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EVALUATING THE HAZARDS OF DISPOSING OF WASTES FROM ENERGY PRODUCTION

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ABSTRACT

Inherent in the production of energy by almost any method is the generation of waste products, some of which can be potentially toxic. This paper evaluates the potential toxicity of these wastes and the measures which will be necessary to insure their proper handling and safe disposal. This evaluation consists of the following:

1. A comparison of the status of recent Federal regulations that will probably govern these wastes in the future.

2. The development of a toxicity index to assess the potential for groundwater contamination from burial waste. This index is then used to compare the potential toxicity of the radioactive waste from the nuclear fuel cycle to the hazardous waste from major industries, in order to provide a unique perspective on the relative toxicity of the radioactive wastes.

3. A comparison of the potential toxicity of the wastes from those alternate energy sources which are currently definable.

4. A comparison of the major features of the proposed regulations that would govern the disposal of low-level radioactive waste and hazardous waste.

This analysis shows that the wastes from several definable energy sources have a potential toxicity that is generally comparable to the wastes from the nuclear fuel cycle. Nevertheless, it appears as if the regulations for radioactive waste will in general be more stringent than those for hazardous waste.

Even after the Three Mile Island accident, radioactive waste disposal still appears to be the portion of the nuclear fuel cycle which the public perceives to be the most hazardous and incapable of solution. This perception is based primarily on the inordinate public fear of radioactivity and the much abused expression that some the radioisotopes take millions of years to decay to safe levels. This rhetoric has been repeated over and over by the media and anti-nuclear groups with virtually no perspective as to relative toxicities and the relative advantages of the possible solutions. Obviously the Federal government's lack of definitive action in this area further makes this problem appear unsolvable to the general public.

On the other hand, the majority of the public and a large portion of the technical community do not realize that almost every other alternate energy source, including most of the so called "renewables", produce large quantities of potentially toxic waste. These wastes are produced either during operation or result from the large scale manufacturing of components. In almost all cases the toxicity of this waste is due to either heavy metal or naturally occurring radioisotope contamination, both of which have essentially infinite lifetimes in terms of their potential toxicity.

Wastes from energy production are currently governed by a variety of State and Federal regulations which can at best be described as uncoordinated and somewhat inadequate. Most of these wastes are typically treated as industrial wastes, with disposal in open areas or landfills, and totally lack an adequate evaluation or consideration of their potential long-term hazard. Recently several new Federal laws have been passed and/or regulations proposed which would govern how potentially toxic waste from energy production and other sources would be regulated in the future.

The Resource Conservation and Recovery Act (RCRA) which was enacted in 1976 requires that EPA develop regulations which will insure the proper handling and disposal of hazardous waste. Included in the very comprehensive and complex RCRA regulations which were proposed in December 1978[1] are the potentially toxic wastes which are produced by most of the alternate energy sources. These regulations do not apply to those radioisotopes which are covered under the Atomic Energy Act; and although certain naturally occurring radioisotopes are included in these regulations, the authority over uranium mill tailings was given to the NRC by the Uranium Mill Tailings Act of 1978.

A prime example is the waste from the coal fuel cycle which includes fly ash, bottom ash, flue gas scrubber sludge, processing and mining wastes. In the proposed RCRA regulations, if these wastes satisfy the threshold test for toxicity, some would be included as a category of special waste, called utility waste. Because of the large volumes produced and their relatively low potential toxicity, they would be excluded from all but the more general provisions regarding handling and disposal, until additional information can be made available regarding their potential hazard. The EPA currently does not expect to have the necessary information to propose these regulations for special waste until early 1982[2]. Most knowledgable people feel that these regulations for special waste when proposed will be much less stringent, primarily for economic reasons, even though they may satisfy the same criteria as other hazardous waste.

Another example is solar energy. Because of the diffuse nature of this energy source, large number of collectors are typically required. The manufacturing of these collectors in turn requires large quantities of primary metals, when compared to the building of the more conventional energy facilities. In the production of these necessary primary metals potentially toxic waste is generated, primarily in the smelting and refining of the ores. In addition, some of these collectors will require finely finished surfaces which also results in the generation of potentially toxic waste. It currently appears as if some of this waste will meet the threshold toxicity test in the proposed RCRA regulations and would therefore be fully regulated as a hazardous waste.

