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Review Paper

Environmental impact of industrial wastes and ecofriendly technologies for sustaining environmental health

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Abstract

Continued growth of industries results in the accumulation of large quantities of liquid and solid wastes. Indiscriminate disposal of such wastes leads to soil and water pollution in many parts of India. Industrial wastes contain large amounts of organic matter, besides plant nutrients and plant growth promoters. Therefore, there is an increasing interest in the agricultural use of industrial wastes. However, environment-friendly technologies are needed for effective utilization of industrial wastes without any detrimental impact on environmental health. The environmental impact of wastes from sugar and distilleries, pulp and paper mills, tanneries and poultry industries is discussed. Some important eco-friendly technologies developed at Tamil Nadu Agricultural University for sustaining environmental health are presented.

Key words: contaminants, effluent, heavy metals, sludge, soil and water pollution.

INTRODUCTION

Exponential population growth, poverty, resource exhaustion, and environmental pollution are the major challenges which will undoubtedly dominate the economic and social agendas of many countries including India. All these issues are interconnected and interdependent. Environmental neglect by society since the dawn of the industrial revolution has resulted in severe contamination of soil and water resources. For only about few decades or so greater attention has been given to chemical-related environmental issues relevant to the food chain and drinking water. Because of the potential risk to humans and other organisms from these contaminated sites, several countries have made extensive research for developing strategies and technologies for minimizing the environmental impact of industrial wastes. The dissemination of organic and inorganic pollutants in the environment that originate from industrial wastes ensures that a significant portion of the population is exposed to these contaminants. Depending on the degree of exposure and environmental settings, a fraction of the population may be at risk. Another fraction of the population may be at risk due to occupational exposures. Therefore, ecofriendly technologies and mitigation measures are desperately needed for sustaining environmental health. In this paper the environmental impact of some important industrial wastes and the eco-friendly technologies for sustaining environmental protection are discussed.

INDUSTRIAL WASTES

Large quantities of liquid (effluents) and solid (sludge) wastes are continuously generated from various industries such as textile, pulp and paper, sugar and distilleries, tanning, poultry and other chemical industries. Indiscriminate disposal of these wastes had resulted in a series of well-documented environmental problems in India. With the lack of guidelines for effective management, the industrial wastes are continued to accumulate and pose a serious threat to environment. The disposal of industrial wastes and its associated environmental impact is an ongoing major issue, with the list of potential pollutants increasing as new chemicals and processes are developed. In addition, many sites contaminated in the past by sludge disposal or contaminated by a particular industrial process carried out at the site also continue to pose a serious threat to ecosystem. Hence, industrial wastes offer a wide scope of serious environmental problems that are becoming more complex and critical not only in developing countries but also in developed countries.

There is an increasing interest in the agricultural use of industrial wastes, because of the possibility of recycling of valuable components such as organic matter, nitrogen (N), phosphorus (P), potassium (K) and other nutrients, and their suitability for land application. However, the presence of contaminants and their environmental impact may restrict their usage in agriculture. The industrial sludge, in general, contains three major constituents that may affect the degree of safety in their use in agricultural land: nutrients, potentially toxic metals and organic substances, and pathogens. Though pathogens may not be a problem in many industrial sludge, the sludge has also been of environmental concern because of their potential as a public nuisance (obnoxious odour, flies, etc.,).

SUGAR AND DISTILLERY INDUSTRIES

India is a major producer of sugar in the world, and sugar industry offers employment potential and

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contributes substantially to economic development. There are about 579 sugar mills and 285 distilleries in India. Apart from the sugar and alcohol, these factories generate many by-products and waste materials. For example, more than 5 million tonnes of solid waste (pressmud) are being produced from sugar industries. In addition, the industries also generate about 7.5 million tonnes of molasses and 45 million tonnes of bagasse as valuable by-products (Rajukkannu and Manickam, 1997).

Environmental impact

The indiscriminate disposal of distillery spentwash is becoming a serious problem in many parts of India. The contamination of surface and groundwater, destruction of aquatic life, salt accumulation in soil, lowering of pH value of the stream, increase in organic load, depletion of dissolved oxygen, discolouration and foul odour are some of the major pollution problems associated with the disposal of distillery spentwash (Mahimairaja and Bolan, 2004).

Salt accumulation in soil

Distillery spentwash is loaded with organic and inorganic salts. Therefore, upon land application, large amounts of salts accumulate in soil which proves detrimental.The salts have K, Na, Mg and Ca, as the major cations, and Cl, SO_4, CO_3 and HCO_3 as the associated anions. Nitrate and P are also present but normally in lesser concentrations. Accumulation of salts in soil poses serious problem, as it affects crop production. There are three major effects of these salts on plant growth. (i) Direct toxicities of salts (e.g) Cl, Na. (ii) Ionic imbalances in the soil and plant, and (iii) A reduction in the availability of water by lowering the osmotic potential. This has been termed physiological drought because plants are affected by lack of water even though the water content of the soil is apparently adequate for crop needs. These effects of salts on plants are complex, and plant, soil, water and climate interact to influence the salt tolerance of plants.

Leaching of salts and nutrients

The spentwash contains nutrients and salts mostly in dissolved form. Due to rain water and / or irrigation water, these salts and nutrients leach down in the soil profile and contaminate the groundwater and surface water. Though leaching of salts is essential for crop growth its potential in contaminating the groundwater can't be ignored. Without leaching, salts accumulate in direct proportion to the salt loading of the spentwash.

Recently, soil column experiment conducted at Tamilnadu Agricultural University (TNAU), India had shown that there were large amounts of soluble cations ($K^+ >> Ca^{2+} > Mg^{2+} > Na^+$) and anions ($Cl^- > SO4^{2-}$) were found leached from soil amended with distillery spentwash. Higher the levels of spentwash application greater were the amount of cations and anions leached from soil. Even after eight leaching event, the leachates contained higher amount of biochemical oxygen demand (BOD), chemical oxygen demand (COD) and nitrates (NO3), far exceeding the Pollution Control Board's maximum permissible limits (Shenbagavalli, 2007).

One of the major environmental issues associated with the disposal of distillery spentwash is water pollution. Intentionally or unintentionally, the spentwash very often reaches the water bodies and due to its high BOD and COD contents, the oxygen budget in the receiving water body is depleted to the extent that it can lead to heavy fish mortality (Joshi and Kalra, 1995). The excessive dose of K and SO4 of spentwash may result in accumulation of salts in the soil and result ground water pollution due to leaching on subsequent irrigations / rainfall (Mahimairaja, 2007).

The apprehensions about the deterioration of groundwater quality are mainly based on observations on its present status in the vicinity of most of the distilleries. In many cases the surrounding villages are provided with potable water supplies by the distilleries as the tube well or well water is not fit for consumption. Actually this problem arises as a sequel to storage of distillery effluent in big lagoons for primary and secondary treatments and in large number of small pits carved on the land for solar drying of spentwash.

