International Journal of Plant & Soil Science

Volume 35, Issue 19, Page 444-453, 2023; Article no.IJPSS.104551
ISSN: 2320-7035

Paper Mill Effluent is an Alternate for Irrigation and Nutrient Sources in Improving Soil Health and Agricultural Productivity

V. Dhanushkodi [a*], R. Balamurugan [a], M. Baskar [a], S. Rathika [a], S. Shenbagavalli [a], A. Thanga Hemavathy [a], R. Anitha [a] and S. Sangeetha [a]

[a] Anbil Dharmalingam Agricultural College and Research Institute, Trichy District, Tamil Nadu Agricultural University, Tamil Nadu, India.

Authors' contributions

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

Article Information

DOI: 10.9734/IJPSS/2023/v35i193569

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/104551

Review Article

Received: 09/06/2023
Accepted: 13/08/2023
Published: 22/08/2023

ABSTRACT

Consumption of huge fresh water and the generation of a huge volume of toxic wastewater are two most important environmental concerns associated with paper industries. Hence, it is necessary to study the impact of these effluents on soil and crop before they recommended for agricultural purpose. Paper mill effluent is rich in dissolved solids as well as varying amounts of suspended organic materials. Besides, it contain some trace metals like Hg, Pb, and Cr. Discharge from effluents through paper mill, which contain bleach and black liquor, directly reached water bodies, thus causing serious environmental related issues. It contains recalcitrant dissolved organic matter and further it induces a high biochemical oxygen demand. On the other hand, treated paper mill

**Corresponding author: E-mail: dhanushselgi@yahoo.com.au;*

effluent is considered a resource in agriculture and that can be applied for productive uses since it contains nutrients that have the potential for use in agriculture and other activities. So, use of this wastewater efficiently for agricultural crops can be an alternated source for fertilizer as well as irrigation water.

Keywords: Paper mill effluent; toxic elements; treatment; nutrient source; crop yield.

1. INTRODUCTION

"Water is the most valuable resources in the world. Nowadays, in many places water resources are gradually becoming polluted by the addition of huge amounts of sewage, industrial waste, and effluents. These waste and effluents contain materials with varying properties, from simple nutrients to highly toxic substances. The discharge of industrial effluents with varying amounts of pollutants has altered the land and water quality. Among the different major industries, the paper industry is one of the polluter of the environment. There are nearly 700 paper mills in India, with an installed capacity of paper production about 701.4 lakh metric tonnes. During paper production, the mills release a large amount of wastewater containing various physical and chemical agents. They are discharged into land or nearby water bodies. The polluted water is being used for irrigation by nearby farmers. Nowadays, treated effluent is considered a alternates to water and nutrient resource, which may prove beneficial for plant growth. These effluents fall in borderline as saline water, but they can be considered as potential source for irrigation" [1]. "The treated paper mill effluent had higher biological oxygen demand (BOD) and chemical oxygen demand (COD) values with low NPK, while the contents of sodium, calcium, sulphate, and chloride were higher" [2]. "Paper mill effluent irrigation has the greatest potential in increasing crop yields with significant savings in water and nutrients. In the present paper, an attempt has been made to explore the beneficial and adverse effects of using paper mill effluent in soil and crops. Paper making techniques was originated from China and first handmade paper mill India was started during 14th century. Further. More than 10 paper mills were commissioned in this period, and by 1931, the production capacity had reached 45,600 metric tonnes" [3].

2. CLASSIFICATION OF PAPER MILLS

"Paper mills are classified based on the raw material used, plant size, and end products manufactured as follows. A. Wood or forest-based mills: In this type indigenous hardwood pulp from bamboo, eucalyptus and imported pulp etc. are used. Agro-residue-based mills: In this class agricultural residues such as rice straw, wheat, sarkanda grass, bagasse, jute, etc. used as raw materials. Wastepaper-based mills: These mills use imported and indigenous wastepaper, corrugated waste paper, kraft paper, and waste cuttings as raw materials" [4].

