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APPLICATION OF NUCLEAR TECHNIQUES IN ENVIRONMENTAL STUDIES AND POLLUTION CONTROL

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Environmental pollution has become a world wide concern. One of the main sources of such pollution is sewage wastewater and sludge. Their utilization without proper treatment can pollute the ecosystem (plant, soil, surface and ground water). Sewage wastewater and sludge contains several pollutants such as: pathogens, toxic organic compounds, heavy metals, high level of BOD & COD, seed weed. The reuse of sewage water and sludge in agriculture can lead to the transfer of some of these pollutants into the food chain causing health hazard. In addition, most of these contaminants are not biodegradable, becoming dangerous to plant and human health.

Nuclear techniques has recently been used to control environmental pollution. Ionizing radiation provide a fast and reliable means of sewage water and sludge treatment than the conventional methods. Gamma radiation (^{60}Co) and electron beam (accelerator) has been successfully used for alleviation of environmental pollution. Such alleviation includes: disinfection of harmful pathogens, degradation of toxic organic pollutants, destruction of seed weed and reduction of soluble heavy metals, odor and BOD & COD.

The use of radioactive and stable isotopes are a useful tools to investigate the contribution of sludge nutrients to plant nutrition. Nitrogen, using ^{15}N-ammonium sulfate, uptake and translocation by plant from soil amended with sewage sludge was studied under field condition. The contribution of sludge to phosphorus nutrition of plants was quantified using ^{32}P as tracer. In both cases the principal of isotopic dilution technique was applied. The information generated from these experiments could help preserve the environment. It could help optimize the application rate of sludge to meet plant requirements while avoiding the accumulation of N & P in the soil or leaching to the aquifer. Isotope exchange kinetic technique is used to evaluate nutrients availability from sludge. Neutron moisture meter is used to measure soil water content.

INTRODUCTION

Egypt being in the semi-arid region of the world is exposed to water shortage. The River Nile provides the main source of water in Egypt (55.5 x 10^9 m^3/year), additional water is provided by groundwater (0.5 x 10^9 m^3/year), drainage water (16-18 x 10^9 m^3/year) and sewage water (3.5 x 10^9 m^3/year). The amount of sewage wastewater represent 4.5% of the total water available to Egypt. In the meantime, there is an increasing demands for fresh water. This growing demands is a result of increase in population, irrigation and industrial expansion. The necessity for desert reclamation to increase the agriculture production to feed the growing population have increased the burden on fertilizer and water resources. This is because desert soil are lacking organic matter and nutrients. The cultivated area in Egypt exist around the Nile valley and the delta (4%), the remaining 96% are desert soil (sandy or calcareous). This soil are lacking organic matter and nutrients. The industrial development and the necessity for desert reclamation to increase the agriculture production to feed the growing population have increased the burden on fertilizer and water resources. It is a must to reuse non-conventional water resources (urban sewage water) for irrigation and sludge as organic fertilizer after proper treatment. As a consequence, there is an urgent need for conservation and re-use of wastewater. It is a must for reuse of non-conventional water resources for irrigation and sludge for fertilization. However, the reuse of sewage water and sludge without proper treatment is the main source of environmental pollution. Proper treatments should be applied before the reuse can take place.

The different management options of sewage water in Egypt are irrigation or discharge in water bodies, whereas the options for sludge management pumping to the lagoons in the western desert, land fill and/or land application. In Egypt, industrial wastewater is usually mixed with sewage wastewater. The combined water is often used for irrigation purpose. Crops irrigated with such water induce health hazard. Pollutants in such irrigation water could reach groundwater and human food (through the food chain) creating environmental and health problems. This situation started to cause governmental and public concern. In addition, using the conventional methods (primary, secondary and even tertiary treatment including biological treatments) are not sufficient in removing pathogenic organisms and/or toxic organic pollutants. Waste sewage water contains several contaminants: pathogens, toxic organic compounds, heavy metals, high level of BOD and COD. However, if properly treated it could be an important non-conventional water resource for both irrigation and fertilization.

