

Agropotentiality of lime sludge waste from the paper industry

The Nagaon Paper Mill, a public sector pulp and paper mill, a unit of Hindustan Paper Corporation Limited, is located at Jagiroad, Morigaon district, Assam at a distance of about 70 km from the city of Guwahati and generates about 448 tonnes of lime sludge per day as solid waste¹. The generated lime sludge has been disposed in a nearby low-lying area. The lime sludge contains huge amounts of calcium carbonate. As the agricultural soil of Assam is generally acidic in nature, liming is necessary to maintain the soil pH. Instead of marketed lime, lime sludge waste of the paper mill can be used to optimize the pH of the agricultural soil. Keeping this in mind, the present investigation was carried out to study the effect of lime sludge on growth and production of some agricultural crops like mustard, pea and rice as well as physicochemical properties of the soil.

Lime sludge waste was collected in gunny bags from the dumping site of the paper mill. It was first dried in the laboratory and crushed into fine powder which was stored in clean polythene bags.

Soil sample was collected in polythene bags from the agricultural fields and brought to the laboratory. It was spread out on the floor for air drying in the shade. Big lumps were broken down and plant roots, pebbles and other undesirable material were removed. After the soil became completely dry, it was sieved through a 2 mm sieve and the sample was stored in clean polythene bags.

The certified seeds of mustard (*Brassica campestris*, var. CVM 27), pea (*Pisum sativum*, var. Rashna 30) were procured from Assam Seed Corporation, Directorate of Agriculture, Khanapara, Guwahati. One-month-old rice saplings of the variety Aijong (*Oryza sativa* L. Masuri) were procured from a local farmer.

Standard analytical procedures were followed^{2,3} to characterize the soil, lime sludge and different concentrations of sludge amended soil used for the experiments.

Pot culture experiment was carried out to study the effect of lime sludge amended soil on crop production and soil quality. Earthen pots were filled with 3 kg of dry soil and lime sludge containing 0 (control), 10, 20, 30, 40, 50, 60, 70, 80, 100% lime sludge on weight basis.

Sludge (% wt)

0 10 20 30 40 50 60 70 80 100

Soil (% wt)

100 90 80 70 60 50 40 30 20 0

Three sets of earthen pots were prepared for separate treatment of mustard, pea and rice. Three replications were maintained for each treatment. The pots were irrigated with tap water. After one week of submerging and equilibration, pots allocated for rice sapling were prepared for rice cultivation. A bunch of rice saplings were planted in each pot. The water level in the pots of rice crops was continuously kept 5–8 cm above the soil surface throughout the growing season. Before one week of harvest, irrigation was discontinued.

In the rest of the pots, when soil moisture content was close to field capacity, seeds of mustard and pea were sown in pots allocated for these crops. After the seeds germinated, the number of seedlings was reduced to two per pot and grown to full maturity. Thus a total of six plants were maintained for each treatment. Pots of mustard and pea were irrigated with water according to requirement.

The growth of mustard, pea and rice seedlings was constantly monitored and plant height was recorded periodically at an interval of 30 days. At maturity, maximum length of plants was measured (from root tip to the leaf tip and panicle tip) separately in centimetres; number of pods in mustard and pea and number of panicles in rice was recorded. Mature plants were harvested and seeds of mustard, pea and rice were collected. Number of seeds of the three crops was recorded; the seeds were dried in an oven at 45°C and average dry weight of seeds was recorded.

Physicochemical characteristics of lime sludge waste of Nagaon Paper Mill are presented in Table 1. The impact of lime sludge amended soil at different percentages on growth and yield of mustard, pea and rice is presented in Figures 1–4 and the physicochemical characteristics of the lime sludge mixed soil samples are presented in Table 2. The results revealed that height of plants, number of pods, number of seeds and weight of seeds of mustard have shown an increasing trend in up to 20% sludge mixed soil

and from 30% onwards, it declined gradually. The pea plants showed a rising trend in up to 30% sludge mixed soil and from 40% onwards, the growth and yield characteristics of pea declined gradually. In the case of rice, an increasing trend was noticed in up to 20% sludge amended soil and thereafter, it declined gradually.

