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# A State-of-The-Art Technical Review on Chemically Enhanced Primary Treatment Plant

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## Abstract:

This review paper aims to provide a comprehensive assessment of chemically enhanced primary treatment (CEPT) processes in wastewater treatment plants (WWTPs). The outdated and ineffective performance of existing treatment plants has raised concerns regarding public health and environmental safety. CEPT has emerged as a promising alternative approach to enhance the efficiency and effectiveness of primary treatment. By adding chemical coagulants or precipitants to the wastewater, CEPT facilitates the aggregation and settling of suspended solids and contaminants, leading to improved treatment outcomes. This review evaluates the performance and effectiveness of different chemical coagulants, including ferric chloride (FeCl3), polyaluminum chloride (PACl), and alum, in terms of their ability to remove various pollutants such as suspended solids, turbidity, organic matter, nutrients, and emerging contaminants.

The findings from the reviewed studies indicate that different coagulants exhibit varying efficiencies in removing specific parameters such as turbidity, total suspended solids (TSS), chemical oxygen demand (COD), and phosphorous. Alum, ferric chloride, and ferric sulfate showed effectiveness in tannery wastewater treatment, while PACl maximized the removal of macro pollutants. The use of organic carbon sources and sludge recycling demonstrated cost reductions and improved nutrient removal. CEPT was found to be effective in TSS and BOD removal, potentially allowing for compact treatment facilities and enhancing the capacity of biological treatment units. The utilization of recovered alum from water treatment sludge (WTS) in CEPT showed comparable efficiencies to fresh alum. The paper also identifies research gaps and future directions in the field of chemically enhanced primary treatment, while discussing the challenges and limitations associated with CEPT processes. While the reviewed studies provide valuable insights into the performance of different coagulants and coagulant aids, further research is necessary to assess their long-term effects and cost-effectiveness in large-scale applications. The optimal choice of coagulant depends on specific wastewater characteristics and treatment goals. Understanding and optimizing CEPT processes will contribute to the development of innovative solutions for challenges in wastewater treatment systems caused by urbanization, population growth, and emerging contaminants in the major city like Kathmandu.

***Keywords:*** *WWTPs, CEPT, COD, BOD, TSS, WTS, ARG.*

## 1. Introduction

When it comes to basic sanitation, Nepal lags behind all the other nations of South Asia as well as most other developing countries. It has been estimated that only 27% of the population of Nepal has access to sanitation (Human Development Report, 2003), while the average is 44% among developing countries worldwide (UNICEF, 2003). Nepal's per capita gross domestic product (GDP) is $240 US, and only 0.5% of this (annually $1.20 US per capita) is spent on drinking water and sanitation (Human Development Report, 2003). Wastewater is a valuable resource that can be reused after proper treatment. The treatment procedure helps to bring the water to a usable condition, which is human-friendly in nature. Therefore, it is necessary to have an effective wastewater treatment system in place. The existing treatment plants inside Kathmandu are outdated and unable to handle the load from the growing population. As a result, they are ineffective in their performance, which poses a serious threat to public health and the environment.

In urban areas like the cities within Kathmandu Valley (population 1.3 million) and especially Kathmandu City (population 500,000), the lack of basic sanitation has been devastating to the quality of local streams and rivers, namely the Bagmati and Bishnumati Rivers. Kathmandu Valley currently has five municipal wastewater treatment plants (WWTP): an activated sludge plant at Guheshwori, non-aerated lagoons at Kodku and Dhobighat, and aerated lagoons at Sallaghari and Hanumanghat and little wetland system, a treatment facility designed to mimic and optimize the natural removal processes of natural wetlands. But the removal of major impurities (BOD and COD) of effluent after being treated in existing facilities are not significantly reduced which is causing hazardous impact in river ecosystem and in agricultural lands when used for irrigation. Taking all these aspects into consideration we were motivated to explore for the possible solution in the field of waste water treatment in context of Kathmandu.

In recent years, there has been a growing interest in adopting chemically enhanced primary treatment (CEPT) processes as an alternative approach to enhance the efficiency and effectiveness of primary treatment in wastewater treatment plants (WWTPs). CEPT involves adding chemical coagulants or precipitants to the wastewater, facilitating the aggregation and settling of suspended solids and contaminants. CEPT has a number of benefits over traditional treatment, including reduced cost, ease of use, and increased effectiveness. Importantly, it is the most economical method of treating wastewater since it effectively disinfects the effluent. When compared to traditional primary treatment, chemically enhanced primary treatment (CEPT) enables sedimentation basins to operate at twice the overflow rate while still removing large amounts of total suspended solids (TSS) and biochemical oxygen demand (BOD).We will explore the potential impact of CEPT processes on reducing the presence of antibiotic resistance genes (ARGs) and their relative abundances in treated wastewater. Understanding the effects of CEPT on ARGs is crucial due to the growing concern regarding antibiotic resistance in aquatic environments and its potential implications for public health. Moreover, this review aims to identify research gaps and future directions in the field of chemically enhanced primary treatment. We will discuss the challenges and limitations associated with CEPT processes.

This review paper aims to contribute to the advancement and optimization of CEPT processes, promoting effective and sustainable wastewater treatment processes by critically analyzing prior studies' findings. This review paper seeks to advance and optimize CEPT processes while promoting effective and sustainable wastewater treatment procedures by critically evaluating prior studies and their findings. In the end, gaining a better understanding of chemically enhanced primary treatment will aid in the creation of innovative remedies for problems in wastewater treatment systems caused by urbanization, population growth, and emerging contaminants.