3. CHEMICAL CONSTITUENTS OF RAW MATERIALS AND WASTEWATER

"Chemical constituents of paper and pulp industry effluent are given in Table 1. These large quantities of effluents need to be characterized for evolving proper treatment strategy prior to their disposal" [5]. "The manufacturing process in pulp and paper making uses a large amount of fresh water and most notorious sources of industrial pollution. The Ministry of Environment and Forests, Government of India, has categorized the pulp and paper industry as one of the twenty most polluting industries" [6]). "The exact chemical composition of pulp and paper mill effluent is complex and unclear. The pulp and paper mill effluent are contains mostly degrading products of lignin, cellulose, hemicellulose, and wood extractives" [7].

4. DIFFERENT PROCESS IN PAPER PRODUCTION

The typical pulp and paper manufacturing processes involved and different wastewaters generated are shown in Fig. 1.

4.1 Wastewater Treatment

The wastewater treatments are involved both physicochemical and biological methods. Effluent discharge standards for pulp and paper mills under environmental (Protection) Act 1986 is given in Table 2.

4.1.1 Physiochemical treatment

- "Several physicochemical colour removal methods, such as adsorption, rapid sand filtration, chemical precipitation, membrane

Table 1. The organic composition and COD characteristics of pulp and papermill effluents [8]

S.No.	Wastewater	COD (mg/L)	Organic composition % COD	Potential inhibitory compounds
1.	Wet debarking	1300-1400	Tannins 30-35, monomeric phenols 10-20, simple carbohydrates 30-40, resin compounds 5,	Tannins, resin acids
2.	Sulphite spent liquor	120000-220000	lignosulphates 50-60, carbohydrates 15-25	-
3.	Sulphur evaporator condensate SEC	7500-50000	Acetic acid 33-60, methanol 10 -25, fatty acids < 10	Sulphur, organic sulphur
4.	Chlorine bleaching	900-2000	Chlorine lignin polymers 65 -75, Methanol 1 -27	Chlorinated phenols, resin acids
5.	Kraft evaporator condensate KEC	1000-33600	Methanol 60-90	Sulphur,resinacids,fattyacids,volatile terpenes
6.	TMP effluent	1000-5600	Carbohydrates 25-40	Resin acids
7.	CTMP effluent	2300-13000	Polysaccharides 10-15, carbohydrates 25-45, Organic acids 35-40	Sulphur,fatty acids

processes, and electrochemical methods, have been developed and reported in the literature in the past" [8].

- Adsorption methods are increasingly being considered for the removal of synthetic organic chemicals, colour-forming organics, and disinfection byproducts.
- "The membrane techniques require pre-treatment and a large capital investment and efficient technologies" [9]. "The application of the electrochemical method is another way to treat the wastewater from cellulose paper production" [10].
- "Chemical precipitation using alum, ferric chloride, and lime has been extensively studied" [11]. "Despite the short detention time and low capital cost, there are some drawbacks reported, such as the high cost of chemicals for precipitation and pH adjustment, voluminous sludge production due to heavy dosages, dewatering and disposing of generated sludge, and high residual cation levels. The chemical precipitation methods are cheap but produce a large quantity of sludge and do not completely remove toxicity" [59].
- Calcium hypochlorite (1–2% of available chlorine) during alkaline extraction reduced the colour of effluent by 84% and chlorinated backwater (having 0.8% residual chlorine) used during brown stock washing without affecting the quality of pulp. Alum, lime, and magnesium sulphate used to reduce colour, biological oxygen demand and chemical oxygen demand by 97%, 68%, and 52%, respectively.

4.1.2 Biological methods

- Biological methods have the potential to eliminate or reduce the problems associated with physicochemical methods. Numerous bacteria have been reported to decompose lignins and lignin derivatives, some of which include Pseudomonas spp., Flavobacteria, Xanthomonas spp., Bacillus spp., Aeromonas spp., Cellulomonas spp., Chromobacteria, etc.
- "A variety of fungi have been proven to be lignin degraders and are classified into white-rot, soft-rot, and brown-rot fungi based on the type of wood decay carried out by these organisms" [12].

