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Impact of pulp and paper mill effluent on physico-chemical properties of soil

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ABSTRACT

Water requirement to meet agriculture, domestic, industrial and other demands indicate the need for regeneration of waste water. Industrial waste water is being used in dry areas. Waste water of pulp and paper industry (brown with unpleasant smell) is usually alkaline in nature, has high suspended solids, total solids, COD, BOD and toxic odorous substances. It was observed in the study areas that the effluent of paper and pulp mill altered the physico-chemical characteristics of the soil. Irrigation with paper and pulp mill effluent has lead to increase the soil pH (6.6-9.0), electrical conductivity (0.41-0.52 dSm^{-1}), organic carbon (3.2-5.9 gkg^{-1}) and available nutrients. The concentration of N, P, K and Na increased in the soil after irrigation with effluent as compare to irrigation with well water. Soil samples has been collected from the affected areas and from the sites where irrigation done with the help of well water. Irrigation with effluent of pulp and paper mill in this area has lead to a heavy build up of contaminants in the soil. Heavy metals were found not to be in permissible limits.

Keywords: Irrigation, organic carbon, well water, heavy metals, BOD

INTRODUCTION

Land application of waste water is a preferred alternative for its disposal, since soil is believed to have a capacity for receiving and decomposing wastes and pollutants, where organic materials are stabilized through the activity of microbial flora in the soil. The application of waste water from pulp and paper industry leads to the deterioration of soil physical, chemical and biological properties. Pulp and paper industry in the country discharge huge volumes of highly coloured and toxic waste water in the environment and categorized as one of the 17th most polluting industries in the country. 330 m^3 waste water is let out per ton of paper produced per day [1]. Nearly (75-95%) of fresh water used in the paper and pulp mill is discharged as effluent containing organic and inorganic pollutants and colouring materials. These compounds may enhance the growth of crop plants or retard the growth. Yamunanagar is the 2nd biggest industrial town in Haryana. There are many large industrial units established and many of these industries discharges their waste water directly on land for irrigation or in the main drain without any recommended treatment, which will affect the physico-chemical properties of the soil as well as water bodies.

The secondary treated pulp and paper mill waste water contains slowly biodegradable and non- biodegradable components due to the presence of complex organic substances such as lignin, tannic and phenolic compounds [2] etc. Pulp and paper mill situated in Yamunanagar used kraft method for pulping. Generally combined waste water from pulp and paper mill has pH ranging from (7.2-9.4). The pH was alkaline [3] with high electrical conductivity. The combined waste water has BOD: N: P in the proportion of (100: 2: 0.5) which indicated that the waste water is deficient in nitrogen and phosphorous for aerobic treatment [4]. The effluent containing rich organic carbon contents was reported [5]. The higher concentration of calcium, magnesium, sodium chloride, sulphate and bicarbonate were reported. Combined effluent has high amount of heavy metal ions and it was found that they were present in the order of Zn>Cu>Pb>Ni>Co>Mn [6]. Effluent of pulp mill also shows low nutrient content with considerable amount of chloride, sulphate and polyphenols.

Paper mill waste water has appreciable concentration of carbonate and bicarbonate alkalinity and exhibits a tendency to precipitate calcium in the soil as $CaCO_3$, thus increased the resultant proportion of sodium to calcium and magnesium and sodium adsorption ratio of the soil solution. Irrigation with undiluted paper mill effluent led to increased pH, electrical conductivity, organic carbon, and available nutrients. The concentration of N, P, K and Na increased in all soil after irrigation with effluents as compare to irrigation by well water. Therefore, waste water from these industries can be subjected to physical, chemical and biological methods, before disposal on land or into various water bodies. The dark colour of the effluents must be removing because it inhibits the natural process of photosynthesis in streams due to absence of sunlight. Activated sludge process removes ($1/3^{rd}$) of the colour in the waste water by absorption on the sludge. Clay and alum was used for the removal of colour from waste water of pulp mill [7]. Pyrolized char from paper mill sludge was also reported for colour removal from black liquor of pulp mill [7].

Indiscriminate used of partially treated pulp mill waste water directly on land for irrigation must damage the soil health in Yamunanagar areas. In view of this, the present study was undertaken to characterize the physico-chemical behavior of pulp and paper mill waste water and its impact on the physico-chemical properties of the soil with effluent irrigation as compared to the irrigation with well water.

