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# Continuous Biological Treatment of Membrane Concentrates of Deinking Wastewater Streams from Pulp and Paper Industry

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## Author's contribution

*The only author performed the whole short communication work. Author UO optimized the study, performed the daily operational parameters, and wrote the first draft of the manuscript. Author UO read and approved the final manuscript.*

Short Communication

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## ABSTRACT

**Aims:** The aims of this research paper is to investigate the elimination rates of chemical oxygen demand in 5 days (COD<sub>5</sub>), biochemical oxygen demand in 5 days (BOD<sub>5</sub>), suspended solids (SS or AFS) denoted as "food" (F) to biomass (M; microorganism) ratio (F:M), by targeting varying rates and concentrations of influent stream in a continuous biological treatment (CBT).

**Study Design:** The experiment initially consisted of two acrylic cylinders with cone-shape bottom with an inner diameter of 20 cm and 65 cm, respectively. The setup is fitted with a heater and aeration system. Temperature of wastewater range is maintained at 30 – 36 degree Celsius to promote the growth mesophilic microorganism.

**Place and Duration of Study:** Institute for Sanitary Engineering, Water Quality and Solid Waste Management, University of Stuttgart, Bandtale 2, 70569 Stuttgart, Germany, between January 2011 and August 2011.

**Methodology:** The experiments were carried out in continuous activated sludge systems for short periods with variable feeds. COD<sub>5</sub> is the main parameter which is used to evaluate the carbonaceous organic matter removal capacity. COD<sub>5</sub> analysis was performed on the effluent of every experiment. COD<sub>mf</sub> was measured to assess the effect of SS content in the effluent on the COD<sub>5</sub> elimination. COD<sub>mf</sub> analysis was performed in all

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stages of the experimental period and served as an indicator of true COD<sub>5</sub> values. BOD<sub>5</sub> is measured to evaluate whether the effluent is fully biodegraded after the experiments.

**Results:** The COD<sub>5</sub> result showed the highest elimination rate on day 89 at 45%. COD<sub>mf</sub> showed the highest elimination rate on day 89 at 44%. Biological oxygen demand in 5 days results showed the highest elimination rate on day 90 at 89%. Suspended solids (AFS) result showed the highest elimination rate on day 89 at 79% all parameters with Influent rate of 16.7 liters per day. DFZ436 showed the highest elimination rate on day 64 at 82%. DFZ525 and DFZ620 showed the highest elimination rate for both wavelengths recorded on day 64 at 84%, and 79%, respectively, with Influent rate of 7.2 liters per day.

**Conclusion:** High level of elimination of non-biodegradable organics, inorganic and color constituents in the highly toxic and concentrated wastewater is ample proof of the effectiveness of the CBT in combination with the activated sludge system and membrane filtration technologies.

*Keywords: Biochemical oxygen demand in 5 days (BOD<sub>5</sub>); chemical oxygen demand in 5 days (COD<sub>5</sub>); continuous biological treatment (CBT); deinking; suspended solids (SS, AFS); thermal mechanical pulping (TMP).*

## 1. INTRODUCTION

Lignin, a type amorphous polymer found in pulp and paper, is the most prominent impediment in deinking process. The need for deinking process is prominent in wastepaper is to be reused as secondary fiber products. Before deinking process, wastepaper must be sorted and classified as suitable for final products. [1] Deinking procedures are pulping, prewashing, screening, through flow cleaning, forward cleaning, washing, flotation, dispersion, bleaching and water recirculation. The deinking process of pulping of wastepaper is the loading of the collected wastepaper into the pulp, mixed thoroughly in alkaline solution then cooked, to produce stock resulting from the cooked paper. Chemicals are added to dissolve and disperse adhesives, fillers, sizes, ink, pigments, binders and coating. The deinking process produces high amount of contaminants and pollutants of which constituents arises from the chemicals used. A listing of the major pollutants of concern includes adhesives, starches, clays, ink particles and carriers, sizing, fillers, detergents, dispersants, coagulants, lost fiber, solvents, and bleaching chemicals. Pentachlorophenol (PCP) and trichlorophenol are among the most common toxic pollutants in deinking wastewater. [2] The aim of this paper is to investigate the efficiency of continuous biological treatment in combination with the activated sludge system to achieve high removal of pollutants in the highly concentrated membrane concentrate from deinking wastewater from the pulp and paper industry.

### 1.1 Dissolved Air Flotation (DAF) in the Deinking Process

Flotation is used to coagulate organic polymers (i.e. lignin). Flotation is most efficacious against colloidal substances at alkaline environment i.e. ink which are resistant to screening and washing processes. The most commonly used is dissolved air flotation (DAF). [3] DAF is accepted as a removal of suspended solids and has been used in many wastewater treatment process streams in continuous biological treatment. Its efficacy is best at treating "toxic and difficult" prior to secondary biological treatment. [3] Such "toxic and difficult" material is mostly in the deinking treatment process. The uses of flotation units to deink

printed-paper pulp works by collecting dispersed ink particles on air bubbles and trapping them in froth layer [4].