- "The white rot fungi are a group of basidiomycetes that possess an active lignolytic enzyme system, which is the most efficient of the microorganisms that degrade lignin and its modified forms" [13]. "In addition to degrading lignin, these fungi are also capable of degrading a variety of environmentally persistent pollutants, such as chlorinated aromatic compounds, heterocyclic aromatic hydrocarbons, synthetic high polymers, and various dyes" [14].
- "Several authors reported on the capacity of different fungal species to remove color from kraft mill effluent" [15,16,17]. [18] reported "on a substantial reduction of colour chemical oxygen demand by the use of the white-rot fungi, *T. versicolor* and *P. chysosporium"* [19]. indicated that "the white-rot fungi P. chysosporium, in combination with other white-rot fungi (*P. sanguineus*, *P. ostreatus*, and *H. annosum*), and with the use of surfactants, were able to remove color and lignin content" [20]. isolated "a fungal species (*Pencillium sp*.) that was able to remove 50% of the AOX and colour from the soft-wood bleachery effluents in a contact time of 2 days" [21]. stated that "s *T. versicolor* and fungal culture filtrate (FCF) efficiently degrade the dissolved and colloidal substances". "The other white-rot fungi such as *Tinctoporia borbonica, Schizophyllum commune, Aspergillus fumigatus,* and *Pleurotus ostreatu*s, among others" [22].

Table 2. Effluent discharge standards for pulp and paper mills under environmental (Protection) Act 1986

S.No.	Category	Standard	Note
1.	Large (writing & printing) pulp and paper mills	200 m³/tonne of paper 150 m³/T	Standards of discharge for the large pulp & paper mills established from 1992 onward to meet standard of 100 m³/tonne of paper
2.	Agro-residue based	200 m³/ tonne of paper	Agro-residue based mills established from January 1992 onward to meet the standards of 150 m³/tonne of paper
3.	Wastepaper based mill	75 m³/tonne of paper	Wastewater based mills established from January 1992 onward to meet the standards of 50 m³/tonne of paper

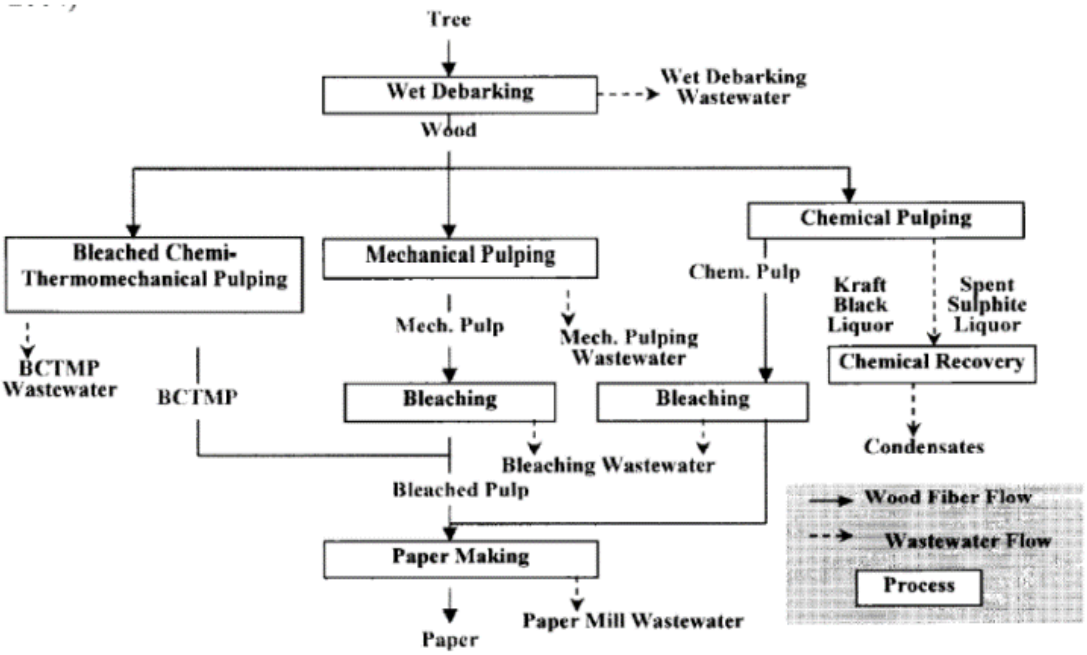

Fig. 1. Different processes involved in pulp and paper production and corresponding wastewater generated [4]

5. EFFECT OF UNTREATED EFFLUENT ON AGRICULTURE

5.1 Effect of Untreated Effluent on Land Quality

"Elements such as magnesium, sodium chloride, and sulphur, which are also common in pulp mill wastewater, can cause nutrient imbalances in crops, increase soil salinity, deteriorate soil structure, and ultimately lower crop productivity in the long run" [23]. Higher values of EC, organic carbon, available K, exchangeable cations (Ca^{2+}, Mg^{2+}), exchangeable anion (Cl-, HCO_3^-), and micronutrient cation (Cu^{2+}) have been reported in soils being irrigated by paper and pulp industry effluents.

