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Agricultural wastes

G. Edd Valentine, Charles C. Ross,
Stephen R. Harper

REVIEWS

The National Technical Information Service (NTIS)[1] released a bibliography with 256 citations (15 new) for selected patents concerning the design and use of incinerators and incinerator components used for the destruction of municipal, industrial, and agricultural solid-waste products. Another NTIS[2] bibliography contained 314 citations (42 new) concerning pollution effects and pollution control of animal wastes and animal processing wastes. Reports were included on feedlot waste pollution and control, pollution from manure used in fertilization, water runoff from farms, dairy and livestock wastes, rendering wastes, poultry processing wastes, ecological aspects, swine house waste control, and pollution control by anaerobic digestion of manures.

AGRICULTURAL WASTE CHARACTERISTICS

Sutton *et al.*[3] provided veal calf waste characteristic data including average waste production (3.96% of calf live weight), total solids (3.4%), total nitrogen (0.41%), phosphorus (0.13%), potassium (0.56%), and pH (8.0). The authors also provided characteristic data on the waste after 17 weeks of anaerobic storage.

A serial washing technique was described by Garg and Bhatnagar[4] for quantitative isolations of microfungi during the biodegradation of agricultural wastes.

FERTILIZER/SOIL SUPPLEMENTS

Nutrient availability

Olayinka and Adebayo[5] reported on a greenhouse soil culture experiment conducted to evaluate the effect of incubation time (0, 2, 4, 6 weeks) of a mixture of sawdust and cow manure prior to application on corn growth, dry-matter yield, and uptake of nutrients. Incubation time was shown to increase soil pH, enhance the uptake of nitrogen and phosphorus, and increase corn dry matter yields while not affecting cation exchange or the uptake of potassium, calcium, magnesium, and sodium. Kapur and Kanwar[6] presented the results of a three-year study on micronutrient availability and uptake by a sugar beet crop that was fertilized with cane waste, filter cake, and cattle manure applied at rates of 10 and 20 t ha^{-1}. The application of cattle manure was shown to increase zinc, iron, and copper content in the sugar beet leaf and to increase soil micronutrient availability. Manganese uptake and availability were not affected.

Prasad *et al.*[7] conducted a field experiment evaluating the effectiveness of biogas slurry, poultry manure, compost, and wastewater sludge as an organic source of zinc for wheat and rice grown on zinc-deficient soils. Soils treated with poultry manure, compost, and a biogas slurry maintained higher levels of available zinc and zinc-uptake than from a zinc sulfate application.

In a companion study, the authors determined that iron enriched biogas slurry, poultry manure, compost, and wastewater sludge augmented iron uptake and increased wheat and rice crop yields more than the application of iron sulfate alone. Sharma and Yadav[8] noted that the addition of farmyard manure increased the availability of iron and had little effect on manganese content of an alkali soil being treated with pyrite.

In a study on the impact on nutrient content and odor emissions of swine manure, slurry from the addition of cement kiln dust, Barrington and Mackenzie[9] reported a reduction in odor levels and an increase in extractable calcium and potassium from a mixture of 5% total solids (TS) manure slurry with this dust at 1:1 and 2:1 ratios. However, the mixture also resulted in a 50% to 85% reduction in extractable phosphorus and a 35% to 50% loss of total N. Overall fertilizer value was shown to increase by a factor of 1.1–4.5.

Mackay *et al.*[10] reported on the results of an 8-yr experiment on an irrigated barley cropping system where 45 t ha^{-1} of manure containing softwood shavings was applied annually with different levels of inorganic nitrogen fertilizers. Soil organic matter and nitrogen content were increased by 70% and 41%, respectively, from the cumulative applications of the shavings and manure. However, it was concluded that the application of manure containing large quantities of softwood shavings had a negligible effect on the nitrogen fertilizer requirements of the crop being grown.

Paul and Beauchamp (1989)[11] evaluated nine different manures, including anaerobically decomposed slurries and aerobic composts, to determine their ability to supply carbon to denitrifying bacteria in waterlogged soil. The slurries had considerably higher water soluble carbon concentrations, with a substantial amount in the form of volatile fatty acids (VFA) in the range of 5.9 to 26.1 g kg^{-1}. The study also evaluated the effectiveness of VFA as carbon sources for denitrifiers in soils amended with these manures and correlated nitrous oxide production with VFA reduction.