The final RCRA regulations were required by Federal court order to be issued by December 31, 1979. However, due primarily to the large volume of public comments received on these proposed regulations and the development of new information, major portions will have to be reproposed. This action will result in the regulations being issued in a piecemeal fashion, with the first portions not being finalized until April 1980. After finalization of all the regulations, the timing of which is currently uncertain, it is estimated that the permitting process for all treatment, storage and disposal facilities will take between five and ten years. In the meantime, the EPA feels that the interim standards will greatly improve the treatment and storage of hazardous waste compared to the present situation[3]; whereby they estimate that 90% of the total quantity of hazardous waste produced is being handled and disposed of in a manner which may not be adequate to protect public health and the environment.[4]

Radioactive waste from the nuclear fuel cycle will be primarily governed in the future by both EPA and NRC regulations. The EPA is responsible for developing generally applicable environmental criteria and standards for all types of radioactive waste, while the NRC is responsible for developing the specific regulations that will be used for site specific licensing.

The EPA generally applicable criteria for all radioactive waste was proposed in November 1978.[5] After receiving wideranging and very deserving criticism, the criteria is still undergoing internal review by EPA and is currently not expected to be released for Presidential review and issued as Federal guidance until late 1980. Meanwhile, the EPA standards for high-level waste are not expected to be proposed until March 1980, while the low-level waste standards will probably not be available until 1982.

Even though the EPA criteria and standards are required to provide a basis for other agency regulations, the NRC has recently issued the proposed regulations for uranium mill tailings[6] and has also released a preliminary draft of the proposed regulations for both high and low-level radioactive waste disposal.[7,8] The high-level waste regulations are currently scheduled for proposal by December 1979, while the low-level waste regulations are scheduled for proposal by September 1980. Since the NRC schedule appears to be well ahead of the EPA's, it is hoped that the two agencies have at least agreed on the basics. Otherwise the standards and regulations may not be compatible and the whole process would have to begin again.

In the meantime, especially considering the recent problems concerning the three remaining low-level waste disposal sites, the radioactive waste situation is becoming critical to the point where it is threatening the continued operation and the future viability of the nuclear option. This is true even though, unlike the hazardous waste situation, the radioactive waste is currently being handled, stored and disposed of in a manner which is not posing an imminent threat to public health and the environment. Furthermore, the proposed regulations for radioactive waste disposal appear to be much more stringent than those for hazardous waste, even though they are of comparable potential toxicity. This comparison of potential toxicity and nonequitable treatment in the proposed regulations will be the subject of the remainder of this paper.

About a year ago at the Health Physics Society Twelfth Midyear Topical Symposium, I presented a paper comparing the relative toxicities of radioactive and hazardous waste.[9] The methodology used for this comparison was not totally unique[10], but the quantative results were, and have added a much needed perspective that heretofore has been somewhat lacking.

The methodology used for comparing the toxicity of hazardous and radioactive waste was that of a toxicity index, which is simply the quantity of potentially toxic material divided by its permissible concentration. Expressed another way, this index is simply the volume of water, in cubic meters, which is required to dilute the total amount of toxic material to permissible concentrations, assuming it is totally soluable. It should be noted that this is a very gross measure of hazard because it does not consider the potential pathways to man. It is therefore not necessarily an accurate indication of the uptake by humans of the toxic material which would be the actual hazard from the waste.

For this comparison the EPA primary drinking water standards[11] were chosen as the appropriate permissible concentrations to use for the determining of the relative toxicity index for both radioactive and non-radioactive toxic material. These standards were considered to be the most appropriate for the following reasons:

1. Since the most feasible method of disposal of toxic waste is in suitable underground formations, the major pathway of concern is contamination of drinking water. Since the geo-toxicity of the waste is therefore the most important consideration, these limits would probably be the first to be exceeded given a failure of the disposal mechanism.

2. These regulations are the only ones which address both radioactive and non-radioactive contamination of drinking water, and therefore the EPA must consider that they provide equal protection for public health considerations. This consideration does not necessarily withstand a rigorous

examination, mainly because the limits for heavy metals are based on criteria which are vaguely defined. Many knowledgeable people, including a National Academy of Sciences' panel[12], are of the opinion that some of the heavy metal limits are probably not as low as they should be to adequately protect public health. On the other hand, the radioisotope limits are well defined and are based on a maximum permissible yearly dose of 4 mrem or a lifetime cancer risk of about 1×10^{-6}, which is considered by most to provide adequate public health protection.

3. The proposed RCRA regulations specify that a waste need not be considered hazardous unless it can be shown to produce a leachate which has concentrations of toxic materials which are ten times these drinking water standards. These standards therefore directly determine whether the waste from alternate energy sources must be treated as hazardous.

Using the above defined relative toxicity index, a direct comparison of the potential toxicity of a typical metric ton of the various types of radioactive waste and hazardous waste is shown in Figure 1. (This comparison is taken from my original referenced paper, but is included here to provide a unique perspective on the toxicity of the nuclear fuel cycle waste which would otherwise be lacking.)

