DEVELOPMENT OF REGULATORY FRAMEWORK FOR IMPLEMENTING RADIOLOGICAL EXEMPTION/CLEARANCE BASED ON ALARA PRINCIPLES AND CURRENT PARACTICES IN KOREA

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ABSTRACT

The exact concepts of exclusion, exemption, and clearance have been addressed along with older terms such as *de minimis* and below regulatory concern (BRC). A series of decision-making procedure for determining the appropriateness of domestic implementation of the concepts were proposed: five primary categories (environmental and radiological factors, domestic social and political factors, economic factors, regulatory factors, technical factors) and four-step approach for establishing regulatory framework were described. Justification of implementing the concepts is to be determined at the first stage of political decision-making. A variety of dose limits and dose constraints, along with exemption/clearance criteria, were summarized in table forms. In addition, each country's exemption/clearance levels for specific radionuclides were compared and displayed. Currently, there exist internationally endorsed exemption levels, however, it seems that the situation is more complicated in the case of clearance levels. Historical review of Korean practices in implementing the concepts was addressed, and current relevant regulations and regulatory system were introduced. In addition, the results of a preliminary dose assessment study for selected nineteen scenarios were given and discussed. They showed that the clearance of moderate amount of very low level of radioactive waste (VLLW) containing radionuclides whose concentrations are below the general clearance levels would not exceed predetermined exemption/clearance criteria (i.e. 10 μSv/y and 1 person·Sv/y), even under very conservative assumptions. It is believed that the basic methodology for deriving domestic clearance levels has been attained in the previous dose assessment study. Finally eleven regulatory issues have been suggested and discussed. It is desirable that the proposed issues are to be resolved before full implementation of the concepts in a country.

INTRODUCTION

Even every natural substance emits a certain level of radiation caused by naturally occurring radionuclides. Until recently, however it has been a general rule to control all wastes regardless of their radionuclides concentrations, once they are classified as radioactive wastes. It is impractical and even impossible to regulate all materials just because they contain some radionuclides. Furthermore, in some cases such as exposure from cosmic rays, ^{40}K in human bodies, unmodified concentrations of radionuclides in raw materials, and so forth, regulatory control of the radiation sources, practices, or exposures is almost impossible. In this context, a series of criteria for discerning the radiation levels to be controlled under or released from radiological regulatory system has been introduced. In addition, the concepts of *de minimis*, *below regulatory concern (BRC)*, *exclusion*, *exemption*, and *clearance* have been introduced and extensively discussed for the last decade and adequately summarized in a series of documents [1-8].

The International Atomic Energy Agency (IAEA) defines radioactive waste as follows: *For legal and regulatory purposes, radioactive waste may be defined as material that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body, and for which no use is foreseen (It should be recognized that this definition is purely for regulatory purposes, and that material with activity concentrations equal to or less than clearance levels is radioactive from a physical viewpoint – although the associated radiological hazards are considered negligible.)* [9]. This statement implies that the VLLW under the predetermined clearance levels may be classified as non-radioactive waste, at least in the regulatory view point, and no regulatory control is needed.

In principle, the criteria for allowing exemption and clearance are to be based upon radiological risks caused by the radioactive waste. Accordingly, the whole practices for implementing the concepts should be proceeded under the as low as reasonably achievable (ALARA) principles. It is believed that there exists a certain international consensus on the needs and advantages of applying the concepts such as (1) maximization of natural resources, (2) effective use of land, and (3) optimization of radiation protection and limited regulatory works, etc. It does not mean, however, that the concepts have to be implemented in all countries. Whether or not adopting the concepts, practical application scopes, and detailed methodology should be determined based upon each country's specific situations. Thorough preparative measures and systematic approach is strongly needed for the country just intends to implement the concepts. In this case, a series of prior experiences, trial-and-errors, and practical problems, which could be learned from the countries formerly implementing the concepts, would be helpful.

GENERAL APPROACH AND METHODOLOGY

Fundamental Concepts and Terms

As a general rule, it is certain that any radioactive sources (i.e. radioactive materials and wastes) and practices which would cause radiation exposure to an extent should be under the regulatory control. In some cases, however, it may be amenable to control the sources under the regulatory system. Cosmic rays, and naturally occurring radionuclides existing in human body and in raw materials are typical examples of this concept, *exclusion*.

On the other hand, it is often the case that the radiological hazard caused by a certain source or practice is trivial and is beyond of regulator's concern. Radiation sources/practices which never enter the regulatory control (i.e. control is not imposed) are defined as exemption, and those which are released from regulatory control (i.e. control is removed) are named as clearance [4]. Other older terms such as *de minimis* and *BRC* have been also introduced prior to exclusion, exemption, and clearance. The concept of de minimis is to be distinguished from BRC [10]. The latter involves broader social and economic factors which encompass but are not limited to the purely risk-based factors addressed by the *de minimis*. That is, *de minimis* is one of the factors that determine the exemption of sources or practices that may result in dose below or above the *de minimis* level. Recently, however, these concepts tend to be covered by the concepts of exclusion, exemption, and clearance. Though the term *de minimis* is still being used in relation to the London Convention, the meaning of *de minimis* is well interpreted in the scope of exemption and clearance [8].

It is natural that no conditions be imposed to the exclusion, since the excluded sources/practices are not intrinsically amenable to control. The term conditional exemption or

clearance has sometimes been used to describe a release from regulatory control under specified conditions such as disposal route or destination. Regulators to ensure the compliance should check the conditions. For unconditional exemption or clearance, the sources/practices may be released from the regulations without regard to their destination. The regulators don't have to follow up the exempted or cleared sources/practices once they have left from regulatory concern. In principle, it is important to avoid imposing any conditions that would imply a need for subsequent regulatory surveillance. Recently, however, the use of the term conditional clearance is not recommended by the IAEA [8].

Criteria and Procedure for Permitting Exclusion, Exemption, and Clearance

It seems that there exists a certain international agreement in the dose criteria for exemption and clearance. Currently, it is generally recommended that the sources/practices meeting individual dose criterion of less than 10 μSv/y, and collective dose criterion of less than 1 person·Sv/y (or radiologically optimized) could be exempted or cleared [1,3]. As shown in TABLE I, the proposed exemption/clearance dose criterion is low enough since the value represents 1/100 of the ICRP-60's recommendations for general inhabitants (i.e. 1 mSv/y) and only 1/250 of the natural background exposure (i.e..2.5 mSv/y). For more convenience, the IAEA has proposed the general concentration criterion of exemption for hundreds of specific radionuclides [3]. These values have been derived from the most conservative scenarios, data, and assumptions.

TABLE I. COMPARISON OF DOSE LIMITS/CONSTRAINTS AND CRITERIA FOR EXEMPTION AND CLEARANCE

	ICRP 60		Criteria for Exemption/Clearance	Criteria for Unrestricted Site Use	Natural Background
	Workers	Inhabitants			
Dose Limit	100 mSv/5y (50 mSv/y)	1 mSv/y	10 μSv/y (Individual) 1 person·Sv /y (Collective)	0.25 mSv/y*	.2.5 mSv/y

* from U.S. Code of Federal Regulations Part 20; 20.1402

FIGURE 1 shows a stepwise regulatory procedure for allowing exclusion, exemption, and clearance of sources/practices. One of the most important assumptions is that the management options (exclusion, exemption or clearance) of the candidate sources/practices should be already justified by the regulatory authority (***justification***). If the sources/practices are not to be excluded, a series of dose criteria are subsequently applied (***dose limit or dose constraint***). Derivation and application of the general concentration criteria is for practical convenience: that is, a series of time-consuming procedure for radiological dose assessment to each candidate case can be remitted once the concentration limit is satisfied. As previously stated, the collective dose criterion is an alternative for proving that exemption or clearance of the practices is an optimized option (***optimization***). Finally it is clear that the implementation of exemption and clearance is proceeded according to the ALARA principles.

