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REMOVAL OF SOLUBLE AND PARTICULATE ORGANIC MATERIAL IN MUNICIPAL WASTEWATER BY A CHEMICAL FLOCCULATION AND BIOFILM PROCESSES

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ABSTRACT

Since the major part of the contaminants in municipal wastewater is associated with particles, direct particle separation is an effective way of lowering the wastewater contaminant level. An additional biological oxidation is usually required to remove the residual soluble contaminants. This paper presents the experimental data on the chemical treatment of municipal wastewater by the Jet Mixed Separator(JMS) which can be used as a unit process for physico-chemical treatment. As simultaneous flocculation and sedimentation occurred, the JMS effluent concentration of phosphorus and suspended solids was low in a hydraulic retention time of less than 1 hour. The removal efficiency of TOC associated with particles with a diameter of more than 0.1 μm was also high. The JMS effluent was treated using an upgraded Rotating Biological Contactor to remove the residual contaminants due to the surface adsorption of particulate contaminants and the biological oxidation of soluble organics and ammonia nitrogen. The performance of the combined system of JMS and RBC was very high in producing the effluent with very low concentrations of TOC, phosphorous and suspended solids in a hydraulic retention time of less than 2 hours.

KEYWORDS

Municipal Wastewater; Particulate contaminants; Physico-chemical treatment;Jet Mixed Separator(JMS); Biological treatment; Rotating Biological Contactor(RBC).

INTRODUCTION

It has been reported that the major part of the contaminants in raw municipal wastewater is associated with particles. The effluent from primary clarifiers contains many organic particles with a size of less than 0.1 mm. In the conventional activated sludge process, such organic particulate contaminants are first biologically dissolved and then oxidized in an aeration tank. This dissolving process usually requires a rather longer reaction time than the biological oxidation process. Chemical treatment has also been used to remove the phosphorus from the wastewater. It has been reported that the direct chemical treatment of municipal wastewater can produce an effluent with a very low concentration of suspended solids and phosphorus (ϕdegaard,1988). However,an additional biological treatment is usually required, because the effluent still contains rather high concentrations of soluble organic compounds and ammonia nitrogen. Therefore,in order to make a more effective and economical control method for the organic material in municipal wastewater,it is necessary to develop a reasonable system combining physico-chemical and biological processes.

The principal objectives of this paper are (1) to present experimental results on the chemical treatment of municipal wastewater using the Jet Mixed Separator(JMS) as a physico-chemical unit process and (2) to show the experimental results of a municipal wastewater treatment system combining the JMS and a Rotating Biological Contactor(RBC) as a biological unit process in which residual particulate organics in the JMS effluent are adsorbed to the biofilm surface and then biologically oxidized together with the soluble organics and ammonia nitrogen.

PHYSICO-CHEMICAL TREATMENT OF MUNICIPAL WASTEWATER USING JMS

Experimental procedures

Watanabe(1984) invented a solid-liquid separator with porous plates inserted vertically in the channel perpendicular to the flow. On one-half of the plate ,alternating from the right to left sides, there are many small holes. Water passes through the holes in the plates, thus creating jets which gently mix the water with itself. If coagulant is added, simultaneous flocculation of suspended particles and sedimentation of grown-flocs occurs in the JMS, because large scale eddies in the vertical plane are almost absent. In the previous paper(Watanabe et al.,1989,1990), the following was described: (1)the development of the theoretical basis of the JMS;(2)a description of the hydraulics of the JMS;(3)a picture of the solid-liquid separation efficiency.

In the present investigation, the JMS was applied to municipal wastewater treatment. Experimental unit is shown in Fig.1. The effective length, width and depth of the unit are 200 cm, 30 cm and 85 cm, respectively.The porous plates, which have 48 holes with a diameter of 0.8 cm on one-half of the plate were arranged at constant distance of 10 or 20 cm. Hydraulic retention time

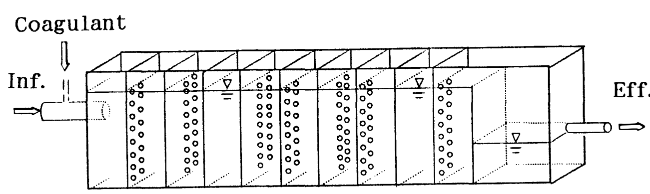

Fig.1 Jet Mixed Separator(L=200 cm,H=85 cm,W=30 cm)

(HRT) in the JMS ranged between 20 and 90 min. The corresponding jet velocity through the holes was between 16.7 and 3.7 cm/sec. Settled municipal wastewater was fed into the JMS. Polymerized aluminum chloride(PAC) was used as the coagulant with the addition of 5 or 10 ppm. Settled sludge was automatically discharged through electric valves at a designed interval. The measured water qualities were as follows:TOC, suspended solids(SS),Turbidity, Phosphorus (PO_4), CODcr.

