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A Case Study for Installation of Dry Washing Process in Kitchen

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주방에서 건식 식기 세척기 설치 및 운전 사례연구

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Abstract

Dry washing by air and sand to clean dishes was investigated for establishing a dry washing process in a kitchen. Thirty seasonings and foods as dirt markers and fourteen kinds of dishes were used for the experiment, and washing efficiency was evaluated by COD-MN (mg/L). It was found that air dry washing effectively reduced COD-MN of some dirt markers but not effective at all to some dirt markers. It could be also said that dirt markers would not be completely removed by air dry washing. The shape of dishes also affected COD-MN reduction by air dry washing. Sand dry washing showed excellent efficiency on COD-MN reduction. Combination of air and sand dry washing may be necessary to make a dish dry washing system which is completely independent from water.

keywords : Dry washing by air, Kitchen, Sand dry washing

1. Introduction

Nowadays, manufacturers in Japan have started to care zero emission policy in their business model, and try to recycle their waste. For recycling of organic waste, there are several ways for recycling such as utilization as feed stock (Abe, 2006), conversion to biogas (JIE, 2002), production of bio-ethanol (Klass, 1998), and composting (Fujitta et al., 1999). However, those recycling ways are "End of pipe" technologies. End of pipe technologies cannot be panacea for zero emission policy. For pursuing zero emission, the manufacturers have to choose the way that how to reduce waste from their factories.

Factories of manufacturers usually have their own restaurants which provide lunch and dinner for their employee in factories. The kitchen of the restaurants usually generates waste such as wastewater and sludge, which hampers zero emission policy of manufacturers. The company in Toyama, Japan, which pursues zero emission of its waste, tried to reduce waste from one of kitchens of its factories. To lessen waste generation, the company had tried composting of kitchen sludge however difficulty of utilization of produced compost gave up the option of composting. To reduce the waste, we proposed installation of dry washing process in the kitchen. Washing dishes is usually done by water because water is a cheap, reliable, and easy-to-access medium to clean up dirty objects. But washing by water possesses a considerable disadvantage. Water becomes wastewater after use and the wastewater has to be treated, which requires more energy, money, and time. Conserving water brings benefits to companies: saving the costs for water use, saving the cost for wastewater treatment, reducing waste which is generated as a result of wastewater treatment, and strengthening company management against the coming water crisis.

The purpose of this study was to examine current situation of the kitchen of the company for applying of a dry washing process and to investigate the dry washing experimentally for its efficiency to reduce COD of wastewater. The dry washing process under development here may apply to the stricken areas of natural disasters or the fronts of peace-keeping activities where access to water is strictly limited.

2. Materials and Methods

2.1. Investigation of kitchen

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2.1.1. Kitchen description

One of six kitchens in a manufacturing company in Toyama, Japan, was selected for investigation. The kitchen was located in a part of a factory building and served 600 lunches and no dinner for employees every five working days. The floor of the kitchen was a dry type. All discharged wastewater from this kitchen flowed into a grease trap tank placed out side of the building. The wastewater flowed out from this tank into the wastewater treatment system of the factory. Annually regular cleaning of the grease trap tank was necessary and the waste produced in this tank such as grease and organic sludge interrupted achievement of zero emission of the company.

2.1.2. Investigation method

Investigation of the steps: carrying food stuff, preparing for cocking, cocking, dishing up, collecting dishes, washing dishes, and drying dishes, in the kitchen was conducted for one week from August 25, 2003 to August 29, 2003. Contamination condition at each step was observed.

2.2. Experiments of dry washing

2.2.1. Dry washing

Air and sand dry washing processes were studied. Dry washing means washing with no water in this paper so that air dry washing and sand dry washing mean cleaning by only air and by only sand, respectively. Air produced by the air compressor SP-07CPB PC02833 (Iwata Toso, Japan) was emitted through the air gun Mach F-206 M100 (Fujimac, Japan) with 9 kg/cm^2 (128 psi). The basic conditions for air dry washing were 45°, 5 cm, and 15 seconds for the angle of the air gun to the surface of a dish, the distance between the surface of the dish and the head of the air gun, and air application time, respectively. Sand which got through 1 mm mesh was used for sand dry washing. Sand washing was done manually.

