International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:5, No:12, 2011

A Study on the Introduction of Wastewater Reuse Facility in Military Barracks by Cost-Benefit Analysis

D. G. Jung, J. B. Lim, J. H. Kim and J. J. Kim

***Abstract*—**The international society focuses on the environment protection and natural energy sources control for the global cooperation against weather change and sustainable growth. The study presents the overview of the water shortage status and the necessity of wastewater reuse facility in military facilities and for the possibility of the introduction, compares the economics by means of cost-benefit analysis. The military features such as the number of users of military barracks and the water use were surveyed by the design principles by facility types, the application method of wastewater reuse facility was selected, the feed water, its application and the volume of reuse volume were defined and the expectation was estimated, confirming the possibility of introducing a wastewater reuse possibility by means of cost-benefit analysis.

***Keywords*—**military barracks, wastewater reuse facility, cost-benefit analysis

I. Introduction

A. Background and Objective of the Study

SINCE the purpose of a public work should seek the public welfare as well as economic profits, it needs a cost-benefit analysis by estimating costs and benefits in consideration of public welfare that is not evaluated in market, that is, benefits [1]. The cost-benefit analysis is a method to determine the economics of a business by comparing cost to benefit, and operating a business efficiently should be based on the accurate cost-benefit analysis. However, like public welfare, the benefit of wastewater reuse facility is difficult to be converted to cost and has vague beneficiaries, so the benefit is usually underestimated or rarely reflected than other fields.

Recently, the international society focuses on the environment protection and natural energy sources control for the global cooperation against weather change and sustainable growth. The Korean government established the 'general measure of water demand control' and framed the policies to control water resources, actively supporting the efforts as '2009 Green Growth National Strategy' and '2010 Low Carbon Green Growth Act' were executed. Meanwhile, the armed forces use1.4%(1,400㎢) of the whole country area and actually use 5.9%(6,000㎢) if including the areas under control of the armed forces such as military facilities and installations [2].

Therefore, that the armed forces controlling 5.9% of the whole country area apply the wastewater reuse facility is necessary according to the social requirements such as the national policy to reserve water resources, measure against weather change and prevention against environmental contamination. In addition, it is necessary to secure the basic circumstance of military facilities as well as to prepare independent measures to overcome, if any, water shortage.

The study, therefore, is intended to present the overview of the water shortage status and the necessity of wastewater reuse facility in military facilities and for the possibility of the introduction, and to compare the economics by means of cost-benefit analysis.

B. Scope and Methodology of the Study

The applications of the wastewater reuse facility in the study limits the scope such as washing/toilet, spraying, gardening and car-wash/cleaning according to the water quality standard of wastewater reclamation and reusing system(Article 20 of the Reinforcement Regulations, the Sewerage Act).

Unlike private works, the public works by the government utilizes 3-y government bond distribution rate(5%), instead of the market interest rates. From the viewpoint that water resources should consider a longer-term than other fields, it is common to apply 6% but the study set 5%, which is 3-y government bond distribution rate as the discount rate.

The persisting period of wastewater reuse facility was set as 15 years in consideration of the proper persisting year of water treatment facility and sludge treatment facility and the replacement interval.

For this, the study surveyed the features of the armed forces such as the number of persons per a military facilities and water usage, based on the design standards by facility types of 2010 and confirmed the possibility of introducing a wastewater reuse possibility by means of cost-benefit analysis by selecting the application method of wastewater reuse facility, defining the feed water, its application and the volume of reuse volume and estimating the expectation.

D. G. Jung is with the Department of Sustainable Architectural Engineering, Hanyang University, Seoul 133-791, Republic of Korea as M.S. Course student (phone: +82-10-9495-4508; fax: +82-2-2296-1583; e-mail: jduckgee@naver.com).

J. B. Lim is with the Department of Sustainable Architectural Engineering, Hanyang University, Seoul 133-791, Republic of Korea as Ph.D. Course student (phone: +82-2-2220-0307; fax: +82-2-2296-1583; e-mail: chiwoovin@nate.com).

J. H. Kim is with the Department of Architectural Engineering, Hanyang University, Seoul 133-791, Republic of Korea as professor (phone: +82-2-2220-0307; fax: +82-2-2296-1583; e-mail: kcr97jhk@hanyang.ac.kr).