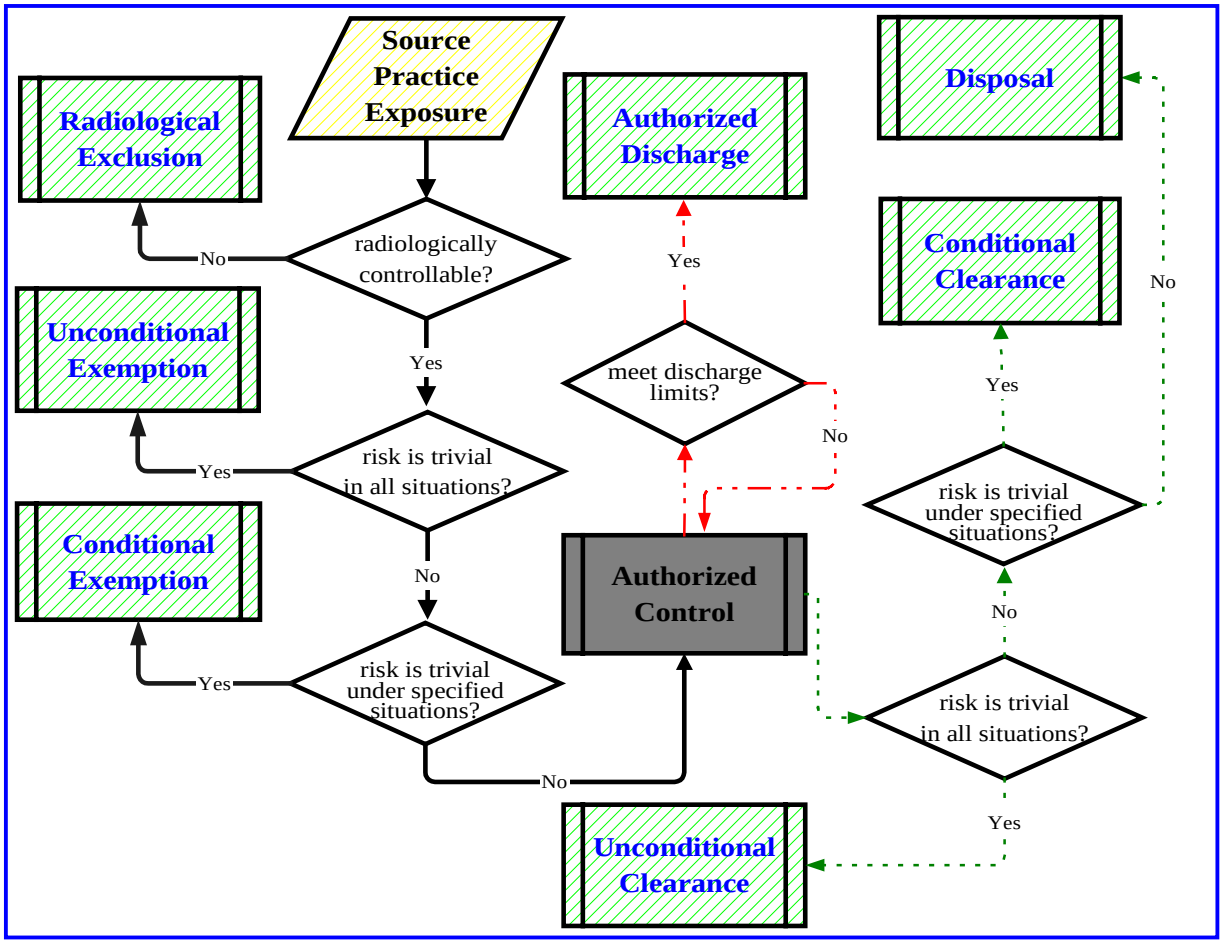

FIGURE 1. STEPWISE PROCEDURE FOR IMPLEMENTING EXCLUSION, EXEMPTION, AND CLEARANCE ALONG WITH AUTHORIZED DISCHARGE AND DISPOSAL (solid line represents all of solid, liquid, and gaseous waste streams; dot line shows only solid waste stream, and dash-dot-dot line depicts both liquid and gaseous waste streams)

Decision-Making Methodology

The scope and extent to which the concepts of exemption or clearance are applied varies widely depending upon each country's policy. The exact options may range from unconditional permission of both exemption and clearance to conditional permission of either exemption or clearance. In addition, solely exemption or only clearance, or just conditional exemption/clearance may be adopted by the regulatory body. First of all, each country's regulatory authority has to review the feasibility of implementing the concepts of exemption and clearance, and decide specified options. In this decision-making process, five primary categories and subsequent tens of secondary categories of factors described below can be taken into account.

- ***Environmental and Radiological Factors***: Effectiveness of land or natural resources use, along with additional exposure dose caused by implementing the concepts may be considered in the decision-making process. In addition, whether the country is operating a VLLW disposal site may affect the preference of each alternative.

- ***Domestic Social and Political Factors***: Public acceptance, population density, size of territory, scale of national nuclear development and waste reuse/recycling programs, and

the amount of VLLW generated or accumulated are the secondary factors to be considered in this primary category.

- ***Economic Factors:*** It is desirable to compare the whole scale of investment, discounted cost, and the result of sensitivity analysis for each option.
- ***Regulatory Aspects:*** The regulatory authority may review the required amount of regulatory works, manpower and relevant institutions, and possibility of transboundary movement of VLLW, in assessing the relative preference of each option.
- ***Technical Aspects:*** The following technical aspects should be also considered: assessment techniques for radionuclide inventory, sampling techniques, radiation measurement techniques, and re-use/recycling techniques, and so on.

Since both quantitative and qualitative factors should be considered in the above process, an appropriate multi-objective decision-making should be preceded [5].

