APPENDIX V

NEW AND UNUSUAL FARMING PRACTICES

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Ostrich Farming

Ostrich Facts

The ostrich, *Struthis camelus*, is the largest living bird. It may stand up to ten feet tall and attain a weight in excess of 300 pounds. Although flightless, the bird can run at sustained speeds of 30 miles per hour (mph) and peak speeds of 45 mph when escaping predators. Its body is covered with large, loosely-structured feathers whose function is to protect the bird from heat and cold (WAL80).

Today, its natural range is limited to Africa, where it lives in open country feeding on plants, fruits, grasses, leaves, and on occasion, insects, lizards, rodents, and small birds. The bird can go for long periods without water, which allows it to survive in arid regions.

Domestic Farming

Ostriches may reach full size in as few as six months, but do not attain sexual maturity until about three years of age. They may live for 30 years or more. Females may lay several eggs weighing up to 3.5 pounds each with an incubation period of 42-43 days.

The first commercial ostrich farm was established in South Africa in 1838. In recent years, a limited number of farmers in the United States have begun to raise ostriches for their meat, leather, feathers, and other byproducts. At the typical age of slaughter (i.e., 10-14 months), the average bird yields about 75-90 pounds of consumable meat, 12-14 square feet of leather, and three to four pounds of feathers. The high protein red meat has a taste much like that of beef, but has a fat and cholesterol content that is even lower than turkey. Ostrich leather is regarded as among the best and most durable of leathers. Ostrich feathers have a wide range of commercial uses (AOA96).

For practical and economic reasons, ostrich farmers generally do not allow birds to forage/graze naturally for food but restrict them to a confined area where they are provided pelletized commercial feed, similar to that used in poultry farming. Adult ostriches eat about three to four pounds of commercial pelletized feed per day.

Human Exposure

The principal pathway for human exposure associated with ostrich farming is the consumption of ostrich meat. Traditionally, for meat consumption such as beef, human exposure is the result of two mechanisms: (1) soil-crop-animal-human, and (2) water-animal-human. Thus, the activity of a given radionuclide in meat that may be consumed by humans is determined by the following generic equation:

$$\text{Activity in Meat (pCi/kg)} = [(\text{Feed consumed-kg/d})(\text{Activity in feed-pCi/kg}) + (\text{water consumed-L/d})(\text{Activity in water-pCi/L})] \times \text{transfer coefficient (d/kg)}$$

To determine the activity in beef, for example, it is generally assumed that the adult cow consumes about nine kilograms (kg) of dry feed and 50 liters (L) of water per day.

Because ostriches are assumed to be raised on imported imported commercial pelletized feed that would be unaffected by potentially contaminated ground water in the vicinity of the Yucca Mountain site, contamination of ostrich meat is limited to the bird's consumption of contaminated water. For ostrich meat derived from commercial farming, the above equation is, therefore, reduced to:

$$\text{Activity (pCi/kg)}_{\text{ostrich}} = (\text{water consumed-L/d})(\text{Activity in water-pCi/L})(\text{transfer coefficient-d/kg})$$

Information regarding water consumption rates by ostriches was provided by Bud Aldrich, DVM (ALD96). Dr. Aldrich, a veterinarian, is not only affiliated with the American Ostrich Association, Fort Worth, TX, but also raises ostriches personally. Based on knowledge and personal observation, he stated that water consumption is highly variable and reflects ambient temperature and the water content of feed. Low water consumption would be expected for temperate climates and feed consisting of succulent vegetation. Conversely, high water consumption rates would be expected for areas with high temperatures/low humidity and feed with low water content (e.g., pelletized feed). Based on the fact that ostriches are between 10 and 14 months of age at time of slaughter, they will experience temperatures that reflect seasonal changes at Yucca Mountain for a full calendar year. On average, the daily water consumption for an adult ostrich is estimated at 12 liters (ALD96).