Sludge is produced as by product of wastewater treatment processes. Sludge generated from such water is a good source of organic fertilizer. Sludge contains beneficial constituents such as macro and micronutrients essential for plant growth and about 50% organic matter (Badawy and El-Motaium, 1999). The use of sewage sludge (biosolid) as a fertilizer or soil conditioner is the best recycling option from agriculture and environmental point of view. Sludge has many advantages in improving soil fertility and increasing crop production (Kumazawa, 1997). Sludge provide the soil with organic matter, nutrients and improve the soil water holding capacity and cations exchange capacity. However, There is environmental and health concern when using sewage water and/or sludge in agriculture. This concern is related to the presence of heavy metals, pesticides and toxic organic pollutants. Treatments should be applied in order to achieve the following: pathogen disinfection, toxic organic pollutants degradation, less available heavy metals, low BOD & COD and destruction of seed weed.

In the United States and some western European countries half of the produced sewage sludge is applied into land for agricultural purposes. The USEPA (1993) has issued 503 rule (40 CFR Part 503), which regulates land application of sewage sludges. The different methods of sludge disinfection and stabilization was evaluated by Brandon (1979). He found that aerobic and anaerobic digestion are not very effective in reducing pathogens; lime treatment is costly, cause odor problem (production of ammonium gas) and requires that a high pH be reached and maintained; heat treatment is effective but is expensive and is energy intensive; composting requires all of the composting sludge reaches an adequate temperature for pathogens inactivation. Gamma irradiation and electron beam are more effective alternative to the conventional methods. Ionizing radiation has been recognized as a fast and reliable means for pathogen removal (Kapila et al., 1981, Pandya et al., 1987 and El-Motaium et al., 2000) and organic pollutant degradation (Abo-Elseoud et al., 2004). Sufficient data are available for gamma radiation treatment of sludge, permitting its application on commercial scale. The possibility of beneficial and safe recycling of gamma-irradiated sludge in agricultural uses is documented.

It is justifiable to use sewage wastewater and sludge in agriculture in Egypt because of the following: limitation in fresh water resources, high demand for organic fertilizer input which is a good source of organic matter and nutrients needed for poor desert soil, sludge increase soil water holding capacity and cation exchange capacity, Egyptian sludge is low in heavy metal content, desert soil are high in $CaCO_3$ content and pH, which help reduces the available forms of heavy metals.

I. NUCLEAR TECHNIQUES IN POLLUTION CONTROL

Effect of Ionizing Radiation on Sewage Sludge and Sewage Water Contaminants

Harmful pathogens, heavy metals, toxic organic pollutants are the major contaminants of sewage sludge and sewage water that affect the public health and the environment.

Pathogenic organisms:

Pathogens removal from sewage water is the main criteria for reuse purpose (WHO, 1989). This high quality sewage water (pathogen free) can not be achieved by conventional method of treatment. Sewage water and sludge contains various harmful pathogenic organisms (bacteria, parasites and viruses). These pathogens are capable to induce several human diseases. Crop irrigated with sewage water and consumed uncooked represent health hazard. Pathogens that survive in the soil and/or in the crops and create such hazards are listed in Table 1.

Table 1. Pathogenic organisms and their associated diseases

	Becterial Pathogens	**Related Disease**
1	Salmonella	Salmonellosis
2	S. typhimurium	Typhoid fever
3	Shigella	Shigellosis
4	Enterococcus (Fecal Streptococci)	Diarrhea
5	E.Coli (Fecal Coliform)	Diarrhea
6	Vibro chloerae	Cholera
7	Camptyobacter jejuni	Gastroenteritis
	Parasites	**Related Disease**
1	Ascaris Lumbricoides	Ascariasis
2	Taenia spp	Abdominal
3	Giardia Lamblia	Giardiasis
4	Entamoeba histolytica	Amoebic dysentery
	Viral Pathogens	**Related Disease**
1	Hepatitis A	Hepatitis
2	Rotavirus	Gastroenteritis and polio
3	Norwalk-like agents	Gastroenteritis
4	Reovirus	Fever, respiratory infection
5	Adenovirus	Respiratory and eye infections