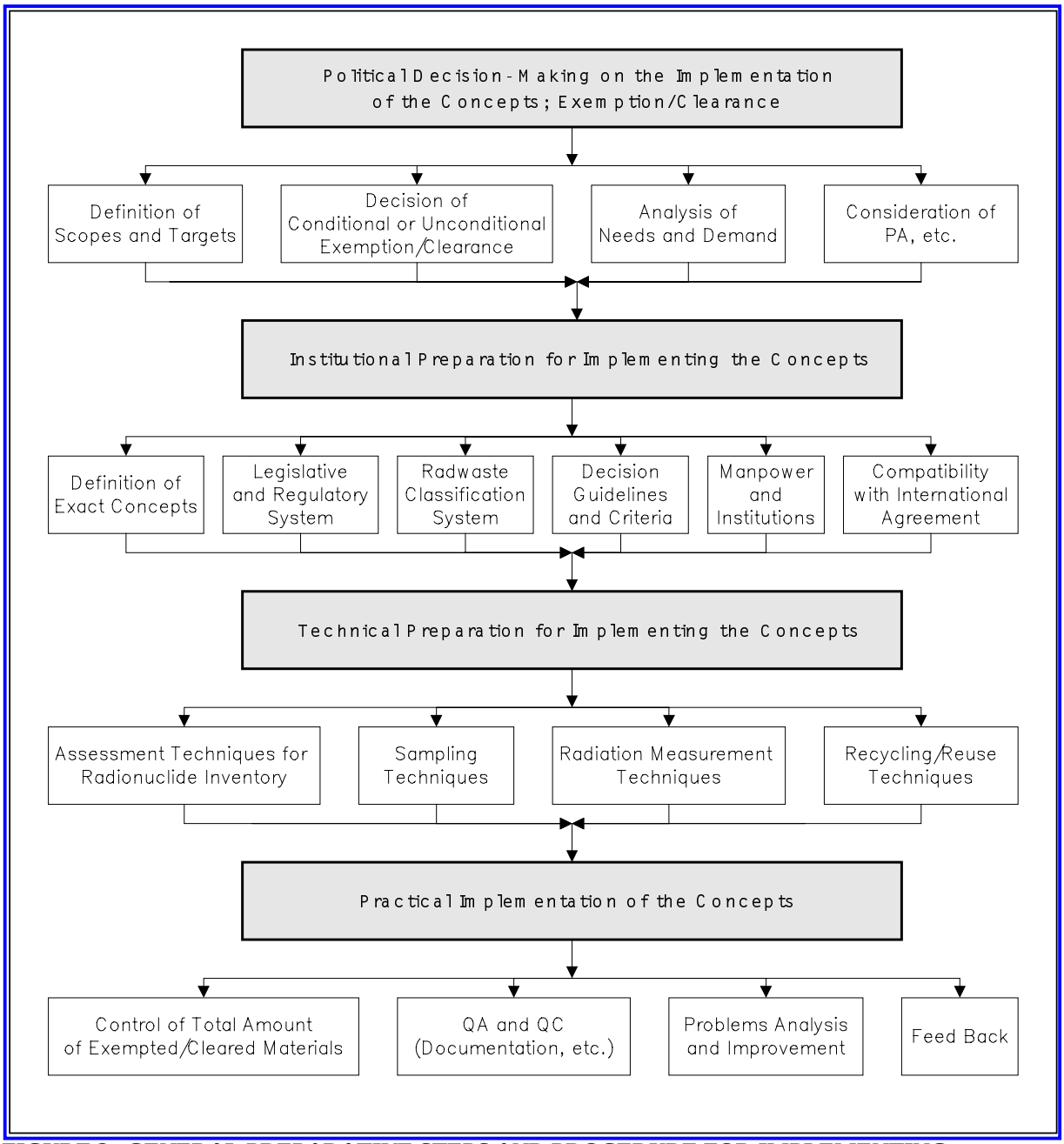

FIGURE 2. GENERAL PREPARATIVE STEPS AND PROCEDURE FOR IMPLEMENTING EXEMPTION AND CLEARANCE CONCEPTS

Stepwise Procedure for Establishing National Regulatory Framework

It is practically required for each country tending to implement the concepts of exemption and clearance, to follow the steps displayed in FIGURE 2. In this stage, (1) how to establish national regulatory system, (2) what to prepare for the implementation, and (3) how to reflect each country's specific situations are the most important aspects to be considered.

According to the IAEA-TECDOC-855, they proposed that two mechanisms could be envisaged for including clearance criteria within regulatory framework: *(1) by conditions placed in the license or authorization of each individual license or authorization holder to whom the clearance applies, and (2) by legislation, wither primary or secondary if suitable primary legislation is in place* [4]. The option (1) assumes that the legislation allows for this approach, and would allow the clearance requirements to be produced to meet the requirements of the individual, while still remaining within the overall framework. On the other hand, the option (2) would ensure that all operators work to the same standards, and that regulators only have to concern themselves with one general set of clearance criteria. This approach would also ensure that no one operator gains at the expense of another. Considering the consistency of the whole regulatory works, the option (2) is relatively preferred.

KOREAN EXPERIENCE AND PRACTICES

History and Current Status

The basic concepts of exemption and clearance have been partly introduced into Korean nuclear regulatory framework since early 1990's. For instance, both the individual dose of less than 10 μ Sv/y and the collective dose of less than 1 person·Sv/y were established as limiting criteria for arbitrary disposition of the materials (e.g. sea dumping), and provided in the decree of Atomic Energy Act as a provision (in 1997). In addition, a series of numerical concentration limits was originally established in the *Notice of the Minister of Science and Technology (MOST)* in 1994 and subsequently revised in 1997. The purpose of the concentration criteria is to permit *self-disposition (equivalent to clearance)* by generators or utilities if the VLLW meets the prescribed criteria, and subsequently a few applications have been permitted by the government, after case-by-case assessments. The present concentration limits are established for several radionuclides (e.g. H-3, C-14, Sr-85, etc. along with β–/γ–emitters of less than 100-day of half-lives) to be 100 Bq/g (in 1994) as shown in TABLE II.

TABLE II. PERMISSION CRITERIA AND RADIONUCLIDE CONCENTRATION FOR CLEARANCE (SELF-DISPOSITION) IN KOREA

Radionuclide	Limiting Concentration*
^{3}H, ^{14}C, ^{18}F, ^{24}Na, ^{32}P, ^{35}S, ^{42}K, ^{45}Ca, ^{47}Ca, ^{46}Sc, ^{51}Cl, ^{59}Fe, ^{67}Ga, ^{71}Ge, ^{75}Se, ^{82}Br, ^{85}Sr, ^{86}Rb, ^{99}Mo, ^{99m}Tc, ^{111}In, ^{113}Sn, ^{123}KI, ^{125}I, ^{131}I, ^{144}Pr, ^{169}Yb, ^{198}Au, ^{201}Tl, ^{203}Hg, *and other β–/γ– emitting radionuclides of less than 100-day of half lives*	100 Bq/g
$\sum \frac{Y_i}{X_i} < 1$	where Y_i is the radioactivity concentration of nuclide i, and X_i is the limiting concentration of the nuclide I, listed in the above table

TABLE III. VLLW WASTE STREAMS AND THEIR SELF-DISPOSITION METHODS IN KOREA

Waste Group	Major Disposition Method		
	Incineration	Landfill	Recycle/Reuse
Combustible Miscellaneous Waste	Woods, Paper, Styrofoam, Plastics, Vinyl products, working tools		Plastics
Non-combustible Miscellaneous Waste	-	Concrete, Insulating Material, Sludge, Asbestos, Iron Oxide	Steel, Concrete
Process Waste	-	Spent Resin, Spent Charcoal	-
Others	Waste Oil	Soil	-

The VLLW which has been permitted for self-disposition in Korea can be classified as TABLE III. Currently, the VLLW satisfying the prescribed criteria given in TABLE II can be disposed of by the waste-generators or their contractors in such ways as landfill, incineration, and reuse/recycling. In this case, just ***notification*** to the regulatory authority is required. On the other hand, the radiological impacts caused by the VLLW containing radionuclides not sepcified in TABLE II are to be reviewed and confirmed by the regulatory authority that it meets both individual and collective dose criteria, and then it can be released from regulatory control through ***special permission***. The total amount of the VLLW which has been released from regulatory control through special permission since 1992 is upto around 842.2 ton and 513 drums as of Oct. 1998 (see TABLE IV). The radionuclides concentrations in the cleared wastes are well less than the lower-limit-on-detection (LLD) and at most below the unconditional clearance levels specified in the IAEA TECDOC-855 [4].

Recently, a series of research projects have been performed to develop the techniques for assessing the radionuclides inventory along with sampling techniques, and recycling or reuse of the VLLW to be generated from decommissioning of the research reactor.

Korean Laws and Regulations for Implementing Exemption and Clearance

Currently, the concepts of exemption and clearance are implemented in Korea based on a series of nuclear laws as shown in TABLE V. Precise provisions are given in the Notice of MOST and can be summarized as follows.