## 1.2 Anaerobic Treatment in the Deinking Process

The absence of free molecular oxygen is the accepted definition of the term, “anaerobic”. Previous experiments carried out using sequential batch reactor raises doubts if the conditions in the anaerobic treatment system were truly anaerobic. Therefore, there is a need for the term “anoxic” due to infiltration of atmospheric oxygen at very low concentration. In anaerobic treatment, the sources of oxygen are nitrate, sulfate, and other anions, already present in the wastewater [2]. Nanofiltration removes most of the organic loads and multivalent ions, such as calcium, iron, aluminum, silicon, magnesium, arsenic and sulphate [5]. The separation of various components of a nanofiltration and ultrafiltration are related directly to their relative transport rate within the membrane, typically 50- $\mu\text{m}$  internal diameter and 100- $\mu\text{m}$  to 200- $\mu\text{m}$  outer diameter; which is determined by their diffusivity and solubility in the membrane material [6]. The fundamental reason for the apparently slow kinetics of anaerobic treatment is low substrate and slower metabolic process. The yield coefficient comparison of anaerobic to aerobic metabolism in biological treatment leaves anaerobic microorganism at a comparative disadvantage. For instance, if aerobic metabolism is 10 times faster than anaerobic metabolism, then the time required for complete treatment by either process can be made nearly equal by increasing the number of active anaerobic organisms to ten times the number of aerobic organisms, for a given volume of wastewater. [1] Optimization of anaerobic system has come in the form of temperature and alkalinity control. Thermal mechanical pulping (TMP) and Deinking anaerobic pretreated wastewater was treated under higher temperature than the conventional 30-35 degree Celsius used in aerobic systems. This is done to promote a degree of mixing and to the increase treatment efficiency through the increase of contact between the microbes and the organic material. When the influent wastewater in the reactor is properly mixed, the mechanism of anaerobic metabolism can be summarized in three acclimation and symbiotic steps: hydrolysis, acidogenesis and methanogenesis. Anaerobic secreted exoenzymes promote hydrolysis of fatty acids, amino acids, simple sugars, nucleic acids, and benzene. Acetic acid, and small amounts of propionic, butyric, and valeric acids, is the product of this process, which is known as acidogenesis. Methonogenesis is when methane and carbon dioxide gases are continually produced within the microbial films surrounding the particles of bed medium in bubbles. The microbial films grow in size until their buoyancy carries them up slowly through the solids settling zone and are collected by a device located above the settling zone of the clarifier.

Management techniques are used in these experiments. In most anaerobic treated wastewater, influent feed was controlled at varying influent rate per day based on F/M ratio calculations. In an upflow anaerobic sludge blanket (UASB), the velocity of flow through the sludge blanket is managed by use of effluent recycling through the reverse sludge apparatus (Fig. 2). When wastewater flow rate decreases, the bead-like microbial solids that make up the sludge blanket will rub against one another and will continually roll and abrade each other's' surfaces. This action keeps the sizes of the individual beads to within the desired range and maintains the desired high value of “active microorganism-to-organic substance,” which accounts for the high performance of the system. [4] The influence of the sludge retention time (SRT), as shown in Table 1, and F/M ratio on the COD load elimination and effluent COD concentration is to be considered.

**Table 1. Solid retention time (SRT) or sludge age [9]**

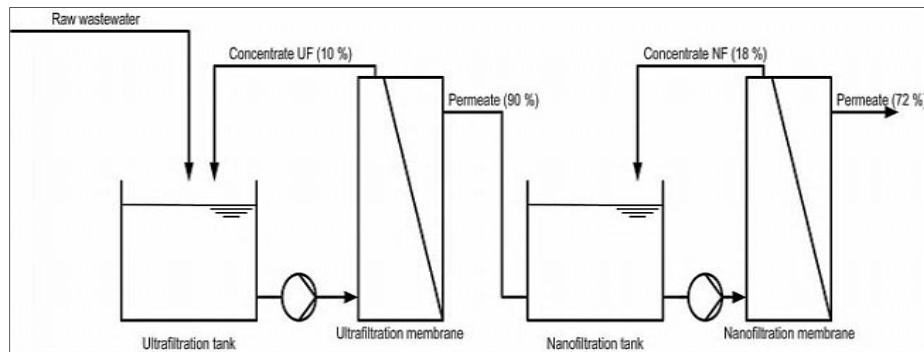
<b>Treatment</b>	<b>SRT range, d</b>
Removal of soluble COD in domestic wastewater	1 - 2
Conversion of particulate organics in domestic wastewater	2 - 4
Develop flocculent biomass for treating domestic wastewater	1 - 3
Develop flocculent biomass for treating domestic wastewater	3 - 5
Provide complete nitrification	3 - 18
Biological phosphorus removal	2 - 4
Stabilization of activated sludge	20 - 40
Degradation of xenophobic compounds	5 - 50

## 2. MATERIALS AND METHODS

Membrane filtration by ultrafiltration (UF) and nanofiltration (NF) applied to the pulp and paper manufacturing process to treat and separate inorganic compounds, microorganisms and color. Ultrafiltration is considered an important physical treatment step in the hierarchy of conventional industrial wastewater treatment schemes. It is the main membrane process employed by the pulp and paper industry. The effectiveness of ultrafiltration process is measured by its extraction of high molar mass of ligneous substances. Nanofiltration application is necessary in order to attain high retention of lignin prior to continuous biological treatment by means of activated sludge. The efficiency gains can attribute to the ultrafiltration in removing higher molar mass compounds and microorganism, thereby accelerating the efficiency of nanofiltration in the consequent filtration step. It is also widely believed that the choice of specific membrane filters and their design also have an influence on energy requirements and overall efficiency thereby removing constituents of industrial wastewater.