Experimental Results

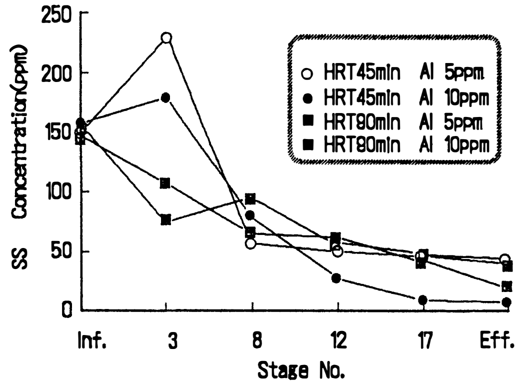

Fig.2 Removal of suspended solids in JMS

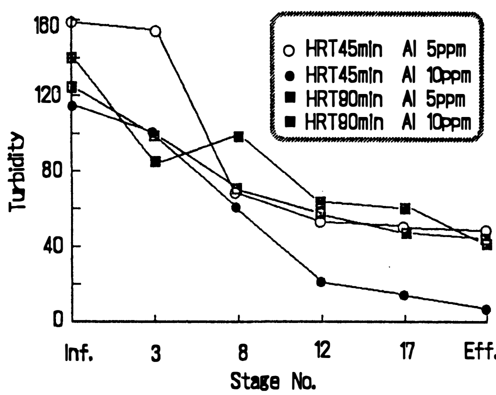

Fig.3 Removal of turbidity in JMS

At a fixed plate distance of 10 cm, a series of experiments were carried out in which the HRT was 45 or 90 min.and the coagulant dosage (as Al) was 5 or 10 ppm. Figs.2 and 3 show the experimental results on the SS and turbidity removal, respectively. As the suspended and colloidal particles were removed, TOC concentration decreased as a result of the removal of particulate organics ,as shown in Fig.4. As seen in these figures, the performance of the JMS operated at the shorter HRT was better, because a good mixing intensity for flocculation occurred at the shorter HRT and grown flocs settled out in the HRT of 45 min. However, when the HRT was 20 or 30 min.,the JMS performance became worse, as seen in Figs. 5 and 6. At a too-short HRT or under too-strong mixing, separation of grown flocs was unsufficient.According to the above experimental results we found the optimum HRT to be around 45 min.in the JMS unit described in Fig.1. At a fixed HRT of 45 min., the effect of plate distance was examined. Figs. 7 and 8 show the overall performance of the JMS at the Al dosage of 10 and 5 ppm, respectively. There was no significant effect in the JMS performance when the first 14 plates were set at a distance of 5 cm from each other to provide stronger mixing,as shown in Figs. 7 and 8. Based on these experimental results,the optimum plate distance is considered to be 20 cm in the JMS unit described in Fig.1.

