

Radiation Processing of Sewage

Sewage Sludge

- **Good fertilizer**
- **Potential animal feed supplement
(economic value ~ 3 times, compared to
fertilizer)**
- **However, pathogen contamination
needs appropriate treatment**

Pathogens Found in Sewage Sludge^a

| Viruses | Disease | Host |
|--|---|--|
| Enteroviruses Poliovirus Coxsackievirus | Gastroenteritis, meningitis, paralysis, cardiac conditions | Humans |
| Rotavirus | Gastroenteritis | Humans, domestic and wild animals |
| Hepatitis A | Infectious hepatitis | Humans |
| Adenovirus | Respiratory disease, conjunctivis | Humans |
| Reovirus | Respiratory infections | Humans, domestic and wild animals |

^a Bennett et al. (1988)

Pathogens Found in Sewage Sludge^a

| Bacteria | Disease | Host |
|---------------------------------|---|---|
| <i>Salmonella sp.</i> | Gastroenteritis, Enteric fever | Human, domestic and wild animals |
| <i>Shigella sp.</i> | Gastroenteritis, Bacillary dysentery | Humans |
| <i>Escherichia coli</i> | Gastroenteritis | Humans, domestic animals |
| <i>Mycobacterium sp.</i> | Tuberculosis | Humans, domestic animals |
| <i>Leptospira sp.</i> | Leptospirosis | Human, domestic and wild animals |

^a Bennett et al. (1988)

Pathogens Found in Sewage Sludge^a

| Organism | Disease | Host |
|--|------------------------------------|--|
| Protozoa <i>Entamoeba histolytica</i> <i>Giardia lamblia</i> | Amoebic dysentery Dysentery | Humans Humans |
| Helminthic Parasites (intestinal worms) <i>Ascaris sp.</i> <i>Trichuris sp.</i> | Ascariasis Whipworm infestation | Humans, cattle, swine Humans, domestic animals |
| <i>Toxocara sp.</i> | Roundworm infestation | Humans, domestic animals |
| <i>Taenia sp</i> | Taeniasis | Humans, swine, cattle |
| <i>Echinococcus sp.</i> | Hydatid disease | Humans, domestic and wild animals |

^a Bennett et al. (1988)

Pathogen Survival in Soil and on Plants

| Pathogen | Soil | | Plants | |
|-----------|------------------|----------------|------------------|----------------|
| | Absolute Maximum | Common Maximum | Absolute Maximum | Common Maximum |
| Bacteria | 1 year | 2 months | 6 months | 1 month |
| Viruses | 6 months | 3 months | 2 months | 1 month |
| Protozoa | 10 days | 2 days | 5 days | 2 days |
| Helminths | 7 years | 2 years | 5 months | 1 month |