In order to completely understand Figure 1, the following important points concerning each of the curves should be mentioned.

1. The average toxic heavy metal and Radium-226 concentrations in a typical metric ton of the earth's crust[10] is shown to provide a baseline for comparison with natural background toxic material concentrations.

2. The high-level radwaste and spent fuel fission product potential toxicities are developed from information in an NRC report[13]; while their long-term toxicities, due primarily to transuranics, are developed by comparing their potential cancer risk to that of Radium-226. The increase in the potential toxicity of spent fuel after about 10^6 years is due to the ingrowth of Radium-226 from the decay of Uranium-238.

3. The low-level radwaste potential toxicity is taken from expected concentrations as given in an NRC report.[14] After about 200 years, the toxicity has decreased below natural background; and the stable component, due primarily to Iodine-129, is about two orders of magnitude less than the long-term toxicity of a typical metric ton of hazardous waste. The increase after about 10^5 years is again due to the ingrowth of Radium-226 from the decay of Uranium-238 which is disposed of as a source material.

4. The potential toxicity of the uranium mill tailings (assumed to be ore with 0.1% uranium) decreases after about 10^4 years because of the decay of the original Radium-226. It then reaches equilibrium below background due to ingrowth of the daughter products of uranium, about 5% of which remain with the tailings.

5. The potential toxicity of a typical metric ton of hazardous waste is a composite of various EPA-sponsored reports on the waste from major industries that will probably meet the threshold toxicity test for hazardous waste. The toxic heavy metal content accounts for the majority of the long-term non-decaying portion, while the broken line decaying portion is due to the highly dangerous chemicals. The magnitude of the potential toxicity of these chemicals can currently only be approximated because most are not as yet included in the primary drinking water standards, except for a few chlorinated hydrocarbons which are used as representative. The physical decay processes of these chemicals are also typically very difficult to define.

Since the previous comparison only considers a typical metric ton of the various wastes, it does not present a true picture of the total national waste problem. This can be represented by multiplying the estimated production rate of the various wastes by their potential toxicity per metric ton. This perspective of the total potential toxicities of hazardous and radioactive waste from all industries for 1977 is shown in Figure 2. This comparison indicates that because hazardous wastes are produced in such large quantities compared to radioactive waste, the long-term toxicity of the total annual production of these wastes is comparable to that of spent fuel and several orders of magnitude greater than that of low-level radwaste.

This concept of a relative toxicity index can also be used to compare the potentially toxic waste which is produced by almost all major energy sources. Currently the only waste products that can be readily compared on a quantitative basis are those from the coal and nuclear fuel cycles and solar thermal electric facilities, the technology for which is fairly well defined and which appears to be typical of the material requirements of other types of solar energy facilities. The waste products from the other renewable energy sources are not easy to quantify because the technologies themselves are still typically in the conceptual design stage or the waste products are currently not readily definable.

With this in mind, information on the various types of quantifiable wastes which are produced during the expected lifetimes of 1000 MWe equivalent alternate energy sources is given in Table 1. These wastes are then compared graphically by use of the relative toxicity index in Figure 3.

Since the previous figure is primarily a comparison of the toxic heavy metals in the coal and solar waste to the radioisotopes in the nuclear waste, it may provide an additional perspective to compare only the potential radiotoxicity of the various wastes. This comparison is shown in Figure 4. The solid curve for coal ash assumes an average coal concentration of 1.2 ppm uranium, which is typical; while the dotted curve assumes a uranium concentration of 43 ppm[14], which appears to be a reasonable upper bound for eastern coal. The solid curve for solar thermal electric is due primarily to the anticipated requirement for about 2×10^4 MT of copper for this facility[22], the tailings from which are reasonably assumed to contain about 10 ppm uranium. The dotted curve is an upper bound for an equivalent solar heating installation using state of the art copper base flat plate collectors, and assuming as a reasonable upper limit 100 ppm average uranium concentration in the copper tailings.[23]

As the previous analysis shows, the hazardous waste from those quantifiable alternate energy sources are at least as potentially toxic over the long term as the low-level radioactive waste, and may approach the potential toxicity of the uranium mill tailings. The spent fuel or high-level radwaste has a much higher short term relative potential toxicity, but over the long term (after about 500 years) is comparable in toxicity to the uranium mill tailings that were generated in producing this fuel. This fact is generally taken into account in the draft proposed NRC regulations for high-level radwaste[7] in that extraordinary measures are specified during handling and by the fact that this waste will require disposal in deep stable geological formations to assure isolation.