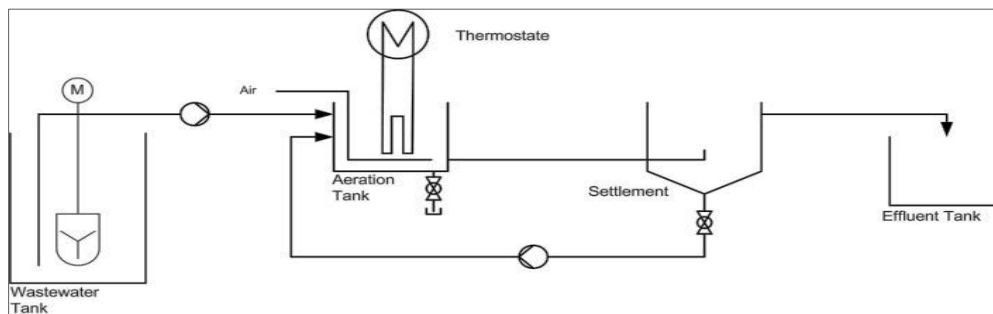
Membrane filtration, especially ultrafiltration (UF) and nanofiltration (NF) applied to the pulp and paper wastewater treatment processes fulfill separation tasks, where the amount of dissolved substances including organic and inorganic compounds, microorganisms and turbidity are reduced. This process was carried out in the wastewater treatment laboratory at WWTP Bösna. Membranes consist of hundreds to thousands of hollow fibers are bundled together to form a module. These membranes consist of a dense film through which permeates are transported by diffusion under the driving force of a pressure, concentration, or electrical potential gradient. Dense membranes can separate permeate of similar size if their solubility in membrane material differs significantly. Symmetrical membranes have nearly homogenous structure all over the thickness of the membrane. Asymmetric membranes are made up of two layers: filter and support. Ultrafiltration is considered an important treatment step in the hierarchy of conventional industrial thermal mechanical pulp and paper wastewater treatment schemes.

Volume reduction of wastewater is a result of membrane filtration. Volume reduction factor in relation to membrane technology is characteristic of feed volume used to study the membrane performance during ultrafiltration and nanofiltration. Two stage membrane filtration (UF-NF) processes was used to obtain concentrated wastewater. Ultra filtration materials and methods were used to obtain 10% concentrated permeate which was subjected to subsequent nanofiltration to attain 18% concentrated permeate, and then stored separately. The 10% UF and 18% NF concentrates were later mixed and treated using continuous biological treatment with aerated activated sludge.



**Fig. 1. 2-stage membrane (UF-NF) filtration process**

The experiment was performed in a continuous batch treatment (CBT) reactor (Fig. 2) in a laboratory in WWTP Büsnau. The wastewater was delivered to WWTP Büsnau by Pulp and Paper mills around Baden Württemberg, Germany. This experiment will focus on the treatment of anaerobically pretreated deinking wastewater as shown in Phase 5 (Day 62 – 93) in Table 2. The CBT apparatus consists of two 50 liters volume capacity acrylic cylinders with an inner diameter of 20 cm and 65 cm with cone-shape bottom, and attached to water heater and aeration system. The temperature of wastewater ranges between 30 – 36 degree Celsius and thermostat are used to continuously to maintain constant and optimal temperature to promote the growth of microorganism. Nutrients, phosphorus (P) and nitrogen (N) were added to influent wastewater prior to the onset each experimental run. Phosphorus was added in the form potassium dihydrogen potassium phosphate ( $\text{KH}_2\text{PO}_4$ ) and nitrogen in the form of urea ( $\text{NH}_2\text{CONH}_2$ ) at a dosing ratio 100C:5N:1P.



**Fig. 2. Continuous biological treatment (CBT)**

The continuous biological treatment (CBT), in combination with UF-NF membrane filtration (Figs. 1 and 2) is used in all experimental phases of the experiment [7]. Unlike the sequential batch reactor (SBR), CBT is more effective at  $\text{BOD}_5$ ,  $\text{COD}_5$ , nutrients, volatile organic carbons (VOC) elimination, due to its design and ability to maintain long sludge retention time. It also allows sludge re-circulations which promotes settling of suspended solids (SS, AFS), therefore reducing its constituents in the effluent.

Daily operations are performed to ensure proper maintenance of the CBT reactor. Parameters requiring daily maintenance are dissolved oxygen, temperature, nutrients, pH, and suspended solids. Dissolved oxygen (DO) must be sufficient for the growth of

microorganisms in the aeration tank. Dissolved oxygen is supplied through aeration. Dissolved oxygen (DO) concentration is maintained at 2.0 mg/L and not allowed below 0.5 mg/l except to promote anoxic conditions in secondary sedimentation tank. These levels promote growth and inhibit bulking and filamentous bacteria growth.