5.2 Effect of Untreated Effluent on CROPS

Pulp and paper mill effluent is also responsible for affecting the quality of crops due to irrigation with polluted water, which damages the soil, growth, quality, and yield of the crop (Table 3).

5.3 Effects of Untreated Effluent on Water Bodies

"The dark colour and high turbidity due to suspended solids can cause problems with both water opacity and blanketing of river or lakebeds and can reduce photosynthetic activity in aquatic plants" [27,28]. Severe blanketing may result in anaerobic decomposition under the blanket, releasing hydrogen sulphide into aquatic ecosystems. Therefore, it becomes necessary to remove colour and toxicity before they can be accepted into surface waters.

5.4 Effect of Untreated Effluent on Soil Biology

Deleterious effect on water bodies is given in Table 5. The paper mill effluents adversely affect the germination of rice seeds and reduce shoot weight [28, 29 &30]

5.5 Effect of Treated Effluent on Soil Properties

The soil has both inherent and dynamic properties. In India, a tropical country, drought conditions and the depletion of groundwater sources necessitate an alternate irrigation source and the positive impact of treated paper mill effluent is given Table 6. The various irrigation sources can be augmented by using the effluent from the pulp and paper industry.

The reuse of industrial effluents for irrigation purposes is an alternate and effective waste disposal method commonly called "agro-recycling" where wastewater and plant nutrients could be recycled to diminish pollution and accomplish additional income (Table 6). The use of industrial effluents for agricultural purposes involves two main principles: the use of soil as a treatment system to reduce pollution of surface water and the use of wastewater as a supplementary source of irrigation. In certain cases, thus, the lack of nutrients can also perhaps be compensated to a limited extent by industrial effluent irrigation.

The adverse effects of effluent irrigation from paper factories could be alleviated by resorting to the application of N, P, and K along with organic and inorganic amendments such as press mud, farmyard manure, and gypsum [48]. Subsequent research on paper mill waste utilisation in agriculture [49] has revealed numerous benefits with no deterioration in crop produce and increased the productivity of various crops (Fig. 2). Part of agricultural land is currently under irrigation, hence to improve agriculture efficient water application technology needs to be critically considered as water scarcity is a major constraint in the agriculture [58].

Table 3. Negative impact of untreated effluent on crops

S. No.	Negative impact
1.	Decrease germination percentage and seedling growth in crops [23]
2.	Inhibiting effect on the germination of crops [24]
3.	Reduces crop growth and gives severe adverse effect on soil properties [25]
4.	Seed germination in Sunflower and maize [26]
5.	Germination of seeds in paddy [28]
6.	Reduction in shoot weight (44%) in paddy [29]
7.	Germination percentage and yield in paddy [30]

Table 4. Effect of untreated effluent on water bodies

S.No.	Impact on water bodies
1.	Accumulate metal (loid)s, salts, and organic compounds might be toxic to soil fauna and flora [30]
2.	Antibiotics are bioactive compounds affecting soil biological activity [31]
3.	Wastewater-borne microorganisms might compete with indigenous microbial communities [32]
4.	Microbiological population from aerobic to anaerobic microorganisms due to short-term oxygen depletion of the topsoil decrease in oxygen diffusion rate [33]
5.	Stimulation of copiotrophic bacteria was observed in the same long-term wastewater irrigation area [34,35]

Table 5. Effect of treated effluent application on improvement in soil physical and chemical properties

