Journal Home page : www.jeb.co.in ★ E-mail : editor@jeb.co.in

JEB
Journal of Environmental Biology

ISSN: 0254-8704
CODEN: JEBIDP

Regeneration and reuse of leachate from a municipal solid waste landfill

Chih-Kuei Chen*, Shang-Lien Lo and Ting-Yu Chen
Graduate Institute of Environmental Engineering, National Taiwan University, 71, Chou-Shan Rd., Taipei, 106, Taiwan, R.O.C.
*Corresponding Author E-mail: cgg@ms22.hinet.net

Publication Info

Paper received:
05 July 2012

Revised received:
20 June 2013

Re-revised received:
28 October 2013

Accepted:
28 February 2014

Abstract

Landfill leachate is deep brown in color with extremely complex composition and difficult to treat in order to meet the effluent standards. The leachate of Keelung City Tien Wai Tien landfill has an average flow of 350 CMD. In the present study following serially connected devices: Activated sludge/contact aeration (AS/CA) combined system, reverse osmosis (RO) and an ammonia stripping tower were used to treat the leachate. After treatment, the COD (removal rate of 91%), BOD (removal rate of 83%), SS (removal rate of 86%) and NH_4^+-N level (removal rate of 98%) significantly reduced in the leachate. The treated effluent was further recycled and used as RO back washing water and for sprinkling roads and watering plants in Keelung City. It is further required to evaluate whether the treated effluent can be reutilized for agriculture and extinguishing fire during shortage of water.

Key words

Landfill leachate, AS/CA, RO, Ammonia stripping tower, Reuse

Introduction

In recent years, because of the increasing water requirement shortage of water is being experienced worldwide. For example, several countries in Mediterranean region have started recycling and reutilizing wastewater due to insufficient water supply, increased water demand stemming from population growth and increased demand of irrigation water. Greece, for instance, also suffered from water shortage, thus craves for recycling and reuse with regard to various water sources (Fadel *et al.*, 2001).

The characteristics and water quality of solid waste landfill leachate depends on the rate of rainfall (Heavey, 2003) and garbage baling methods (Shelef and Azov, 1996). Unlike other industrial waste water, landfill leachate typically has a BOD: COD ratio greater than 0.5 (approximately 10,000 mg l^{-1} COD) during first five year of landfill. This ratio usually decreases between 0.5 and 0.1 during fifth to tenth year. After ten years, the BOD: COD ratio in these old landfills decreases to less than 0.1. That is BOD decreases year by year due to microbial decomposition, although COD remains high (approximately 1,000 mg l^{-1}). The leachate is usually deep brown in color and contains a metals (Nakayama *et al.*, 2010). Scientists have repeatedly investigated potential methods to increase the efficiency of landfill leachate treatment. Eliminating heavy metals from leachate by aeration oxidation and by increasing its pH value (Sletten *et al.*, 1995), or treating small-scale landfill leachate with peat (Tchobanoglous and Angelakis, 1996) are few ways of treating leachate.

In addition to secondary biological system and chemical treatment unit, the Keelung City Tien Wai Tien Landfill Leachate Treatment Plant (350CMD) is currently equipped with advanced facilities of RO and ammonia stripping tower; however, in the past the plant's upflow anaerobic sludge bed (UASB) was ineffective at the function of RO and ammonia stripping tower were limited. In the present study, UASB technology was replaced with activated sludge/contact aeration (AS/CA) combined system with a goal of enhancing the plant's treatment and thereby, recycling and reutilizing the treated effluent for different purposes. The AS/CA system combines suspended attached microbes to provide a longer food chain and complex biophase making the system easy to operate, more stable, and more tolerant of spike loading than the conventional biological treatment process. It is exceptionally suitable for treating wastewater with fluctuating leachate quantity and quality (Chen and Lo, 2006).

The operating and technological cost of treating landfill leachate is extremely high as compared to treatment cost of other wastewaters (Tatsi and Zouboulis, 2002). However, treating landfill leachate by AS/CA system is an acceptable option during period when there is shortage of water. The effluent from Tien Wai Tien Landfill Leachate Treatment Plant is clear with low water quality indices. Thus, four 20 m^3 effluent storage tanks were built to provide back washing water for RO and for sprinkling roads and watering plants in Keelung City. The present study aimed at solving the problem of leachate from a municipal solid waste landfills and the result of the study, showed that the proposed AS/CA combined system was suitable for treating landfill leachate, as it could highly enhance the treatment function.