The conventional method of sewage water treatment includes primary treatment (precipitation), secondary treatment (biological), tertiary treatment (chlorination) and digestion. Chlorination has been used in treating the effluent from conventional treatment plant. Chlorination may eliminate bacteria and amoeba cysts, however it can't influence enteric viruses and/or parasite eggs (Lund, 1975). Chlorine does not penetrate into large particles, thus it can only be applied in purified sewage water. Chlorine can react with the organic residues in the wastewater to form hazardous substances which is carcinogenic. Wastewater chlorination in Europe and the USA has been replaced by UV-irradiation. The different conventional methods of sludge disinfection includes: pasteurization, digestion, aerobic thermophilic treatment, composting, thermal conditioning, incineration, lime treatment, long term storage. Digestion is not capable of getting rid of viruses, bacteria (clostridium), mycobacteria and parasite eggs (Lund, 1975).

Pathogens determination is very complicated procedure, costly and require qualified laboratories and personnel, instead an indicator organism is usually assayed (Chang, 1997). Indicator organism indicate the occurrence of faecal pollution and the presence of microbial pathogens. Faecal coliform can be used as reliable indicator for bacterial pathogens. Ascaris eggs are frequently used as an indicator organism to test the efficency of a particular treatment.

There is a worldwide interest in the use of ionizing radiation as a new method to eliminate pathogens in sewage sludge (Lessel 1988 and USEPA 1993) and wastewater. Both gamma radiation and electron beam can be used for disinfection purpose. The lethal dose vary between the two types of radiation, lower dose of gamma radiation is required relative to the electron beam to achieve the same pathogen removal (El-Motaium et al., 2005). The lethal dose also vary according to the pathogens initial count, type of pathogens, previous treatment and sludge moisture content. The source of ionizing radiation that could be used for disinfection purpose are gamma radiation (cobalt-60 or Cesium-137) and electron beam (e-beam accelerators).

In the opinion of radiation scientists, 3-5 KGy of ionizing radiation is adequate to completely inactivate pathogens in sewage sludge (Pikaev 1997). A dose of 10 KGy is required by USEPA (1993) for Ascaris ova elimination from sludge. Brandon (1979) indicated that 1 Mrad was a sufficient dose to ensure the inactivation of Ascaris eggs naturally present in digested sludge filter cake and in composted sludge. Suess (1977) has reported a dose of 3 KGy for sludge decontamination but Takehisa (1980) and Hashimoto et al., (1988) found that 5 KGy is the appropriate disinfection dose for dewatered sludge, whereas El-Motaium et al., (2000) found that 1 KGy and 6 KGy dose of gamma radiation are sufficient for disinfection of sewage water and sewage sludge, respectively, Table 2. McCaslin and Sivinski (1980) found that 1 Mrad of gamma irradiation effectively destroys pathogenic bacteria and parasites in dried sewage sludge. Capizzi et al (1999) have investigated the efficiency of radiation treatment on Ascaris ova viability and concluded that Ascaris ova should be effectively eliminated from sludge by the 10 KGy dose required by EPA regulation (USEPA, 1993).

The D_{10} value is the radiation dose required for 90% reduction in the organism count. The D_{10} for total coliform was higher, 0.50 KGy, using electron beam than using gamma radiation, 0.25 KGy, (El-Motaium et al., 2005). The D_{10} for total coliform in sludge was 0.67 KGy using gamma radiation (El-Motaium et al., 2000). Virus have relatively high resistance to inactivation by ionizing radiation, Chang (1997). The D_{10} value is 2.5 KGy for virus inactivation in sewage sludge.

The regrowth of pathogens may occur after conventional treatment of sewage water and/or sludge as it reduce the initial bacterial count by only 2 log cycle. However, with radiation treatment we can avoid the regrowth problem as the radiation cause complete death of the pathogenic organisms. Destruction of pathogens is mainly related to the total energy absorbed rather than the dose rate received by the sludge.