The types of waste which are currently the most directly comparable in terms of treatment by their respective proposed regulations are low-level radioactive waste and hazardous waste, since both are specified as requiring disposal in high-integrity landfills. This comparison of the salient features of the EPA proposed regulations for hazardous waste[1], the EPA proposed criteria for all radioactive wastes[5] and the NRC draft proposed regulations for low-level radwaste[8] is shown in Table 2.

A close scrutiny of this tabular comparison of these proposed regulations generally confirms the notion that the low-level radioactive waste regulations will be more stringent than those for hazardous waste. This nonequitable treatment certainly cannot be justified when considering the previous comparisons of the relative potential toxicities of these wastes.

It is truly unfortunate that the majority of the public perceives the disposal of radioactive waste from the nuclear fuel cycle to be a totally unique and unparalleled problem. Because in fact, an objective quantitative comparison of the potential toxicity of radioactive waste and the hazardous waste from various industries and alternate energy sources indicate that these wastes are generally comparable. Based on this and other factors, such as easier traceability and measurability, radioactive waste may prove to be the more manageable and therefore present less of a risk to public health and safety than hazardous waste.

Even though this fact may be true, it appears as if the regulations for radioactive waste will be much more stringent than those for hazardous waste. The obvious question becomes whether the various Federal agencies and interagency programs are properly coordinated to assure that the public is being equally protected from equal hazards to their health and the environment. The solution is obviously not to ease the stringent requirements that will be necessary for the safe disposal of radioactive waste. However, if economic or political considerations rather than public health considerations dictate that hazardous waste cannot be managed as well as radioactive wastes, then the public deserves to be made aware of this fact.

Radioactive waste disposal has been receiving a disproportionate share of the criticism and attention and the time has come to recognize that this is indeed a manageable problem. The constant rhetoric and indecision should cease, and we should get on with the very formidable task of developing and implementing a rational plan for the safe disposal of radioactive waste.

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TABLE 1

Wastes Generated Over the Lifetime of Various Equivalent 1000 MWe Alternate Energy Sources

Energy Source	Type of Waste	Total Quantity of Waste Produced Over Lifetime (1) (Metric Tons)	Total Quantity of Waste Which May be Considered Hazardous (Metric Tons)	Major Constituents and Typical Concentrations of Toxic Materials
Nuclear	Spent Fuel (2)	1.05×10^3	1.05×10^3	Sr^{90} - 7.8×10^4 curies/MT Cs^{137} - 1.0×10^5 curies/MT Pu^{239} - 3.2×10^2 curies/MT
	Uranium Tailings (2)	8.16×10^6	8.16×10^6	Ra^{226} - 290 μc/MT
	Low-Level Radwaste (3)	5.67×10^4	5.67×10^4	Cs^{137} - 1.1 curies/MT Sr^{90} - 2.3×10^{-3} curies/MT I^{129} - 3.9×10^{-6} curies/MT
Coal	Flyash/bottom ash (4)	2.03×10^6	2.03×10^6	Cr - 720 ppm As - 480 ppm Pb - 150 ppm
	Scrubber Sludge (4)	3.57×10^6	Unknown	Trace heavy metals
	Coal processing wastes (4)	21.8×10^6	Unknown	Trace heavy metals
Solar Thermal Electric	Primary metals production (5)	4.35×10^5	1.63×10^4	Pb - 8700 ppm Cr - 840 ppm
	Metal Finishing (6)	6.86×10^3	6.86×10^3	Cr - 135,000 ppm Pb - 8060 ppm Cd - 7010 ppm

(1) Assumed to be 30 years for all energy sources.

(2) From Ref. 13. Uranium mill tailings are assumed to result from processing ore with 0.1% uranium.

(3) From Ref. 20.

(4) From Ref. 21. Assuming Northern Appalachian coal which has been washed. Unwashed coal would approximately double the ash and sludge wastes but eliminate the coal processing wastes.

(5) From Ref. 16 and 22. Assuming an equivalent base-loaded plant in an average U. S. location.

(6) From Ref. 15 and 22. Assuming all collector surfaces require finishing.

