September 2001 and February 2002. The experts concluded that an alternative ISD-RW was required since the ISD-RW selected by DESA:

- does not derive or use a baseline against which progress can be judged,
- does not acknowledge waste that is under management control,
- makes no distinction between wastes from different activities (e.g. Fuel Cycle, medical use etc.),
- makes no attempt to discriminate between the relative hazards of waste types (e.g. low-level waste (LLW) and high-level waste (HLW)),
- uses a metric (volume) that is dominated by low risk waste (LLW),
- appears to penalize nations with nuclear power plants even if they manage their wastes in a sustainable manner (since the only metric is volume),
- has no clear definition of an end point (when is sustainability reached?),
- fails to distinguish between wastes with and without a defined disposition, and
- uses an unproven supposition that the volume of waste is linked to environmental impact and human health.

As a consequence of the consultancies, a new ISD-RW was developed and is described next.

2. THE INDICATOR OF SUSTAINABLE DEVELOPMENT FOR RADIOACTIVE WASTE MANAGEMENT

The ISD-RW developed by NEFW:

- recognizes the shortcomings of a purely volume based approach for an indicator,
- is a single, dimensionless indicator that includes a consideration of waste volumes in its derivation, and
- provides a measure of both the current status of radioactive waste management at any point in time and the progress made over time towards the sustainability of radioactive waste management. This measure can be at the national level for a country or it can be at sectoral levels, such as nuclear applications (e.g., medical and industrial applications).

Sustainability is the point at which the amount of radioactive waste awaiting disposal is not increasing, the waste is in the final form required for disposal and it is being safely stored. Note, since currently there is an international debate about whether or not disposal is the ***endpoint*** for waste management (some have proposed alternatives such as indefinite storage), the use of the term disposal in the context of the ISD-RW implies any internationally acknowledged alternative to disposal.

The ISD-RW only considers managed waste, it does not consider the intentional release of radioactivity into the environment (the "dilute and disperse" option). The ISD-RW does not require countries to base reporting of the indicator on (1) historic waste (except as a recognized component of a backlog of waste), (2) contaminated sites or (3) NORM[(1)] waste; however, these waste may be factored in on a voluntary basis.

The ISD-RW is based upon two factors that are applied to each of the waste classes used and reported by a country. Each factor has 4 states that indicate progress by way of milestones. The use of these two factors results in the ISD-RW being expressed as a dimensionless number between 0 and 100 with 0 being the least sustainable condition and 100 being the most sustainable condition.

FORM FACTOR

indicates the **suitability** of waste for storage or its endpoint

Factor	Value	Description
F1	0	waste not established as acceptable or known not to be acceptable for storage
F2	10	capability exists to process waste for storage
F3	25	capability exists to process waste for endpoint condition
F4	50	inventory of waste not in its endpoint condition is not increasing

ENDPOINT FACTOR

indicates the **status** of waste relative to its endpoint

Factor	Value	Description
E1	0	no planned endpoint established
E2	10	design and site approved
E3	25	facility operational
E4	50	inventory of waste not placed into its endpoint is not increasing

Note: Factors F4 and E4 indicate a capacity to manage waste as opposed to a capability to manage

The two factors are to be applied to **each** of the waste classes that are used and reported by a country. By way of example only, the ISD-RW limiting conditions that follow assume that a country uses three waste classes (LILW-SL, LILW-LL and HLW). Note: it is not necessary to define LILW-SL, etc. since the ISD-RW allows countries to report according to their own waste classes, which are too numerous and diverse to define herein. It is only necessary to realize that nationally-based waste classes are used.

(1) Naturally Occurring Radioactive Material

Limiting Condition - Least Sustainable Condition

Waste Class	Form Factor	Endpoint Factor	Sum of Factors
LILW-SL	0	0	0
LILW-LL	0	0	0
HLW	0	0	0

Limiting Condition - Most Sustainable Condition

Waste Class	Form Factor	Endpoint Factor	Sum of Factors
LILW-SL	50	50	100
LILW-LL	50	50	100
HLW	50	50	100

Note: While the indicator is most useful when it is calculated and reported for each waste class used within a country, it is possible to derive a single, consolidated indicator based upon the average for each waste class. **The use of an average value should be used with caution since it might lead to a meaningless, misleading or unwanted result.**

The two factors were derived to reflect the management of waste and to cover the major activities of waste processing coupled with the final endpoint of the waste. The factors are presented as independent but are linked. For example, the capability of processing of waste to a form suitable for its endpoint requires a knowledge of the endpoint (but not necessarily the full achievement of factor E2). The factors are described next:

F1: Acceptability for storage can be achieved by regulatory acceptance or conformance with international guidance (for example, IAEA Safety Standards). Possible reasons for failing to achieve acceptance include:

- absence of a regulator or failure to satisfy the regulator,
- no mechanism to assess or present the justification for storage, and
- no assessment carried out

F2: The capability to prepare waste for storage implies that the waste can be put into a form that can be demonstrated to satisfy, as a minimum, international guidance for the storage of waste. Examples include:

- tanks that are acceptable for liquid waste,
- the containerization of loose waste,
- treatment to stabilize waste, and
- conditioning

This state implies the availability of a suitable facility to store the waste.