The disinfection mechanism is explained by two major effect, the direct effect (damage of DNA) and the indirect effect (reaction with free radical). Gamma radiation induces production of free radicals which in turn cause denaturation of cell protoplasm and damage of membranes and cell walls. These processes lead to lysis of organisms (Chang, 1997).

Table 2. Effect of gamma radiation on bacteria and parasites in sewage sludge and sewage water (El-Motaium et al., 2000)

Treatments (KGy)	Bacteria		Parasites	
	Sewage Sludge	Sewage Water	Sewage Sludge	Sewage Water
Control	10^9	10^6	Veg&Cysts	Veg&Cysts
1	10^9	nil	"	Cysts
2	10^9	nil	"	"
3	10^5	nil	"	"
4	10^3	nil	"	"
5	10^2	nil	"	"
6	nil	nil	Cysts	"
7	nil	nil	"	"
8	nil	nil	"	"
9	nil	nil	"	"
10	nil	nil	"	"

Toxic organic pollutants:

A large number of persistent organic pollutant (POP) exist in sewage sludge. They can persist through treatment such as anaerobic digestion. These persistent compound are hydrophobic and they bind to soil organic matter. There is a large range of hydrophobicity and volatility involved (McGrath, 1999). Examples of toxic organic compounds are (chlorinated hydrocarbons "PCBs", polycyclic aromatic hydrocarbon "PAH", phenolic compounds, dioxins, phthalates and surfactants). These compounds are very toxic, carcinogenic and highly resistant to degradation. They can enter soil and plant through sewage sludge application to agricultural land (Wang and Jones, 1994) and even non-polar ones, can be assimilated by intact plants or in-vitro cell culture system (Harms, 1995). The amount taken up by plant depends on plant species and the physico-chemical properties of the compound (Harms, 1995). The uptake rate are higher with low-molecular weight and polar compounds.

Polychlorinated biphenyl (PCBs) is one of the most important xenobiotics persistant pollutant in the environment (Alcock et al., 1995). Polychlorinated biphenyls (PCBs) are industrial compounds. Although the production of PCBs was stopped in most of the industrial countries, PCBs still belong to the most important pollutants in the environment due to their persistence (Harms, 2002). Plant uptake of PCBs can occure through two path ways the root system or atmospheric deposition (Pal et al., 1980 and Ye et al., 1991). It was shown that chlorination grade, substitution and molecular configuration plays an important role in PCBs metabolism in plants. The lower the chlorination grade the higher the metabolism rates in plant (Wilken et al., 1995).

PAHs are non-polar and hydrophobic compounds that are difficult to mobilize due to their low water solubility. Solubility decreases as the number of rings increases. They are lipophilic and accumulate in soils by binding to organic matter. These compounds exist in the environment due to human activities. Their main sources are 1) combustion of organic materials such as wood 2) combustion of synthetic organic materials such as gasoline. They are components of petroleum (crude and refined) coal. They released to the soil via solid by-product, to the aquatic environment via oil spill and to the air via combustion of organic materials as airborne particulates. The lowest molecular weight compound in this group is naphthalene and the highest is graphite (Neff, 1985). Human can be exposed to PAHs via air, water and food. The main reason for the concern about PAH in the environment is the fact that some of them can cause cancer in human. Fluoranthene is one of the most abundant PAHs that has been detected in air, water, soils, sediments and even in biota including man.