The colour of the distillery spentwash persists even after the anaerobic treatment and poses a serious threat to the environment. The distillery spentwash has brown to very dark brown colour, which is of organic nature. Even though, several successful treatments of distillery spentwash, including anaerobic process that result in energy rich methane are available, none of them reduce the colour in the spentwash. The dark brown colour is one of the major problems in the distillery spentwash disposal. Several processes are associated with the formation of colour in molasses and distillery spentwash. Since the colour of the effluent is dark brown, it induces immediate reaction of fear amongst the farmers. However, the colour has nothing to do with the toxicity as it is primarily the colour of the charred sugar produced due to burning of starch during sugar manufacturing process.

Impact of spentwash on groundwater / soil quality

The impact of spentwash application on groundwater quality and soil characteristics was assessed in areas previously applied with biomethanated spentwash in Namakkal district (Shenbagavalli, 2007). The results showed that most of the groundwaters sampled from open wells near spentwash applied fields were brown to dark brown in colour, with high pH (7.9 – 8.6) and EC (>1.5dSm^{-1}). The water samples contained large amount of salts, particularly K^+ and Cl^- suggesting that the water contamination is mainly due to the application of distillery spentwash. The samples had high BOD, which were far exceeding the maximum permissible limit of Pollution Control Boards. Most of the samples, due to contamination of spentwash, were found unsuitable for irrigation purpose. The groundwater samples had shown greater potential for salinity hazards than sodicity problem. Though no marked evidence was observed on the characteristics of soil collected from spentwash applied fields, the nutrients (N, P, K) and salt (Na, Ca, Mg, Cl and SO_4) contents were relatively higher in these soil.

Utilization of pressmud in agriculture

Pressmud is a by-product obtained from sugar industry. About 3% of pressmud is obtained for the total quantity of cane crushed. Annually about 6.83 lakhs tonnes of pressmud are produced from 37 sugar industries in Tamil Nadu. The pressmud is a softy, amorphous and dark brown to brownish white material containing sugar, fiber, coagulated colloids including can- wax, aluminous inorganic salts and soil particles. Its composition and properties vary depending on the quality of cane crushed and the process followed for clarification. The raw sugarcane juice obtained during milling of sugarcane contains suspended and dissolved impurities. The suspended impurities include the disperse soil, bagasse particles, wax, fats, proteins, gums, pectin, tannins and colouring matter which remain in colloidal form in the juice. The dissolved impurities present in the juice are the reducing sugars and inorganic salts of N, K, and P etc. which are plant metabolites, intermediates and constituents. Two types of processes namely sulphitation and carbonation are commonly used to clarify the cane juice to obtain crystal sugars from the juice. Sulphitation process is carried out with the help of lime and sulphur dioxide which forms calcium sulphate as a byproduct along with other impurities. Lime and CO_2 are used during the carbonation process to get the clear cane juices which form calcium carbonate as a byproduct along with other impurities. Being originated from plant sources, pressmud contains substantial amounts of plant nutrients (N, P, K, Ca, Mg, S) and organic matter (Table 1).

Table 1. Composition of raw and composted pressmud from sugar factories of Tamil Nadu, India

Composition	Raw pressmud	Pressmud compost
pH	6.0 – 7.0	7.1-7.6
EC (dSm^{-1})	3.0 – 3.3	1.5-2.3
C:N	16 – 36	10-11.4
Nitrogen (mg/l)	1.0 – 1.5	2.7-3.5
Phosphorus (mg/l)	1.4 – 4.0	3.0-4.0
Potassium (mg/l)	0.5 – 2.0	3.0-3.5
Calcium (mg/l)	3.2 – 12.0	4.0-6.2
Magnesium (mg/l)	1.0 – 2.0	2.0-2.16
Sulphur (mg/l)	0.1 – 0.5	2.0-3.0
Organic carbon (mg/l)	15.0 - 36.0	30-40
Iron (mg/l)	0.08 – 0.3	1.6-1.8
Manganese (mg/l)	0.01 – 0.3	0.21-0.22
Zinc (mg/l)	0.14 – 0.04	0.19-0.42
Copper (mg/l)	0.01 – 0.03	0.72-1.0

It is estimated that on an average each tonne of pressmud contains about 10-15 kg N, 14-40 kg P, 5-20 kg K and 32-120 kg Ca. Therefore, it could be used as a source of plant nutrients and as soil amendment. The pressmud has been mainly used as a source of plant nutrients and ameliorant for acidic and saline-sodic soils as a medium for raising sugarcane seedlings and as a carrier for preparation of *Rhizobium* inoculants. Currently, pressmud is completely used for preparing bio-compost/ bio-manure by the sugar industries. The pressmud has been well recognized as organic manure and is being effectively utilized by sugarcane farmers. It has been found that the residual effect of pressmud was found equal to the effect obtained with 20 tonnes FYM ha^{-1}. At a rate of 5 t ha^{-1}, the pressmud application supplies approximately 175, 200 and 175 kg of N, P and K respectively, with a fertilizer equivalent of Rs. 7160 (Table 2), besides large amounts of secondary nutrients, organic matter and micronutrients.

It has been found from soil test crop response (STCR) studies that wherever FYM or composted coir waste or pressmud is applied @ 12.5 t ha^{-1}, on an average, 40, 22 and 40 kg of N, P_2O_5 and K_2O can be reduced from the recommended fertilizer nutrient doses. The fertilizer equivalence of 10 t ha^{-1} of sulphitation pressmud cake is 50 %, while that of carbonation pressmud was 28 % of fertilizer recommendation for rice. The beneficial effect of pressmud in enhancing the cane yield of sugarcane was observed up to 12.5 t ha^{-1}. Significant improvement in organic carbon and nutrients (NPK and micronutrients) availability was observed due to pressmud application. The sulphitation pressmud is more effective than carbonation pressmud.

Management of soil physical constraints: Chisel ploughing at 0.5m apart and application of pressmud at a rate of 10 t ha^{-1} is recommended for managing the sub soil hardpan (soils having impervious layer at shallow depth). Pressmud application reduces the soil bulk density and increases the hydraulic conductivity. Considerable improvement in the structural parameters like aggregate stability, mean weight diameter and per cent water stable aggregates could be achieved by pressmud application.

Reclamation of sodic soils: Pressmud, being rich in calcium and sulphate, is recommended at a rate of 12.5 t ha^{-1} for the reclamation of sodic soils.