2.2.2. Dirt markers

Thirty seasonings and foods, very common items in Japanese cooking, were selected as dirt markers for evaluating washing efficiency (Table 1).

Table 1. Seasonings and foods used as indicator and their viscosity

Symbols	Seasonings and foods (Dirt markers)	Viscosity (Sangyo, 2006) (cP)
SC	Sauce (conc.*)	400-1000
SR	Sauce (regular)	3
S1	Sauce (heavily conc.1)	850-4500
S2	Sauce (heavily conc.2)	850-4500
OS	Oyster sauce	850-4500
TK	Tomato ketchup	2000-20000
TP	Tomato puree	700-25000
PS	Tomato pizza sauce	2000-20000
MS	Meat sauce	1000-50000
DC	Dressing (Chinese)	< 30000[#]
DS	Dressing (Sesame)	< 30000[#]
DF	Dressing (French)	< 30000[#]
DI	Dressing (1000 Islands)	< 30000[#]
MY	Mayonnaise	4000-100000
TS	Tartar sauce	> 30000[$]
MD	Mustard	100-700
SG	Sauce for grilled meats	<30000[#]
SSJ	Soy sauce with citrus fruits juice	<30000[#]
SGG	Sauce with ginger for grilled meats	<30000[#]
SS	Soy sauce	6
KJ	Kochujang	25000-200000
TA	Tabasco	2000-20000
QP	Quick preparation paste for Kimchi	2000-20000
RC	Retort carry roux	4000-200000
RS	Retort stew (cream)	8000-80000
CC	Chocolate cream	80000-150000
PC	Peanut cream	50000-450000
WA	Wasabi	5000-150000
JM	Japanese mustard	25000-200000
CM	Condensed milk	3000-10000

Note: *: concentrated, #: lower values was not found, $: upper value was not found

2.2.3. Dishes

Fourteen kinds of dishes were used for the experiments. They included tea cups, noodle bowls, rice bowls, soup bowls, and large and small dishes for side dishes. Parameter D/H was used for conveniently describing the shapes of dishes. D and H stood for diameter and height of the dishes, respectively. The smaller the value of D/H was, the taller the dishes were.

2.2.4. COD as parameter and COD measurement

Washing efficiency was evaluated by COD-MN (COD measured with $KMnO_4$) and it was measured with Digital COD meter Type HC-607 (Central Kagaku, Japan). It was found that COD-MN of the wastewater from the kitchen was 450 mg/L.

2.2.5. Method of dry washing experiments

For producing COD-MN 450 mg/L of wastewater in order to mimic wastewater of the kitchen, the amount of each dirt marker to 15 litters of water was determined and was divided by 14, the number of dishes, in order to know the amount of dirt marker to be spread for each one of dishes. The amount of dirt marker placed on each of dishes was spread by a flat blade and then air dry washing was applied for cleaning up. Next, the dish was washed in a large container with 15 litters of water. After finishing treatment of all 14 dishes, COD-MN of the 15 litters of water was determined for evaluating air or sand washing efficiency. In case of sand dry washing, it was done after air dry washing.

3. Results and Discussions

3.1. Investigation of kitchen

According to the investigation on the steps of carrying food stuff, preparing for cocking, cocking, dishing up, collecting dishes, washing dishes, and drying dishes, the step of washing dishes was the largest producer of high COD wastewater. Fig. 1 showed the process of washing dishes they currently followed. Mechanical washing, following manual washing, was the final step of washing and was also sterilization step. The water in the sink became blown color due to dissolving of seasonings and foods and the floating materials which were vegetables left over by customers were recognized. Those organic matters dissolved in wastewater and floated at the surface of the wastewater were a main cause for generation of kitchen sludge. Then, the proposal of dry kitchen was made as Fig. 2.