TABLE 2

A Comparison of the Regulations Governing Low-Level Radioactive Waste and Hazardous Waste

Characteristic	Proposed EPA/RCRA Regulations for Hazardous Waste	Proposed EPA Criteria for All Types of Radwaste	Proposed NRC Regulations for Low-Level Radwaste
"De minimus" concentrations	A "de minimus" level is defined such that the leachate must be 10 times the EPA drinking water standards for a waste to be considered hazardous, regardless of the concentration of toxic material in the waste.	This criteria precludes the establishment of any general "de minimus" for the waste itself and does not even consider the leachability of the waste form in determining potential hazard.	A "de minimus" concentration is not defined or is any credit given for non-leachability of the required solid waste forms.
Maximum concentrations	There is no defined maximum concentration of toxic material where more stringent requirements might be necessary to provide adequate protection.		Maximum allowable concentrations of radioisotopes based on pathway analysis are specified above which the waste would not generally be acceptable for shallow land burial facilities as defined by these regulations.
Waste form	Hazardous waste can be disposed of in a liquid form		Prior to disposal, all waste must be in a dry, solid form unless there is no practicable means for solidification and then it must be assured that the liquid will be completely contained over the hazardous lifeline of the waste.
Naturally-occurring radioactivity	Waste containing less than 5 pc/g Ra^{226} for solid waste, less than 50 pc/l Ri^{226} and Ra^{228} for liquid waste or less than 10 μc Ra^{226} in a discrete source does not meet the threshold test for regulation as a hazardous waste.	Waste containing diffuse, naturally-occuring radioactive material would be considered radioactive and, therefore, governed by the regulations if it can be shown that greater radiation exposure can occur through any pathway compared to if the material had not been disturbed by human activity.	

TABLE 2 cont'd

A Comparison of the Regulations Governing Low-Level Radioactive Waste and Hazardous Waste

Characteristic	Proposed EPA/RCRA Regulations for Hazardous Waste	Proposed EPA Criteria for All Types of Radwaste	Proposed NRC Regulations for Low-Level Radwaste
Other qualifying requirements	Those waste generators which produce less than 100 Kg/month of hazardous waste are exempted from all of the regulations except the requirement for disposal in permitted facilities which could include sanitary landfills.		
Burial site design	Generally comparable with, but more detailed than, the LLW disposal facility design requirements in the proposed NRC regulations for LLW.		
Post closure requirements	After closure, post closure care, consisting of certain monitoring and maintenance operations, must continue for a period of at least 20 years. After then no perpetual care is specified.	The fundamental goal for controlling any type of radioactive waste should be complete isolation over its hazardous lifetime. Institutional controls are only appropriate for the short term and cannot be relied upon for longer than 100 years.	After closure, a period of at least 5 years of active observation and maintenance is required prior to the termination of the license. A fund to cover the costs of 100 years of surveillance and monitoring is required after termination of the license to provide assurance of perpetual care by the site owner.

