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Impact of Paper Board Industry Effluent Irrigation to Agroforestry System on Changes in Soil Quality

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study assessed the impact of paper board industry effluent irrigation on soil quality under agroforestry system. The agroforestry system was maintained at the Tamil Nadu Newsprint and Paper Limited (TNPL) - Unit II located at Mondipatti Village, Manaparai Taluk, Trichy district, Tamil Nadu. The site is situated at the intersection of latitude 10º 41' N and longitude 78º 26" E. The soil analysis were carried out for various quality parameter as per standard procedure. The results reveals that application paper board industry effluent were significantly influenced the organic carbon, Available P, and K. Hydraulic conductivity of surface soils was ranged from 2.02 to 4.39 cm h^{-1} with the mean value of 3.27 cm h^{-1}. Infiltration rate was ranged from 6.6 to 52.5 cm h^{-1} with the mean value of 23.0 cm h^{-1}. Among the micronutrients status zinc was recorded below the critical level whereas cupper, iron and manganese were recorded above the critical level. Microbial biomass carbon (MBC), Soil microbial population (Bacteria, Fungi and Actinomycetes) and enzyme activities (Urease and Phosphatase) were significantly higher when application with paper board industry effluents under agroforestry system. The activity of soil enzymes and MBC showed significant positive correlation with organic carbon, available water and pH. These findings reveal that paper board industry effluent act as an irrigation source and fertigation under agroforestry system.

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Keywords: Paper board industry effluent; agroforestry system; soil quality; infiltration rate and Organic Carbon (OC).

1. INTRODUCTION

The papermaking process produces a large amount of effluent, which must be treated before being disposed of in accordance with environmental regulations [1]. As a result, irrigation as an ultimate destination for these effluent, which are now drained into surface waters, could be an attractive option (both environmentally and economically). In addition to avoiding an additional treatment step, wastewater can be used as a source of not only water but also additional nutrients [1]. Various authors have reported on the use of various types of wastewater for irrigation [2,3]. However, there are few research on the reuse of paper board effluent and their possible application in forest soils, particularly for tropical soils and effluents from the industrial Kraft bleaching process. Reusing wastewater on forest soils is a viable option and trees require more water than other crops, so larger volumes of water can be applied to smaller areas; and trees have high C and N retention in their biomass (mostly in the trunk), which represents an important long-term mechanism for storing these elements in the ecosystem [4]. The benefits of reusing effluent from paper mill operations on forest soil are supported by the relatively close proximity of industry facilities to wooded areas.

Effluents has contains nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) as well as zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), nickel (Ni), and cadmium (Cd), all of which contribute to eutrophication in aquatic ecosystems [5]. Wastewater irrigation, on the other hand, transfers a wide range of nutrients/elements into the soil environment [6]. Some of these elements, such as N, P, and K, are critical plant nutrients that, if inadequate at the application site, can lead to higher crop yields [7].

Long-term irrigation with effluents raises organic carbon (C) content in soil, and [8]. In recent years, the use of industrial waste as a soil amendment and irrigation for agricultural crops. Most crops have higher potential yields when irrigated with wastewater, which eliminates the need for artificial fertilizers and saves farmers' money. As a result, it is critical to understand the crop – effluent interface in order to apply them appropriately in irrigation systems [9]. The current work was done to use of paper board industry effluent as a source of irrigation through drip irrigation in agroforestry system. These research focused on use of paper board industry effluent on changes in soil physical, physico-chemical and biological properties under agroforestry system over the period last three year.

2. MATERIALS AND METHODS

2.1 Study Area Description

Tamil Nadu Newsprint and Paper Limited (TNPL) - Unit II located at Mondipatti Village, Manaparai Taluk, Trichy district, Tamil Nadu is an industry producing Multi-Layer Coated Paper Boards from imported pulp and waste papers as raw materials. The site is situated at the intersection of latitude 10º 41' N and longitude 78º 26" E (Fig. 1). The production capacity of the factory is around 2,00,000 tonnes per annum and it discharges around 5,000 m^3 of wastewater per day. The wastewater is properly treated through modernized Effluent Treatment Plant (ETP) and is being completely utilized for irrigation in about 570 acres of land in the factory area. The TNPL - II factory has already planted 6, 80,000 trees in 68 varieties including teak, mango, neem, coconut and many other flowering trees. The treated wastewater is being entirely used for the above plantation, through drip irrigation to enable the area to get a very high green cover.