A review of the scientific literature reveals a lack of data regarding the uptake and retention of ingested elements in the ostrich from which radionuclide-specific transfer coefficients are derived. This is not surprising since historically the ostrich has not posed a significant link in the food chain leading to human exposure. In spite of acknowledged anatomical and physiological features that are unique to the ostrich (e.g., it is the only bird that eliminates its urine separately from its feces), its metabolism of food products is generally considered equal or similar to that of the chicken, turkey, and other domestic poultry (ALD96). Radionuclide transfer coefficients derived for poultry have, therefore, been applied to the ostrich in deriving meat activity levels for drinking water contaminated at one pCi/L. These values are compared to those of beef inTable V-1. On a per unit weight basis, seven of the 19 radionuclides assessed in Table V-1 are estimated to be present in ostrich meat at a higher level than those of beef (conversely beef is estimated to exhibit higher levels for 12 of the 19 radionuclides).

In summary, ostrich farming and the substitution of ostrich meat for beef is not likely to have a significant impact on dose/risk estimates.

Catfish Farming

The growing interest in aquaculture and its expansion into various geographic areas, including the desert Southwest, is due to several factors:

- Overfishing and environmental factors have steadily reduced harvests of marine fish
- There is an increased demand for fish that is influenced by population growth and dietary concerns regarding animal fats/cholesterol
- Aquaculture is based on proven methods and has the support of an established infrastructure (i.e., how-to information, equipment, fish feed, processing, and wholesale/retail outlets)
- Aquaculture is currently the most lucrative sector within U.S. agriculture (GEL94)

Table V-1. Comparative Data Pertaining to Ostrich Farming

Radionuclides	Ostrich Data		Beef Data	
	Transfer Coeff. (d/kg)	Activity in Ostrich Meat[1] (pCi/kg)	Transfer Coeff. (d/kg)	Activity in Beef (pCi/kg)
U-234	1.2E+0	1.4E+1	3.0E-4	5.0E-1
U-238	1.2E+0	1.4E+1	3.0E-4	5.1E-1
Th-230	4.0E-3	4.8E-2	6.0E-6	1.0E-2
Tc-99	3.0E-2	3.6E-1	1.0E-4	6.0E-1
Se-79	5.5E+0	6.6E+1	1.5E-2	2.4E+1
Ra-226	9.9E-4	1.2E-2	9.0E-4	1.1E+0
Pu-239	1.5E-4	1.8E-3	1.0E-5	2.0E-2
Pu-240	1.5E-4	1.8E-3	1.0E-5	2.0E-2
Pb-210	9.9E-4	1.2E-2	4.0E-4	1.2E+0
Np-237	4.0E-3	4.8E-2	1.0E-3	2.0E+0
Ni-59	1.0E-3	1.2E-2	5.0E-3	8.1E+0
Nb-94	3.1E-4	3.7E-3	3.0E-7	1.0E-3
I-129	1.8E-2	2.2E-1	4.0E-2	5.8E+1
Cs-137	4.4E+0	5.3E+1	5.0E-2	7.8E+1
Cs-135	4.4E+0	5.3E+1	5.0E-2	8.0E+1
Cm-246	4.0E-3	4.8E-2	3.5E-6	6.0E-3
Cm-245	4.0E-3	4.8E-2	3.5E-6	6.0E-3
Am-243	2.0E-4	2.4E-3	4.0E-5	6.0E-2
Am-241	2.0E-4	2.4E-3	4.0E-5	6.0E-2

[1] Activity level (pCi/kg) in ostrich meat is based on consumption of 12 liters of water per day at 1 pCi/L.

Aquaculture Facts

Data regarding aquaculture were obtained by personal communication from *Arid Lands Fish Production* located in Chino Valley, Arizona. Aquaculture facilities can be characterized as either "warm" or "cold" water operations. Cold water fish farms are generally located in areas that are suitable for maintaining water temperatures below 60°F and principally involve various species of trout.

Warm water facilities in southern states and in desert regions of the Southwest take advantage of a climate that allows for water temperatures above 70°F. For example, Arizona fish farmers currently produce about 500,000 pounds of fish per year. Fish farming in Arizona consists mainly of family operations. Warm water fish include catfish, large-mouth bass, and tilapia. Warm climates favor fish farming due to the fact that fish metabolism (and therefore growth rate) increases with ambient water temperature.