TABLE IV. History of VLLW Self-Disposition in Korean Nuclear Power Plants

ID	Date (Application/ Permission)	Waste Generation Sources	Generated Waste Streams	Applied Amount	Permitted Amount
1	1995.7.20 (1997.1)	4 NPPs	Waste Oil	225 drums	173 drums
2	1996.10.24 (1996.11)	5 NPPs	Waste Oil	340 drums	340 drums
3	1996.11.19 (1996.12)	1 NPPs	Combustible & Non-Combustible Miscellaneous Wastes, Spent Container, Spent Charcoal, etc.	92 ton	92 ton
4	1996.12.5 (1997.1~2)	1 NPPs	Combustible Miscellaneous Waste, Spent Resin	11.7 ton	11.7 ton
5	1997.9.4 (1997.9~12)	3 NPPs	Combustible & Non-Combustible Miscellaneous Wastes, Spent Container, Spent Charcoal, Soil, Waste Oil, etc.	166.5 ton	166.5 ton
6	1998.2.27 (1998.7.29)	7 NPPs	Combustible & Non-Combustible Miscellaneous Wastes, Spent Container, Spent Charcoal, Soil, Waste Oil, etc.	572 ton	Under review process

- ***Regulatory Clearance***: In order to be exempted or cleared, the candidate radioactive waste should meet all the guidelines specified in the Notice. Symbols and signs representing radioactive material/waste should be removed, and then disposed of.
- ***Restrictions***: Radioactive waste not satisfying predetermined concentration limits (i.e. TABLE II) or containing other radionuclides not specified in the Notice should not be disposed of arbitrarily. The candidate radioactive waste should be neither diluted nor mixed with different types of wastes.
- ***Segregation and Prevention of Adulteration***: The candidate waste should be stored separately from other types of wastes, and excluded from possible adulteration.
- ***Procedure***: Waste generators should submit a self-disposition procedure to the Minister of MOST, and perform the self-disposition according to the procedure proposed in this Notice. The procedure may describe the following items: (1) radionuclides inventory, (2) storage period and assessment method for each radionuclide and radioactive waste, (3) method of separate storage of the waste, (4) relevant records and formatted documents, (5) radiation/radioactivity measuring method, (6) method of self-disposition, and (7) disposition method of by-products.
- ***Notification***: The applicants should notify their intent of self-disposition through submitting Radioactive Waste Self-Disposition Report to the Minister of MOST. The following information should be described in the report: (1) origin, class, amount and surface dose rate of the waste, (2) radonuclides inventory and concentrations, and (3) amount of by-products. The candidate wastes notified may be self-disposed of after 1 month of the notification.
- ***Conservation of Records***: The applicants should conserve the following records at least for 5 years after disposition: (1) origin, class, amount and surface dose rate of the waste, (2) date of disposition, and (3) disposition method.
- ***Confirmation of Disposition***: The Minister may confirm the appropriateness in all aspects of the self-disposition through periodic or occasional inspection, and demand the related documents.

- ***Special Permission***: Other utilities who want to perform self-disposition of the waste containing other radionuclides not specified in the TABLE II may perform self-disposition only through special permission issued by the Minister.

TABLE V. STRUCTURE OF KOREAN LAWAS AND REGULATIONS RELATED TO EXEMPTION AND CLEARANCE

Laws / Regulations	Related Provisions	Revised Year
Atomic Energy Act (AEA)	Definition of Radioactive Waste	1996
	Restrictions for Disposal of Radioactive Waste	1996
Decree of the AEA	Dose Criteria for Exemption/Clearance	1997
Notice of Minister of MOST	Numerical GCC and Procedure for Self-Disposition	1997
	Numerical GCC for Exemption	1998

Preliminary Dose Assessment Study for Nineteen Scenarios

Totally nineteen VLLW self-disposition scenarios were selected based upon the petitions submitted to Korea Institute of Nuclear Safety in 1998. With the exemption of the recycle/reuse scenarios whose exact pathways have not been analyzed, annual individual and collective doses were assessed only for seven landfill scenarios and eleven incineration scenarios (see TABLE VI). The basic assessment methodology originally proposed in IMPACTS-BRC Ver.2.1 was adopted into this study, and a series of domestic input data (waste characteristics, environmental parameters, etc.) were partially introduced. In the landfill scenarios, the waste is assumed to be disposed of at municipal landfills. It is also assumed that the combustible miscellaneous waste and waste oil are to be incinerated at municipal incineration facilities. Both landfills and incinerators are conservatively assumed to be located at urban area.

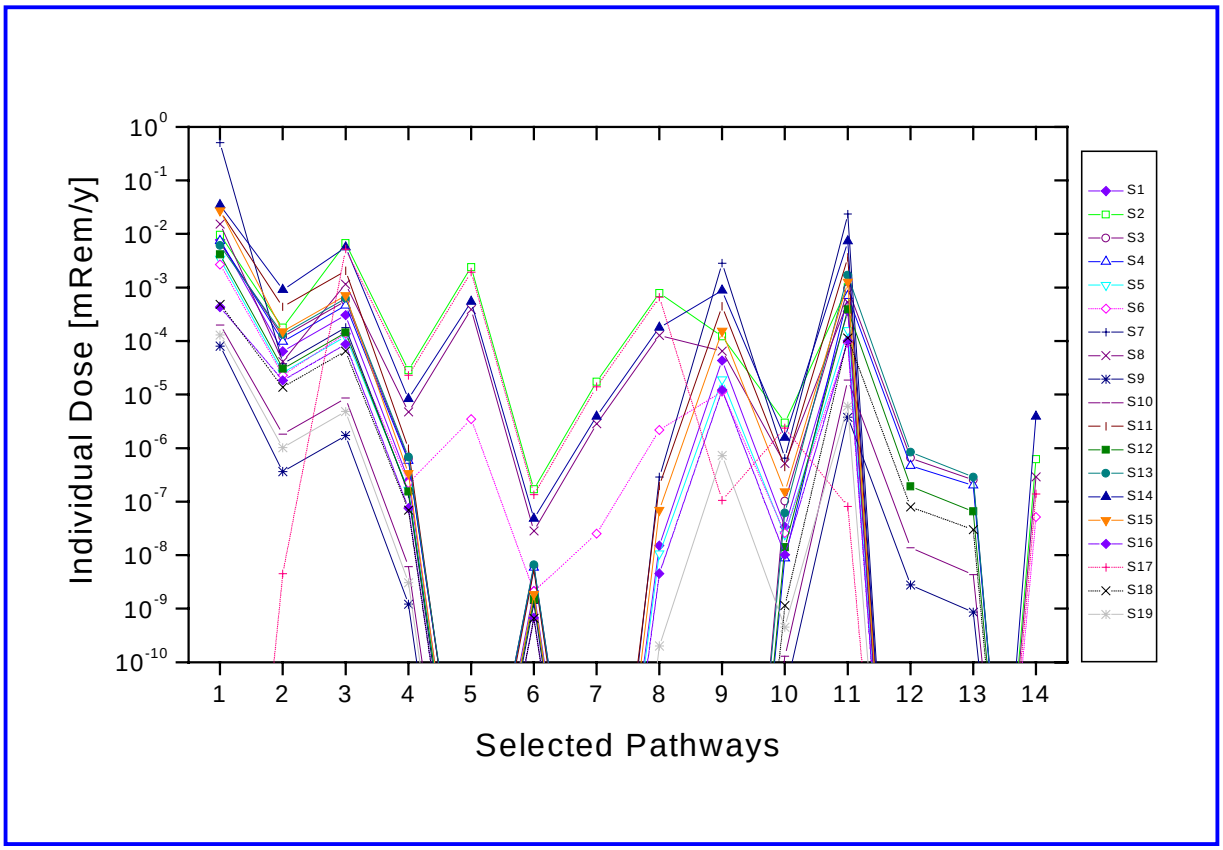

FIGURE 3. ANNUAL INDIVIDUAL DOSES CALCULATED FROM FOURTEEN PATHWAYS FOR NINETEEN SCENARIOS (the pathways are as follows: #1 = maximum transportation impact, #2 = intruder construction, #3 = intruder agriculture, #4 =intruder airborne, #5 = erosion airborne, #6 = intruder water, #7 = erosion water, #8 = incineration individual, #9 = incineration maximum worker, #10 = operation individual, #11 = operation maximum worker, #12 = leachate treatment, #13 = leachate overflow, and #14 = metal package reuse)

