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FEASIBILITY ANALYSIS ON INDUSTRIAL SYMBIOSIS BETWEEN CEMENT INDUSTRY AND TEA INDUSTRY

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Abstract

The project aims at analyzing the feasibility of utilizing cement kiln dust (CKD) in treating wastewater from tea industry with the concept of industrial symbiosis. CKD is the dust collected at the air pollution control device(s) associated with a kiln system from cement industry. A very less percent of CKD is recycled and the rest is land filled /stockpiled; disrupts groundwater through leaching of minerals. Cement Kiln Dust (CKD), rich in CaO, SiO_2, behaves as a neutralizing as well as stabilizing agent for tea effluent treatment. The ability of CKD to reduce the BOD, COD, TSS, and phosphates in tea effluent was analyzed and the optimum dosage is determined. The effect of different dosages of Cement Kiln Dust ranging from (1-3) gm/l has been discussed on the bench scale tests. The results show that, for different CKD concentrations, high removal efficiencies of 94.4 and 99.0, 58.9 for BOD, TSS, phosphates and a lower efficiency for COD with 9.09 are achieved for 2.5gm/l. The persistent presence of color providing proteins *theaflavins* (TF) and *thearubigins* (TR) from the leftover tea leaves in the effluent imparts the low removal efficiencies of COD. However, the COD value is within the dischargeable limits (CPCB standards). Moreover, a considerable removal efficiency and high SVI of 0.181 makes CKD a feasible coagulant in treating tea effluent with optimum dosage of 2.5g/l. The objective of developing industrial symbiosis network was thus achieved using the CKD to treat wastewater from tea industries.

Keywords: Industrial Symbiosis; Cement Kiln Dust; Tea Effluent; Optimum Dosage; High SVI.

Introduction

Industrialization is a major factor initiating various pollutions in the form of improper solid waste management, untreated effluent discharge and uncontrolled air pollutant emissions. With the increase in population of India, industrialization cannot be controlled since products are necessary to meet the demand. However, the solution to the problem stated can be defined in terms of Industrial Symbiosis. Industrial symbiosis counts not only on solid waste management, but also on resource conservation and optimization through recycling of waste products from industries.

The concept of industrial symbiosis ages back to 1961, in which a group of community in Kalundburg, Denmark, utilized surface water for an oil refinery to resist the consumption of ground water. However, the term "Industrial Symbiosis" was coined by Fosch and Gallopoukos, in the journal Scientific American, in 1989. According to them, industrial symbiosis can be defined as the utilization of waste material from one industry by another industry. However, at least three entities should be involved in the exchanging process and at least two different resources to be counted as a basic type of industrial symbiosis the sharing of utilities (Chertow *et al.,* 2007).

The practice of industrial symbiosis has been developing over the years with more advancement and better understanding. A study by Zeng *et al.,* (2013) on vulnerability analysis of industrial eco-parks shows that industrial population thrives on the basis of resource availability. Industrial eco-parks are group of communal industries that share utilities among them. Zeng *et al.,* (2013) created a network model in which nodes of the network are industries which generate waste. The produced waste products are transported as resource to other industries. The waste nodes and byproducts nodes are considered to be ecological nodes and the agents are the raw materials. According to his model, eco-industrial parks are developed in an area with considerable number of industries in it. The resources/wastes do not have to flow beyond the boundaries of the parks. However, failure of the model can be triggered by removal of any single node of the network. Thus, in his paper he explicitly explained the necessity of participation of all industries if included in the network of eco-industrial parks (Zeng *et al.,* 2013).

Similarly, another agent based model by Bichraoui *et al.,* (2013) focuses on cultural and behavioral aspects of industries. According to them, they insist industries to participate toward a common goal to conserve resource, low carbon emissions, production emission and economic viability. In their paper, they associated economic activities with the natural environment to organize industrial eco-parks. In their model, the eco-industrial park does not involve with various connecting nodes. Any node can connect to any other node depending on the process, operation and waste material generated from the industries. The amount of waste generation and raw material requirement are also studied and the model is created on the basis of behavioral pattern of industrial population to participate in the network. (Bichraoui *et al.,* 2013). Thus, it is evident that with the notion of conserving environment and natural resources eco-industrial parks are necessary provided that any node of industry can trade (send/receive) the waste as resource to any industry.

Thus, this paper aims to use waste product (Cement Kiln Dust) from cement industries as a raw material (coagulant) in tea industrial effluent treatment.

Cement Kiln Dust (CKD) is a powdery substance which is generated as a by-product in the cement manufacturing process. It is highly alkaline in nature and considered and discarded as solid waste; though very small percent is reused as a raw material for cement production in some cement plants. India hosts 188 large cement plants with several small scale sectors. The annual production accounts 366 MT with 190 kg per capita consumption. The production is expected to escalate to 395 MT by next three years (IBEF, 2015); hence, the generation of CKD. The nature and amount of CKD generation can be significantly affected by the design and operation materials used in a cement kiln. The common disposal methods practiced in India are stockpilation and landfilling (IBEF, 2015).