Materials and Methods

Fig. 1 shows a flowchart of the treatment process followed at Tien Wai Tien Landfill Leachate Treatment Plant (2009). Table 1 shows the specifications of RO membranes. The details of main treatment units of leachate treatment plant and their dimensions with hydraulic retention time are given in Table 2. The treatment plant consisted of two activated sludge tank, two contact aeration tank, one secondary settling tank, 324 sets of RO treatment facilities, one ammonia stripping tower and one sludge collecting tank, respectively. Table 3 shows a comparison between present leachate quality and designed conditions. Present leachate quantity is more than designed condition, however its quality is also better than designed condition.

For physico-chemical analysis, the leachate was collected daily form: collection tank, activated sludge tank, contact aeration tank, secondary settling tank, tertiary settling tank, RO pretreatment tank, RO facilities and ammonia stripping tower for estimation of suspend solid (SS), chemical oxygen demand (COD), pH, temperature and conductivity of the effluent. The level of oil and grease, bio-chemical oxygen demand (BOD), nitrate-nitrogen, and ammonia-nitrogen in each tank were measured weekly. Level of Cu, Fe, Pb, Cr, Zn and Cd in the effluent was estimated monthly. The sludge volume index (SVI) and dissolved oxygen (DO) values in the activated sludge tank were recorded daily. Analysis and assessment of monitored

Table 1 : Performance of the RO membranes

Parameter	Unit	Measurements	Remarks
Initial flux (0.35w% NaCl)	1/m2.h	50±10	0.35w% NaCl at pH 6
Rejection (0.35w% NaCl)	%	99.0±0.5	25ÚC and 4 MPa
Transmembrane pressure	kPa	-20..+6,000	
pH		2-10	at 25ºC
Chlorine exposure	no exposure		
Temperature	°C	1-70	at pH 3-9 and 4,000kPa
Pore size	nm	25	

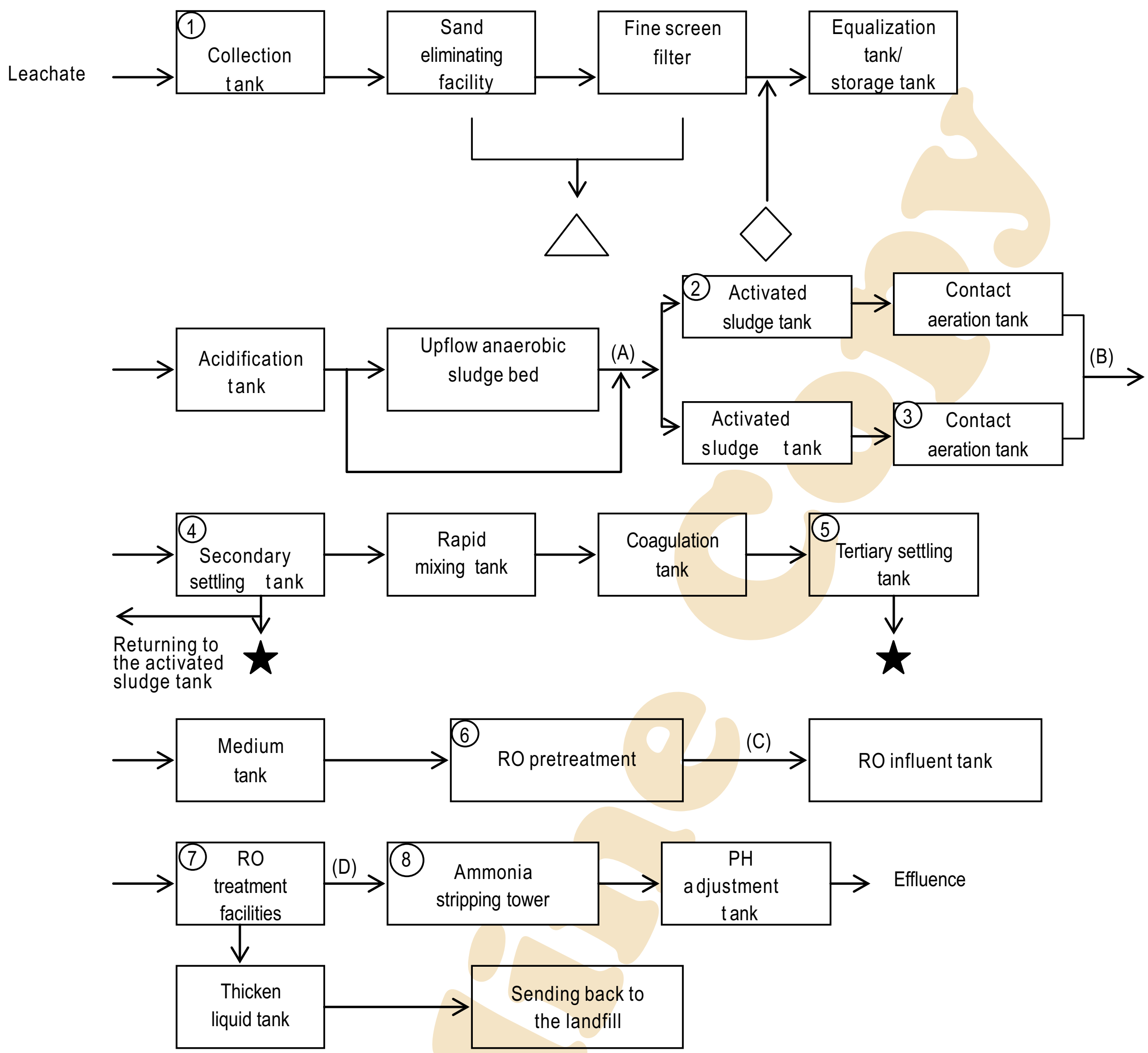
Membrane material is composed of thin film polyamide/polysulfone composite.