S.No.	Effect of treated effluent application on improvement in soil physical and chemical properties
1.	Soil physical and hydraulic properties [36]
2.	Soil aggregate stability [37]
3.	Bulk density and porosity induced [38, 39]
4.	Actinomycetes and fungi population [40]
5.	Soil nutrients status [41]
6.	N, PO4, Na, K, Mg, and Ca ([42]
7.	Na, and extractable S, Zn, Fe, Mn, Pb, and Ni [43]
8.	Soil pH and organic C, N, P, and K. [44]
9.	Organic carbon (3.2–5.9 gkg1), and concentrations of N, P, K, and Na [45]
10.	Long-term wastewater irrigation affects total microbial biomass and/or soil enzyme activities in different soils [46]
11.	Increase in bacterial counts and bacterial activity [47]
12.	Increased the soil bacteria, actinomycetes, fungi, rhizobia, and yeasts, and the populations of soil microorganisms [44])

Table 6. Effect of treated effluent on crop growth

S.No.	Effect of paper mill effluent irrigation on positive impact of crop growth
1.	Germination percentage, plant height, crop growth rate (CGR), and relative growth rate (RGR), of sorghum, maize, and sunflower [47]
2.	Pod yield and oil content of the groundnut [48]
3.	Yield parameters of tomato, viz., number of fruiting clusters, fruit weight, and fruit yield were higher [49]
4.	Quality traits of bhendi and amaranthus improved [50]
5.	Cowpea yield by up to 28 percent and the nodule formation [51]
6.	Higher chlorophyll, protein content, root length, shoot length, leaf area, and total biomass in black grammes at a 10% concentration of paper mill effluent irrigation. [42]
7.	Bacterial, fungal, and nodule counts had also increased in blackgram up to 50% concentration [52]
8.	Germination and growth of peas[53]
9.	Pod (2608 kg ha-1) and kernel yield (1534 kg/ ha) [54]
10.	Length of seedlings after germination in vegetable crops [55]
11.	Yield and biominerals viz., Ca and Fe, of banana [56]
12.	Paper mill effluent on germination, seedling growth and chlorophyll content in Zea mays L [57]
13.	Increase in chlorophyll content, plant height, shoot and root biomass, grain yield etc. in *Triticum aestivum* L. [28]

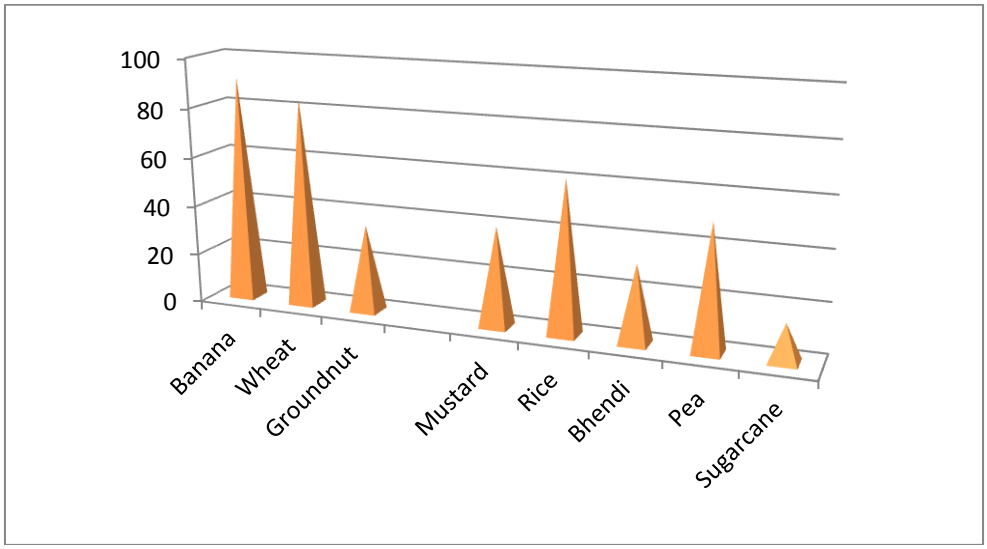

Fig. 2. Effect of paper mill effluent on yield in various crops (%)

