Paper mill sludge in agricultural soil amendment and effluent water for irrigation

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ABSTRACT

Greening of earth along with environmental control have been conceived by efficient utilization of the effluent water and sludge generated by Indian pulp and paper mills for irrigation and agricultural soil amendment. The N, P, K Values and other properties of primary, secondary sludges and composted primary sludge from paper mill have been evaluated for agricultural purpose. The soil amendment procedures adopted for cultivation of brinjal, onion, sunflower, banana, flowering plants and pulp wood such as eucalyptus and Gmelina arborea are described. Data are presented showing normal or better growth of these plants in soil amended with composted sludge than in soil treated with manure. Height and yield data for some plants are also given. Use of effluent water for irrigation of food crops and pulp wood trees is discussed and results of effluent water treatment in eucalyptus are presented

Introduction :

Greening of earth has apparently become the global theme (16) of this decade and all technologically advanced industries will have to strive hard for attaining environmental stewardship (11) by the turn of the century. In order to make the green programme (4) economically attractive in pulp and paper industry, growing of pulp wood tree using the effluent water and sludges could be the appropriate approach. The paper mill sludges, can become a rich source of fertilizer (3) for large scale vegetative propogation (8) of pulp wood trees as well as agricultural food crops which will not only become a boon in greening of earth but also solve pollution problem.

The amount of waste effluent water generated by the pulp and paper mills in India (7) is 700—800 M m^3 and 30,000 tons of sludge annually. The effluent water generated by paper mills having secondary clarifier (17) meets the specifications laid by Indian pollution regulation(2) and has been used for cultivation of food crops (14,20). However, reports on efficient use of the effluent sludge in India are rare.

Sludge was previously used essentially for land filling in USA and Canada but by applying advanced composting technology (3), it is being considered as ideal fertilizer for food crops such as wheat, corn, soyabean, tomato, pepper, grapes etc. (6,12,18)Application of sludge after composting is economical as it can reduce transportation cost. Reduction in volume can be 40-50% after exposing to weather (3) for 220-236 days, As the degraded and other waste lands are normally N—deficient (8), the sludge can be applied for growing Pulp wood trees-

The sludge has many other indirect benefits (3, 9), such as increase in water holding capacity of sandy soil, change in soil morphological, physical and chemical properties, reducing odour of the sludge and

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degradation of toxic compounds by the micro-organisms. Effluent water has been used for agricultural purpose far growing rice, wheat, sugercane, Potato, corn, bean, cabbage, carrot, tomato, ground nut, black gram and sunflower (13,16). 12 varieties of paddy were cultivated using effluent water without observation of any adverse effect (20). Effluent water is reported to be used for regular irrigation in another mill in South for sugarcane (14).

Eucalyptus, cotton and grasses (13) have also been reported to grown with the effluent water normally. 20,000 gallons/hour of raw effluent was pumped (10) in 30 acres of land for 250 days for 8 years for eucalyptus and no adverse effect was found.

Source	Termed here as	Conditioning
Primary Clarifier	— Primary sludge	Exposed to natural weathering for 2 months (November-January)
Secondary clarifier	— Secondary Sludge	Dried in the sun over drying beds for 25 days.
Primary clarifier	— Composted primary sludge	Sludge thrown into a pile for about 2 years.

The present work encompasses food crops not studied previously in USA or Canada and are quite common in India namely, brinjal, onion, sunflower and banana. Eucalyptus and Gmelina arborea are the two pulp wood trees taken for study.

Experimental :

Effluent water used for the study was collected from the secondary clarifier of the nearby paper mill producing quality papers.

The 3 sludge samples used were also from the same mill, conditioned to weather as shown above :

The sludge was brought in a tractor to the site and allowed to dry in the sun. Subsequently dried sludge was scrapped and transferred to a brick lined pit for further drying. The lumps were disintegrate into small lumps when fairly dried.

Amendment procedure :

Brinjal :

Experimental area (6 × 4 metres) was dug manually and divided into 3 plots of size 2m × 4m. Sludge 50 t/hac OD basis, Farm yard manure (12.5 t/hac OD basis) and Control (without sludge or manure) was applied to each row. The sludge and farm yard manure was spread over the soil and then mixed with soil. The seedlings were planted after 26 days in all the three plots. After 2 months, 180 grams of urea was added. The plants were irrigated as usual.