Table 2 : Features of main treatment units at the leachate treatment plant

Title	Number of tanks	Dimensions	Retention time
Activated sludge tank	2	7.8m(L)× 4.1m(W)× 3m(H)	6.5 hours
Contact aeration tank	2	7.8m(L)× 4.lm(W)× 3m(H)	6.5 hours
Secondary settling tank	1	5.5m (Ø)× 3m(H)	5 hours
Ro treatment facilities	324 sets	A set of 7 pieces of membrane ×a piece of membrane with dimensions of 14.4mm(Ø) × 6m(L)	
Ammonia stripping tower	1	boiler, pH adjustment system, gas reactor, and heat exchanger	
Sludge collection tank	1	4.5m(L)× 2.3m(W)× 3.lm(H)	

Table 3 : Comparison between present and initially targeted leachate quality

Item	Designed leachate quality	Present leachate quality (sunny days)	Present leachate quality (rainy days)
Amount of leachate (CMD)	350	500~700	above 700
pH	7.5~8.5	7.5~8.5	7.3~8.0
COD(mg l^{-1})	10,000	1,000~1,500	600~1,000
SS(mg l^{-1})	400	20~50	50~110
NH4+-N (mg l^{-1})	500	500~700	400~600



Remarks : △ : Removing, transporting and disposing large sand-like, granular dirt; ★ : A waste sludge tank, sending back to the landfill; ◇ : Household sewage in the leachate treatment plant. A set of deodorization tanks; Removing the stink of NH_3 and mercaptan emitted from the leachate treatment system. Number 1-8 indicates points samples collection

Fig.1 : Flowchart of the treatment process in the plant

underground well water quality was performed quarterly by the Taiwan Effluent Standard (Environmental Protection Administration Executive Yuan, 2014). Report of water quality was presented yearly.

To confirm the efficiency of aqueous organic substance removal—by biological treatment and RO systems—three leachate samples were taken at each of the four stages: before biological treatment (A); after biological treatment (B); before RO treatment (C); and after RO treatment (D), respectively. Each sample was analyzed (Lindsay and Kealey, 1987) for the level of organic substances by High Performance Liquid Chromatography (HPLC).

Results and Discussion

A decreasing trend in COD and BOD level in individual reactors during the leachate treatment process was observed (Fig. 2 a, b). This indicated that during the past year each reactor exhibited its stable treatment function. These findings showed a marked decrease in the average COD and BOD level from the collection tank to AS/CA system. The AS/CA system which contained both suspended and attached microorganisms was characterized by multiple biological phases, longer food chains of microorganisms was thus a stable system with powerful treatment function (Chen *et al.*, 2005). The AS/CA system

