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PERSPECTIVES OF UPGRADED *JOKASO* (ONSITE WASTEWATER TREATMENT UNIT) SYSTEM IN AUSTRALIA

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ABSTRACT

The tightly engineered contact filtration process of Fuji Clean's *Jokaso* (onsite wastewater treatment unit) system, which leads to excellent functional treatment performance is described. The design and mix of various proprietary media is critical to achieve optimal treatment performance. Controlled, hydraulic management through mechancial processes such as flow equalization and sludge return is also essential for assuring high level performance; in particular for biological nitrogen removal. Phosphorus is removed electrochemically by immersed electrodes. Australian field research has demonstrated that the typical sludge pumpout interval from the Fuji Clean *Jokaso* should be once every four years.

INTRODUCTION

Japan is a densely populated island nation. The *Jokaso* treatment process has been utilized in Japan for over 40 years and the total number of installations is about 8 million. *Jokaso* is a generic term to describe an aerobic system and literally means "purification tank." The Fuji Clean *Jokaso* system is a fibre-reinforced plastic tank which has been available in the Australian market since 2010 (Otowa *et al.* 2012). This paper examines the various technical process flow details of the Fuji Clean *Jokaso* system that assure advanced treatment performance.

RESULTS AND DISCUSSION

Structure and function of *Jokaso* system

The Fuji Clean *Jokaso* system is composed of several functional aerobic/anaerobic chambers. A plastic media on which microbe colonies can live and digest organic substances is introduced into both aerobic and anaerobic chambers. Media (shown in Figure 1) is of critical importance to high level performance and each media type has characteristics that assure optimal treatment within a selected chamber. Surface area is the most well known media characteristic for bacteria to grow and form protective colonies on, but another important role of the media is to work as a filter. Therefore, optimization of media design requires continuous field testing evaluating both bacteria development and filtering capabilities of multiple media shape iterations.

Mechanical processes such as flow equalization and sludge return are also essential for optimal treatment performance. As shown in Figure 2, flow is equalized by additional upper level capacity in each chamber, which functions as a buffer to accommodate variable rate inflow. The result of this design feature is that relatively constant flow is transferred to the final treatment chamber by an air-lift pump, irrespective of inflow variability, as shown in Figure 3. Sludge return from storage (clarification) chamber to sedimentation (primary) chamber is also accomplished by an air-lift pump. Air-lift pumps are powered by a single, appropriately sized, reliable linear diaphragm blower (air pump) designed and manufactured by Fuji Clean. This air pump also supplies a steady source of oxygen to the aerobic chamber.

Figure 1. Various media with different microbe hosting and filtering capabilities for anaerobic and aerobic treatment.

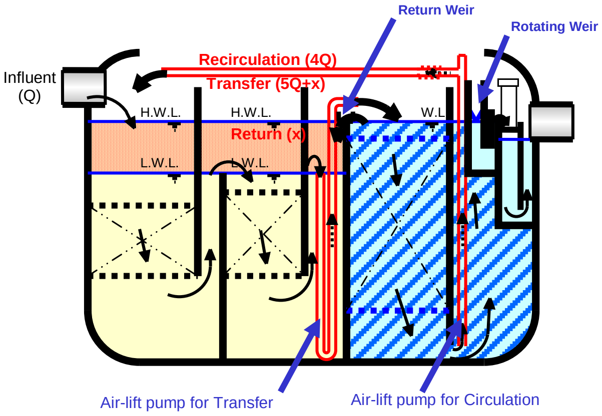

Figure 2. Flow equalization feature in a tank.

A regulated amount of water is transferred to the third chamber by an air-lift pump. The level of the first two chambers moves between HWL and LWL, depending upon the inflow rate.

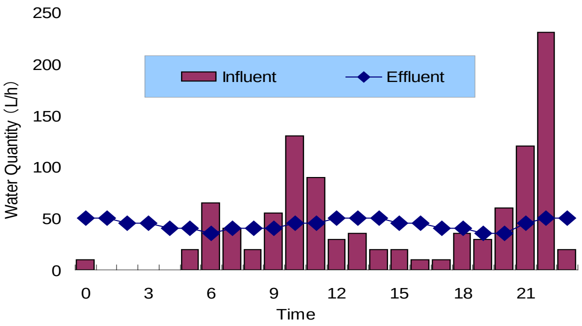

Figure 3. Typical flow equalization result.

Nutrient removal (Nitrogen).