Temperature is maintained constantly in all experimental phases (Table 2) between 30-35 degrees Celsius. This promotes higher percent elimination rates by maintain microorganism growth. A constant thermostat is used to obtain daily temperature values. A minimum of three measurements was performed per experimental day for dissolved oxygen (DO), pH and temperature were measured every experimental day and sample was taken before mixture at the start of each experimental day at the top of the aeration tank (reaction tank) for measurement of MLSS and MLVSS. The analysis of effluent parameters chemical oxygen demand in 5 days (COD<sub>5</sub>), soluble chemical oxygen demand in 5 days (COD<sub>5 mf</sub>), biochemical oxygen demand (BOD<sub>5</sub>), suspended solids (SS, AFS), and absorbance (% Transmittance, DFZ) at three wavelengths 436, 525, 620 nm, respectively was performed through sampling three times every week. Influent and daily operation parameters were taken 1 to 3 times per experimental period. This is dependent on the length of the experimental period, changes in biodegradability of influent concentration, and the availability of staff to perform the extra analysis. Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (P<sub>tot</sub>) were analysed at the author's discretion based on F/M results.

**Table 2. Treatment schemes of wastewater in all experimental phases**

Influent	Experimental phase	Experimental days	Treatment method	Temperature (° C)	Volume loading rate (g/(l. d))
TMP Raw wastewater	1	0 - 32	Aerobic (CBT)	32 ± 2	Variable
TMP Concentrate	2	33 – 45	Aerobic (CBT)	32 ± 2	Variable
TMP Concentrate Ana35	3	46 – 55	Aerobic (CBT)	32 ± 2	Variable
TMP Concentrate- Ana55	4	56 - 65	Aerobic (CBT)	32 ± 2	Variable
Deink Concentrate- Ana Palm D	5	64 - 93	Aerobic (CBT)	32 ± 2	Variable
Deink Concentrate- Ana- Palm A	6	66 - 92	Aerobic (CBT)	32 ± 2	Variable
Deink Concentrate- Ana-Ozone-Aer	7	90- 104	Aerobic (CBT)	32 ± 2	Variable
Deink – Concentrate- Ana-Fen-Aer	8	99 - 114	Aerobic (CBT)	32 ± 2	Variable

### 3. RESULTS AND DISCUSSION

The CBT is designed to promote continuous and constant aeration by dissolved oxygen, temperature and pH measurements. The result is the optimum elimination rates of target parameters through precise control of the influent rates of wastewater stream. [7,8] Precise control of influent rates provides the continuous substrate for the enzymes and microorganisms in the aeration tank to utilize as “food” to promote organic degradation. The analysis of the effluent sample parameters was principally carried out using the German Standard in Water Quality Analysis ATV-DVWK (2002) as shown in Table 3. As a consequence, SS is denoted as AFS, absorbance spectrum (DFZ), soluble chemical oxygen demand and chemical oxygen demand in five days, COD (CSB), and biochemical oxygen demand in 5 days (BSB<sub>5</sub>) in the figures presented in the results section.

**Table 3. German water quality analysis standards ATV-DVWK 2002**

Parameters	Abbreviation	Unit	DIN
Chemical oxygen demand	COD	mg/L	DIN 38409 Teil 41-2
Soluble chemical oxygen demand	COD <sub>mf</sub>	mg/L	DIN 38409 Teil 41-2
Biochemical oxygen demand in 5 days	BOD <sub>5</sub>	mg/L	DIN 38409 Teil 52 (8-2)
Suspended solids	SS, AFS	mg/L	DIN 38409 Teil 2-2 (5.2)
Mixed liquor suspended solids	MLSS	mg/L	DIN 38414 Teil 10
Mixed liquor volatile suspended solids	MLVSS	mg/L	DIN 38414 Teil 10
Total phosphorus	P <sub>tot</sub>	mg/L	DIN 38405 Teil 11
Total Kjeldahl nitrogen	TKN	mg/L	DIN EN 25663
pH	pH	-	DIN 38404 Teil 5
Dissolved oxygen	DO	mg/L	DIN EN 25814
Temperature	T	°C	DIN 38404 Teil 4

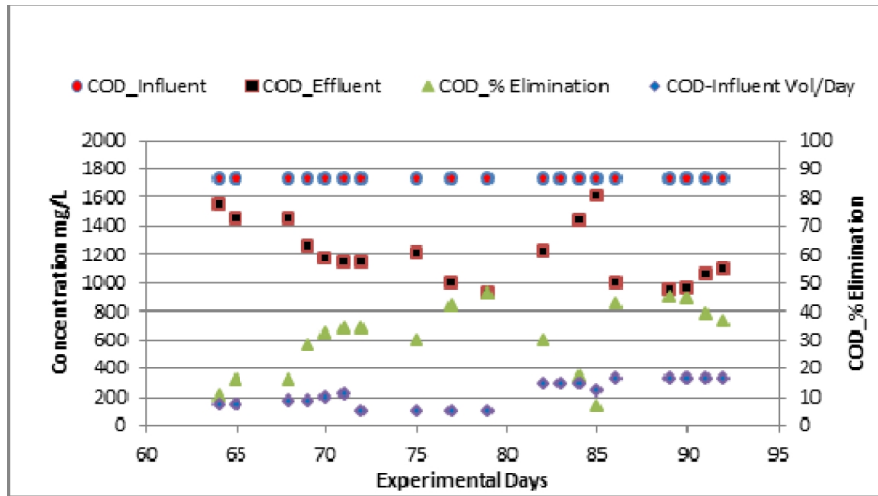
The results summarized in Table 4 have an experimental period ranging from day 64 to 93. The COD results showed the highest elimination rate on day 89 at 45% with influent rate of 16.7 liters per day. COD<sub>mf</sub> showed the highest elimination rate on day 89 at 44% with influent rate of 16.7 liters per day. The elimination rate steadily increased for both settled and soluble COD parameters during the experimentation phase 5, starting from day 64 – 93 of deinking anaerobic pretreated wastewater coming from the pulp and paper industry and reached a peak elimination rate on day 89 as shown in Fig. 3.