2.2 Soil Sampling and Processing

The soil samples were collected from different blocks of (Block 1 to 12) TNPL Unit II factory site to assess the impact of paper board effluent irrigation to agroforestry system on status of soil quality. The sampling point were geo referenced using Global Positioning System (GPS) (Table. 1). The collected soil samples were air dried, grounded and sieved through 2 mm sieve and stored in clean polythene bags for laboratory analysis *viz.,* physical, chemical and biological properties.

2.3 Laboratory Analysis

The bulk density (BD), particle density (PD) and percent pore space (%PS) were determined from both the apparent and true volumes of the soil measured by adding a known quantity of water to measuring cylinder containing weighed quantity of soil [10]. The particle size analysis was carried out by international pipette method as described by Piper, [11]. The texture of the soil was determined by relative distribution of per cent sand, silt and clay in the sample whereas, the textural classification was made using USDA textural triangle. Saturated hydraulic conductivity was determined by following constant head method and calculated according to Darcy‟s equation (USDA handbook No. 60). Infiltration characteristics were studied using double ring infiltrometers. Moisture retention characteristics of soils were determined at 0.33 and 15 bar suction by using pressure plate apparatus [12]. Moisture retention between 0.33 and 15 bar suction was used to calculate available water contents.

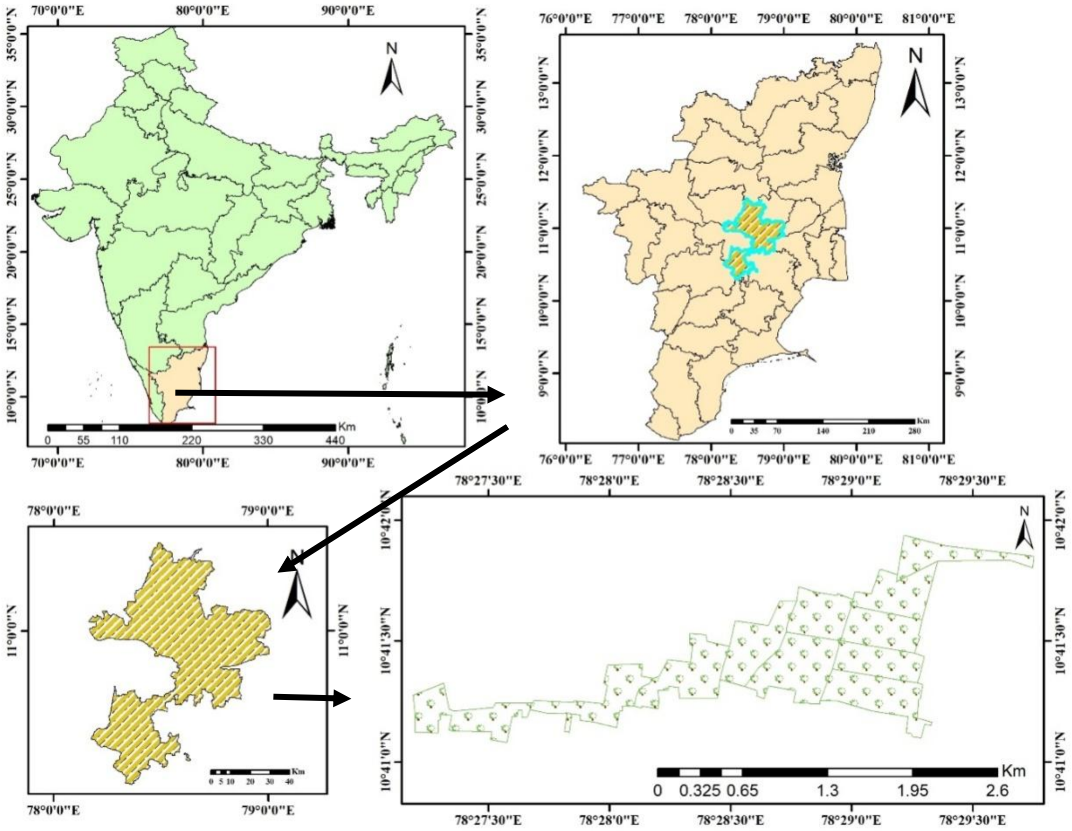

Fig. 1. Location map of the study area

Table 1. Soil sampling locations of TNPL Unit II factory site with GPS position

S. No	Location	GPS	
		Latitude	Longitude
1.	Block 1	10.6862876°	78.457245°
2.	Block 2	10.6862876°	78.4663728°
3.	Block 3	10.6898991°	78.4719123°
4.	Block 4	10.6917602°	78.4782580°
5.	Block 5	10.6933077°	78.4805386°
6.	Block 6	10.6901723°	78.4785041°
7.	Block 7	10.6892788°	78.4839738°
8.	Block 8	10.6895789°	78.4841368°
9.	Block 9	10.6910964°	78.4837633°
10.	Block 10	10.6953167°	78.4860177°
11.	Block 11	10.6975313°	78.4895847°
12.	Block 12	10.6962592°	78.4902475°

The pH of the soil sample was measured in a 1:2.5 soil/water suspension and electrical conductivity EC of the soil sample was measured in a 1:2.5 soil/water extract [13]. Calcium carbonate was determined by rapid titration method as described by [11]. The soil organic carbon estimated by wet digestion method with chromic acid and sulfuric acid was outlined by Walkley and Black [14], available Nitrogen by alkaline permanganate method was outline by Subbiah and Asija [15]. The available phosphorus was extracted by Olsen's Extractant (0.5 N $NaHCO_3$ at pH 8.5) [16] and Bray's Method [17]. The color developed with freshly prepared reagent B (ascorbic acid) was measured with the help of spectrophotometer at 660 nm wave length [18] Available potassium was extracted with Neutral Normal Ammonium acetate (N NH_4OAc) and then measured by flame photometer [18]. Cation exchange capacity was estimated by neutral normal ammonium acetate method by Chapman, (1965) [19]. The exchangeable cations *viz.