Phenolic compounds such as Pentachlorophenol (PCP) has been used as wood protectants and as a herbicides in rice due to its antimicrobial, herbicide and insecticide properties. There is concern on the possible transfer of PCDD/Fs (e.g. pentachlorophenol, PCP) and PCBs from sludge into human food chains (McLachlan et al., 1994 and Wild et al., 1994). The source of PCDD/Fs in sludges is atmospheric deposition followed by runoff. In contrast, Horstmann and McLachlan (1994) identified household (laundry wastewater) wastewater as a more important source of PCDD/Fs than runoff. Pentachlorophenol (PCP) is a priority organic pollutant that is mainly used as a fungicides and insecticide in commercial wood treatment (Cirelli, 1978). The use of PCP has lead to its widespread in air, food, sediment (Bevenue and Beckman, 1967), water, and municipal sewage sludge (Buhler et al., 1973). The lowest PCP concentration that cause significant decrease in rhizobial population was 120 mg PCP Kg^{-1} soil. POP accumulate in the soil, but the persistence varies between different groups and specific compounds within each group, it increase generally in the order: PCBs>CBa>PAHs>PCDD/Fs (McGrath, 1999).

Table 3. Abundance and concentration range of the main hazardous compounds in sewage sludges Harms (2002)

Substance	**Abundance %**	**Residue level mg Kg^{-1}**	
		Range	**Mean**
Chlorinated Hydrocarbons			
PCBs	100	0.05-1	0.5
Lindane	40-60	<0.01-0.07	0.02
p,p'-DDT+ p,p'-DDE	30-60	<0.01-0.25	0.1
PAHs			
Fluoranthene	100	0.5-60	5
Benzo(a)pyrene	100	0.1-15	3
Benzo(b)fluoranthene	100	0.1-14	3
Phenolic Compounds			
Phenol	30-50	0.002-300	2
Pentachlorophenol	20-30	0.03-8500	0.2
Phthalates			
Di-(2-ethylhexyl)-phthalate	>95	2.4-320	80
Surfactants			
LAS	100	50-16000	5000
Nonylphenol	100	10-2500	500

Sewage sludge contains various hazardous compounds, Table 3. The German rules prohibit the use of sewage sludge when the sum of Toxicity Equivalent (TEQ) values is greater than 1000 ng Kg^{-1} (German Federal Ministry of the Environment, 1992).They stated the limiting value in sewage sludge for PCDD/F as 100 ng/Kg dry matter and that for PCB as 0.2 mg/Kg DM for sewage sludge to be used in agricultural management in Germany.

Different treatments methods has been investigated for removal of organic compounds from waters. Ionizing radiation, γ rays or e-beam, can decompose the water itself in a process called radiolysis. Radiolysis of water results in the formation of hydroxyl radicals (OH˙) and solvated electrons e_{aq} and H˙ (Cooper et al., 2001). Advanced oxidation processes (AOP) is a new treatment that is defined as those technologies that utilize the hydroxyl radical (OH˙) for oxidatively decompose pollutants. This result in either part or complete mineralization of the compound (to form CO_2, H_2O, and salt).The (AOP) could be used to destroy toxic compounds in aqueous solution such as MTBE (Kavanaugh et al., 2004). Organic contaminants in aqueous solution are destroyed either by the direct or indirect interaction with radiation. The major destruction of the chemicals is due to the reaction with radiolysis products of water (Cooper et al., 2001). Researchers have found that irradiation of contaminated water decomposes chlorines containing organic compounds (Bryan et al., 1992). In addition, research conducted by MIT (1980) demonstrated the destruction of 96% of the trace amount of polychlorinated biphenyls (PCBs) in pure water and of water-dissolved herbicide of the urea type-monuron, using dosages as low as 10 Krad. Their destruction was explained by the attack of hydroxyl radicals (OH˙) formed by dissociation of water molecules when exposed to ionizing electron energy.

A study on the effect of different doses (0, 2, 4, 6, 8, 10 KGy) of gamma radiation on the degradation of PAH in moist and dry raw sewage sludge was conducted by Abo El-Seoud et al., (2004). They found that gamma radiation caused decline in PAH content and the magnitude of decline varied according to the radiation dose received and the sample moisture content, Table 4. The highest efficient gamma radiation dose on the decomposition of PAH seems to be attainable at 6 KGy (79% reduction) for moist sludge and at 10 KGy (64% reduction) for dry sludge.