F3: The capability to prepare waste for the endpoint implies that (a) an endpoint has been identified and (b) that the waste form meets endpoint acceptance criteria. This state also implies that the waste form can be stored in an acceptable facility and this facility has a sufficient design life to contain the waste until consigned to its endpoint.

In some cases, the F3 state will be identical to the F2 state; however, the state will be supported by additional evidence that the waste will meet the endpoint criteria (as a minimum to international guidelines).

F4: This state requires that the inventory of waste that is not suitable for its endpoint is not increasing, which requires a knowledge of both the rate of waste generation and the rate that it is put into its endpoint condition. If waste is generated in a form that is not suitable for its endpoint condition, processing facilities must be available and processing it to a form suitable for its endpoint at a rate equal to or greater than the rate of its arising.

E1: This state implies that there are no plans for an endpoint for the waste or that the plans are insufficiently well formulated to give confidence that an endpoint can be achieved on a defined time scale. An example might be that disposal is the endpoint but neither a facility design nor a site has been approved (e.g., *accepted by the regulato*r).

E2: In this state, a major hurdle has been overcome. A site and a facility design have been approved thereby overcoming one of the major impediments to putting waste into its endpoint.

E3: In this state, the endpoint facility has been licensed and its operability demonstrated. It does not imply that it is fully operational or receiving waste, only that it is possible to put waste into its endpoint.

E4: This state requires that the inventory of waste waiting to be put into its endpoint is not increasing, which requires a knowledge of both the rate of waste generation and the rate that it is put into its endpoint. This state indicates that progress is being made to reduce the inventory of wastes not in its the endpoint. An understanding of the volume changes related to processing is also required to determine this state.

The following is a theoretical example of calculating the ISD-RW for each waste class reported by a country. The example assumes the following conditions exist in a country:

- the country uses the waste classes GCC, HLW, LLW, TRU, and SF,
- the amount of LLW and TRU that is unsuitable for disposal is not increasing and the amount of waste awaiting disposal is not increasing,
- the capability exists to put GCC into a safe storage condition, details of a disposal facility have not been established,
- the capability exists to put HLW into its endpoint condition, details of a disposal facility have not been established,
- SF is in a safe storage condition, details of disposal facility have not been established.

Waste Class	**Form Factor**	**Endpoint Factor**	**Sum of Factors**
LLW	50	50	100
TRU	50	50	100
GCC	10	0	10
HLW	25	0	25
SF	10	0	10

Note, for some waste, like SF, if the waste, as generated, is in a form suitable for storage, a country would use Form Factor F2 (since processing is not required, a value equivalent to having the necessary processing is used). A similar approached is used for waste that, as generated, is suitable for disposal.

The following provides guidance for calculating the ISD-RW. The guidance is based upon IAEA consultants' meetings held September 2002 and September 2004 and revised October 2004.

3. GUIDANCE FOR CALCULATING THE ISD-RW

To calculate the ISD-RW, the first step is to identify the various classes of radioactive waste that are managed in a county [2],[3],[4]. Next, the ISD-RW is calculated for each waste class. This process can lead to misleading or unwanted results if the waste classification scheme(s) used by a country:

- is not "endpoint" based

  As stated previously, "*Sustainability is the point at which the amount of radioactive waste awaiting* ***disposal*** *is not increasing, the waste is in the final form required for* ***disposal*** *and it is being safely stored*". The ISD-RW was developed to reflect sustainability and, therefore, is best applied to waste classes that are "endpoint" based. For example, one country uses the following waste classes, which are endpoint based:

  LLW-A, LLW-B, LLW-C (surface / near surface disposal)

  LLW-GCC (not suitable for surface / near surface disposal)

  HLW (geological disposal)

  This waste classification scheme is suitable for calculating the ISD-RW. However, schemes that are based on, for example, handling waste (using radiation field and contamination levels) may not be suitable for calculating the ISD-RW.

  Countries should not re-classify wastes simply to be able to calculate the ISD-RW if they determine that calculations with their existing waste classes lead to misleading or unwanted results. Instead, these countries should undertake a review of their waste classification scheme(s) in the context of its applicability to the full life cycle management of waste. If after this review countries adopt a revised waste classification scheme, the ISD-RW can be recalculated for the new classes.

- does not adequately separate waste into suitable classes

  The classification scheme shown above is a good example of separating wastes into a sufficient number of classes to facilitate the effective, long-term management of wastes. However, some countries may have waste classes that could lead to unwanted results when calculating the ISD-RW.

  For example, suppose that LLW-A, LLW-B, LLW-C and LLW-GCC were rolled into a single waste class called LLW. Calculating the ISD-RW could "penalize" the country for grouping waste unsuitable for surface disposal into the same class as waste suitable for surface disposal. When calculating the ISD-RW, it is not possible to "break out" a sub-set of waste from a class, therefore, the ISD-RW calculation for LLW would have to be based upon the management of the GCC component ("worst case") and would not properly reflect the country's sustainability for the management of A, B and C waste. As stated above, countries should not re-classify wastes simply to be able to calculate the ISD-RW.