6. CONCLUSION

Several studies have been done on the impact of various industrial effluents on various crops. Paper mill effluent is reported to be rich in mineral nutrition which could improve growth and yield. Maintaining good soil quality and minimizing soil pollution and degradation are of fundamental importance to preserving agriculture and developing the economy of the country. For enhancing food production, proper and effective use of available land, water and fertilizer resources are essential. Nowadays, treated wastewater is considered a potential water and nutrient resource because it contains a considerable amount of nutrients, which may prove beneficial for plant growth. Raw paper mill effluent has an adverse effect on the growth and development of crops and soil, but treated paper mill effluent in lower concentrations is no toxic on crop and also in soil. The beneficial effects of effluent on crops are proved by many studies. Hence, it can be recommended for appropriate dilution of the effluent of a paper mill for agricultural crops and it could be used for irrigation in agricultural fields to enhance crop productivity. Thus, from the foregone review, it could be concluded that the treated paperboard mill effluent and solid wastes could be used for crop production without any adverse effect on yield and quality of produce.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gomathi V, Oblisami G. Effect of pulp and paper mill effluent on germination of tree crops. Indian Journal of Environmental Health. 1992;34(4):326-8.
2. Sharmila S, Kalaichelvi K, Rajeswari M. Effect of paper mill effluent on soil, growth and biochemical constituents of *Vigna radiata* (L.) Wilczek. Asian Journal of Bio Science. 2009;4(1):79-82.
3. Singh P, Thakur IS. Colour removal of anaerobically treated pulp and paper mill effluent by microorganisms in two steps bioreactor. Bioresource Technology. 2006;1;97(2):218-23.
4. Kumaraswamy NK, Singh P, Sarethy IP. Aerobic and anaerobic treatment of paper industry wastewater. Research in Environment Life and Science. 2011; 4(4):141-8.
5. Shankar Singh U, Tripathi YC. Characteristics and treatment of pulp and paper mill effluents–a review. International Journal of Engineering and Technical Research. 10(-11):313-318.
6. Singh P, Jain P, Verma R, Jagadish RS. Characterization of lignin peroxidase from Paecilomyces species for decolorisation of pulp and paper mill effluent. Journal of Scientific and Industrial Research. 2016;63:941-944.
7. Jukka A, Rintala JA, Puhakka D. Anaerobic treatment in pulp and paper mill waste mamagement: A review. Bioresource Technol.1994;47:1-18.

