Basic Study of Detergency for Reducing Environmental Pollution (Part V)

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1. Introduction

Laundry of clothing (referred to as washing) is of great importance in maintaining comfortable clothes life with cleanliness. In recent years though, water pollution by washing drainage and influences on the natural environment by dry cleaning solvent have developed into a global problem.

It is an urgent issue to study and establish new detergents as well as washing methods that would not greatly give damage to the environment in the 21st century. However, according to the results of a survey[1] performed concerning washing at home in Toyama, in spite of the decease in the necessary amount of detergent used per washing, there is no substantial decline in the total amount of detergent being used. This is probably because the washing frequency has increased in recent families together with the enlargement of the capacity of washing machines today.

Based on such situation, we have approached this issue from studies on the surfactants and mechanical power of washing machines in the past. In this study, we have paid attention to the water itself used in washing in order to reduce the damage to natural environment[2)3)].We suggest the possibilities using functional water which should be gentle concerning damages to the environment compared to the use of tap water together with the standard amount of detergent.

Various kinds of functional water[4) 5)] are shown in table 2. Recently some reports concerning products using functional water can be found in medical fields, food, agricultural fields and cosmetics. Little reports are seen in the field of washing though. Within the various types of what's called functional water, here, we have performed fundamental examinations on the asking performance by the use of alkaline electrolyzed functional water (referred to as electrolyzed water) as a trial to reduce the load to the environment by washing of clothing.

2. Experimental

2.1 Materials

The experimental samples were as follows:

Test cloth : Artificially soiled cloths (provided by the Association for Laundry Science) ,based cotton fabric before soiled. Washing solvents : Tap water (Toyama area), Ion water generated by WBEM580072-020712 (Organo corporation), Alkaline electrolyzed water generated by AMANO α-900 (AMANO Corporation) Protein degrading enzymes : everlase, kannase, esperase (Novozymes Corporation) Detergent : SDS (WAKO Pure Chemical Industries Ltd.), Commercially available detergent (KAO Corporation)

2.2 Washing Method

Five sheets(5cm×5cm) artificially soiled cloths were washed in Terg-O-Tometer under several conditions as shown in table 1. The temperature of the water was set to 20℃～ 40℃and the samples were washed with and without surface active agents (SDS) and enzymes in 1L solvent.

Using a Terg-O-Tometer (40rpm, 80rpm, 120rpm, 160rpm), the samples were washed for 10 minutes, rinsed for 1minute 2 times and air dried

Table 1 Conditions under which the Terg-O-Tometer was used

Parameters	Condition
Temperature of solvent	20℃， 30℃， 40℃
Surfactant	SDS (0,2,4,10,12,16 mmol)
Kind of enzyme	Everlase 8.0T / Kannase 24TK / Eslerase 4.0T
Concentration of enzyme	0.005%， 0.01%， 0.02%， 0.03%
Power of washing	40,80,100,120,160 r.p.m.
Washing Time	10 min.
Rinse	2 times(1 min.)

2.3 Evaluation (D) of Detergency

Surface reflectance of the sample cloths was measured by a color difference meter (Nippon Densyoku Industries Co,Ltd.,NW-1),and the K/S value was calculated from equation **(1).** The degree of detergency (removal efficiency) was calculated from equation**(2).**

$$K/S = (1-R)^2/2R \qquad (1)$$

$$D(\%) = \{(K/S)_s - (K/S)_w\} / \{(K/S)_s - (K/S)_o\} \times 100 \qquad (2)$$

K: coefficient of reflectivity S: coefficient of light scattering

R: observed fraction of monochromatic light which is reflected

D: detergency (%)

K/Ss: K/S value of soiled cloth

K/Sw: K/S value of washed soiled cloth

K/So: K/S value of original cloth

Surface reflectance was obtained from the average of the values analyzed at 5 points close to its center where the soil looks fairly uniform for each cloth at both on the front and back sides.

Five pieces of soiled cloth and cotton cloth before soiled were analyzed. The detergency was calculated for each soiled cloth and the average of the 5 pieces of the cloths was used for analysis.

3. Results and Discussion

3.1 Properties of the Washing Solvent

Functional water in general is referred to as kinds of water as shown in the table 2 below. In our research, we have focused on using alkaline electrolyzed water.

The pH, electric conductivity, hardness of the washing solvents are shown in Table3. Alkaline electrolyzed water was generated by using a separating membrane and collecting water at the negative electrode.