Table 4. Effect of Gamma Radiation on PAH Degradation in Sewage Sludge (Abo El-Seoud et al., 2004)

Dose (KGy)	Moist sludge mg/Kg	Dry sludge mg/Kg
0	29.0	5.4
2	13.7	4.0
4	6.8	2.4
6	6.1	3.1
8	10.1	2.8
10	7.2	2.0

Heavy metals:

Heavy metals is defined as those metals that have relative density higher than 5g/cm^3. The application of sewage sludge to soils provide organic matter and nutrients, however it also increase heavy metals concentrations in the soil. Sludge can introduce potentially toxic metals that is toxic to plants and human at high concentrations (Chaney, 1980). Sewage wastewater and sludge, particularly when mixed with industrial waste, contain a large amount of potentially toxic metals such as Hg, Cr, Pb, Cd, Ni, Co, Cu, Zn, Fe, Mn (Viets, 1962). Heavy metals exist in different forms (water soluble, exchangeable, organically complexed and occluded or held in primary minerals). These forms differ in their mobility in soils and extractability by plants.

There is a growing concern about heavy metal contamination of soils and their effect on the food chain. Several metals uptake studies have shown that, the water soluble fraction of metals, such as cadmium, lead, mercury and chromium can be accumulated by living plants and thus enter the animal and human food chain. Some of these heavy metals are essential plant nutrients (Fe, Cu, Mn, Zn, Co, Mo, Ni) while others (Cd, Pb, Cr, Hg, As) are not. The non-essential heavy metals have unknown beneficial physiological function (McGrath, 2001) and are considered toxic to plant.

Cadmium accumulation in agricultural soils occurs mainly from atmospheric deposition, phosphorus fertilizer and sewage sludge (Ryan et al., 1982). Cadmium is one of the most toxic metals to human (Friberg et al., 1974) and the most hazardous to the food chain (McLaughlin et al., 1999). Therefore, cadmium concentration in the agricultural products can have serious implications for its sale in the international markets. Cadmium toxicity affects primarily kidneys thus disturb P& Ca metabolism, other organs can also be affected (e.g. cause bone diseases). The hazardous effect of lead on human health is through causing brain damage. Excess nickel cause cancer, allergy and respiratory disorder. Arsenic can reach human body via ingestion of water and food (Chappell et al., 1997). Arsenic is associated with skin cancer and other organ's cancer, bladder, liver, lung, kidney and colon.

The effect of ionizing radiation on the bioavailability of heavy metals was not well investigated. The Massachusetts Institute of Technology (MIT, 1980). found that electron beam significantly reduce the water-soluble fraction of several potentially toxic metals. This effect would tend to render metals less available for plant uptake. They suggests that electron treatment can bind water-dissolved metals to sludge components. Some workers in the United States have claimed decreased solubility of metals in irradiated sludge (Sheppard and Mayoh. 1986). Along the same line, Ahlstrom (1985) found that irradiation did not increase the extractability and plant uptake of a broad range of nutrients and heavy metals from sludge-amended soils. This finding was supported by our results in Egypt (El-Motaium and Badawy, 2001). However, more studies are required in order to quantify this finding and understand the mechanisms involved.

Seed weeds:

Seed weeds can represent a kind of contaminant in sewage sludge. McCaslin and Sivinski (1980), found that 1 Mrad of gamma radiation effectively destroys plant seeds in dried sewage sludge.

BOD and COD:

Biological oxygen demand (BOD) is the amount of oxygen required by microorganism during a specified incubation period for the biochemical degradation of organic material, whereas the chemical oxygen demand (COD) is the measure of oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong oxidant (Clesceri et al., 1998). While pathogen removal is the most important parameter of treated wastewater for reuse purpose, BOD reduction is required for pollution control (WHO, 1989).