J. J. Kim is with the Department of Architectural Engineering, Hanyang University, Seoul 133-791, Republic of Korea as professor (phone: +82-2-2220-0307; fax: +82-2-2296-1583; e-mail: jjkim@hanyang.ac.kr).

II. Theoretical Consideration

A. Water Shortage Status

The rainfall of Korea is about 1,274㎜/y, higher than the world's average rainfall, 973㎜/y. However, due to higher population density and small area, the total rainfall is just 2,755 ㎥/y, only 12.5% of the world's total rainfall, 22,096㎥/y (see Table I).

TABLE I
RAINFALL OF ADVANCED COUNTRIES

Item	Population (1,000)	Area (1,000 ㎢)	Rainfall (㎜/y)	Total rainfall (B㎥/y)	Total rainfall per person (㎥/y)
World	5,892,480	133,816	973	130,203	22,096
Korea	45,991	99	1,274	127	2,755
Japan	125,672	378	1,405	531	4,227
U.S.	208,189	9,364	982	9,191	34,270
U.K.	53,587	245	753	184	3,147
Germany	81,845	357	584	281	2,548
Canada	30,101	9,971	318	3,174	105,437
France	58,433	522	648	348	6,121

※ Handbook of Water Resources in Korea, 1998 [3]

In addition, according to a report of UN PAI, the available water usage per person in Korea was reduced from 3,247㎥ in 1950 to 1,472㎥ in 1995, anticipating 1,258㎥ in 2025. If the available water usage per person is lower than 1,700㎥, the country is classified into a water shortage country, on which Korea is one of water shortage countries.

The water demand of Korea continues to increase as the industry has been developed and the quality of wellness has been increased and according to the water resource long-term plan(2006-2020) of the Ministry of Land, Transport and Maritime Affairs, it is estimated that the country will face 1 billion ㎥ a year of the water shortage in 2020. Then, the plan, showing the estimation of annual water supply, estimates the water shortage of 426 M ㎥ in 2006, 488 M ㎥ in 2011, 978 M ㎥ in 2016 and 1,020 M㎥ in 2020.

Therefore, the wastewater reuse in military facilities is necessary according to the social requirements such as the national policy to reserve water resources, measure against weather change and prevention against environmental contamination. In addition, it is necessary to secure the basic circumstance of military barracks as well as to prepare independent measures to overcome, if any, water shortage.

B. Wastewater Reuse in Military Facilities

Currently, the military facilities do not have any examples of applying wastewater reuse facility to reuse wastewater and secure the water resources and the standards to install them. According to the survey of the ratio of wastewater reuse by mean of case study, it was found that the wastewater reuse ratio of military facilities was just 0.003%, lower than 14% of the general(non-military) facilities(see Table II).

TABLE II
TOTAL WATER USAGE AND REUSE USAGE OF GENERAL/MILITARY FACILITIES

Type	Total water usage(㎥)	Water reuse usage(㎥)	Ratio
General	5,747,390,000	810,000,000	14%
Military	68,619,000	1,934.5	0.003%

※ Target Selection investigation of the Ministry of Defense in Korea

C. Features of Military Wastewater reuse facility

The general applications of wastewater reuse facility include standalone use, complex use and public use. The standalone use is the way available when buildings are distributed; the complex use is available when buildings alike built in a block are densely stood. The last one, public use can be applied to the area around sewage treatment plants [4].

Since the arrangement of the armed forces is planned to be away by and between buildings in consideration of a war, the distance is far. In addition, the facilities have a limited number of facilities using a large volume of water, so the standalone use method can be applied.

Therefore, considering the above-mentioned layout and usage by facility types, the available wastewater reuse facility by unit facility is military barracks, which have large amount of water that can be highly reusable in consideration of the number of users.

D. Cost-Benefit Analysis

The cost-benefit analysis is to analyze the economic viability by comparing the cost and benefit input for the installation and maintenance [5].

The cost-benefit analysis has been adopted to analyze the economics according to the crop type, irrigation and cultivation schemes by means of two indexes, NPV(Financial net present values) and IRR(Financial internal rate of return) to utilize rainfall in semiarid areas such as China [6]. Also, it has been used in terms of the maximization of the social welfare during or after a public work plan [7].