The proposal was that the processes which generate high COD wastewater shown in Fig. 1 were replaced by dry

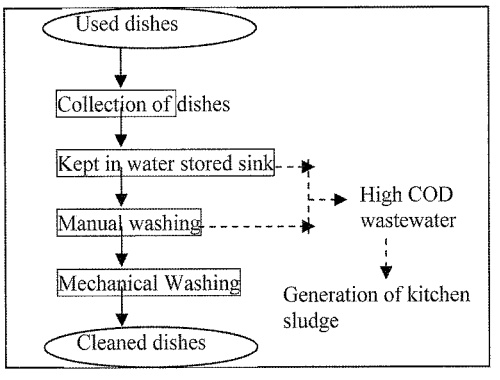

Fig. 1. Current washing process.

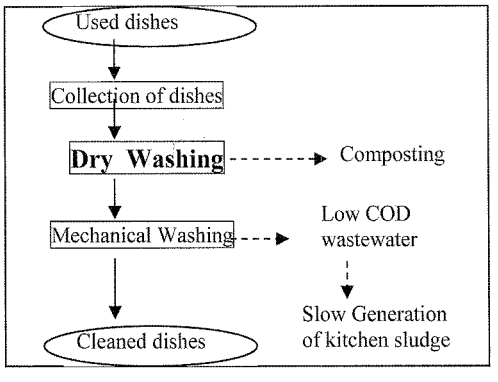

Fig. 2. Dry washing process proposed.

washing process and the organic matters removed by dry washing were treated by composting. Mechanical washing after dry washing was a very small contributor of high COD in wastewater so that remain of this mechanical washing in the proposal did not virtually hamper the purpose of reduction of COD in wastewater, and was reasonable from hygienic point of view.

3.2. Experiments of dry washing

3.2.1. Air dry washing

Fig. 3 showed the results of COD reduction by air dry washing. Two conditions for air dry washing were studied here. One condition was as follow. Air dry washing was applied right after a dirt marker was spread on the dish (Condition 1). The other condition was that air dry washing was done 30 minutes later after a dirt marker was spread and dried on the dish (Condition 2). According to the results, four patterns in COD reduction were found; large COD reduction on the both conditions (Pattern 1), virtually no reduction on the both conditions (Pattern 2), larger COD reduction on Condition 1 than Condition 2 (Pattern 3), and larger COD reduction on Condition 2 than Condition 1 (Pattern 4). Most of dirt markers fell in Pattern 1. Kochujang (KJ) and Chocolate cream (CC) showed Pattern 2 and had very strong resistant to air spray. COD reduction on Dressing (French) (DF), Dressing (1000 Islands) (DI), and Tabasco (TA) were in Pattern 3. Those non

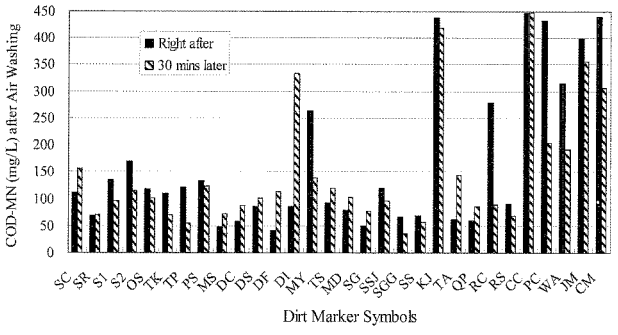

Fig. 3. COD reduction after air dry washing.

Newtonian fluids showed a strong resistant after 30 minutes left in room. Dirt markers with high viscosity such as Peanut cream (PC), Wasabi (WA), Japanese mustard (JM), and Condensed milk (CM), showed Pattern 4. They might be dried up after 30 minutes left in room, which made them remove much easier than Condition 1.