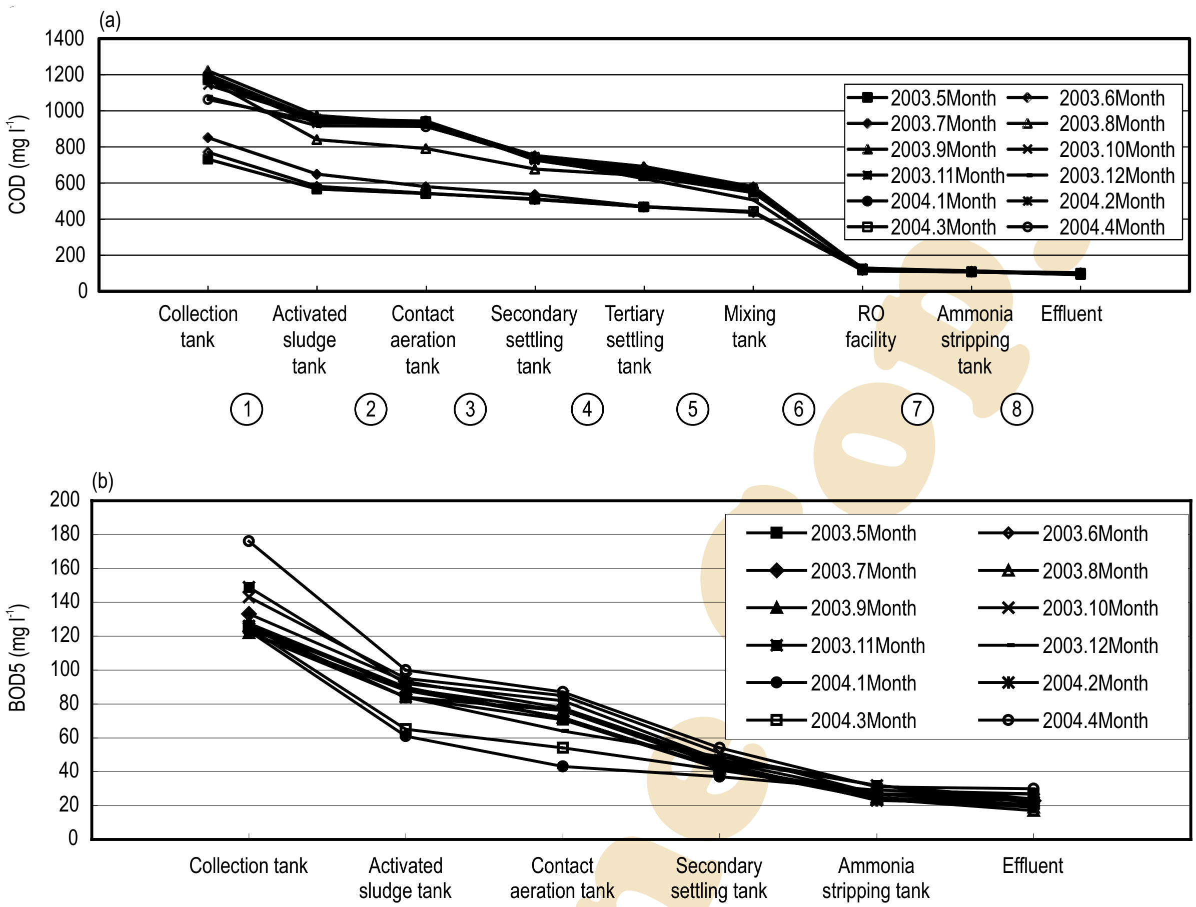


Fig. 2 : (a) Average COD values in individual tanks measured daily over the past year; (b) Average BOD values in individual tanks measured daily over the past year

efficiently decomposed the non-biodegradable leachate, resulting in 35.2 ~ 42.5% reduction in COD and 59.9 ~ 65.4% reduction in BOD level; which was considered acceptable within the current parameters for leachate treatment. The food to microorganism ratio (F/M) was about $0.091 d^{-1}$ after considering that for time being the sludge return rate was 30% with average influent BOD level of 105 mg l^{-1}, BOD removal rate of 62.1% and mixed liquid volatile suspend solid (MLVSS) of 1,300 mg l^{-1}; and extended aeration process should be adopted in practice for obtaining stable effluent quality with limited amount of waste sludge. After extended aeration, the removal rate of NH_3-N ranged between 43.2 to 56.8%, drawing a conclusion that up to half of the NH_3-N is oxidized and forms nitrate-nitrogen.