III. Structure Of Wastewater Reuse Facility Of Military Barracks

A. Estimation of the usage by the size of military barracks

The determination of the water usage is the item to estimate the secured feed water and the treated water volume, so it should be reviewed before applying the facility. The methods to determine the water usage by applications plan the usage by referring to estimating the daily water supply, estimating the avg. water supply per hour, estimating the max. water supply per hour and estimating the instantaneous max. water supply as follows.

1) estimating the daily water supply

$$Q_d(l/d) = N(n) \times q_d(l/n \cdot d) + Q_c(l/d) \quad (1)$$

Q_d : Daily water supply N: No. of users in a building

q_d : Daily water supplied per person,

Q_c : Qty. supplied of divices

2) estimating the avg. water supply per hour

$$Q_h(l/d) = \frac{Q_d(l/d)}{T(h)} \quad (2)$$

Q_h: Avg. water supply per hour, T:Avg. duration of usage

3) estimating the max. water supply per hour

$$Q_m(l/h) = (1.5 \sim 2.0) \times Q_h(l/h) \quad (3)$$

Q_m : Avg. water supply per hour

4) estimating the instantaneous max. water supply

$$Q_n(l/d) = \frac{(3 \sim 4) \times Q_h(l/h)}{60} \quad (4)$$

Q_n : Instantaneous max. water supply

The study surveyed the features of the armed forces such as the number of persons per a military barracks and water usage, based on the design standards by facility types of 2010. As seen in table III, the water usage was estimated. The number of users and usage by sizes of military barracks were 150 persons and 40 ㎥/d of water usage for a company, 450 persons and 125㎥/d of water usage for a battalion and 1,000 persons and 280㎥/d of water usage for a regiment.

TABLE III
NO. OF USERS AND WATER USAGE BY SIZES OF MILITARY BARRACKS

Type	No. of users	Water usage
Company	150	40㎥/d
Battalion	450	125㎥/d
Regiment	1,000	280㎥/d

B. Selection of feed water for wastewater reuse facility

As seen in table IV, the results of measuring water quality items show that the water contamination for washing/bathing was lower than other water supply, which may have simplified water resource reuse system, cost saving and higher adaptation when selecting feed water. Therefore, the contamination level of washing/bathing is lower than other water supply. Hence, the low contaminated feed water may be more beneficial such as simplified facilities and cost saving, so the water supply for washing/bathing should be selected reasonably.

TABLE IV
WATER QUALITY BY APPLICATIONS

Type		COD cr (mg/L)	BOD (mg/L)	SS (mg/L)	ABS (mg/L)	pH	NH4-N (mg/L)
Washing	Summer	106	49	41	2.8	7.6	-
	Winter	155	80	101	2.0	6.5	-
Bathing		-	48.8	15.4	0.2	-	-
Kitchen	Summer	732	480	218	54.4	5.4	-
	Winter	844	418	296	21.7	6.0	-
Toilet	Summer	597	197	170	8.7	8.7	91
	Winter	719	328	444	0.7	8.6	141

※ Guideline of wastewater reclamation and reusing system, MMTM, 1994

C. Application/usage of wastewater reuse facility

The applications of wastewater reuse water contain cleaning buildings, cleaning toilets, gardening, supplying it to artifacts, cooling water or boiler water. However, cooling/boiler water accounts for a small ratio of the total volume and is limited by seasons, making it impossible to use it all over the year.

In addition, according to the water quality standards of wastewater reclamation and reusing system(Article 20 of the Reinforcement Regulations, the Sewerage Act), the standards of water quality by applications are described as the water for cleaning/toilet, spraying, gardening or car-washing/cleaning.

Therefore, since the military barracks have a lot of water for toilet and are easy to secure it, the facility is available. Table □ shows the application and usage by sizes.

TABLE V
APPLICATION/WATER USAGE BY SIZES OF MILITARY BARRACKS

Type	Water usage	Water reuse usage (for toilet)	Water usage (for drinking/shower)
Company	40㎥/d	20㎥/d	20㎥/d
Battalion	125㎥/d	45㎥/d	80㎥/d
Regiment	280㎥/d	85㎥/d	195㎥/d

D. Selecting the treatment method of wastewater reuse facility

The wastewater reuse facility is divided by rainfall utilization facility and wastewater reclamation and reusing system and the treatment method was selected with the following reason.