To assist with calculating the ISD-RW, two flowcharts were developed in the September 2002 consultancy on the ISD-RW. The flowcharts (Figures 1 and 2) and supporting text (Table I) were revised as a result of the September 2004 consultancy. The revisions were implemented to make the ISD-RW more understandable by persons whose first language is not English. For each decision node in the flowcharts, explanations are given in Table I. As stated earlier, disposal in the flowcharts and table implies any internationally acceptable "endpoint" that is an alternative to disposal.

Note: Some persons have questioned the point system used (0, 10, 25, 50). The system was a matter of great debate during development of the ISD-RW. Since "% complete" is a common practice worldwide (e.g., 0 to 100% complete), the point system calculates sustainability on a scale of 0 to 100. While it can be debated whether a progression step should be 10 or 25 points, the relevant issue is that progress is measured by an increase in points – absolute values are not highly relevant.

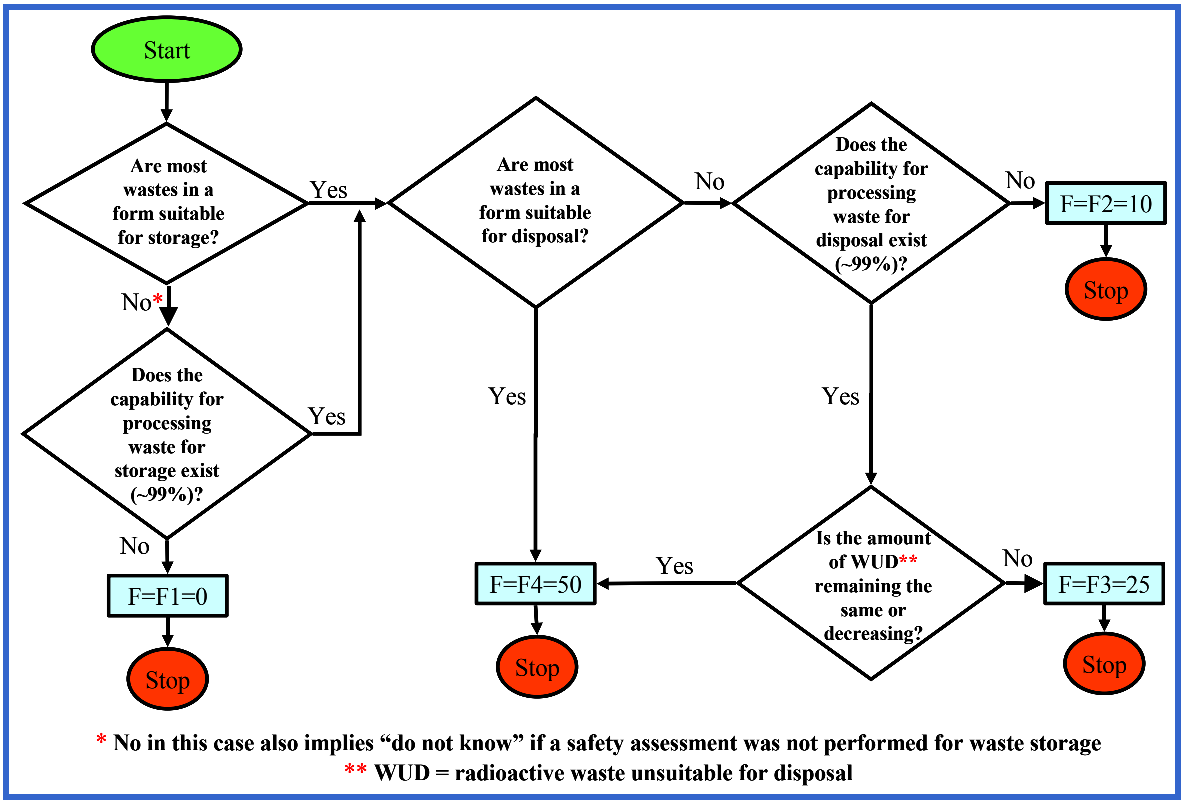

Figure 1: Guidance for Calculating the Form Factor (Flowchart 1)