Since the amount of CKD generated mounts every year, the cost for storage and disposal also hikes. Thus, cement manufacturer's hypothesis the application of CKD in various sectors to minimize financial loss. The physical and chemical characteristics of CKD find its varying applications in cement brick manufacturing, soil neutralization and wastewater treatment facilities. The free lime presence makes it a soil neutralizer and good coagulant in wastewater treatment plants. The high content of cementitious material in CKD replaces Portland cement and other cements (Abd El-Aleem *et al.*, 2005).

Hence, the objective of this project is to analyze the feasibility of utilizing CKD as a coagulant in tea effluent treatment plants replacing alum; thus to reduce the amount of solid waste disposed as landfill or stockpiles. Moreover, the paper intents to create Industrial Symbiosis network between cement and tea industries along with a healthy mutual tradeoff between them.

India is one of the important producers of tea and thus tea plays a significant role in uplifting the nation's GNP with huge foreign exchanges. Tea is one the agro-industrial crops, which grow mostly in hilly areas. In India, around 5, 07,000 hectares are cultivated with tea plantations and produces about 800 million kg annually. Moreover, the tea industry processes only on tea leaves with little use of chemicals in fermentation stage. Apart from this, the whole process takes place with only tea leaves (Kavitha *et al.*, 2014). Thus, the wastewater generated from tea factories is high in BOD due to organic content, total suspended solids and high color index. Thus, effluent from the industry requires necessary treatment to reduce the polluting factors; to reach the normal dischargeable standards (Otieno *et al.*, 2014; Justin *et al.*, 2009).

With the coagulating nature of CKD, it is assumed to settle the organic load in the effluent with optimum dosage; thus reducing the BOD of the effluent to the permissible dischargeable limits. The work is done with comparison of treatment efficiencies of BOD, COD, Total Suspended Solids and Phosphorous with tea effluent and to evaluate the optimum dose of CKD as a coagulant. The wastewater resulting after all the processes and operations taken place in tea production is taken into consideration in this paper.

Materials and Methods

Sampling

CKD Sample Collection

Cement Kiln Dust is the particulate matter collected at the outlet of rotary kiln in a cement industry with the help of air pollution control devices. Hence, for the purpose of this project, CKD sample was collected from "Tamilnadu Cement Manufacturers (Government Cement Factory)," located in Ariyalur, Trichy, Tamilnadu. The plant is located 2 km interior to the town of the Ariyalur where it provides employment to the local inhabitants. The superior officers are provided with staff quarters within the boundary of the factory.

The plant utilizes 8,000 tons of raw materials per day for the cement production. Jaisalmar, the yellow limestone rich in iron content, along with sand and clay are used as raw materials. At the end of the operation, the factory collects around 600 tons of CKD from a pair of Electrostatic Precipitators installed at the outlet of the kiln. The kiln runs at 1300^{o}C; hence the CKD collected was hot at the time of collection and gradually the temperature decreased. The outlet of ESP's has 5 collection points. The sample was collected from the 3rd collection point in a wooden box initially. Later, the sample was transferred to a microwave steam bag and sealed tightly. The color of the CKD sample was creamy pink.

Tea Sample Collection

The wastewater discharged after all the processes and operation was considered for the purpose of this paper. The tea effluent sample was collected in one of the factories in Munnar, Kerala. The waste effluent from tea factories mainly consists of wash overs after the operations of withering, size reduction, drying, and sorting; constitutes organic matter of tea particulates. A small portion of the wastewater comprises the washed water from fermentation tank which is a combination of chemical and algal slurry. The wastewater treatment employed in the tea factory comprises a settling tank followed by a sand filter.

The effluent is allowed to settle for 24 hours residence time; hence 35% of BOD removed. However, the color of the water does not reduce due to the presence of *theaflavins* (TF), and *thearubigins* (TR), the color pigments of the tea plant. The water that comes from the settling tank is filtered through a sand bed which provides transparent and clear treated water. However, on observation, algal blooms as a result of eutrophication are visible in the upstream of the river where treated water is discharged. This illustrates the presence of significant amount of phosphates even after the treatment methodologies.

Hence, for the purpose of the experimental study, the tea effluent sample was collected at the entrance of the sedimentation tank; prior to the treatment operation. The sample collected in acid washed PET bottles. The effluent was a darkish brown in color with suspended particles that added the turbidity of the fluid. The pH of the sample was 4.5; thus slightly acidic in nature. Storage was done as per the IS 3025 Part I norms.

The method of analysis (physical and chemical testing) was done as per norm IS 3025 regulations.

Analysis

Parameters

The parameters analyzed are as given in the table below.

Table 1: List of Parameters analyzed

S.No.	Parameters Testing	Test Method	Regulation
1.	pH	pH meter	IS 3025 (Part 32)
2.	Total Suspended Solids	Gravimetric Method	IS 3025 (Part 17)
3.	Biochemical Oxygen Demand	Azide Method	IS 3025 (Part 44)
4.	Chemical Oxygen Demand	Open reflux arc method	IS 3025 (Part 58)
5.	Phosphates	Stannous Chloride Method	IS 3025 (Part 31)

The tea effluent sample was primarily tested for initial pH, Total Suspended Solids, Biochemical Oxygen Demand, Chemical Oxygen Demand and Phosphates before the addition of varying concentration of CKD (Table 1). The readings were noted and considered as inlet values. The sample was analyzed before and after the addition of CKD to determine the optimum CKD dosage.