Table 2. Amount of nutrients added through application of pressmud at a rate of 5 t ha^{-1} and its fertilizer value

Nutrient	Content in Pressmud (%)	Amount added to soil (kg ha^{-1})	Equivalent to commercial fertilizer	Cost equivalent to commercial fertilizers (Rs)
Nitrogen	3.5	175	380 kg of urea	1860.25
Phosphorus	4.0	200	200 kg of super-phosphate	4032.00
Potassium	3.5	175	292 kg of muriate of potash	1267.00
		Total		7159.25

Composting of pressmud **:** It has been proved that the pressmud could be effectively composted in combination with either coir pith or trash or bagasse at 1:1 ratio using distillery effluents (2.5 m^3 / tonne of pressmud) and can be applied at a rate of 2.5 – 5 t ha^{-1}. The rate of application varies depending upon crop nutrient requirements. Due to its high demand and market value the pressmud based bio-compost is being sold by most of the sugar and distillery industries. Bio-compost is prepared by using pressmud and distillery effluent. Pressmud is spread in the compost yard to form a heap of 1.5 m with 3.0 m length and 3.5 m breadth. For a tonne of pressmud ten litres of bacterial culture (diluted with water at 1:10) is used. After 3 days, distillery effluent is sprayed on the heaps to a moisture level of 60 per cent and the pressmud heap is allowed overnight to absorb the effluent. Then the heap is thoroughly mixed by aero-tiller. When the moisture level drops below 30-40 per cent, again the effluent is sprayed, mixed with pressmud and heap is formed. The effluent should be sprayed once or twice a week depending on the moisture content of pressmud heap. Mixing of effluent and heap formation should be repeated for 8 weeks so that the pressmud and effluent proportion reaches an optimum ratio of 1:3. The heaps are then allowed for curing for a month. During the process of composting, the temperature of the heap may increase to 60 to 68^oC during the second week and reach a maximum of 80^oC on the seventh week. The compost obtained from this process is neutral in pH with an EC of 3 to 6 dSm^{-1}. The bio-compost contains 2.7-3.5% N, 3-4% P, 3-3.5% K along with Ca, S and micronutrients in considerable amounts.

Distillery spentwash

Molasses is used as a raw material in the distillery industries where alcohol is produced from two types of fermentation processes, *Praj type* and *Alfa Laval distillation*. In Praj type, for one litre of alcohol produced about 12-15 litres of waste water (spentwash) are generated, whereas, in the Alfa Laval continuous fermentation and distillation process only 7-8 litres of waste water per litre of alcohol are produced as it uses boilers for concentrating the effluents. Currently, about 40.72 million m^3 of spentwash is generated annually from distilleries alone in India.

The spentwash is acidic (pH 3.94 to 4.30) and loaded with organic and inorganic salts, resulting in high EC (30 - 45 dSm^{-1}). Being plant originated, the spentwash contains considerable amount of plant nutrients and organic matter (Table 3). Nitrogen (N) content in spentwash ranges from 1660 to 4200 mg L^{-1}, P from 225 to 3038 mg L^{-1} and K from 9600 to 17475 mg L^{-1} and Calcium, Mg, SO_4 and Cl are also present in appreciable amounts. Thus, it can be effectively used as a source of plant nutrients and as soil amendment. Recently, the presence of appreciable amounts of plant growth, promoters viz., gibberellic acid (GA) and indole acetic acid (IAA) has also been detected which further enhances the nutrient value of spentwash (Murugaragavan, 2002). The high concentration of Ca (2050–7000 mgL^{-1}) in spentwash may have the potential of reclaiming the sodic soils similar to that of gypsum effect.

Though the spentwash generally does not contain any toxic metal, it is characterized by high BOD and COD levels. Therefore, high BOD, COD and other organic compounds such as phenols, lignin and oil and greases in spentwash are likely to deteriorate soil and environmental health. The unpleasant odour due to the presence of skatole, indole and other sulphur compounds, which are not effectively decomposed by yeast, or methanogenic bacteria during distillation, is also an issue of public concern. The beneficial effect of spentwash on crop production is well documented (Rajukkannu and Manickam 1997).

Technology and application

More than a decade, distilleries sponsored collaborative research programmes are being carried out at Tamil Nadu Agricultural University, India to develop strategies for effective utilization of spentwash in agriculture. The results from a number of experiments (laboratory, pot and field) conducted at different locations to evaluate the suitability and use of spent wash in agriculture are summarized and presented as follows:

1. One time application of raw and diluted biomethanated spentwash: One time application of raw and diluted spentwash at a rate of 100 m^3ha^{-1} was found effective in improving yield in several crops.

Table 3. Some important chemical characteristics of spentwash from the distilleries of Tamilnadu, India

Parameters	Range values
pH	3.9 – 4.3
EC (dSm^{-1})	30.5 – 45.2
Biological Oxygen Demand (mg/l)	46100 – 96000
Chemical Oxygen Demand (mg/l)	104000 – 134400
Total Dissolved Solids (mg/l)	79000 – 87990
Nitrogen (mg/l)	1660 – 4200
Phosphorus (mg/l)	225 – 3038
Potassium (mg/l)	9600 – 17475
Calcium (mg/l)	2050 – 7000
Magnesium (mg/l)	1715 – 2100
Sodium (mg/l)	492 – 670
Sulphate (mg/l)	3240 – 3425
Chloride (mg/l)	7238 – 42096
Sodium Adsorption Ratio	5.0 – 7.3
Zinc (mg/l)	3.5 – 10.4
Copper (mg/l)	0.4 – 2.1
Manganese (mg/l)	4.6 – 5.1
Gibberellic acid (mg/l)	3246 – 4943
Indole acetic acid (mg/l)	25 – 61

(Sources : Rajukkannu and Manickam, 1997; Valliappan, 1998; Murugaragavan, 2002)

Table 4. Crop responses to spentwash application

Crop	Responses
Sugarcane *CO8021, CO853*	26 irrigations with 50 times dilution of spentwash increased the yield.
COC771	Higher yield was obtained up to 20 times dilution
Banana (*Poovan*)	No yield reduction up to 40 – 50 times dilution of 25 irrigations
Grass (*Cumbu*)	Higher biomass yield up to 20 times dilution
Gingelly (*TMV 5*)	Yield increased when grown as a residual crop after rice (spentwash applied)
Groundnut (*TMV 7*)	7 – 8 irrigations with 30 times dilution increased the yield
Soybean (*CO1*)	7 – 8 irrigations with 30 times dilution increased the yield
Sunflower (*CO1*)	7 – 8 irrigations with 30 times dilution increased the yield and oil content
Maize	8 – 10 irrigations with 50 times dilution increased the yield
Bhendi (*PKM-1*)	50 – 75 times dilution increased the yield and improved the fruit quality

2. *Fertigation with spentwash*: Fertilizer application through irrigation water is being recommended to improve the fertilizer use efficiency. The spentwash, being concentrated, could be successfully used in fertigation through which spentwash is diluted (1:10) and applied one or two times to crop along with irrigation water. The rate of application depends on crop requirements and duration.

Distillery spentwash at 40 to 50 times dilution increased the yield of sugarcane, banana, gingelly and rice. Similar effect was also observed in the ratoon crops. Crop responses towards application of diluted spentwash are summarized in table 4. At a rate of 100 m^3 ha^{-1}, the spentwash application supplies approximately 180, 40 and 1000 kg of n, p and k, respectively, with a fertilizer equivalent of Rs. 9962/- (Table 5), besides large amounts of secondary nutrients, organic matter and micronutrients.