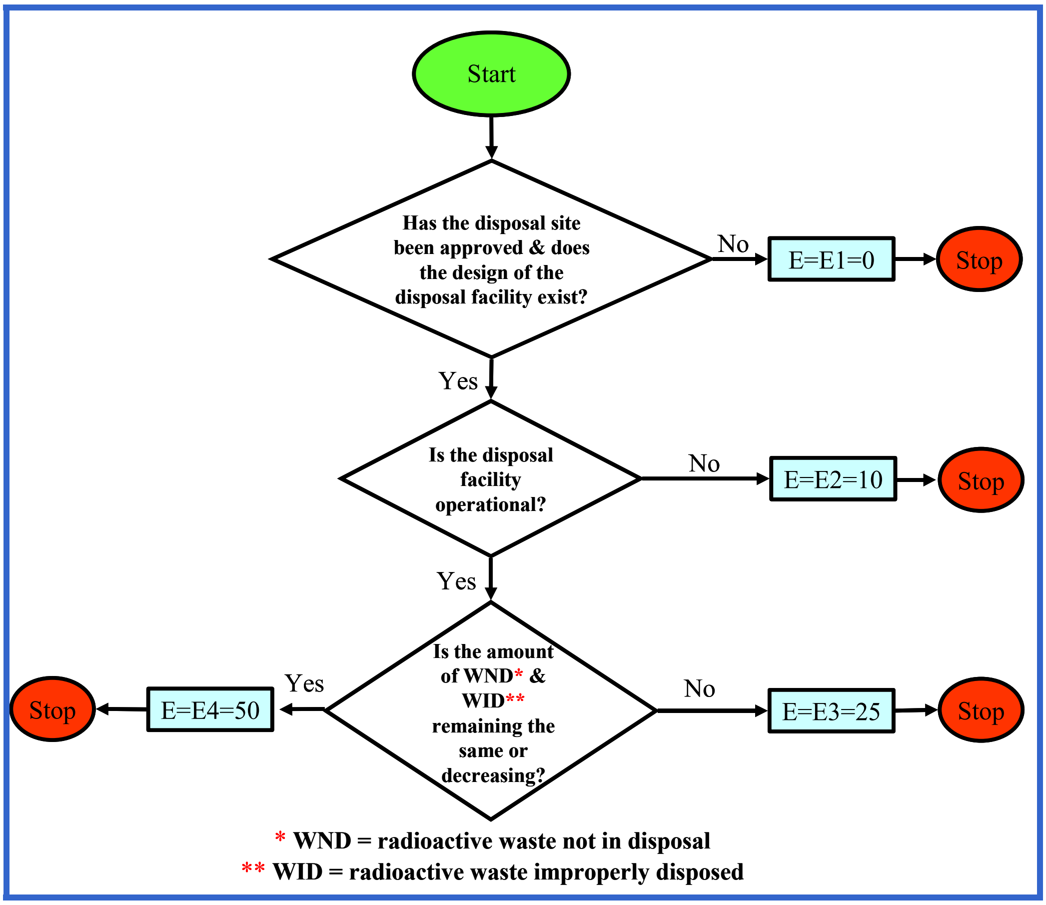

Figure 2: Guidance for Calculating the Endpoint Factor (Flowchart 2)

Table I. Guidance for Computing the ISD-RW Factors

Flowchart 1 & 2 questions	Explanation of the questions
1. Are most of current wastes in a form suitable for storage and is it estimated that predicted future waste will be in a form suitable for storage?	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Did you perform an assessment of existing and future waste regarding their suitability for storage*? Question: Did the assessment show that existing waste is in a form suitable for storage? Question: Did the assessment show that existing waste will continue to be in a suitable form under the conditions and time of storage? Question: Did the assessment show that future waste will in a form suitable for storage? * Form suitable for storage means that for the conditions and time of storage, packages remain retrievable (without package degradation that would cause significant health, safety or environmental impacts). The assessment should consider the waste package as well as the facility.
2. Does the capability of processing most waste to a form suitable for storage exist (~ 99% of the waste)? Note: 99% is a guide – it indicates that the capability exists for most waste. Note: for waste that is suitable for storage as generated (it does not need to be processed), a Yes answer applies.	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Are the technology and know-how for processing most waste* to forms suitable for storage** available? * Most waste means 99% of amounts (volume or mass) and activities of all existing and future waste. Question: Are financial and human resources available? Question: Are the necessary processing facilities licensed for operation? ** Waste may not be made suitable for storage but instead made suitable for disposal and stored (therefore suitable for storage is implied)
3. Are most of current wastes in a form suitable for disposal and is it estimated that predicted future waste will be in a form suitable for disposal?	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Did you perform an assessment of existing and future waste regarding their suitability for disposal? Question: Did the assessment indicate that waste currently in storage* and waste already disposed are/were in a suitable condition for disposal**? Question: Did the assessment indicate that most future waste would be suitable for disposal? * For waste in storage, it must be in a form suitable for the intended repository until the time of retrieval from storage and emplacement into the repository. For waste disposed, it must have been in a form suitable for disposal at the time of its emplacement in the repository. ** An assessment might indicate that some waste had been improperly disposed (WID = waste improperly disposed), that is, it was Unsuitable for Disposal (WUD) in currently operated or previously operated repositories if disposal practices do not meet present day standards.
4. Does the capability for processing most WUD to forms suitable for disposal exist (~ 99% of the waste)? Note: 99% is a guide – it indicates that the capability exists for most waste.	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Are the technology and know-how for processing most WUD* to forms suitable for disposal available? *Most WUD means 99% of volumes and activities of all existing and future WUD. Question: Are financial and human resources available?