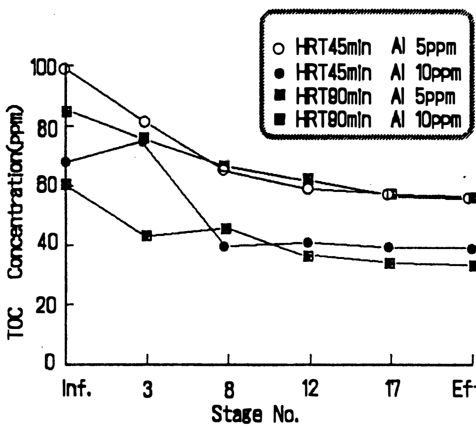

Fig.4 Removal of TOC in JMS

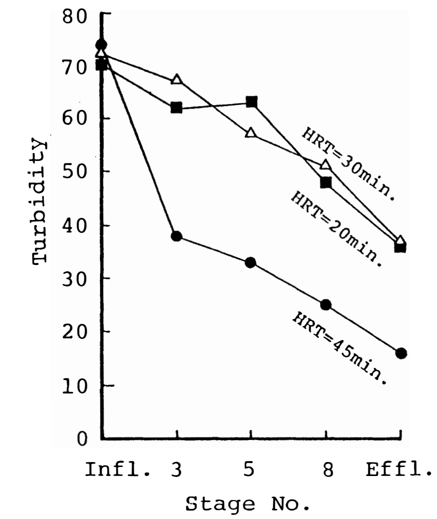

Fig.5 Removal of turbidity in JMS with shorter HRT

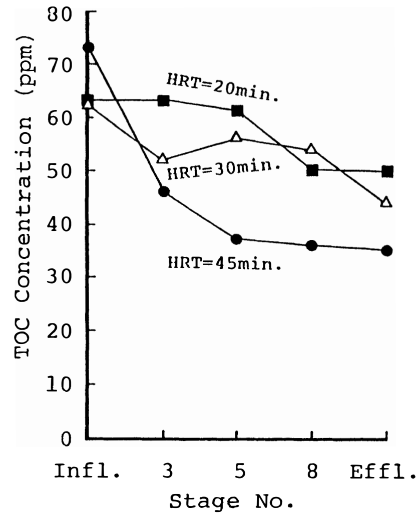

Fig.6 Removal of TOC in JMS with shorter HRT

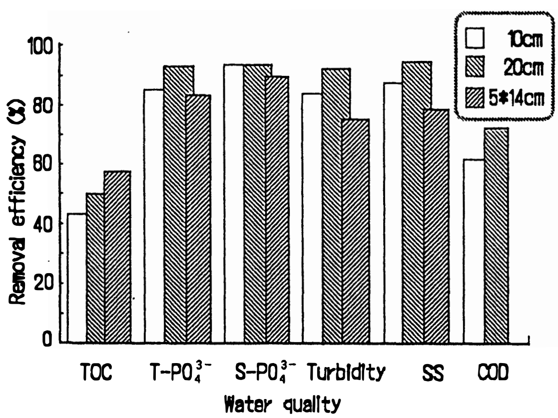

Fig.7 Removal efficiency of contaminants in JMS (Al dosage=10 ppm)

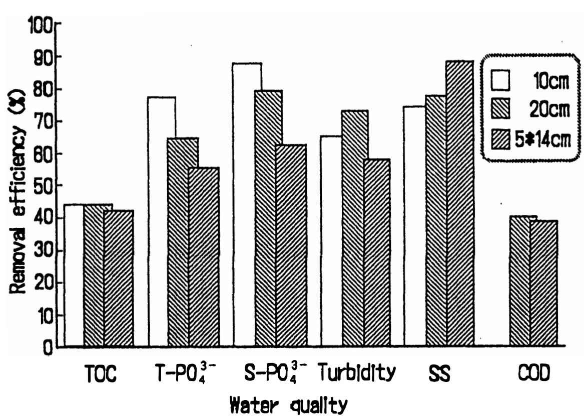

Fig.8 Removal efficiency of contaminants in JMS (Al dosage=5 ppm)

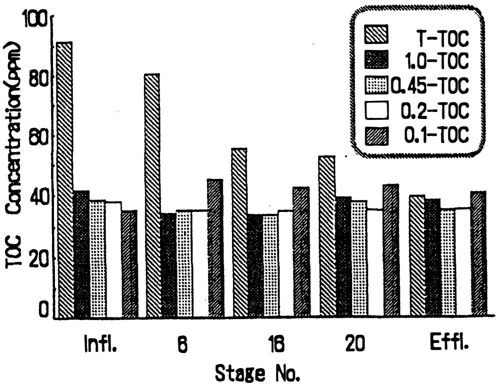

Fig.9 Size distribution of TOC in JMS (Plate distance=10 cm,Al dosage=10 ppm)

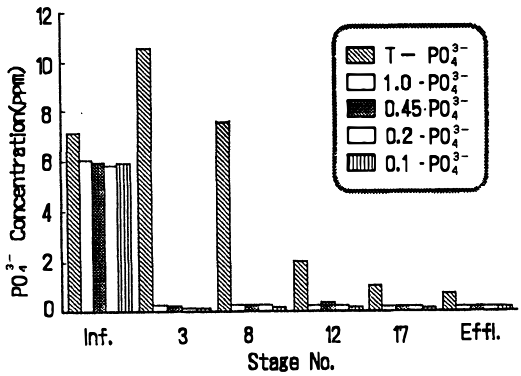

Fig.10 Size distribution of phosphorus in JMS (Plate distance=10 cm,Al dosage=10 ppm)

Figs.9 and 10 show the size distribution of the residual TOC and phosphorus (as PO_4) in each stage of the JMS. T-TOC or PO_4 represents the concentration of all organic material or PO_4. The TOC or PO_4 concentrations in the filtrate through the membrane filters were identical to the pore size 1.0, 0.45, 0.2 and 0.1 μm. As seen in Fig.8, organic material with a size of more than 0.1 μm was almost totally removed by simultaneous flocculation and sedimentation in the JMS. Fig.10 demonstrates that the soluble PO_4 existing in the influent was precipitated and then settled in the JMS to give a very high phosphorus removal efficiency.