## 2. Literature Review

Since wastewater is a significant environmental problem that is always on the rise, there has been some research on its treatment methods. Thus, new technologies have been developed and many more are in research phase to find out the best possible treatment method. Chemically Enhanced Primary Treatment

(CEPT) is a method for treating sewage that includes adding chemicals to primary sedimentation basins, usually metal salts. When upgrading overworked or inadequately designed current systems, CEPT can be done using a dedicated CEPT tank, retrofitting a typical primary treatment plant, or employing stabilization ponds. Modern CEPT procedures only require small amounts of coagulants (10–50 mg/L), and the chemicals themselves little affect the overall generation of sludge. Hence, much research has been carried out to find out the optimal selection and dosage of coagulants, potential impacts on pH and subsequent biological treatment, and the overall cost-effectiveness and feasibility of implementing CEPT in different wastewater treatment scenarios. Researchers extract data from different journal, research papers, and experimental results in order to conduct their research on the best ways to tackle this problem.

**(Ju et al., 2016**)

This study was conducted to use AD (Anaerobic Digestion) to reduce sludge quantity for disposal and generate biogas as a renewable energy source. The focus is on the AD performance of CEPT (Chemically Enhanced Primary Treatment Plant) sludge coagulated with FeCl3 and AlCl3, as well as the microbial community structure. The study addressed the effects of operational parameters such as coagulant dosing, organic loading rate, temperature, hydraulic retention time, and salinity on AD performance. The microbial community structure in AD of CEPT sludge is compared with that of combined sludge digesters.

The study setup involved anaerobic digestion of sulfate-rich saline CEPT sludge and non-saline CEPT sludge in semi-continuous digesters. The AD performance of CEPT sludge was compared with conventional combined sludge. A total of 297 measurements were conducted under different operational conditions to evaluate the AD performance and analyze the structure of the microbial community. The results demonstrated that AD of CEPT sludge showed promising average performance, including a 58% reduction in volatile solids, a specific biogas production (biogas yield) of 0.92 $m^3$/kg volatile solids destroyed, and an average methane content of 65.4%. The addition of FeCl3 significantly improved specific methane production by 38-54% and reduced hydrogen sulfide (H2S) content in biogas, leading to higher methane recovery and simplifying biogas cleaning for power generation

The research gap identified in the paper is the need of microbiological data from more AD reactors under comparable operational conditions to completely resolve the effects of various chemical characteristics of feed sludge on the structure and performance of methanogenic microbial communities.

**(Huang & Li, 2000)**

The study was done to develop a new technology that significantly increases the removal of soluble and colloidal COD without excessive organic oxidation, thus reducing capital and operating costs associated with the new treatment method.

The method involved in the study is recycling a small portion of the primary sludge and aerating it for 30 minutes to activate its bio absorptive and flocculent properties. The aerated sludge was then mixed with raw sewage to facilitate rapid bio absorption of soluble COD and flocculation of colloidal organics. The mixture was settled in a regular primary clarifier. Unlike traditional methods, the raw sewage was not aerated, resulting in minimized sludge aeration tank volume and energy requirements. In fact, with 30 minutes of sludge aeration, the volume and energy requirements were only 1.25% and 8.5%, respectively, of those in the conventional activated sludge system. By implementing this modified approach with a 15% sludge recycle rate and 30 minutes of sludge aeration, the COD removal efficiency is significantly improved by 43.9% compared to regular primary treatment

The limitation of the study lies in lack of absorptive or flocculative properties in the raw primary sludge, which hinders the removal of soluble and colloidal COD. Additionally, the study acknowledges the minimal oxidation of soluble sewage organics and the reduced energy requirements during aeration. Further research could focus on quantifying the energy savings achieved and investigating ways to further minimize the aeration tank volume requirement in order to optimize the overall cost-effectiveness of the modified treatment technology.

**(Li et al., 2020)**

The study was conducted to explore the use of chemically enhanced primary sedimentation (CEPS) sludge fermentation liquor (CEPS-FL) as a carbon source for denitrification in municipal wastewater treatment. The researchers aimed to recover organic carbon from CEPS sludge through hydrolysis and acidogenesis, resulting in VFAs-rich fermentation liquor. The study aimed to assess the feasibility and effectiveness of CEPS-FL as a carbon source for denitrification and compare its performance and impact on microbial communities with commonly used commercial carbon sources.

This study collected raw municipal wastewater and conducted chemically enhanced primary sedimentation (CEPS) to concentrate organic matter into CEPS sludge. The sludge underwent fermentation to produce VFAs-rich fermentation liquor (CEPS-FL). Denitrification sludge was acclimated using different carbon sources. Batch tests were performed to analyze nitrate uptake rate (NUR) and nitrous oxide (N2O) emission rate. DNA extraction and 16S rDNA sequence analysis were conducted to assess microbial communities and species diversity in the samples.

In the study, it was found that ferric iron-based chemically enhanced primary sedimentation (CEPS) effectively removed over 70% of organics from municipal wastewater into sludge. Acidogenic fermentation further converted 27.9% of solid organic substances in the CEPS sludge into soluble volatile fatty acids (VFAs). The study concluded that integrating CEPS with sludge fermentation could reduce the organic load on subsequent treatment processes, improve nitrogen removal performance, and offer a cost-effective and energy-efficient approach to wastewater treatment.

There are some potential research gaps that could be addressed: Further investigation is needed to assess the long-term stability and sustainability of this method under varying operational conditions and fluctuations in wastewater composition. While the study compares CEPS-FL with methanol and sodium acetate as external carbon sources, it would be beneficial to include a wider range of commercial carbon sources commonly used in wastewater treatment.