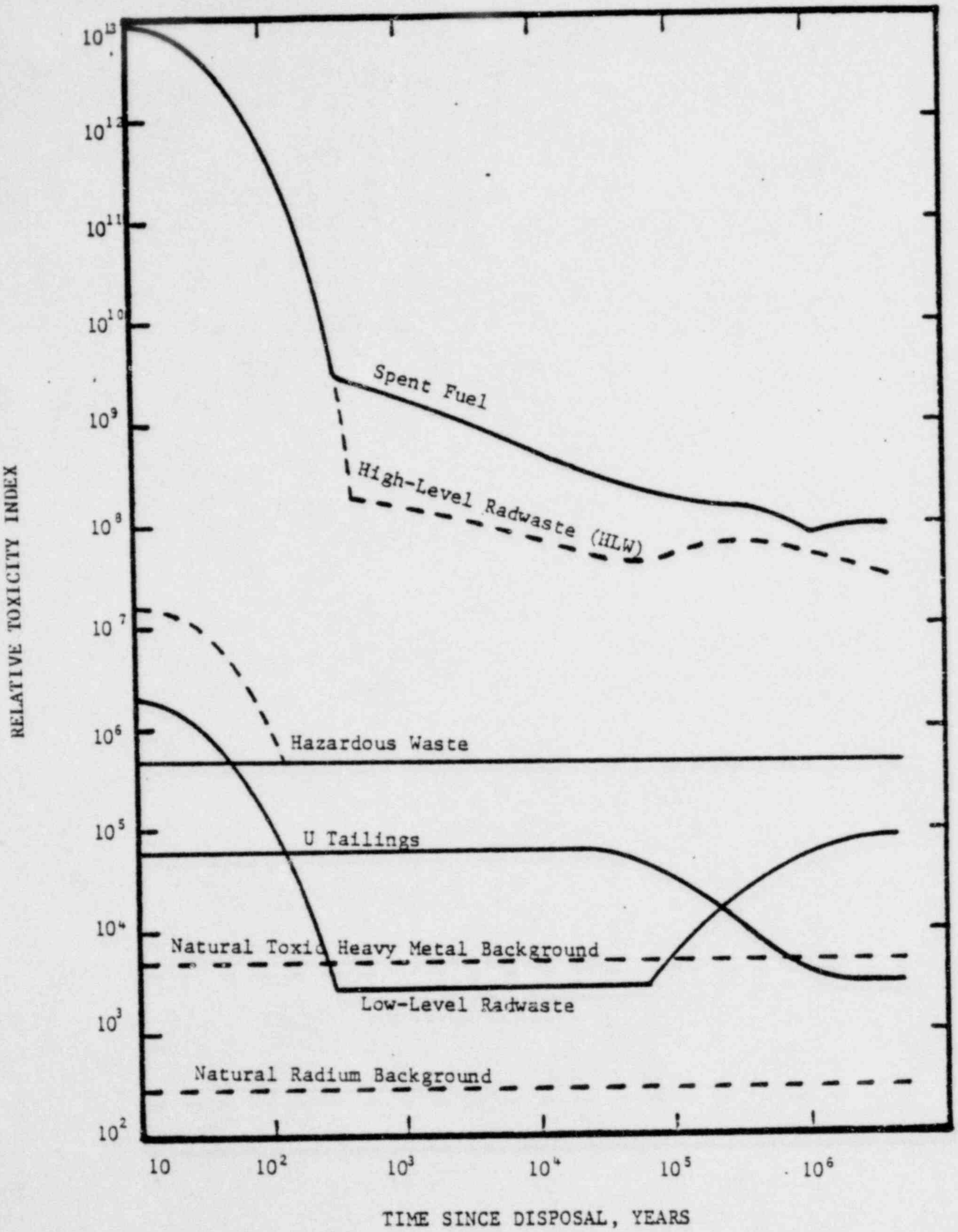

Figure 1: Relative Toxicity of A Typical Metric Ton of Hazardous Versus Radioactive Waste