TREATMENT OF MUNICIPAL WASTEWATER BY COMBINED SYSTEM OF JMS AND UPGRADED RBC

Experimental unit and procedure

The Rotating Biological Contactor(RBC) is an aerobic biofilm reactor for treating domestic and industrial wastewater. It consists of a series of large-diameter media, mounted on a horizontal shaft and placed in a trough. The biofilm, which naturally develops on the media surface, consists of various bacteria such as heterotrophs and autotrophs. Dominant species and properties of the biofilm depend on the wastewater characteristics and reactor operating conditions. The media slowly rotate with approximately 40 to 50 % of the surface area submerged in the wastewater to be treated. The rotation of the media plays an important role on the oxygen and mass transfer to the biofilm. The biofilm consists of cells immobilized at a substratum or medium and frequently embedded in an organic polymer matrix of microbial origin. Therefore, the biofilm attached to the rotating substratum adsorbs particulate contaminants. Adsorbed organic particles are first dissolved and then biologically oxidized, together with soluble organic material, by the microorganisms inhabiting the biofilm.

Solid state media such as plastic or styrofoam have been used, and a final clarifier has been provided to separate the detached biomass from the treated wastewater. The detached biomass is exposed to the turbulent shear in the trough during the transport to the final clarifier. Due to such exposure, the detached biomass is broken down into smaller particles which can not settle in the clarifier. As a result, it has been reported that the effluent from the RBC system contains many small organic particles. To overcome this problem, Watanabe(1987) invented a two-story RBC which is designed to achieve the simultaneous removal of detached biomass in the trough. Its upper and lower parts function as the RBC trough and storage space of settled biomass,respectively. In addition to this improvement, Watanabe(1990) made a stainless net(30 mesh and 0.25 mm diameter) medium with 8 protrusions 5 mm high, for rapid and stable biofilm development and promotion of external mass transfer to the biofilm. Fig.11 shows the upgraded RBC which was used in this study. It was set in a municipal wastewater treatment plant and the primary clarifier effluent was fed into it. It is a three-stage unit. Each stage has 14 stainless net media with a diameter of 30 cm.Each media submerged ratio was 40 %. The media rotating speed was fixed at 9 rpm . The experimental study was divided into two parts. In the first part,performance of the upgraded RBC was examined,and in the second part,the JMS effluent was fed into the upgraded RBC to find the municipal wastewater treatment efficiency of the system combining the JMS and RBC.

