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A HAZARD INDEX FOR UNDERGROUND TOXIC MATERIAL

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Most alternative methods for disposal of radioactive waste involve its burial in geologic media. To characterize the relative hazard involved, a geotoxicity hazard index has been developed.

The approach taken was to review previous work on toxic material hazard measures and from that review either select or develop an appropriate index. Some of the desired features of such an index are:

- o The capability to assess hazardous effects of non-radioactive as well as radioactive toxic material
- o Assessment of natural mineral deposits as well as man made waste repositories containing radioactive or other toxic wastes
- o Simplicity in form, making it understandable and applicable
- o Sufficient structure to characterize parameters of primary importance including:
 - Toxicity
 - Persistence (longevity)
 - Availability (transport potential)
 - Progeny buildup

Following the review of previous work, it was concluded that, although factors currently used in toxicity measures appear to have received some degree of acceptance, other parameters of importance (persistence, availability, and progeny buildup) have not been satisfactorily accommodated.

Since the long-term chronic effects resulting from ingestion of material released via water-borne pathways was of overriding importance only the effects due to chronic ingestion were considered in developing this index. Where potential acute effects (e.g., those resulting from direct intrusion into and inhalation of the underground toxic material) are of concern, other hazard indices would need to be utilized.

A mathematical framework defining a theoretical measure of hazard was derived. From this, a Geotoxicity Hazard Index (GHI) was developed which has the following form for any given material (i):

$$GHI_{(i)} = TI_i \cdot P_i \cdot A_i \cdot C_i$$

For mixtures:

$$GHI = \sum GHI_i$$

TI is a basic toxicity index and P, A, and C are modifying factors related respectively to persistence, availability, and buildup of progeny more toxic than the parent material. Specifically:

$$TI = Q/MPC \text{ or } Q/DWS$$

where:

Q = Quantity of Material (Ci or gm)

MPC = Maximum permissible concentration for radionuclides in public drinking water supplies (ci/m³)

DWS = Drinking water standard - permissible concentration of stable toxic materials in public drinking water supplies (gm/m³)

Dimensionally, TI is expressed in units of volume (m³). Conceptually, TI indicates the volume of water required to dilute a given quantity of toxic material to drinking water levels. Since TI does not convey all the information required to characterize the overall hazard, it is modified by the following dimensionless parameters:

o The persistence factor (P):

$$P = \frac{1 - \exp(-300 \lambda)}{300 \lambda}$$

where λ is the decay constant in (years⁻¹). P corresponds to the mean fractional quantity of material in existence during a reference 300 year time period.

For stable materials P = 1.0 and for decaying material, 0 < P < 1.0.

o The availability factor (A) for material (i) is related to the "reference" availability (Ao) of the same material (element) as it occurs naturally in the earth's crust.

$$A_{o_i} = \frac{\frac{\text{Ingestion rate (i)}}{\text{Crustal abundance (i)}}}{\frac{\text{Ingestion rate (Ra-226)}}{\text{Crustal abundance (Ra-226)}}}$$

From the above formula, it can be seen that the natural availability for any element is referenced to that of naturally occurring Ra-226 so that by definition, $A_o(\text{Ra-226}) = 1.0$. Finally,

$$A_i = m \cdot A_o_i$$

where m describes the modification of availability for any given waste or mineral component considering its chemical and physical form and conditions of burial relative to that of its naturally occurring analog. Increasing degrees of isolation would result in lower values of m . As a first approximation, it could be assumed that $m = 1.0$. However, as new generic or site-specific information is obtained through data acquisition, modelling, or other means, this value may be revised to incorporate the new knowledge. Improvement in estimation of m is seen as an iterative process.

- o The buildup correction factor (C) applies to materials which transform into progeny more toxic than the parent material.

$$C = \frac{TI_{(\text{max})}}{TI_o}$$

where:

$TI_{(\text{max})}$ = the maximum toxicity index of the parent plus progeny material at any future time

TI_o = Initial toxicity index of parent material

Some sample cases were calculated to demonstrate application of the GHI: A high level waste repository, a low level waste repository, and natural uranium, lead, and mercury ore deposits were evaluated. Results indicate that the low level waste repository has a geotoxic hazard which is significantly lower than that of the other sample cases considered. The cursory examples were assessed primarily to evaluate the methodology and provide some insight to the relative importance of the components of the index. Further refinement of the calculational parameters, particularly the availability factor(A), can be readily accommodated to provide increased confidence in the results.