ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

Development and Applicability Evaluationof Advanced Process for Sewage Treatment Improvement using Fluidized Media

Sung Soo Yoo

Postdoctoral research fellow, Department of Land, Water and Environment Research, Korea Institute of Civil Engineering and Building Technology, 283, Goyangdae-Ro, Ilsanseo-Gu, Goyang, Gyeonggi-Do, 10223, Korea

ABSTRACT: In this study, a process for sewage treatment improvement using a fluidized media was developed, and the process was evaluated in terms of field applicability by analyzing effluent concentrations. The results showed that standard for effluent was satisfied well despite the low microbial activity in winter season. In the case of organic matter, it was found that the effluent water quality was maintained stably even if the inflow pollutant load rapidly changed due to the high MLSS concentration. Although T-N satisfied the standard for the effluent, reductions in removal efficiency were observed in terms of nitrification and denitrification, similar to the suspended-growth microorganism method, suggesting the necessity of further construction including heating device in order to obtain more stable treated water quality. The installation of high efficiency oxygen supply system also should be considered because of high consumption of DO by MLSS of high concentration in oxidation and nitrification. In the case of T-P, it was found that the standard for effluent was satisfied well despite of the changes in pH influent concentration. The proposed process was considered to show high treatment efficiency when it was applied to small-medium scale sewage treatment where high concentrations of pollutants are introduced.

KEYWORDS: Fluidized media, sewage treatment improvement, attached-growth microorganism, applicability evaluation.

I.INTRODUCTION

With the improvement in quality of life, the quality standards for effluent from sewage treatment plants have been strengthened gradually, which has led to a problem of increasing surplus sludge. Most public sewage treatment facilities in Korea have been suffered from high cost for treatment of excessively generated sludge [1]. The local governments lacking budget, however, use a method of circulating excess sludge in the system, which causes accumulation of sludge in the system, leading to the problem of failing in quality standard for effluents [2-4].

The sewages of new town and urban redevelopment area are separate sewage one that does not have a septic tank, and the sewer maintenance projects in some old downtown areas has resulted in the total nitrogen (TN) concentration in sewage treatment plant influent more than twice the average concentration of general plant, 40 mg/L[5-8]. It means that, in case of sewage treatment facility designed to have conventional TN inflow load as 40 mg/L, it is difficult to remove nitrogen even if it is designed to apply advanced treatment process[9-11]. It is urgent, therefore, to develop an improvement method to solve the problem of increasing the amount of influent load and to achieve the goal of sludge reduction in the advanced treatment facilities for removal of nitrogen and phosphorus [12,13].

As a solution for the problem of increase in high concentration nitrogen inflow and in sludge, the Ministry of Environment suggests improvement of treatment efficiency by optimization of operation parameters rather than facility improvement[14]. The optimization of operation factors is feasible as a solution in the large sewage treatment plants with little fluctuation of inflow load however, in the case of small-medium scale plants where fluctuation of inflow load is large, the method has limitation, suggesting that the facility improvement for reduction in sludge and energy is only solution [15-17].

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

Currently, the improvement method for sewage treatment facility that is under most active research is the membrane process and the fluidized media process, which can achieve excellent treatment performance with minimal facility improvement[18,19]. The membrane process has advantages of easiness in operation and stability in obtaining treated water [20], while in the fluidized media process, the operation without external transport sludge is possible since the contaminants are removed by the adherent microorganisms, allowing sludge reduction[21]. The research results showed that this process is, compared to membrane process, more economical in terms of cost of installation and operation and more stable in terms of treatment efficiency, thus more suitable for improvement and upgrading of small-medium scale sewage treatment facilities[22,23].

The purpose of this study was, accordingly, to propose a process, using the fluidized media process, for sewage treatment with higher treatment efficiency and lower sludge generation rate compared to conventional treatment process and to evaluate the field applicability. The proposed process for sewage treatment improvement basically, like the A/O process, consists of anoxic tank and aerobic tank, and for increase inthe treatment efficiency and the sludge reduction efficiency, the newly developed fluidized media was injected into the anoxic tank and the aerobic tank.In addition, a nano bubble device was added to the internal transfer line to reduce the amount of sludge generated and the external carbon source used. The proposed process was manufactured in pilot-scale and subjected to long-term operation and the changes of BOD, COD, SS, NO_3-N, NH_3-N, T-N and T-P were analyzed, and field applicability was evaluated based on the analysis results.

