FATE OF HAZARDOUS MATERIALS IN BIOSPHERE

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Abstract

- Nuclear power is expanding as a major global energy source
- Radioactive waste disposal nuclear fuel cycle poses challenges
- Perception: Nuclear wastes present unique threats to humans.
- Nuclear wastes risks comparable to other hazardous materials
- Radioactive mat'ls decay and reduce in time unlike stable elements.
- Risk reduced by radioactive decay, dilution, dispersion by natural events
- Adequate and safe disposal of nuclear waste possible.
- Ultimate sink for hazardous wastes are oceans (dilution & containment)

INTRODUCTION

US Energy Act 2005 major commitment to resume nuclear power

China and Japan also expanding development of nuclear power
Advanced nuclear plants (APWR, ABWR, EPR, & Generation IV) offer passive safety, improved economics, & dependable energy

Reduction green house gases and "hydrogen economy" make nuclear best choice for 21st century.

Nuclear power renaissance dependent on resolution of technical, social, and political issues.

Major issue: Management/disposal rad waste from nuclear fuel cycle

Nuclear fuel cycle (LLW, HLW, TRU, mill tailings) pose challenges

Nuclear development could be stalled/ended over public and political concerns over nuclear waste management.

RISKS FROM NUCLEAR WASTE

Nuclear critics claim nuclear fuel cycle wastes uniquely dangerous.
   In 1979 Nader and Abbots stated:

"Storage of nuclear waste is much more than a problem of technology. Safe storage requires stable geological formations, a guarantee which is beyond promise of technology. Safe storage also requires development of stable human institutions to exist for thousands of year to prevent waste from leaking and contaminating biosphere."

Nuclear Waste Policy Act of 1982 defined HLW as
(note: "permanent")

"…highly radioactive material resulting from reprocessing of used nuclear fuel and other highly radioactive material that…. requires *permanent* isolation."

Managing and safe disposal nuclear waste perceived as intractable
 posing great risk to society.

RISK FROM NUCLEAR FUEL CYCLE WASTES

Actually radioactive materials from fuel cycle pose no unique, interminable or irresolvable threats.

Health risks from nuclear waste not fundamentally different from natural radioactive and stable hazardous and toxic materials

Average super market has sufficient hazardous materials fatally poison all living in surrounding community.

Typical US household has lethal doses of chlorine bleach, outdoor pesticides, toxic washing compounds, overdosing medicines, etc.

Consider – Hazardous, ubiquitous lead (Pb).

- known carcinogen and mutagen.
- particularly harmful for children from lead paint.
- additive for gasoline (~1900 to 1980) and lead-acid batteries.

Annual production of lead (if ingested) kills more people than all Pu

Lead waste often not properly disposed and found in agricultural soils, ground water, drinking water.

So paraphrasing "Nader and Abbots 1979 statement" for "lead"

"Storage of *lead* waste is much more than a problem of technology. Safe storage of *lead* requires stable geological formations, a guarantee which is beyond promise of technology. Safe storage also requires development of stable human institutions to exist *forever* to prevent *lead* from leaking and contaminating biosphere."

Nature provides dispersal and chemical degradation so lead's bioavailability very low, but still greater than actinides.

Final decay product of natural and man-made actinides is lead So actinides processed similarly by nature.

Naturally occurring radionuclides can pose greater risk than man-made cousins such as Pu.

Inventory of natural radium (e.g., Ra-226) in ocean 80 million tons Radium equivalent in toxicity to ingestion of 100 billion tons of Pu But total inventory of Pu about 1000 tons

So disposal of Pu in oceans equivalent radiotoxicity less than 1 ton of radium or 0.000001% of toxicity of natural occurring radium

QUANTIFYING HAZARDOUS MATERIALS

Health effects for ionizing radiation based on linear no threshold (LNT) model and collective dose hypothesis

LNT results in heavy regulatory burden for management of radioactive materials

If LNT imposed on production, use, and disposal of stable hazardous compounds then industry, manufacturing, commerce and even agriculture are threatened.

Most materials in biosphere hazardous at some level of exposure
Even obesity from overeating is a serious health threat.

LNT model would imply that any increment of food intake produces proportional health risks observed with obesity such as diabetes.

Lack of food greater risk to health as evidenced by world famines
Some ubiquitous, common materials pose risk at any level.

SAMPLE COMMON HAZARDOUS MATERIALS

These include fossil fuels, pesticides, arsenic, asbestos, beryllium, chlorine, heavy metals, PCBs, natural/man-made organic compounds.

To quantify hazardous materials in biosphere a useful measure is unit of mass of given material that results in acute 30LD50 dose

This unit is dose of given hazardous material in or exposing body that results in lethal dose to 50% of population within 30 days.

Acute health effects extrapolated in absence of medical treatment.

For ionizing radiation, 30LD50 adult dose about 500 rem received internally or externally in 24-hour period.

Reduction of this lethal dose by a factor of 1 million gives a dose of 0.5 mrem/day comparable to exposure from natural background.

Reduction of 30LD50 dose with decay thru 20 half-lives gives source concentration reduction of one million.

Reduction by dilution and dispersion is primary means stable hazardous materials are detoxified by nature.

Similar $_{30}LD_{50}$ values for non-radioactive materials developed for stable hazardous compounds.

Annual US production of selected toxic materials given in Table 1 with total lethal doses for each material and ratio to lethal dose of nuclear waste after 10 years of decay.

Most US water supplies treated with chlorine for potability.

Evaporation of chlorine sources and ubiquitous water supply pose threat 2000 times greater than nuclear waste.

