Wastewater chemically enhanced primary treatment combined with adsorption of activated sludge: AS-CEPT in wastewater treatment

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Abstract: Activated sludge-chemically enhanced primary treatment (AS-CEPT) —— an effective process to enhance pollutants removal was investigated in this study. CEPT in municipal wastewater treatment is particularly suitable for rapidly growing cities. The adsorption behaviours of soluble organic contaminants from sewage with activated sludge were characterized in this paper. The effects of MLSS/COD value and ferric sulphate concentration on removal rates of turbidity, COD, SCOD, non-SCOD, UV_254, TP and PO_4-P were investigated. CEPT combined with adsorption of activated sludge exhibited higher removal rates than those using activated sludge or CEPT only. AS-CEPT utilizes excessive activated sludge to promote pollutants removal with decrease of sludge disposal.

Keywords: Activated sludge; adsorption; AS-CEPT; CEPT; SCOD; wastewater

INTRODUCTION
Chemically Enhanced Primary Treatment (CEPT) in municipal wastewater treatment is particularly suitable for developing countries and can be used as an alternative for the treatment of sewage to traditional biological processes (Harleman D. R. F. and Morrissey S. P., 1990; Shao Y.J. et al., 1996; Harleman D. R. F. and Murcott S., 1999; Poon C.S. and Chu C.W., 1999). Generally it was found that in wastewater about 25% of the COD was in stable form with the size < 0.08µm, 15% of the organic matter was found to be appearing as colloidal (0.08-1.0µm), about 25% as supracolloidal (1-100µm) and about 35% as settleable (>100µm) (Ødegård H., 1998); it is found to be responsible for settleable and colloidal organic matter removal and total phosphorus (TP) removal; however, it is little effective to soluble COD (SCOD) removal. A special property of activated sludge is its adsorption capacity. When activated sludge is brought into contact with wastewater, it has been observed that the disappearance of organic material is faster than the consumption of oxygen, which indicates that it is adsorbed onto the activated sludge flocs (Torrijos M., et al., 1994). Further, the difference in adsorption capacity between high (≥ 5mg L^-1) and low (<0.5mg L^-1) DO concentration was small (Wiên B. M. and Balmér P., 1998). With 15% primary sludge recycle rate and 30-min sludge aeration, the COD removal efficiency was 43.9% higher than that of the regular primary treatment (Huang J. C. and Li L., 2000a, b).

Many experiments indicated that activated sludge biomass is a suitable adsorbent for various basic dyes (Chu H. C. and Chen K. M., 2002), pentachlorophenol (PCP) (Wang J. et al., 2000), AOX (Bornhardt C. et al., 1997) and other organic matter. The removal of SCOD from domestic water was studied using excessive activated sludge biomass as an adsorbent. The experimental results showed that adsorption by activated sludge biomass was not only feasible but also effective.

MATERIALS AND METHODS
The sewage was collected from the sewer of the residential section in Harbin institute of technology, China. The live activated sludge was realized in a sequencing batch reactor fed with the sewage mentioned above on the condition of organic loading rate (OLR) at about 0.8-1.2gCOD L^-1 day, and dissolved oxygen (DO) at 2-5mg L^-1. The activated sludge was pre-concentrated by sedimentation, then the supernatant was discarded and the
Pre-concentrated sludge was further concentrated by centrifugation (1500rpm, 1min). Centrifugation supernatants were discarded. Finally the resultant sludge was mixed with the fresh wastewater in a 1L beaker by aeration, and the aeration air flow was 50L h⁻¹.

When CEPT combined with activated sludge adsorption, the optimum procedure was as following: dosing ferric sulfate under the jar test of 400rpm, 10s; 120rpm, 1min, then dosing activated sludge by 40min-aeration. Turbidity was detected by the Turbid meter (A14, Wuxi), UV₂₅₄ was measured using 752 spectrophotometer (Shanghai) with 1cm quartz cell at 254nm, COD values were measured using 752 spectrophotometer at 620nm after two hours heating reaction in the COD Reactor (HACH, U.S.A.) and TP was determined in accordance with Standard Methods (APHA et al., 1985).

RESULTS AND DISCUSSION

Adsorption on activated sludge

Effect of aeration time. Changing aeration time from 10min to 100min with a constant MLSS/COD value (MLSS is mixed-liquor suspended solids and COD is for the raw water) of 2.5 for sewage disposal in a 1L beaker were studied (shown in Figure 1). SCOD sorption capacity of activated sludge was saturated after 40min-aeration.