***3. Biocompost from spentwash*:** The distillery spentwash do not contain any toxic compound, but rich in plant nutrients, organic carbon and proteinaceous substances. Therefore, it could be safely used for composting or co-composting of organic/biological wastes. Biocompost is prepared by using pressmud and distillery spentwash. Studies on the agronomic effectiveness of bio-compost prepared from composting of the yeast sludge, pressmud and rock phosphate using the spentwash have shown that the application of bio-compost prepared from spentwash at a rate of 2.5 t ha^{-1} along with the recommended dose of NPK increased the cane yield significantly.

In crops like groundnut and sugarcane, application of enriched composts had reduced the fertilizer dose up to 25 %, increased the yield significantly and found to be superior over 100 % NPK application either alone or in combination with FYM. Hence, the conversion of pressmud and treated distillery spentwash along with other agro-industrial wastes to high quality compost could effectively be introduced in integrated nutrient management systems to enhance the crop yield with reduced fertilizer usage. It can be recommended to the farmers as a valuable tool for supplementing plant nutrients and maintaining soil productivity (Thiyagarajan and Mahimairaja, 2002).

Field experiments conducted have demonstrated that distillery yeast sludge and spentwash could be profitably used for composting farm wastes and agro based industrial byproducts like coirpith (Lekshmi Kumar, 2001). Further, the results indicated that pressmud could be effectively composted in combination with either coir pith or trash or bagasse at 1:1 ratio using distillery spentwash (200 litre t^{-1} of compost). The biocompost prepared by using pressmud and distillery spentwash increased the yield of sugarcane and rice when applied at a rate of 2 t ac^{-1} and 250 kg ac^{-1} respectively (Ramadurai *et al.*,1996). The pressmud with 1:3 ratio of distillery spentwash along with suitable additives was found to be optimum for bio-earth compost preparation (Devarajan *et al*., 1998).

The yeast sludge and the spentwash produced from the distillery industries are rich in plant nutrients and do not contain any toxic compounds. Therefore, it could be safely used for composting or co-composting of organic / biological wastes (@ 2.5 m^3 / tonne of pressmud).

***4.Reclamation of sodic soil*:** The raw distillery spentwash is acidic and rich in Ca and SO_4. Therefore, it could be used as an amendment for reclamation of sodic soil similar to gypsum (Thiyagarajan and Mahimairaja, 2002). Experiments conducted at different locations in Trichy district by Rajukkannu *et al*. (1996) revealed that application of spentwash @ 5 lakhs litre ha^{-1} to the non-saline sodic soils followed by two or three leaching could effectively reclaim sodic soil and suggested a fair period of 60 days required from the days of its application and transplanting of rice seedlings for the establishment of rice.

According to Valliappan *et at.* (2001) one time application of spentwash at 150 ml kg^{-1} of soil was found optimum for the reclamation of non-saline sodic soils. Two leachings were found enough to leach soluble salts added through the spentwash to the level below 1.0 dSm^{-1}.

5. Seed hardening using spentwash: Seed hardening is a specific treatment given to seed before sowing especially during adverse soil moisture conditions. It is highly recommended for better establishment of seeds in rainfed agriculture. In pre-sowing hardening treatment the physiological and biochemical nature of the seed is modified to resist drought at the time of sowing. Seed hardening normally practiced with water, could be improved by chemicals *viz.*, 0.5% potassium dihydrogen phosphate, 2% KCl and 100 ppm of $ZnSO_4$ etc. It has been shown that the seed hardening with spentwash (10 and 20 per cent) significantly improved the germination and growth parameters of dry land crops viz., ragi, groundnut, gingelly, sorghum and greengram (Murugaragavan, 2002).

PULP AND PAPER INDUSTRIES

Paper industry is one of the major industries in India that contributes pollutants to water and soil. The level of paper consumption in India is 4.2 mt that generates 0.5 mt of sludge and is expected to grow. At present there are 525 pulp and paper mills with a total installed capacity of around 6.25 million tonnes per annum with a capacity utilization of about 67 per cent. The aggregate installed capacity by 2010 for paper and paperboard is expected to reach 8.3 mt and 1.5 mt for newsprint. The solid wastes (bagasse pith, effluent treatment plant (ETP)-sludge) and wastewater generated from paper mills are rich in essential nutrients which could enhance the crop growth.

Managing paper mill effluent

Nearly 80% of fresh water used in paper and pulp mill is discharged as effluent containing organic and inorganic pollutants which require treatment and disposal. The land application of treated effluent is considered to be an innovative approach for its safe disposal. The field experiments conducted revealed that the treated effluent can be safely used for irrigation with appropriate amendments like pressmud at a rate of 5 t ha^{-1}, fortified pressmud at a rate of 25 t ha^{-1} or daincha as *in situ* green manure. Though there were perceptible changes in soil pH, electrical conductivity, available N, P, K, exchangeable cations, exchangeable sodium percent (ESP) and sodium adsorption ratio (SAR), there was no detrimental effect due to Na either in soil or on plants in sandy loam soils with good drainage facilities. The following crops and varieties were found suitable for cultivation along with appropriate amendments and recommended levels of NPK.

Rice	:	IR 20, TRY1, CO43
Maize	:	CO 1
Sunflower	:	CO2

Table 5. Amount of nutrients added through one time application of spentwash at a rate of 100 m^3 ha^{-1} and its fertilizer value

Nutrient	Content in spentwash (mg L^{-1})	Amount added to soil (kg ha^{-1})	Equivalent to commercial fertilizer	Cost equivalent to commercial fertilizers (Rs)
Nitrogen	1800	180	391 kg of urea	1913
Phosphorous	400	40	250 kg of super-phosphate	806
Potassium	10000	1000	1667 kg of muriate of potash	7242
	Total			9962

Groundnut	:	TMV 2, TMV 7
Soyabean	:	CO 1
Sugarcane	:	COC 92061, COC 671, COC 6304, COC 91604
Fodder grasses	:	Cumbu-Napier hybrid, Paragrass, Guinea grass

Managing paper mill sludge

Due to high content of organic matter and nutrient content in paper sludge (Table 6), composting and land application is an attractive alternate method for disposal. Organic constituents in these sludge are potential soil conditioners, which improve biochemical properties.

The biocomposts prepared from paper mill sludge were evaluated along with FYM and pressmud under treated paper mill effluent irrigation to assess their influence on yield and quality of sugarcane, tapioca, paddy, groundnut, sunflower, maize, marigold and vegetable crops (Table 7). The economic yield levels increased from 5 to 10 per cent invariably in all crops due to biocompost application (5 t ha^{-1}) over FYM, and the yield levels were comparable with that of pressmud (5 t ha^{-1}). The quality of the crop produces and soil quality parameters in the above test crops had not deteriorated due to compost addition under continuous paper mill effluent irrigation.

TANNING INDUSTRIES

The leather industry is one of the major export industries in India, earning about 8000 crore rupees annually. It is estimated that about 70% of the total exports of leather and leather products are from Tamil Nadu. However, it is also one of the major sources of pollution in this state. Animal skins and hides are converted into non-biodegradable, stable and quality leathers through a process known as tanning. This process includes dehairing, removal of flesh and fat, and treatment with either plant extracts (vegetable tanning) or chemicals (chrome tanning). Several chemicals, including salts and heavy metals, are used in chemical tanning. Such process results in large quantities of effluents (approximately 680 million litres per day) and sludge (124400 tonnes per year) from 1008 small and 75 large tanneries in India.