8. Srivastava N, Singh P. Degradation of toxic pollutants from pulp & paper mill effluent. Discovery. 2015;40(183):221-7.
9. Manjunath DL, Mehrotra I. Removal of reactive dyes using alum lignin sludge. Indian J Environ Health.2019;23(4):309-315.
10. Christoskova SG, Lazarov LD. Electrochemical method for purification and dissolution of cellulose paper industry wastewater. Environ. Prot. Eng. 1988;14(3-4):69-76.
11. Lathia SG, TW Joyce. Removal of colour from carbonate pulping effluent: the calcium-magnesium coagulation process. TAPPI J. 1986;61(10):67-70.
12. El-Bestawy E, El-Sokkary I, Hussein H, Keela AF. Pollution control in pulp and paper industrial effluents using integrated chemical–biological treatment sequences. Journal of Industrial Microbiology and Biotechnology. 2008; 35(11):1517-29.
13. Pokhrel D, Viraraghavan T. Treatment of pulp and paper mill wastewater—a review. Science of the Total Environment. 2004;333(1):37-58.
14. Ohkuma M, Maeda Y, Johjima T, Kudo T. Lignin degradation and roles of white rot fungi: Study on an efficient symbiotic system in fungus-growing termites and its application to bioremediation. Riken Review. 2001;39-42.
15. Gökçay CF, Dilek FB. Treatment of effluents from hemp-based pulp and paper industry II. Biological treatability of pulping effluents. Water Science and Technology. 1994 ;29(9):165-8.
16. Durán N, Esposito E, Innocentini-Mei LH, Canhos VP. A new alternative process for Kraft E1 effluent treatment: A combination of photochemical and biological methods. Biodegradation. 1994;5:13-9.
17. Sakurai A, Yamamoto T, Makabe A, Kinoshita S, Sakakibara M. Removal of lignin in a liquid system by an isolated fungus. Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology. 2002;77(1):9-14.
18. Prasad GK, Gupta RK.Decolourization of pulp and paper mill effluent by two White-rot fungi. Indian J Environ Health. 1997;39(2):89–96.
19. Saxena N, Gupta RK. Decolourization and delignification of pulp and paper mill effluent by white rot fungi. Indian J Exp Biol. 1998;36:1049–51.
20. Taseli B, Gokcay CF. Biological treatment of paper pulping effluents by using a fungal reactor. Water Sci Technol.1999;40(11–12):93– 9.
21. Zhang X, Stebbing DW, Saddler JN. Enzyme treatment of the dissolved and colloidal substances present in mill white water and the effects of the resulting paper properties. J Wood Chem Technol. 2000; 20(3):321– 35.
22. Sundari S, Kanakarani P. The effect of pulp unit effluent on agriculture. Journal of Industrial Pollution Control. 2001;17(1):83-97.
23. Xiong X, Stagnitti F, Peterson J, Allinson G, Turoczy N. Heavy metal contamination of pasture soils by irrigated municipal sewage. Bulletin of Environmental Contamination and Toxicology. 2001;67: 535-40.
24. Somshekar RK, Gowda MTG, Shettigar SCN, srinath KP. Effect of industrial effluents on crop plants. Indian J. Environ. Health.1984;26(2):136-146.
25. Garg*VK.– Kaushik P. Influence of textile mill wastewater irrigation on the growth of sorghum cultivars. Applied Ecology And Environmental Research 2008;6(2):1-12.
26. Sahai RN, Shukla N, Jabeen S and Saxena PK. Pollution effect of distillery waste on the growth behavior of phaseolus radiates. Environ. Pollution. 1985;37:245-253
27. Singh A, Agrawal SB, Rai JP, Singh P. Assessment of the pulp and paper mill effluent on growth, yield and nutrient quality of wheat (*Triticum aestivum* L.). Journal of Environmental biology. 2002;1;23(3):283-8.
28. Mishra PC, Sahoo S. Agropotentiality of paper mill wastewater. Soil Pollution and Soil Organisms (Ed: PC Mishra), Ashish Publishing House, New Delhi. 1989:97-120.
29. Dutta SK, Boissya CL. Effect of Paper Mill Effluent on Germination of Rice Seed (*Oryza Satira* L. Var Masuri) and Growth Behaviour of its Seedlings. Journal of Industrial Pollution Control. 1996;12:123-8.
30. Müller K, Magesan GN, Bolan NS. A critical review of the influence of effluent irrigation on the fate of pesticides in soil. Agriculture, Ecosystems & Environment. 2007;120(2-4):93-116.
31. Kinney CA, Furlong ET, Werner SL, Cahill JD. Presence and distribution of wastewater-derived pharmaceuticals in soil irrigated with reclaimed water.

Environmental Toxicology and Chemistry: An International Journal. 2006;25(2):317-26.