The rainfall utilization facility, as seen in Table VI, selected the rainfall treatment method suitable for microorganism sterilization and anaerobic prevention by comparing the advanced rainfall treatment to chlorine chemical treatment.

The method applied to wastewater reclamation and reusing system was membrane separation + advanced oxidization process, which can save cost, be easy to maintain and have high floating matters elimination/sterilization.

The advanced oxidization technique of membrane separation + advanced oxidization process forms OH radicals by using ozone, eliminating underwater colon bacillus, virus and non-biodegradable COD, color and odor. Ozone and ultraviolet

photolysis forms peroxide and the formed peroxide and ultraviolet ray creates OH radicals, improving water quality hugely (see Table VII).

TABLE VI
COMPARISON OF RAINFALL TREATMENT TECHNIQUES

Type	Advanced Process	Chlorine Chemical
Components	-UV lamp -Floating device -Air supplying device	-Chlorine supplier -Neutralizer(Line Mixer)
Principles	Sterilizing microorganisms by UV from UV lamps and supplying air by air supplying device, preventing anaerobic status	Improving piping/reservoir structure(chlorine mixing). Chlorine supplied sterilizes microorganisms in water, resolves chemical, which is continuously supplied by metering pump. At the moment, a facility to control the accurate concentration of chlorine
Advantages	-Strong ultraviolet ray sterilization kills microorganisms including virus -Strong adaptation to fluctuating flow and water quality -Low power consumption/maintenance cost -Safe due to little chemical side effect -Available anaerobic prevention by supplying air continuously(DO supply) -Free of maintenance due to simplification -Odorless and no residues after sterilization -Excellent response to frequently changing water level	-Simple facility to supply a chemical -Effective sterilization to bacteria -Using chlorine easy to purchase and inexpensive
Disadvantages	-Installation is expensive than chemical technique -Needs of electricity conduit/air supply piping -Annually replacing lamps(once a year)	-Severe odor of disinfectant -Occurrence of secondary contaminant(trihalomethane) -Difficult and expensive maintenance -Weak response to fluctuating flow/water level -Long contact time(15~30mins)

※ Introduction of rainfall use and wastewater reclamation facility in army facility, 2010 [8]

Therefore, the applicable method was selected by comparing the treatment methods and table VIII shows the applications by methods.

TABLE VII
COMPARISON OF WASTEWATER RECLAMATION AND REUSING SYSTEM

Type	Advanced Process	Chlorine Chemcial
Principles	Performing the separation organic matters by passing through filtration membrane submerged and sterilizing non-biodegradable materials through the process, maximizing the process efficiency	Filling the contact matters in an aeration tank, maximizing the proliferation of anaerobic/aerotropic microorganisms, assimilating, dissimilating and sel-oxidizing biodegradable matters
Advantages	-Utilizing organic matters in de-nitrification to the max and suitable for low concentration -50-70% of the existing process area(saving the budget) -Saving the electricity due to no need of sedimentation/filtration(saving energy) -Reduced excessive sludge saves the cost of final process of wastes -complete elimination of pathogenic bacteria and use of domestic separation membrane saves the cost and provides a complete post treatment -Higher floating material elimination and complete removal of colon bacillus	-Long lives of sludge residues -Higher biochemical stability -Less surplus sludge created -Special response in low concentration and low load
Dis-advantages	-Regular cleaning of separation membrane (once per 6mths)	-Difficult to regulate the volume of microorganism attached on contact material -Need to return from sediment to air tank -Inflow load and water quality specially controlled

※ Introduction of rainfall use and wastewater reclamation facility in army facility, 2010 [8]

TABLE VIII
SELECTION OF AVAILABLE METHODS BY APPLICATION OF WASTEWATER REUSE FACILITY IN MILITARY BARRACKS

Type	Available Methods
Rainfall use facility	Rainfall advanced process
Wastewater reclamation and reusing system	membrane separation + advanced oxidization process

IV. COST-BENEFIT ANALYSIS OF WASTEWATER REUSE FACILITY IN MILITARY BARRACKS

A. Investment

It was estimated by dividing it into facility installation cost and operation cost by sizes of military barracks. Table IX shows the investment amount of water supply facility when wastewater reuse facility is not installed. Table X shows the investment when the wastewater reuse facility using rainfall is

installed. Table XI shows the investment when the wastewater reuse facility using wastewater reclamation and reusing system is installed.