*, sodium, potassium, calcium and magnesium were extracted with neutral normal ammonium acetate. Sodium and potassium were determined flame photometrically while, calcium and magnesium were determined by versanate titration method. The available micronutrient was determined by using the method outlined by Lindsay and Norvell, [20]. The Microbial Biomass Carbon (MBC) was determined by standard method [21]. The enumeration of microbial population done by using serial-dilution and plating technique with appropriate media. The soil dehydrogenase activity done by using standard method [22]. The urease activity was done by standard method [23]. The phosphatase activity done by using Tabatabai [23] method.

3. RESULTS AND DISCUSSION

3.1 Effect on Soil Physical Properties

The bulk density varied from 1.33 to 1.54 Mg m^{-3} with the mean value of 1.42 Mg m^{-3}, particle density ranged from 2.00 to 2.22 Mg m^{-3} with the mean value of 2.11 Mg $m^{-3}$and the pore space ranged from 28.5 to 40.0 per cent with the mean value of 32.83 per cent (Table 2). Among the various blocks of TNPL Unit II factory site, the Block 2 and 9 recorded the highest bulk density with the value of 1.54 Mg m^{-3} and Block 4 recorded the highest particle density and per cent pore space with the value of 2.22 Mg m^{-3} and 40.0 per cent, respectively. The bulk density value mainly depends on organic matter present in the soil. The bulk density increased with distance from paper mill in the northeren, the western and eastern directions of nagaon pulp and paper mill of Assam, India [24]. The lowest total porosity in treated effluent mainly due to presents of higher micropore and lowest macropore within the soil [25].

The sand content was ranged from 60.3 to 88.3 per cent with the mean value of 82.12% and highest sand content was observed in Block 9 (88.3%). The silt content varied from 4.63 to 16.37 per cent with mean value of 8.80 per cent. The clay content was ranged from 3.06 to 23.33 per cent with the mean value of 9.07 per cent (Table 2) and highest clay content was observed in Block 1 (23.33%). Field capacity (FC) was ranged from 5.22 to 18.46 per cent with the mean value of 8.58 % and highest FC were noticed in Block 1 (18.46%) and soil sample collected in Block 7 has recorded the lowest FC of 5.22 per cent. Permanent Wilting Point (PWP) was ranged from 3.74 to 15.92 per cent with the mean value of 6.27% and highest PWP were noticed in Block 1 (15.92%) and soil sample in Block 7 has recorded the lowest PWP of 3.74 per cent. Available Water (AW) content varied from 1.48 to 3.17 per cent with the mean value of 2.31 % and highest AW content observed at Block 12 (3.17%) and lowest AW content observed at Block 7 (1.48%). The available water were significantly depends on the organic matter and clay content of the soil. The water holding capacity were small near the mill due to accumulation of hydrophobic organic waste forming a coating over the soil [24]. Because of the stronger influence of organic matter on soil physical conditions, one may expect detectable differences of organic matter content (Brady and [26]. However application of paper board effluents under agroforestry seems to be major factors of disturbances that may cause marked changes in soil physical properties. Available water content of soils largely depends on organic matter content, relative proportion of micro-pores, BD and total porosity of soils.