Flowchart 1 & 2 questions	**Explanation of the questions**
Note: for waste that is suitable for disposal as generated (it does not need to be processed), a Yes answer applies.	Question: Are the necessary processing facilities licensed for operation?
5. Is the amount (volume or mass) of WUD remaining the same or decreasing?	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Have you compared the existing amount of WUD with the past amount of WUD? Question: Does the comparison show that the amount WUD remained the same or is decreasing? Question: Have you compared the existing amount of WUD with predicted future amount of WUD? Question: Does the comparison show that no increase in the amount of WUD is expected to occur in the near future, e.g. in the next 2 to 5 years?
6. Has the disposal site(s) been approved and does the design of disposal facility(ies) exist?	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Has the disposal site(s) been approved by the regulatory authority? Question: Has the design of the disposal facility(ies) been completed? Question: Has the application for construction approval been submitted to the regulatory authority?
7. Is the disposal facility(ies) operational?	To get a "Yes" answer, the answer to the following question must be "Yes": Question: Has the facility been approved for operation by the regulatory authority?
8. Is the amount (volume or mass) of WND* and WID** remaining the same or decreasing? *WND: Radioactive waste not in disposal **WID : Radioactive waste improperly disposed	To get a "Yes" answer, the answers to all the following questions must be "Yes": Question: Have you compared the existing amounts of WND and WID with the past amounts of WND and WID? Question: Does the comparison show that the amounts of WND and WID remained the same or are decreasing? Question: Have you compared the existing amounts of WND and WID with predicted future amounts of WND and WID? Question: Does the comparison show that no increases in the amounts of WND and WID are expected to occur in the near future, e.g. in the next 2 to 5 years?

4. THE INTERNATIONAL ATOMIC ENERGY AGENCY'S NET ENABLED WASTE MANAGEMENT DATABASE IN THE CONTEXT OF THE ISD-RW

One of the reasons the International Atomic Energy Agency (IAEA) developed its Net Enabled Waste Management Database (NEWMDB) [3] to [8] was to provide support for the ISD-RW. The NEWMDB is an international database, however, per UN guidance, all indicators are required to satisfy the following:

- **national** in scale and scope,
- relevant to assessing progress towards sustainable development,
- understandable, that is to say, clear, simple and unambiguous,
- realizable within the capacities of **national** Governments,
- conceptually well founded,

- open-ended and adaptable to future development,
- dependent on data that are readily available or available at a reasonable cost benefit ratio, and
- adequately documented, of known quality and updated at regular intervals.

To ensure that any indicator that was developed would be useful to and could be used by countries, the UN had activities on capacity building and training (1995-1999) and country testing (1996-1999). Since the ISD-RW was only developed in late 2001 and finalized in early 2002, it was not part of any capacity building, training or country testing activities. This issue was recognized during the development of the NEWMDB.

If it could be demonstrated that the NEWMDB could be used to collect and compile the same nationally-based data that would be required to compute an ISD-RW, then use of the NEWMDB could be considered as the capacity building, training and country testing activities applied to other indicators.

The first data collection cycle with the NEWMDB was conducted from July 2001 to March 2002. A review of the information collected was carried out in the context of the ISD-RW during the consultancy held in September 2002. The conclusions and recommendations of the consultants were:

- *"…The NEWMDB does not have all the information to compute the ISD-RW. However, countries that prepare NEWMDB submissions should be able to calculate the ISD-RW based on those submissions plus supplemental information that is likely to be available (such as qualitative information that is needed to answer the guidance questions).*
- *An ISD-RW questionnaire, based on the guidance in this document, should be added to the NEWMDB to provide an effective way of compiling the information needed to compute the ISD-RW.*
- *Since the ISD-RW is computed for each waste class used by a country, understanding and use of both the NEWMDB and the ISD-RW should be harmonized by way of achieving international consensus on radioactive waste classification…"*

The "ISD-RW questionnaire" cited above was implemented as an "ISD-RW calculator" in the Public Area of the NEWMDB version II – see Figure 3. The additional information that is cited in Figure 3 can be accessed from the following Internet page (see Figure 4):

http://www-newmdb.iaea.org/showhelp.asp?Topic=21-3-1

Note: Access to the Public Area of the NEWMDB requires registration as a Public User (described in the next paragraph). However, because the ISD-RW is for national use only, the results of calculations using the ISD-RW calculator are not stored in the NEWMDB or retained in any way by the IAEA. The results of calculations are stored in web browser "cookies" on the computer of the person who performed the calculations. The IAEA has not requested and will not request the results of calculations. The IAEA's only responsibility was to develop the ISD-RW and, as needed, to update it. The IAEA does not have the mandate to monitor use of the ISD-RW to assess the sustainability of radioactive waste management. The continuing role of the IAEA is to ensure that the indicator is clearly understood by those who wish to assess the sustainability of radioactive waste management in their own country and, as needed, to provide assistance for use of the ISD-RW calculator.