TABLE IX
EXPENSES OF WATER SUPPLY/SEWAGE FACILITY
(UNIT :1,000WON)

Type		Company (40㎥/d)	Battalion (125㎥/d)	Regiment (280㎥/d)
Installation	Device	32,122	63,453	133,626
	Piping	16,700	67,000	100,000
	Electricity	2,000	2,000	2,000
	Sub-total	50,822	132,453	235,626
Operation	Electricity	13,493	50,598	68,997
	Maintenance	5,251	10,373	21,845
	Sub-total	18,744	60,971	90,842
Total		69,566	193,424	326,468

※ Operating expense is the sum for persisting period(15 yrs), discount rate: 5%

TABLE X
EXPENSE OF WASTEWATER REUSE FACILITY(RAINFALL)
(UNIT :1,000WON)

Type		Company (20㎥/d)	Battalion (45㎥/d)	Regiment (85㎥/d)
Installation	Device	84,800	90,000	99,800
	Piping	19,000	75,760	113,640
	Machine room	40,229	90,515	170,973
	Electricity	3,000	3,500	3,500
	Sub-total	147,029	259,775	387,913
Operation	Electricity	33,242	57,388	71,076
	Maintenance	16,784	16,784	16,784
	Sub-total	50,026	74,172	87,860
Total		197,055	333,947	475,773

※ Operating expense is the sum for persisting period(15 yrs), discount rate: 5%

TABLE XI
EXPENSE OF WASTEWATER RUSE FACILITY(WASTEWATER RECLAMATION AND REUSING SYSTEM)
(UNIT :1,000WON)

Type		Company (20㎥/d)	Battalion (45㎥/d)	Regiment (85㎥/d)
Installation	Device	130,800	209,000	266,800
	Piping	19,000	75,760	113,640
	Machine room	49,448	111,258	210,154
	Electricity	3,000	3,500	3,500
	Sub-total	202,248	399,518	594,094
Operation	Electricity	64,195	123,157	165,169
	Maintenance	16,566	26,702	49,262
	Sub-total	80,761	149,859	214,431
Total		283,009	549,377	808,525

※ Operating expense is the sum for persisting period(15 yrs), discount rate: 5%

B. Private Benefit

The private benefit according to the application of wastewater reuse facility in military barracks can be estimated as the saved amount of water supply/sewage. Table XII shows the private benefit when the wastewater reuse facility using rainfall is installed. Table XIII shows the private benefit when the wastewater reuse facility using wastewater reclamation and reusing system is installed.

TABLE XII
EXPENSE OF WASTEWATER REUSE FACILITY(RAINFALL) PRIVATE BENEFIT
(UNIT: 1,000WON/YEAR)

Size		Water supply rate (①)	Rate for using the wastewater (②)	Private profit (① - ②)	
COMPANY	Water supply	15,476	12,381	3,095	3,095
	Sewage	2,993	2,993	-	
BATTALION	Water supply	48,363	44,494	3,869	3,869
	Sewage	9,353	9,353	-	
Regiment	Water supply	108,332	100,594	7,738	7,738
	Sewage	20,951	20,951	-	

TABLE XIII
EXPENSE OF WASTEWATER RUSE FACILITY(WASTEWATER RECLAMATION AND REUSING SYSTEM) PRIVATE BENEFIT
(UNIT: 1,000WON/YEAR)

Size		Water supply rate	reclamation & reuse system	Private profit	
COMPANY	Water supply	15,476	7,738	7,738	9,235
	Sewage	2,993	1,496	1,497	
BATTALION	Water supply	48,363	30,952	17,411	20,778
	Sewage	9,353	5,986	3,367	
Regiment	Water supply	108,332	75,445	32,887	39,247
	Sewage	20,951	14,591	6,360	

C. Social Benefit

The effects and other benefits from the application of wastewater reuse facility contain volumetric benefit relating to water resource, water quality and environmental contaminant reduction and it also contains the benefit relating to national defense/military facility and the national/social effect.

The volumetric benefit contains reduction of water pipe construction, benefit from reduced construction around multipurpose dam, reduction of water supply facility construction and reduced water demand in dry seasons.