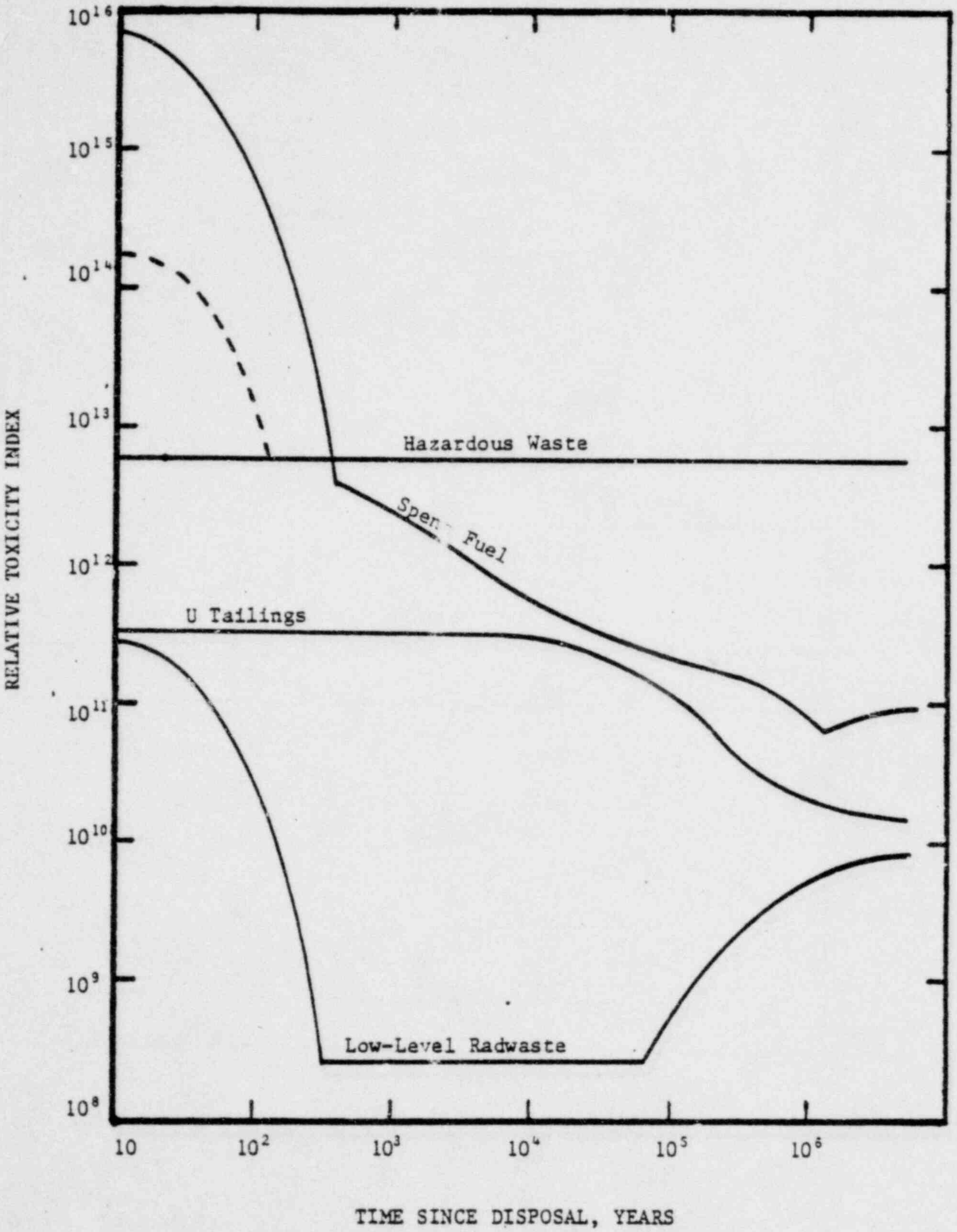

Figure 2: Relative Toxicity of the Total Quantity of Hazardous Versus Radioactive Waste Produced in 1977

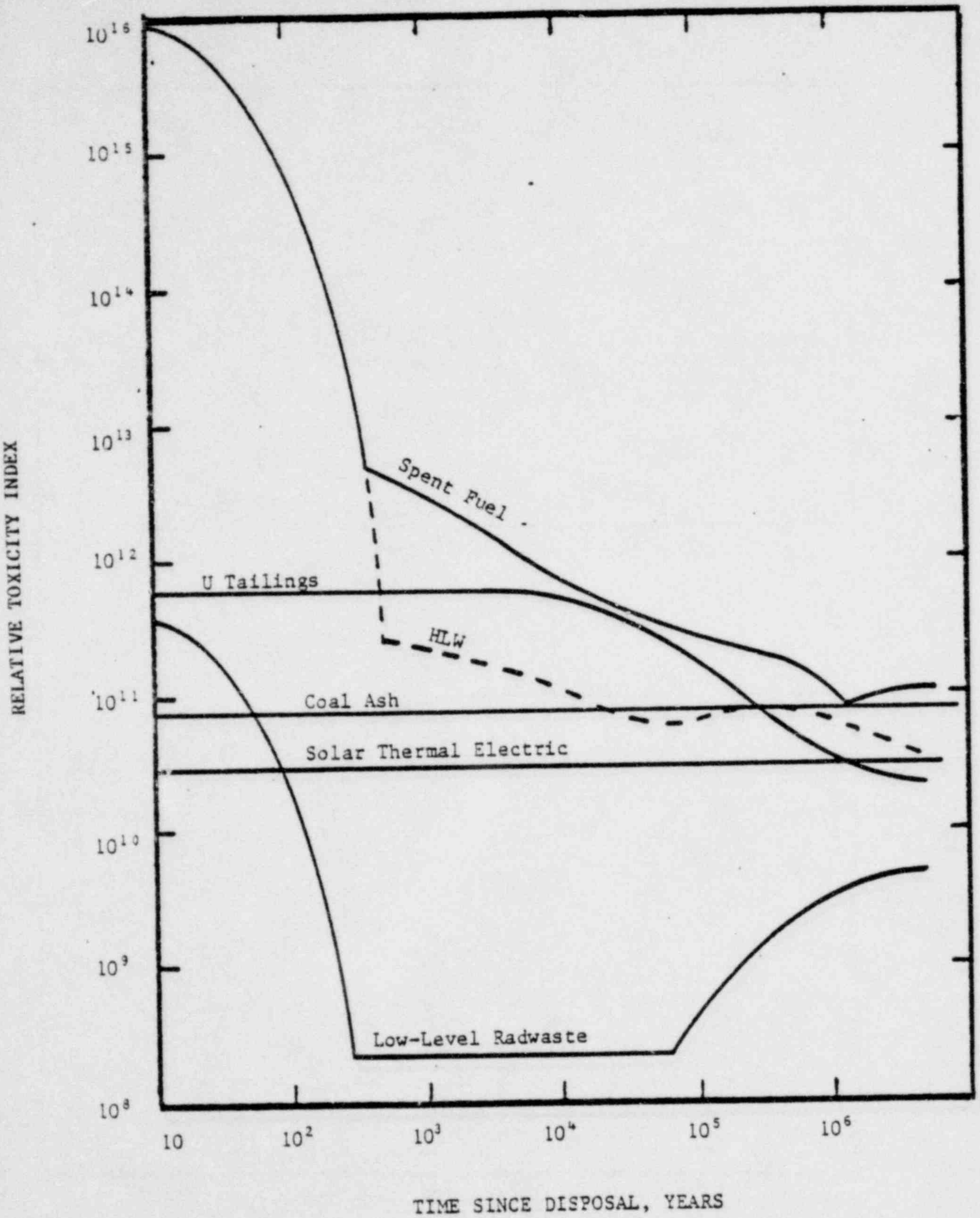

Figure 3: Relative Toxicity of the Wastes Generated Over the Lifetime of Various Equivalent 1000 MWe Alternative Energy Sources.