COD reduction might be related to the shape of dish. To find the relationship, D/H was used for describing the shape of dish. Tomato ketchup and soy sauce were selected as the representatives of non Newtonian fluids and Newtonian fluids, respectively. The certain amounts of tomato ketchup and soy sauce which generated approximately COD-MN 950 mg/L and 520 mg/L of wastewater, respectively, were spread to each one of 14 kinds of dishes and, then, air dry washing was applied. After air dry washing, COD-MN was measured for each one of the dishes. The results were shown in Figs 4 and 5. No relationship between COD and D/H was found in Tomato ketchup, whereas the relationship of inverse proportion was found in case of soy sauce. According to the results, removal efficiency of soy sauce, a Newtonian fluid, from dish became higher with increase of D/H, which meant that soy sauce would be blown away easier when the shape of dishes was getting more flat. In case of tomato ketchup (non Newtonian fluid), the COD was still very high when the D/H became the highest. Comparing the results of Figs 4 and 5 with the result of Fig. 3, the remaining COD of tomato ketchup and soy sauce in Figs 4 and 5 were apparently higher than the COD in Fig. 3. The reason of this phenomenon was the larger amount application of tomato ketchup and soy sauce to each one of dishes in the experiments of Figs 4 and 5 although air dry washing time was 15 seconds as same as the experiment in Fig. 3. It could be said that 15 seconds of air dry washing was not enough when large amount of dirt markers were spread on the dishes.

3.2.2. Sand dry washing

According to Fig. 3, almost all dirt markers showed 50 mg/L of COD remained at least. This fact implied that it was impossible to remove completely any kinds of seasonings and foods by only air dry washing. Then, it can be said that to achieve more COD reduction in wastewater air dry washing was not enough. The performance of sand dry washing was investigated here. Sand dry washing was done after air dry washing to minimize organic matters hold by sand. Six representative of dirt markers; SR, TK, DF, SG, SS, and KJ were used for experiments.

Experimental results were shown in Fig. 6 and Table 3. In Fig. 6, low COD-MN was seen on all dirt markers. Control of COD-MN was 450 mg/L. Except for SG, all

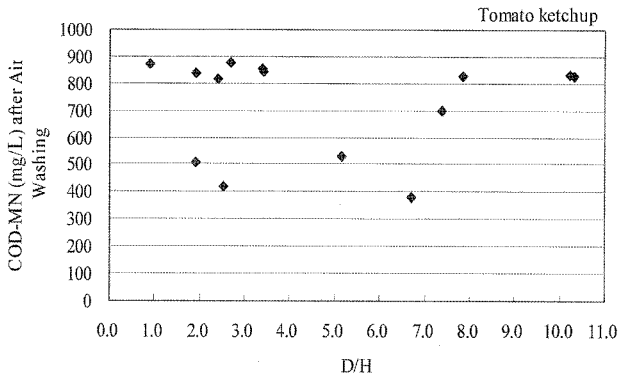

Fig. 4. COD vs. D/H on Tomato ketchup (non-Newtonian fluid).

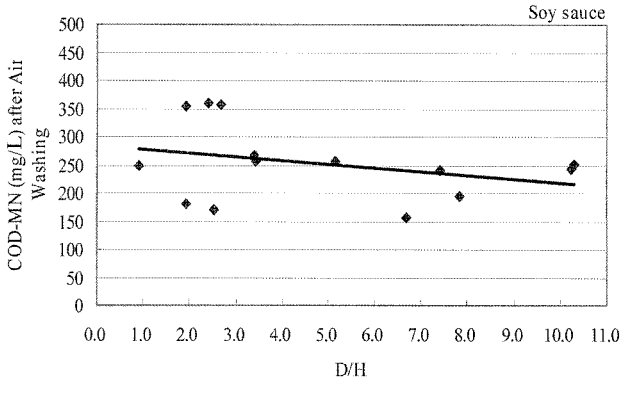

Fig. 5. COD vs. D/H on Soy sauce (Newtonian fluid).

Table 2. Dish descriptions and D/H values

Dish#	D(cm)	H(cm)	D/H
1	12.5	6.5	1.9
2	8.7	1.3	6.7
3	14.8	2.0	7.4
4	15.0	5.6	2.7
5	15.5	3.0	5.2
6	11.4	4.5	2.5
7	15.0	6.2	2.4
8	11.0	5.7	1.9
9	6.7	7.4	0.9
10	15.4	4.5	3.4
11	14.1	1.8	7.8
12	22.7	2.2	10.3
13	21.5	2.1	10.2
14	19.0	5.6	3.4

Table 3. COD reduction percentage after sand dry washing corresponding to the results of Fig. 6.