Environmental impact

The effluent and sludge discharged from these tanneries into rivers and onto land has led to extensive degradation of productive land. The tannery wastes contain high concentration of salts (Na, Cl, SO_4 etc.,) and chromium (Cr) (Table 8). The indiscriminate disposal of these wastes had resulted in severe pollution of soil and water in Vellore and Dindigul districts of Tamil Nadu, India where most of the tanneries exist. Pollution of soil and water drastically reduced the crop yields (25 to 40%) over the years and total area under cropping significantly. Within 20 years, the total cultivated area has fallen about 10.5% in Vellore district and 41% in Dindigul district.

Studies conducted at TNAU showed that the soil and water around tanneries in Vellore and Dindigal districts of Tamil Nadu were severely affected due to the disposal of tannery wastes. Large amount of Na (2405 to 77711 mg kg^{-1}), Cl (4587-8175 mg kg^{-1}) and Cr (16731- 79865 mg kg^{-1}) were found in surface and subsurface of polluted soils in Vellore districts (Mahimairaja *et al*., 2000a).

The accumulation of Cr in soil exceeded the maximum threshold limits prescribed in various developed countries. The concentration of Cr in ground waters of Vellore district ranged from 50 to 990 $\mu g\ L^{-1}$. In majority of the water samples, the Cr concentration exceeded the maximum permissible level (50 $\mu g\ L^{-1}$). The greater concern is the finding that 89-96% of the Cr in most of the borewell waters was toxic form of Cr (VI) (Mahimairaja *et al*., 2000b). The accumulation of salts and Cr in soil, due to effluent or sludge, is of concern because of the possible phytotoxicity or increased movement of metals into the food chain and the potential for surface and groundwater contamination. Even in cases where there is low or zero metal contamination, pollution of surface water and groundwater may also be of concern because of excessive N and P loading of potable water supplies.

Currently, more than 50,000 ha of productive agricultural lands have been contaminated with Cr alone due to the disposal of tannery wastes in Tamil Nadu (Mahimairaja *et al*, 2000a and b). Remediation technologies will not only help sustaining agriculture, but also minimizing the adverse environmental impacts.

Potential and problem of tannery sludge

The tannery sludge is characterized by a large variety of organic (proteinaceous) and inorganic (mineral) compounds. Presence of appreciable amounts of organic matter (32 to 48%), N (0.5 to 4.8%), P (0.18 to 0.51%), K (0.1 to 0.3%), besides Ca and S reflects the potential of tannery sludge to be used as organic manure or soil amendments. It does not usually contain pathogens and therefore under normal conditions requires no disinfections.

As sodium chloride (NaCl) and chromium sulphate [$Cr_2(SO_4)_3$] are extensively used in the chemical tanning, the resultant sludge is rich in both sodium (Na) and chromium (Cr). Characterization of tannery sludge from different tanneries in Tamil Nadu showed a wide variation in the chemical composition. The Na in sludge ranged from 10021 to 49451 mg kg^{-1} and the Cr from 1605 to 16158 mg kg^{-1}, besides small amounts of Cu

Table 6. Composition of solid wastes generated from pulp and paper industries of Tamilnadu, India

Particulars	Pulp and Paper mill wastes		Paperboard mill sludge
	Bagasse pith	ETP Sludge	
pH	7.54	8.23	7.90
EC (dSm^{-1})	0.23	2.19	0.90
Organic carbon (%)	46.8	38.8	23.2
Total N (%)	0.36	0.46	0.30
Total P (%)	0.03	0.05	0.04
Total K (%)	0.14	0.17	0.50
C: N ratio	130	83	73: 1

Table 7. Increase in crop yield due to the addition of biocompost @ 5 t ha^{-1}

Type of Compost and Crop	Variety of Crop	Per cent increase over farmer's practice
Paper sludge compost		
	ADT 36	11.4
Paddy	IR 20	4.10
	White ponni	6.00
Maize	CO 1	17.0
	COSI 95071	8.00
	CO 6304	11.4
Sugarcane	CO 86032	7.10
	COSI 86071	6.50
	COC 92102	2.00
Groundnut	TMV 7	17.6
Sunflower	CO 2	18.2
Bhendi	Parbhani kranti	13.6
Tapioca	Mulluvadi	2.00
Paper Board sludge compost		
Maize	CO 1	18.8
Sunflower	CO 4	24.7
Cowpea	CO 2	27.5
Radish	Pusa chetki	18.8
Onion	Andhra fibro	22.6
Marigold	MDU 1	40.0

(19 - 42 mg kg^{-1}) and Zn (51- 121 mg kg^{-1}). At high concentration Na and Cr could deteriorate the soil and groundwater, and exert toxic effect on plant and organisms. The subsequent entry of these metals into the food chain may cause health disorders in animals and human beings.

Only a small quantity of tannery sludge is used as organic manure in agriculture. The use of sludge for fertilizing and conditioning of productive soils can be environmentally and economically beneficial to farmers as well as to the tannery. The reuse potential of sludge for agriculture was evaluated through laboratory, pot and field experiments. Results showed that the flower crop, *Jasminum auriculatum*, more tolerant up to 1000 mg sludge-Cr g^{-1} soil while *Crossandra infundibuliformis* and *Jasminum sambac*, were very sensitive at this concentration. There was no deleterious effect of sludge-Cr on the yield of vegetables up to 750 mg Cr kg^{-1} and above which a sharp decline in bhendi and brinjal was observed. Sunflower hyperaccumulated Cr from soil amended with tannery sludge. There was no significant effect of sludge-Cr on sunflower yield up to 7500 mg Cr kg^{-1}.

Guidelines, specifying the maximum permissible concentration of Cr and Na in sludge, annual loading under different soil environment, and phytotoxicity of Cr in different field crops, should be developed based on scientific research. A stringent law and regulation for restricting the open dumping and indiscriminate disposal of sludge on land and water should also be required for effective management of tannery sludge in future.

Phytoremediation of chromium contaminated soils

Results from field experiment showed that the *Jasminum* species and tuberose appeared to have high tolerance towards Cr and therefore, the effect was clearly reflected on flower yield. Further, high pH of soil also might have counteracted the effect of added Cr in soil thereby prevented any ill effects associated with the use of effluent irrigation. These plants survive at a high level of Cr contamination in soil. Therefore, such Cr-tolerant crops may be suitable for phytoremediation of Cr-contaminated soil. Evidently in the study none of the flower crops showed any toxicity symptoms at high Cr concentration. This suggests that even at this high concentration of Cr the flower crops could grow well and therefore could safely be used for remediating the Cr-contaminated soils.