Waste oil is assumed to be packaged in carbon steel container and to be transported to the incineration facilities, and then the container is to be reused. Other wastes are assumed to be handled and transported without any packages. The important pathways are (1) exposure to the workers who are responsible for transportation, incineration, and landfill, (2) external exposure from the airborne (gaseous material or particulate) discharges at incinerator, (3) internal exposure from leachate (surface and ground water) at landfills and subsequent food chains, and (4) intruder exposure during post-closure of landfill facilities.

Totally fourteen individual exposure pathways were considered for each target scenario, and the results are displayed in FIGURE 3. All individual exposure doses are under the predetermined criterion, 10 μSv/y, and the external dose of the workers who are responsible for transporting the wastes in scenario #7 (incineration of combustible miscellaneous waste) shows the maximum exposure. The collective dose of the inhabitants near the incineration facilities in scenarios #2 and #7 show the maximum value of 7.45×10^{-4} person·Sv/y, which is also well below the collective dose criterion of 1 person·Sv/y.

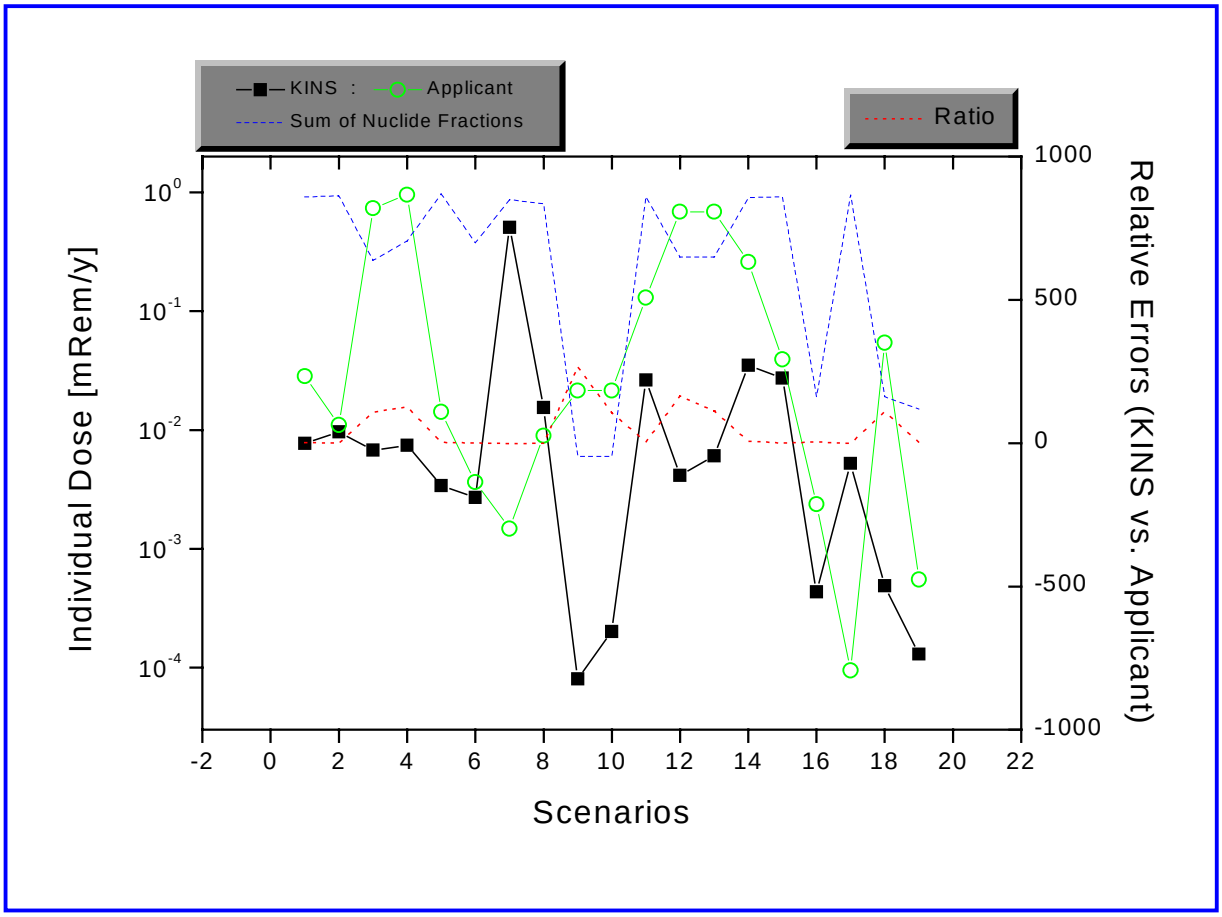

FIGURE 4. COMPARISON OF MAXIMUM ANNUAL INDIVIDUAL DOSES CALCULATED FOR NINETEEN SCENARIOS: RESULTS OF THIS STUDY (KINS) AND APPLICANT'S RESULTS

FIGURE 4 displays the applicant's dose assessment results along with the results performed in this study. Among nineteen scenarios considered, the results of this study are proved to be relatively conservative compared to those submitted by the applicant, in most cases (sixteen cases out of nineteen scenarios). The general conservatism of this study may result from more conservative assumptions and input parameters adopted in the dose assessment. For the comparison, the sums of raduinuclide fractions based on general clearance levels are simultaneously displayed in FIGURE 4. The plot of the sum of radionuclide fractions shows almost the same trends as the plot of maximum individual doses assessed in this study. This phenomenon justifies the use of general concentration criteria and its sum-of-fraction rule.

Future Planning

Though the concepts of exemption and clearance have been partly implemented in Korea, some political decisions (i.e. full-scale or partial implementation, scopes and extent, etc.) haven't yet made. It is expected that the general decision-making procedure may be performed in the near future. The decision is to be made considering lots of factors (ranging from the industrial needs and demand to conservative public acceptance), and a certain compromised option will be established. Though more additional institutional and technical preparations are to be reinforced, however, more expanded implementation of the exemption or clearance is ultimately expected. It is finally anticipated that the following issues are to be further discussed: (1) selection of the best option among the possible alternatives, (2) establishment of adequate radioactive waste

classification system in conformance with the exemption or clearance concept, (3) revision and updating of the current concentration limits, and (4) reviewing of the appropriateness of the present dose criteria, and so forth.

FURTHER CONSIDERATIONS AND CONCLUDING REMARKS

On our way to considering implementation of exemption and clearance, we have experienced a few problems and confusion in practically implementing and interpreting the concepts. It is believed that the following aspects should be further discussed and concluded.

