Chemically Enhanced Primary Treatment of Screened De – Gritted Sewage Effluent

Edison Muzenda

Abstract**—**Effective, low – cost wastewater treatment plants that allows for the removal of pollutants and deactivation of pathogens is essential in the protection of public health. The use of chemically enhanced primary treatment (CEPT) for screened de-gritted sewage effluent was studied. The effectiveness of CEPT in reducing the chemical oxygen demand (COD) and soluble reactive phosphorus (SRP) and total phosphates (TP) was evaluated. Studies were on a laboratory and plant scale. For laboratory studies, ferric chloride ($FeCl_3$) concentrations were in the range of 25-200 mg/L while concentrations of 50 mg/l and 70 mg/l were used for plant trials. A dosage of 75 mg/L $FeCl_3$ was to be the optimum dosage giving the highest COD, SRP and TP removal rates under laboratory conditions. Application of CEPT at a plant scale resulted in maximum removal efficiencies of 36% of the COD and 64% of the SRP. CEPT was also found to reduce the organic load to the biological treatment unit, improve sludge settling and dehydration properties. Thus, it was found to be a more cost effective method for treating screened de-gritted sewage effluent especially in plants with additional anaerobic digester capacity.

Keywords**—**Chemically enhanced primary treatment, effluent, ferric chloride, treatment, pollutants

I. Introduction

Pollution of natural waters by effluent discharges from sewage treatment plants has been a major environmental concern over the years. Problems such as eutrophication, pesticide and heavy metal contamination are some of the problems experienced. The rapid urban population growth in developing countries coupled with the increased industrialization has increased the complexity of these problems. Thus, most public sewage treatment plants in developing countries have to deal with hydraulic loads above their design capacity and complex industrial waste which is not amenable to treatment by methods employed in most sewage treatment plants. Given the current scarcity of fresh water resources in most countries effective treatment of sewage effluent by cost-effective methods is imperative.

Convectional sewage treatment processes normally involve screening, de-gritting, primary settling, biological treatment, secondary settling, disinfection and dechlorination. Screening involves the use of bar screens to remove large solid objects such as sticks and rags. After the bar screen, the effluent is slowed down by passing it through a grit tank which allows sand, gravel, and other heavy material that was small enough not to be caught by the bar screen to settle to the bottom. The screened de-gritted effluent is then pumped to the primary settlers where it is held for several hours allowing solid particles to settle to the bottom of the tank allowing also the oils and grease to float at the top. Thereafter the effluent undergoes biological treatment to remove dissolved organic material by the use of activated sludge and/or biofilters before being sent to the secondary settling tanks. Primary solids from the primary settling tank and secondary solids from the clarifier are sent to the anaerobic digester. Disinfection normally involves chlorination to kill harmful microorganisms. The process of dechlorination also involves adding a solution of sodium bisulphite to the chlorinated effluent to remove residual chlorine. After disinfection and dechlorination, the treated wastewater, effluent is discharged to natural watercourses.

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II. Chemically Enhanced Primary Treatment

The name Chemically Enhanced Primary Treatment (CEPT) indicates the goal of this process to increase the efficiencies of primary waste treatment through a physical process. CEPT is a process in which chemicals and / or polymers are added to a waste stream to enhance settling. This process includes coagulation, flocculation and sedimentation, which can be described as the formation of larger particles, or flocs from the small particles in wastewater. The practice of utilizing chemical coagulants in the treatment of water containing suspended solids is not a new technology. It has been utilized for over a century now in the removal of suspended solids in various applications ranging from portable water supply to industrial manufacturing effluent in the first world countries such as Hong Kong, Brazil, China and the United States of America [1]. Some of these processes utilize the formation of pecipitates which readily settle out from solution once formed [2]. Others seek to increase the size of suspended particles and hence their removal rate within a primary treatment system.