From a laboratory study on the effect of organic amendments on soil structure, Avenimelech and Cohen[12] determined that optimum soil density and soil aggregate stability occurred from the application of substrates with a carbon:nitrogen ratio range of 20–40.

Ammonia volatilization

In a laboratory study on nitrogen losses through leaching and ammonia (NH_3) volatilization from soils amended with animal manure over one season, Ghaly[13] noted that the potential for groundwater pollution was minimal. However, ammonia volatilization was considered substantial and could constitute a source of air pollution. Lenis[14] provided a review of legislation covering animal manure application limitations in the Netherlands while stressing the need to better manage the nutrient requirements of animals to reduce the amounts of nitrogen produced. The author cited an example where reducing the protein content in the diets of growing pigs by 2% would reduce nitrogen excretion by 25%.

Pain *et al.*[15] used a micrometeorological mass balance method to determine ammonia volatilization fluxes following the application of swine and dairy manure slurries via a vacuum tanker to grasslands in the United Kingdom and the Netherlands. Between 5% and 27% of the nitrogen applied was lost in the form of ammonia after spreading, with 85% of that loss occurring within 12 hours of application. The highest rate of loss measured (12.1 kg NH_3-N ha^{-1}) was recorded immediately after application.

In a similar study, Lockyer *et al.*[16] used a wind tunnel method to monitor ammonia volatilization rates from different types of manure applied to grasslands. Manure moisture content and animal type were established as primary variables controlling ammonia volatilization with 80% of the total NH_3-N loss occurred within 48 hours of application. Total annual ammonia emissions were estimated for four different types of poultry housing using various types of waste management schemes. Ammonia emissions were higher for housing systems producing high moisture content waste than for structures with air dried manure (50% and 12% total-nitrogen loss, respectively).

Witter and Kirchmann[17] reported on the use of calcium and magnesium salts to reduce NH_3 volatilization during aerobic decomposition of poultry manure. Ammonia loss was reduced from 85% to 100% over a 48-day decomposition period to 23% to 52%. $MgCl_2$ was shown to be more effective in retaining ammonia than $CaCl_2$, while $MgSO_4$ was shown to be less effective than either chloride salts.

In a companion study, Witter and Kirchmann[18] monitored the effectiveness of using sphagnum peat, zeolite, and basalt to control ammonia losses during aerobic manure decomposition. Results indicate that peat had a high adsorption capacity (23.4 mg NH_3-N g^{-1}) and, when placed in the spent air-stream of the system, was effective in adsorbing up to 50% of the ammonia released. Similarly, zeolite captured 16% and basalt 6%. All adsorbents were considerably less effective in reducing ammonia losses when mixed with the manure.

Kirchmann and Witter[19] also provided data on the use of straw in reducing the volatilization of ammonia from poultry manure during anaerobic and aerobic decomposition. Alkaline conditions were predominant during aerobic decomposition, resulting in 9% to 44% of nitrogen volatilized as ammonia. The addition of straw resulted in reduced ammonia volatilization for manure undergoing aerobic decomposition but not under anaerobic conditions.

Long-term impact

Maidl and Fischbeck[20] reported a 9% to 14% increase in sugarbeet yields from the application of swine manure slurry on fields (75 m^3 ha^{-1} in the autumn or spring) that had not had an application since 1962. Conversely, the authors noted reduced root yields, lower root sugar content, and higher alpha-amino nitrogen, sodium, and potassium concentrations from fields, continuously spread with the slurry since 1968, receiving additional applications. Ndayegamiye and Cote[21] presented the results of a long-term study on the effects of continued applications of cattle manure (20, 40, and 60 Mg ha^{-1}, biannually) and swine manure slurry (60, 120 m^3 ha^{-1}, annually) on a silty loam soil cultivated in corn. Neither treatment significantly affected soil pH values, total nitrogen contents, and carbon:nitrogen ratios. Soil organic carbon, microbial activity, and mineralizable nitrogen were shown to increase under the higher application rates.

A laboratory study by Mbagwu[22] on the effect of incorporating stabilized cattle feedlot manure on soil physical characteristics indicated increased water-holding and available water capacities, increased soil plastic limits, and increased aggregate stability for most of the soils tested. In a study of the effect of cattle manure on the aggregate stability of a sandy loam soil. Fortun *et al.*[23] reported that while manure alone had no effect, stability was significantly improved by the addition of organic fractions from manure after two weeks of incubation.