**(Taboada-Santos et al., 2020**)

The study was aimed to compare two novel wastewater treatment plants (WWTPs) that utilize chemically enhanced primary treatment (CEPT) and high-rate activated sludge (HRAS) for organic carbon pre concentration. The focus is on evaluating energy demand, operational costs, as well as the removal of organic micropollutants (OMPs) and viruses. The research aimed to address the need for more energetically efficient and environmentally friendly WWTPs, considering the goals of the 2030 Agenda for Sustainable Development and initiatives to enhance OMP and virus removal in wastewater treatment.

The study conducted wastewater and sludge analysis in the context of a wastewater treatment plant (WWTP) in Santiago de Compostela, Spain. The wastewater samples were characterized for various parameters such as pH, total suspended solids (TSS), volatile suspended solids (VSS), total chemical oxygen demand (CODtot), soluble ammonium (NH4+), and phosphate (PO43-). Coagulation experiments were performed Organic micropollutants (OMPs) were analyzed, including musk fragrances, anti-inflammatories, antibiotics, neurodrugs, endocrine-disrupting compounds, and hormones. The samples were subjected to solid phase extraction and analyzed using gas chromatography and mass spectrometry.

This study compared two approaches, chemically enhanced primary treatment (CEPT) and high-rate activated sludge (HRAS), for improving energy efficiency in wastewater treatment plants (WWTPs). The CEPT plant achieved high phosphate removal efficiency (>99%) but required a minimum dose of 150 mg/L ferric chloride (FeCl3) to meet the desired COD-to-ammonium ratio. The HRAS reactor had slightly lower COD recovery but improved phosphate removal efficiency with FeCl3 addition. CEPT was less energy-intensive but had higher operational costs than HRAS. HRAS outperformed CEPT in removing organic micro pollutants (OMP) with higher removal efficiencies (>80%) compared to CEPT (4-55%). However, both configurations had biotransformation efficiencies below 55% for other OMPs. CEPT was less effective than HRAS in virus removal. HRAS followed by $FeCl_3$ post-treatment was identified as a more efficient alternative for COD pre-concentration in WWTPs, considering energy efficiency, operational costs, OMP removal, and virus removal.

The research gap in the study is as follows: Although the HRAS-based configuration had higher energy demand compared to CEPT, it had lower operational costs and demonstrated greater removal efficiencies for organic micro pollutants (OMP) and viruses. However, the results for recalcitrant compounds were comparable and low in both systems. Overall, the HRAS configuration appeared to be a more effective novel WWTP configuration, but there were significant variations in virus removal performance depending on the virus type.

**(Wong et al., 2016**)

This study explored the challenges of chemically enhanced primary treatment (CEPT) in wastewater treatment such as problem such as generation of large volume of odorous sludge with high water content, containing higher amounts of nitrogen, phosphorus, and heavy metals compared to conventionally treated sludges. Dewatering the CEPT sludge is costly, and synthetic polymer-based flocculants, currently used as sludge conditioners, are expensive and environmentally problematic. Bioleaching using Acidithiobacillus ferrooxidans has shown promise in improving sludge dewatering by bio-oxidizing ferrous iron and producing ferric iron that enhances coagulation and flocculation. The study aims to evaluate different fractions of A. ferrooxidans culture as conditioning agents to enhance the dewaterability of CEPT sludge.

In this study, CEPT sludge collected from Stonecutters Island Sewage Treatment Works in Hong Kong was used. The sludge was stored at 4°C until the experiments. The iron-oxidizing bacterium Acidithiobacillus ferrooxidans ANYL-1, isolated from anaerobically digested sludge, was prepared for sludge conditioning. Sludge treatment was performed in flasks with sludge and A. ferrooxidans culture, cells, or filtrate. Some treatments included supplementing Fe2+ as an energy substrate. Sludge dewaterability was evaluated using capillary suction time (CST), time to filtration (TTF), and specific resistance to filtration (SRF). Various parameters were measured, including sludge pH, oxidation-reduction potential (ORP), total solids, organic matter, and residual ferrous iron content. Statistical analysis was conducted to determine significant differences between treatments.

The findings of this study demonstrate the effectiveness of bioleaching in significantly improving sludge dewaterability, as evidenced by a substantial reduction in capillary suction time (20 seconds) and specific resistance to filtration (90%). However, bioleaching requires an adaptation period of 1-2 days. On the other hand, the biogenic flocculant produced by A. ferrooxidans shows promising results by reducing the time-to-filtration and enhancing dewaterability within just 4 hours. These results suggest that the use of biogenic flocculants offers a rapid and viable alternative to synthetic organic polymers for sludge dewatering.

The research gap addressed in this study is the improvement of CEPT sludge dewaterability using A. ferrooxidans culture and culture filtrate. The study confirms the efficiency of A. ferrooxidans in enhancing dewaterability, but acknowledges that bioleaching requires significant time. As a solution, the culture filtrate of A. ferrooxidans can be utilized as a flocculant without the addition of Fe2+ to achieve rapid flocculation and dewatering of CEPT sludge. This approach offers a potential alternative to commonly used organic polymers in sludge dewatering.

**Abdel Fatah & Al Bazedi, 2019**

This research paper presents an experimental study on different coagulants used for chemically enhanced primary treatment and obtaining their appropriate dosage, mixing rate, settling time for maximum removal efficiencies of TSS, $COD_5$, and Turbidity.

Coagulants used for analysis include Alum, Ferric Chloride and lime.