Test Procedure

The pH of the sample was tested immediately after the sampling. It was measured with a pen type pH meter according to IS 3025 (Part 32) regulation. Jar test, which is also known as coagulation test was done to determine the coalescing nature of CKD in varying dosages from 1g/l – 3g/l following IS 3025 (Part 50). Similarly, total suspended solids present in the sample was determined as per the IS 3025 (Part 17) in which the weight of an empty filter paper was detected from one which was filtered with 20ml of sample. The filtered paper was kept for 24 hours for complete filtration to take place. The filter papers were weighed in an electronic weighting machine. However, determination of BOD, COD and phosphates required long procedures (Freese *et al.,* 2003).

The BOD_5 was calculated following IS 3025 (Part 44) norms for sample. The COD and Phosphates were subsequently determined according to IS 3025 (Part 58) and IS 3025 (Part 31) directives. The obtained results were considered as inlet values.

Table 2: Inlet Values

S. No:	Parameters	Result	Unit
1.	pH	4.5	
2.	Total Suspended Solids	5.75	mg/l
3.	Biochemical Oxygen Demand	830	mg/l
4.	Chemical Oxygen Demand	264	mg/l
5.	Phosphates	2.39	mg/l

Figure 1: The process of coagulation analysis by jar test method with CKD dosages of 1g/l, 1.5g/l, 2g/l, 2.5g/l, and 3g/l.

After the inlet readings were noted, CKD dosages of 1g/l, 1.5g/l, 2g/l, 2.5g/l, and 3g/l were subsequently added in each litre of tea effluent to examine the optimum coagulating dosage of CKD; the solution was allowed to settle for 10 minutes. The sludge settled was observed and noted. The resultant mixed liquid suspended solids (MLSS) was collected and the parameters mentioned initially were tested for each dosage. These were considered as outlet values.

Table 3: Outlet Values

Dosage/Parameter	1g/l	1.5g/l	2g/l	2.5g/l	3g/l
pH	4.84	5.92	6.2	7.63	8.3
Biochemical Oxygen Demand	740	560	210	47	96
Chemical Oxygen Demand	257	253	249	240	269
Total Suspended Solids	4.30	2.74	0.186	0.054	0.98
Phosphates	1.98	1.57	1.10	0.98	0.965
Sludge Settled (cm)	1.1	1.3	1.9	2.3	2.1

Figure 2: **Settled sludge after the jar test analysis**

Removal efficiencies for BOD, COD, TSS, phosphates (as P) and SVI were calculated using the equation below:

Removal Efficiency = ((Inlet value – Outlet value)/ inlet value)*100

Determination of Sludge Volume Index is an important step in case of coagulation and flocculation experiments. It helps to identify the optimum dosage of coagulant in a wastewater treatment plant in which the volume of sludge settled indicates the SVI. The higher the sludge settled, the higher is SVI. Hence, Sludge Volume Index can be calculated using the following equation.

Sludge Volume Index = Settled Sludge Vol_{30} (ml/L) *1000 / MLSS (mg/L)

The SVI and removal efficiencies were calculated using the above equations.