It was revealed from the results that lime sludge amended soil increases height of plants, number of pods/panicles, number of seeds and weight of seeds of mustard, pea and rice. Application of lime sludge from 20 to 30% increased the height of the plants, number of pods or panicles, the number of seeds and weight of seeds of all the three experimental

Table 1. Physicochemical properties of lime sludge waste of Nagaon Paper Mill

Parameters	Average value
pH	10.88
Conductivity (mS cm ⁻¹)	0.765
Water holding capacity (%)	70.9
Organic carbon (%)	0.14
Total nitrogen (%)	0.03
Available phosphorus (mg/kg)	0.079
Potassium (meq/kg)	45.38
Sodium (meq/kg)	237.0
Calcium (meq/kg)	752.08
Magnesium (meq/kg)	188.25
Calcium carbonate (%)	67.43
Heavy metals	
Zn (mg/kg)	0.463
Mn (mg/kg)	1.675
Cu (mg/kg)	0.165
Pb (mg/kg)	0.364
Ni (mg/kg)	0.268

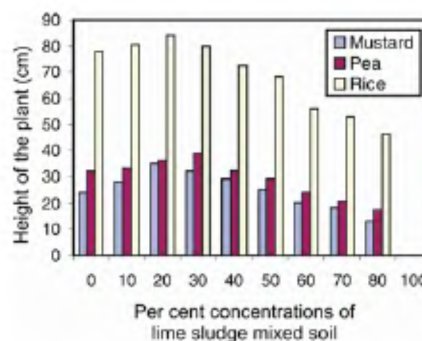


Figure 1. Height of the crops in different concentrations of lime sludge mixed soil.

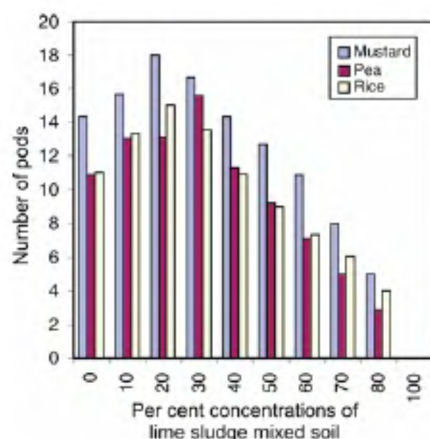


Figure 2. Number of pods/panicles of different crops in different concentrations of lime sludge mixed soil.

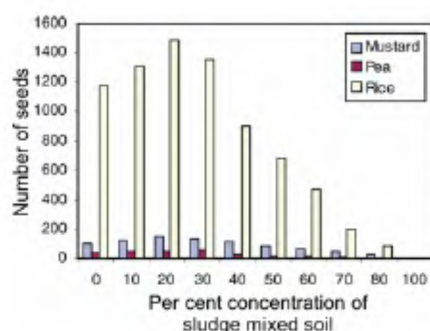


Figure 3. Number of seeds of crops in different concentrations of sludge mixed soil.

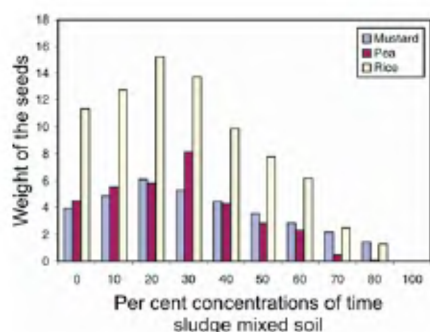


Figure 4. Weight of the seeds of different crops in different concentration of lime sludge mixed soil.

crops. The increased growth and production response at 20–30% sludge concentration might be due to the improvement of chemical properties of the soil. It was observed that growth parameters like the height of plants, number of pods/panicles, number of seeds and weight of seeds of mustard, pea and rice were reduced with further increase in sludge

concentration. No growth response was found at 100% sludge concentration. This might be due to the toxic effect of lime sludge on plant growth. Application of low percentage of lime sludge could enhance the growth and development of crops⁴.