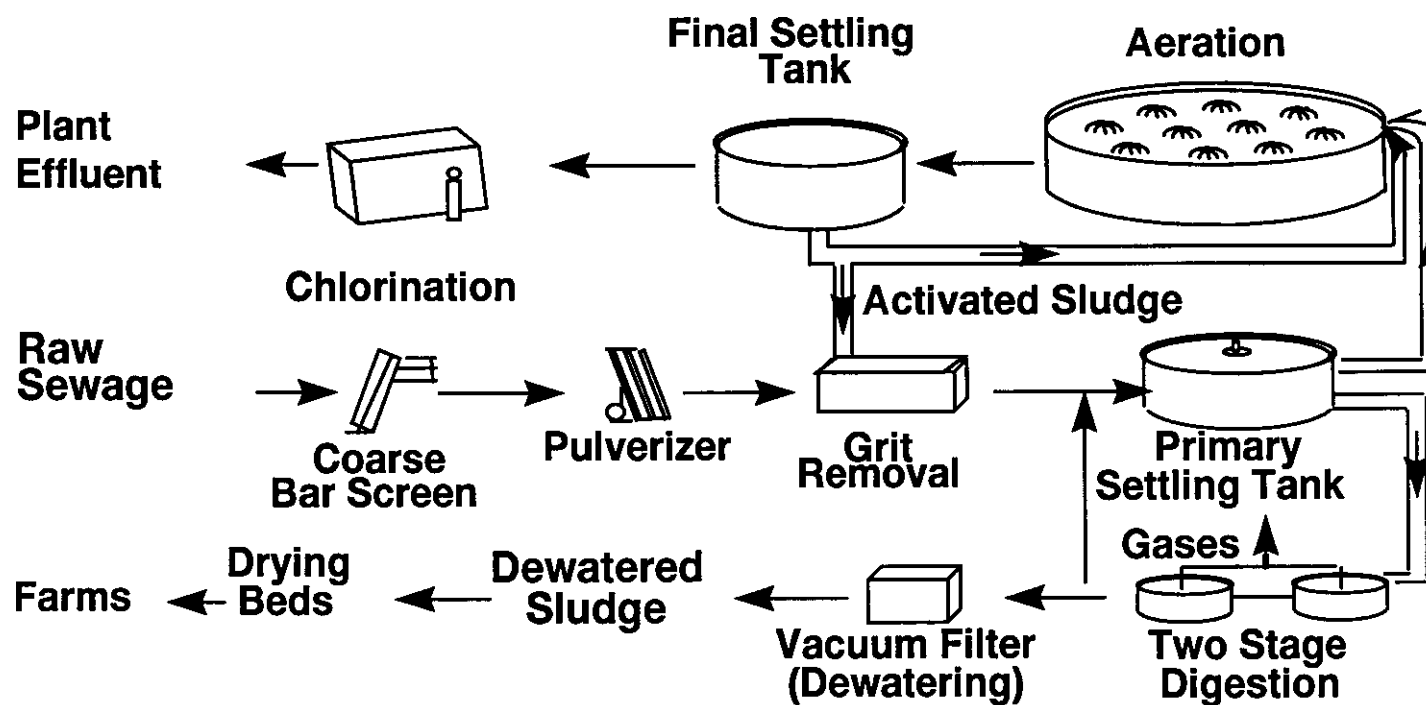
Sewage Treatment

- **Sewage contaminated with a variety of pathogens**
- **Raw sewage a health hazard**
- **Conventional treatment**
 - **Separate sewage sludge**
 - **Biologically treat sewage sludge**
 - **Chemically treat waste water**
- **Sewage sludge a rich source of plant nutrients, and a potential source of animal feed supplement**
- **Radiation processing can facilitate both uses of sewage sludge and improve quality of waste water**

Conventional Treatment of Sewage

- **Anaerobic digestion of sludge (15 to 20°C, 40 to 60 days)**
- **Aerobic digestion (20-35°C, 15 - 60 days)**
- **Air drying (3 months)**
- **Composting (40-70°C)**
- **Aeration and chlorination of waste water**