Sunflower :

Area covered for sunflower is 7 × 7.5 and 3 × 12 meters in two kyars. The first area was divided into two equal parts for treatment of sludge and manure. The land was dug and levelled. Sludge was spread at the rate of 50 t/hac and manure was applied at the rate of 9 t/hac. The land was again ploughed to mix the sludge and soil. Sunflower seedlings were planted at a spacing of 0.6-0.7 metres, one month after treatment application. The plants were irrigated as usual.

In the second row, the plantation was made at spacing of 0.45 × 0.45 metres.

Onion :

3 plots of land were selected for studying the growth of onions with effluent sludge. The first plot devided into 3 sub plot for (1) sludge, 16 × 14 meteres manure, (2) 16 × 12 metres, (3) Sludge + Manure, 7.5 × 12 meters.

The land was dug and levelled manually. In the First plot, sludge was applied at the rate of 65 t/hac, manure at the rate of 25 t/hac and sludge + manure at the rate of 20 + 5 t/hac respectively. After 22 days, the sludge dried completely which was throughly mixed and the onion bulbs were planted in rows at a spacing of 0.3 × 0.3 meters.

The 2nd plot, sludge was applied at the rate of 50 t/hac after digging and levelling. After 25 days, the land was dug again for mixing the sludge and soil.

The land was left for weathering for 4 weeks. The seedlings were planted 10 weeks after spreading of sludge at a spacing of 0.3×0.3 meters.

In the 3rd plot, sludge was applied at the rate of 25 t/hac and left for weathering. The sludge was mixed with the soil after 6 weeks and the bulbs were planted 10 weeks after spreading of the sludge at a spacing of 0.3×0.3 metres. The plants were irrigated as usual.

3.6 kg/plant was the rate of application of composted sludge in eucalyptus.

Chemical analysis of N, P, K and other elements were carried out following to standard methods (1, 5).

Results and discussion :

Analysis of sludge :

Analysis results of sludge samples are shown in Table 1. The primary sludge sample was collected from the Mill and then kept outside for 2 months before analysis. As the socondary sludge was produced in the drying bed, it is likely to have contamination of the sand bed. The third sample was collected from the pit of primary sludge which was outside for about two years. As it resembles to composted sludge, it has been termed here as "composted primary sludge".

pH values of all the three sludge samples are slightly alkaline (7.5—8) which is probably due to residual NaOH and CaO. The N. content was relatively lower (table-1) than those reported (11) from USA and Canda (0.14—4.1%). On the other hand, sludge used for study had 0.34% of phosphorus, which is average value found in USA. Potassium content in the composted.

Primary sludge in particular is also high (0.2%) which is higher than the average values found in sludge samples in American paper industries. Ca is quite high in the present composted primary sludge. 10.4% of Ca have been reported as the highest value in American sludge samples. As the bleaching process followed was CEHH, amount of CaO found in the sludge is quite high. Mg was found to be as high as 2.5% in this sludge which is much above the analysis results found in USA. The high amount of Mg also may be from lime used for preparation of bleach liquor. Formation of Mg $(OH)_2$ along with Ca $(OH)_2$ is quite common when the source of lime is dolomitic (Mg Co_3) lime stone. The ash contents in all the three present samples are quite high and specially in the composted primary sludge because of high Ca and Mg in the sludge. Na content in the composted sludge is in the higher side of the 0.05 — 0.41 range reported in American paper mill sludge. As the sludge had

Table — 1

Analysis of sludge, manure and soil

Property		Fresh primary Sludge	Fresh secondary sludge	Composted primary sludge	Manure	Soil
pH		7.5	8.0	8.0	8.5	6.5
Bulk density,	kg/M³	185	842	606	—	—
N,	%	0.02	0.11	0.07	0.23	0.03
P,	%	0.12	0.34	0.17	0.24	0.07
K,	%	0.02	0.07	0.20	0 84	1.56
Na,	%	0.10	0.25	0.37	0.45	0.29
Ca,	%	2.1	2.44	8.43	2.02	0.74
Mg,	%	1.26	2.13	2.46	1.01	0.56
Ash,	%	45,0	61.7	73.4	51.2	95.0
Organic matter	%	55.0	38,3	26.6	48 8	5.0

been heaped outside, the soil contamination is also responsible for high ash content. The ash content in the composted sludge is found to be as high as 73.4%. Mg can also come from talc used as filler.