Though the mustard crop was reported to accumulate large amounts of Cr our study demonstrated that this crop may not be suitable for the remediation of Cr-contaminated soil. The sunflower crop established very well and tolerated a high concentration of soil Cr. However, accumulation of Cr in seeds raises concern that Cr may enter into food chain and therefore it diminishes its potential for remediation. Results from field experiment showed that flower crops such as 'gundu malli', 'jathi' malli and tuberose have a high degree of tolerance towards salinity, sodicity and chromium. Roots of flower crops found to accumulate large amounts of Cr and Na. It has been shown that the treated tannery effluent with 50% dilution could safely be used for flower crops with minimal pollution problem.

Flower crops, such as *Jasminum auriculatum*, can tolerate up to 1000 µg sludge-Cr g^{-1} soil while other species (*Crossandra infundibuliformis* and *Jasminum sambac*) are sensitive to low Cr concentrations. There was no deleterious effect of sludge-Cr on vegetable yield up to a concentration of 750 mg Cr kg^{-1}. However, above this concentration, a sharp decline in the yield of bhendi and brinjal was observed. Sunflowers was found to

Table 8. Some important characteristics of tannery effluents of Tamil Nadu, India

Parameters	Effluent
pH	3.1 – 3.8
EC (dSm^{-1})	37.6 – 57.0
Total dissolved solids (mg/l)	24064 - 36480
BOD (mg/l)	430 – 1000
COD (mg/l)	1520 – 16300
Total Cr (mg/l)	1623 – 6990
Cr (VI) (mg/l)	Trace – 2
Na (mg/l)	11090 – 14830
Cl (mg/l)	1720 – 3670
S (mg/l)	2130 – 3612
Ca (mg/l)	156 – 538

hyper accumulate Cr from soil amended with tannery sludge. There was no significant effect of sludge-Cr on sunflower yield up to a concentration of 7555 mg Cr kg^{-1}.

Bioremediation of chromium contaminated soil

The effect of biological wastes (coir pith and poultry manure) on reducing the bioavailability and biotransformation of Cr in soils amended with tannery sludge was examined. The result showed that irrespective of soils, both coir pith (@ 12.5 t ha^{-1}) and poultry manure (@ 5 t ha^{-1}) markedly reduced the concentration of soluble plus exchangeable-Cr which represent toxic forms of Cr in soils (Fig. 1) while 61 (clay loam) and 75 (silt clay loam) per cent reduction in the concentration of soluble plus exchangeable-Cr was observed with the application of coir pith, a reduction of 62.3 (clay loam) and 68 (silt clay loam) per cent were observed due to poultry manure addition.

Application of biological wastes rich in the chemical factors can inactivate toxic Cr (VI) and reduce its potential for phytotoxicity and therefore could offer great potential for solving soil remediation needs in many countries. Such materials would also correct the severe infertility of metal contaminated sites, correct phytotoxicity caused by co-contaminants, and provide improved soil physical properties and organic-N which would facilitate development of a remediated ecosystem at a contaminated site.

The reed bed treatment system (RBTS), developed by integrating a multilayered substrates of gravels, sand, sawdust, vermiculite and soil, and the reed species was proved very effective in achieving a zero concentration of Cr in the tannery effluent (Fig. 2). Besides Cr, the acidic pH (3.21) of the effluent became neutral (7.27 to 7.46) and there was a remarkable reduction in salt loading of effluent due to treatment in RBTS. Though sawdust was an adsorbent in the reed bed, it was found to impart unacceptable colour to the treated effluent and hence its usage as a substrate in the reed bed system is discouraged. While the RBTS without plants reduced the BOD and COD by 25 and 72 per cent, respectively, the RBTS with plants achieved more than 95 per cent reduction in BOD and 80 per cent reduction in COD (Fig. 3). However, the COD of the treated effluent still exceeded the permissible limit (250 mg L^{-1}) of the Tamil Nadu Pollution Control Board (TNPCB). A combination of biological, physical and chemical processes including adsorption, precipitation, chelation, sedimentation and organic matter decomposition was found responsible for the reduction of various pollution parameters.

The results suggest that the integrated reed bed treatment system, with vermiculite and macrophytes as components, has intrinsic potential to treat the Cr-rich tannery effluent which could minimize its pollution hazards. The system by and large could have high ecological and economic values. However, the RBTS should be test verified in small scale tanneries on pilot-scale for confirmation of results and computing its economic values.

POULTRY WASTE

Poultry industry is one of the largest and fastest growing agro-based industries in the world. In India, this industry has attained a spectacular growth, especially in the last decade of the twentieth century. Poultry production in India during 1996-97 was estimated to be 30000 million eggs, 235 million broilers and 454,000 tonnes of poultry meat (IPI, 1994). Currently, India is the world's sixth largest producer of eggs. Over 50 per cent of the egg and broiler production comes from just four states, namely, Andhra Pradesh, Maharashtra, Punjab and Tamil Nadu. A large network of hatcheries across the country, hundreds of feed mills, veterinary pharmaceuticals and equipment manufacturers have made poultry a dynamic agri-business which plays a vital role in Indian economy.

Although economically successful, the poultry industry is currently facing a number of highly complex and challenging environmental problems. One of the major problems is the accumulation of large amount of wastes generated by intensive production. For example, one kg of litter is produced per broiler in one production of India cycle and an average of 48 g dry matter is voided by a layer as poultry droppings per day. Thus, on the basis of present poultry production it is estimated that approximately 4.0 million tonnes of poultry wastes are generated annually in India. Large-scale accumulation of these wastes will continue to pose disposal and pollution problems unless eco-friendly management technologies are evolved.

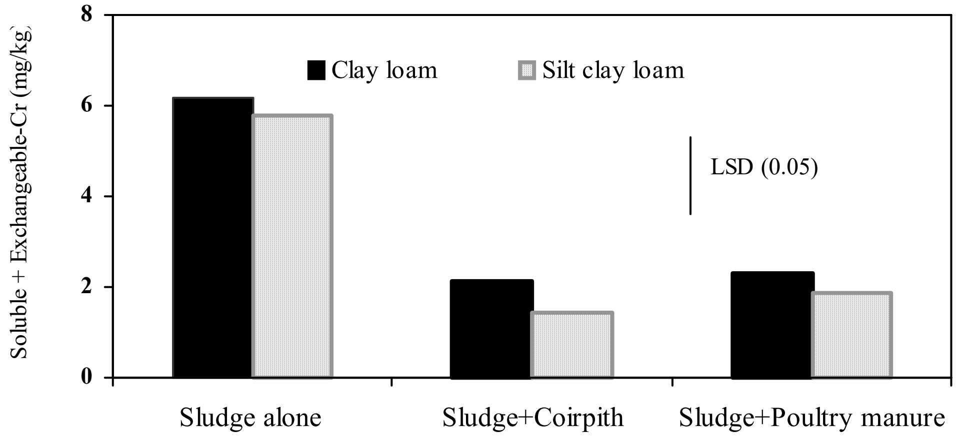

Figure 1. Effect of biological wastes (coir pith and poultry manure) on soluble and exchangeable - Cr in soils amended with tannery sludge