So, the appropriate parameters for each of the coagulants are summarized below on table shown:

**Table 1: coagulants parameters**

| Optimum Parameters | Alum | Ferric Chloride | Lime |
|---|---|---|---|
| **pH** | 5.5-6 | 4 | 9-10 |
| **Dosage** | 70-80 mg/lt | 40mg/lt | 600mg/lt |
| **Slow mixing-rate** | 50 rpm | 30 rpm | 30 rpm |
| **Mixing time(slow)** | 10 mins | 10 mins | 10 mins |
| **Settling time** | 20 mins | 10-20 mins | 10-20 mins |
| **Any additions** | Nil | Nil | Nil |
| **Mixtures of coagulants** | Nil | Nil | Nil |
| **Turbidity** | 90% | 96% | 90% |
| **TSS** | 95% | 96% | 94% |
| **$COD_5$** | 75% | 90% | 62% |

Also, sea water was used as additive and had very minimal addition to the removal efficiencies. Though it is not even feasible in case of landlocked countries. So, conclusion can be derived that either using Alum or Ferric chloride as per availability is the best with appropriate dosing as per article.

**(Xu et al., 2009)**

This study investigated the feasibility of recovering Alum from coagulation sludges and reusing it in the chemically enhanced primary treatment (CEPT) process for improved cost-effectiveness and resource recovery. The acidification method was optimized to achieve efficient Alum recovery from coagulation sludge.

This study focused on the quality of water samples collected from Songhua River in China, which represented the raw water used in a drinking water treatment plant. The study employed specific hydraulic conditions for coagulation in both river water treatment and wastewater treatment. Sludge samples were prepared by centrifuging water samples after coagulation and sedimentation with a specified amount of coagulant. The sludge samples were then stored for further analysis. The acid used in the research was sulfuric acid (H2SO4) at a concentration of 1 M. The quality of the water samples, including turbidity, color, temperature, pH, CODCr, SCODCr, and UV254, were determined. The effect of different dosages of $Al_2(SO4)_3$ (alum) on coagulation properties in water treatment was also investigated.

The results showed that at the highest recovery rate of 84.5%, the sludge reduction rate was 35.5%. The recovered coagulant demonstrated a removal efficiency of 96% for turbidity, 46% for UV254, and 53% for COD. These findings indicate that the recovered coagulants can be effectively used in CEPT, with pollutant removal efficiency comparable to fresh coagulant. Although some substances may be enriched during recycling, they have minimal impact on the quality of treated wastewater. The experiments confirm that recovering Alum from coagulation sludges in water and chemical wastewater treatment is an advisable and cost-effective approach that can be further recycled in CEPT, leading to sludge volume reduction.

**(Shin et al., 2022)**

The study was conducted to evaluate the potential of a chemically enhanced primary treatment (CEPT) process in reducing the antibiotic resistome (ARGs) in the influent of a wastewater treatment plant (WWTP). Specifically, the study was to assess the simultaneous reduction of ARGs and common pollutants in wastewater through CEPT compared to primary sedimentation. The researchers also aim to identify suitable indicators that are correlated with controlling ARGs in the enhanced primary treatment process by analyzing the relationships between major ARGs, intI1 (class 1 integron), physicochemical parameters, and the effluent of CEPT.

The influent was collected from a full-scale WWTP. The characteristics of the influent were analyzed. To simulate the CEPT process, jar tests were conducted using different coagulants (FeCl3, alum, PACl) in the influent. The effectiveness of each coagulant in reducing turbidity was tested by varying the dosages. The experimental setup involved rapid mixing, slow mixing, and settling.

The study found that CEPT processes using different coagulants in a municipal WWTP effectively reduced antibiotic resistance genes (ARGs), integrons, and pollutants compared to non-CEPT processes. The average log-removal of ARGs reached up to 1.77 ± 0.41, with a 90% reduction in turbidity. There were no significant differences in ARG abundance among the coagulants, except for PACl, which showed a different correlation with turbidity reduction. The relative abundance of ARGs decreased with higher turbidity reduction when FeCl3 or alum were used, possibly due to pH changes caused by the coagulants.

The study suggests that turbidity or T-P can serve as indicators for changes in ARG abundance during CEPT, highlighting its potential for controlling ARG flow in WWTPs while redirecting carbon and removing phosphorus. Further investigation into the effects of pH drop on treatment processes is needed.

**Luo et al., 2014**

In this research paper, the batch experiments were conducted in a 1000ml beaker. The mixture was first swirled for one minute at a speed of about 200 rpm, followed by 15 minutes at a speed of about 50 rpm, while remaining stationary for 30 minutes, adopting different flocculants (PAC, PAFC, PAM) to treat sewage wastewater samples that were taken from sewage treatment station of China University of Mining and Technology. The findings of this investigation demonstrated that the TP removal efficiency increased to around 90.0%, COD removal rate to approximately 40%, and SS removal efficiency to approximately 78.1% when PAC dosage was 200 mg/L. With the PAC dosage being increased, it had minimal impact on removal rate. The turbidity of the effluent remained at 6 NTU or below within a specific range. All effluent quality indicators improved significantly following coagulation and filtration treatments, bringing the turbidity down to 3 NTU or below. For engineering significance, the precipitation duration is crucial; the size of the sedimentation tank design must be huge with a long precipitation period, and the expenditures that go along with that increase as well. After 40 minutes of precipitation, the clearance rates of TP, COD, and SS increased marginally as the time of precipitation increased for PAC, PAFC, and PAM. The research of this article is that it briefly touches upon process parameters and chemical dosing, but it lacks an in-depth investigation into process optimization. A more extensive study focusing on the optimal dosages, reaction times, mixing conditions, and other operational factors would help identify the most efficient and cost-effective practices for CEPT.