**Table 4. Deinking concentrate anaerobe influent and effluent (highest-lowest)**

Parameters	Unit	Influent	Effluent
<b>COD</b>	mg/L	1730	1550 – 929
<b>COD<sub>mf</sub></b>	mg/L	1390	1190 – 701
<b>BOD<sub>5</sub></b>	mg/L	310	55 – 24
<b>BOD<sub>5</sub>/COD<sub>5</sub></b>	-	0.18	0.035 – 0.34
<b>SS</b>	mg/L	370	925 – 350

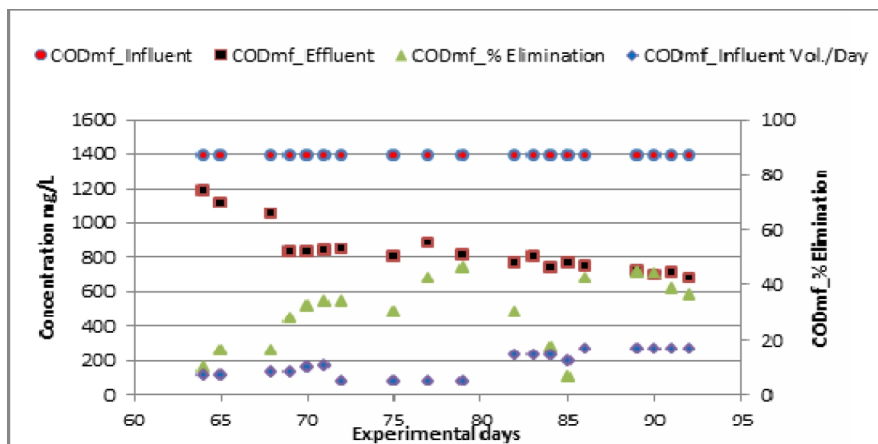
  

Parameter	Unit	Influent	Effluent
<b>DFZ436</b>	1/m	30.1	176 – 50.7
<b>DFZ525</b>	1/m	12	75.3 – 19.1
<b>DFZ620</b>	1/m	6.22	29.8 – 6.3



**Fig. 3. Graph of chemical oxygen demand result of deinking anaerobic pretreated concentrate wastewater**

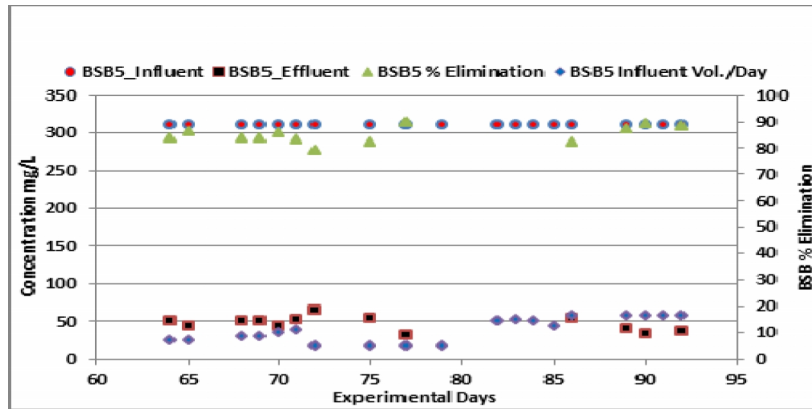
The CBT utilizes oxygen in the activated sludge process. The experiment provides continuous dissolved oxygen at a minimum of 2 mg/L (peak aeration at 5 mg/L) to meet the sludge demand and promote microorganism growth which promotes BOD<sub>5</sub>, COD<sub>5</sub> degradation. The efficacy of activated sludge in industrial wastewater treatment is proving widely because of its effectiveness in the reduction of wastewater parameters of interest, in the effluent sample. High removal rates have made the activated sludge treatment system a more efficient means in achieving emission reduction, water conservation and management. Aerobic treatment of activated sludge systems increases degradation of total, settled and soluble COD<sub>5</sub> (Fig. 4), in the effluent with high organic loading rate and low nutrient levels [7] [8]. The high organic degradation during the course of aerobic treatment leads to an increase in sludge production. It is best to monitor the sludge in the clarifier and withdraw occasionally to prevent excess suspended solids (SS, AFS) in the effluent.