MATERIALS AND METHODS

Pulp and Paper mill and the experimental fields are located in the industrial area of twin cities Yamunanagar and Jagadhri, Haryana, India. The effluent of pulp and paper mill and well water from the adjoining wells were collected and various physico-chemical studies i.e. pH, conductivity, alkalinity, free CO_2, total hardness, permanent hardness, temporary hardness, total solids, total dissolved solids, total suspended solids, chloride contents, DO, BOD, COD, calcium, magnesium were undertaken by using the standard methods of water analysis [8]. Representative surface soil samples (0-15 cm) and subsurface soil (15-30 cm) collected from effluent and well water irrigated fields in different seasons. These soil samples were air dried ground with the help of wooden pestle mortar and then passed through 2 mm stainless steel sieve. After mixing thoroughly these soil samples were stored in polythene bags and used for various physical and chemical analysis using the standard methods of soil analysis [9]. pH and electrical conductivity were determined in (1:2) soil water suspension with the help of glass electrode pH meter and conductivity meter bridge respectively. Organic carbon was estimated by following the Walkly & Black rapid titration method as described by Jackson [10]. Total Phosphorous was estimated [11]. Nitrogen was determined by Kjeldahl's method [12]. Potassium and sodium was determined in ammonium acetate extract using flame photometer [12]. DTPA extraction method was used to determine heavy metals with the help of atomic absorption spectrophotometer [13].

RESULTS AND DISCUSSION

The colour of the effluent from pulp and paper mill was brown with unpleasant smell. Colour of waste water is due to the presence of lignin and their derivatives which are not easily biodegradable and hence increase BOD and COD level in the waste water. pH value of the effluent was (7.9-8.5) with high electrical conductivity(1.24-1.92 dSm^{-1}). The effluent contained considerable amount of total solids suspended and total dissolved solids in the present studies, it varied from (2420-2560 mgL^{-1}), (436-526 mgL^{-1}) and (1908-2124 mgL^{-1}) in different seasons. It is an important parameter for evaluating the suitability of effluent for irrigation purpose because these total solids might clog both the solid pore and component of water distribution system. The pH of effluent was alkaline. Paper mill effluent has appreciable concentration of carbonate and bicarbonate alkalinity and exhibits a tendency to precipitated calcium in the soil as $CaCO_3$, thus increased the proportion of sodium to calcium and magnesium and sodium absorption ratio of the soil solution as compare to well water samples. The high value of turbidity in effluent led to very high biochemical oxygen demand in different season which ranged from (5600-6200 mgL^{-1}). Similarly chemical oxygen demand of the effluent was very high (6780-7432 mgL^{-1}) whereas it was very low (6.0 mgL^{-1}) and (12.8 mgL^{-1}) resp. for well water (Table 1) similarly total hardness (2685-2758 mgL^{-1}) and permanent hardness of effluents (1448-1582 mgL^{-1}) were also very high as compare to well water (660 mgL^{-1}) and (345 mgL^{-1}). The cationic concentration Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} was relatively high (128 mgL^{-1}, 78 mgL^{-1}, 72 mgL^{-1}, 48 mgL^{-1}) in the effluent than well water (22 mgL^{-1}, 14 mgL^{-1}, 16 mgL^{-1}, 9 mgL^{-1}). The cationic concentration was higher in summer season followed by winter and rainy seasons. The similar observation was also reported [14].

Table 1: Physico-chemical Studies of Pulp and Paper Mill Effluent and Adjoining Well Water

Parameters	Seasons			Mean	Well water
	Summer	Rainy	Winter		
Temperature	38	28	32	32.6	29
Colour	Brownish grey	Brownish	Brownish grey	--	--
Odour	Unpleasant	Unpleasant	Unpleasant		
pH	8.5	7.9	8.2	8.2	7.5
EC (dSm^{-1})	1.92	1.24	1.81	1.65	0.34
Total solids (mgL^{-1})	2478	2560	2420	2486	240
Dissolved solids(mgL^{-1})	1951	2124	1908	1994	110
Suspended solids(mgL^{-1})	527	436	512	491	130
DO(mgL^{-1})	2.45	4.8	3.60	3.61	6.79
BOD(mgL^{-1})	6200	5600	6198	5999	6.0
COD(mgL^{-1})	7432	6780	7124	7112	12.8
Total hardness(mgL^{-1})	2758	2685	2724	2722	660
Permanent hardness(mgL^{-1})	1582	1448	1548	1526	345
Temporary hardness(mgL^{-1})	1176	1237	1176	1196	315
Calcium (mgL^{-1})	128	98	112	112	22
Magnesium (mgL^{-1})	78	54	62	64	14
Sodium (mgL^{-1})	72	58	66	66	16
Potassium (mgL^{-1})	48	34	42	41	9