Costa *et al.*,[24] in a comparison of mineralization rates of various organic wastes applied to a calcareous soil with low organic matter content, reported that chicken manure and city refuse mineralized more rapidly than swine manure and organic fertilizer. Sharma and Deb[25] noted that the application of farmyard, poultry, and swine manure increased the soil diffusion coefficient for chlorine.

Application methods

Safley *et al.*[26] conducted a 3-year field experiment with liquid dairy manure to determine the effects of application rate, application timing, injector spacing, and injector type on corn silage yield and nitrogen recovery. Harvested nitrogen was increased over control plots by chisel injection (versus sweep), narrow injector spacing (0.48 vs. 0.96 m), spring manure applications (versus fall), and a high application rate (160 vs. 80 m^3 ha^{-1}). The authors determined that manurial nitrogen concentration combined with application rate had more influence on silage yield than application timing, injection spacing, or type.

From a study comparing knife injection, sweep injection, and broadcast application of cattle manure slurry with the application of inorganic nitrogen fertilizer on corn grain yields, Sawyer[27] noted a reduction in yields from knife injection 2 out of the 4 years of the study. The reduction was attributed to root growth inhibition from ammonia toxicity, high moisture content, and low O_2. Sweep injection and broadcast application methods resulted in plant nitrogen concentrations and grain yields equivalent to those with inorganic nitrogen fertilizer.

A field comparison of nitrogen, phosphorus, and potassium availability to corn from injected dairy manure versus inorganic fertilizer indicated a generally higher recovery of nutrients from the inorganic fertilizer. The study by Motavalli *et al.*[28] also showed substantial variability across rate, location, and year with standard deviations often about 50% of the mean. The authors also compared measured changes in NH_4-N from a 1 week anaerobic incubation at 40°C and a 16-hour autoclaving in 0.01 M $CaCl_2$ solution with TKN and inorganic nitrogen levels in the top 30 cm of soil 4 to 6 weeks after application as correlated to plant nitrogen uptake as indexes of nitrogen availability. While inorganic nitrogen levels provided a better index of nitrogen availability, a more reliable biological or chemical index was recommended for use on a routine basis.

WASTE RECYCLING AND REUSE

Animal feedstuffs

The composition and digestibility of screened manure fiber when treated with ozone and sodium hydroxide was investigated by Ben-Ghedalia *et al.*[29] Ozone treatment produced significantly better results in terms of fiber content, lignin content, hemicellulose values, and *in vitro* organic matter digestion effect. The 6% sodium hydroxide treatment showed a slight improvement over the nontreated. The nutritional effect of urea on ensiling of sorghum stover was investigated by Mehra *et al.*[30] Urea levels of 0, 2, 4, 6 and 8% were tested at 0, 15, 30 and 45 days of ensiling. Crude protein uptake was highest in the 8% urea group at 30 days, while fiber disappearance was highest at 4% urea at 30 days.

The chemical composition of steam-exploded wheat straw after enzymatic hydrolysis for 24 hours was studied by Ternrud *et al.*[31] The hydrolysis resulted in a 90% degree of saccharification. Vriens, *et al.*[32] reviewed the use of activated sludges as animal feed. The fundamentals, chemical composition, feeding experiments results, and factors maximizing the nutritional value of activated sludge are covered in the more than 200 references. Stumborg and Craig[33] examined collection costs and system savings associated with packaging, collecting, and transporting chaff against its value as a ruminant animal feed in Saskatchewan. Results of the survey showed that 50% of all producers were able to save at least one tillage operation per year through chaff collection; 67% of producers were able to reduce input costs as a result of reduced herbicide use and/or saving of tillage operations; and 90% of those who collect chaff off their land and remove it from the field experience an agronomic benefit.

Aquaculture

The results of a study by Ernst *et al.*[34] suggested that while nursery rearing of Florida red tilapia in seawater pools fertilized with chicken manure was feasible, considerable variability in fish performance among pools could be expected, despite identical management methods. In pools receiving prepared feed, high growth rates, survival through adult, and marketable sizes suggested a potential for commercial production of Florida red tilapia in seawater.