Note: Pb, Cu, Ba, & arsenic poses about same risk as 10-year-old nuclear waste.

Table 1. US production of selected toxic materials-1976

Material	Lethal doses	Ratio to nuclear @ 10 yr
INHALATION		
Chlorine	4E14	2000
Phosgene	2E13	200
Ammonia	6E12	30
Hydrogen cyanide	6E12	30
Nuclear Waste (@10 yr)	2E11	1
Nuclear Waste (@500 yr)	5E10	0.3
INGESTION		
Barium	9E10	3
Copper	9E10	3
Arsenic	1E10	0.3
Lead	0.1	0.1
Nuclear Waste (@10 yr)	3E10	1
Nuclear Waste (@500 yr)	1E7	0.0003

- Note: 1E10 = 1x1010, nuclear waste (@10 yr or 500 yr) time after removal from reactor

Table 2

Crustal abundance of toxic materials in soil and water together with hazard index shown in Table 2.

Nature's inventory of indigenous hazard materials to compare risks from radioactive (viz., U) & naturally occurring, stable compounds.

Hazard index is useful measure for modeling risk and is defined as volume of water required to dilute given hazardous material to current US EPA drinking water standards.

All these hazardous materials occur in ocean water that is the eventual disposal site for most hazardous materials.

Note that oceans can dilute U to EPA drinking water standards, but not dilute other hazardous materials to these standards.

Table 2. Crustal abundance of hazardous materials

Material	Hazard index(m^3)	Crustal abundance(kg)
Uranium	3.5E17	4.0E16
Selenium	1.8E20	1.8E15
Cadmium	3.6E20	3.6E15
Arsenic	2.0E21	1.0E17
Mercury	5.0E21	1.0E16
Lead	6.4E21	3.2E17
Barium	8.6E18	6.4E21
Chromium	830E22	8.6E18
	Volume	Mass
Ocean	1.7E18	1.7E21

NATURAL & ENGINEERED HAZARDOUS MATERIAL DISPOSAL

Considerable time, effort and expense committed to manage rad waste from nuclear fuel cycle.

Regulations demand sequestering this waste in few limited sites both in shallow land disposal units and in deep geological beds for "adequate time periods" ranging from a hundred years for LLW to 10,000 years for spent nuclear fuel.

Many man-made short-life isotopes decay through 10 to 20 half lives in a few hundred years.

Focus for nuclear critics is Pu and its isotopes.

Pu-239 is principal fissile material in nuclear weapons and carries great burden of fear and contempt.

Pu-239 has 24,000 yr half-life and is major nuclear fuel cycle Pu isotope

Thousand-fold reduction in Pu activity requires 240,000 years.

However, hazard index of Pu after 10,000 years decay less than natural uranium ore

10,000 years is long period compared to documented human residency on earth.

Likely any disposal unit for rad or stable hazardous material designed by humans will not sequester waste for ten millennia.

Fact: Some of these nuclear materials may eventually escape.
But these materials will be subject to natural forces and events that disturb and disrupt earth's crust.

Earthquakes, tornados, hurricanes, glaciation followed by melting, surface and ground water transport, flooding, erosion, volcanism, meteor strikes, and even human intrusion may eventually release these materials to biosphere.

But despite inability to accurately predict and accurately model future action of natural forces and events for disruption, One natural law is irrevocable and will prevail throughout lifetime of these materials and indeed lifetime of universe, viz.

"Second law of Thermodynamics."

Total entropy of any closed natural system increases over time.

Entropy produces dilution, dispersion, advection, and diffusion of any concentrated material at a given location in the universe.

Increase in entropy of disposed waste produces reduction in concentration and dispersion of these hazardous materials.

Atmosphere, combined with surface and ground water as cleansing agents, transports these contaminants anywhere they are deposited into ocean.

Ocean serves as depository for all nature's toxic substances. Because of vast volume and mass of earth's oceans, a cubic meter of hazardous material dissociated into seawater is reduced in concentration by a factor of 10^{18}.

A kilogram of hazardous material mixed within ocean water is reduced by a factor of 10^{21}.

REQUIRED REDUCTION FOR NUCLEAR WASTES

- Dilution to parts per million or less is generally adequate to contain risks from nuclear waste

- Dilution is universal mechanism by which nature cleanses its contaminated land surface and discharges waste into ocean.

- Indeed, hazards from nuclear waste will be rendered impotent and attendant risk from nuclear waste will be dissolved in vast oceans of earth from which life originally sprang

ULTIMATE OCEANIC DISPOSAL

Oceanic disposal likely provides safest means of immediate disposal of both nuclear and hazardous waste.

Nature will eventually transport nuclear waste wherever it is initially deposited to oceans along with other natural and hazardous materials present on earth.

Human body and all fauna contain trace materials at levels similar to contents of ocean water.

Many of these trace materials (Se, Fe, Co, Sb, etc.) are known to be toxic at higher concentrations within body.

CONCLUSIONS

Nuclear waste hazard not greater than natural and manmade hazardous materials.

Excessive concern over long half-life rad materials (e.g., Pu) inconsistent with stable toxic materials in greater abundance

 e.g., lead (autos), cadmium (batteries), selenium (solar cells), mercury (lights), petroleum; all with infinite half-lives not reduced by radioactive decay

Well-engineered geological nuclear waste disposal coupled with radioactive decay and natural dispersion, dilution, and diffusion yields concentration reduction by at least a million.

With entropy acting, nuclear waste risks are commensurate with risks from naturally occurring radioactive and hazardous materials.