II. MATERIALS AND METHODS

Experimental Setup

The process for sewage treatment improvement proposed in this study was installed in a wastewater treatment plant located in Ilsan City, Gyeonggi Province and has treatment capacity of 30 m^3/d. The operation period was six months including winter when the microbial activity is lowest. The influent water was sampled three times per a week at rear side of primary settling tank and was used in analyzing BOD, COD, SS, NO_3-N, NH_3-N, T-N, T-P and pH. Table 1 shows the properties of influent water.

Table 1. Properties of influent water sampled in proposed process

Factor	Concentration of raw water		
	Max.	Min.	Ave.
BOD (mg/L)	210.0	60.6	134.2
COD (mg/L)	60.2	31.5	43.6
SS (mg/L)	162.0	44.0	80.2
T-N (mg/L)	67.0	35.0	45.1
NH3-N (mg/L)	43.7	29.5	35.9
NO3-N (mg/L)	0.8	N.D	0.23
T-P (mg/L)	23.2	4.4	12.4
pH	8.1	5.7	7.1
Temperature (℃)	19.5	11.1	15.2

The process for In the proposed process for sewage treatment improvement, degassing tank was placed at the front side of anoxic tank and a cohesion reactor and a sedimentation tank for T-P treatment were installed at the rear side of anoxic tank. The anoxic tank and aerobic tank were filled with the developed fluidized media (moving snail-form carrier, MSC) by 50%, respectively. Considering the characteristics of the adhered-growth microorganisms, the aerobic tanks were divided into two tanks for oxidation of organic matter and for nitrification, respectively, with the aim of increasing oxidation efficiency of nitrogen and organic matters. The high-basicity polyaluminium chloride (PAC), which is more resistant to changes in pH, was used as coagulant. Fig. 1 shows the schematic diagram of the proposed process, and the operating conditions of each tank such as hydraulic retention time (HRT) and dissolved oxygen (DO) are shown in Table 2.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

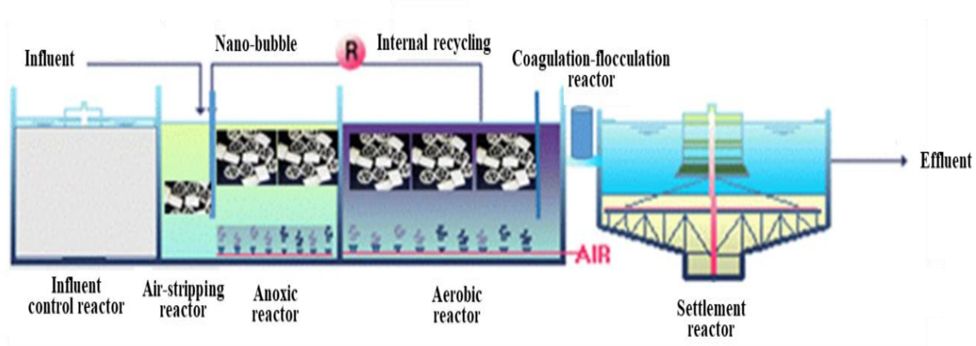


Fig. 1. Schematic diagram of sludge-reducing sewage treatment process

Table 2. Operating conditions of each tank

Reactor	**Operation factor**		**Operation condition**
	Factor	**Unit**	**Min. – Max.**
Air-stripping	DO	mg/L	2.9 – 5.0
	HRT	hr	0.59
Anoxic	DO	mg/L	0.3 – 0.8
	HRT	hr	3.72
	MLSS	mg/L	3,500 – 4,500
	Methanol	L/d	1.0
Aerobic	DO	mg/L	3.5 – 5.1
	HRT	hr	4.09
	MLSS	mg/L	6,000 – 7,000
	Internal recycling rate	Q_{in}	2 – 3
	BOD volume loading	$Kg/m^3 \cdot d$	0.21 – 0.74
Coagulation	HRT	hr	0.05
	Injection amount	L/d	1 – 2
Treated water	Sludge amount	m^3/d	4.0 – 5.0
	effluent	m^3/d	25 - 26

MSC Media used

A) Material of MSC media

The media made of the foam rubber with shape of conventional cube or sponge-like materials had problems of floating into water surface too much in the reaction tank and difficulty in the contact between the microorganisms and the contaminants. To solve these problems by using materials with specific gravity similar to water, the polyethylene having a specific gravity (0.92-0.96kg/dm^3) slightly smaller than that of water was selected.