Colloidal and suspended particles in wastewater often posses negatively charged anionic materials. These particles tend to repel one another, if small enough they can remain in suspension overcoming the effects of gravity and Van-der-wall forces of attraction. According to [3], coagulation is the destabilization of the charge that exists on colloidal and suspended particles. The most commonly used coagulants in CEPT are metal salts such aluminium sulphate (alum), ferric chloride and ferric sulphate [3]. The destabilization of the particle charge allows suspended materials to come into close contact, forming large particles. This process is called flocculation where particles collide with another through motion and adhere to form large particles. The collisions which cause this formation are a result of three mechanisms: Brownian motion (perikinetic flocculation), shear force (orthokinetic flocculation) and differential settlement (a special case of orthokinetic flocculation). Brownian motion is due to the thermal energy of the fluid, and is of primary importance for collisions between particles less than 1µm. Shear forces are caused by fluid motion as a result of mixing and affects collisions between particles greater than 1µm. Differential settlement is a result of external forces for example gravity acting on particles causing some to settle faster than others. As a result of this, collisions occur vertically as large particles collide with small particles. Rapid mixing can have a negative effect on all flocculation mechanisms breaking the already formed flocs. In most municipal waters with relatively dilute suspended particle concentrations, flocculation occurs as a natural process during settling [2].

The purpose of CEPT is to speed up the natural process of flocculation through the introduction of coagulants which release positively charged metal ions. The attraction of negatively charged colloidal suspended solids to positively charged cations increases the size of particles in wastewater [4], increasing settling velocities, thus enhancing greater removal efficiencies. The larger conglomerates enhance the sedimentation process since large particles settle much faster. This phenomenon is best explained by Stokes Law of settling which states that the settling velocity is proportional to the square of particle diameter. Stokes law can be written as (1) [5].

$$V_c = g(\rho_s - \rho)d^2 / 18\mu \tag{1}$$

Where: V_c, g, ρ_s, ρ, d, and μ are terminal velocity of particle, acceleration due to gravity, density of particle, density of fluid, diameter of particle and dynamic viscosity respectively. Adding to the effect of Stokes law, is that fact that when these large particles settle, they also carry with them smaller particles they collide with on their way to the bottom [6]. The increase in removal efficiency helps overloaded plants to meet the regulatory requirements for effluent quality especially for situations where expansion is not immediately feasible. The implementation of CEPT also increases the plant life until further capital improvements can be realized. When considering the feasibility of various treatment technologies, the following factors come into play: desired water quality, affordability, practical aspects of implementation, alternative technologies and cost.

There three main methods which can be used to quantify the level of performance of a wastewater treatment plant are: (i) The quantification of the amounts of solids in wastewater sample (ii) Chemical oxygen demand (iii) Biological oxygen demand. Although there are several classifications within the broad definition of solids analysis, the most common method is to measure the total suspended solids (TSS). Solids analysis is important in the control of biological and physical waste water treatment processes and for assessing compliance with regulatory wastewater effluent limitations [7].

The objective of this work was to implement the concept of CEPT in sewage treatment plants in South Africa. South Africa is a fast developing country in the third world and the demand for proper sanitation is increasing. The rate of growth has placed lots of pressure to the current infrastructure. Expansion of the current plant infrastructure requires huge capital investment. However, the use CEPT can greatly improve the performance of the current infrastructure. The major parameters considered in this study were the chemical oxygen demand (COD), total phosphates (TP) and soluble reactive phosphorus (SRP). In this work the CEPT process was conducted by dosing the ferric chloride without the polymer.

III. Materials And Methods

A. Materials

For the experimental work, screened de-gritted sewage effluent was used. Jars fitted with stirrers for mixing and coagulation were used for laboratory experiments while primary settling tanks were used on a plant scale. The pH of the effluent was adjusted using sodium carbonate / lime and ferric chloride was used as a coagulant.