Farming methods vary depending on the availability and cost of water. In southern states, where water can be readily diverted from proximal bodies of surface water, fish production commonly employs rectangular, levee-style ponds constructed on flat land that are similar to cranberry bogs. Alternatively, natural depressions in the valleys of hilly terrain may be used for the construction of watershed ponds that rely on runoffs from rain as their primary water source.

For arid areas that lack available surface water and have limited ground water resources, fish farming is generally conducted in large tanks filled with ground water that is continuously filtered and aerated.

Independent of whether fish are raised in levee-style ponds, natural depression ponds, or tanks, their food is limited to commercial pelletized floating feed that is introduced daily.

Catfish are generally harvested at around 200 days when they attain a body weight of about one pound. At time of harvest, the catfish will have consumed about two pounds of feed yielding a feed to body weight ratio of two.

Like other terrestrial human food chains, the aquatic food chain also consists of multiple trophic levels. Trophic levels represent individual steps in the food chain and are generally more complex for aquatic systems than for those of the terrestrial world. This is due to the fact that aquatic species often consume several types of prey that represent different trophic levels (Figure V-1). To further complicate matters, physicochemical parameters of radionuclides and, thus, their transfer from one organism to another are generally more variable in aquatic ecosystems than in terrestrial ecosystems. Important parameters that affect a radionuclide's distribution in aquatic ecosystems include its tendency for colloid formation, co-precipitation, and adsorption-desorption on sediments and suspended solids (NRC83).

Over the past several decades, a significant number of studies have been conducted in which radionuclides have been introduced into the water medium of a natural ecosystem or under controlled laboratory conditions (FRE67, LLL68, ORN76, LLL78, BLA82, PNL86 and POS88).

A common and primary objective of these studies was the determination of concentration factors of radionuclides that pose environmental risks. The concentration factor (L/kg) for aquatic species is the ratio of a given element/radionuclide concentration in the organism to that in water.

Radionuclides with high concentration factors are those with established biological significance or chemical similarity to biologically-active elements. Biological significance, however, varies among species within and among different trophic levels. While the majority of radionuclides in the environment do not increase in concentration with trophic level, a limited number of highly-