Hydraulic conductivity mainly depends on soil texture (especially sand and clay per cent), pore space and organic matter of the soil. Hydraulic conductivity of surface soils were ranged from 2.02 to 4.39 cm h^{-1} with the mean value of 3.27 cm h^{-1} (Fig. 2) and highest hydraulic conductivity observed at Block 7 (4.39 cm h^{-1}). Hydraulic conductivity of subsurface soils were ranged from 2.61 to 8.43 cm h^{-1} with the mean value of 4.65 cm h^{-1} (Fig. 3) and highest hydraulic conductivity noticed at Block 7 (8.43 cm h^{-1}) followed by Block 5 (6.53 cm h^{-1}). The lowest saturated hydraulic conductivity of treated effluent soil was due to higher bulk density and lowest total porosity of the soil [25]. Infiltration rate was ranged from 6.6 to 52.5 cm h^{-1} with the mean value of 23.0 cm h^{-1} (Fig. 3) and Block 7 recorded the highest infiltration rate (52.5 cm h^{-1}) and lowest infiltration observed at Block 11 (6.6 cm h^{-1}).The application of effluent resulted in a considerable increase in infiltration rate and decreased in bulk density of an Inceptisol [27].

3.2 Effects of Soil Physico-chemical Properties

Application of paper board industry effluent were significantly affect the pH and EC of the soil from the over a the period time. The EC of the soil ranged from 0.03 to 0.33 dS m^{-1} with the mean value of 0.14 dS m^{-1} and highest EC were observed in Block 5 (0.33 dS m^{-1}). Ramesh [28] reported that EC was varied from 0.05 – 0.41 per cent with the mean value of 0.18 dS m^{-1}. When compared with this findings, there is no variation observed to application of paper board industry effluent irrigated soil under agroforestry system.

The soil reaction was ranged from 6.0 to 8.5 with highest pH were noticed in Block 1 (8.5). Ramesh [28] reported that pH was varied from 4.9 – 7.9 with the mean value of 6.89. When compared with above findings, over a period of time soil reaction was decreased by application of paper board industry effluent under agroforestry system. This might be due to decomposition leaf litter and other organic waste releases organic acids responsible for variation in soil pH. The calcium carbonate content ranged from 0.5 to 3.0 per cent with highest calcium carbonate observed at Block 1 (3.0%).

Table 2. Impact of paper board industry effluent on physical properties of soil samples

Particular	Range	Mean
Bulk density (Mg m^{-3})	1.33-1.54	1.42
Particle density (Mg m^{-3})	2.00-2.22	2.11
Pore space (%)	28.5-40.0	32.83
Sand (%)	60.3-88.3	82.12
Silt (%)	4.63-16.37	8.80
Clay (%)	3.06-23.33	9.07
FC (%) (0.33 bar)	5.22-18.46	8.58
PWP (%) (-15 bar)	3.74-15.92	6.27
AW(%)=FC-PWP	1.48-3.17	2.31
Hydraulic Conductivity (Ks) (cm h^{-1}) - Surface	2.02-4.39	3.27
Hydraulic Conductivity (Ks) (cm h^{-1}) – Sub surface	2.61-8.43	4.65
Infiltration rate (cm h^{-1})	6.6-52.5	23.0