B. Method

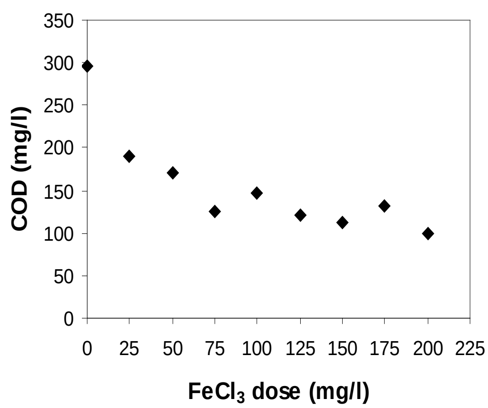
For laboratory trials, the pH of the screened de-gritted sewage effluent was adjusted to 7-8 by adding 6-8 ml of a 10 g/L sodium carbonate solution to each jar. The solution was then agitated for 1 min at a stirrer speed 100 rpm while simultaneously dosing with a pre-determined dose of ferric chloride. Thereafter, the stirrer speed was reduced to 40 rpm and mixing continued for a further 40 min. Agitation was then stopped and settling of the mixture was allowed for 30 minutes. Thereafter a sample of the supernatant was taken for subsequent COD, TP SRP and total Kjeldahl nitrogen (TKN). For plant runs the screened de-gritted effluent was first sampled then dosed with ferric chloride at the parshall flume. Thereafter the effluent was pumped to the primary settling tanks, where the sample overflow was collected after a period of 2 hours. The samples were then analysed for COD, TP and SRP.

The methods of analysis were adopted from the Hach spectrophotometer handbook [8]. The COD was determined by closed reflux method using a Hach COD reactor (Model 45600) followed by calorimetric determination of Cr^{3+} at a wavelength of 620 nm using a Hach spectrophotometer (Model DR 2010). SRP were determined by cadmium and ascorbic acid reduction respectively, followed by calorimetric determination on a Hach spectrophotometer. The same method was used for total phosphates with the exception that 25 ml of the sample was digested with 2 ml of 5.25 N H_2SO_4 before the phosphate measurement. TKN was measured per sulphate digestion followed by colorimetric determination.

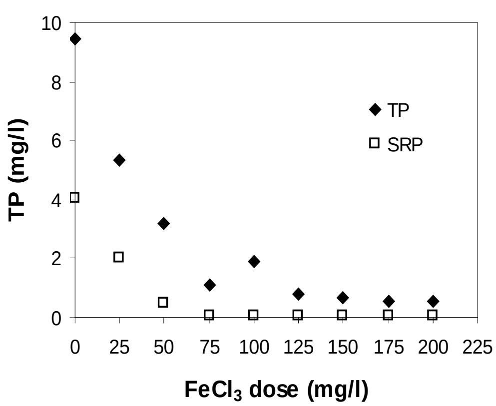
IV. Results And Discussion

A. Laboratory Trials

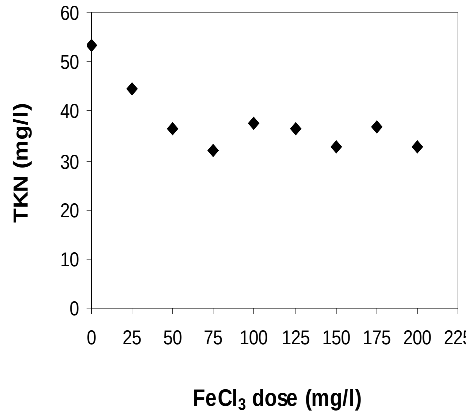
The variation of the effluent COD, SRP, TP and (TKN) levels with increasing dosages of ferric chloride for experiments conducted on a laboratory scale is shown in Fig. 1. From the laboratory trial results (Fig. 1) a dosage of 75 mg/l of $FeCl_3$ was considered to be the optimum dosage with regards to both removal efficiency and reagent cost. The COD, TP, SRP and TKN removal efficiencies at 75 mg/l were 58%, 88%, 98% and 40% respectively. Higher removal efficiencies were obtained by using an anionic polymer in addition to the ferric chloride [9]. In this work, the polymer was not used due to cost limitations.



(a)



(b)



(c)

Fig. 1. Variation of COD levels **(a)**; TP and SRP levels **(b)** and TKN **(c)** with increasing $FeCl_3$ dosages

B. Plant Trials

Fig. 2 shows the % reduction in the COD and SRP for plant trials conducted at a $FeCl_3$ dosage of 50 mg/l. The maximum % removal for the COD and SRP was found to be 36% and 64% respectively.