Establishment of Standard Sampling and Analysis Method

A series of standardized methods of sampling to attain the representative specimens, concentration averaging procedures, and proper instrumentation/measurement to cover minimum detectable concentration (MDC) have to be established since the concepts of exemption/clearance are to be applied to the materials containing very low concentration of radionuclides. The sampling and instrumentation methods in order to verify the appropriateness of exemption/clearance can be divided into the following two steps [4]:

- to segregate the target wastes/materials according to their features and generation origins, as homogeneously as possible – makes it possible to attain the homogeneous radionuclides spectra,
- to measure radionuclides spectra of the representative specimens sampled from target waste – in this step, all the attainable information about the waste history should be taken into account, and relevant methods of measurement, instrumentation, and calibration are to be chosen.

In the case of large amount of wastes, the maximum mass or area for which the averaging is allowed should be determined and their averaging procedure should also be established. The cleared wastes can be broken into pieces afterwards, and some parts of them may exceed the clearance levels. The possibility of this problem may be minimized by reducing the allowable averaging area or mass of the target wastes. According to the Reg. Guide 1.86 and DOE Order 5400.5, the allowable averaging area for surface contamination is determined to be less than 1 m^2 [11]. If the area or volume of the wastes is tremendously large and therefore direct measurement for the whole area or volume is impossible, a series of statistical sampling and measurement methods is strongly needed. Application of scaling factors for some difficult-to-measure radionuclides such as α-emitters and weak β-emitters may be considered. The meaningful scaling factors can be derived only for well-specified waste streams, however, the applicability of the scaling factors may be quite limited.

It is known that the concentrations of naturally occurring radionuclides (e.g. Ra-226, Th-232, U-238, etc.) in unmodified natural materials are in the range of 0.01 ~ 0.1 Bq/g. In addition, the clearance levels for the above radionuclides are around 0.1 ~ 1.0 Bq/g. The slight difference between the clearance levels and natural background levels may cause some measurement and instrumentation problems in implementing the clearance to those radionuclides [4].

In analyzing the concentration of radionuclides for surface or volumetric contamination, the MDC of the relevant measurement/instrumentation techniques should be maintained at least 1/10 of the clearance levels. The MDC for the volumetric contamination in laboratory measurement is predicted by the following equation [12]:

$$MDC = \frac{3 + 4.65\sqrt{B_R \times t}}{t \cdot Y_i \cdot \varepsilon_i \cdot M \cdot R}, \qquad \text{(Eq. 1)}$$

where, MDC = minimum detectable concentration [pCi/g], B_R = background counting rate of the detector [cpm], t = counting time [sec], Y_i = yield for i [ptcle/d], ε_i = detector efficiency for i [c/ptcle], M = mass of the speciemen [g], R = chemical yield.

On the other hand, the MDC for the small surface contamination in scanning method is given by the following equation [12]:

$$MDC = \frac{3 + 4.65\sqrt{B_R \cdot \frac{W}{60 \cdot V}}}{\frac{W}{60 \cdot V} \cdot \left(\sum Y_1 \cdot \varepsilon_i\right) \cdot \frac{A}{100} \cdot HF}, \qquad \text{(Eq. 2)}$$

where, MDC = minimum detectable concentration [dpm/100cm^2], B_R = background counting rate of the detector [cpm], W = detector with [cm], 60 = conversion factor [sec/min], V = detector scanning rate [cm/sec], Y_i = yield for i [ptcle/d], ε_i = detector efficiency for i [c/ptcle], A = detector area [cm^2], HF = surveyor efficiency [%].

Also, the MDC for the large surface contamination is calculated as follows [12]:

$$MDC = \frac{3 + 4.65\sqrt{B_R \cdot \frac{2 \cdot \tau}{60}}}{\frac{2 \cdot \tau}{60} \cdot \left(\sum Y_1 \cdot \varepsilon_i\right) \cdot \frac{A}{100} \cdot HF}, \qquad \text{(Eq. 3)}$$

where, MDC = minimum detectable concentration [dpm/100cm^2], B_R = background counting rate of the detector [cpm], τ = meter time constant, 60 = conversion factor [sec/min], Y_i = yield for i [ptcle/d], ε_i = detector efficiency for i [c/ptcle], A = detector area [cm^2], HF = surveyor efficiency [%].

The MDC for direct measurement of the surface contamination is given as follows [12]:

$$MDC = \frac{3 + 4.65\sqrt{B_R \cdot \frac{t}{60}}}{\frac{t}{60} \cdot \left(\sum Y_1 \cdot \varepsilon_i\right) \cdot \frac{A}{100}}, \qquad \text{(Eq. 4)}$$

where, MDC = minimum detectable concentration [dpm/100cm^2], B_R = background counting rate of the detector [cpm], t = counting time [sec], 60 = conversion factor [sec/min], Y_i = yield for i [ptcle/d], ε_i = detector efficiency for i [c/particle], A = detector area [cm^2].

Definition of Unit Source or Practice

Exact definition of unit practice removes possible confusion and misapprehension in reviewing the appropriateness of exemption and clearance for each candidate source/practice. Let's assume a situation where various types of VLLW are generated by a utility. The waste generator may apply for exemption/clearance to each batch of the waste, or to the whole amount, at the same time. It is probable that clearance of the whole amount may exceed the prescribed dose criteria, but some or all of the batch applications may satisfy the dose criteria. This paradox arouses a heated controversy among specialists, and still remains to be unresolved. The situation becomes worse in the case of exemption levels where total activity limits are applied along with concentration limits.

Consideration of Optimization, Cost-Benefit Analysis or Assessment of Collective Dose

When the general concentration limits for all radionuclides existing in the candidate sources are not established, both individual and collective dose criteria should be met, based upon a series of conservative scenarios. This case-by-case approach is the case partly occurring in Korea. Some waste generators may often insist that assessment of the collective dose may be just a time-consuming, since all the results until now have shown that the collective effective dose are at most 10^{-5} person·Sv/y. Furthermore, they also feel it's quite impractical to show exemption/clearance is the most optimized option for each case. This problem has already been recognized by the IAEA as: *From consideration of the collective dose which could be accumulated as a result of the clearance of materials it seems that fairly substantial quantities in terms if mass would behave to be involved before collective dose commitments of more than 1 person·Sv/y of practice would be delivered. Nevertheless, this is an aspect which national regulatory authorities need to keep under review in granting clearance* [4]. The importance of the collective dose requirement is also a controversial issue still being argued [4,13,14].

Scopes of Exemption/Clearance (Conditional, Unconditional, or Mixed Options)

Theoretically, conditional clearance or exemption belongs to a branch of the general VLLW management options. The conditional option, however, can be often contradictory to the fundamental concepts of exemption or clearance, where the needs for subsequent regulatory surveillance are not to be imposed. In principle, it is desirable not to implement conditional options [8]. However, the number of possible scenarios to be considered in deriving concentration limits is limited, and the VLLW disposition methods may be variable owing to the variation of technical factors or socio-economic environments. Accordingly even once established clearance levels would be varied. As currently being done in the United States, conditional clearance is to be a desirable option, especially in the case of metal scrap recycling, where direct contact with the source material or long-term exposure is anticipated.

Compliance between Clearance and Exemption

It has been reported that even once unconditionally cleared sources would be reentered the regulatory control system [7]. This contradiction is to be caused, since the criteria for exemption and clearance are not complied. Although the dose criteria are the same for exemption and clearance, the concentration limits derived from different scenarios/models can be varied. The compliance between clearance and exemption can be attained in two ways: (1) by

establishing the clearance criteria more conservatively, and/or (2) by assuring that the concentration limits for clearance is always equivalent to or less than those for exemption.