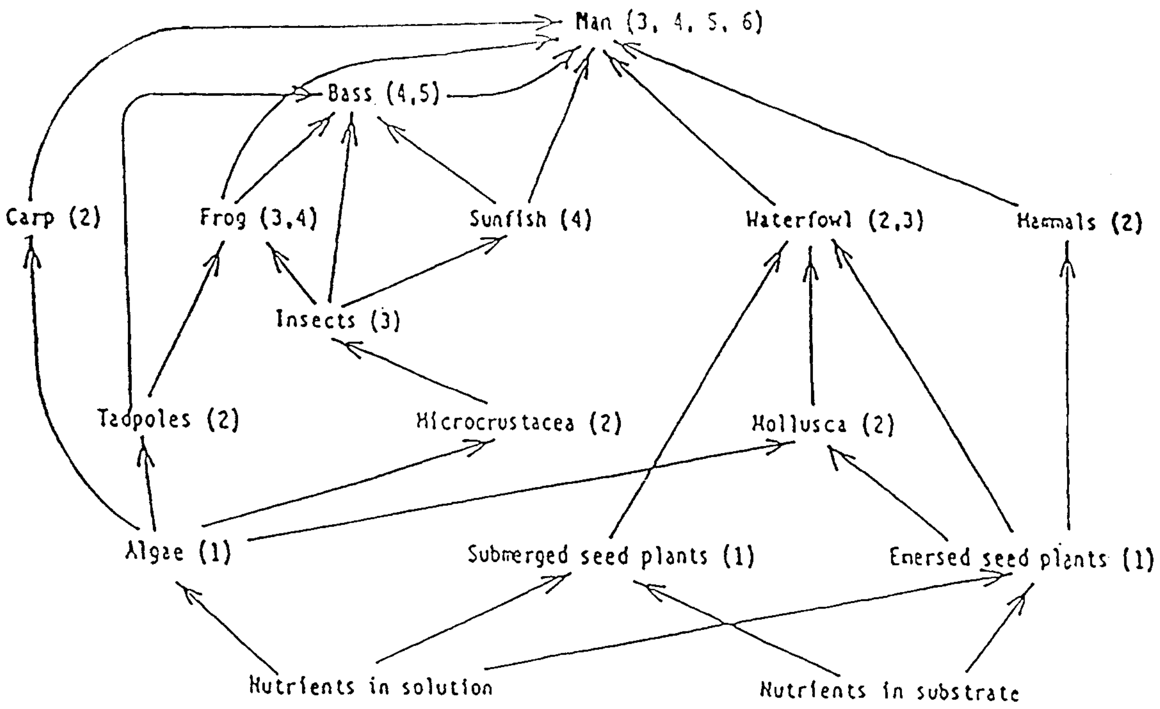

Figure V-1. A Simplified Lake Ecosystem (parenthesized numbers note the trophic level) soluble radionuclides with mineral nutrient value do in fact increase with trophic level (PEN65). For example, the concentration of plutonium and strontium generally decreases at higher trophic levels due to decreased efficiencies in assimilating the ingested radionuclides (Figure V-2). In contrast, measurements of the concentration of cesium-137 in freshwater fish show that larger predacious fish tend to have a markedly higher cesium concentration than smaller fish (lower trophic level), zooplankton, algae, and other components of the aquatic food web inclusive of waterfowl, raptor, and terrestrial species (Figure V-3). Concentration factors are also high among fish like the catfish that are bottom-feeders, since cesium has a strong affinity for clay-containing sediments/mud.

In an extensive review of the scientific literature, the International Atomic Energy Agency recently compiled bioaccumulation factors for the edible portions of freshwater fish (IAE94). Table V-2 summarizes the range of reported values and cites a best value for specific elements and their associated long-lived radionuclides.

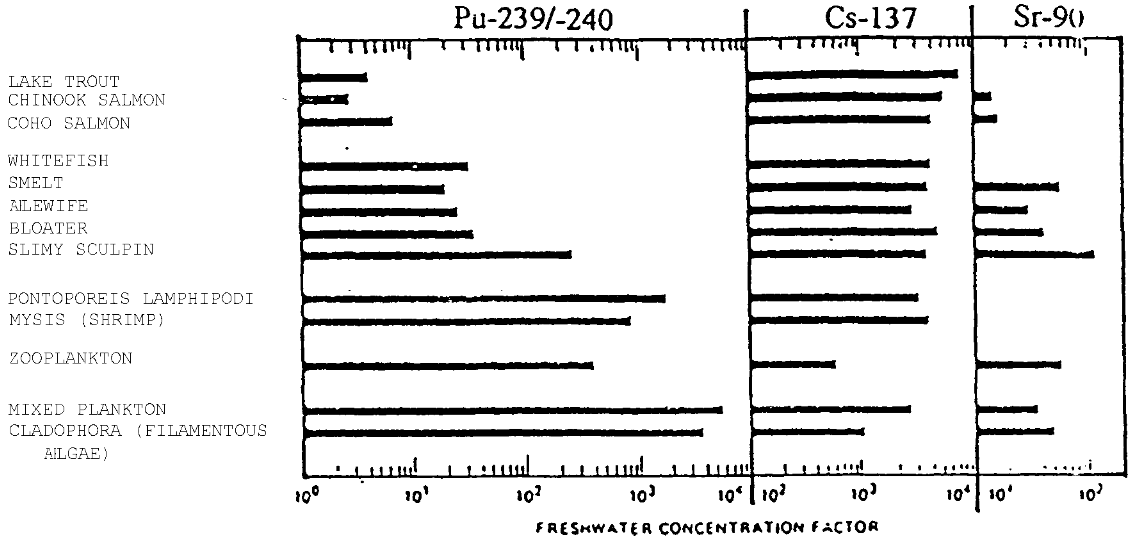

Figure V-2. The Concentration Factors for Pu-239/240, Cs-137, and Sr-90 in a Freshwater Ecosystem (WAH75)