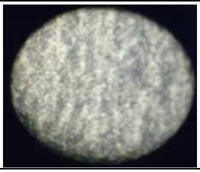
Polyethylene has good tensile strength and impact resistance, and high softening point, hardness and strength. This material has molecular weight of 50,000-100,000 and composed of only CH2, therefore has high volume resistivity of 1019 10^{19} Ω· cmdue to excellent electrical insulation. In addition, the structure of this material is symmetrical around the chain of C, meaning excellent characteristic as high-frequency insulation material.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

B) Characteristics of MSC media

In order to smooth the contacts with air and water, increase surface area per unit volume, and prevent closure due to too many internal partitions, the shape of the snail was simulated inside the cylinder. In addition, it was designed to provide optimum conditions for microbial cultivation and protection when the media is circulated in water by making the structure with the longitudinal fin in the outside. The media was named as moving snail-form carrier following the internal shape of the snail. The media has a surface area of about 600 $m^2/m^3$for attachment of microorganisms, which is 1.3 times larger than that of conventional media. The porous foamed rubber or sponge type have surface area much larger than that of MSC media, however the actual effective surface area is smaller than that of MSC media in this study because microorganisms grow only in the outer surface, not in the inner pore of the media. This means that the microbial film on the outer surface interferes with the access of water and organic matter to the inner space. The characteristic of MSC shows in table 3.

Table 3. Characteristic of MSC

Name	Shape	Surface	Size (mm)	Surface area (m^2/m^3)
MSC media			Diameter : 15, Height : 8	600

Sampling and Analysis

To evaluate the field applicability, BOD, COD, SS, NO_3-N, NH_3-N, T-N, T-P, pH and DO were measured by sampling the effluent of each reactor three times a week. SS and temperature were measured using model 3100 (insiteig), and DO and pH were measured using YK2005WA (LUTRON). BOD, COD, NO_3-N, NH_3-N, T-N and T-P concentrations were measured using the standard method. For economic evaluation, electricity cost, pharmaceutical spending, sludge disposal fee, repair expense, etc during operation period were calculated.

III. RESULTS AND DISCUSSION

Removal Efficiencies of Propose Process

A) BOD Removal Efficiency

During the evaluation period, the average BOD was 134.2 (60.6-210.0) mg/ℓ in influent water and 4.9 (1.5-9.8) mg/ℓ in final effluent water. The average BOD removal efficiency of this facility was, based on them,96.4 (92.3-99.0) %. The graph of BOD removal efficiency change is shown in Fig. 2.

This was reduce by about 2% compared to the summer treatment efficiency, but satisfied well the standard for effluent of sewage treatment plant, 10mg/L. This was probably because MLSS in the aerobic tank increased from about 3000 to 6,000 mg/L due to the filling of the fluidized media, making this device to cope with fluctuation of influent pollutant load more stably.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

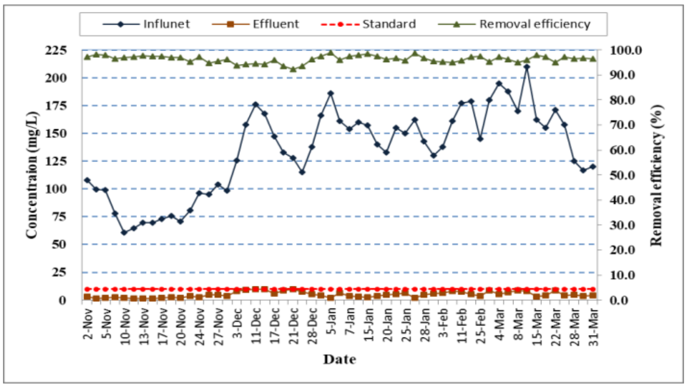


Fig.2. BOD removal efficiency of propose process

B) BOD Removal Efficiency

During the evaluation period, the average $COD_{mn}$was 43.6 (31.5-60.2)㎎/ℓ in influent water and 11.0 (1.8-19.5) ㎎/ℓ in final effluent water. The average COD_{mn} removal efficiency of this facility was, based on them,75.0 (58.4-96.0) %. The graph of COD_{mn} removal efficiency change is shown in Fig. 3.