Administrative Requirements (Notification, Registration, or Licensing)

It is natural that sources or practices are allowed to be beyond of regulatory control, through administrative requirements such as notification or authorization (registration and licensing) [3]. The levels of administrative requirements may be varied depending upon national regulatory authority's decision considering each country's specific conditions. Once the national regulatory framework for implementing the concepts is fully established, only notification is enough for permission. However, the appropriateness of exemption or clearance of large amount of VLLW may be reviewed by the regulatory body, through more strict requirements (i.e. registration or licensing). Involvement of the regulatory body, to an extent, in the process of performing exemption or clearance is inevitable, in order to control the total amount of sources released from regulatory boundary and to perform inspection, as required.

Compliance to Radwaste Classification System

There exist two options in adopting the dose criteria for deciding the adequacy of exemption or clearance of the VLLW: (1) by applying the criteria separately from the national radwaste classification system, and (2) by incorporating the criteria into the radwaste classification system. The option (1) may cause a certain self-contradiction, since some VLLW are beyond of regulatory control but they are still classified as radioactive waste. The radwaste classification system proposed by the IAEA in 1994 defines the VLLW as the waste below clearance levels [9]. In that case, like the option (2), the possible misapprehension can be eliminated.

Compliance between Domestic and International Criteria

In principle, the exemption/clearance criteria are to be derived from a series of scenarios and input parameters, where country-specific situations are reflected. TABLE VII shows various exemption/clearance levels derived by a few countries and international organizations. On the other hand, the concepts have been developed internationally in relation to transboundary movement or sea-dumping issues, and the needs for international standards have been increased. The following two facts emphasize the importance of internationally agreed criteria: (1) six international organizations (FAO, IAEA, ILO, OECD/NEA, PAHO, and WHO) have endorsed the Safety Standards (i.e. IAEA-SS-115) where exemption levels are compiled, (2) the IAEA has been requested by the London Convention to propose *de minimis* levels of radioactive material which has not to be dumped into the sea. More adequate criteria may be derived and implemented country-by-country. However, it is desirable to establish the domestic criteria compatible with internal standards, in order to avoid the troubles that may frequently occur in international trades.

Compliance to Other Waste Management Regulations – Environmental Protection Acts

One of the most frequent misapprehensions in the process of implementing the concepts is that once exempted or cleared materials/wastes can be released from all regulations. Even the VLLW cleared from radiological regulatory control must be under the control of other

apposite environmental regulations dealing with waste management. That is, biological or chemical hazards of the cleared wastes are still under the control of other environmental regulations. In Korea, for instance, the cleared waste should be managed in conforming to a series of environmental regulations, such as Waste Management Act, Atmospheric Environmental Protection Act, Water Quality Protection Act, etc.

Compliance to Other Radiation Protection Regulations

In Korea, the surface contamination criteria are not implemented in applying the concepts of exemption or clearance. However, so called *carry-out guideline* has been established and in force. According to the guideline, α-(surface) contaminated material of less than 3.7×10^{-4} Bq/cm^2 and β- or γ-(surface) contaminated material of under 3.7×10^{-3} Bq/cm^2 can be carried out of the controlled area, without any restrictions. It is believed that the *carry-out guideline* would be more conservative than the typical exemption or clearance levels. Furthermore, the *carry-out guideline* can be considered as a minimum limits for the exemption or clerance. Accordingly, the radiation protection regulations such as the *carry-out guideline* should be also taken in mind, in establishing regulatory framework for implementing exemption or clearance.

Implementation to Solid, Liquid, or Gaseous Wastes

As shown in FIGURE 1, it has been known that the exemption criteria are applied to all physicochemical forms of wastes (i.e. solid, liquid, and gaseous wastes), and the clearance criteria are to be applied only to the solid waste streams. It is natural that the liquid and gaseous wastes are under the control of authorized discharge. In this context, the IAEA-TECDOC-855 proposes draft clearance levels solely for the solid waste streams [4]. However, more recent document (i.e. IAEA-TECDOC-1000) includes both liquid and gaseous wastes into the subjects of implementing the clearance, and their annual clearance levels are given by *Bq/y*, along with the clearance levels for solid waste given by *Bq/g*. It is anticipated that this may be another controversial issue afterwards.

Only by considering each country's specific situations, the merits of the exemption and clearance could be materialized. The conceptual procedure for determining exemption, clearance or exclusion was summarized in FIGURE 1, and the four-step-approach, as proposed in FIGURE 2, shows the general methodology to establish a country's regulatory framework for implementing the exemption and clearance. The first stage is to be the very political decision-making considering domestic industrial demands, needs, and public acceptance for the concepts. In this stage, the possible alternatives and the sample hierarchy described in this paper may play important roles as comprehensive guidelines for the decision-making. Undoubtedly, more specific conditions of each country are to be considered and reflected in applying the guidelines.

Korea is still trying to complete the national regulatory framework for implementing exemption and clearance. A series of research and development program for deriving and verifying clearance levels are now under way, and more definite results would be produced at least in two years. Totally eleven issues proposed in this paper would be thoroughly discussed and reviewed in the way of performing the R&D program, and the results are to be reflected in establishing more concrete regulatory framework for practical implementation.

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TABLE VI. SELECTED VLLW SELF-DISPOSITION SCENARIOS FOR RADIOLOGICAL IMPACTS ANALYSIS

ID	Waste Stream	Amount of Waste [ton]	Radionuclides Concentration [Bq/g]	Disposition Method
S1	Combustible Miscellaneous Waste	1.5	Co-60 : 1.25×10^{-1}, Cs-137 : 1.50×10^{-1}	Incineration
S2	Waste Oil	11.0	Co-60 : 5.00×10^{-2}, Cs-137 : 5.00×10^{-2}, H-3 : $3.00\times10^{+1}$, C-14 : $3.00\times10^{+1}$	Incineration
S3	Iron oxides & Sludge	15.0	Co-60 : 1.25×10^{-1}, Cs-137 : 1.50×10^{-1}	Landfill
S4	Insulating Materials	8.6	Co-60 : 3.35×10^{-2}, Cs-137 : 8.35×10^{-2}	Landfill
S5	Combustible Miscellaneous Waste	0.96	Co-60 : 2.79×10^{-2}, Cs-134 : 3.37×10^{-2} Cs-137 : 1.85×10^{-1}, Mn-54 : 4.44×10^{-2}	Incineration
S6	Waste Oil	2.4	Co-60 : 4.44×10^{-3}, Cs-137 : 8.51×10^{-2}, H-3 : 7.50×10^{0}, C-14 : 2.00×10^{-1}	Incineration
S7	Combustible Miscellaneous Waste	2.0	Co-58 : 2.00×10^{-1}, Co-60 : 5.00×10^{-2}, Cs-134 : 5.00×10^{-2}, Cs-137 : 5.00×10^{-2}, Mn-54 : 5.00×10^{-2}	Incineration
S8	Waste Oil	3.6	C-14 : $1.50\times10^{+1}$, H-3 : $1.50\times10^{+1}$, Ag-110m : 3.00×10^{-2}, Mn-54 : 3.00×10^{-2}, Co-60 : 3.00×10^{-2}, Cs-134 : 3.00×10^{-2} Cs-137 : 3.00×10^{-2}	Incineration
S9	Spent Charcoal	2.0	Co-60 : 1.14×10^{-3}, Cs-137 : 5.59×10^{-4}	Landfill
S10	Spent resin	10.0	Co-60 : 1.14×10^{-3}, Cs-137 : 5.59×10^{-4}	Landfill
S11	Combustible Miscellaneous Waste	14.5	Mn-54 : 1.20×10^{-1}, Co-60 : 1.20×10^{-1}, Cs-134 : 3.00×10^{-3}, Cs-137 : 3.00×10^{-2}, Ce-144 : 2.50×10^{-1}	Incineration
S12	Spent Charcoal	6.015	Mn-54 : 3.00×10^{-2}, Co-60 : 2.00×10^{-2}, Cs-134 : 3.00×10^{-3}, Cs-137 : 3.00×10^{-2}, Ce-144 : 2.50×10^{-1}	Landfill
S13	Spent resin	26.4	Mn-54 : 3.00×10^{-2}, Co-60 : 2.00×10^{-2}, Cs-134 : 3.00×10^{-3}, Cs-137 : 3.00×10^{-2}, Ce-144 : 2.50×10^{-1}	Landfill
S14	Waste Oil	30.0	Mn-54 : 1.00×10^{-1}, Co-60 : 1.20×10^{-1}, Cs-134 : 3.00×10^{-3}, Cs-137 : 3.00×10^{-2}, Ce-144 : 2.50×10^{-1}, C-14 : 2.50×10^{0}, H-3 : 2.50×10^{0}	Incineration
S15	Combustible Miscellaneous Waste	5.0	Mn-54 : 1.20×10^{-1}, Co-60 : 1.20×10^{-1}, Cs-134 : 3.00×10^{-3}, Cs-137 : 3.00×10^{-2}, Ce-144 : 2.50×10^{-1}	Incineration
S16	Combustible Miscellaneous Waste	21.74	Co-60 : 2.33×10^{-3}, Cs-137 : 3.27×10^{-3}	Incineration
S17	Waste Oil	9.72	C-14 : $2.75\times10^{+1}$, H-3 : $6.75\times10^{+1}$	Incineration
S18	Spent Charcoal	24.384	Co-60 : 2.33×10^{-3}, Cs-137 : 3.27×10^{-3}	Landfill
S19	Combustible Miscellaneous Waste	1.34	Co-60 : 2.64×10^{-3}, Cs-137 : 1.71×10^{-3}	Incineration