To register as a Public User for the NEWMDB, please access the NEWMDB's home page [8] at the following Internet address, then click on the Public Area tab (see Figure 5):

http://www-newmdb.iaea.org

Figure 6 shows the main screen for the ISD-RW calculator and gives basic instructions for using the calculator.

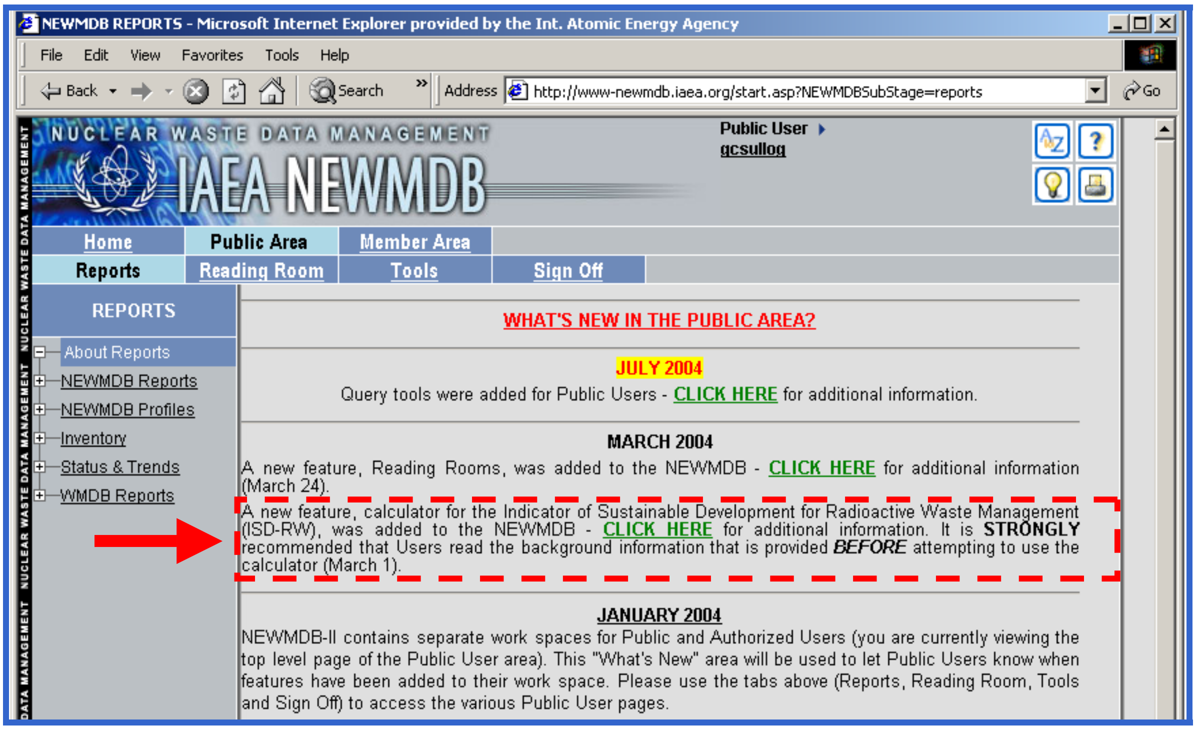

Figure 3: Announcement of the ISD-RW Calculator (see Figure 4)