Table 2 Kinds of Functional Water

Method to make Functional Water	Main Treatment	Type of Water
Energy processing in Electric Field,MagneticField,andSupersonic wave	Electrolyzed Treatment	Alkaline Electrolyzed Water Acid Water
	Electric Field Processing	Electric Water
	Magnetic Field Processing	Magnetic Water Rod Water (by esonated magnetic processing)
	Far Infrared Rays	Far Infrared Ray Processed Water
	Supersonic Waves	Super sonicWave Processed Water
Addition of Minerals	Mineral Processing	Ceramic Processed Water Mineral Processed Water Bakuhanseki Water, π Water
Removal of Substance	Deaeration	Deaerated Water

Table 3 Properties of the washing solvent

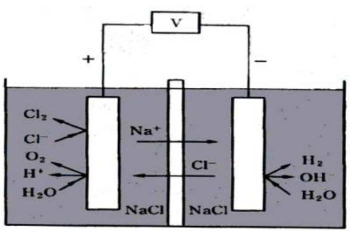
Kind of Water	pH	Electric Conductivity (μ 有/cm)	$CaCO_3$(ppm)
Tap water	7.3	145	15
Ion water	8.52	3.71	0.1
Electrolytic Reduction Water	9.5	350	38
Alkaline	9.5	1.81×10^3	4
Electrolyzed Water(1)	11.5	1.81×10^3	—
Alkaline Electrolyzed Water(2)			

Principle of fabricating electrolyzed water

$2H_2O + 2e^- \rightarrow 2OH^- + H_2\uparrow$

$Na^+ + e^- \rightarrow Na$

$Na + H_2O \rightarrow 1/2\,H_2 + NaOH$



Acid Barrier Alkaline

Fig.1 Generation of Strong Electrolyzed Water

3.2 The effect of machine power and solvent temperature on detergency

The detergency, using various solvents were performed under various machine power (40rpm, 80rpm, 120rpm, 160rpm) and temperatures (20℃, 30℃, 40℃). As a result, the higher the machine power becomes, the higher the remove soil from the cloth, i.e. the higher the obtained detergency, especially evident when washing with alkaline electrolyzed water.

Concerning the temperature of solvents, higher detergency was seen by higher temperatures though washing at 40℃, 160rpm showed a slight decline in detergency.(Fig.2～Fig.5)

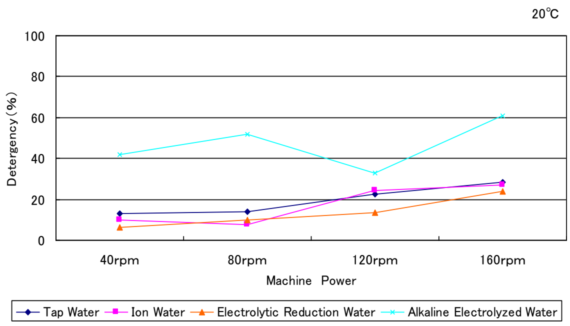


Fig.2 Relationship between Detergency and Machine Power(20℃)

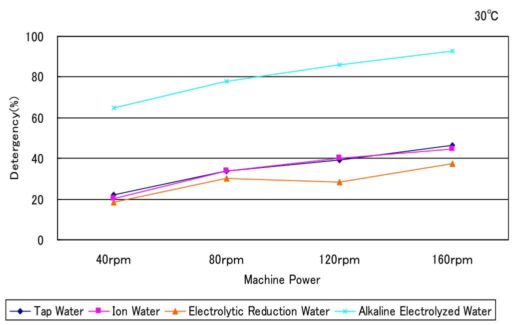


Fig.3 Relationship between Detergency and Machine Power(30℃)

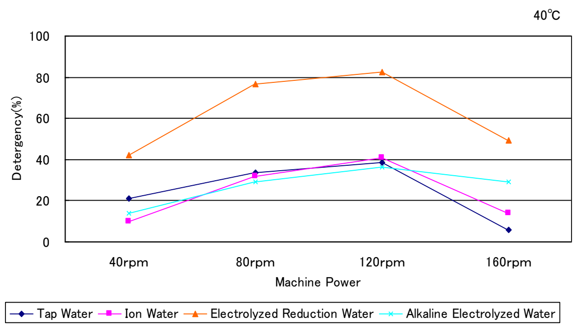


Fig.4 Relationship between Detergency and Machine Power（40℃）

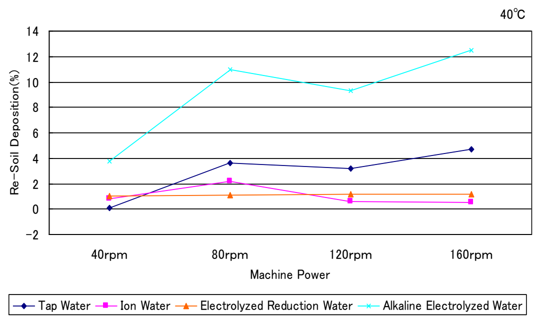


Fig.5 Detergency vs. Re-Soil Deposition (40℃)