**Alameddine et al.**

This work's major goal was to assess how well various coagulants and coagulant aids performed during the improved primary treatment of municipal wastewater under wet weather conditions. 50 and 125 mg/L of alum were chosen for this study since they reflect a fair range of values. The appropriate PACl and FeCl3 doses were then determined using metal-equivalent dose calculations. And after a number of experiments, it was determined that the greatest coagulant for the EPT (Enhanced Primary Treatment) is alum. In fact, under varied mixing conditions, both alum and PACl were able to maximize the removal of significant macropollutants. However, the Alum was taken into consideration for future optimization because it was cost-effective. Without the use of any polymers, a dose of 75 mg/L alum was guaranteed to meet the desired TSS levels, reduce turbidity by 87%, and ortho-P by 71%. Although adding polymer as a coagulant aid is now a practice at the WWTP, but the results indicated that this is neither sustainable economically nor environmentally because it raises costs by raising the need for chemicals with only a minimal impact on the decrease of loads.

The research gap lies in the challenges and discrepancies that can occur during the scale-up process from bench to full-scale for real-world treatment plants.

**(Olive, 2002)**

The article provides a comprehensive overview of the CEPT plant design, the strategy employed for sludge management, and the analysis of its impact on the reservoir of Alfenas, Brazil. It looks at how the usage of CEPT in the area might lead to an improvement in the water quality in the Furnas reservoir. The reservoir's bacterial and nutrient levels are measured through testing and contrasted with the expectedly lower levels after CEPT treatment. A neutral synthetic polymer, Tanfloc, $FeCl_3$, and alum were among the chemicals studied. Tanfloc alone removed 68% of the suspended particles at the same overflow rate, compared to 65% for $FeCl_3$ + Tanfloc. This indicates that, under anticipated operational conditions, the TSS removal efficiencies for both approaches are comparable. $FeCl_3$ treatment of wastewaters results in the formation of inorganic precipitates, such as ferric hydroxides and ferric phosphates, which raises the number of solids produced throughout the process and lowers the effectiveness of TSS removal. Being a natural polymer, tanfloc is not anticipated to produce as many precipitates. In conclusion, the two approaches' TSS removal efficiencies are close, with the Tanfloc alone option having a tiny edge. When examining the data for turbidity, it's crucial to keep in mind that $FeCl_3$ not only creates a greater range of solid precipitates, some of which are insoluble, but also colors the water yellow. A treatment dosage of 30 mg/L of ferric chloride and 10 mg/L of Tanfloc is recommended as it will provide optimal removal efficiencies with locally available and affordable chemicals. Further disinfection is required to meet Brazilian regulations for effluent discharge to surface water bodies. When these two elements ($FeCl_3$ + Tanfloc) combined together results in a turbidity removal efficiency of about 55% as opposed to Tanfloc alone of about 70% at the same overflow rate. Since sludge treatment was also a main focus to convert the waste products produced by the CEPT plant into a valuable resource for the local community by lime addition for disinfection, thickening and drying leading to land application for agriculture purpose. Although the article mentions the analysis of reservoir impact after the implementation of CEPT, there may be a research gap in terms of the extent and depth of the analysis. Further investigation could include a more comprehensive assessment of the long-term effects of CEPT on the reservoir ecosystem.

**Haydar & Aziz, 2009**

The article presents a case study of Saddiq Leather Works, examining the wastewater characteristics, the application of CEPT, and the treatability of the wastewater. The study evaluates the performance of CEPT in terms of pollutant removal efficiency, including the reduction of organic matter and the removal of heavy metals. It also examines the impact of process parameters, such as chemical dosage, pH adjustment, and coagulant selection, on the treatment performance. Thus, finding the optimal conditions for CEPT application to achieve desirable treatment outcomes.

As coagulants, evaluation of alum, ferric chloride and ferric sulfate was done. A series of preliminary jar tests were carried out to (1) examine the comparative suitability of various metal salts; and (2) to determine their optimum dose range. Only turbidity measurements were made. From three series of jar tests the amounts of alum, ferric chloride, and ferric sulfate were discovered where Alum was the most effective coagulant for tannery wastewater in the dose range of 200-240 mg/l in case rapid mix and flocculation units were provided prior to primary sedimentation tank .And without these unit 400mg/l dosage is needed in equalization tank. Thus, Turbidity, total suspended solids (TSS), chemical oxygen demand (COD), and chromium removal efficiency with alum was determined to be 98.7-99.8, 94.3-97.1, 53.3-60.9, and 98.9-99.7%, respectively. Research gaps:

Use of Ferric chloride and Ferric Sulphate was not possible due to generation of black colour although appreciable removal rate due to no further tests.

There is a lack of comprehensive evaluation of the sludge management strategies employed. Further research could delve into the optimization of sludge treatment and disposal method.

The stability and durability of CEPT over extended periods, considering variations in influent wastewater characteristics, seasonal fluctuations, and potential changes in operational conditions.