**Fig. 4. Graph of soluble chemical oxygen demand result of deinking anaerobic pretreated concentrate wastewater**

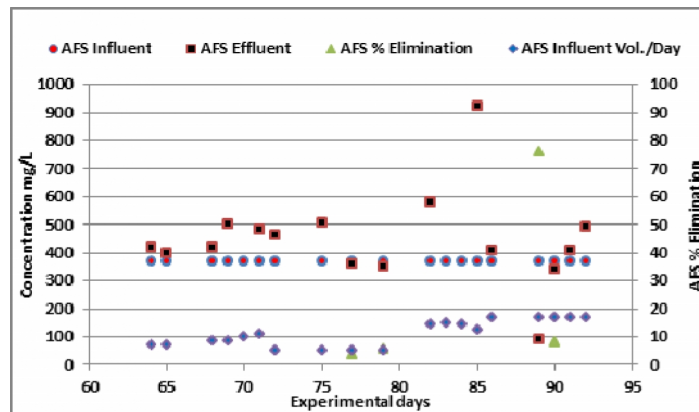


High degradation and removal of biochemical oxygen demand in 5 days (BOD<sub>5</sub>) was observed after influent and effluent sample analysis. Analysis of the result showed the highest elimination rate on day 89 at 79% with Influent rate of 16.7 liters per day. Typically, F/M ratios (Fig. 10) in the range 0.05 to 0.1 result in BOD removal efficiencies of about 95 to 99%. Between 0.1 and 0.2 the removal efficiency may be about 90 to 95% [9]. The sludge age or Mean Cell Residence Time (MCRT) may be defined as the mass of solids (MLSS) in the plant at any time divided by the mass of new solids made each day.



**Fig. 5. Biochemical oxygen demand result of deinking wastewater concentrate anaerobic pretreated- aerobic treatment**

The higher the F/M loading the shorter the sludge age and vice versa. This is because new biomass is produced at a fast rate when food supply is high, and at a slower rate as food supply is reduced. For this reason, the sludge age can be thought of as a measure of the rate of turnover of solids in the CBT system (Fig. 2); hence the alternative name Mean Cell Residence Time (MCRT) or sludge retention time (SRT). Sludge age is typically about 20 - 30 days (Table 1) in activated sludge plants operating at high BOD<sub>5</sub> removal efficiencies as shown in Fig. 5. A long sludge is required for certain specific objectives, nitrification being the most usual [9].



**Fig. 6. Graph of suspended solids (AFS) results of deinking anaerobic pretreated concentrate wastewater**

High elimination of AFS (>80%) as shown in Fig. 6 is an indicator of the efficacy of the CBT reactor. Continuous recirculation of sludge between the reaction tank and clarifier (SST) promotes nitrification and denitrification of effluent and settling of solids. Nitrification of wastewater will occur after most of the BOD has been removed. If enough dissolved oxygen is available, nitrifying bacteria like *Nitrobacter* and *Nitrosomonas* will begin oxidizing ammonia (NH<sub>3</sub>) into nitrites (NO<sub>2</sub>) first and then nitrates (NO<sub>3</sub>). [9] Dissolved oxygen levels need to be in the 4-6 mg/L range to accomplish nitrification. [9,10] Alkalinity is also removed during this process. Nitrification usually occurs in the latter stages of the multi-staged activated sludge systems and extended aeration systems. Long sludge retention times give the microorganisms' time to oxidize the BOD and then oxidize the ammonia to nitrates.

Denitrification follows the nitrification process. It utilizes denitrifying bacteria to remove the oxygen from the nitrate compounds. Nitrates are converted into nitrogen gas (N<sub>2</sub>), which effectively removes the nitrogen from the waste flow. The anaerobic and facultative bacteria are in need oxygen in this environment. In the absence of DO, anaerobic and facultative bacteria obtain oxygen by stripping oxygen from sugars, starches, and sulfates (releasing CO<sub>2</sub>, CH<sub>4</sub>, and H<sub>2</sub>S in the process) [10]. This is a gas stripping process that causes the water to give up nitrogen gas as it absorbs the oxygen. The effluent DO levels should be brought back up to 2.0 mg/L. Denitrifying bacteria are facultative and can use oxygen from nitrates. In order for them to use this chemically bound oxygen, the DO must be less than 0.1 mg/L. Anoxia is the chemical equivalent of anaerobic biological conditions in the secondary sedimentation tank. A high suspended solid in the effluent samples is an indicator of an inefficient reactor system and presence of filamentous bacteria causing sludge suspension (blanket) and mobility into the effluent sample; thereby, affecting the samples results. The importance of CBT reactor design and its influence on functionality and efficacy cannot be overestimated.