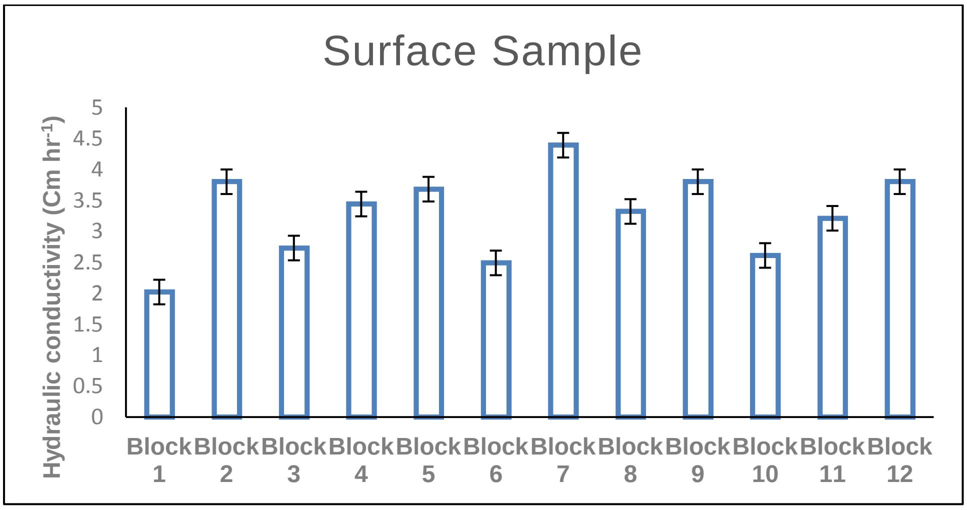

Fig. 2. Effect of paper board industry effluent irrigated soils on Hydraulic conductivity (Ks) (cm hr^{-1}) of surface soil

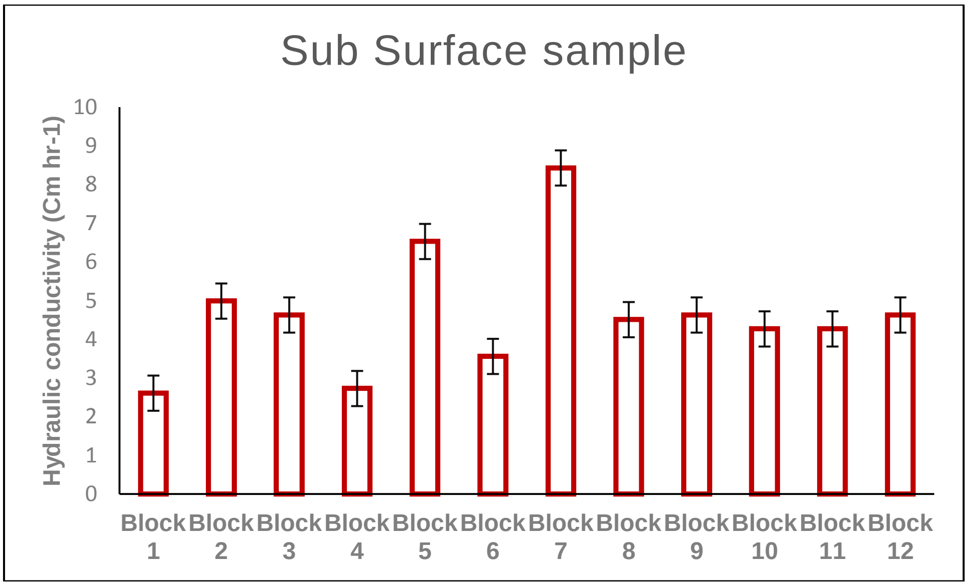

Fig. 3. Effect of paper board industry effluent irrigated soils on Hydraulic conductivity (Ks) (cm hr^{-1}) of sub surface soil