Table 5. Effect of gamma radiation and electron beam on BOD and COD of raw sewage wastewater of El-Gabal El-Asfer WWTP (El-Motaium et al.. 2005)

Dose	Gamma radiation				Electron beam			
KGy	BOD	%reduction	COD	%reduction	BOD	%reduction	COD	%reduction
0.0	233		417		233		417	
1.0	140	40	260	38	153	34	281	33
2.0	123	47	239	43	144	38	273	35
3.0	99	58	190	54	136	42	216	48
4.0	75	68	150	64	100	57	200	52

Radiation treatment of sewage water was reported to reduce BOD (Helena and Sampa,1997). A comparison study between gamma radiation and electron beam on sewage water BOD and COD was conducted by El-Motaium et al.. (2005), Table 5. They found that

BOD value went from 233 to 75 mg/l, whereas COD value went from 417 to 150 mg/l after gamma radiation treatment dose of 4 KGy (~70% reduction). However, the same dose (4 KGy) of electron beam caused a reduction from 233 to 100 mg/l in BOD and from 417 to 200mg/l in COD (~55% reduction). The reduction in BOD and COD caused by radiation could be due to its direct and/or indirect effect on the destruction of organic materials (Cooper et al., 2001). The indirect effect is due to the free radicals produced by water radiolysis, i.e. e_{aq}, $H^{\cdot}$, OH, H_2O_2.

Beneficial effect of radiation on sewage water and sludge

-Disinfection

-Bond rupture

- -Oxidation of organic pollutants
- -Reduction of BOD and COD
- -Replace chlorination and stabilization processes
- -Reduce odor
- -Radiation can replace digestion

Examples of Operating Sewage Sludge Irradiation Plants in the World

I. Gamma Radiation

The advantages of using gamma radiation in sewage water and sludge treatment are as follows:: excellent penetration power, environmentally clean, uniform dosage in materials, complete disinfection, small energy consumption, neither toxic chemicals nor residual radioactivity are produced in the material, simple operation, radiation can replace chlorination.

1) The facility at Baroda (India)

Uses coblt-60 to irradiates anaerobically digested liquid sludge in a batch process

2) The facility at Tucuman (Argentina)

Uses coblt-60 to irradiate anaerobic ally digested liquid sludge in a batch process

II. Electron Beam

The advantages or using electron beam in sewage water and sludge treatment are as follows:: high capacity per unit time, the energy can be switched off, no radioactive material is needed

1) The facility in Korea

Electron beam facility has been constructed in Taegu Dyeing Industrial Complex to treat 10,000 m^3 /day of wastewater from dying industries. It has been constructed and operated since 1998. E-beam irradiation has shown much improvement in removing impurities than the chemical treatment

2) The facility in Brazil

A pilot plant was set up to treat wastewater and industrial effluent at IPEN,s Electron beam facility. The electron beam accelerator is a 1.5 MeV Dynamitron type from Radiation Dynamics Inc. USA. The accelerating voltage ranges from 500KeV to 1.5 MeV and the beam current from 1 mA to 25 mA. The beam wth a frequency of 100 Hz was adjusted to scan an area of 60 cm length and 2 cm width. The e-beam was used to degrade toxic pollutants from industrial origins (pharmaceutical chemical industry and industrial wastewater).

3) Mobile electron beam in the USA

II. NUCLEAR TECHNIQUES IN ENVIRONMENTAL STUDIES

Radioactive Isotope, Stable Isotope and Neutron Moisture Meter

Radioactive Isotope

The contribution of sewage sludge to phosphorus nutrition of tomato plants was quantified by applying the principal of isotope dilution technique and using ^{32}P (carrier free) tracer technique.

A significant increase in dry matter production, plant tissue P concentration, P uptake, percent P derived from sludge and soil P was observed as a result of applying sewage sludge to sandy soil (El-Motaium 2001). The sludge phosphorus yield is highest (13.2 mg/pot) using irradiated sewage sludge at 80t/ha application rate. The maximum recovery of sludge P reached 3.3%. Total phosphorus uptake increased by 2.5 fold from that of the control treatment (mineral fertilizer) at 80t/ha application rate. Sewage sludge contributed by 64% to 79% of tomato phosphorus requirements. Sludge can provide plants with sufficient amount of phosphorus that is required for growth and development without the need for mineral fertilizer.