The results regarding the irrigation with paper mill effluent and its effects on the physical and chemical properties of soil and irrigation with well water are presented in (Table 2 & Fig.1). The data shows pH of the soil ranged from (6.6-9.0) and (7.5-9.2) in surface and subsurface samples as compare to well water irrigated soil from (7.2-8.0) and (7.2-8.1) resp. The electrical conductivity for surface and subsurface varied from (0.41-0.52 dSm^{-1}) and (0.32-0.46 dSm^{-1}) as compare to well water (0.26-0.32 dSm^{-1}) and (0.26-0.30 dSm^{-1}) resp. The organic carbon in general is higher in surface than subsurface soil. There was increased in organic carbon content due to effluent irrigation and it ranged from (3.2-5.9 gkg^{-1}) and (2.8-4.2 gkg^{-1}) whereas in surface and subsurface of well water irrigated soil it was (1.2-2.4 gkg^{-1}) and (1.6-2.0 gkg^{-1}). The organic carbon frequently clogs the pores and decreases the hydraulic conductivity causing soil sickness.

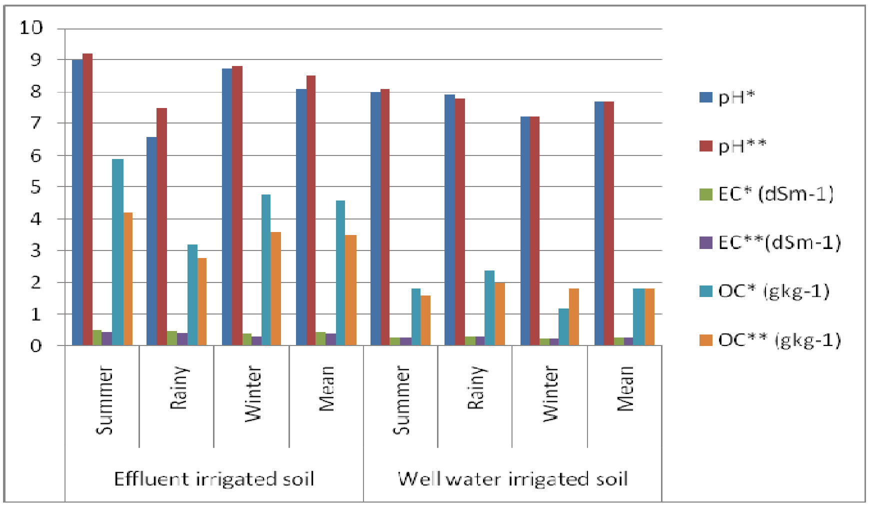

Figure 1

Table 2: Effect of Pulp and Paper Mill Effluent on Physico-chemical Properties of Soil and Soil Irrigated with Well Water

Parameters	Effluent irrigated soil				Well water irrigated soil			
	Summer	Rainy	Winter	Mean	Summer	Rainy	Winter	Mean
pH	9.0*	6.6	8.7	8.1	8.0	7.9	7.2	7.7
	9.2**	7.5	8.8	8.5	8.1	7.8	7.2	7.7
EC(dSm^{-1})	0 .52*	0.48	0.41	0.47	0.28	0.32	0.26	0.28
	0.46**	0.42	0.32	0.4	0.27	0.30	0.26	0.27
Organic Carbon (gkg^{-1})	5.9*	3.2	4.8	4.6	1.8	2.4	1.2	1.8
	4.2**	2.8	3.6	3.5	1.6	2.0	1.8	1.8

* *indicate the value in surface soil (0-15 cm); ** indicate the value in subsurface soil (15-30 cm)*
Each value is the average of four samples