Membrane technology has already been used as an efficient tool for removing impurities from wastewater. Fig.2 (a) shows that before RO treatment, COD level in leachate was greater than 400 mg l^{-1}, which decreased approximately to a value slightly higher than 100 mg l^{-1} after RO treatment. Challenges that leachate treatment plants have to face is mainly due to complex nature of leachate, the RO contamination concentration load is greater and lead to the formation of various kinds of scale. The current biological treatment process produces biological scale like lichen. The biological scale problem is to be treated with a view of reducing the frequency and cost of membrane replacement. The current ratio of the RO system effluent to returned sewage is 5:1, a ratio that greatly shortens the life of RO membranes. As a result, the number of RO membranes used every year is between 500 and 700 costing US$ 100,000. Hence, targets for future ratios of effluent to returned sewage should be 4:1 or 3:1, or even to 2:1. Such a reduction would increase the flow and shear of the scale-removing water, increase the life of RO membranes, and amount of returning sewage. However, the method is fit to increase the effluent to returned sewage ratio during summer when evaporation is fast (Lee and Lueptow, 2001).

Fig. 3 (b) shows the HPLC analysis of leachate before and after RO treatment. The peaks observed in the HPLC analysis before RO treatment was higher than those observed after RO treatment. A similar comparison of the wavelength