This was, like BOD, reduce by about 8% compared to the summer treatment efficiency (83%), but satisfied well the standard for effluent, 40mg/L. This was probably because the addition of the fluidized media the same size reactors resulted in a treatment efficiency of 1.5 times or more in the same HRT. However, the decrease of DO with increasing MLSS was remarkable, suggesting that, in economic terms, the installation of high efficiency oxygen supply system should be considered when applying the fluidized media process.

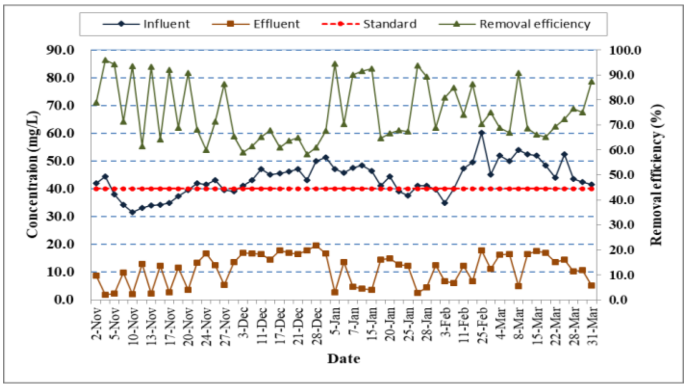


Fig.3. COD_{mn}removal efficiency of propose process

C) SS Removal Efficiency

During the evaluation period, the average SSwas 80.2 (44.0-162.0)㎎/ℓ in influent water and 6.2 (2.0-9.4) ㎎/ℓ in final effluent water. The average SS removal efficiency of this facility was, based on them,91.7 (84.4-6.6) %. The graph of SS removal efficiency change is shown in Fig. 4.

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 5, Issue 7 , July 2018

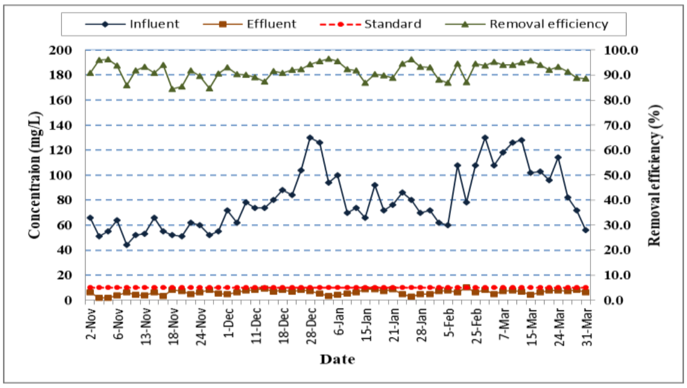


Fig.4. SSremoval efficiency of propose process

The mean concentration of SS in treated water during the winter was expected to be greatly improved due to a significant decrease in microbial activity compared to the summer, however did not show any significant difference. This is because most of the microorganisms are removed through self-oxidation, unlike floating-growth microorganisms due to the characteristics of the media process using adhered-growth microorganisms. This was confirmed by the SS concentration analysis of each reaction tank where the averages concentrations of SS were 143.1 and 160.5 mg/L for influent water and anoxic tank, respectively, and 174.2 and 6.2 mg/L for aerobic tank and treated water, respectively. It was found that, as shown in above, unlike the suspended-growth microorganism where the MLSS in the reaction tank is measured by SS and the variation of SS concentration is large depending on the season, the media process is not significantly affected by temperature.

D) T-N Removal Efficiency

During the evaluation period, the average T-Nwas 45.1 (35.0-67.0)㎎/ℓ in influent water and 14.2 (4.6-19.1) ㎎/ℓ in final effluent water. The average T-N removal efficiency of this facility was, based on them,67.9 (46.3-88.9) %. The graph of T-N removal efficiency change is shown in Fig. 5.