The soil irrigated with pulp and paper mill effluent has higher concentration of available N, P, K and Na (Table-3 & Fig.2). In surface layer available N ranged from (128.26-222.28 $kgha^{-1}$) and in subsurface from (118.42-204.16 $kgha^{-1}$). In contrast to this N content in well water irrigation surface soil is from (70.65-120.16 $kgha^{-1}$) and in subsurface soil is from (68.28-116.12 $kgha^{-1}$). Available P in the soil irrigated with effluent has higher (8.24-17.42 $kgha^{-1}$) than well water irrigated soil (5.98-9.48 $kgha^{-1}$). Effluent irrigated soil has higher content of available K (180-430 $kgha^{-1}$) than well water irrigated soil (130-330 $kgha^{-1}$). Similarly higher content of available Na (228-292 $kgha^{-1}$) as compare to well water irrigated soil (188-224 $kgha^{-1}$).

Table 3: Effect of Pulp and Paper Mill Effluent on Concentration of N, P, K & Na of Soil and Soil Irrigated with Well Water

Parameters	Effluent irrigated soil				Well water irrigated soil			
	Summer	Rainy	Winter	Mean	Summer	Rainy	Winter	Mean
Total N ($kgha^{-1}$)	220.36*	222.28	128.26	190.3	110.48	120.16	70.65	100.43
	186.48**	204.16	118.42	169.68	108.36	116.12	68.28	97.58
Total P ($kgha^{-1}$)	14.46*	8.24	17.42	13.37	8.98	8.42	9.48	8.96
	12.40**	10.48	16.28	13.05	4.46	7.86	8.94	7.08
Available K ($kgha^{-1}$)	180*	348	430	319	130	280	330	247
	160**	324	380	288	180	260	310	250
Available Na ($kgha^{-1}$)	228*	292	276	265	188	224	192	201
	184**	268	229	227	192	228	220	213

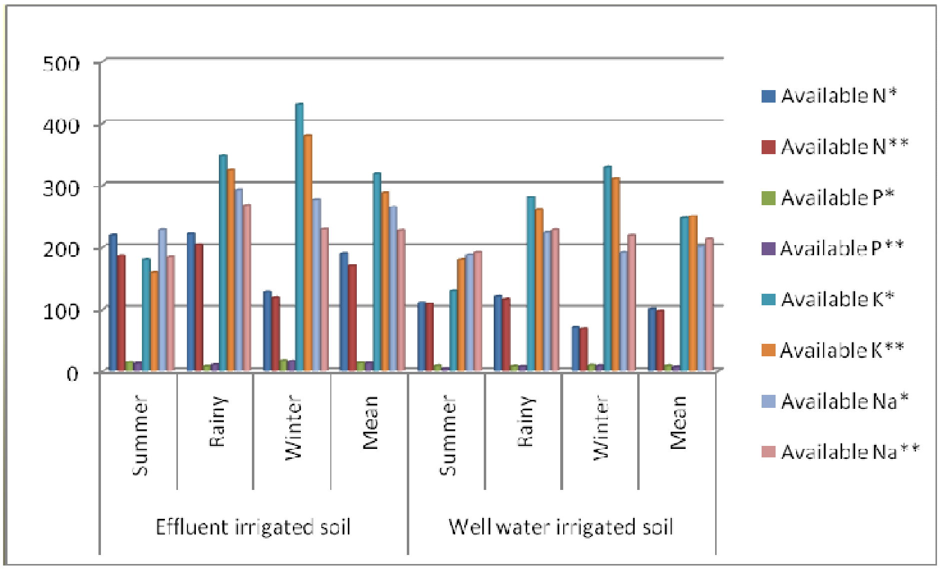

Figure 2

The surface layer has higher concentration of heavy metals were found higher in surface layer than the subsurface layer of soil (Table 4 & Fig 3) owing to their chelating with organic carbon and did not move downwards. Concentrations of Zn^{2+}, Cu^{2+}, Fe^{2+} and Mn^{2+} varied from (6.8-14.48 $mgkg^{-1}$), (3.72-8.84 $mgkg^{-1}$), (10.42-16.46 $mgkg^{-1}$) and (4.42-12.45 $mgkg^{-1}$) respectively in effluent irrigated soil and (1.24-3.24 $mgkg^{-1}$), (3.48-6.28 $mgkg^{-1}$), (7.46-10.42 mgkg^{-1}) and (1.96-4.28 mgkg^{-1}), respectively in well irrigated soil, similar observation has also been reported [15]. Concentration of these elements was higher in summer season.