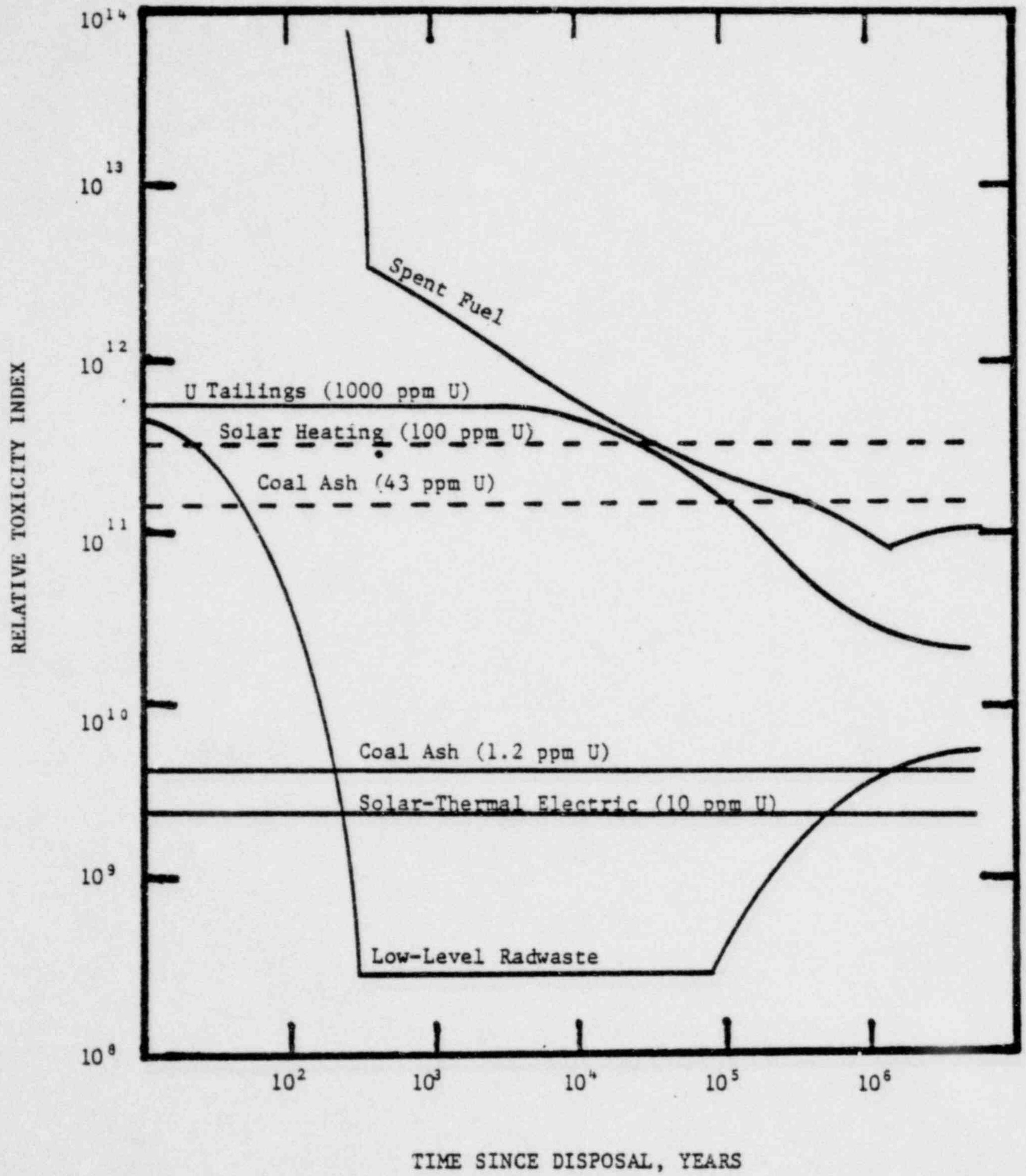

Figure 4: Relative Toxicity of Only the Radioisotope Contamination in the Wastes Generated Over the Lifetime of Various Equivalent 1000 MWe Alternate Erergy Sources.