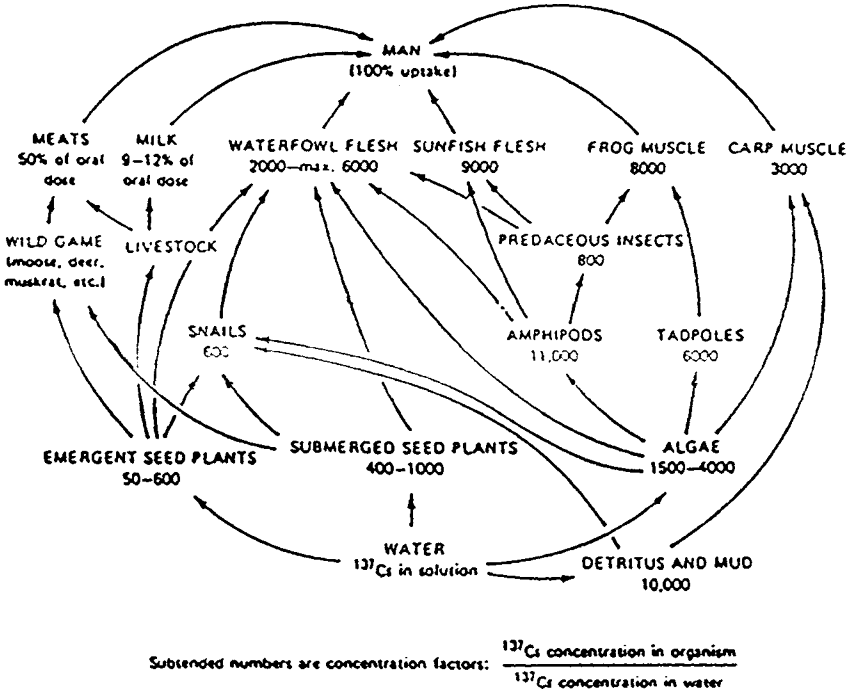

Figure V-3. A Freshwater Food Web Illustrating the Pathway to Human for Cesium-137 in Aquatic Environment (PEN58)

Table V-2. Concentration Factors for Edible Portions of Freshwater Fish (L/kg)

Element	Recommended Value	Range
H-3	1	6×10^{-1} - 1
He	1	
Be	1×10^{2}	
C	5×10^{4}	5×10^{3} - 5×10^{4}
N	2×10^{5}	
O	1	
Na	2×10^{1}	2×10^{1} - 1×10^{2}
P	5×10^{4}	3×10^{3} - 1×10^{5}
S	8×10^{2}	
Sc	1×10^{2}	2 - 1×10^{2}
Cr	2×10^{2}	4×10^{1} - 2×10^{3}
Mn	4×10^{2}	5×10^{1} - 2×10^{3}
Fe	2×10^{2}	5×10^{1} - 5×10^{2}
Co	3×10^{2}	10 - 3×10^{2}
Ni	1×10^{2}	
Cu	2×10^{2}	5×10^{1} - 2×10^{2}
Zn	1×10^{3}	1×10^{2} - 3×10^{3}
Br	4×10^{2}	
Rb	2×10^{3}	2×10^{2} - 9×10^{3}
Sr	6×10^{1}	1 - 1×10^{3}
Y	3×10^{1}	
Zr	3×10^{2}	3 - 3×10^{2}
Nb	3×10^{2}	1×10^{2} - 3×10^{4}
Mo	10	
Tc	2×10^{1}	2 - 8×10^{1}
Ru	10	10 - 2×10^{2}
Rh	10	
Ag	5	2×10^{-1} - 10
Sn	3×10^{3}	

Table V-2. Concentration Factors for Edible Portions of Freshwater Fish (L/kg) (continued)