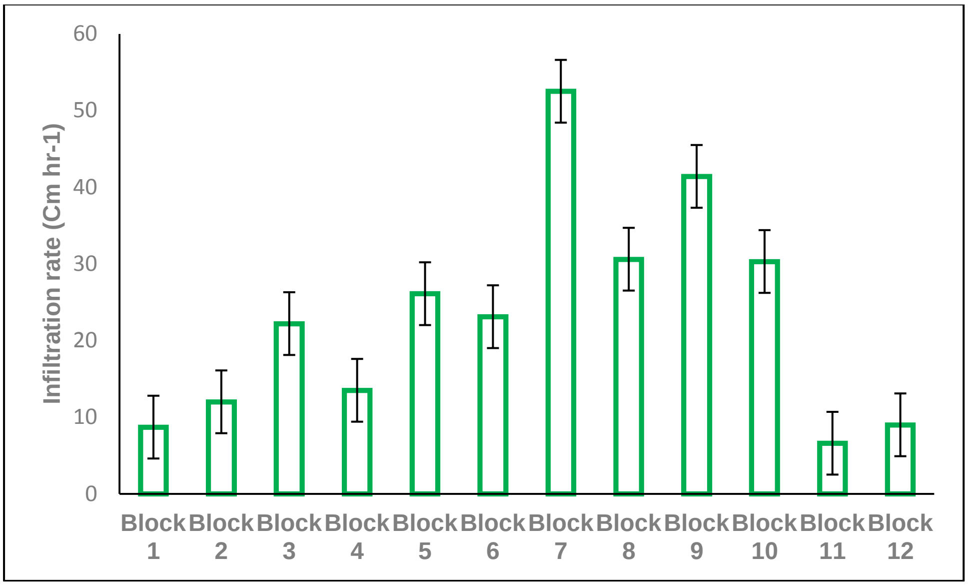

Fig. 4. Effect of paper board industry effluent irrigated soils on Infiltration rate (cm hr^{-1})

The organic carbon content was ranged from 0.39 to 0.93 per cent with the mean value of 0.67 per cent and highest organic carbon was noticed in Block 7 (0.93%) followed by Block 10 (0.87%). Ramesh [28] reported that organic carbon was varied from 0.29 – 0.85% with the mean value of 0.55%. The results showed that there is increased organic carbon which might be due to use of paper board industry effluent over a period of time. The higher organic C content of effluent-irrigated soils was due to the high quantities of suspended and dissolved particles in the effluent and decomposition leaf litter may be the reason for variation of organic carbon content.

The cation exchange capacity ranged from 3.4 to 12.9 C mol (p^+) kg^{-1} with the mean value of 7.26 C mol (p^+) kg^{-1} and highest CEC were recorded in Block 1 (12.9 C mol (p^+) kg^{-1}) followed by Block 11 (10.2 C mol (p^+) kg^{-1}) and lowest CEC were noticed in Block 4 (3.4 C mol (p^+) kg^{-1}).

High cation exchange capacity of the effluent irrigated soils could probably be due to changes in soil pH [29]. The H^+ ion retained by organic colloids and silicate clays becomes ionised and replaced when the pH of the soils rises. Additionally, the adsorbed aluminium hydroxy ions are released, releasing additional exchange sites on the mineral colloids, resulting in increase of negative charge sites on the colloids and as a result, an increase in the soils cation exchange capacity [30].

The Exchangeable bases *viz.,* Ca, Mg, Na and K were ranged from 1.5 to 6.0, 0.50 to 2.51, 0.12 to 2.08 and 0.03 to 3.32 C mol (p^+) kg^{-1} respectively, The highest content of Mg and K were observed in Block 11 (2.51 C mol (p^+) kg^{-1}) and Block 1 (3.32 C mol (p^+) kg^{-1}) respectively and highest content of Ca and Na were observed in Block 1 (6.0 C mol (p^+) kg^{-1}) and Block 2 (2.08 C mol (p^+) kg^{-1}) respectively. Total exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) were found to be greater in effluent irrigated soils. H^+ ions in the clay exchange complex were replaced by Ca^{2+}, Mg^{2+}, Na^+, and K^+ ions from the effluent in effluent irrigated soils [29]. In the effluent irrigated soil, this was clearly reflected in increased per cent base saturation and a decrease in exchangeable hydrogen and aluminium (H^+, Al^{3+}). The base saturation was ranged from 77.9 to 97.7 per cent with highest base saturation was recorded in Block 1 (97.7%) and lowest base saturation noticed in Block 4 (77.9%) (Table 3).

3.3 Effect on Soil Fertility Characteristics

3.3.1 Macronutrients

The available nitrogen status ranged from 90.95 to 185.02 kg ha^{-1} with the mean value of 131.71 kg ha^{-1} (Table 3.) and highest N status were noticed in Block 3 (185.02 kg ha^{-1}), and lowest N status observed in Block 6 & 7 (90.95 kg ha^{-1}). Ramesh [28] reported that available nitrogen content of effluent treated soil varied from 290.11 to 330.20 kg ha^{-1} with the mean value of 307.97 kg ha^{-1}. The results shows that application of paper board industry effluent decreases the available nitrogen content over a period of time. The external additions of N through effluent were not sufficient to enhance the N content of the effluent irrigated soil. It is possible that denitrification and ammonia volatilization losses of N occurred from these soils [29].