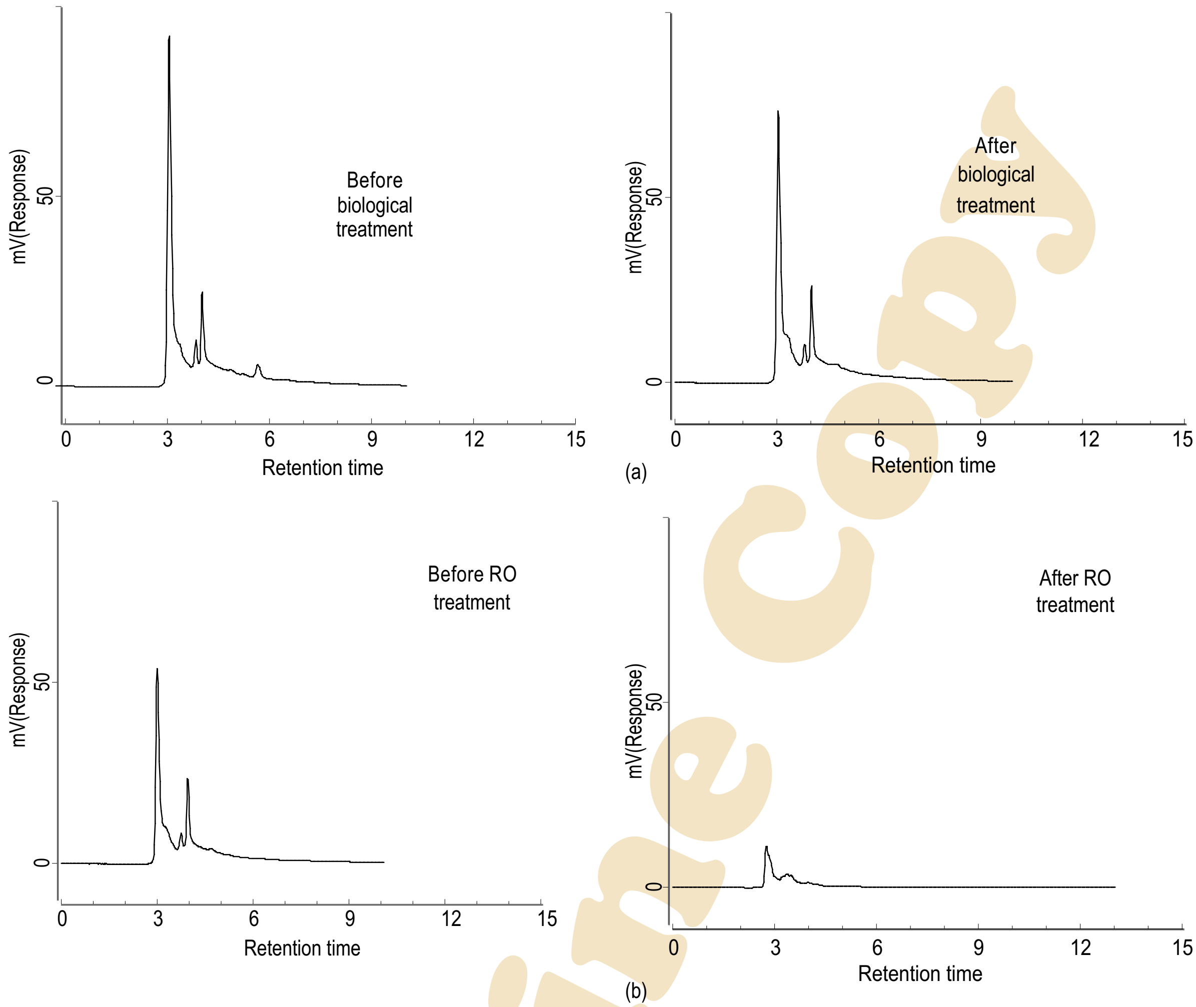


Fig. 3 : (a) Comparison between HPLC illustrations before biological treatment and after biological treatment; (b) Comparison between HPLC illustrations before RO treatment and after RO treatment

Table 4 : Comparison between current leachate quality at the Tien Wai Tien Leachate Treatment Plant and the national effluent standards for effluent

Item analyzed	Influent quality	Effluent quality	Effluent standard
pH—0-0	7.8~8.2	7.3~7.8	6.0~9.0
SS (mg l^{-1})	30~50	5~10	f≤50
BOD5 (mg l^{-1})	90~120	<20	——
COD (mg l^{-1})	900~1,200	80~120	f≤200
NH4+-N (mg l^{-1})	550~900	17	f≤10
NO3~-N (mg l^{-1})	45~50	15~20	f≤50
PO4-3 (mg l^{-1})	——	0.25	f≤4
Fe (mg l^{-1})	——	0.1	f≤10
Cr (mg l^{-1})	——	ND	f≤2
Zn (mg l^{-1})	——	0.07	f≤5
Cd (mg l^{-1})	——	ND	f≤1
Cu (mg l^{-1})	——	ND	f≤3