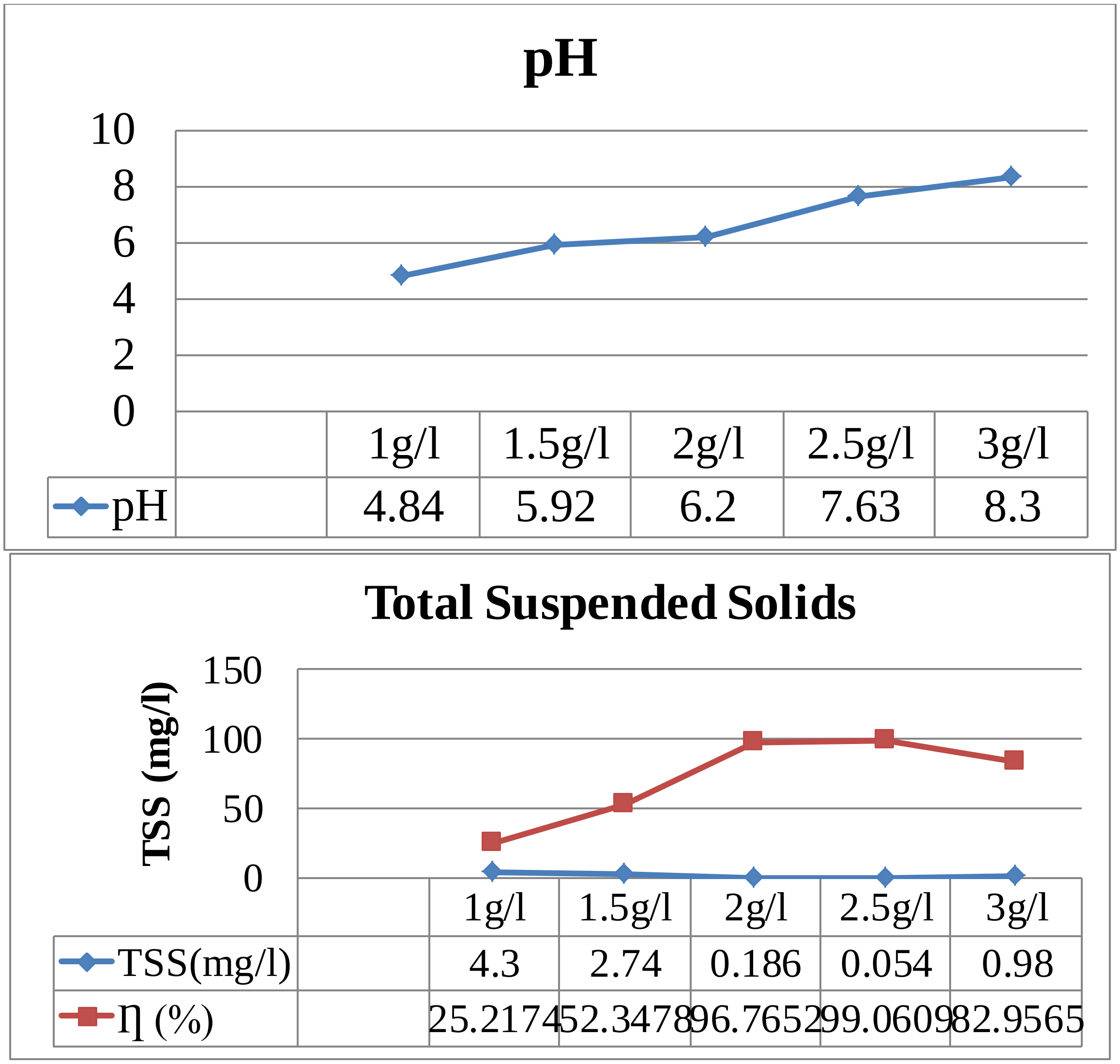
Table 4: Table showing removal efficiencies according to various dosages of CKD

Dosage/Parameter	0g/l	1g/l	1.5g/l	2g/l	2.5g/l	3g/l
pH	4.5	4.84	5.92	6.2	7.63	8.3
BOD(mg/l)	830	740	560	210	47	96
η (%)		10.84	32.53	74.69	94.33	88.43
COD(mg/l)	264	257	253	249	240	269
η (%)		2.65	4.16	5.68	9.09	-1.89
TSS(mg/l)	5.75	4.3	2.74	0.186	0.054	0.98
η (%)		25.21	52.34	96.76	99.06	82.95
Phosphates(mg/l)	2.39	1.98	1.57	1.1	0.98	0.965
η (%)		17.15	34.30	53.97	58.99	59.62
Sludge Volume Index		0.079	0.0949	0.145	0.181	0.162

Graphs were plotted using the recorded data. The inlet and outlet values were compared with the help of graphs along with the removal efficiencies. The optimum dosage of CKD was determined with the help of graphical representations of the obtained results.

Results and Discussions

The results obtained from the analysis were tabulated accordingly. Graphs were plotted using Microsoft Excel sheets. Thus, from the graphs, results were discussed.