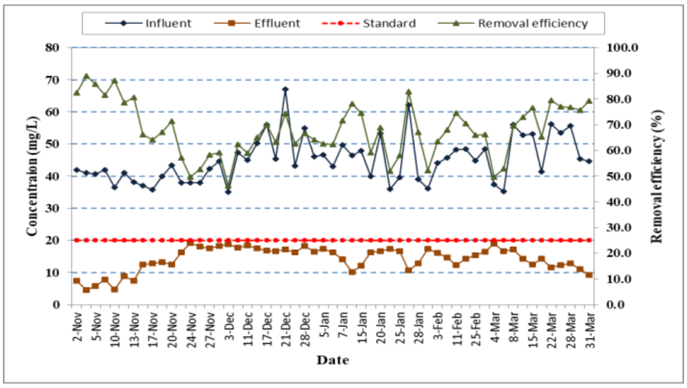


Fig.5. T-Nremoval efficiency of propose process

The T-N treatment efficiency satisfied the standard for effluent water during the winter (20 mg/L), however the safety rate was very low compared to other items. It also showed a 15% decrease compared to the summer. As shown in the previous studies, it was probably due to decrease in activity of nitrifying microorganisms according to water temperature.

The nitrification rate according to the water temperature was analyzed (Fig. 6) and the results showed that the change of water temperature from 10.8 to 19.7 ℃, the nitrification rate of NH_4^+-N decreased from the highest 89.9% to the lowest 78.7%. the denitrification rate was also decreased by 10% or more similar to nitrification rate. These T-N

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

removal rates tending to be similar between suspended- and attached-growth micro organism suggested that it is necessary to propose an additional heating device to solve the problem.

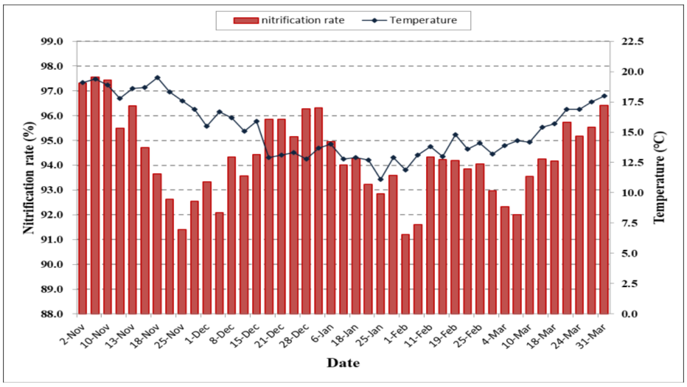


Fig.6. Change in nitrification by change in water temperature

E) T-P Removal Efficiency

During the evaluation period, the average T-Pwas 12.4 (4.4-23.2)㎎/ℓ in influent water and 0.4 (0.03-0.9) ㎎/ℓ in final effluent water. The average T-P removal efficiency of this facility was, based on them,97.1 (92.6-99.7) %, satisfying the standard for effluent water, 0.5 mg/L. The graph of T-P removal efficiency change is shown in Fig. 7.

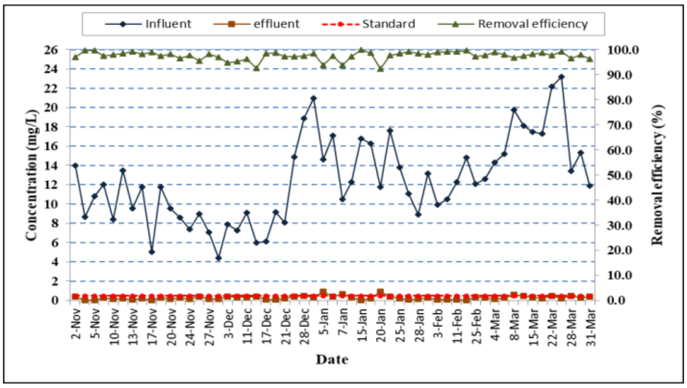


Fig.7. T-Premoval efficiency of propose process

In the case of T-P removal efficiency according to the change of the coagulant loading rate (50%, 25% dilution), it was confirmed that the T-P removal efficiency decreased due to the decrease of the coagulation efficiency in the sedimentation tank with decrease incoagulant loading rate. In the case of the change of T-P removal efficiency according to the pH change of the aerobic tank, it is generally known that appropriate pH in coagulation through PAC is 6-7 and that it is difficult to achieve high removal efficiency in other ranges. In this study, high-salinity PAC was used to prevent decrease in pH due to low alkalinity in high T-P contents in influent water, resulting in high removal efficiency even when the pH of the aerobic tank was low as 5.2. Therefore, it was judged that the pH of the aerobic tank did not affect the T-P removal efficiency.