**Al Bazedi & Abdel-Fatah, 2020**

The article aims to explore how different operating parameters impact the effectiveness of CEPT in removing pollutants from wastewater. The article discusses the statistical analysis and modeling techniques employed to establish correlations between the operating parameters and the removal efficiency. Samples of the effluent from the primary settling tank and of the grit removal chamber from the municipal wastewater treatment plant of Zenein were collected for the work. Different types of coagulant ($FeCl_3$, alum, lime, and Magna-floc155), as well as different treatment capacities, were investigated. $FeCl_3$ and Alum were highly effective coagulants for turbidity, with removal efficiency above 90%, for around 40mg/l and 50mg/l coagulant dosages respectively. Lime shows to be less adequate and mediocre, where the removal efficiency reaches 80% when using a lime with a dose of 400 mg/l. With the application of alum as a coagulant, high clearance efficiencies of 100% of total suspended solids (TSS) were observed. $FeCl_3$ likewise produced high removals (> 90%), although lime only produced a "TSS removal" of about 80%. The experiments revealed that it is better to use each coagulant alone due to interference between coagulant mixtures, which leads to undesired change in pH. Treatment with the use of Alum was proved to be more efficient than when using $FeCl_3$ and lime with reduced corrosion problems. Multivariate regression model empirical model was developed using the simulation data obtained from the the experimental studies using different types of coagulant ($FeCl_3$, alum, lime, and Magna-floc 155). The removal efficiencies of COD and TSS can be predicted to be ($R^2$ = 0.973 and 0.978, respectively). The advantage of this model is that it would allow a better process control.Although having great benefits it still lagged in some aspects like:

While the article focuses on the correlation between operating parameters and removal efficiency,no consideration of energy consumption and cost optimization is mentioned.

The article provides insights into the correlation between operating parameters and removal efficiency in a CEPT system. However, there may be a research gap in terms of validating these findings in different CEPT systems treating diverse wastewater sources.

**Bezirgiannidis et al., 2019**

This article explores a combined treatment approach using chemically enhanced primary sedimentation (CEPT) and biofiltration for low-cost municipal wastewater treatment. The article aims to investigate the effectiveness and feasibility of this combined process as an alternative and cost-effective solution for wastewater treatment. In this study, chemically enhanced primary treatment (CEPT) and a pilot-scale treatment unit were used to depurate municipal wastewater that included a storage tank (1 $m^3$ ), rapid mixing tank, flocculation tank and sedimentation tank, and a biological trickling filter accompanied by a secondary settling tank. The effectiveness of removing organic load and low operational cost were selection criteria. Through the addition of polyaluminum chloride (PAC) and the cationic polyelectrolyte (Zetag 8180), the coagulation-flocculation process was carried out. The ideal chemical dosage was established using lab-scale experiments (Jar-tests) and were 10mg/l PAC and 1.5 mg/l poly-electrolyte. Comparative evaluation was carried out of CEPT-Trickling filter with similar schemes from previous studies and CEPT paired with trickling filter has the most efficient performance for any organic and inorganic impurities. The overall removal efficiencies achieved in the CEPT-trickling filter were Total Chemical Oxygen Demand (tCOD), soluble Chemical Oxygen Demand (sCOD), BOD5 (5-day Biochemical Oxygen Demand), NH4 -N, Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), and PO4 3-P removal efficiencies were estimated to be 89, 82, 93, 60, 96, 96, and 78%, respectively. The effluent that was rich in ammonia nitrogen was used for restricted irrigation. Also operating cost was estimated to be 0.04 e/m3 (0.045 $/m3 ) for the PAC and 0.01 e/m3 (0.011 $/m3 ) for the polyelectrolyte. Thus this article states data from head to toe operation of the treatment operation accompanied although scalability might be an issue.

**Ayoub et al., 2017**

It investigates the application of recovered alum from water treatment sludge for chemically enhanced primary treatment (CEPT) of sewage. The study focuses on utilizing alum as a coagulant in a model hydraulic clari-flocculator to enhance primary treatment processes and improve the removal of pollutants from sewage. This strategy is based on two factors at once. The first part involves using the recovered alum from Water Treatment Sludge as a coagulant in CEPT of wastewater and comparing the results with those obtained from the fresh alum under identical operational circumstances and wastewater characteristics. Additionally, the second component examines the swirl flow hydraulic clari-flocculator model to finish the CEPT of wastewater in a straightforward and affordable model. Tests were carried out which includes coagulation, flocculation and sedimentation that were performed via a jar test apparatus as a mechanical flocculation system.  the swirl flow hydraulic clari-flocculator used was a prototype to treat raw sewage in which Flocculation process took about 33% of total retention time, whereas the sedimentation process takes about 67% of total retention time. Although certainly the hydraulic clari-flocculation is more economical than the mechanical mixing, mechanical mixing is somewhat more efficient than hydraulic clariflocculation from view points of the mixing control and the solids separation. The appropriate fresh alum dosage to obtain good amount recovered alum for further use was 120mg/l. With the help of the recovered alum, it was possible to remove BOD5, COD, TSS, PO4, and NO3 with removal efficiencies of up to 85.5%, 74.5%, 84.46%, 95.8%, and 30.4%, respectively. The largest removal efficiency differences between using fresh and recovered alum were often only 2.94% of BOD5, 8.11% of COD, 1.68% of TSS, 3.11% of PO4, and 11.33% of NO3. Although the removal efficiencies are lower than the fresh one but the recovered alum is significantly better than the fresh alum as per viewpoint of environmental impacts. Although this article addresses the economic and environmental aspects of utilizing recovered alum, including its potential as a sustainable and cost-effective coagulant.however, there may be a research gap in terms of a comprehensive assessment of these parameters. Further research could investigate the interactions and optimization of parameters such as alum dosage, pH adjustment, mixing intensity, and settling time to maximize the treatment efficiency and minimize operational costs.