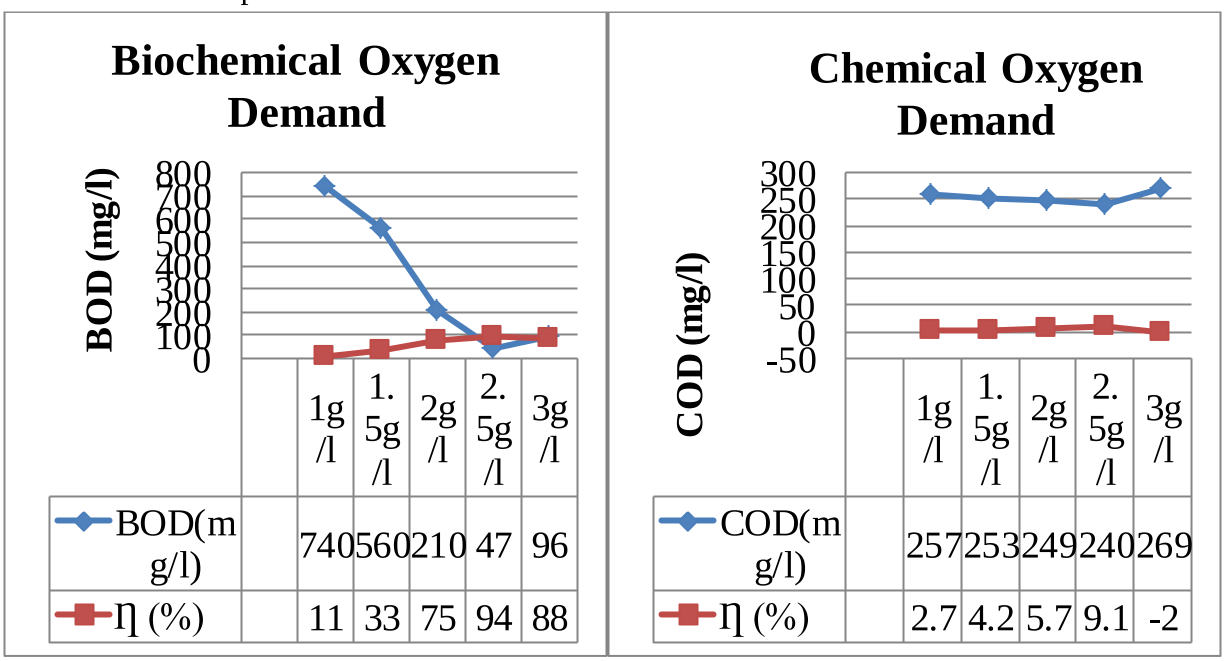


(A) **(B)**

Figure 3: Graphs showing changes in pH (A) and changes in total suspended solids (B) with varying concentrations of CKD

From the Figure 3 (A), the graph shows the change of pH of the sample with the addition of varying concentrations of CKD. The initial pH of the sample was acidic in nature (Table 4). However, with the addition of CKD with varying subsequent dosages, the pH tend to increase. ie. The effluent after the jar test became alkaline in nature. This is because of the presence of CaO present in the CKD. With the increase in concentration of Calcium, the fluid tends to be more acidic. Alkalinity is one factor that determines the coagulation of a chemical. Thus, the coagulation depends on the ability of the coagulant to produce more OH^- anions for soluble precipitate formation. Thus, increase in pH aids in better coagulation of the waste constituents. However, the pH of the treated water should not exceed the dischargeable limits. Hence, the pH of 7.63 is considered to be ideal for discharge into inland surface water according to the normal dischargeable limits of industrial effluents to inland surface water (Table 5).

Total Suspended Solids is another factor to be considered while treating a waste effluent from an industry. These are the factors responsible for the presence of turbidity in water. The turbidity in water causes health impacts not only for humans but also for aqatic life. The suspended solids fills the gills of the fish population and disturbs their respiratory tracts and may kill them. Thus, causing imbalance in the aquatic ecosystem. The initial TSS in the inlet water was reported as 5.75 (Table 4). However, there was gradual decrease in the TSS at varying increasing concentrations of CKD. Similarly, the removal efficiencies also increased gradually (Figure 3 (B)). But, it started increasing after the dosage of 2.5g/l. This is because, the wastes present in an effluent coagulates and settles to some extent. According to the theory of coagulation, the zeta potential of the floc starts to reduce with excess addition of coagulants. Hence, the flocs starts to destabilize and thus starts to collapse. This increases TSS in the water. Thus, the dosage before the commencement of floc collapse, (increased TSS) is considered to be optimum dosage for the tea effluent treatment. Moreover, the residual CKD after optimum level treatment adds to the TSS.



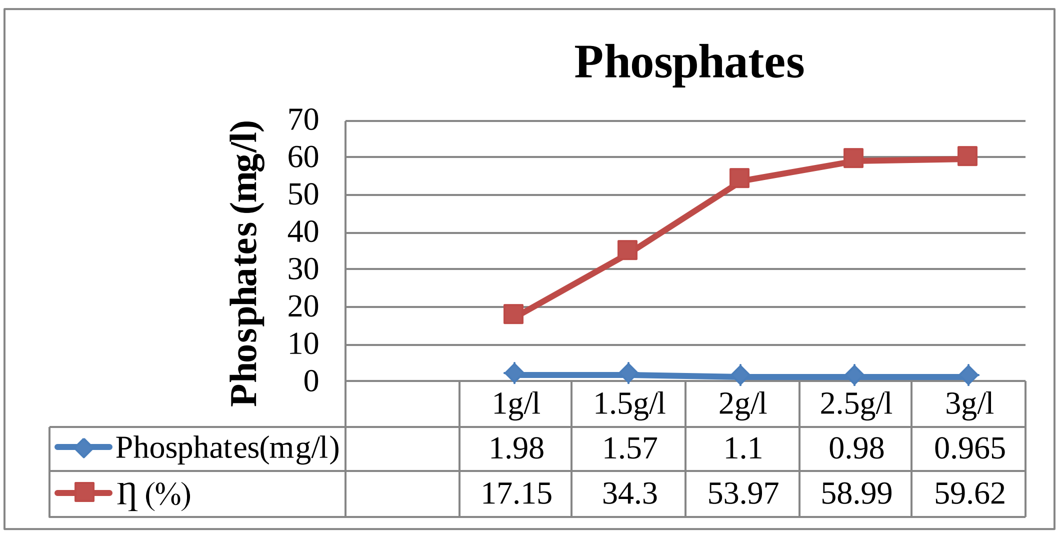
(A) **(B)**

Figure 4:Graphs showing changes in biochemical oxygen demand (A) and changes in chemical Oxygen demand (B) with varying concentrations of CKD