The water quality benefit contains the reduction of sewage pipe construction, reduced sewage treatment plant construction, reduced water source protection area and reduced damage on humans due to reduced water quality deterioration.

The benefit from reduced environmental contaminants contains the benefit from natural resource reservation, benefit from reduced water quality deterioration, benefit from reduced ecosystem destruction, benefit from reduced sewage treatment plant, benefit from surroundings' environment improvement and benefit from CO2 reduction due to reduced power consumption used to produce water supply.

The benefit from national defense/military facility contains the benefit from the effect achieving military policies, benefit from improving the military barracks, benefit from reinforced fighting power by stably supplying water and benefit from improved image of green troops.

The social/national benefit contains the benefit from supplying water stably, benefit from better quality of welfare by improving the whole country's environment and benefit from corresponding to weather change and reduced environmental load (see Table X IV).

TABLE X IV
SOCIAL BENEFIT OF USING WASTEWATER REUSE FACILITY IN MILITARY BARRACKS

Type		Applied technique
Benefit from using water resource	Volumetric	- benefit from reduced construction around multipurpose dam - reduction of water supply facility construction and reduced water demand in dry seasons
	Water quality	- reduction of sewage pipe construction - reduced water source protection area - reduced damage on humans due to reduced water quality deterioration
	Reduction of environmental contamination	-Natural resource reservation from reduced dam construction - reduced water quality deterioration and reduced ecosystem destruction - CO2 reduction due to reduced power consumption used to produce water supply
Benefit from military/defense facilities		- effect achieving military policies - improving the military barracks - reinforced fighting power by stably supplying water - improved image of green troops
National/social benefits		- Benefit from improving the whole country's policies - Benefit from the quality of wellness by environmental improvement - corresponding to weather change and reduced environmental load

The study estimated the benefit as prevent value by partially utilizing the social benefit of the existing analyses(Ministry of Environment, 1999) as seen in table X V, by considering that some benefit items may be limited to measure and some may not be measured.

TABLE X V
SOCIAL BENEFIT FROM WASTEWATER REUSE FACILITY IN MILITARY BARRACKS
(UNIT :1,000WON)

Type	Benefit
Production cost of water supply/sewage	667.0
Realistic general cost of water supply/sewage	10.9
Saving the cost by tones of water in a dam	12.85
Reduced cost to protect surroundings of a dam and water source areas	1.632
Reduced administration cost around water source	116.27
Saved environmental cost	5.05
Total	813.702

※ Guideline to expand wastewater reclamation and reusing system, Ministry of Environment, 1999

The NPV of social benefits, as seen in table X VI, is calculated by dividing the price level of the present by the price level at the reference point(1999) and multiplying the results by the social benefits as follows.

TABLE X VI
PRODUCER PRICE INDEX BY YEARS(ELECTRICITY/WATER/CITY GAS)

Year	PPI	Year	PPI
1997	4.7	2004	0.9
1998	14.1	2005	1.2
1999	0.4	2006	7.3
2000	8.6	2007	3.6
2001	8.4	2008	4.2
2002	-3.2	2009	6.7
2003	3	2010	4.0

※ Statistics Korea, 2011

As a result, the NVP from saving water resource was 1,253won/y as table X VII.

TABLE X VII
NPV OF SOCIAL BENEFIT FROM INTRODUCING WASTEWATER REUSE FACILITY TO MILITARY BARRACKS
(UNIT: WON/㎥)

Type	1999	2010
Production cost of water supply/sewage	667.0	1027.53
Realistic general cost of water supply/sewage	10.9	16.79
Saving the cost by tones of water in a dam	12.85	19.80
Reduced cost to protect surroundings of a dam and water source areas	1.632	2.51
Reduced administration cost around water source	116.27	179.12
Saved environmental cost	5.05	7.78
Total	813.702	1,252.53

D.Decision making by analysis

The analysis techniques in the study compare the economic appropriateness of wastewater reuse facility by estimating PP, B/C ratio, NPV and IRR.

As seen in table X VIII, the economic analysis considering both private and social benefits shows that the B/C ratio in military barracks of a regiment was 1 and higher, NPV is positive, the payback period would be 8.8 years.