The effect of weekly applications of similar quantities of nitrogen and phosphorus from layer chicken litter, dairy cow manure, and chemical fertilizer on the production of *Oreochromis niloticus* was studied by Green *et al.*[35] in 0.1-ha earthen ponds. Mean total net production after 150 dys was greater with chicken litter. Dhawan and Toor[36] also reported that the growth rate of fish was significantly higher in ponds receiving poultry droppings alone and in combination with cow manure. However, cow manure alone failed to increase the pond productivity and hence, the growth of fish.

Chemical feedstocks

In studies by Azzam,[37] pretreatment of cane bagasse with alkaline hydrogen peroxide greatly enhanced its susceptibility to enzymatic cellulolysis and subsequent ethanol production. Results showed that about 50% of lignin and most of the hemicellulose content of cane bagasse was solubilized by 2% alkaline hydrogen peroxide at 30°C within 8 hrs. The efficiency of ethanol production from the insoluble fraction was 90% compared to about 50% for untreated cane bagasse. A kinetic model for enzymatic hydrolysis of pretreated wheat straw that considered only the macroscopic properties of enzyme and substrate was developed by Gonzalez *et al.*[38] In this study, Michaelis-Menten equations were used for different reaction schemes to fit experimental results.

Energy conversion

Albertson[39] examined the engineering design and startup of a small power station in El Nido, California. The fuels to be fired at this facility included a variety of straws, cotton stalks, and orchard prunings. Most of these fuels had low bulk densities and high ash contents that made their handling and combustion relatively difficult. Pilot testing of the various fuels preparatory to full-scale design was addressed, including emission of various criteria pollutants. Design of the full-scale power plant was described, and plant startup problems and projected long-term maintenance were presented. Heating values and ultimate analysis of groundnut shell, coconut shell, and palm kernel shell were reported by Olufayo.[40] The quantity of air required for perfect combustion, volume of products of combustion, and the temperature of the combustion products were calculated. The moisture-free higher calorific values of palm kernel shell, groundnut shell, and coconut shell were 25.46, 15.70, and 22.89 MJ/kg, respectively.

A preliminary study of the pyrolysis of grain screenings (wheat) was carried out by Utioh *et al.*[41] using a batch pyrolysis unit operating at atmospheric pressure. Reaction conditions were varied to determine the effect of these changes on the final product (tar, gas, and char). The yields of ethylene were higher than those of ethane. Grain screenings impregnated with 15% potassium carbonate catalyst produced higher gas yields. With the experimental setup used in the study, the mass balances achieved were low and ranged between 65% and 77% of the weight of the grain screenings used. The operation of a gasoline and a diesel engine in a fluidized bed gasifier system using rich hulls product gas was reported by Flanigan *et al.*[42] The gasoline engine could be operated on 100% product gas, while the diesel engine could be operated with a minimum of diesel fuel oil as pilot injection fuel. Both engines were capable of higher generator load outputs at reduced speeds. The study showed that a fluidized bed gasifier engine system could be an effective energy conversion system for loose, high ash and high temperature sensitive fuels such as rice hulls. Briqueting of biomass residues to produce fuel was investigated by Lindley and Vossoughi.[43] Three materials—flax straw, wheat straw, and sunflower stalks—were considered. The briquets produced were about 1.8 cm thick by 5 cm diameter and had densities greater than 1.0 g/cm^3, with the sunflower stalks having the highest average density. Sunflower stalks also tested better as far as resistance to handling and moisture penetration. However, even from the straw briquets, average losses were less than 3%. A related study was conducted by Khaukari *et al.*[44] on the densification characteristics of rice hulls. The effect of pressure and preheating temperature on density, volume expansion, and durability of the pellets was reported.

AGRICULTURAL WASTES TREATMENT

Anaerobic treatment

Cattle wastes. Robbins[45] found that ammonia concentrations of 50 to 300 mM had short-term inhibitory effects on digestion of cattle slurries, with the most pronounced effect on acetate conversion. Digester instability was also related to input protein concentrations. Lo and Liao[46] treated a mixture of cheese whey and dairy manure in an anaerobic rotating biological contactor and obtained up to 46% COD removal with 1.4 to 3.7 liters of methane per reactor volume per day; 93% of the COD remaining after anaerobic treatment was removed by aerobic treatment in sequencing batch reactors at 22°C. Langerwerf[47] treated cattle manure at 11% to 15% solids in a full-scale plug-flow digester at 97° to 103°F and produced 1.5 liters of biogas (60% methane) per liter of reactor per day. Koelsch *et al.*[48] reviewed three full-scale cattle manure digesters and found that the prime considerations in success of these systems was the availability of skilled labor for operation and maintenance of the cogeneration systems and that financial returns would be maximized by production of electricity and hot water. Improvements were also found to be needed in odor control and digested solids separation.