While considering the biochemical oxygen demand of the effluent, the inlet value obtained exceeds the permissible limits (Table 4 and Table 5). The addition of coagulant influenced the agglomeration of the organic matter present in the wastewater and thus gradually flocs are formed (Schulz *et al.*, 1984). However, with the addition of CKD at varying concentrations, there was gradual decrease in BOD level. From Figure 4 (A), it is visible that there is steady decrease in the removal of BOD level in the effluents. However, the BOD increased after the 2.5g/l of CKD dosage. This indicates that there is a chance for the growth of algae from the fermentation drum algal colony floc; the spontaneous action of

CKD in wastewater stimulates the growth of microbes with ideal temperature to thrive in. The BOD can further be removed using advanced oxidation methods. A high BOD results in depletion of DO in water. This gradually affect the aquatic ecosystem (Penn *et al.*,). Thus, the industries should discharge effluents under the dischargeable limits into the receiving streams.

Similarly, considering the effect of CKD on chemical oxygen demand of the water, only little changes were observed (Figure 4 (B)). The COD obtained at inlet was higher than the inlet BOD value, which is unusual (Table 4). However, this fact can be effectively reasoned (Punrattanasin, 1997). The fermentation during the tea process releases huge amount of the color producing pigments *theaflavins* and *thearubigins*. The oxidation process takes place by the conversion of catechins into orthoquinones which in turn demerize to produce *theaflavins* (TF) and *thearubigins* (TR). These are the color producing pigments (Karmakar, 2005). Hence, the leftover tea particulates during the operations of drying and sorting are generally huge in number. Thus, the chemical content in the tea effluent is gradually high in nature than the organic matter (Milin, 1987). Thus, the COD was similarly higher. However, CKD addition did not have a drastic effect on COD of the effluent since the removal efficiency is lower.



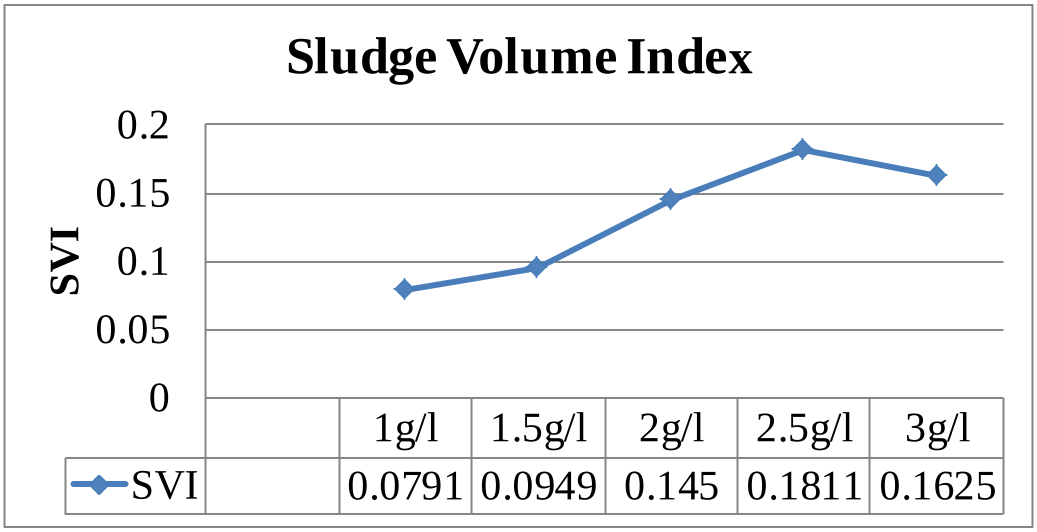


Figure 5: **Graphs showing changes in phosphate level (A) and sludge volume index (B) with varying concentrations of CKD**

Phosphates as P is present in all life forms. In humans, these are present as proteins such as DNA, RNA etc. Similarly, phosphorous is one of the essential growth factor for plants. Thus, phosphorous is not present in its elemental form. It is mostly present as phosphates (Panasiuk, 2010). Tea gardens are nurtured with the help of fertilizers for the successful and steady growth of the plant. Fertilizers such as urea, NPK are major constituent of phosphorous. Thus, tea plants have huge amount of phosphates. The inlet value for phosphate was 2.39 (Table 4). However, it gradually decreased at the rate of addition of CKD dosages. The removal efficiency was also high. Though at some point, the removal efficiency decreased because of the continuos addition of CKD. CKD contains phosphates in very trace amount. Thus, after the optimum dosage of CKD, the water was left with no solids to settle. Hence, the addition of CKD is considered as sludge which add to increased phosphates concentration (Figure (A)).

Similarly, from Figure (B), it is seen that the SVI for different dosages of CKD showed a higher value in which it was a good result. SVI is the parameter that decides the optimum dosage of a coagulant to treat wastewater. It theorizes that the higher SVI represents increased efficiency of the coagulant to destabilize the waste particles and thus, agglomerate the destabilized matter in floc formation to facilitate in fast settling. The higher the SVI, the higher the efficiency of the coagulation process. Thus, the SVI at CKD dosage of 2.5g/l is considered as optimum since it could destabilize the waste constituents in 30 minutes and could provide a clear treated water.