Soil amended with lime sludge undergoes various changes. An upward shift in pH was noticed from 5.6 to 10.88. The electrical conductivity values of sludge-amended soil were between 0.162 and 0.765 mS cm⁻¹. The increased soil pH after amendment with lime sludge may be attributed to the presence of calcium carbonate, calcium oxide, magnesium oxide and sodium, which form hydroxides in the presence of water. Electrical conductivity positively correlated with pH and reflected the concentration of soluble cations and anions. pH is a very important property of soil because it determines the growth of plants, availability of nutrients, bacterial activity and physical condition of soil⁵. High pH is not suitable for most of the agricultural crops⁶. Electrical conductivity values are important in determining the nutrient status of a crop or the harmful effect of the soil on growth of crops. The elevated salt level of the soil treated with lime waste sludge has a direct effect on crop growth. The water holding capacity of the soil was significantly raised by the application of lime sludge. Water retention capacity of lime sludge is more than that of the soil. This effect could be ascribed to increase in total porosity of soil on account of altered mechanical composition of the treated soil⁷. Increased water holding capacity of soil upon lime sludge addition (at lower concentrations) is likely to provide better soil–water relationship for growing plants but later the growth was checked when some other factors (like alkalinity, etc.) limited the process. Organic carbon content of different percentages of sludge amended soil was 0.88–0.14. Application of lime sludge in the soil (at lower percentages) contributes a little amount of organic carbon content that may help in physical and chemical changes in soil and finally benefit crop production⁸. Soil organic matter supplies nitrogen, phosphorus and sulphur for plant growth, serves as an energy source for soil microorganisms and promotes good soil structure⁹. Microorganisms decompose these substances into carbon, which then gets fixed in soil. The fixed carbon is used by plants for

their growth and nutrition. But further increase in lime sludge percentage decreases organic carbon content possibly due to increase in soil pH. Under alkaline conditions, activities of microorganisms are greatly affected.

The decreasing values of nitrogen and phosphorus in the sludge amended soil indicate low levels of nitrogenous matter and phosphorus in the lime sludge. In the pot experiments, soil sludge mixture was taken on weight basis. When the percentages of sludge increase, alkalinity increases rapidly. Alkalinity might have led to depression in microbial activity for fixing atmospheric nitrogen in the soil. The decrease of phosphorus content in sludge-amended soil might account for its breakdown through hydrolysis in soil. The application of lime sludge increased the content of potassium in soil. The potassium content of different percentages of sludge-amended soil was 3.46–45.38 meq/kg and the sodium content of sludge-amended soil of the experiment was 16.30–237.0 meq/kg. Presence of sodium in the sludge has certainly increased the pH of the soil samples because it is well known that high sodium content leads to alkalinity^{10,11}. Calcium and magnesium (Table 1) occurred in the lime sludge in large amounts. The calcium content of different percentages of sludge amended soil was 40.35–752.08 meq/kg and the magnesium content of different percentages of sludge amended soil was 23.16–188.25 meq/kg. Calcium and magnesium have apparently no harmful effects on plants but large amounts of calcium and magnesium influence soil acidity and are known to alter the ionic balance of soil¹². High concentrations of calcium, magnesium and sodium affect soil permeability and texture and might be responsible for reducing rate of water intake. Sodium also acts as a deflocculating agent and displaces divalent cations like calcium and magnesium and the soil loses its productivity cumulatively¹³.