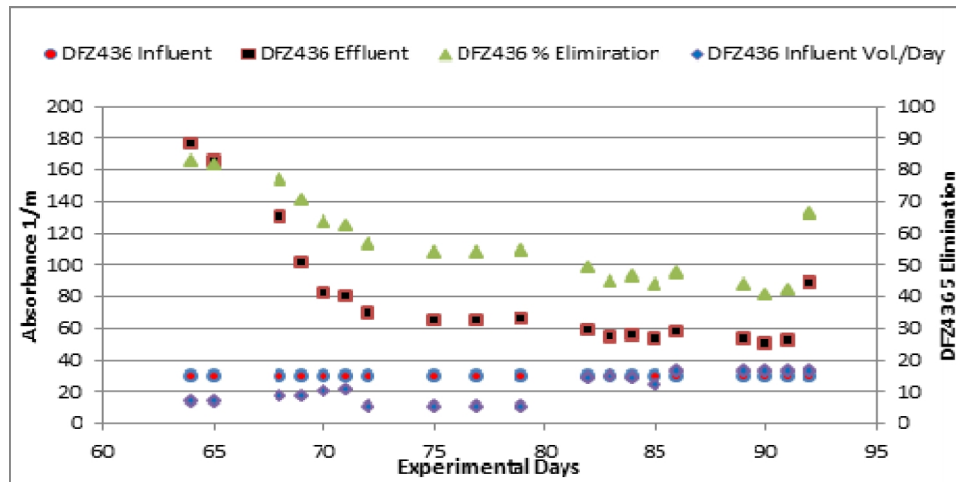
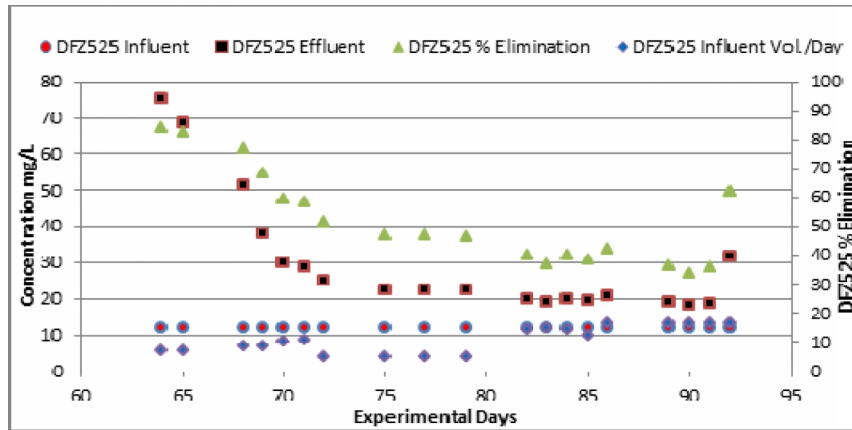


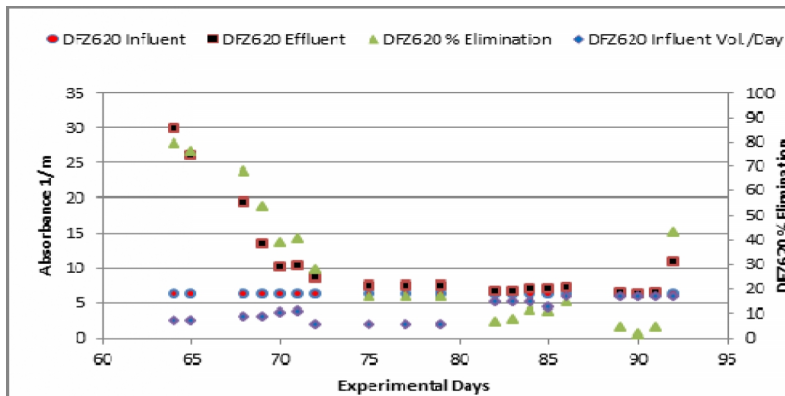
Fig. 7. Graph of DFZ436 results of deinking anaerobic pretreated concentrate wastewater



**Fig. 8. Graph of DFZ525 results of deinking anaerobic pretreated concentrate wastewater**

Color rejection is the first indicator of the efficiency activated sludge reaction process after careful visual observation. The availability of a spectrophotometer permits a more scientific and qualitative approach in determining color rejection in wastewater from the pulp and paper industry. The analysis result of DFZ436 showed the highest elimination rate on day 64 at 82% at an influent rate of 7.2 liters per day as shown in Fig. 7. DFZ525 and DFZ620 (see Figs. 8 and 9) also achieved similar level of color rejection after sample analysis; with the highest elimination rate on day 64 at 84%, and 79%, respectively, and at an influent rate of 7.2 liters per day. A similar trend line was observed of higher activity correlation with higher influent rate due to high availability of substrate for food degradation, high sludge (SRT) and microorganism growth.

Color may be indicative of dissolved organic material, inadequate treatment, high disinfectant demand and the potential for the production of excess amounts of disinfectant by-products. [11] Inorganic contaminants such as metals are also common causes of color. High sample color and turbidity may also cause interference and give inaccurate reading therefore it best to measure the reading at three different wavelengths.