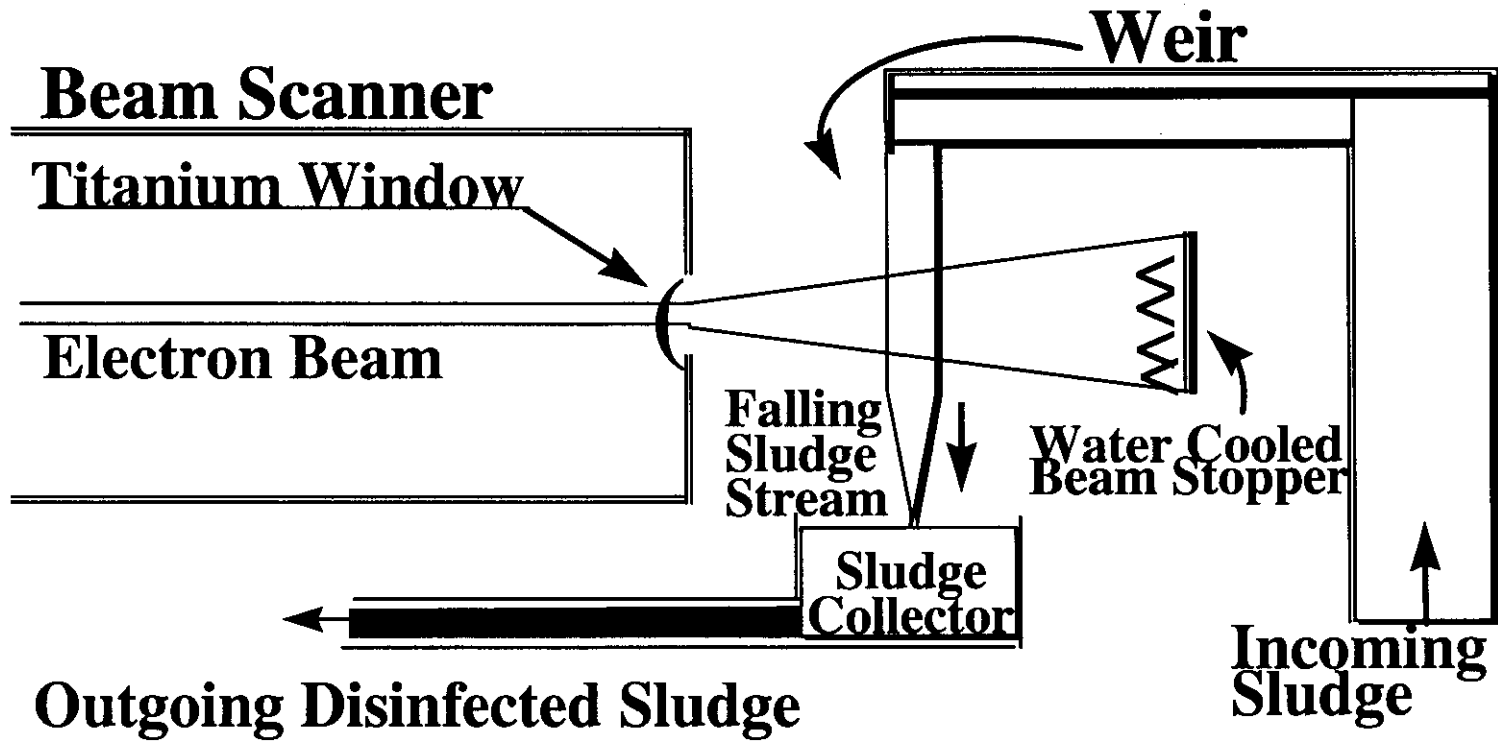
CONVENTIONAL ACTIVATED SLUDGE TREATMENT OF SEWAGE



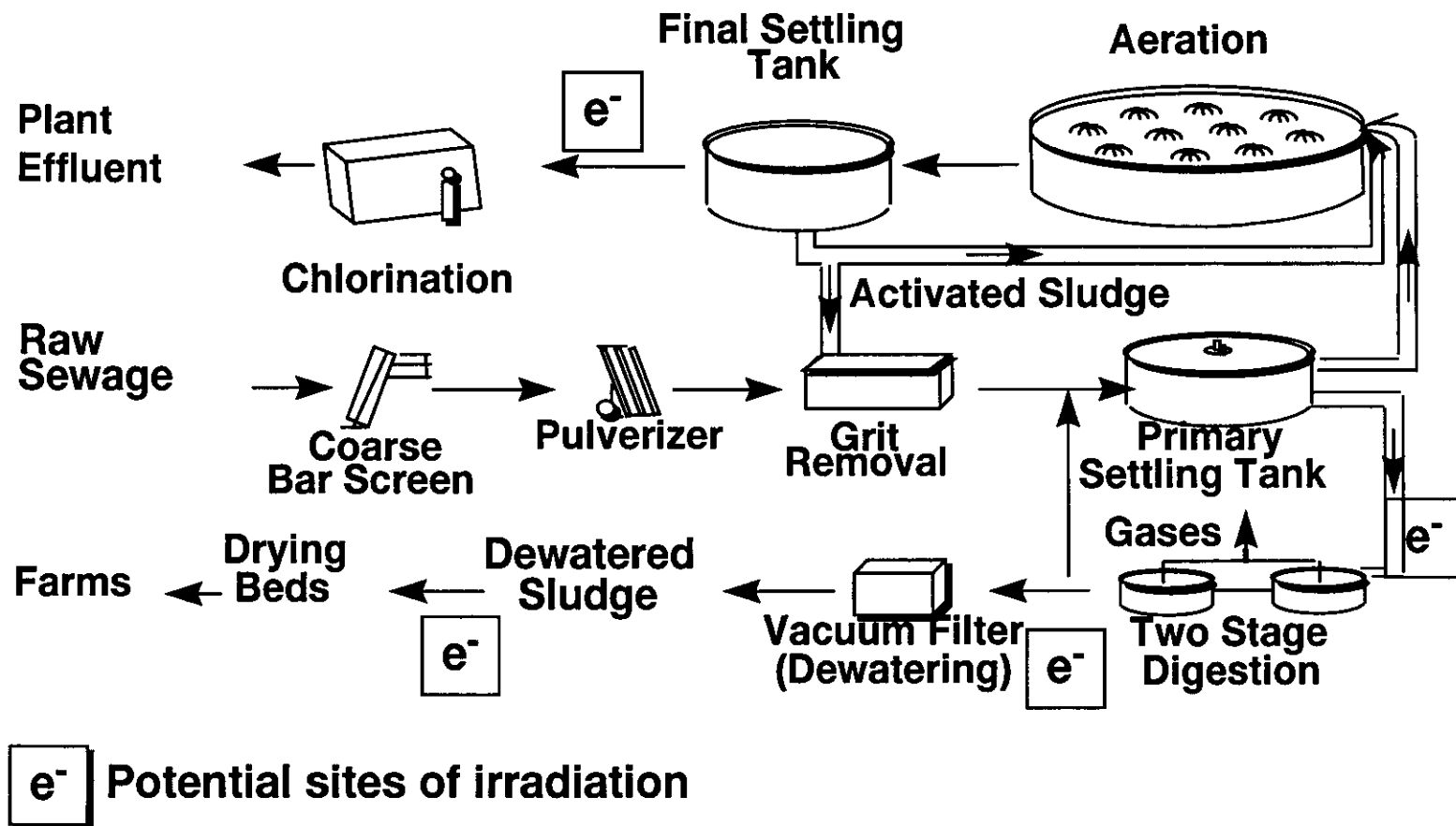
Radiation Processing of Sewage

- **3-10 kGy, sludge can be applied to agricultural land directly (based on local regulations)**
- **~ 25 kGy, sludge can be used as animal feed supplement (check regulations)**
- **2-3 kGy, preferably in presence of O₃**
 - **Effective decontamination of waste water**

ELECTRON BEAM TREATMENT OF SEWAGE SLUDGE



Irradiation and Conventional Activated Sludge Treatment of Sewage



Typical Counts (per mL) of Bacteria in Anaerobically Digested Sewage Sludge (Deer Island)

| Bacteria | 0 kGy | 4 kGy |
|---------------------------|-----------------|------------------|
| Total bacteria | 4×10^6 | 10^2 |
| Total coliforms | 8×10^5 | bdl ^a |
| Fecal coliforms | 1×10^5 | bdl ^a |
| <i>Salmonellae</i> | 4×10^1 | bdl ^a |
| <i>Fecal streptococci</i> | 5×10^3 | ≤ 10 |
| <i>Clostridia</i> | 6×10^4 | $\leq 10^2$ |

^a below detectable levels

Pilot and Industrial Plants for Sewage Irradiation

- **Münich, Germany; ^{60}Co ; pilot plant, 1973-1980; commercial, since 1980; dose 3 kGy; 145 m³/day (+O₂, 2 kGy, 180 m³/day)**
- **Baroda, India, ^{60}Co ; 5 kGy; 110 m³/day**
- **Takasaki, Japan; electron accelerator, 5 kGy, 300 kg/h**
- **Plants also in Ukraine and Russia**

Metal Content Considerations for Sewage Sludge Application to Agricultural Land in Ontario, Canada (Bennett et al., 1988)