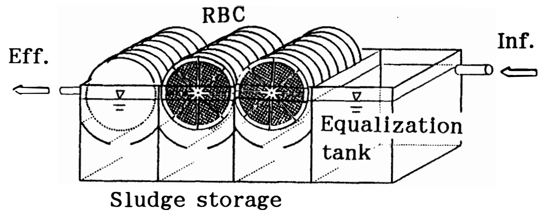

Fig.11 Upgraded rotating biological contactor

Experimental results

(a) Performance of upgraded RBC

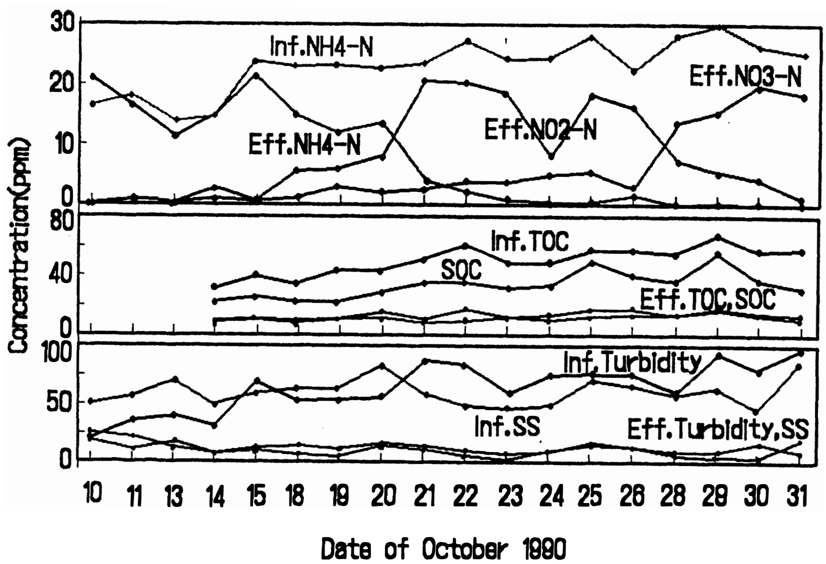

Fig.12 Performance of upgraded RBC

In the first part of the experimental study, the operation of the RBC started on 9 October 1990. The hydraulic loading was 90 L/m^2/day. Corresponding average BOD loading was about 12 g BOD/m^2/day, and hydraulic retention time based on the upper trough volume was 1.5 hours. Fig.12 shows the influent and effluent concentrations of NH_4-N, TOC, SOC(soluble part of TOC), SS and Turbidity during October. Average water temperature during the experiment was around 20 °C. Figs.13 and 14 show the TOC and SOC concentration,and the SS concentration and turbidity in each stage on 28 October. As demonstrated by the small difference between TOC and SOC concentrations, particulate organic concentration in the RBC effluent was very low. Fig.15 shows the amount of attached biomass and the sedimentation rate of detached biomass which were measured after 3 weeks operation(9 to 31 October).

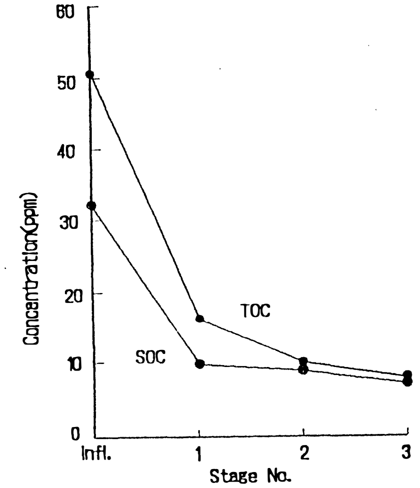

Fig.13 TOC and SOC concentration in each stage

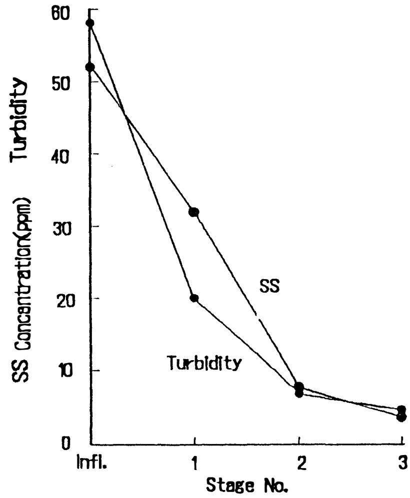

Fig.14 SS concentration and turbidity in each stage

(b) Performance of combined system of JMS and RBC system

In the second part of the experimental study, a part of the JMS effluent was fed into the RBC. The experiment was carried out during the winter and water temperature was between 10 and 15 °C. Therefore,the hydraulic loading in the RBC was set at 50 L/m^2/day. PAC was added to the JMS influent at an Al concentration of 2.5, 5 and 10 ppm. Fig.16 shows the Turbidity profiles in the combined system. Fig.17 shows the TOC concentration profile in the system. Fig.18 shows the PO_4 concentration profile in the system. The lower the Al dosage the higher the JMS effluent concentration of each of the

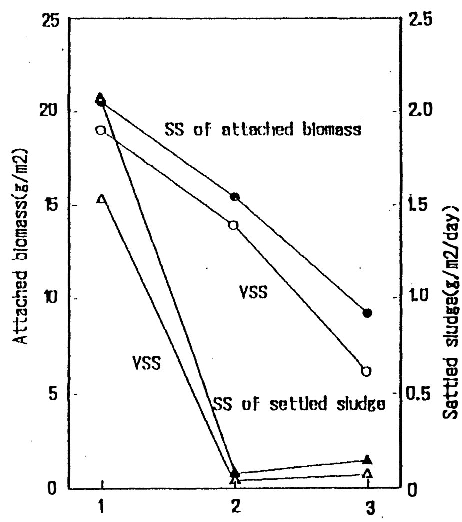

Fig.15 Amount of biomass and sedimentation rate of detached biomass in upgraded RBC