Dirt marker symbols	COD-MN reduction (%)
SR	99.4
TK	99.4
DF	98.8
SG	97.0
SS	99.5
KJ	99.9

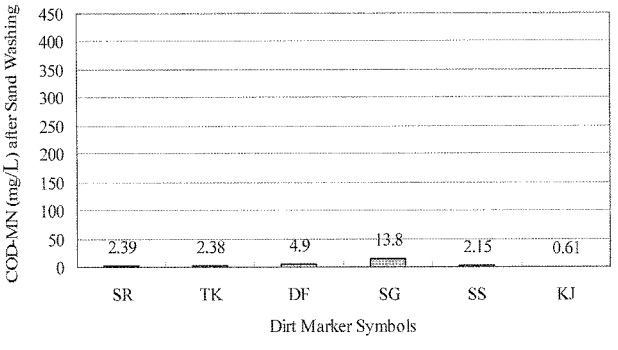

Fig. 6. COD reduction after sand dry washing.

COD-MN was reduced to level of one digit which was extraordinary clean as wastewater. As seen in Table 3, all COD-MN reduction percentage was more than 97%. From the results, it could be concluded that sand dry washing was very effective to remove remained seasonings and foods which could not be blown away by air dry washing. As stated earlier, sand dry washing this time was performed with combination of air dry washing. It could be imagined that sand dry washing showed very high performance of COD-MN reduction without the prior process of air dry washing. However, considering the treatment of organic matters removed by sand, the amounts of the organic matters in the sand must be minimized in order to make the treatment of the organic matters much easier. Sand dry washing was not necessary for this kitchen in this case because the mechanical washing was already installed in the kitchen. Sand dry washing was investigated because it was found that through this study that sand dry washing was essential process for the ultimate design of complete independence system from water.

3.2.3. Proposed design of dry washing process

The ideal system of dry washing might be the one as shown in Fig. 7. Used dishes will be cleaned through air and sand dry washing.

Organic matters removed by air dry washing is treated by composting and then finally retuned to soil. The organic matters removed by sand dry washing which stick to sand are heated by oil or electric energy with sand. The heated sand is returned to sand dry washing process to clean and sterilize dishes.

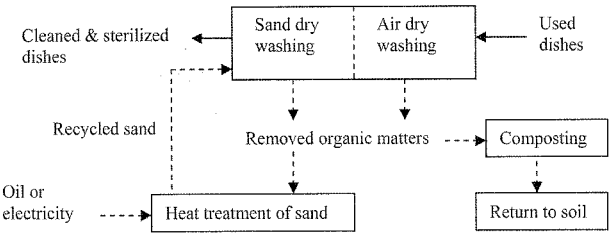

Fig. 7. Ideal dry washing system proposed.

4. Conclusions

Following conclusions were drawn from this study.

- In current washing process, washing in a water stored sink mostly contributed COD of the wastewater from the kitchen.
- Washing efficiency on air dry washing totally depended on characteristics of dirt makers.
- Some COD-MN always remained in the case of air dry washing.
- Shape of dishes also influenced washing efficiency by air dry washing.
- Newtonian fluid might be able to be removed much easier from flat dishes.
- Sand washing was very efficient and COD-MN removal was almost 100%.
- Dry washing processes showed highly promised efficiency.

For further work, we need to install a dry washing process in the kitchen and check its efficiency according to generation of kitchen sludge and operating cost benefits. However, the installation requires a major renovation of the kitchen and a full change of its system. A pilot scale trial of dry washing process should need before a real scale trial.

국문요약

공기와 모래를 이용한 건식 식기세척기를 주방에 설치하여 운전하였다. 실험을 위하여 30여종의 양념(Dirt 마커) 과 14종의 접시를 사용하였으며 세척효율은 COD-MN에 의해 평가하였다. 건식 공기세척은 일부 양념에는 효과적이었으나 일부 양념에는 전혀 효과가 없는 것으로 분석되었다. 또한 건식공기세척을 통해서 양념의 완벽한 제거는 불가능하였다. 접시의 형태에 따라 세척효율에 큰 차이를 보였다. 모래와 공기에 의한 세척은 COD-MN 제거에 탁월한 성능을 보였다. 본 연구를 통하여 물을 사용하지 않고 모래와 공기에 의한 건식세척 방법이 가능함이 입증되었다.

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