COD adsorption capacity of a healthy activated sludge increases with the flow along the aeration units (Tan K. N. and Chua H., 1997). As shown in Figure 1, aeration time made a great influence on turbidity COD SCOD UV₂₅₄ and TP removal. With aeration time increasing, turbidity COD SCOD UV₂₅₄ and TP removal rates was also increasing; when adsorptive capacity of activated sludge floc got saturated gradually, its adsorption capacity tent to be stable and its oxidation capacity enhanced gradually, but the oxidizing action was limited, so the following turbidity COD SCOD UV₂₄ and TP removal rates increased slowly. The removal rates curve of COD and SCOD was adjacent, after aeration for 40min, their removal rates was between 62%–66%; but turbidity removal rate was stable after 80min-aeration, generally between 71%–73%.

The reasons were that, after aerating for a while, the activated sludge adsorbed lots of organics, bacteria propagated in large amounts, dissociating bacteria increased, high energy of activated sludge floc made against sludge sedimentation, as aeration time lengthening, the adsorbed organic matters on the sludge were degraded, and the energy of the sludge floc also were decreased, so dissociating bacteria collided on each other, and the enhanced coagulation enhanced the formation of zoogloea with well settlement, and made the suspended solids in the effluent decrease and made the removal of turbidity increasing. The increasing of UV₂₅₄ with the aeration time showed that, during the aeration the activated sludge could adsorb hydroxybenzene, aromatic hydrocarbon, aromatic ketone, aromatic aldehyde which all have C=C or C=O with them. As be known, the activated sludge adsorb phosphorus when aerobicosis and release phosphorus with anaerobic environment. So aerating with 10min–40min, the removal of TP was similar, but the removal of TP increasing sharply when aerating more than 40min. When aerating 50min, the removal rate of TP increased 12% when compared with aerating 40min. And from then on, the removal rate of TP was kept on 23%–30% steadily.

Effect of MLSS/COD value. Changing MLSS/COD value from 0.5 to 20 with a constant aeration time of 40min for sewage disposal in a 1L beaker were studied (shown in Figure 2). SCOD sorption capacity of activated sludge was saturated when MLSS/COD value was 3.3.

As seen from Figure 2, turbidity, COD, SCOD and UV₂₅₄ could be affected by MLSS/COD greatly. As MLSS/COD went up, the removal of turbidity, COD, SCOD and UV₂₅₄ also went up. When MLSS/COD went from 0.5 to 3.3, the removal rate of COD and SCOD went up 44% and 53%, separately. When the concentration of activated sludge increased again, the removal rate of COD and SCOD did not have visible change, they were kept on 63%–64% and 68%–69%, separately. Activated sludge could adsorb soluble organic matter by microbe or physical reaction, so from the experiments, it could be seen that the increase of activated sludge concentration is profitable to the removal of COD and SCOD. The removal of turbidity and UV₂₅₄ increased with the increasing of activated sludge concentration. The activated sludge was used as coagulant, so as the dosage of the coagulant increase, the removal of pollutant increase correspondingly. And under the condition of aeration
and mixing, the removal rate of turbidity and UV254 increased with the going up of the activated sludge dosage. But, the removal rate of TP did not change with the changing of sludge dosage. So it can be concluded that the activated sludge dosage is not part of the major factors. To have a satisfied result, MLSS/COD should more than 3, it means that when the COD of the influent is 400mg L⁻¹, the sludge dosage should more than 1.2g L⁻¹ in order to get to a better result.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** The removal rates at various aeration MLSS/COD as 40-min aeration  
**Figure 2.** The removal rates at various time as 2.5 MLSS/COD

Chemically enhanced primary treatment

**Effect of ferric sulphate concentration.** Changing ferric sulphate concentrations from 0 to 120mg L⁻¹ were studied (shown in Figure 3).

![Figure 3](image3.png)

**Figure 3** The removal rates at various ferric dosages

As seen from Figure 3, with hydrodynamic mixing, the ferric sulphate dosage had obvious effects on the removal rate of turbidity, COD, SCOD, TP, PO₄-P and NSCOD. Turbidity, COD, SCOD and TP went up with the going up of the ferric dosage. The removal rate of NSCOD got to the max value 95% when the ferric dosage was 60mg L⁻¹, and then decreased a little. But CEPT had small effect on the removal of the SCOD, it was only about 14%, so CEPT can mainly remove insoluble COD that were colloid and suspended pollutants. When ferric dosage was 60mg L⁻¹, the removal rate of COD got to the max value, it was 60%. The removal rate of PO₄-P was kept on 100% all the time, and when ferric dosage was 60mg L⁻¹, the removal rate of TP could get to 97%, so as seen, CEPT has great effect on the removal of phosphorus.