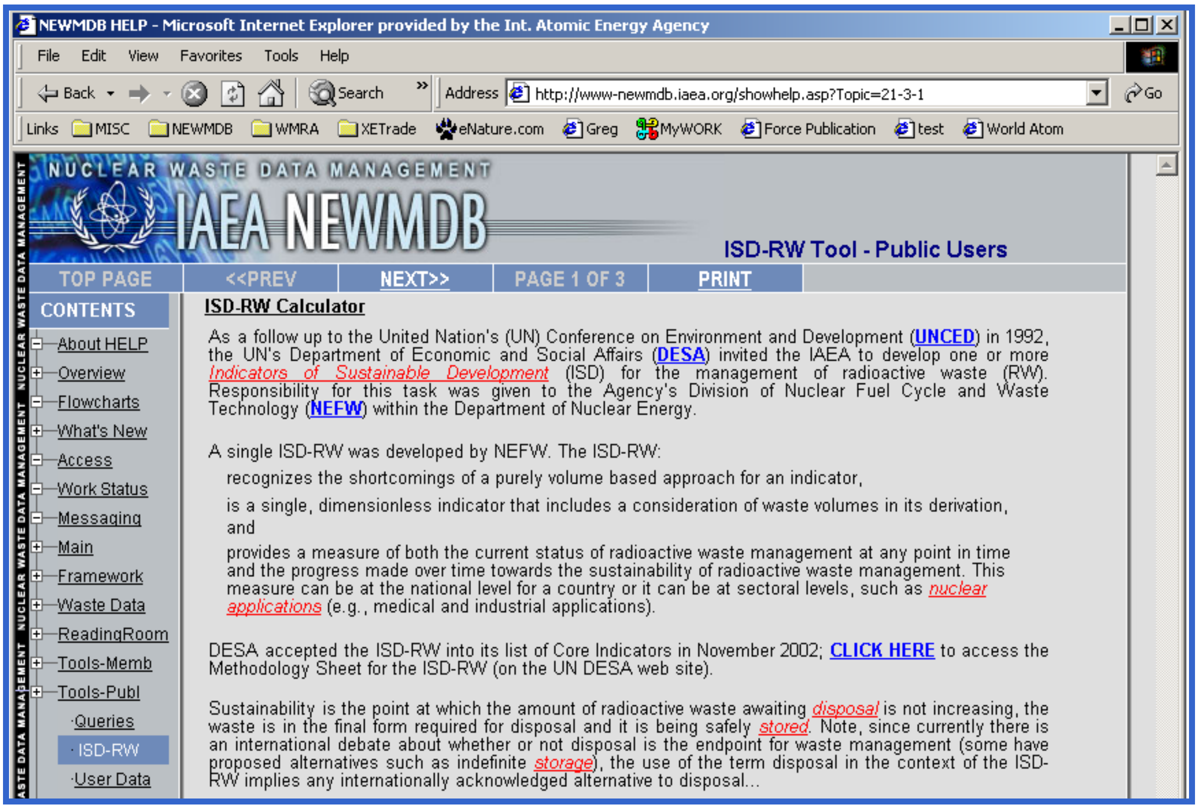

Figure 4: On Line Background Information for the ISD-RW (see Figure 3)