Several biological nitrogen removal procedures have been deployed in the onsite treatment industry, such as 1) Series process of BOD removal - Nitrification, Denitrification followed by carbon removal, 2) Aerobic-Anaerobic recirculation; 3) Sequential aeration/non-aeration process. One of the most commonly adopted procedures for residential onsite units in Japan is the aerobic-anaerobic recirculation process. Total nitrogen is removed by the combination of aerobic and anaerobic biodegradations. Four distinctive steps (chemical and mechanical) are involved in this process. The first is the anaerobic hydrolysis reaction for protein and amino acid to decompose and form ammonium nitrogen. The second, is a process in an aerobic chamber, bacteria nitrify (oxidize) ammonium nitrogen to form nitrite and then nitrate ions (biological nitrification):

$$NH_4^+ + 2O_2 + 2OH^- \rightarrow NO_3^- + 3H_2O.$$

Oxygen and pH buffer capability (i.e. alkalinity) are essential for this reaction. The amount of oxygen stoichiometrically needed for this reaction is calculated as 3.6 kg of oxygen per 1 kg of ammonium nitrogen. In the third step, which is mechanical, liquid containing NO_2^- and NO_3^- ions is returned to the anaerobic chamber by an air-lift pump. Then, in the fourth step these ions are reduced by anaerobic bacteria and organic substances (i.e. Biochemical Oxygen Demand or “BOD”) to form nitrogen gas (biological denitrification).:

$$NO_3^- + 5H \rightarrow 0.5N_2 + 2H_2O + OH^-.$$

Since free oxygen will inhibit this process, the final reaction must take place in an anaerobic environment. Anaerobic bacteria use molecular oxygen from nitrogen oxides. The amount of oxygen stoichiometrically needed for this reaction is calculated as 2.9 kg per 1 kg of Nitrogen. Various parameters, such as NH_4 concentration, BOD, Dissolved Oxygen, Temperature and pH influence biological nitrification, while NO_3 concentration, Carbon Content, Temperature and pH are critical factors for biological *de*nitrification. Among these parameters, temperature is the most influential factor. Furthermore, in this process, the nitrogen removal ratio (N) is regulated by the following equation due to the basic nature of this recycling process:

$$N = RQ / (Q + RQ)$$

where Q is the inflow rate and RQ is the recirculation rate. Therefore, 60-80% of the nitrogen removal rate can be achieved by properly adjusting the recirculation rate (in the Fuji Clean CE series). Most recent practical research at Fuji Clean revealed that the N value could be further increased by introducing "aerobic digestion" in the primary chamber, which reduced accumulated sludge and improved nitrogen removal to greater than 90% (Ichinari *et al.* 2008). The aerobic digestion feature was incorporated into the most recent Fuji Clean unit (CF series) and has been available in Japanese market since 2011.

Nutrient removal (Phosphorus).

Fuji Clean treatment technology offers the option of removing phosphorus through an electrochemical process (Fuji Clean CRX series). This process, which removes phosphorus via iron electrolysis forming a removable precipitant of iron phosphate, is depicted in Figures 4 and 5. Direct current (typically 10V x 1A) is applied to a predetermined number of iron electrodes, which are immersed in the aerobic chamber. The Fe^{2+} ion is dissolved from the anode and further oxidized to Fe^{3+} by dissolved oxygen in water. The Fe^{3+} and PO_4^{3-} combine and precipitate as $FePO_4$, which is transferred to the first anaerobic chamber using air lift pumps and is eventually removed as sludge. Polarity is altered periodically so that electrodes are worn evenly. Electrodes need to be changed every 4-6 months, which is easily done by pulling and replacing the electrode cells. (Figure 5)

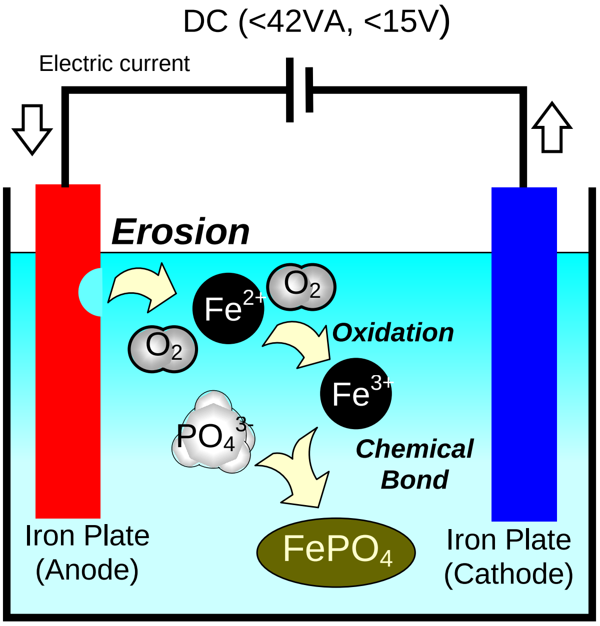

Figure 4. Phosphorus removal by electrochemical process.

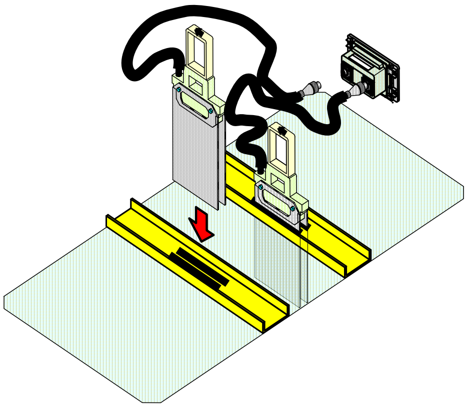

Figure 5.Diagram of typical Phosphorus removal unit.