32. Jatinder Sidhu RA. Gibbs, Goen Ho, I Unkovich. Selection of *Salmonella typhimurium* as an indicator for pathogen regrowth potential in composted biosolids. Letters in Applied Microbiology. 1999;29(5):303-7
33. Blume HP, Horn R. Belastung und Belastbarkeit der Berliner RieselfeldernacheinemJahrhundertAbwasserberieselung. Z. f. Kulturtechnik u. Flurbereinigung. 1982;23, 236–248.
34. Filip Z, Kanazawa S, Berthelin J. Characterization of effects of a long-term wastewater irrigation on soil quality by microbiological and biochemical parameters. Journal of Plant Nutrition and Soil Science. 1999;162(4):409-13.
35. Daniel TC, Bouma J. Column studies of soil clogging in a slowly permeable soil as a function of effluent quality. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America; 1974.
36. Magesan GN. Changes in soil physical properties after irrigation of two forested soils with municipal wastewater. N. Z. J. For. Sci. 2001;31:188–195.
37. Vogeler I. Effect of long-term wastewater application on physical soil properties. Water, air, and soil pollution. 2009;196(1-4):385-92.
38. Surabhi Yadav, Nidhi Yadav. Impact of paper mill effluent on the quality of receiving soil- Asian Journal of Science and Technology. 2017;08(11):6345-6347.
39. Chhonkar PK., Siba Datta HC. Joshi Surendra Pathak. Impact of industrial effluents on soil health and agriculture - Indian experience: Part II-tannery and textile industrial effluents. Journal of Scientific & Industrial Research. 2000;59(6):446-454.
40. Hameed Sulaiman SM, Udayasoorian C. Metals in soil environment and the growth of Eucalyptus seedlings as influenced by paper mill wastes. In. Proc. Environ. Impacts of Metals. International Workshop, Department of Environmental Sciences, Tamil Nadu Agric. Univ., Coimbatore. 1999;22:22-23.
41. Bano S. Impact of paper mill effluent on growth characteristics of Vigna Mungo T-9. IJAR. 2016;2(10):136-41.
42. Giri J, Srivastava A, Pachauri SP, Srivastava PC. Effluents from paper and pulp industries and their impact on soil properties and chemical composition of plants in Uttarakhand, India. J Environ Waste Manag. 2014;1(1):26-30.
43. Kannan K, Oblisami G. Influence of irrigation with pulp and paper mill effluent on soil chemical and microbiological properties. Biology and Fertility of Soils. 1990;10:197-201.
44. Vijay S, Garg UK, Deepak A. Impact of pulp and paper mill effluent on physico-chemical properties of soil. Archives of Applied Science Research. 2014;6(2): 12-7.
45. Barkle GF, Stenger R, Singleton PL, Painter DJ. Effect of regular irrigation with dairy farm effluent on soil organic matter and soil microbial biomass. Soil Research. 2000;38(6):1087-97.
46. Shapir N, Mandelbaum RT, Fine P. Atrazine mineralization by indigenous and introduced Pseudomonas sp. strain ADP in sand irrigated with municipal wastewater and amended with composted sludge. Soil Biology and Biochemistry. 2000;32(7):887-97.
47. Dhevagi P. Studies on the impact of paper mill effluent on agro-ecosystem. PhD [ENS] Dissertation, TNAU, Coimbatore; 1996.
48. Udayasoorian C, Prabu PC. Mini K. Influence of composted bagasse pith and treated paper mill effluent irrigation on groundnut. Madras Agric. J. 2004;91:126-129.
49. Sandana KM. Studies on the effect of liquid and solid wastes from industries and the growth of certain crops. M. Sc. (Env. Sciences) Thesis, Tamil Nadu Agricultural University. Coimbatore; 1995.
50. Malathi G. Impact of treated pulp and paper mill effluent on vegetables-soil ecosystem. M. Sc., (Env. Sciences) Thesis, Tamil Nadu Agric. Univ., Coimbatore; 2001.
51. Prasanthrajan M. Biocompost from paper board mill solid wastes. M. Sc.(Env. Sciences) Thesis, Tamil Nadu Agric. Univ, Coimbatore; 2001.
52. Sharmila S, Kalaichelvi K, Rajeswari M. Effect of paper mill effluent on soil, growth and biochemical constituents of Vigna radiata (L.) Wilczek. Asian Journal of Bio Science. 2009;4(1):79-82.
53. Sharma RK. Effect of paper mill effluent on seed germination and seedling growth of pea-Asian Journal of Environmental Science. 2011;6(1):29-31.

54. Sanjeeva Gandhi M, Udayasoorian C, Natesan R, Ponmani S.performance evaluation of groundnut by treated paper mill effluent irrigation along with various amendments- International Journal of Agricultural Sciences.2010;1:311-319
55. Mahato Rabindra Kumar, Haffij Nafij, Awasthi Shashank, Bhatnagar Tripti. A study on the effect of paper mill effluent on seed germination of vegetables- World Wide. Journal of Multidisciplinary Research and Development. 2022;3(6):20-24
56. Prabakaran C. Effect of treated effluent irrigation on yield and biominerals of banana. International Journal of Engineering Research and Technology. 2020;9(7):1460-764.
57. Choudhury SK, Jha AN, Srivastava DK. Effect of paper mill effluent on seed germination and seedling growth of maize. Environ. Eco. 1987;5(2): 285-287.
58. Assefa T, Jha M, Reyes M, Worqlul AW, Doro L, Tilahun S. Conservation agriculture with drip irrigation: Effects on soil quality and crop yield in sub-Saharan Africa. Journal of Soil and Water Conservation. 2020;75(2):209-217.
59. Singh P, Srivastava N, Singh P, Geetha S, Usharani N, Jagadish RS, Upadhyay A. Effect of toxic pollutants from pulp and paper mill on water and soil quality and its remediation. International Journal of Lakes and Rivers. 2019;12(1):1-20.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/104551