Thus, the table 5 comparisons the obtained results for the parameters for 2.5g/l of CKD with the dischargeable limits of parameters into inland surface water according to CPCB manual.

Table 5:Comparison of standard values with the obtained values. (As per CPCB guidance manual)

S. No:	Parameters	Dischargeable limits (Inland surface water) (mg/l)	Obtained result for 2.5g/l CKD addition (mg/l)
1.	pH	5.5 - 9.0	7.63
2.	Total Suspended Solids	100	0.054
3.	Biochemical Oxygen Demand	30	47
4.	Chemical Oxygen Demand	250	240
5	Phosphates	5.0	0.98

This indicated that the parameters' values did not exceed the limits except for BOD. The effluent can then be treated with single stage of sand filtration to a small extent and then can be discharged in to the inland surface water or can be used for other purposes such as gardening, and agricultural purposes (CPCB manual).

Conclusion

The study concluded that it is feasible to treat waste effluent from tea industry using Cement Kiln Dust. The optimal dosage to be used is 2.5g/l in which the removal efficiencies for BOD, COD, TSS and Phosphates show gradual increase. The color of the effluent changes from darkish brown to clear liquid in which it is obvious that the pollutant level has decreased to a considerable rate. The higher value of SVI at the same dosage also indicates the improved efficiency of coagulation. Thus, with this concept, the need for two stage sand filters can be omitted in the tea factories as the color, phosphates are already removed in the settling process. One stage filtration can be done to reduce the BOD of the effluent within the permissible limit. Thus, all the major removal processes are achieved in one operation. The treated water then can be used for watering the plants. If needed, the water can be treated with reverse osmosis to remove all the ions and then can be used as potable water. Thus, the cement manufacturers can develop a network tradeoff with other industries in order to manage the disposal of the huge amount of CKD generation and the industries can buy the waste material for cheap cost. Thus, industrial symbiosis relationships could be developed among these two industries.

References

Abd El Aleem, S., Abd El Aziz, M.A., Heikal, M. and El Didamony, H., 2005. Effect of Cement Kiln Dust Substitution on Chemical and Physical Properties and Comprehensive Strength of Portland and Slag Cement. *The Arabian Journal for Science and Engineering*, 30, 263-273.

Abukhashaba, M.I., Mostafa, M.A. and Adam, I.A., 2014. Behaviour of Self – Compacting Fiver Reinforced Concrete containing Cement Kiln Dust," *Alexandra Engineering Journal*, 53, 341-354.

Ahmed Hashad, Mohie El Mashad, 2014. Assessment of Soil Mixing with Cement Kiln Dust to reduce Soil Lateral Pressure Compared to Other Soil Improvement Methods. *HBRC*, 10, 169-175.

Bichraoui, N., Guillaume, B. and Halog, A., 2013. Agent – Based Modelling Simulation for the Development of an Industrial Symbiosis –Preliminary Results. *Procedia Environmental Sciences*, 17, 195-204.

Bratby, J., 2006. Coagulants, in Coagulation and Flocculation in Water and Wastewater Treatment. *IWA Publishing*, London, (2), 50-68.

Chan, H., 2013. Separation of Pollutants from Restaurant Effluents as Animal Feed, Fertilizer and Renewable Energy to Produce High Water Quality in a Compact Area. *Water Resources and Industry*, 3, 35-47.

Daous, M.A., 2004. Utilization of Cement Kiln Dust and Fly Ash in Cement Blends in Saudi Arabia. *JKAU: Eng. Sci.*, 15, 33-45.

Dennett, K.E., Amirtharajah, A., Moran, T. F. and Gould, J.P., 1996. Coagulation: It's Effect on Organic Matter. *Journal AWWA*, 88(4), 129 –142.

Dennis O.O., Anil Kumar, Maurice, S., Onyango, O.A., 2014. Treatment of Tea Industry Wastewater using a Combined Adsorption and Advanced Oxidation Process. *Proceedings of 2014 International Conference on Sustainable Research and Innovation*, Volume 5.

El Shahate Ismaiel Saraya, M. and El Saied Aboul Fetouh, M., 2014. Utilization from Cement Kiln Dust in Removal of Acid Dyes," *America Journal of Environmental Sciences*, 8, 16-24.

El-Zahar, M., 2010. Dewatering Waste Activated Sludge Using Greenhouse-Gas Flotation followed by Centrifugation. *International Journal of Environmental Science and Development*, 1, 199-204.

Erkman, S. and Ramaswamy, R., 2000. Cleaner Production at the System Level: Industrial Ecology as a Tool for Development Planning (Case Studies in India).UNEP's 6th International High-Level Seminar on Cleaner Production, Montreal, Canada, 16-17.

Francesco, C. and Raffaele, C., 2013. Use of Cement Kiln Dust, Blast Furnace Slag and Marble Sludge in the Manufacture of Sustainable Artificial Aggregates by Means of Cold Bonding Pelletization. *Materials*, 6, 3139-3159.