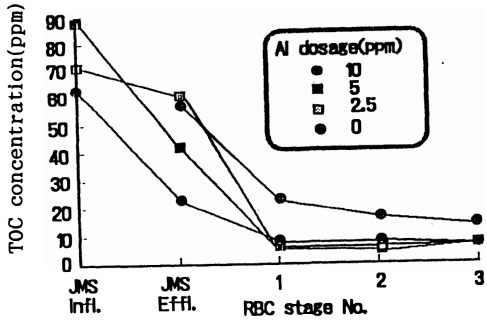

Fig.16 Turbidity profile in combined system

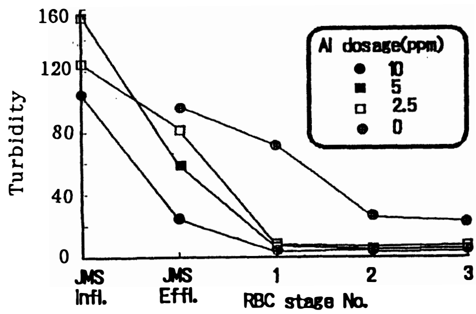

Fig.17 TOC concentration profile in combined system

water quality items.However,concentrations of the water quality items in the first stage of the RBC were almost the same, independent of the Al dosage. This means that unsettleable small flocs produced at the low Al dosage were adsorbed to the biofilm. Fig.19 shows the concentration profile of SS , TOC, NH_4-N and total PO_4 when polymerized ferric was added at the dosage of 5 ppm. As the pH was much higher than the optimum value (no pH control), removal efficiency of SS ,TOC and total PO_4 was quite low in the JMS, but microflocs were adsorbed to the biofilm to produce a good effluent water quality.

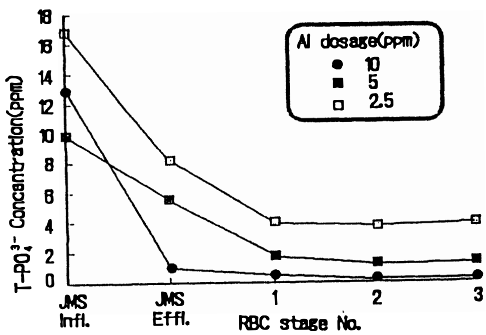

Fig.18 Total PO_4 concentration profile in combined system

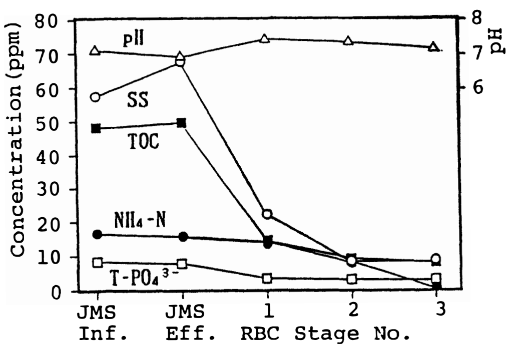

Fig.19 Effect of polymerized Fe on system performance

SUMMARY AND CONCLUSIONS

Since the major part of contaminants in municipal wastewater is associated with particles, direct particle separation is an effective way of lowering wastewater contaminant levels. However,an additional biological oxidation is required to remove the residual soluble organic compounds and ammonia nitrogen. Based on the above, it is necessary to develop an economical and effective municipal wastewater treatment system composed of physico-chemical and biological methods to meet more strict effluent standards.

In this paper experimental data were presented on the chemical treatment of municipal wastewater using the Jet Mixed Separator(JMS) which can be used as a unit process for physico-chemical treatment. The JMS, in which simultaneous flocculation and sedimentation occur, produced an effluent with low SS and phosphorus concentrations at a hydraulic retention time of less than 1 hour. Removal efficiency of TOC associated with particles of more than 0.1μm size was also high. However,the JMS effluent needs to be biologically treated to oxidize soluble organic compounds and ammonia nitrogen.

This paper also demonstrated the municipal wastewater treatment efficiency of the system combining the JMS and an upgraded Rotating Biological Contactor(RBC) which can be used as a unit process for biological treatment. The performance of the combined system was very high in producing the effluent with very low concentrations of TOC, phosphorus and SS at a short hydraulic retention time of less than 2 hours.

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