| Metal | Average content of soil (mg/L) | Maximum recommended in soil (mg/L) | Maximum acceptable in sludge (mg/L) |
|-------------------|---|---|--|
| Cadmium | 0.8 | 1.6 | 10 |
| Cobalt | 5 | 20 | 150 |
| Copper | 25 | 100 | 750 |
| Mercury | 0.1 | 0.5 | 4 |
| Molybdenum | 2 | 4.0 | 20 |
| Nickel | 16 | 32 | 160 |
| Lead | 15 | 60 | 450 |

- Metal content of sludge is an important factor in determining how much should be applied to land**

Response of Humans, Animals and Plants to the Metal Content of Sewage Sludge Applied to Agricultural Land (Bennett et al., 1988)

Potentially harmful to humans, concentrate in plants and animals

Cd, Pb, Hg, Ni

Cause phytotoxicity; concentrate in livestock eating sludge

Co, Cu, Fe¹, Mo

Concentrate in plants, some phytotoxicity

B, Mn¹, Zn

No effect

Sb, As, Be, Cr, Se, Ag, Tl, Sn, W

¹ naturally abundant in soil

Conclusions

- **Radiation treatment of sewage sludge and wastewater can help improve the environment and provide soil-conditioning fertilizer and good animal feed supplement**
- **The effectiveness of sewage irradiation has been established**
- **The extent of use of sewage sludge depends on its heavy metal content, which can be controlled by regulations and appropriate monitoring**
- **Radiation processing of sewage is a potential growth area, facilitated by the availability of high power electron accelerators, and the synergistic effects of ozone for wastewater treatment**