Analysis of trace metals was not carried out. However, based on elemental analysis shown in USA (11), most of these elements are likely to be present in the present sample also. The corresponding values found in soft woods and hard woods are also given to indicate source of origin of these metallic elements. N_2, P, K, Ca, Mg, Fe, Mn, Zn, Na and Al are from wood but the concentration of Fe, Na etc. increases during the pulping process. Cd and As are metals, toxic to the plant. Many of these alements are likely to come in traces Mg,Ca,Na,K, P & N we determined experimentally. All the nitrogen present in the composted sludge will be immobilized. As the time of composting was 2 years, mineralization effect is likely to be over (1).

Effluent water for eucalyptus

Analysis of effluent water from the secondary clarifier, is shown in Table 2. It can be seen that all the parameters (2) were within the Indian standards (Table 2). The colour of the effluent was light brown.

Table-2

Analysis of effluent used for plantation

Property	Values in ppm	*Tolerance limit, ppm
Ca	80	—
Mg	20	—
P	0.007	—
Na	150	60
K	6	—
**B	0.1	2.0
N	0.01	—
Cl^-	515	600
Total suspended solid	90	—
Total dissolved solid	600	2100
BOD_5 (20°C)	45	500
COD	260	—

*According to BIS No. 3307 (1977).
**According to (14).

Table—3

Growth of pulp wood trees with effluent sludge and effluent water (Increase in height in cm)

	Gmelina arborea				Eucalyptus			
	with sludge		with manure		with sludge	without sludge	with effluent	without effluent
Row no.	After 1 month	After 2 months	After 1 month	After 2 months	After 2 months	After 2 months	After 6 months	After 6 months
1	9	32	7	16	43	38	110	109
2	13	20	15	27	39	31	121	100
3	12	24	10	23	51	34	99	112
4	9	24	6	26	55	26	75	91
5	22	52	16	33	70	44	80	86
6	5	19	10	11	65	25	—	—
Average	12	29	11	23	54	33	97	100

As urea and phosphate are added in the effluent before entering to the lagoon, the effluent water is enriched with N, P, K values. Laboratory studies conducted on eucalyptus produced by clonal technology showed normal growth on using effluent water (Table 3). No adverse effect was observed after 6 months of treatment with the effluent water.

A field study was conducted to find out effect of effluent discharged into a river at night. It was observed that the nursery situated 4 km down from the discharge point and using the river water has faced no adverse effect on growth of vegetables, flowers and banana for last five years. The river water collected had a Na content of 11-16 ppm. According to the district horticulturist, the water gives better growth and yield of vegetables etc than water without effluent.

Pulp wood tree with effluent sludge

The treatment procedures are already described in the experimental part. Growth of eucalyptus and gmelina arborea in terms of height of trees with soil amended with sludge and without amendment is quite distinct. Onion has been grown in the vacant spaces of Gmelina arborea.

The growth of eucalyptus is to be monitored for 4—5 years to establish the long run effect of sludge. Effluent water treatment was made on few sludge treated trees. The overall bio-mass and growth pattern of sludge + effluent treated trees are found to be quite encouraging. The difference in gmelina arborea in soil treated with sludge, and non-treated trees is also quite remarkable. The sludge treated trees give similar growth as manure treated trees.

Food crops with effluent sludge

Banana

Banana planted in soil with sludge has been showing practically same growth as the manure treated trees. The overall effect will be known when the fruiting will start.

Onion

Experimentation with onion has been carried out in large area and growth has been in favour of using sludge as fertilizer. Effect of varying proportion of sludge on onion production (Table 4) has been studied by amending soil with rate of 65, 50 and 25 t/hac. The results indicate that 25 t/hac sludge application is most ideal for onion.