Also, the change of sludge generation amount according to the coagulant loading rate was measured. The coagulant was diluted to 50%, 25% and 0%, and the amount of generated sludge was calculated based on the withdrawal amount and the concentration. It was fund that the average sludge production rate was 2.9kg/d, and the variation of sludge production by the input rate was not significant. It was probably because, in this plant, a high concentration of T-P is input due to recycle water, so that a larger amount of coagulant than normal condition is introduced.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

Economic Evaluation of Propose Process

For economic evaluation of applicable process, annual maintenance and administration fee was analyzed based on electricity cost, pharmaceutical spending, sludge disposal fee, and repair expense during six months of operation period. In electricity cost, it was calculated that 2.33KWHh per 1 m3 was used and this caused spending of 1,266 $/year. In repair expense, 0.2% of total occupancy expense was applied and it caused spending of 216 $/yr on an annual basis. In sludge disposal fee, daily amount of sludge in the applicable process was 2.9kg, recovery factor and total moisture content were 90% and 78%, respectively and thus the daily amount of sludge cake was 0.01 ton. It was calculated that the unit price for sludge processing was 89$/ton and annual sludge processing cost was 326 $/yr. In pharmaceutical spending, it was calculated based on high basicity pac for T-P processing and methanol injection for C/N ratio and the cost was found to be 427 $/yr annually. Therefore, total maintenance and administration fee was 2,235 $/yr, which appeared to be inexpensive more than 30% compared to when the membrane process was improved. This suggests that the economic efficiency of the applicable process is enough.

IV. CONCLUSION

In this study, a process for sewage treatment improvement using a fluidized media was developed, and the process was manufactured as pilot-scale and evaluated in terms of field applicability during the winter season by analyzing BOD, COD, SS, NO_3-N, NH_3-N, T-N and T-P. The results showed that standard for effluent water was satisfied well despite the low microbial activity in winter season. In the case of organic matter (BOD, COD), it was found that the effluent water quality was maintained stably even if the inflow pollutant load rapidly changed due to the high MLSS concentration. Although T-N satisfied the standard for the effluent water, reductions in treatment efficiency were observed in terms of nitrification and denitrification, similar to the suspended-growth microorganism method, suggesting the necessity of further construction including heating device in order to obtain more stable treated water quality. The installation of high efficiency oxygen supply system also should be considered because of high consumption of DO by MLSS of high concentration in oxidation and nitrification of organic matters. In the case of T-P, it was found that the standard for effluent water quality was satisfied well despite of the changes in pH influent concentration. The newly developed and proposed process for sewage treatment improvement, based on the results, was considered to show high treatment efficiency when it was applied to small-medium scale sewage treatment facilities where high concentrations of pollutants are introduced.

REFERENCES

[1] Ahn, K.-H., Cha, H.-Y., Song, K.-G. "Retrofitting municipal sewage treatment plants using an innovative membrane-bioreactor system". Desalination, , 1999, pgno: 279-286.
[2] Ko, E.-J., Kim, K.-W., Kang, S.-Y., Kim, S.-D., Bang, S.-B., Hamm, S.-Y., Kim, D.-W. "Monitoring of environmental phenolic endocrine disrupting compounds in treatment effluents and river waters, korea" Talanta, 2007, pgno: 674-683.
[3] Yeom, D.-H., Lee, S.-A., Kang, G.S., Seo, J., Lee, S.-K. "Stressor identification and health assessment of fish exposed to wastewater effluents in miho stream, south korea" Chemosphere, 2007, pgno: 2282-2292.
[4] Choi, K., Kim, Y., Jung, J., Kim, M.H., Kim, C.S., Kim, N.H., Park, J. "Occurrences and ecological risks of roxithromycin, trimethoprim, and chloramphenicol in the han river, korea" Environmental Toxicology and Chemistry: An International Journal, 2008, pgno: 711-719.
[5] Shon, H., Vigneswaran, S., Kim, I.S., Cho, J., Ngo, H. "Fouling of ultrafiltration membrane by effluent organic matter: A detailed characterization using different organic fractions in wastewater" Journal of Membrane Science, 2006, pgno: 232-238.
[6] Ryu, J., Oh, J., Snyder, S.A., Yoon, Y. "Determination of micropollutants in combined sewer overflows and their removal in a wastewater treatment plant (seoul, south korea)" Environmental monitoring and assessment, 2014, pgno: 3239-3251.
[7] Chang, H. "Spatial analysis of water quality trends in the han river basin, south korea" Water research, 2008, pgno: 3285-3304.
[8] Kim, G., Yur, J., Kim, J. "Diffuse pollution loading from urban stormwater runoff in daejeon city, korea" Journal of environmental management, 2007, pgno: 9-16.
[9] Oller, I., Malato, S., Sánchez-Pérez, J. "Combination of advanced oxidation processes and biological treatments for wastewater decontamination—a review" Science of the total environment, 2011, pgno: 4141-4166.
[10] Hidaka, T., Tsuno, H., Kishimoto, N. "Advanced treatment of sewage by pre-coagulation and biological filtration process" Water research, 2003, pgno:4259-4269.
[11] Feng, F., Xu, Z., Li, X.., You, W., Zhen, Y. "Advanced treatment of dyeing wastewater towards reuse by the combined fenton oxidation and membrane bioreactor process" Journal of Environmental Sciences, 2010, pgno: 1657-1665.
[12] Saktaywin, W., Tsuno, H., Nagare, H., Soyama, T., Weerapakkaroon, J. "Advanced sewage treatment process with excess sludge reduction and phosphorus recovery" Water research, 2005, pgno: 902-910.
[13] Yan, P., Ji, F., Wang, J., Fan, J., Guan, W., Chen, Q. "Evaluation of sludge reduction and carbon source recovery from excess sludge by the advanced sludge reduction, inorganic solids separation, phosphorus recovery, and enhanced nutrient removal (siper) wastewater treatment process" Bioresource technology, 2013, pgno: 344-351.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 7 , July 2018