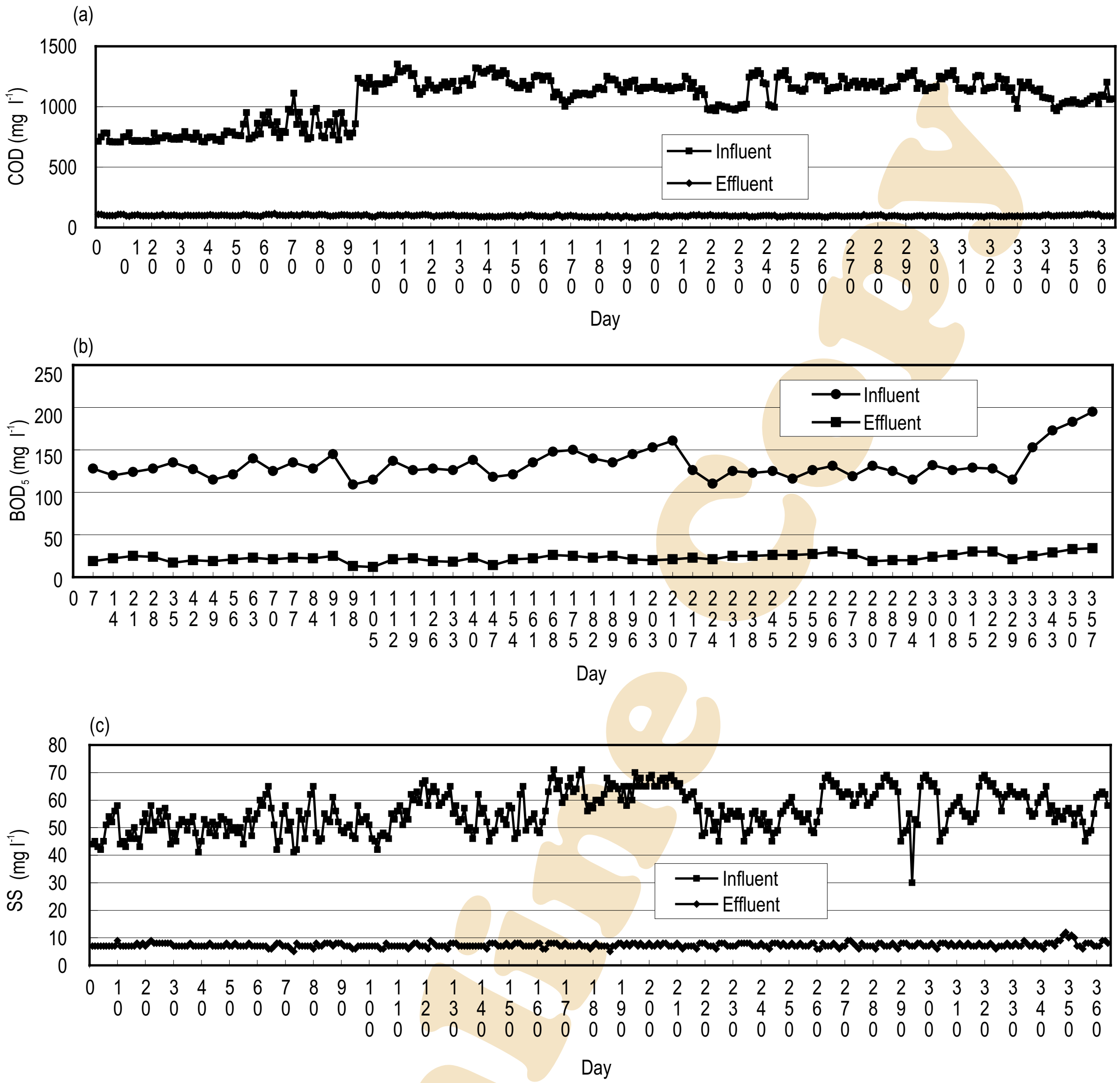


Fig. 4 : (a) COD values of influent and effluent measured daily over the past year; (b) BOD values of influent and effluent measured weekly over the past year; (c) SS values of influent and effluent measured daily over the past year

before RO treatment was found to be longer than those observed after RO treatment. This demonstrates that the level of aqueous organic matter in leachate before RO treatment was greater than that estimated after RO treatment. The result of the present study is in confirmation with the previous study of Salahi *et al.* (2010) where RO system was found suitable in treating and recycling oil refinery wastewater effluent.

Fig. 4 shows that the COD, BOD and SS values of the effluent were found stable throughout the year. On average, the removal rate of COD (91%), BOD (83%) and SS (86%) indicated that the wastewater plant was functioning well and met the Taiwan effluent standards. These findings demonstrate that the regenerated water after leachate treatment could be reused (Asano and. Levine, 1996).

pH and temperature are two important parameters for operating the ammonia stripping tower. The optimal control range depends on the cost and target quality of treated leachate. Higher the pH and temperature, more readily the gaseous NH_3-N is released, though it is necessary to take into account the operating cost (Yu *et al.*, 2012).

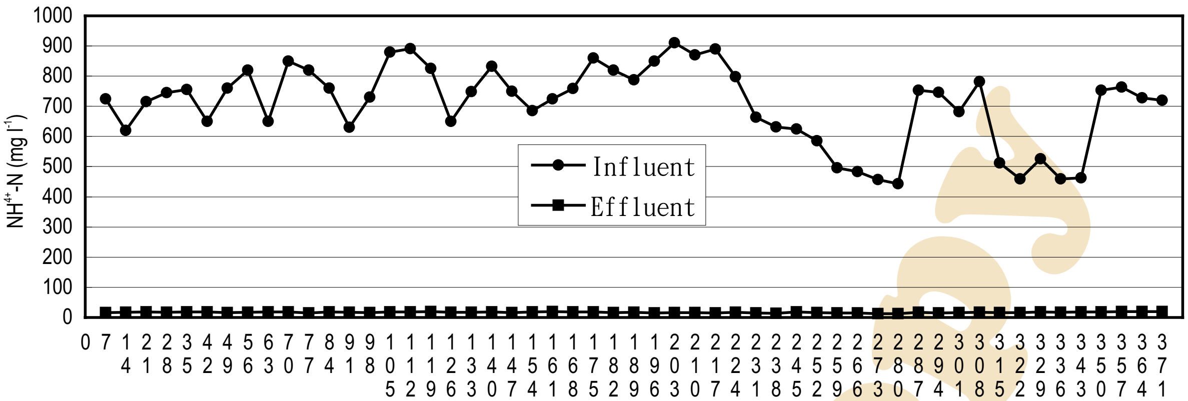


Fig. 5 : NH^{4+}-N values of influent and effluent measured weekly over the past year

The current removal rate of NH_4^+-N from the effluent by ammonia stripping tower was high (98%) (Fig.5). With a boiler heating system and a system to increase pH installed in front of ammonia stripping tower, the temperature and pH of the water could be increased to 50˚C and 11, respectively. With heat exchange system and a system to decrease pH installed behind ammonia stripping tower, the temperature of water could be reduced to 35˚C and pH below 9, following the Taiwan Effluent Standard (Environmental Protection Administration Executive Yuan, 2014).