3.3 The effect of SDS and enzyme on detergency

Addition of SDS to the washing solvent showed effective detergency at various temperatures of electrolyzed water. However, when using electrolyzed reduction water, a slight decline was seen in the detergency. Among the variety of condition systems used for washing, the effect to the detergency was not so notable except with the addition of enzymes to electrolyzed water where an evident effect was seen, especially at the solvent temperature of 30℃.

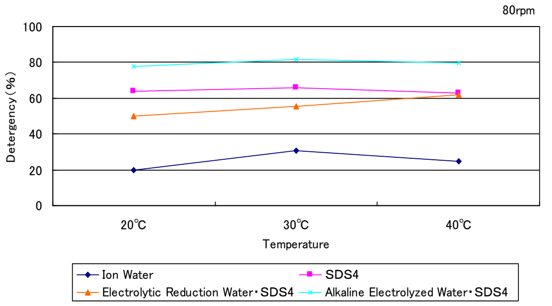


Fig.6 Detergency vs. washing temperature addition SDS

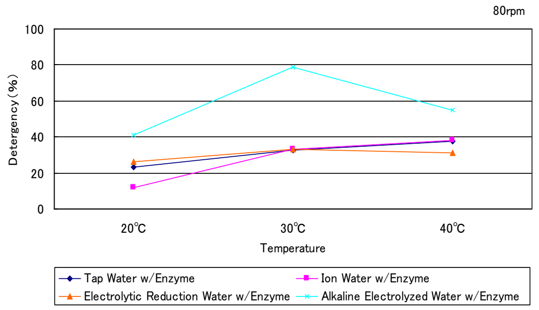


Fig.7 Detergency vs. Washing temperature addition Enzyme

3.4 The effect of Enzyme (Everlase , Kannase) concentration

Using alkaline electrolyzed water which was notably effective to detergency in washing, the effects were analyzed with the addition of 2 kinds of enzymes one at a time. As shown in Fig8～Fig.11, addition of 0.05% of each enzyme was enough to yield an evident effect in detergency.

The concentration of Everlase added to the washing solvent was varied between 0.005% and 0.03%. An evident effect in removing oil was detected not so much with higher concentration of the enzyme but rather with higher pH of the electrolyzed water. Concerning the temperature of the water, the washing was more effective with electrolyzed water at 30 degrees centigrade than at 20.

In between the enzyme concentrations of 0.005% and 0.03%, washing ability was more effective with higher concentrations especially at the water temperature of 20 degrees centigrade, neutral pH. However, higher the pH, i.e. the more alkaline the solvent becomes, the greater the ability to remove soil from the cloths, not depending on the concentration of Kannase. The addition of 0.03% Kannase to electrolyzed water at the temperature of 30 degrees centigrade showed almost an equal effect as with washing using commercially available detergents.