TABLE VII. COMPARISON OF VARIOUS EXEMPTION/CLEARANCE LEVELS [UNIT: Bq/g]

Nuclide	IEX	KCL	E01	E10	E150	ICL	ICA	IST	IAL	IBS	IBV	IEQ	JCm	JCM	GUC	GCC
Ag-110m	1E1	--	7.4E-3	7.4E-2	7.4E-1	3E-1	--	--	--	--	--	--	--	--	--	--
Am-241	1E0	--	2.96E-3	2.96E-2	3.7E-1	3E-1	3E-1	1E0	9E-1	2E-1	3E-1	7E-1	1E-1	1E0	--	--
C-14	1E4	1E2	3.7E0	3.7E1	7.4E2	3E2	--	--	--	--	--	--	1E1	1E2	2E2	2E2
Co-58	1E1	--	--	--	--	3E0	--	--	--	--	--	--	--	--	--	--
Co-60	1E1	--	3.7E-3	3.7E-2	7.4E-1	3E-1	1E-1	3E-1	3E-1	1E-1	1E0	1E1	1E-1	1E0	1E-1	2E0
Cs-134	1E1	--	1.48E-2	1.48E-1	2.22E0	3E-1	--	--	--	--	--	--	1E-1	1E0	--	--
Cs-137*	1E1	--	3.7E-2	3.7E-1	7.4E0	3E-1	5E-1	1E0	1E0	4E-1	4E0	4E1	1E-1	1E0	5E-1	7E0
Fe-55	1E4	--	3.7E2	3.7E3	7.4E4	3E2	1E4	1E3	2E5	9E1	9E2	5E3	1E3	1E4	3E3	1E4
Fe-59	1E1	1E2	--	--	--	3E0	--	--	--	--	--	--	--	--	--	--
H-3	1E6	1E2	--	--	--	3E3	--	--	--	--	--	--	1E1	1E2	3E2	3E2
I-129	1E2	--	3.7E-3	3.7E-2	7.4E-1	3E1	--	--	--	--	--	--	1E-1	1E0	4E-2	4E-2
I-131	1E2	1E2	--	--	--	3E0	--	--	--	--	--	--	--	--	--	--
Mn-54	1E1	--	1.85E-2	1.85E-1	2.96E0	3E-1	4E-1	1E0	1E0	4E-1	4E0	4E1	1E0	1E1	--	--
Na-24	1E1	1E2	--	--	--	3E-1	--	--	--	--	--	--	--	--	--	--
Ni-59	1E4	--	7.4E2	7.4E3	1.11E5	--	--	--	--	--	--	--	1E3	1E4	--	--
Np-237*	1E0	--	2.59E-3	2.59E-2	3.7E-1	3E-1	--	--	--	--	--	--	--	--	--	--
Pu-239	1E0	--	3.7E-3	3.7E-2	7.4E-1	3E-1	3E-1	1E0	9E-1	2E-1	3E-1	7E-1	1E-1	1E0	4E-2	1E0
Ra-228*	1E1	--	1.11E-2	1.11E-1	1.48E0	3E-1	--	--	--	--	--	--	--	--	--	--
Sr-89	1E3	--	--	--	--	3E2	--	--	--	--	--	--	--	--	--	--
Sr-90*	1E2	--	7.4E-3	7.4E-2	1.11E0	3E0	5E1	2E2	3E2	1E1	7E1	4E1	1E0	1E1	1E1	1E1
Tc-99	1E4	--	1.85E2	1.85E3	2.59E4	3E2	7E3	2E4	5E4	1E3	9E3	5E3	1E0	1E1	4E0	4E0
Tc-99m	1E2	1E2	--	--	--	3E1	--	--	--	--	--	--	--	--	--	--
Th-228*	1E0	--	2.59E-3	2.59E-2	3.7E-1	3E-1	--	--	--	--	--	--	--	--	--	--
Th-230	1E0	--	7.4E-3	7.4E-2	7.4E-1	3E-1	--	--	--	--	--	--	--	--	--	--
Th-232	1E0	--	1.48E-3	1.48E-2	1.85E-1	3E-1	--	--	--	--	--	--	--	--	--	--
U-234	1E1	--	1.11E-2	1.11E-1	1.85E0	3E-1	--	--	--	--	--	--	--	--	--	--
U-235*	1E1	--	1.11E-2	1.11E-1	1.85E0	3E-1	--	--	--	--	--	--	--	--	1E-1	3E0
U-238*	1E1	--	1.11E-2	1.11E-1	1.85E0	3E-1	1E0	5E0	3E0	1E0	1E0	4E0	--	--	1E-1	4E0
Zn-65	1E1	--	3.7E-2	3.7E-1	7.4E0	3E-1	6E-1	2E0	2E0	6E-1	6E0	5E1	1E0	1E1	--	--

- IEX : Exemption Levels (IAEA-SS-115, BSS), Ref. [3]
- KCL : Clearance Levels in Korea
- E01, E10, E150: Draft Clearance Levels for Metal Scrap Recycling at Criteria of 0.1mrem, 1.0mrem, 15mrem per year, respectively (US EPA), Ref. [12]
- ICL : Clearance Levels of IAEA (IAEA-TECDOC-855), Ref. [4]
- ICA, IST, IAL, IBS, IBV, IEQ : Clearance Levels of IAEA for recycling scenarios, concrete, steel, aluminum, surface-contaminated building, volumetric contaminated building, contaminated equipment, respectively (IAEA-SS-111-P-1.1), Ref. [2]
- JCm, JCM : Japanese Draft Clearance Levels, minimum and maximum values, respectively (IAEA-TECDOC-1031)
- GUC, GCC : Unconditional and Conditional Clearance Levels of Germany (SSK Draft Recommendations, 1995)