Radiation Processing of Sewage

Sewage Sludge

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

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
Salmonella sp.	Gastroenteritis, Enteric fever	Human, domestic and wild animals
Shigella sp.	Gastroenteritis, Bacillary dysentery	Humans
Escherichia coli	Gastroenteritis	Humans, domestic animals
Mycobacterium sp.	Tuberculosis	Humans, domestic animals
Leptospira sp.	Leptospirosis	Human, domestic and wild animals

[a] Bennett et al. (1988)

Pathogens Found in Sewage Sludge[a]

Organism	Disease	Host
Protozoa		
Entamoeba hystolytica	Amoebic dysentery	Humans
Giardia lamblia	Dysentery	Humans
Helminthic Parasites (intestinal worms)		
Ascaris sp.	Ascariasis	Humans, cattle, swine
Trichuris sp.	Whipworm infestation	Humans, domestic animals
Toxocara sp.	Roundworm infestation	Humans, domestic animals
Taenia sp	Taeniasis	Humans, swine, cattle
Echinococcus sp.	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

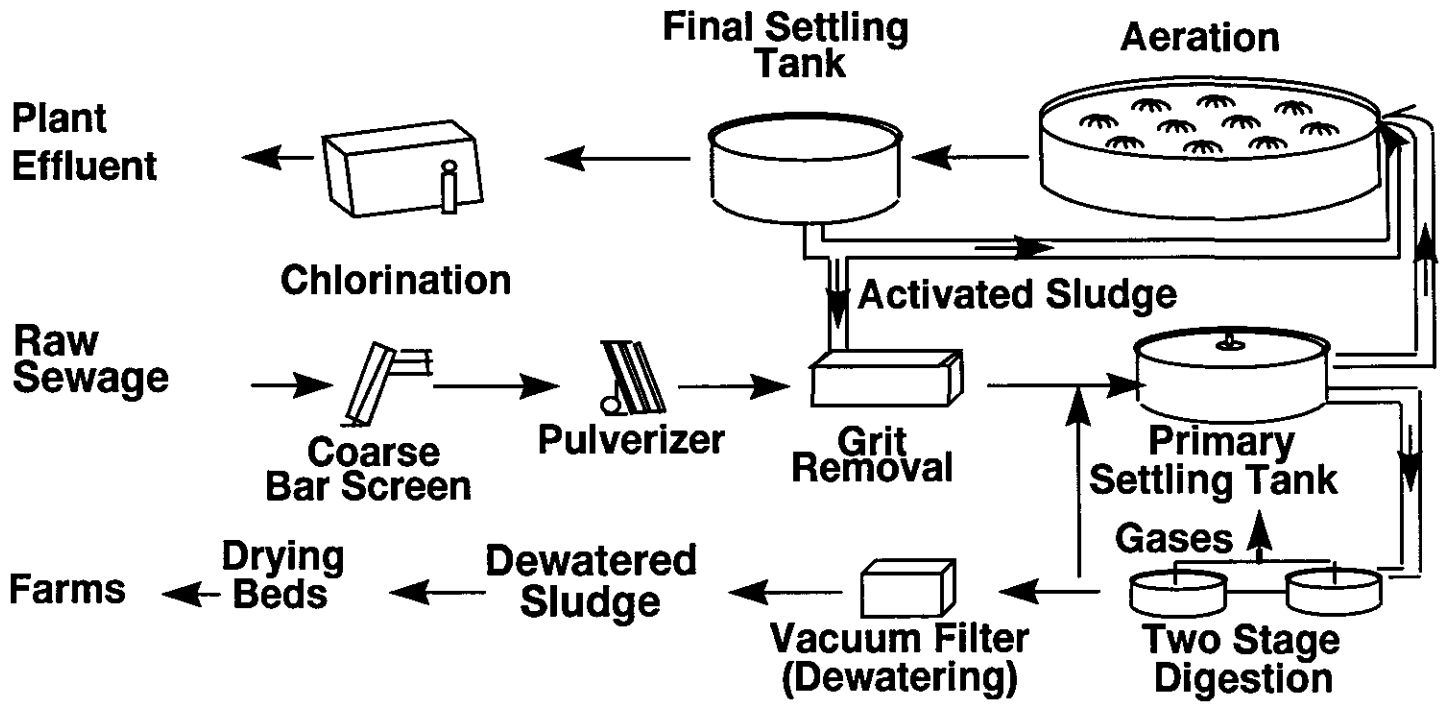
Sewage Treatment

- 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

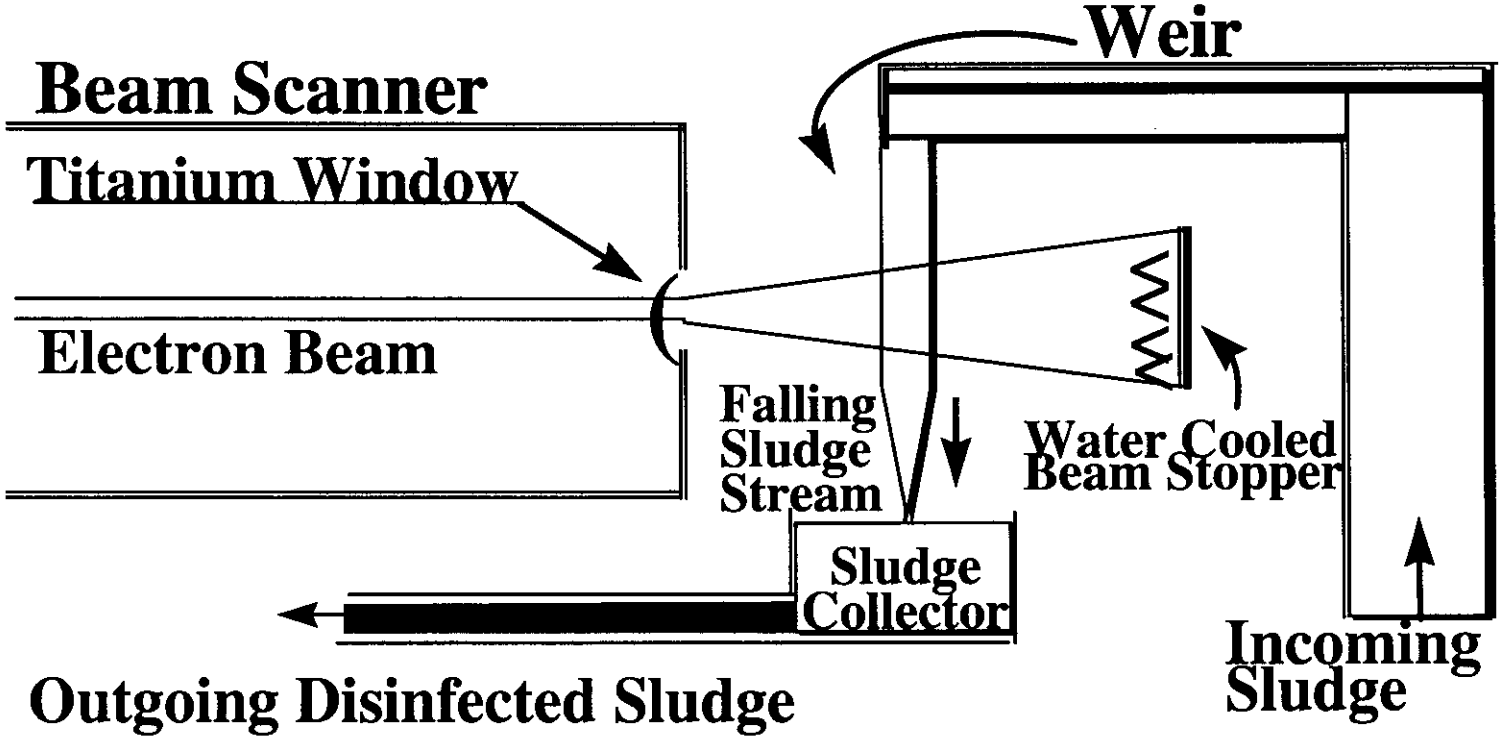
CONVENTIONAL ACTIVATED SLUDGE TREATMENT OF SEWAGE