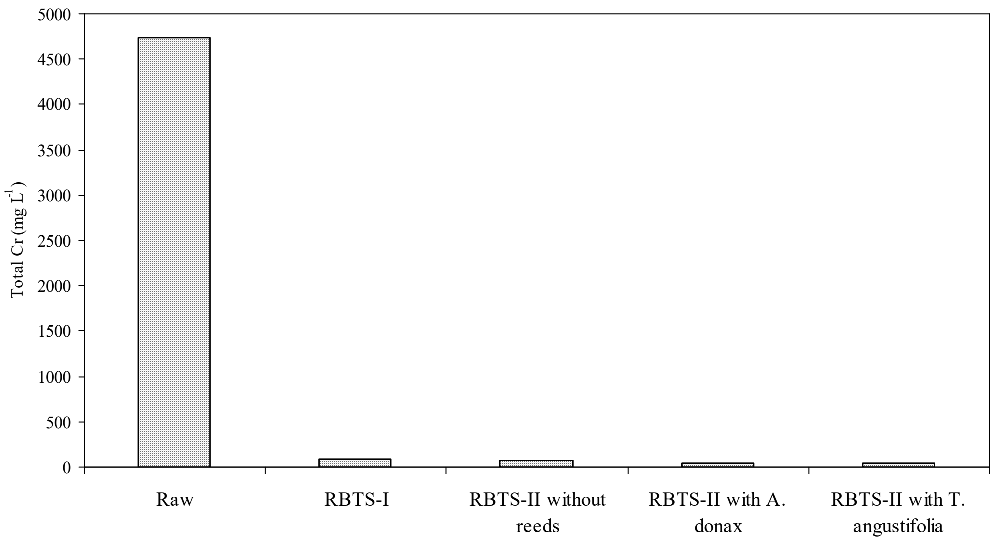

Figure 2. Reduction in chromium content of the effluent due to treatment in reed bed treatment systems (RTBT)

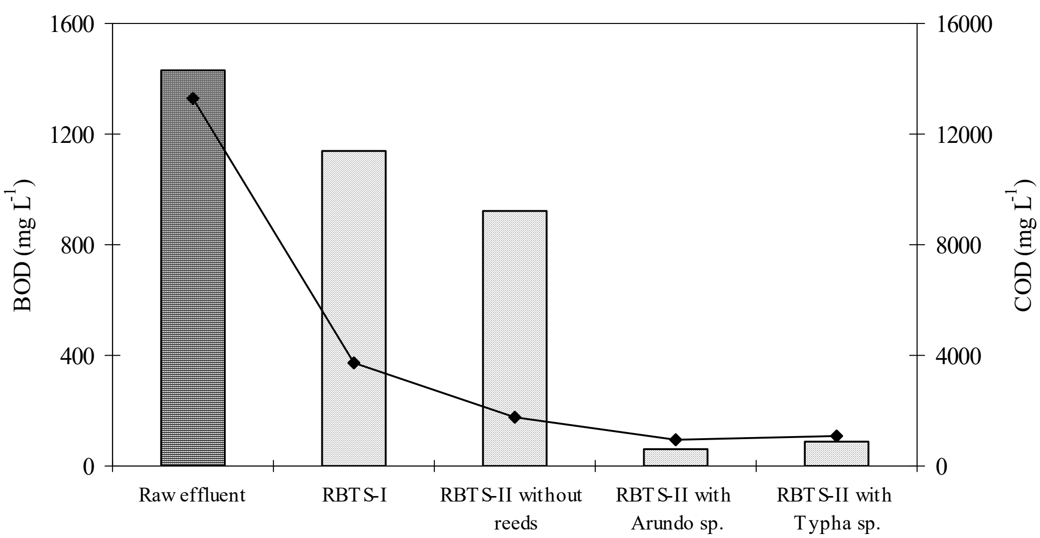

Figure 3. Reduction in BOD and COD of the effluent due to treatment in reed bed treatment systems (RTBT)

Traditionally poultry wastes, either as fresh or air/ sun-dried, have been used as organic manure for maintaining the soil fertility. Dried poultry wastes, a mixture of droppings (urine and excreta) and bedding materials (groundnut husk, straw or shavings) from either deep litter or broiler litter systems contain considerably higher dry matter than other manures and are rich in plant nutrients (Table 9). Poultry waste contains all essential nutrients including micronutrients and it has been well documented that it provides a valuable source of plant nutrients. Experiments have shown that the nutrients supplied by poultry manure are more efficient than those applied through inorganic source (chemical fertilizers) and have relatively larger residual effect on the succeeding crops.

Environmental impact

Fresh poultry waste, particularly from cage system, is very difficult to handle due to high moisture content. The obnoxious odour, further, aggravates the problem by making it unpleasant to handle the waste. Another important problem of poultry waste is the loss of nitrogen (N) during the storage, air/sun drying, handling, and subsequent land application. The loss of N occurs mainly through ammonia (NH_3) volatilization and denitrification during handling and nitrate leaching after application to land. Gaseous losses of N are of particular concern because they not only reduce the fertilizer value of poultry waste, but also form atmospheric pollutants, and deteriorate the environmental health. From an agricultural perspective, poultry wastes play a major role in the contamination of ground water by increasing nitrate N (NO_3-N) content. The eutrophication of surface water by the enrichment of N and P also poses a threat to environmental health. Improper management of this valuable resource could not only be damaging the crops but also lead to pollution of surface and ground waters.

Innovative options

Appropriate technologies, which are environmentally viable and economically feasible, are needed for efficient management of poultry waste. These may be accomplished through composting. As a natural process, composting has several advantages: it reduces the bulkiness of the waste and yields a stabilized product suitable for handling and land application. Composting eliminates animal and human pathogens and could reduce the risks of polluting groundwater. Development of appropriate methods of composting poultry waste with suitable amendments could greatly reduce the nutrient losses and at the same time minimise environmental pollution.

Two types of composts namely, *phosphocompost* (blending poultry waste with woodchip and rock phosphate) and *sulphocompost* (blending poultry waste with woodchip, rock phosphate and elemental sulphur, S^o) were prepared and their effect on soil and crop was examined.

Anaerobic composting / storage is found very effective in reducing the N losses, but is not always feasible. Aerobic composting with cereal straw, which contains readily decomposable carbon, is most effective in reducing the N loss. Addition of S^o and zeolite helps to reduce the N losses from poultry waste. Addition of small amount of S^o reduces the pH of the compost and thereby reduces the volatilization losses of ammonia. It also enhances the dissolution of rock phosphate and enriches the compost with phosphorus and sulphur nutrients. The *phosphocompost* and *sulphocomposts* are 12% and 60% as effective as urea during the first year of application, but are as effective as urea during second year. Thus, a nutrient-rich ecofriendly compost could be prepared by composting poultry waste with phosphate rock and S^o.

Management consideration

Strict regulations governing the safe disposal and handling of poultry waste should be required in order to minimise its environmental impact. Management of poultry waste must be integrated into a broader nutrient management programme in agriculture. Guidelines on specific land application, optimal loading rates, and permissible limits of nutrients, heavy metals, antibiotics, and coccidiostats in poultry waste, are needed. Research-based information on the content and availability of nutrients and heavy metals in poultry wastes is needed not only for crop management, but also for the development of state or regional land use plans. Recycling of poultry waste in fish and cattle feed and in power (electricity) generation should also be given consideration for efficient and profitable management of poultry waste.