The available phosphorus status ranged from 3.36 to 30.24 kg ha^{-1} with the mean value of 11.57 kg ha^{-1} (Table 3) highest available P status was noticed in Block 6 (30.24 kg ha^{-1}) followed by Block 1 & 3 (19.04 kg ha^{-1}). Ramesh [28] reported that available phosphorus content of effluent treated soils varied from 10.90 to 13.20 kg ha^{-1} with the mean value of 12.0 kg ha^{-1}. When compared with the above findings, there is no difference observed by application of paper board industry effluent under agroforestry system from over a period of time.

Table 3. Impact of paper board industry effluent on physico- chemical properties of soil samples

Particular	Range	Mean
pH	6.0-8.5	7.21
Electrical conductivity (dSm^{-1})	0.03-0.33	0.14
Free CaCO3 (%)	0.50-3.00	1.33
Organic carbon (%)	0.39-0.93	0.67
CEC C mol (p^+) kg^{-1}	3.4-12.9	7.26
Exchangeable Ca C mol (p^+) kg^{-1}	1.50-6.00	3.44
Exchangeable Mg C mol (p^+) kg^{-1}	0.50-2.51	1.43
Exchangeable Na C mol (p^+) kg^{-1}	0.34-2.08	0.95
Exchangeable K C mol (p^+) kg^{-1}	0.03-3.32	0.71
Base saturation percentage	77.9-97.7	88.13
Available nitrogen (Kg ha^{-1})	90.95-185.02	131.71
Available Phosphorus (Kg ha^{-1})	3.36-30.24	11.57
Available potassium (Kg ha^{-1})	43.12-426.72	223.67
Available Sulphur (mg g^{-1})	1.79-6.95	2.97
Iron (mg g^{-1})	8.48-29.96	14.75
Zinc (mg g^{-1})	0.41-0.92	0.64
Cupper (mg g^{-1})	0.84-6.93	2.25
Manganese (mg g^{-1})	7.56-49.72	21.81

The available potassium status ranged from 43.12 to 426.72 kg ha^{-1} with the mean value of 223.67 kg ha^{-1} (Table 3) highest available K status was noticed in Block 1 (426.72 kg ha^{-1}) and lowest available K status was observed in Block 5 (43.12 kg ha^{-1}). Ramesh [28] reported that available potassium content of effluent treated soils varied from 115.78 to 134.14 kg ha^{-1} with the mean value of 126.09 kg ha^{-1}. When compared to above findings the application of paper board industry effluent increases the available potassium content over a period a time under agroforestry system. The available sulphur status was ranged from 1.79 to 6.95 mg kg^{-1} with highest available sulphur was noticed in Block 5 (6.95 mg kg^{-1}). Continuous application of the effluent containing organic and inorganic compounds increases the nitrogen, phosphorus and potassium content of the soil [31].

3.3.2 Micronutrients

The available micronutrients *viz*., Copper, Zinc, Manganese and Iron were ranged from 0.84 to 6.93 mg kg^{-1}, 0.41 to 0.92 mg kg^{-1}, 7.56 to 49.72 mg kg^{-1} and 8.48 to 29.96 mg kg^{-1}, respectively (Table 3). The highest Zn and Mn status were noticed in Block 11 (0.92 mg kg^{-1}) and Block 3 (49.72 mg kg^{-1}), respectively. The highest Cu and Fe status were recorded in Block 1 (6.93 mg kg^{-1}) and Block 5 (29.96 mg kg^{-1}), respectively. Among the different micronutrients Zn recorded below the critical level and Cu, Fe and Mn recorded above the critical level. The large iron contents of the soil near the paper mill might have been contributed by the fly ash (containing > 5% Fe_2O_3) dumping in the low-lying areas [24]. It is evident that the presence of certain heavy metals like iron and manganese in agricultural soil greatly influences the availability of the nutrients for plant growth [32].