Table 4: Effect of Pulp and Paper Mill Effluent on Concentrations of Heavy Metals in Soil and Soil Irrigated with Well Water

DTPA extractable (mg kg^{-1})	Effluent irrigated soil				Well water irrigated soil			
	Summer	Rainy	Winter	Mean	Summer	Rainy	Winter	Mean
Zn^{2+}	14.48*	12.38	6.80	11.22	3.24	1.24	2.80	2.42
	12.28**	10.42	5.36	9.35	2.98	1.18	2.44	2.2
Cu^{2+}	8.84*	3.72	5.26	5.94	6.28	3.48	5.64	5.13
	6.24**	2.98	4.42	4.54	5.42	2.88	4.98	4.42
Fe^{2+}	16.46*	10.42	12.38	13.08	10.42	7.46	9.84	9.24
	14.22**	8.36	10.94	11.17	9.80	6.88	8.24	8.30
Mn^{2+}	12.45*	4.42	10.88	9.25	4.28	1.96	3.64	3.29
	11.34**	3.98	10.42	8.58	3.98	1.42	2.88	2.76

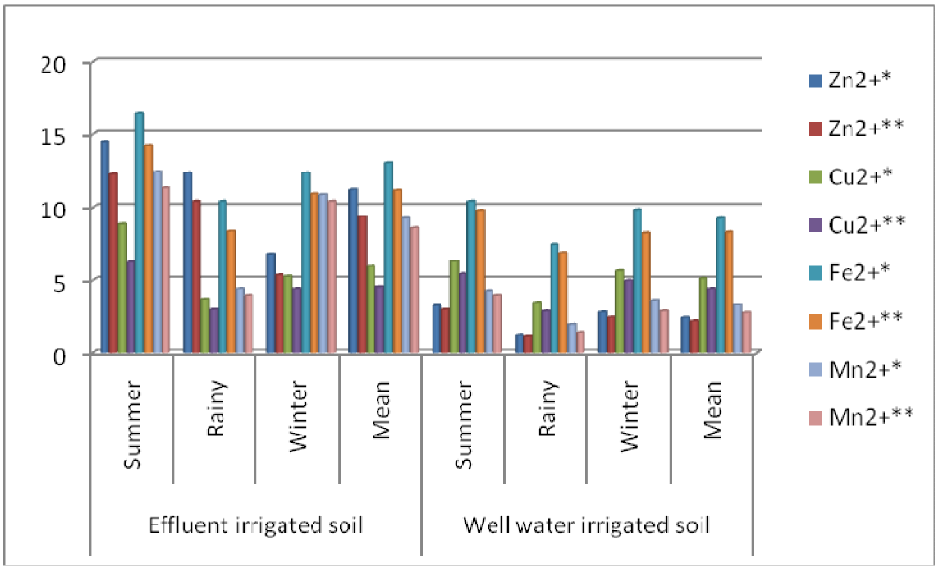

Figure 3

CONCLUSION

It is a common practice in India to dispose effluent of pulp and paper mill on land for irrigation but that effluent should be treated before its direct disposal on land. BOD loading is usually limited to (250 kgha^{-1}day^{-1}). pH should be between (6.0-9.0) and sodium adsorption ratio should be less than 8. Pulp and paper mill effluent discharge on land in Yamunanagar contained high BOD, COD, TDS, total hardness and suspended solids which were increasing the pH, nitrogen, phosphorous, sodium, potassium and heavy metals in the soil but use of effluent for irrigation may pose health problem if used for longer period of time without giving recommended treatment. The treated effluent did not cause any adverse effect on physico-chemical property of soil but it will increase the soil fertility due to the presence of some available nutrients. Therefore, recycling and reuse of pulp and paper mill effluents in agriculture is not only helpful for conserving the water for irrigation, also the plant nutrients. So, it is essential that the implification of the use of industrial effluents in the crop field and their effect should be analyzed before recommending for use in the irrigation.

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