**(Shewa & Dagnew, 2020)**

The article aims to revisit the CEPT process, summarize its key aspects, and assess its performance in removing pollutants from wastewater. This research examines the CEPT application, current chemical usage, removal effectiveness, difficulties, and environmental effects. The two most often utilized coagulants in CEPT are alum and iron salts. As flocculants, a variety of anionic, cationic, and uncharged polymers are used, with poly aluminum chloride (PACL) and polyacrylamide (PAM) being the most common. CEPT is used to significantly lower the organic load on secondary treatment procedures and improve carbon redirection for recovery. Depending on the properties of the wastewater being treated and the type of coagulants and/or flocculants employed, CEPTs can remove between 43.1 and 95.6% of COD, 70 to 99.5% of suspended particles, and 40 to 99.3% of phosphate. Thus,It presents a summary of research studies and case studies that have evaluated the effectiveness of CEPT in different wastewater treatment scenarios. Although this review article covers almost all the aspects regarding the CEPT implementations in a treatment plant but there may be a research gap in terms of addressing emerging contaminants. Emerging contaminants, such as pharmaceuticals, personal care products, and microplastics, pose new challenges in wastewater treatment. Further there may be a research gap in terms of standardized guidelines and optimization approaches for CEPT implementation.

**Mahmoued, 2014**

This article explores the potential use of cement kiln dust (CKD) for chemically enhanced primary treatment (CEPT) of municipal wastewater. It aims to investigate the feasibility and effectiveness of CKD as a coagulant. The jar tests was carried out to choose the best coagulant among chemicals of aluminum sulfate (alum), cement kiln dust (CKD), and cationic polymer. As a result two options were taken for comparison and the percentage of the removals of COD, BOD, and $PO_3$ from raw wastewater for CKD+PAM was better than alum+PAM options. The use of CKD and alum with cationic polymer showed improvement in removal of COD and BOD. Moreover, the addition of polymer with CKD and alum resulted in the formation of big flocs. The primary ingredients of CKD, an alkaline waste material with a pH of 12.3, are calcium carbonate (47.6%), aluminum oxides (4.2%), iron (2.8%), magnesium (2.3%), free lime (4.8%), and a few alkali salts like sodium and potassium. It was concluded that BOD, COD, phosphorous, and fecal coliform (FC) could all be reduced by amounts greater than 79, 85, 95, and 99.9%, respectively, with the addition of 50 mg l1 of CKD and 0.2 mg l1 of polyacrylamide flocculant (PAM). Heavy metal, salinity, sodici- ty, phosphorous concentrations, and pH of the treated wastewater of CEPT (CKD+PAM) are within the acceptable range for irrigation. Cost of the chemicals to treat one cubic meter of wastewater was below $ 0.05m/3. Thus, CEPT (CKD+PAM) can be used as a simple low-cost technology and low-cost for municipal wastewater treatment to improve the efficiency of CKD disposal.Some limitations that may arrive can be summed up as: there may be a research gap in terms of evaluating the long-term performance and stability of CKD-based treatment systems. Further research could focus on long-term studies to assess the durability and stability of CKD-based CEPT systems under varying operating conditions and influent wastewater characteristics.

The article mentions the potential benefits of CKD application, including reduced sludge production; however, there may be a research gap in terms of investigating the impact of CKD on sludge characteristics and disposal. This would provide a comprehensive understanding of the overall treatment process and its implications for sludge management.

**(Hyldahl & Hopson, 2001)**

The goal of the study was to assess the feasibility and effectiveness of this retrofitting option as a solution to the wastewater treatment issues in the region. Wastewater treatment is highly valued in Puerto Rico, and the project focused on two existing wastewater treatment plants (WWTPs) located in Vega Baja and Fajardo. Vega Baja is situated about 27 kilometers from San Juan, while Fajardo is approximately 50 kilometers away. Both WWTPs are positioned on the northeastern side of the island, and their effluents ultimately flow into the Atlantic Ocean. Given the heavily populated northern coast and the influx of tourists during certain months, maintaining high-quality effluent from the WWTPs is crucial for preserving coastal beauty and public health.

Two wastewater treatment plants (WWTPs) in Puerto Rico, Vega Baja and Fajardo, evaluated the application of chemically enhanced primary treatment (CEPT). Both facilities had main settling tanks followed by fixed-film trickling filters, and they were both working at above-design capacities. Aluminum chlorohydrate was dosed at the Vega Baja WWTP at a rate of 20 or 40 mg/L for nine hours each day. Aluminum chlorohydrate, with an Al concentration of 12.4%, was first employed by the Fajardo WWTP at a dosage of 43.5 mg/L for 14 hours. Later, the application lasted for 17 hours but with a different aluminum chlorohydrate solution (Al concentration of 11.6%).

At the Vega Baja WWTP, CEPT enhanced TSS removal by four times to 47% while tripling BOD removal in the primary clarifier to 65%. The effluent BOD content with CEPT was 12.5 mg/L, surpassing the local compliance regulation limit of 5 mg/L but still a significant improvement. The effluent TSS content was 12 mg/L, which is significantly less than the local compliance level of TSS of 30 mg/L.

The effluent concentrations at the Fajardo WWTP were decreased by CEPT to an average of 14 mg/L for BOD and 16 mg/L for TSS, both of which were below the local compliance permit limitations. At Fajardo, various coagulant solutions were tested; one of them offered a better cure at a lower price.