[14] Arslan-Alaton, I., Tureli, G., Olmez-Hanci, T. "Treatment of azo dye production wastewaters using photo-fenton-like advanced oxidation processes: Optimization by response surface methodology" Journal of photochemistry and Photobiology A: Chemistry, 2009,pgno: 142-153.
[15] Hodaifa, G., Ochando-Pulido, J., Rodriguez-Vives, S., Martinez-Ferez, A. "Optimization of continuous reactor at pilot scale for olive-oil mill wastewater treatment by fenton-like process" Chemical engineering journal, 2013,pgno: 117-124.
[16] Abelleira, J., Pérez-Elvira, S.I., Portela, J.R., Sánchez-Oneto, J., Nebot, E. "Advanced thermal hydrolysis: Optimization of a novel thermochemical process to aid sewage sludge treatment" Environmental science & technology, 2012,pgno: 6158-6166.
[17] Ward, A.J., Hobbs, P.J., Holliman, P.J., Jones, D.L. "Optimisation of the anaerobic digestion of agricultural resources" Bioresource technology, 2008, pgno: 7928-7940.
[18] Aslam, M., McCarty, P.L., Bae, J., Kim, J. "The effect of fluidized media characteristics on membrane fouling and energy consumption in anaerobic fluidized membrane bioreactors" Separation and Purification Technology, 2014, pgno**:** 10-15.
[19] Yoon, C.-H., Kim, M.-S., Kim, S.-H. "Characteristics of biological nitrogen removal for low c/n ratio municipal wastewater using methanol as an external carbon source in fluidized media process" Journal of Korean Society of Environmental Engineers, 2006, pgno: 687-692.
[20] Krzeminski, P., van der Graaf, J.H., van Lier, J.B. "Specific energy consumption of membrane bioreactor (mbr) for sewage treatment" Water Science and Technology, 2012, pgno**:** 380-392.
[21] Reboleiro-Rivas, P., Martín-Pascual, J., Juárez-Jiménez, B., Poyatos, J., Vílchez-Vargas, R., Vlaeminck, S., Rodelas, B., González-López, J. "Nitrogen removal in a moving bed membrane bioreactor for municipal sewage treatment: Community differentiation in attached biofilm and suspended biomass" Chemical Engineering Journal, 2015, pgno**:** 209-218.
[22] Barwal, A., Chaudhary, R. "To study the performance of biocarriers in moving bed biofilm reactor (mbbr) technology and kinetics of biofilm for retrofitting the existing aerobic treatment systems: A review" Reviews in Environmental Science and Bio/Technology, 2014, pgno: 285-299.
[23] Zhang, S., Wang, Y., He, W., Wu, M., Xing, M., Yang, J., Gao, N., Pan, M. "Impacts of temperature and nitrifying community on nitrification kinetics in a moving-bed biofilm reactor treating polluted raw water" Chemical Engineering Journal, 2014, pgno: 242-250.