From the study it was revealed that application of lower doses of lime sludge (20–30%) to the acidic soil has increased the growth and production of crops without any adverse effect. But lime sludge application to the soil is detrimental at higher percentages. Our observation also revealed that paper mill sludge contributed to some significant alteration of soil quality and natural soil composition. The contributing factors due to application of

Table 2. Change in physicochemical properties of different percentages of sludge mixed soil at the beginning of the experiment

Parameters	Lime sludge treatment (%)									
	Control (0)	10	20	30	40	50	60	70	80	100
pH	5.60	7.15	7.22	7.43	8.08	8.62	8.92	9.47	9.94	10.86
Conductivity (mS cm ⁻¹)	0.162	0.218	0.245	0.266	0.288	0.328	0.347	0.463	0.509	0.765
Water holding capacity (%)	56.46	57.83	59.21	60.86	62.18	63.85	65.19	66.86	68.55	70.9
Organic carbon (%)	0.88	0.84	0.81	0.76	0.68	0.62	0.46	0.38	0.26	0.14
Total nitrogen (%)	0.055	0.055	0.052	0.050	0.048	0.042	0.036	0.028	0.019	0.009
Available phosphorus (mg/kg)	0.644	0.623	0.604	0.536	0.457	0.359	0.324	0.270	0.144	0.078
Exchangeable potassium (meq/kg)	3.46	5.73	9.88	12.57	18.48	21.83	28.65	36.47	41.94	45.38
Sodium (meq/kg)	16.30	34.82	41.39	58.43	77.18	98.56	116.75	146.94	191.36	237.00
Calcium (meq/kg)	40.35	90.62	112.24	146.73	211.16	324.89	411.67	536.30	687.43	752.08
Magnesium (meq/kg)	23.16	27.48	38.25	57.94	68.72	82.59	97.64	118.27	161.91	188.25

lime sludge have been established by increasing the water holding capacity, pH, calcium, potassium and sodium concentrations. In addition, there was no significant change in the quality of soil at lower percentages of sludge but the higher percentages of sludge have an adverse effect on the soil quality, which may lead to reduction of crop production and increased toxicity.

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Received 27 December 2007; revised accepted 12 October 2009

UTPAL JYOTI MEDHI¹
ANUP KUMAR TALUKDAR²
SURESH DEKA^{3,*}

¹Department of Chemistry,
Pub Kamrup College,
Baihata Chariali,
Assam, India

²Department of Chemistry,
Gauhati University,
Guwahati 781 014, India

³Resource Management and
Environment Division,
Institute of Advanced Study in
Science and Technology,
Garchuk,
Guwahati 781 035, India

*For correspondence.
e-mail: sureshdeka@yahoo.com

Rediscovery of naturally occurring seagrass *Caulerpa lentillifera* from the Gulf of Mannar and its mariculture

The cultivation of seaweeds for food, pharmaceutical and industrial uses represents a substantial portion of the world marine harvest. India has yet to fully capitalize on seaweed aquaculture despite its long shoreline with varied climatic conditions¹. The Food and Agriculture Organization, as early as 1998, included in its recommendation, the expansion of mariculture potential in India through transplantation of *Eucheuma* and *Caulerpa lentillifera*². However, introduction of non-native species for aquaculture in Indian waters caused unforeseen consequences as in the recent case of an introduced species, *Kappaphycus alvarezii*, a

red algae used as raw material for the extraction of carrageenan. This commercial effort unfortunately resulted in *K. alvarezii* invasion of the adjacent Gulf of Mannar Marine National Park, resulting in widespread destruction of the endangered coral reef area³. For this reason, extreme caution is exercised in non-native introduction into Indian waters despite its large commercial potential.

C. lentillifera, also known as seagrass or green caviar, is a high value seaweed eaten fresh or as a salt-preserved form in Japan, Korea, Philippines and other southeast Asian countries. In Japan, it is cultured in tanks particularly in Okinawa

where it is known locally as 'umi-budo' and consumed as fresh salad. Philippine seagrass is called 'lato' and grown in fishponds during the dry season⁴. *C. lentillifera* was first reported to exist in Krusadai island in the Gulf of Mannar in 1955, but was never recorded again despite repeated marine surveys⁵. This species was thought to have become extinct from Indian waters until Mantri in 2004 reported the discovery of this species in Samiani Island situated in the mouth of Gulf of Kutch in the west coast of India⁶. Our marine science discovery programme considered the seagrass project of sufficient national importance to