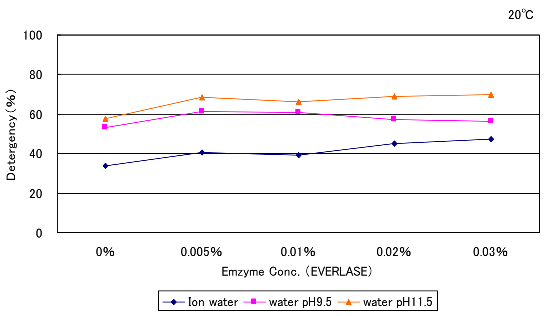


Fig.8 Relationship between Detergency and Enzyme Concentration(Everlase) 20℃

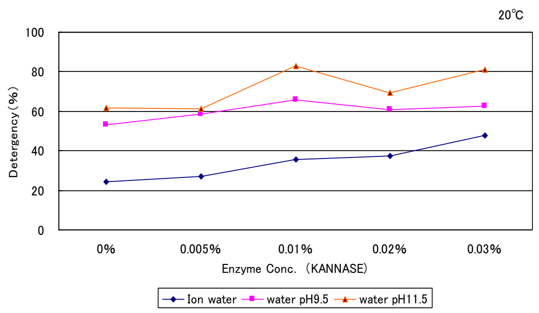


Fig9 Relationship between Detergency and Enzyme Concentration (Kannase) 20℃

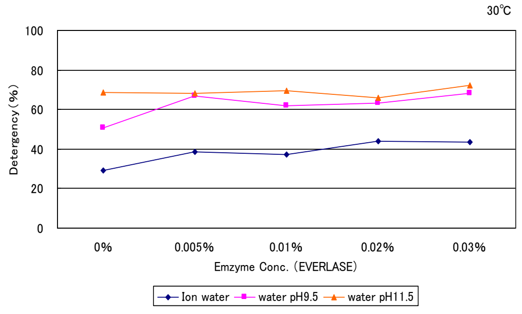


Fig.10 Relationship between Detergency and Enzyme Concentration (Everlase) 30℃

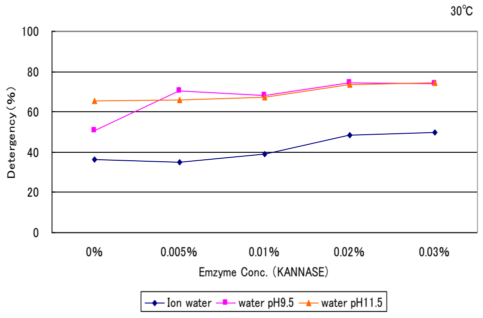


Fig.11 Relationship between Detergency and Enzyme Concentration (Kannase) 30℃

3.5 The effect of the mixture of SDS and enzyme

Under the highly effective condition system where Kannase was added at a concentration of 0.01%, the detergency was compared at various concentrations of SDS. As shown in Fig.12, the most effective result was obtained when alkaline electrolyzed water was used with 4mmol/l of SDS and 0.01% Kannase. The effect seen here is almost to the level with washing using standard amount of commercially available detergents. In order to analyze the mechanism behind this phenomenon, the surface tension was measured as shown in Fig.13.

With the use of alkaline electrolyzed water, the amount of SDS could be reduced to half the amount necessary with tap water. The c.m.c. is thought to have been lowered by the effect of alkaline electrolyzed water.

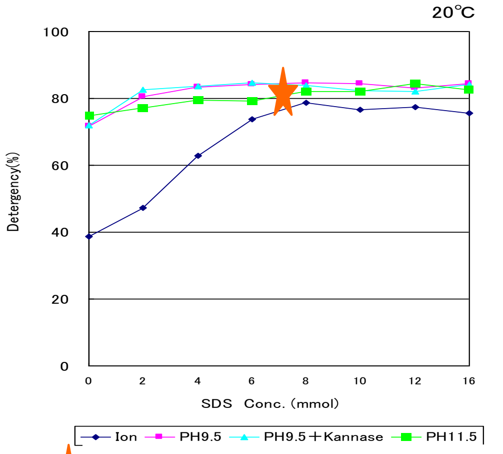


Fig.12 Relationship between Detergency and Concentration of SDS Solution

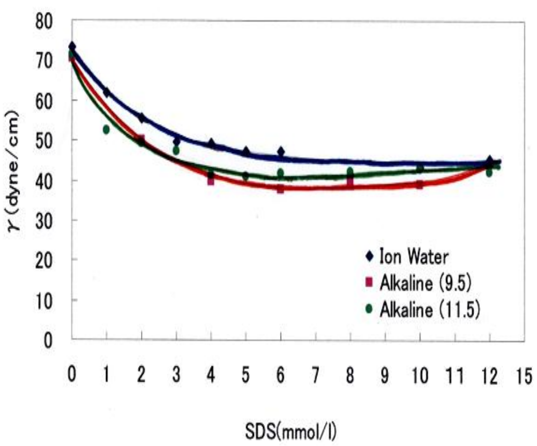


Fig.13 Relationship between Surface Tension and Concentration of SDS Solution

4. Conclusion

We propose a washing method that would reduce the contamination to the water environment. The results were as follows:

1) Washing with the addition of enzyme in alkaline electrolyzed water at a temperature of 30℃ was almost as equally effective as with washing using commercially available detergents.

2) Using alkaline electrolyzed water and enzymes could decrease the amount of SDS to half the amount thus reducing the load to the water environment.

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