Table 4 shows the physico-chemical characteristics of influent and effluent before and after treatment at Tein Wai Tien Leachate Treatment Plant. It was found that the treatment plant efficiently reduced the physico-chemical properties like SS, BOD, COD, NH_4^+-N and NO_3^--N and heavy metal content (Fe, Cr, Zn, Cd, Cu and Pb) of the leachate below permissible limit of Taiwan effluent (Environmental Protection Administration Executive Yuan, 2014).

The characteristic of landfill leachate varied with landfill time. At initial stage, BOD values were high and could be treated by a biological and chemical tertiary treatment process. However, during the middle and later stage, advanced treatment facilities, such as RO facilities and an ammonia stripping tower, were indispensable to effective leachate treatment.

Hence, regeneration of landfill leachate having complex composition is inspiring and can encourage government to promote its reutilization for various purposes, especially during period when there is shortage of water.

Acknowledgment

The authors would like to thank the National Science Council of the Republic of China, Taiwan for financially supporting this research under Contract No. NSC 91-2622-E-002- 011-003 and NSC 91-2211-E-002-056.

References

Asano, T. and A.D. Levine: Wastewater reclamation, recycling and reuse: past, present, and future. *Wat. Sci. Tech.*, **33**, 1-14 (1996).

Chen, C.K. and S.L. Lo: Treating restaurant wastewater using a combined activated sludge-contact aeration system. *J. Environ. Biol.*, **27**, 167-173 (2006).

Chen, C.K., S.L. Lo and R.S. Lu: Feasibility study of activated sludge/ contact aeration combined system treating slaughterhouse wastewater. *Environ. Engi. Sci.*, **22**, 479-487 (2005).

Environmental Protection Administration Executive Yuan, R.O.C. (Taiwan). (http://ivy5.epa.gov.tw/epalaw/search/LordiDispFull.aspx) (2014).

Fadel, M.E., E.B. Zeid, W. Chahine and B. Alayli: Temporal variation of leachate quality from pre-sorted and baled municipal solid waste with high organic and moisture content. *Waste Manag.*, **22**, 26-282 (2001).

Heavey, H.: Low-cost treatment of landfill leachate using peat, *Waste Management*., **23**, 447-454 (2003).

Lee, S. and R.M. Lueptow: Reverse osmosis filtration for space mission wastewater: Membrane properties and operating conditions. *J. Memb. Sci.*, **182**, 77-90 (2001).

Lindsay, S. and D. Kealey: High performance liquid chromatography. *New York: John Wiley and Sons* (1987).

Nakayama, M., E. Keijiro and K. Akiko: Behavior of Landfill Leachate Permeating into Soil and Effects of pH and CEC. *Sustain. Environ. Res.,* **20**, 299-303 (2010).

Salahi, A., T. Mohammadi, F. Rekabdar and H. Mahdavi: Reverse osmosis of refinery oily wastewater effluents. *Iran. J. Environ. Hlth. Sci. Eng.*, **7**, 413-422 (2010).

Shelef, G. and Y. Azov: The coming era of intensive wastewater reuse in the Mediterranean region. *Wat. Sci. Tech*., **33**, 115-125 (1996).

Sletten, R.S., M.M. Benjamin, J.J. Horng and J.F. Ferguson: Physical-chemical treatment of landfill leachate for metals removal. *Wat. Res.*, **29**, 2376-2386 (1995).

Tatsi, A.A. and A.I. Zouboulis: A field investigation of the quantity and quality of leachate from a municipal solid waste landfill in a Mediterranean climate. *Adva. Environ. Res.,* **6**, 207-219 (2002).

Tchobanoglous, G. and A.N. Angelakis: Technologies for wastewater treatment appropriate for reuse: Potential for applications in greece. *Wat. Sci. Tech*., **33**, 15-24 (1996).

Yu, Cai-Hong, Ya Wang, Tao Guo, Wan-Xin Shen and Ming-Xin Gu: Isolation and Identification of Ammonia Nitrogen Degradation