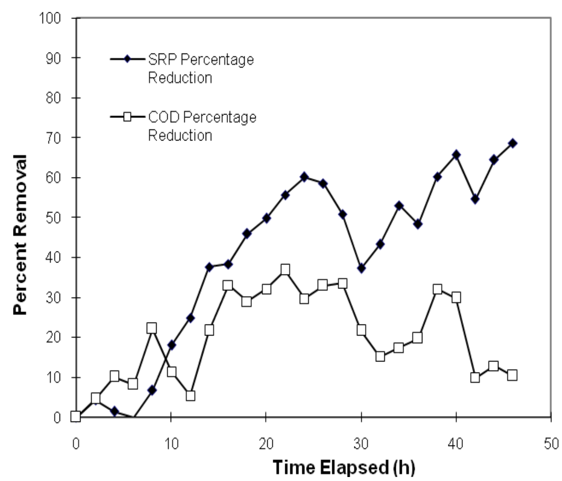


Fig. 2. % COD and SRP reduction at a $FeCl_3$ dosage of 50 mg/l

C. Plant Runs

Fig. 3 shows the COD results for the raw and CEPT treated effluent from the primary settling tank over a period of 3 months. The effluent was dosed with $FeCl_3$ at 70 mg/l. From the seven-day simple moving average trendline of the raw and CEPT treated effluent, Fig. 3, significant reductions in the COD levels were noted. In a majority of the instances the average removal efficiencies were greater than 33 %. The removal efficiencies obtained were not significantly greater than those obtained at 50 mg/l. Thus, a dosage of 50 mg/l was recommended for future plant runs for economic reasons.

COD and phosphorus removal efficiencies were lower in the plant as compared to the laboratory trials largely due to more efficient mixing on a smaller scale. Biological treatment employed in sewage treatment was designed to effectively remove the particulate COD fraction which constitutes a large proportion of household effluent. Thus, the use of CEPT helps reduce the organic loading to the biological treatment unit by redirecting the COD load to the anaerobic sludge digesters.

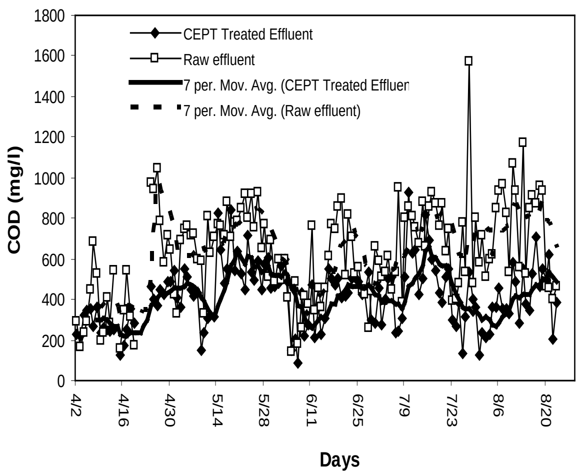


Fig. 3 Comparison of COD levels for raw and CEPT treated effluent

V. Conclusion

CEPT was found to be very effective in removing phosphates with average removal rates of 50% at a $FeCl_3$ dosage of 50 mg/L. COD removal levels were lower and on average around 30%, however, CEPT was found to improve sludge settling and dehydration properties, thus decreasing the overall treatment cost. Since most plants in South Africa are overloaded hydraulically but have spare anaerobic digestion capacity, CEPT helps direct some of the COD of the effluent to the anaerobic digesters. Chemically Enhanced Primary Treatment vastly improves the effectiveness of an existing waste water treatment facility, enabling the plant not to only meet increasing flow demands but to attain higher flow removal efficiencies at the same time. New treatment facilities can be designed to treat larger amounts or the designed size can be decreased by as much as half and still meet the required capacity.

Acknowledgment

The author wishes to acknowledge Joyce Nyeleti Mafenya Kayombo, formerly with NCP for helping in performing both laboratory and plant trials and for her critical evaluations, suggestions and comments in the writing up of this article. The financial support for conference attendance from the University of Johannesburg is greatly appreciated.

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