Element	Recommended Value	Range
Sb	1×10^2	$1 - 2 \times 10^2$
Te	4×10^2	$4 \times 10^2 - 1 \times 10^3$
I	4×10^1	$2 \times 10^1 - 6 \times 10^2$
Cs	2×10^3	$3 \times 10^1 - 3 \times 10^3$
Ba	4	$4 - 2 \times 10^2$
La	3×10^1	
Ce	3×10^1	$3 \times 10^1 - 5 \times 10^2$
Pr	1×10^2	$3 \times 10^1 - 1 \times 10^2$
Nd	1×10^2	$3 \times 10^1 - 1 \times 10^2$
Pm	3×10^1	$10 - 2 \times 10^2$
Eu	5×10^1	$10 - 2 \times 10^2$
Ta	1×10^2	$1 \times 10^2 - 3 \times 10^4$
W	10	$10 - 1 \times 10^3$
Hg	1×10^3	
Pb	3×10^2	$1 \times 10^2 - 3 \times 10^2$
Bi	10	
Po	5×10^1	$10 - 5 \times 10^2$
Ra	5×10^1	$10 - 2 \times 10^2$
Th	1×10^2	$3 \times 10^1 - 1 \times 10^4$
Pa	10	
U	10	$2 - 5 \times 10^1$
Np	3×10^1	$10 - 3 \times 10^3$
Pu	3×10^1	$4 - 3 \times 10^2$
Am	3×10^1	$3 \times 10^1 - 3 \times 10^2$
Cm	3×10^1	$3 \times 10^1 - 3 \times 10^2$

Source: IAE94
Highlighted elements represent radionuclides under consideration in this report.

The applicability of concentration factors cited in Table V-2 to catfish farming, however, is highly dubious for the following reasons:

(1) Derived concentration factors generally represent ecological conditions in which the radionuclide was assumed to exist in a steady-state or equilibrium condition in all trophic levels and compartments that define the ecosystem.

(2) In freshwater fish, the uptake of biologically significant elements (and radionuclides) that leads to bioaccumulation occurs principally through the <u>ingestion</u> of food and <u>not</u> through direct sorption from water (FLE70, KIN61, WIL61, HAS63, EHS63, RIC66). For this reason, reported concentration factors observed in natural environments commonly exceed those of laboratory conditions by several orders of magnitude (IAE75).

(3) For catfish provided pelletized feed and raised in tanks, exposure to radioactivity is, therefore, limited to water that is assumed to be contaminated at activity levels of one pCi per liter. (Since water is continuously aerated and mechanically filtered, tanks are assumed to contain insignificant amounts of sediment or suspended particulates.)

In the absence of scientific data regarding concentration factors that are limited to the direct sorption of radionuclides contained in water and applicable to the unique conditions of aquaculture, <u>expert opinion</u> was sought from individuals associated with SENES Oak Ridge Inc., Center for Risk Analysis (APO96). Although reluctant to suggest specific bioaccumulation values, experts did not object to EPA using traditional concentration factors like those in Table V-2 and applying an adjustment factor that reduces bioaccumulation by one-hundred fold with a lower-limit concentration factor of one. For example, direct sorption of Cs-137, Pb-210 and Th-230 would yield concentration factors of 20, three, and one, respectively (Table V-3).

On the basis of bioaccumulation factors that are derived for direct sorption, it is concluded that activity levels in catfish raised under controlled conditions are low. Previous estimates of individual dose/risk that may result from substituting catfish for beef consumption are, therefore, not significantly affected.

Table V-3. Assumed Concentration Factors Limited to Direct Sorption for Edible Portions of Freshwater Fish

Radionuclide	Conc. Factor (L/kg)	Activity in Catfish Meat[*] (pCi/kg)
U-234	1	1
U-238	1	1
Th-230	1	1
Tc-99	1	1
Se-79	1	1
Ra-226	1	1
Pu-239	1	1
Pu-240	1	1
Pb-210	3	3
Np-237	1	1
Ni-59	1	1
Nb-94	3	3
I-129	1	1
Cs-137	20	20
Cs-135	20	20
Cm-246	1	1
Cm-245	1	1
Am-243	1	1
Am-241	1	1

[*] Activity in catfish corresponds to a water concentration of one pCi/L.