The study's findings shows that chemically enhanced primary treatment (CEPT) is effective in enhancing BOD and TSS removal at the Vega Baja and Fajardo WWTPs in Puerto Rico but there are still few gaps in this research, which are mentioned bellow;

- ✓ Analyzing additional water quality metrics: More thorough knowledge of CEPT's overall effectiveness would come from evaluating its effects on other water quality metrics, such as nutrient concentrations (for example, nitrogen and phosphate), pathogens, or emerging pollutants.
- ✓ Long-term operating performance and stability: The study offers insightful information on how well CEPT performed initially at the WWTPs. To evaluate the operational performance and stability of CEPT systems over the long term, nevertheless, a longer monitoring period would be required. System performance may alter over time as a result of variables such

**He et al., 2016**

The study presents a case study conducted on Qingshan wastewater treatment facility in Huangshi, Hubei Province to evaluate the effectiveness and potential for optimization of CEPT as a wastewater treatment process. By comparing the removal performance of three inorganic chemical coagulants polyaluminum chloride, polyaluminum ferric chloride [PAFC], and poly ferric sulfate individually or in combination with poly acrylamide, and optimizing the conditions during CEPT by both single factor analysis and orthogonal test designs, the feasibility of this process for the treatment of wastewater was thoroughly investigated. The findings of this study showed that CEPT was a successful method for treating wastewater, with PAFC serving as the ideal coagulant and demonstrating a superior ability to remove chemical oxygen demand, total phosphorus, and SS. Following points were concluded from the experiment:

As per CEPT, PAFC was the best coagulant for the work. PAM was less effective as compared to PAFC, PAC, and PFS, however 0.5 mg L-1 PAM might reduce the settling time. The ideal velocity gradient for the mixing and reaction phases was 174.80 and 15.56 s-1, respectively, with GT values of 1.049x104 and 1.027x104. The ideal pH was 7.0, the settling time was 15 minutes, and the quantity of the coagulants depend on the quality of the raw water.

The article focuses on the feasibility and optimization of CEPT in terms of wastewater treatment efficiency; however, there may be a research gap in terms of addressing the environmental and health risk assessments associated with CEPT.

**(Rashed et al., 2013)**

The aim of the study "Optimization of chemical precipitation to improve the primary treatment of water" was to select the best coagulant or coagulant mixture for the chemical precipitation of wastewater, specifically focusing on alum and alum supported with sea-salt. The study aimed to improve the removal efficiencies of total suspended solids (TSS), biochemical oxygen demand (BOD5), chemical oxygen demand (COD), and nutrients before the biological treatment, in order to reduce the organic load in the influent to the secondary treatment. The goal was to achieve economic feasibility by reducing the cost of coagulant usage and controlling pH variation to meet the suitable range for biological treatment.

The study conducted experiments in laboratory settings, including the Sanitary Engineering laboratory at Tanta University in Egypt, using direct precipitation processes simulated in standard jar tests. The effects of alum doses and sea salt doses on the removal efficiencies of COD, BOD5, TSS, T-P, and T-N were evaluated. The study also explored the use of mixtures of alum and sea-salt as coagulants to reduce costs and determine the optimal type of coagulant.

The findings of the study showed that direct chemical precipitation of wastewater can significantly improve the removal efficiencies, achieving up to 87% COD removal, 93% BOD5 removal, 94% TSS removal, 96% T-P removal, and 20% T-N removal. This approach also greatly reduces the settling time in the primary treatment compared to conventional primary sedimentation. The use of chemical precipitation can remove approximately 50% of the organic load in the influent, allowing for the treatment of additional quantities of wastewater and increasing the capacity of wastewater treatment plants.

The study found that sea-salt as a sole coagulant had limitations, such as its relatively low charge cation and increased pH value, which may inhibit the action of microorganisms in subsequent biological treatment. However, the use of homogenous mixtures of alum and sea-salt as coagulants showed satisfactory results in terms of removal efficiencies and pH variation. The study used the analytical hierarchy process (AHP) for evaluation and ranked the mixtures of alum and sea-salt as the top choices based on the criteria of removal efficiencies, sludge volume after 30 minutes, coagulant cost, and pH variation.

## 3. Summary and Conclusion

In conclusion, the studies mentioned provide insights into the effectiveness of various coagulants and coagulant aids in the treatment of wastewater. The findings suggest that different coagulants have varying removal efficiencies for different parameters such as turbidity, total suspended solids (TSS), chemical oxygen demand (COD), and phosphorous.

Alum (aluminum sulfate) showed high turbidity removal and COD reduction at optimal dosages, while ferric chloride (FeCl3) demonstrated high turbidity reduction. PACl (polyaluminum chloride) was found to be effective in maximizing the removal of macro pollutants. Tan floc alone and polymeric coagulant aids were also evaluated, with tan floc showing comparable TSS removal efficiency to FeCl3 + Tan floc. Alum, ferric chloride, and ferric sulfate were effective coagulants for tannery wastewater treatment. Additionally, a modified primary treatment approach using activated sludge and sludge recycling showed improved removal of soluble and colloidal COD.

The studies also highlighted the potential of using organic carbon sources like CEPS sludge supernatant and acidogenic sludge fermentation for biological denitrification, leading to cost reductions and improved nutrient removal. Chemically enhanced primary treatment (CEPT) was compared to high-rate activated sludge (HRAS), with FeCl3 and ferric sulfate as common coagulants, showing similar COD removal rates but different impacts on NH4+ and PO43- concentrations.

CEPT was found to be an effective method for TSS and BOD removal, allowing for compact treatment facilities and the potential to reduce the size of future biological treatment units or enhance the capacity of existing ones. The use of recovered alum from water treatment sludge (WTS) in CEPT showed comparable removal efficiencies to fresh alum, emphasizing its practical and environmentally beneficial application. Various coagulants and flocculants, such as alum, iron salts, PACL, and PAM, were explored in CEPT, offering significant reductions in organic load and improvement in carbon redirection.

Overall, the studies provide valuable information on the performance and efficiency of different coagulants and coagulant aids in wastewater treatment. However, the optimal choice of coagulant depends on specific wastewater characteristics and treatment goals, and further research is needed to assess their long-term effects and cost-effectiveness in large-scale applications.

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