Stable Isotope

Sewage sludge is a potential organic fertilizer for sandy soil due to its high content of nitrogen and organic matter. Isotope aided study could be used to quantify the availability of nitrogen to plant from sewage sludge. This will help contribute to environmental preservation by reducing NO_3 leaching to surface and ground water. To quantify the availability and utilization of nitrogen from sewage sludge to plant, the ^{15}N labeled nitrogen fertilizer $[(NH_4)_2SO_4]$ and isotope dilution technique were applied. Non-irradiated and irradiated sewage sludge (6 KGy of gamma radiation) was investigated.

Sewage sludge application to sandy soil have increased plants dry matter production, nitrogen yield and recovery. The increase was significantly higher in irradiated than non-irradiated sewage sludge. A high significant correlation (0.945**) was found between dry matter production and nitrogen derived from sludge. Percent nitrogen recovery reached 38.5% under sludge application, whereas it was only 13.8% under mineral fertilizer. Percent nitrogen derived from sewage sludge was in the 88-92% range. Sewage sludge can conserve nitrogen over a long period of time in contrast with nitrogen mineral fertilizer (El-Motaium 2001).

Neutron moisture meter

Neutron moisture meter was used to study the effect of sludge on soil hydrophysical properties. The neutron moisture probe is a device that is used to measure the soil moisture content in the field. It consist of (shield, electron counting system, fast neutron source "radium + beryllium", pre-amplifier, slow neutron detector"). The energy of the neutrons emitted by the source vary from 1 to 15 MeV and the activity is in the range of 370 to 1,850 MBq (10-50 mCi), IAEA (2002). The working principal of the device is that the radioactive source emits fast and high energy neutrons. The fast neutrons are emitted radically into the soil, which slow down by colliding repeatedly with atoms of comparable mass (H^+ atoms in soil water). The neutrons lose some of their kinetic energy and become slow neutrons. Low energy slow neutrons are counted by the detector as count ratio. Thus the detector measure the density of water in the soil. A calibration curve of water content vs. neutron meter count ratio, is used to determine soil water content.

Results indicated that the application of sewage sludge to sandy soil has improved the soil physical and hydrophysical characteristics (El-Motaium and El-Gendy 2005). The characteristics that was improved are: saturation point, residual moisture content, field capacity, wilting point, soil moisture retention curve, soil pore diameter and soil hydraulic conductivity.

CONCLUSION

Sewage wastewater and sludge are the main source for environmental pollution. Treatment should be applied in order to eliminate the different contaminants in the sludge before land application. Ionizing radiation is a fast and reliable tool for pollution control. Isotope aided study could be used to quantify the availability of nutrients to plant from sludge, as a consequence the proper application rate could be achieved in order to preserve the environment.

It is concluded that 1) utilization of radiation technology is the best recommended means for controlling environmental pollution 2) sewage sludge disinfection dose is 6 KGy whereas but only 1 KGy is required for sewage water 3) Radiation could replace chlorination which form carcinogenic compounds with solid residues 4) The reuse of irradiated sewage water and sludge is environmentally safe for recycling in agriculture 5) Irradiated sewage sludge applied at a rate of (80t/ha) proved to be a good organic fertilizer for sandy and calcareous soils without any need for mineral fertilizer 6) Irradiated sewage sludge resemble a slow release fertilizer capable for sustaining crop production without harming the environment 7) the isotope aided study (^{32}P & ^{15}N) proved that, it is possible to quantify the amount of nutrients (N and/or P) in sewage sludge that can contribute to plant nutrition. This information could be utilized further to determine the amount of sludge to be added to the soil to avoid the risk of extra dose and thus help preserve the environment.

Reliable data on the concentrations of organic contaminants and heavy metals in sewage sludge are required to assess the risks associated with land use. Very low concentrations of some chemicals may represent serious health and environmental hazards. More legislative control of the environmental contamination problems is a demand for the future of human welfare.

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