Frank, B., Wouter, S. and Yannis, M., 2011. Erratum to "The Dynamics of Industrial Symbiosis: A Proposal for a Conceptual Framework Based Upon a Comprehensive Literature Review. *Journal of Cleaner Production*, 19, 1773-1776.

Giani, A., Redha, K. and Ionel, C., 2011. Optimization of Coagulation Flocculation Process with Aluminium Sulfate Based on Response Surface Methodology.*U.P.B. Sci. Bull*, 73 (2), 77-84.

Harris, S., Berkel, R.V. and Kurup, B., 2008. Fostering Industrial Symbiosis for Regional Sustainable Development Outcomes. *CRRC*, 1-21.

Henri, D., Thosphile, P., Morris, S. and Noemie, P., 2000. Direct Land Application of Cement Kiln Dust- and Lime-Sanitized Biosolids: Extractability of trace metals and organic matter quality. *Geoderma*, 96, 307-320.

Hiremath, A.M., Pandey, S.K., Kumar, D. and Asolekar, S.R., 2014. Ecological Engineering, Industrial Ecology and Eco-Industrial Networking Aspects of Ship Recycling Sector in India. *APCBEE Procedia,* 10, 159-163.

Islam, L.N., Rahman, A., Mahmud, Z., NurunNabi, A.H.M., Mahmud Hossain Mohasin, M., 2015.Assessment of Physiochemical and Biochemical Qualities of Tannery Effluents of Hazaribagh, Dhaka, and Comparison with Non-Tannery Water Samples. *International Journal of Environment*, volume 4, Issue 1, 68-81.

Justin, K., Mghanga, F.K., Segor, Lazare Etiegni, Lusweti, J., 2009.Electrocoagulation Methodfor Color Removal in Tea Effluent: A Case Study of Chemomi Tea Factory in Rift Valley, Kenya. Bull. *Chem. Soc. Ethiop*., 23(3), 371-381.

Kavitha, G., Jamuna, R.M., 2014. A Study on Problems and Prospects of Tea Growers with Particular Reference to Nilgiris District (TN) in India. *International Journal of Research in Commerce, IT, and Management*, 4 (1), 7-10.

Kouloumbos, V.N., Schaffer, A. and Corvini, P.F.X., 2008. Impact of Sewage Sludge Conditioning and Dewatering on the fate of Nonlyphenol in Sludge –Amended Soils. *Water Research*, 42, 3941-3951.

Mills, N., Prearce, P., Farrow, J., Thorpe, R.B. and Kirkby, N.F., 2014. Environmental & Economic Life Cycle Assessment of Current & Future Sewage Sludge to Energy Technologies. Waste Management, 34, 185-195.

Mostafa, A.H., 2012. Effect of Cement Kiln Dust Addition on Activated Sludge Process without Primary Settling for Reuse Applications. *HBRC*, 8, 14-25.

Oza, J.B. and Gundaliyab, P.J., 2013. Study of Black Cotton Soil Characteristics with Cement Waste Dust and Lime. *Procedia Engineering*, 51, 110 – 118.

Prakash, N.B., VimalaSockan, Jayakaran, P., 2014. Wastewater Treatment by Coagulation and Flocculation. *International Journal of Engineering Science and Innovative Technology (IJESIT),* 3 (2), 479-484.

Rahman, M.K., Rehman, S., Al Amoudi, O. S. B., 2011. Literature Review on Cement Kiln DustUsage in Soil and Waste Stabilization and Experimental Investigation. *IJRRAS,* 7 (1), 77-87.

Semmens, M.J. and Field, T.K., 1980. Coagulation: Experiences in Organics Removal. *Journal AWWA*, 72(8), 476-483.

Smoczynski, L., Ratnaweera, H., Kosobucka, M. and Smoczynski, M., 2014.Image Analysis of Sludge Aggregates. *Separation and Purification Technology,* 122, 412-420.

Sokka, L., Lehtoranta, S., Nissinen, A. and Melanen, M., 2010. Analyzing the Environmental Benefits of Industrial Symbiosis-Life Cycle Assessment Applied to a Finnish Forest Industry Compel. *Journal of Industrial Ecology,* 15, 137-155.

Tiwari, A., Sharma, G. and Gupta, P.K., 2014. Quantification of the Reduced Environmental Impacts with Use of Co-Processing in Cement Kilns in India. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 8, 20-30.

Ulhasanah, N. and Goto, N., 2012. Preliminery Design of Eco-City by Using Industrial Symbiosis and Waste Co-Processing Based on MFA, LCA, and MFCA of Cement Industry in Indonesia. *International Journal of Environmental Science and Development*, 3, 553-561.

Zeng, Y., Iao, R. and Li, I., 2013. Vulnerability Analysis of Symbiosis Networks of Industrial Ecology Parks. *Procedia Computer Science*, 17, 965-972.

Zheng, H.M., Zhang, Y. and Yang, N.J., 2012. Evaluation of an Eco-industrial Park Based on a Social Network Analysis. *Procedia Environmental Sciences*, 13, 1624 – 1629.