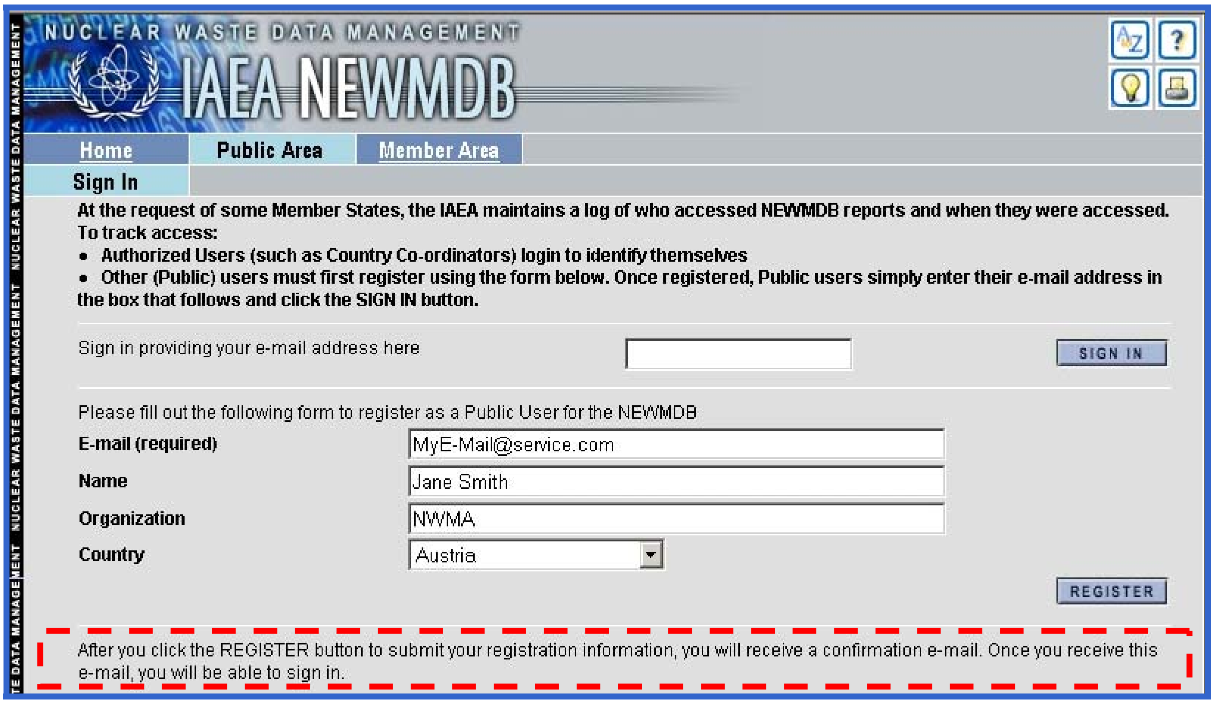

Figure 5: NEWMDB Public User Registration Screen

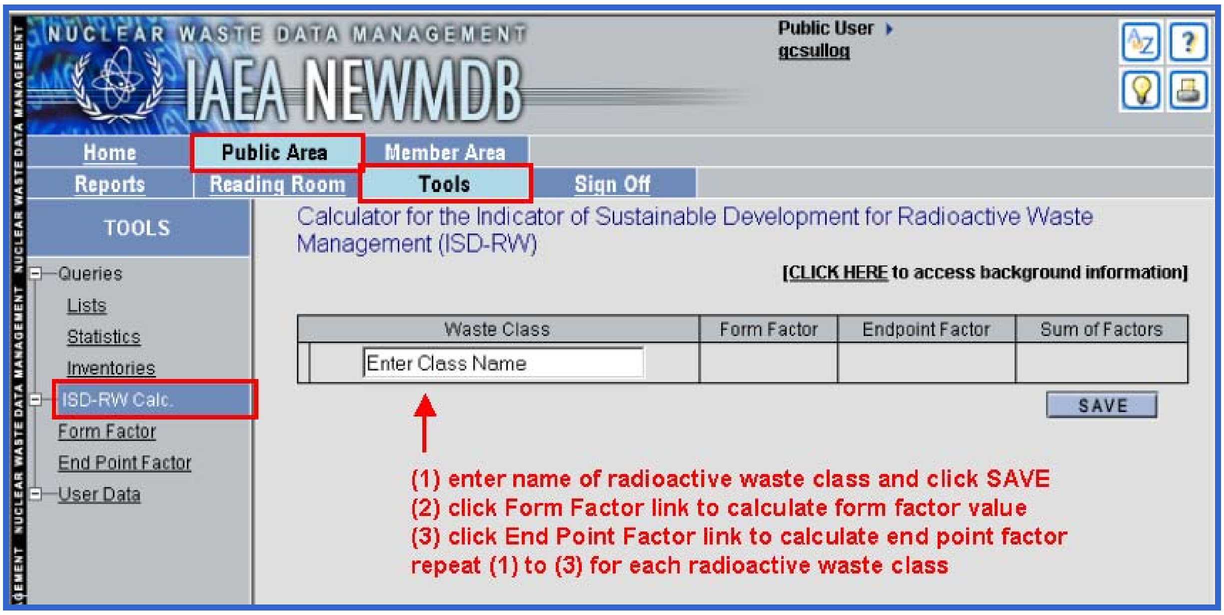

Figure 6: Screen capture of ISD-RW Calculator in the NEWMDB

5. SUMMARY

During late 2001, the IAEA developed an indicator of sustainable development for radioactive waste management (ISD-RW) in the context of Agenda 21. This indicator was further refined in early 2002. The indicator was subjected to testing in September 2002 by consultants from four IAEA Member States. The consultants found the ISD-RW acceptable but did not like the guidance that had been developed by the IAEA. New guidance for computing the ISD-RW was developed. The ISD-RW and its guidance were posted on the DESA website along with the other core indicators of sustainable development [9].

In March 2004, an "ISD-RW calculator" was added to the Public Area of the IAEA's Net Enabled Waste Management Database (NEMWDB) to facilitate use of the ISD-RW. In September 2004, an IAEA consultants' meeting was held to assess the ISD-RW and the calculator. Consultants from six IAEA Member States participated in the consultancy – for all consultants, English was not their first language. Based on the consultancy, guidance for the ISD-RW was updated to improve its use by persons whose first language was not English.

In November 2004, the updated ISD-RW guidance document was submitted to DESA for posting on its web site. In addition, the ISD-RW calculator was updated to reflect the new guidance.

6. REFERENCES

[1] "Report of the United Nations Conference on Environment and Development", United Nations General Assembly Report A/CONF.151/26, 28 September 1992.

[2] "Classification of Radioactive Wastes", International Atomic Energy Agency Safety Guide, Safety Series 111-G-1.1, IAEA, Vienna, 1994.

[3] G.W. Csullog, H. Selling, R. Holmes and J.C. Benitez, "The Net Enabled Waste Management Database in the Context of an Indicator of Sustainable Development for Radioactive Waste Management", International Conference on Issues and Trends in Radioactive Waste Management, Vienna, Austria, December 9-13, 2002.

[4] G.W. Csullog, A. Petö, D. Tonkay and R. Burcl, "The Net Enabled Waste Management Database in the Context of Radioactive Waste Classification", International Conference on Issues and Trends in Radioactive Waste Management, Vienna, Austria, December 9-13, 2002.

[5] G.W. Csullog, I. Pozdniakov, G. Petison, V. Kostitsin, U. Shah, M.J. Bell, "The IAEA's Net Enabled Waste Management Database: Overview and Current Status" , International Conference on Issues and Trends in Radioactive Waste Management, Vienna, Austria, December 9-13, 2002.

[6] G.W. Csullog, I. Pozdniakov, U. Shah, V. Kostitsin, M.J. Bell, "The International Atomic Energy Agency's Net-Enabled Waste Management Database", Waste Management 2001 Symposium, Tucson, Arizona, USA, February 2001.

[7] G.W. Csullog, W.E. Falck, and S.T.W. Miaw, "The IAEA Perspective on International and National Radioactive Waste Management Information Systems", Proceedings of the "International Symposium on the Management of Radioactive Waste from Non-Power Applications - Sharing the Experience", Malta, November 2001, IAEA (in preparation).

[8] home page of the NEWMDB
http://www-newmdb.iaea.org

[9] "Management of Radioactive Waste", United Nations Department of Economic and Social Affairs, Division for Sustainable Development, Indicators of Sustainable Development, CSD Thematic Indicator Framework, Economic, Waste Generation and Management.
http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/isd-ms2001economicB.htm#radioactivewaste