Hydroponic Farming[*]

Hydroponics is the science of growing plants without soil. Nutrient solution alone provides a more direct and efficient way to provide the essential constituents for plant growth. No soil means no weeds that compete for nutrients or soil-born parasites that require pesticides. By controlling nutrient concentrations near optimal levels, the root systems are proportionately smaller than plants grown in soils with varying nutrient contents. This implies that plants not

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[*] General information was obtained from *InterUrban Water Farms*, Riverside, California.

only grow faster, but can channel growth on the edible plant mass rather than on an extensive root system.

Aside from nutrients, the growing media in hydroponic farming is totally inert. There are various methods of growing plants hydroponically that include highly aerated water, moist humid air, or a solid, but hydroscopic, inert medium:

- Water culture: Narrow open troughs commonly fashioned from rain gutters or bisected PVS pipes are commonly used to hold plants. An aerated nutrient solution is circulated around the root system submerged in the trough.

- Aeroponics: Humid air provides the environment in which the plant roots grow. Troughs or bags are commonly used to hold/support the plant while nutrient solution is sprayed to keep roots moist.

- Media culture: A number of different inert media may be used to provide support for roots. Common media include rockwool (a fibrous sponge-like material made from molten rock) or geolite (a ceramic kiln-fired pebble). When placed in troughs or bags, their porosity and/or particle size of this media allows for free circulation of nutrient-containing water.

Depending on climatic conditions, hydroponic farming can be conducted in greenhouses or outdoors and is suitable for a variety of plants including tomatoes, sweet peppers, snow-peas, bean-sprouts, etc.

The limiting factor for outdoor hydroponic farming is the relative humidity. The threat of rapid plant/root dehydration in the hot and arid climate of Yucca Mountain would limit hydroponic farming to hot-houses (for commercial production) and indoor gardens (for personnal production).

Currently, there are commercial vendors who market a variety of equipment and supplies for both large-scale and small-scale production. Relative to conventional farming, the cost of hydroponic farming is low. It is estimated that the yearly cost of fertilizer and pH control products for a personal-use system that produces about 200 pounds of tomatoes annually averages around $60 to $80. This is about thirty to forty cents per pound of tomatoes.

Radionuclide Content of Hydroponically Grown Vegetables

The principal method by which plants, inclusive of vegetables and fruits, incorporate radionuclides contained in soil is by root uptake. Root uptake requires that the contaminant is dissolved in water that occupies soil pore spaces within the plant's root zone. For modeling and calculational purposes, it would, therefore, appear appropriate for bioaccumulation factors to be defined as the ratio of the radionuclide activity per unit mass of plant to the radionuclide activity per unit volume of soil water.

However, the water content of most soils is highly variable with time due to the episodic nature of precipitation. Additionally, pore space water represents a small fraction of the total soil mass and is difficult to remove under normal conditions. For these reasons, the traditional method for modeling food pathways is to base the expected radioactivity levels in plantson those of the soil in which they are grown.

In Section 8.3.4.1, food transfer factors are discussed in terms of a concentration ratio (CR) where:

$$CR = \frac{Radionuclide\ activity\ per\ unit\ mass\ of\ plant}{Radionuclide\ activity\ per\ unit\ mass\ of\ soil}$$

It should be noted, however, that CR values, even for a specific radionuclide, are not constant. They reflect the complex physical/chemical behavior of the contaminant in soil.

For Yucca Mountain, the vegetable exposure scenario is based on the fact that when soil is repeatedly irrigated with contaminated ground water, there is a steady buildup of soil contaminants over time. At some point, however, an equilibrium condition is reached when further irrigation is off-set by the removal rate of contaminants by the combined effects of radioactive decay and various removal mechanisms, such as soil leaching. Plants grown in soil at equilibrium soil conditions can be expected to have the highest radionuclide concentration.