AGRICULTURAL RESIDUES / ORGANIC WASTES

Continuous cropping constantly removes plant nutrients and exports them out of the farm in harvested produces. Mobilizing sources of plant nutrients external to the cropped area to replenish plant nutrient stocks mined by the harvests and sustaining soil health becomes very important for sustaining crop production. Animal and poultry manures are valuable and renewable nutrient sources which have been used successfully for maintaining soil fertility until the mid-twentieth century. With the introduction of low cost chemically synthesized fertilizers, suitable for high yielding crop varieties, the use of manures became less cost effective, and in many cropping systems the organic manures have been largely replaced. As a result, they have become wastes and have created disposal problems. The continuous use of large quantities of chemical fertilizers on high yielding crop varieties has also resulted in deterioration of environmental quality. Unless appropriate methods of

Table 9. Nutrient content of animal and poultry manures (g kg^{-1} dry weight basis)

Nutrient	Cattle	Sheep	Pig	Horse	Poultry
Nitrogen	25 - 40	20 – 45	20 – 45	17 – 30	28 – 62
Phosphorus	4 – 10	4 - 11	6 – 12	3 – 7	9 – 29
Potassium	7 – 25	20 - 29	15 – 48	15 – 18	8 – 29
Calcium	5 – 8	8 – 19	3 – 20	7 – 29	17 – 69
Magnesium	5 – 8	3 – 6	2 – 3	3 – 5	3 – 8
Sulphur	3 – 4	2 – 3	3 – 5	1 – 3	4 – 7

managements of these manures are evolved, large scale accumulation of manure from housed animals will continue to pose disposal and pollution problems.

About one fourth of N, more than 50 per cent of P, and 100 per cent of K are imported by the country in the form of raw materials or finished products of the total consumption. This is due to increased consumption of fertilizers. Tamil Nadu recorded substantial growth in fertilizer consumption. The import cost of such high value fertilizers is causing a serious strain on the foreign exchange reserves. The current consumption of fertilizers in Tamil Nadu is about 7.91 lakhs tonnes per year. It has been estimated that currently approximately 89.4 million tonnes of animal and poultry wastes, 11.2 million tonnes of crop residues, and 38.4 lakh tones of urban and agro-industrial wastes are available in Tamil Nadu. These organic wastes have a potential to supply about 4.29, 1.85, and 4.59 lakh tonnes of N, P and K, respectively, besides a potential source of soil organic matter. There is, therefore, a renewed interest in the efficient use of organic manures. If appropriate technology is developed, manure, once again, will become a potentially valuable resource in agriculture. Eco-friendly technologies are needed for effective utilization of organic wastes in agriculture. This could be accomplished through composting whereby the organic component of the solid wastes is biologically decomposed and stabilized under controlled conditions to a state where it can be handled, stored and/or applied to the land to supply plant nutrients without adversely affecting quality of the environment.

Composting technology

Composting allows the organic materials to decompose under more or less controlled conditions to produce a stabilized product that can be used as a fertilizer and/or soil amendment. In the recent technology of composting, forced aeration, mechanical shredding, mixing, grinding, drying, and even inoculation with microbial decomposers have been introduced. Composting is basically a microbial bio-oxidative process. Its purpose is to change the properties of an organic material or a mixture of organic biomass into a stabilized product that is safe to apply to crops as fertilizer or soil conditioner. The critical factors that affect composting and their interrelationships must be thoroughly understood to ensure optimum composting conditions and to produce quality composts. The value of organic wastes as soil conditioners can be estimated in a number of ways, depending on the ultimate objectives of their use. Inoculants of mixed cultures of beneficial microorganisms have considerable potential for controlling the soil microbiological equilibrium, thus providing a more favourable environment for plant growth and protection.

Compost has been considered as a valuable soil amendment for centuries. Most of the people are aware of the fact that usage of composts is an effective way to increase healthy plant production, help save money, reduce the use of chemical fertilizers, and conserve natural resources. Compost provides a stable organic matter that improves the physical, chemical and biological properties of soils and thereby enhancing soil quality and crop production. When correctly applied, compost has beneficial effects on soil properties, thus creating favourable conditions for root development, and consequently promoting higher yield and better quality of crops.

Compost absorbs odors and degrades volatile organic compounds. It binds heavy metals by forming complexes and thus reduces their biotoxicity and potential in ground water contamination. It degrades and completely eliminates wood preservatives, petroleum products, pesticides, and both chlorinated and nonchlorinated hydrocarbons in contaminated soils. Composting of raw manures can minimize any potential environmental or nuisance problems.

Vermicomposting

Vermicomposting is the process of degradation of organic wastes by earthworms to achieve three objectives *viz;* i) to upgrade the value of organic waste materials so that it can be reused, ii) to produce upgraded materials *in-situ*, and iii) to obtain a final product free of chemical or biological pollutants. Vermicompost can be enriched with beneficial microorganism such as *Azotobacter, Azospirillum, Phosphobacteria,* and *Pseudomonas.* This enrichment process will give high nutritive value and high biological value of vermicompost. In the enriched vermicompost, apart from high nutrient content, the number of beneficial organism is more. For one tonne of waste processing, one kg of *Azophos* (which contains both *Azospirillum* and *Phosphobacteria*) should be inoculated twenty days after putting the waste into the vermibed. For one hectare of land 5 tonne of vermicompost is recommended for field application. For garden pot soil 10-40 parts vermicompost can be mixed in soil before filling pots for transporting seedlings. Some experts even opine that 20-30% recommended dose of chemical fertilizers be substituted with vermicompost.

CONCLUSION

Decline in the availability and quality of land and water due to pollution is becoming a catastrophe in several parts of India. Organic and inorganic chemicals (pollutants) are introduced into the soil and water ecosystem through the disposal of industrial wastes. They may persist in the environment for a long period, thereby posing a serious risk to environmental and human health. Remediation of polluted environment hinges upon the development of sustainable technologies, which will ensure environmental protection. Hundreds and thousands of small scale as well as large scale industries like tanneries, distilleries and paper mills generate millions of litres of waste waters and huge amounts of sludge. If sustainable technologies are developed for treatment, they can be effectively used as a source of irrigation and nutrients for agricultural crops.

In the present day context, there is a necessity to produce more food grains to feed the increasing population, which means more use of inputs like fertilizers and pesticides which leads to pollution of soil and water ecosystem. There is also a need to have increased transport facilities, which means increased use of fuel leading to the air pollution. Industrial expansion is needed to sustain the economy and meeting the public requirements and this necessarily leads to production of industrial wastes causing concern on the pollution of soil and ground water. It may not be possible to stop all these activities as they form part of human livelihood. But it is also our responsibility to take all steps to minimize and reduce the pollution hazards by adopting "Integrated Environmental Management (IEM) Technologies.

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