Table 1. Effluent quality of Fuji Clean CE series in Japan and Australia.

	JAPAN		AUSTRALIA					
	Actual Field		AS/NZS1546.3 Data			Actual Field		
# of sites/data	7,668	677	50	48	16	76	76	49
% of total (%)	BOD (mg/L)	TN (mg/L)	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	BOD (mg/L)	TSS (mg/L)	TN (mg/L)
10		7.4	2.0	2.0	14	2.0	1.7	3.2
20	2.5	9.0	2.0	2.0	15	2.0	2.5	5.1
50	7.5	17	2.0	4.0	19	4.7	6.0	10
80	19	31	4.0	6.0	21	12	15	23
90	28	38	5.0	8.0	22	17	35	37
100	99	99	7.0	9.0	22	45	190	70
Average (mg/L)	11.20	20.70	2.80	4.27	18.34	8.35	14.90	15.50
Removal ratio (%)	94	62	98	99	51	96	95	63

Data of the Fuji Clean System in Australia

Various data for Fuji Clean CE1500EX system were collected at Caboolture (QLD) Sewage Plant and summarized in the Table 1. They were collected in the course of obtaining AS/NZS1546.3 accreditation. Average nitrogen reduction in the first six month period was 51%. Actual field effluent data (grab samples) are also summarized in the Table 1. These samples were collected from Fuji Clean CE1500EX sites in NSW, QLD and WA states and are consistent with a large sample of field data from Japan.

Upgraded units such as CRX system were developed by Fuji Clean in order to further reduce nutrients such as phosphorus. Results in Table 2 for Japan and Australia show 79-98% of BOD, TSS, Total Nitrogen and Total Phosphorus removed.

Table 2. Effluent quality of upgraded Fuji Clean CRX series in Japan and Australia.

	Field Data in Japan				AS/NZS1546.3 Data in Australia			
# of sites/data	134	134	134	36	64	64	64	78
% of total (%)	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
10	2	1	6	0.20	2	2	3	0.06
20	3	2	7	0.28	2	3	7	0.09
50	5	3	10	0.88	2	7	10	0.28
80	12	8	15	1.30	6	10	14	0.54
90	15	10	20	1.60	8	13	17	0.78
100	40	22	30	5.30	31	31	21	2.33
Average (mg/L)	8.1	4.8	10.9	0.98	4.83	7.37	9.80	0.40
Removal ratio (%)	96	97	81	80	98	98	79	95

Easy maintenance and low energy rate

Fuji Clean CE system in Australia (CE1500EX) is relatively light (430kg) and compact, with a tank size measuring 1440mm (width) x 2510mm (length) x 1870mm (height). Simple operation of three valves in the aeration chamber at each inspection visit makes regular maintenance easy and routine. Accumulated sludge can be easily pumped out through each baffle section. As shown in Figure 6, typical cleaning (pump out) frequency has been determined to be once every four (4) years based on field data in Australia. Energy consumption of blowers (80 liter/min for CE1500EX) manufactured by Fuji Clean is as low as 54W.

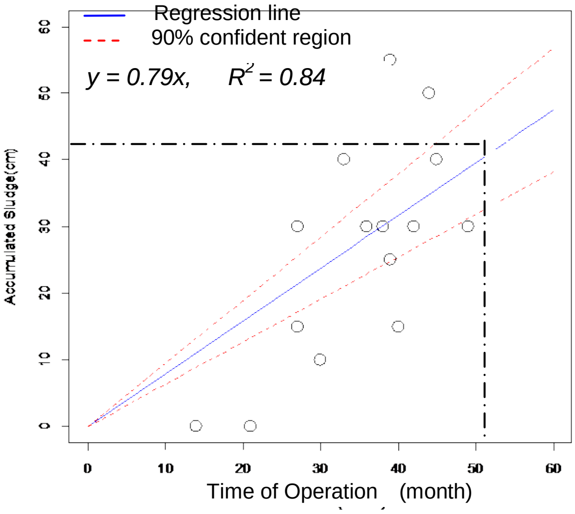

Figure 6. Accumulated Sludge during the time of operation of CE1500EX in Australia.
Solid line (Regression line): y=0.79x, $R^2 = 0.84$
Broken line (90% confident region)
Sludge level depth necessary to trigger a pumpout is defined as when accumulated sludge in anaerobic chamber reaches 40cm or more.

CONCLUSIONS

The Fuji Clean CE1500EX system was accredited as an advanced secondary system (BOD<10, TSS<10) in Queensland State and as a secondary system in all other states of Australia. About 2,000 CE systems have been sold in Australia in last five years and effluent data show consistent and reliable performance. Further nutrient removal can be achieved by an upgraded unit such as Fuji Clean CRX system.

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