CEPT combined with adsorption of activated sludge

**Effect of ferric sulphate concentration.** Changing ferric sulphate concentrations from 0 to 120mg L⁻¹ with a constant MLSS/COD value of 3.3 were studied (shown in Figure 4).
As seen in Figure 4, the ferric sulphate dosage had obvious effects on the removal rate of turbidity, COD, SCOD, UV\textsubscript{254}, TP, PO\textsubscript{4}-P and NSCOD. Turbidity, COD, SCOD TP and NSCOD went up with the going up of the ferric dosage. The curves of the removal rates of turbidity, TP and NSCOD were adjacent. When ferric dosage got to 60 mg L\textsuperscript{-1}, turbidity, COD, SCOD TP and NSCOD went to steady values, they were 93%, 82%, 69%, 50%, 94%, 100% and 93%, separately. And comparing to those without ferric sulphate, the removal rate increased 23%, 16%, 7%, 22%, 74%, 86% and 24%, separately. When ferric dosage was 20 mg L\textsuperscript{-1}, PO\textsubscript{4}-P was almost removed out from the effluent. The removal rate of SCOD increased slowly with the increasing of ferric dosage, because the major factor of the SCOD removal was activated sludge but not ferric dosage. When the ferric dosage went up, the removal rate of UV\textsubscript{254} increased firstly and then decreased a little. This phenomenon shows that when ferric sulphate was over dosage, the activation of the chemical-activated sludge to UV\textsubscript{254} was bated.

**Effect of MLSS/COD value.** Changing MLSS/COD value from 0 to 10 with a constant ferric sulphate concentrations of 40mg L\textsuperscript{-1} for sewage disposal were studied (shown in Figure 5). As activated sludge of 2.5 MLSS/COD value was used, the removal rates of COD, SCOD and UV\textsubscript{254} increased 27%, 58% and 21% respectively.

See from Figure 5, MLSS/COD has big effects on the removal rates of turbidity, COD, SCOD, UV\textsubscript{254}, TP, PO\textsubscript{4}-P and NSCOD. COD SCOD and UV\textsubscript{254} went up with the increasing of MLSS/COD. Activated sludge has great effect on the removal of SCOD. When without activated sludge, the removal rate of SCOD was only 12%, but when MLSS/COD went up to 2.5, the removal rate of SCOD got to 70%, it increased 58%. When the removal rate of SCOD increased, the removal rate of COD also increased correspondingly, and when MLSS/COD increased to 2.5, the removal rate of COD got to 80%, it increased 27% compared to that without activated sludge. And when MLSS/COD increased to more than 2.5, the removal rate of COD, SCOD and UV\textsubscript{254} was almost steady, the removal rate of UV\textsubscript{254} could get the max value that was 48%. But when the ferric sulphate dosage was 60mg L\textsuperscript{-1} without activated sludge, turbidity, NSCOD and TP were all at the max value, they were 95%, 96% and 97%, separately. The values were all more than those got from the condition with activated sludge. So they showed that activated sludge was against the removal of turbidity, NSCOD and TP. Maybe the reason is that during the aeration, bacteria reproduce abundantly, the amount of dissociative bacteria increased, so the settlement of the sludge gets worse. And there is another possibility, that is the overdose of ferric sulphate reduces the removal capability of the chemical-activated sludge to turbidity, NSCOD and TP. When the concentration of the activated sludge went up, the removal rate of turbidity, NSCOD and TP increased a little, and they went to keep on steady values.

**CONCLUSION**

AS-CEPT is an effective and a feasible way in wastewater treatment. Activated sludge plays a significant role in the removal of soluble organics. The experimental results showed that adsorption by activated sludge biomass was not only feasible but also effective. The results showed that the removal efficiencies of turbidity, COD, SCOD, non-SCOD, UV\textsubscript{254}, TP, PO\textsubscript{4}-P reached 87%, 80%, 70%, 89%, 44%, 90%, 100% respectively as
40mg L⁻¹ ferric sulphate and 2.5 MLSS/COD. CEPT combined with adsorption of activated sludge exhibited higher removal rates than those using activated sludge or CEPT only. AS-CEPT utilizes excessive activated sludge to promote pollutants removal with decrease of sludge disposal.

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