**Fig. 9. Graph of DFZ620 results of deinking anaerobic pretreated concentrate wastewater**

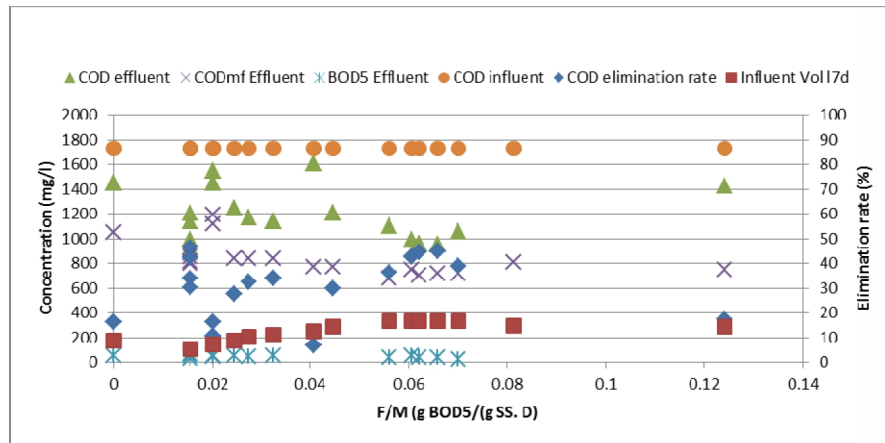


Fig. 10. Graph of F/M ratio deinking anaerobic pretreated concentrate wastewater

#### 4. CONCLUSION

Integrated water resources management (IWRM) emphasizes the growing need in minimizing deinking wastewater products. Recycling of water can have a significant impact on high water use evident in the delignification of paper in deinking facilities. For example, deinking plant must be washed down due to periodic spill and leaks largely attributed to the deinking process. Implementation of strategies on spills and leak prevention should include cost effective measures like collection and treatment thereby reducing the overexploitation of available water resources.

Activated sludge treatment of the collected deinking wastewater concentrate was implemented in this experimental phase of continuous biological treatment of industrial wastewater from the pulp and paper industry. After analysis of the results, we discovered that long sludge age or solid retention time (SRT) is highly influential in the performance of continuous biological treatment process of deinking concentrate. SRT is the ideal choice used in the preliminary design and selection of reactor volume, sludge production volume and aeration requirement. High SRT is an indicator of high reproducibility of microorganism and increased efficiency in the degradation and removal of organic pollutants from the system.

High level of elimination of non-biodegradable organics, inorganic and color constituents in the highly toxic and concentrated deinking wastewater is ample proof of the effectiveness of the CBT in combination with the activated sludge system and membrane technology (UF-NF). It is also evident from the results that the hybrid process of UF-NF membrane filtration is more efficacious than the single unit process.[11] A hybrid ultrafiltration and nanofiltration (UF-NF) of in combination with the CBT pilot plant was efficient in removing the dissolved organic and inorganic substances, the color and contaminants of the concentrated deinking wastewater. The pollutant levels of the effluent parameters are below the maximum contaminant level. This is attributed to the efficacy of membranes technologies for pretreating concentrated deinking anaerobic wastewater by varying feed pressure, pH and feed rates and concentrations.

With the exception of settled and soluble COD<sub>5</sub> (44%), all parameters showed peak elimination rates over 75 percent (Fig. 3). The low COD degradation and elimination can be attributed to low dissolved oxygen saturation in the reactor due to the anaerobic pretreatment of the wastewater and low F/M ratio of influent wastewater; which below theoretical value of 0.3. It is widely accepted that higher F/M ratio leads to higher COD elimination rates. As it is observed that the highest elimination rate for COD<sub>5</sub> was observed in latter stages of the experiments. Future studies will focus on longer treatment time to countenance the acclimation of microorganisms for the degradation of lignin and other toxic polymer in concentrated deinking wastewater.

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## COMPETING INTERESTS

Author has declared that no competing interests exist.

## REFERENCES

1. Yuzhong Zhanga, Chunming Maa, Feng Yeb, Ying Konga, Hong Lia. The Treatment of Wastewater of Paper Mill with Integrated Membrane Process Desalination 236. 2009;349–356.
2. Woodard and Curran Inc., Industrial Waste Treatment Handbook Second Edition by Woodard & Curran, Inc. © 2006 Elsevier.
3. G. Thompson A, J. Swain B, M. Kay B, Forster CF. The Treatment of Pulp and Paper Mill Effluent: A Review Accepted 4 April 2000. Bioresource Technology. 2001;77(3):275-286.
4. Drelich J, Miller J. Improved Flotation Deinking of Sorted Office Papers by Flocculation of Ink Particles Progress in Paper Recycling. 2001;11(1):38-46.
5. Harisha RS, Hosamani KM, Keri RS, Nataraj SK, Aminabhavi TM. Arsenic removal from drinking water using thin film composite nanofiltration membrane, Desalination. March 2010;252(1–3):75–80.
6. Nataraj SK, Hosamani KM, Aminabhavi TM. Nanofiltration and reverse osmosis thin film composite membrane module for the removal of dye and salts from the simulated mixtures, Desalination. 30 November 2009;249(1):12–17.
7. Nataraj SK, Hosamani KM, Aminabhavi TM. Distillery wastewater treatment by the membrane-based nanofiltration and reverse osmosis processes, Water Res. 2006 Jul; 40(12):2349-56. Epub 2006 Jun 6.
8. Nataraj SK, Sridhar S, Shaikha IN, Reddy DS, Aminabhavi TM. Membrane-based microfiltration/electrodialysis hybrid process for the treatment of paper industry wastewater, Separation and Purification Technology - SEP PURIF TECHNOL. 2007;57(1):185-192.
9. Metcalf Eddy, Inc. Wastewater Engineering: Treatment and Reuse. 4<sup>th</sup> Edition. McGraw-Hill, New York, NY; 2003.
10. CSUS. Operation of Wastewater Treatment Plants. Volume 2. 4<sup>th</sup> Edition. California State University, Sacramento, CA; 1993.

11. APHA. Standard methods for the Examination of Water and Wastewater. 21<sup>st</sup> Edition. American Public Health Association, Washington, D.C; 2005.

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