This complex relationship of contaminant buildup/removal in soil and plant uptake is strongly influenced by the partitioning coefficient of the radionuclide contaminants, previously defined as its K_d value, where:

$$K_d = \frac{concentration\ of\ radionuclide\ adsorbed\ on\ soil\ particles\ (pCi/kg)}{concentration\ of\ contaminant\ in\ water\ occupying\ soil\ pore\ space\ (pCi/L)}$$

The impact of K_d values on soil buildup and plant uptake do not parallel each other for the following reasons:

(1) When soil conditions yield a high K_d value, the radionuclide can be expected to strongly adhere to soil particles and resist removal by leaching. This leads to a higher equilibrium soil concentration value.

(2) Increased K_d values, however, imply that radionuclides are not readily removed by pore-space water, which reduces the opportunity for plant uptake.

From the combined values of concentration ratios for plants grown in soil and their assumed soil partitioning coefficient, a concentration ratio value can be derived for plants grown hydroponically by the following relationship:

$$Plant\ CR_{Hydroponically\,grown} = \frac{radionuclide\ activity\ per\ unit\ mass\ of\ plant}{radionuclide\ activity\ per\ unit\ volume\ of\ water\ in\ root\ zone}$$

$$= (CR_{soil\,grown})(K_d)$$

$$= \left(\frac{activity\ per\ unit\ masss\ of\ plant}{activity\ per\ unit\ mass\ soil}\right)\left(\frac{activity\ per\ unit\ mass\ of\ soil\ particles}{activity\ per\ unit\ volume\ water\ in\ root\ zone}\right)$$

Table V-4 cites the concentration ratios of plants grown hydroponically ($CR_{Hydroponic}$) for radionuclides under assessment for Yucca Mountain. These data were derived from the K_d values in Table 8-3 and concentration ratios for plants grown in soil cited in Tables 8-4 and 8-6. These latter tables appear in Section 8.3.4 of this chapter.

Concentration ratios for plants grown hydroponically in a contaminated water medium clearly show which elements appear in higher concentrations in plant matter than in the water from which they were removed. For example, when Am-243 is present in water at one pCi/L, leafy vegetables grown hydroponically would be expected to have an activity level of about 0.12 pCi/kg. Similarly, leafy vegetables would be expected to exhibit about 33 pCi/kg of Cs-137 when grown hydroponically in a contaminated water medium.

A quantitative assessment of the potential impact of substituting hydroponically-grown vegetables for soil-grown vegetables in dose assessments is not possible at this time. This is due to the fact that previous dose/risk models associated with soil-grown plants did not consider soil buildup (See Section 8.3.4.1). It is reasonable, however, to conclude that soil-grown vegetables grown hydroponically would be expected to have lower activity levels than those grown in soil.

Table V-4. Inferred Concentration Ratios for Plants Grown Hydroponically

Radio-nuclides	**Concentration Ratio** $(\frac{pCi/kg\ plant}{pCi/L\ water})$		
	Leafy Vegetables	**Other Vegetables**	**Fruit**
U-234	6.0E+0	2.9E+0	2.9E+0
U-238	6.0E+0	2.9E+0	2.9E+0
Th-230	1.1E+0	3.4E-2	3.4E-2
Tc-99	9.5E+0	1.1E-1	1.1E-1
Se-79	4.8E-1	4.8E-1	4.8E-1
Ra-226	4.5E+1	7.3E+0	7.3E+0
Pu-239	1.7E-2	1.1E-2	1.1E-2
Pu-240	1.7E-2	1.1E-2	1.1E-2
Pb-210	8.1E-1	4.7E+0	4.7E+0
Np-237	6.9E+0	2.7E+0	2.7E+0
Ni-59	1.3E+1	2.1E+0	2.1E+0
Nb-94	6.0E+0	2.0E+0	2.0E+0
I-129	3.4E-4	2.0E-3	2.0E-3
Cs-137	3.3E+1	2.2E+1	2.2E+1
Cs-135	3.3E+1	2.2E+1	2.2E+1
Cm-246	2.9E+0	1.5E+0	1.5E+0
Cm-245	2.9E+0	1.5E+0	1.5E+0
Am-243	1.2E-1	4.7E-2	4.7E-2
Am-241	1.2E-1	4.7E-2	4.7E-2

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