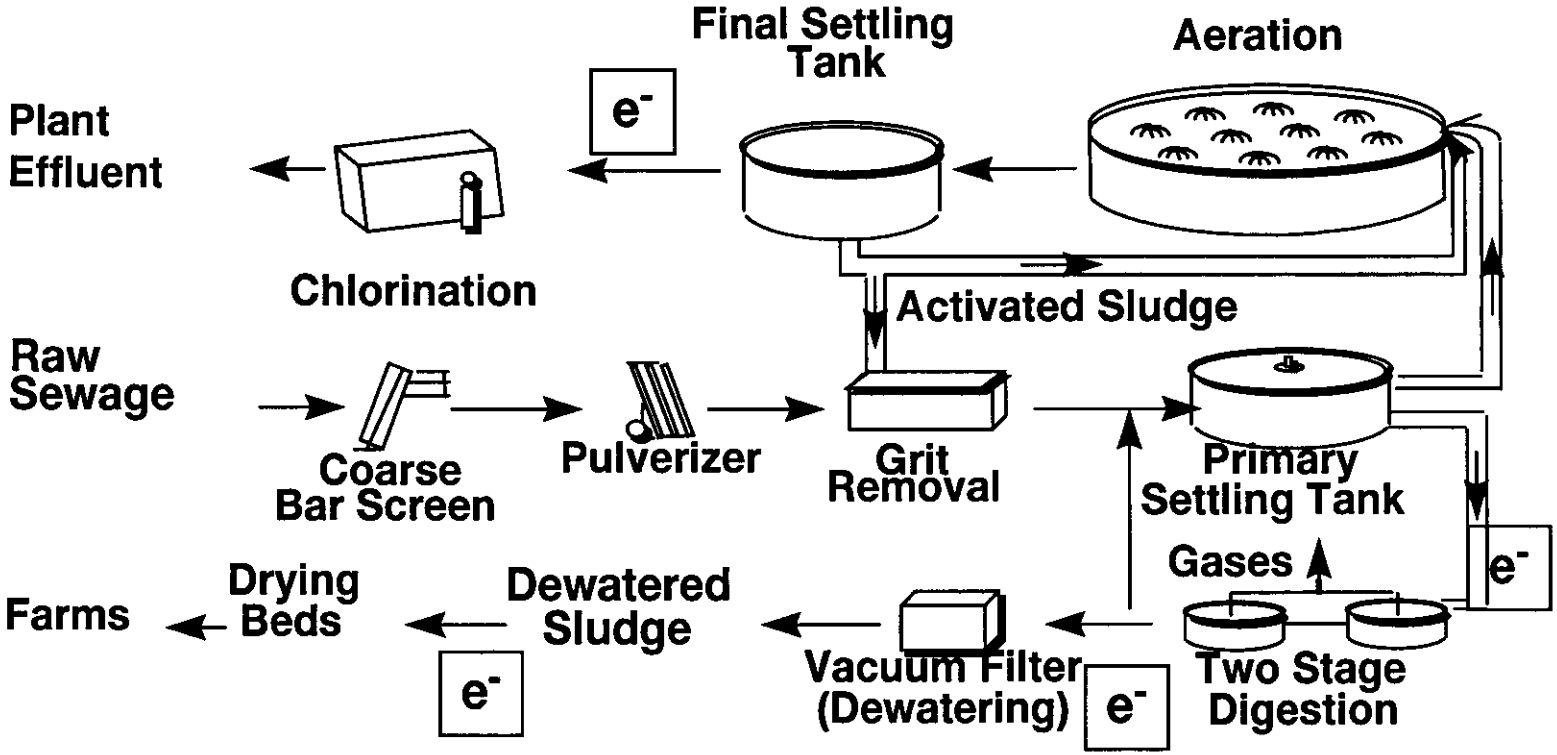
Radiation Processing of Sewage

- 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 O_3
  - 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]
Salmonellae	4×10^1	bdl[a]
Fecal streptococci	5×10^3	≤ 10
Clostridia	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 m^3/day (+O_2, 2 kGy, 180 m^3/day)
- Baroda, India, ^{60}Co; 5 kGy; 110 m^3/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, Fe[1], Mo
Concentrate in plants, some phytotoxicity	B, Mn[1], 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