3.4 Effect on Soil Biological Properties

The microbial biomass carbon was ranged from 0.99 to 29.7 µg CO_2-C g^{-1} with highest microbial biomass carbon was noticed in Block 12 (29.7 µg CO_2-C g^{-1}) (Table 4). Ramesh [28] reported that available phosphorus content of effluent treated soils varied from 0.99 to 2.48 µg CO_2-C g^{-1} with the mean value of 1.60. When compared to above findings the MBC was increased over a period of time by application of paper board industry effluent under agroforestry system. Microbial biomass carbon in soil is normally related to the organic C content of the soil [33]. Microbial biomass C typically comprises of 1-4% of total organic carbon [14] whereas MBC content in the studied soil was less than 1% of total organic carbon. In effluent irrigated soils, Effluent irrigation for several years might have adversely affected MBC in these soils. These observations suggest that a proportionately higher amount of non-microbial carbon was accumulated in the organic carbon fraction of the clayey soils. This was probably be due to decreased decomposition and greater stabilization of organic carbon in soils with higher clay content as was reported by Nowak and Nowak [34].

Application of paper board industry effluent to agroforestry changes in soil biological and biochemical properties. The bacterial population were ranged from 4×10^6 to 53.5×10^6 CFU g^{-1}, fungi population were ranged from 1.0×10^5 to 22.5×10^5 CFU g^{-1} of soil and actinomycetes population were ranged from 6×10^4 to 202×10^4 CFU g^{-1}. Ramesh [28] reported that application of paper board industry effluent increases the bacteria, fungi and actinomycetes population under agroforestry system. Srinivas et al. [35] noted that in general, there is a positive relationship between soil C content and soil microbial biomass, and concluded that any practice that decrease the amount and incorporation of organic residues into the soil decreases biological activity. In general the acidification exerts a detrimental effect on microbial community decreases the microbial biomass [36]. The changes in soil enzyme activities can be attributed to the increase in OC, MBC, available water content and pH of the agroforestry soil.

The enzymatic activities *viz.,* urease, phosphatase and dehydrogenase (Table 4) were ranged from 14.0 to 35.0 µg NH_4-N g^{-1} h^{-1}, 33.06 to 47.58 µg p-nitrophenol g of $soil^{-1}$ h^{-1} and 0.02 to 0.82 µg TPF g of $soil^{-1}$ day^{-1} respectively. The highest urease status was recorded at Block 1 (35.0 µg NH_4-N g^{-1} h^{-1}) followed by Block 9 (28.0 µg NH_4-N g^{-1} h^{-1}). The highest phosphatase activity was recorded at Block 2 (47.58 µg p-nitrophenol g of $soil^{-1}$ h^{-1}) followed by Block 3 (39.63 µg p-nitrophenol g of $soil^{-1}$ h^{-1}). The highest dehydrogenase activity was noticed in Block 6 (0.82 µg TPF g of $soil^{-1}$ day^{-1}) followed by Block 1 (0.54 µg TPF g of $soil^{-1}$ day^{-1}). Ramesh (2019) reported that there is a increase in urease and phosphatase activity and decrease in dehydrogenase activity by application of paper board effluent irrigation under agroforestry over a period of time.

Table 4. Impact of paper board industry effluent on biological properties of soil Samples

Particular	Range	Mean
MBC (µg CO_2C g^{-1} soil)	0.99-29.7	13.28
Bacteria (× 10^6 CFU g^{-1})	4.0-53.5	33
Fungi (× 10^5 CFU g^{-1})	1.0-22.5	6.3
Actinomycetes (× 10^4 CFU g^{-1})	6.0-202.0	61.67
Urease (µg NH_4 N g^{-1} soil h^{-1})	14.0-35.0	21.0
Phosphatase (µg of p-nitrophenol g of $soil^{-1}$ h^{-1})	33.06-47.58	35.80
Dehydrogenase (µg TPF g of $soil^{-1}$ day^{-1})	0.02-0.82	0.24

4. CONCLUSION

This study clearly indicated that the differences in application of paper board industry effluent changes in soil quality under agroforestry system. Paper board industry effluent increased the soil organic carbon, available phosphorus, available potassium, phosphatase activity, urease activity, soil microbial population (Bacteria, Fungi and Actinomycetes) and decrease the pH, available nitrogen and dehydrogenase activity under agroforestry system although there is no variation among EC. These data may be useful for concerned agencies in taking up appropriate measures for effluent usage in agroforestry system. Hence, treated effluent is now considered as a potential source of water to supplement the fresh water supplies.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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