TABLE X VIII
COST-BENEFIT ANALYSIS - EXPENSE OF WASTEWATER REUSE FACILITY(RAINFALL)
(UNIT: 1,000WON)

Type	Company (20㎥/d)	Battalion (45㎥/d)	Regiment (85㎥/d)
Input expense	127,489	140,523	149,305
Private benefit	33,731	42,167	84,334
Social benefit	39,878	49,839	99,690
Payback period	None	None	8.8 years
B/C Ratio	0.58	0.65	1.23
NPV	-54,652	-50,379	24,720
IRR(%)	-	-	7.47

※ Applying 15 yrs of persisting period and 5% discount

As in table X IX, the results of economic analysis considering both private and social benefits of wastewater reuse facility(wastewater reclamation and reusing

system)shows that the B/C ratio in military barracks for a regiment and a battalion was 1 and higher, NPV was positive and the payback period would be 8.6 and 6.2 yrs, respectively.

TABLE X IX
COST-BENEFIT ANALSIS - EXPENSE OF WASTEWATER REUSE FACILITY(WASTEWATER RECLAMATION AND REUSING SYSTEM)
(UNIT: 1,000WON)

Type	Company (20㎥/d)	Battalion (45㎥/d)	Regiment (85㎥/d)
Input expense	213,443	355,953	482,057
Private benefit	100,649	226,452	427,739
Social benefit	99,690	224,305	423,674
Payback period	None	8.6 years	6.2 years
B/C Ratio	0.94	1.27	1.77
NPV	-21.566	69,847	313.155
IRR(%)	3.39	7.91	13.91

※ Applying 15 yrs of persisting period and 5% discount

In a size of military barracks for a company, either rainfall or wastewater reclamation and reusing system was selectable but as seen in Table X VIII and X IX, it was found that the military barracks for a battalion and more would better apply wastewater reuse facility(wastewater reclamation and reusing system).

V. CONCLUSION

The study selected a method to introduce wastewater reuse facility in military barracks by selecting the application method of wastewater reuse facility from the features of military facilities, defining the feed water and applications, analyzing the usage by sizes, on which the initial investment and private/social benefits have been deprived, performing the cost-benefit analysis.

Applying wastewater reuse facilities is to prepare a proper measure for corresponding to weather change, environmental contamination prevention, meeting the green growth policies, improving the military barracks and overcoming resources supply in case of emergency and is to be actively executed in terms of saving defense budget.

The study compares the economics by means of cost-benefit analysis to introduce wastewater reuse facility in military barracks. In the future, a case study to compare the investment to the expectation is to be performed.

ACKNOWLEDGMENT

This work was supported by the Korean Institute of Construction & Transportation Technology Evaluation and Planning (KICTEP). (Grant No: 06-Unified & Advanced Construction Technology Program-D01)

REFERENCES

[1] J. D. Kim, M. K. Cho, "An Economic Feasibility Analysis of A Public Project Using Contingent Valuation method," in *Environmental and Resource Economics Review*, vol. 14, no. 1, March 2005, pp. 101–134.
[2] E. S. Yeom, "A Research Saving Water in Military by Reusing Water System," in *Industry and Technology, Dongguk University, Graduate School of Environmental Studies Thesis*, 2002.
[3] W. G. Kim, H. S. Cha, D. I. Kim, "Handbook of Water Resources in Korea", in *Korea Water Resources Corporation*, 1998.
[4] H. S. Jung, "Economic analysis of wastewater reuse system", in *Korea Environmental Technology Research Institute*, 1996.
[5] J. S. Mun, M. Y. Han, "An Economical analysis of the rainwater harvesting(RWH) system at the S residential and commercial complex", in *The Architectural Institute of Korea*, vol. 25, no. 12, 2009, pp. 173–181.
[6] T. Yuan, L. Fengmin, L. Puhai, "Economic analysis of rainwater harvesting and irrigation methods, with an example from China", in *Agricultural Water Management*, vol. 60, no. 3, 2003, pp. 217–226.
[7] M. P. Sim, "Introduction to economic analysis of water resources (4)", in *Magazine of Korea Water Resources Association*, vol. 33, no. 6, 2000, pp. 114–123.
[8] "Introduction of rainfall use and wastewater reclamation facility in army facility", in *Ministry of National Defense*, 2010.