Poultry wastes. Studies on the effects of avilamycin (up to 20 mg/kg) in poultry diets and swine diets (up to 80 mg/kg) by Sutton *et al.*[49] showed no inhibition of methanogenic cultures from mesophilic digesters maintained at a 15-d HRT.

Swine wastes. Ng[50] was successful in treating swine manure using a microprocessor-controlled sequencing batch reactor, achieving 53% to 85% TCOD removal while producing biogas with 76% to 80% methane. Wong and Cheung[51] investigated the addition of cardboard, sawdust, newspaper, and sugar cane waste as a carbon supplement to swine manure during batch digestion and determined that sawdust provided the highest stimulation of gas production, while sugar cane waste provided the best post-digestion stimulation of ryegrass growth. Zhang and North[52] summarized full-scale results of mesophilic swine manure digestion in a completely mixed reactor, where 0.4 L of methane were produced per liter of reactor per day by 73% reduction of COD at a loading rate of 1.7 $kgVS/m^3 \cdot d$. Hill and Bolte,[53] using packed-bed and conventional digesters, reaffirmed conclusions from earlier work detailing the utility of iso-butyric and iso-valeric acids as indicators of process stress during the digestion of flushed swine waste.

Biomass products. Sharma *et al.*[54] demonstrated the importance of pH control during batch digestion of *Ipomea carnea* plant stems and cattle manure in various combinations and with stem pretreatments consisting of grinding and/or pre-incubation in water. The digestion of crude vine shoots in municipal sludge and pig manure was investigated by Jimenez *et al.*[55] at loading rates ranging from 0.5 to 2.0 $gL^{-1}d^{-1}$ and with retention times of 5 to 25 days. Optimum digestion occurred at 1 $gL^{-1}d^{-1}$ and HRT of 15 to 20 days. Molnar and Bartha[56] surrounded an anaerobic digester treating a mixture of wheat straw and cattle manure with an aerobic composting reactor, which provided the heat for batch thermophilic or mesophilic digestion. The compost reactor provided sufficient heat to allow 30 days of batch digestion, during which the temperature slowly decreased from 55° to 35°C.

Aerobic treatment

DeLa Noue and Basseres[57] tested the ability of three microalgae species to polish the effluent from a swine manure anaerobic digester. Batch tests demonstrated that all three cultures were capable of removing ammonia completely, phosphorus by over 90% and residual COD by 60% to 90% within 12 days. Aerobic treatment tests of cattle, swine, and poultry manure conducted by Paul and Beauchamp[58] demonstrated that the pH of the manure slurries was dependent on fatty acid to ammonia ratios and that 44 days of aeration was sufficient to remove volatile acids and neutralize pH, which also contributed to some loss of ammonia.

Gonzales *et al.*[59] demonstrated that composting of 80% pig slurry with 10% clay soil and 10% of either poultry or cattle manure yielded a product with good agrochemical and hydrophysical properties within 70 days. Thambirajah and Kuthubutheen[60] composted palm fibers with poultry litter for 8 weeks, whereupon C/N ratios decreased from 26:1 to 16:1 and resulted in enhanced crop production when mixed into a sandy loam soil. Tiwari *et al.*[61] demonstrated that 10% cattle manure plus 2% rock phosphate was sufficient to seed and biocatalyze the composting of wool wastes.

Miscellaneous treatment

Sievers[62] reported on jar tests of ferric iron or chitosan coagulation as a means of settling suspended solids from dilute cattle, poultry, and swine manure slurries. Six different reverse osmosis membranes were tested by Dunlea and Dodd[63] for removal of suspended solids from manures at solids concentrations ranging from 2 to 12%. Although COD and solids removal efficiencies were high, permeate fluxes of 2 to 18 $L/m^2 \cdot h$ were too low to be practical on the farm.