Increasing sludge content in soil does not help any improvement in onion production. Results in Table 4 show that when the sludge is mixed with manure, the growth is better than when treated alone with sludge.

In the soil, amended with sludge+manure at the rate of 25 t/hac (20+5), the total biomass and weight of bulbs as well as leaves are found to be much higher in soil amended with sludge and manure separately (Table 4). At the end of 8 weeks, the total biomass was 360 and 455 gm respectively for sludge alone and sludge+manure; which is 95 and 120 gm respectively for onion bulbs. As the yield in soil amended with sludge+manure is higher than manure treated soil, supplementing of manure with sludge has quite beneficial effect on onion. The N content in the sludge being poor, it is apparently supplemented by the manure as it has 0.23% (Table 1) compared to 0.7% in the composted sludge. Corn grown in soil with 45, 67.5 and 90 tonnes of sludge/hac did not show any change in yield (21).

Sunflower

Sunflower grown in soil amended with sludge showed much better growth than soil treated with manure. At the end of 8 weeks, the height of sunflower in amended soil was 26 cm while in manure treated soil, a height of 17 cm was observed.

Brinjal

Brinjal grows extremely well with sludge treated soil, the growth pattern seen from the 4th week to 16th week. Though flowering started more or less at the same time in the three plots, yield of brinjal was highest in soil treated with sludge. In the soil without any treatment or treated with manure showed less than half of sludge treated soil.

Flowering plants :

Five flowering plants have been grown in sludge treated soil; flower beds treated with effluent sludge:

Dahlia single, Dahlia double, Phlox drummondii, Lupinus, Canna.

Fig.—1 : Eucalyptus grown in soil amended with composted sludge (S) and without amendment (WS)

Fig.—2 : Gmelina arborea grown in soil amended with composted sludge (S) and manure (M) with onion in vacant spaces (O)

Fig.—3 : Onion in soil amended with sludge

Fig.—4 : Sunflower in soil amended with sludge (S) and manure (M)

Fig.—5 : Brinjal in soil amended with sludge (S) and manure (M)

Fig.—6 : Flower plants in soil amended with sludge.
1. Dahlia double 2. Phlox drumondii 3. Lupinus

TABLE—4

Growth of onion with sludge, manure and sludge+manure and varying amounts of sludge

Observations		Sludge	Manure	Sludge + Manure	26 t/acre	20 t/acre	10 t/acre
Height after 1 week,	cm	8	3	6	8	12	10
Height after 2 weeks,	cm	16	10	10	16	18	18
Height after 4 weeks,	cm	16	15	12	16	25	23
Height after 8 weeks,	cm	30	30	35	30	35	40
Weight of bulb,	g	95	100	120	—	—	—
Weight of leaves,	g	265	290	335	—	—	—
Total biomass (from 8 plants)	g	360	390	455	—	—	—

No adverse effect has been observed on using the effluent with the flowering plants

Production of composted sludge from the primary or secondary sludges requires highly advanced composting technology (3) and studies pertaining to biotechnology.

In a country like India where there is acute shortage of water in Summer in particular, efforts for using effluent water for irrigation is highly imperative to be undertaken. Extensive R & D works need to be initiated to make the effluent water acceptable for plant kingdom, namely by reducing colour, BOD, COD, soda etc. Efficient utilization of the waste materials will certainly be promising for greening of earth.

Summary :

Sludge can be utilized after composting as fertilizer for brinjal, onion, banana and sunflower. Eucalyptus and Gmelina arborea can also grow normally in effluent water and composted sludge. The composted sludge has comparatively small amount of N and high P,K, Ca and Mg. Onion grows best in soil amended with mixture of composted sludge and farm yard manure. Nursery flowering plants can also be grown in sludge treated soil.

Acknowledgement :

The authors are grateful to M/s. Straw Products Ltd., Jaykaypur for sponsoring the project and to Dr. B.L. Bihani, Chief Executive (PM), J.K. Paper Mills in particular for suggesting to undertake works in the plants studied. The authors also express gratitude to the Management of Pulp and Paper Research Institute for permission to publish this paper.

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