Snowdon *et al.*[64] provide a review of the potential hazards (bacteria, parasites, and viruses) and design considerations (land use and application method) from the mixing of human septic tank effluent with animal wastes for subsequent land application. From a study on the potential public health hazards from mixing septic tank effluent with stored animal wastes for land application, Snowdon *et al.*[65] reported on the inactivation of a human enteric virus through the storage of septic tank sewage with dairy manure slurry under different temperature regimes (5°, 15°, and 25°C).

ENVIRONMENTAL IMPACT

Earthen storage pits of clay and sand were evaluated for manure storage by Culley and Phillips,[66] who found that nitrogen losses by downward transport were significant, with ammonia recoveries of only 43% in clayey loam, and slightly lower in sandy loam storage pits. Brynildson[67] detailed problems resulting from manure storage pits at a layer hen facility in Minnesota, including the transfer of environmental liabilities from farmer to lender upon default of the loan on the farm property.

Nitrate losses and resulting pollution from agricultural activities in Italy were studied by Dosi and Stellin,[68] who recommended procedures for minimizing problems by reallocation of crops and improved manure handling. Brown *et al.*[69] looked at controls on barnyard phosphorus losses imposed to protect the Delaware River under the New York Model Implementation Program, and found that reductions of 50 to 90% of phosphorus loadings were possible through runoff controls, and 35% reductions were possible by properly scheduled manure spreadings, even in the absence of manure storage ponds. Sodal[70] examined the trade-off between economic losses and environmental protection resulting from environmental regulations calling for densification of animal production into smaller, centralized areas in Norway. Smolen and Smith[71] summarized the objectives of the Rural Clean Water Program (RCWP) authorized by the U. S. Congress in 1977, and detailed the costs of practices employed at 21 RCWP projects across the country. Wegenhoft *et al.*[72] compared the costs of applying various waste management alternatives (scrap hauling, confinement area cleaning, storage lagoons) in southwest Louisiana to their environmental benefits. Waste management costs ranged from $97 to $453 per cow, depending on the type of treatment, for herds of 75 or 150 cows.

Deizman *et al.*[73] detailed the use of CREAMS-NT, a mathematical model that simulates nitrogen transport and transformations. Sharpley and Smith[74] modeled the transport of phosphorus based on desorption kinetics and an effective depth of soil-runoff interaction, and calibrated the model using rainfall events from 20 watershed areas in the U. S. Southern Plains over a ten-year period.

The NTIS has added 19 citations to its bibliography of odor pollution,[75] which covers odors from agricultural and livestock wastes as well as wastewater and industrial wastes, vehicular wastes, hospitals, and polluted water streams. Ritter[76] used gas chromatography to identify 75 specific odorous compounds emanating from livestock buildings, feedlots, waste storage units, and land spreading operations. Methods for controlling odors and managing wastes to prevent odors are also presented. Manninen *et al.*[77] evaluated the effects of different litter materials on ammonia volatilization and odor problems. Peat was found to diminish ammonia volatilization best (62%) when used as a litter material, followed by vermiculite (28%), superphosphate (20%), and Enso bark (only 9%).

OTHER

European and FAO research programs on using and processing problems of farm waste were summarized by Neilsen.[78] EEC guidelines for veterinary and other aspects of manure and slurry storage and application to land were listed. Prevention and control of odors were also discussed. Future European legislation was briefly considered. New legislation in the Netherlands restricts manure application and disposal. A decision support system (DSS) was developed by de Mol[79] to gain a better insight into the logistical problem on a regional level. A mathematical model was used to estimate levels of application on the farm and origin and in the neighborhood and optimized application and processing, including storage and processing locations.

The possibility of developing an enhanced biological sealing mechanism for earthen manure storage was investigated by Ghaly.[80] A bacterial species was selected and used for the production of insoluble polysaccharides, which were effective in plugging the soil pores. The developed mechanism was very effective in reducing the seepage rate as well as total solids concentration, COD, and nitrogen in the leachates.

G. Edd Valentine, Charles C. Ross, and Stephen R. Harper are with the Environmental Sciences Technology Division of the Georgia Tech Research Institute, Atlanta, GA 30332. Correspondence should be addressed to G. Edd Valentine at this address.

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Textile wastes

Sue Coia-Ahlman,
Kimberly A. Groff

GENERAL

Various treatment methods, environmental regulations, management issues, and environmental concerns with regard to textile manufacturing wastewater and wastes have been examined.[1–2] Kothe[3] reviewed pollution problems attributed to