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ENVIRONMENTAL IMPACT ASSESSMENT OF WASTEWATER TREATMENT SYSTEM BY LCA TECHNIQUE

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Abstract

Social systems and production systems in modern society are closely related over a wide field, and therefore complicated. Various environmental problems exist in the social structure. It is necessary to analyze the effect from various sides for the solution of such problems. Especially, the load to the environment may be made to increase in the integrated network infrastructure, if consideration from the stage of planning and design to environmental harmony is not sufficiently carried out. In this study, the viewpoint of life cycle of facilities until disposal from the design, and environmental effects of disposal, operation and construction in a social foundation utility was determined quantitatively. Considering this background, as one step in solving these environmental problems the Life Cycle Assessment (LCA) technique for environmental impact assessment will be examined in this research. As a result, the LCA technique is shown in application to social utilities represented as a waste water treatment system which is possible and, in addition, a large scale environmental problem to be an object of LCA is possible, that quantitative evaluation can be conducted, and that it is a very effective environmental impact assessment technique.

1. INTRODUCTION

Recently, a methodology called LCA (life cycle assessment) has gained notice as an environmental impact assessment technique. LCA technique attempts to look at and evaluate the environmental impact of a product through that product's entire life, from raw materials and energy use, through production, use, and disposal.

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Especially, it seems to be effective for the case in which the environmental problem of different space and time scale is handled, and case in which the environment cost in the plan and design is optimized. The framework has been composed of 4 stages: ① the interpretation of purpose and clarification, ② inventory analysis, ⑧ effect evaluation, and ④ result of range.

To begin with, the interpretation of purpose and clarification is to concretely show the purpose of the LCA, and to set the object range in proportion to the purpose. Next, the inventory analysis analyzes the examination object material in detail in the life cycle, and input in the life cycle and preparation of the output table become a last result. In addition, the effect evaluation analyzes situation and environmental effect of the environmental loading on the basis of input and output analysis, and the evaluation is carried out. Finally, the result will be understood. In comparison with improvement goal set in result and analysis at the beginning of the evaluation, improvement and improvement of the system are examined. It necessarily responds, the result is fed back in each stage. The LCA technique is recently spreading, therefore, the methodology is hard to be called sufficiently established. However, various guidelines have been advocated with the height of the worldwide interest on the LCA in order to give consistency and universality to the LCA by multiple organizations mainly in Europe and America. It is the stage at which the standardization is advanced in ISO. The comparison between analytical results by the LCA technique becomes easy, if the uniform standard based on such international mutual agreement is possible, and it will be also connected for the establishment of the methodology in consequence.

From the viewpoint of life cycle until disposal from system design, this study evaluated the environmental effect of the construction of social utilities. That is to say, this study quantitatively compared the load of both systems to the environment using the LCA technique for usual tertiary treatment systems and new wastewater treatment systems using hydroponics.

2. RESEARCH CONTENTS AND METHODS

(1) Wastewater treatment system

1) Wastewater treatment system at Huis Ten Bosch (HTB)

The wastewater treatment system under evaluation is the sewerage disposing facility at HTB, theme park in the Huis Ten Bosch town in Sasebo City, Nagasaki Prefecture. Figure. 1 shows the geographical information of the focal area.

Figure. 2 shows the information of treatment system. The examined process is the tertiary treatment process of this facility, and it is catalytic oxidation processing, then activated sludge processing, and then to the limen outside filtration processing. Quantity of treated water by this system was made to be average quantity of treated water 3400 m^3 /day at HTB.

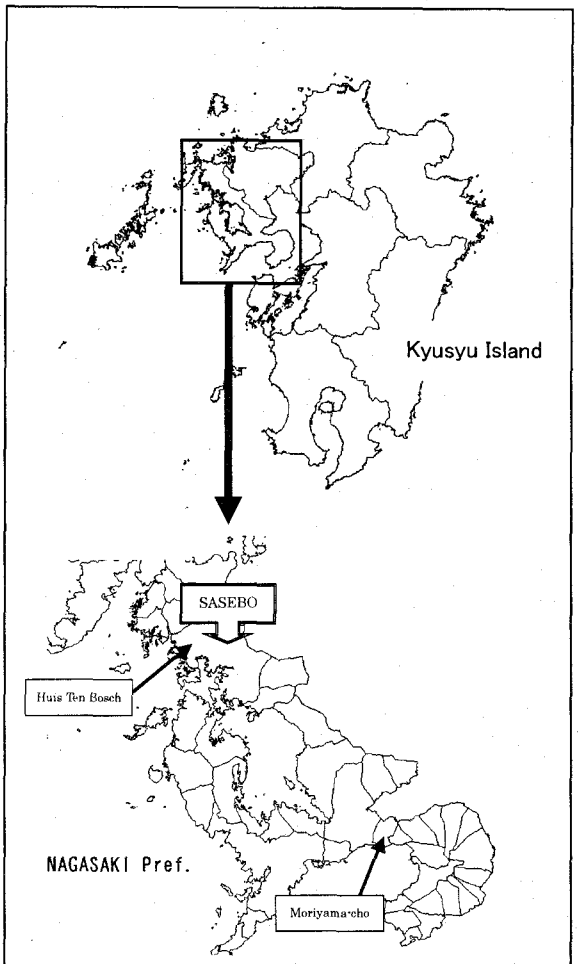

Fig.1 The geographical information of the focal area

2) Wastewater treatment system using hydroponics

The evaluation object system was made to be the purification system using hydroponics in the Kitatakaki District Moriyama town in Nagasaki Prefecture, where the Nagasaki prefectural office carries out research. Figure. 1 shows the geographical information of the focal area. However, the wastewater treatment system was assumed referring to the research result, because this system was an experimental plant. Figure. 3 shows the information of treatment system. Concretely, it was designed in order to become a throughput which is

equivalent to quantity of treated water (3,400 m^3/day) of waste water treatment system at HTB, and the environmental effect was compared.

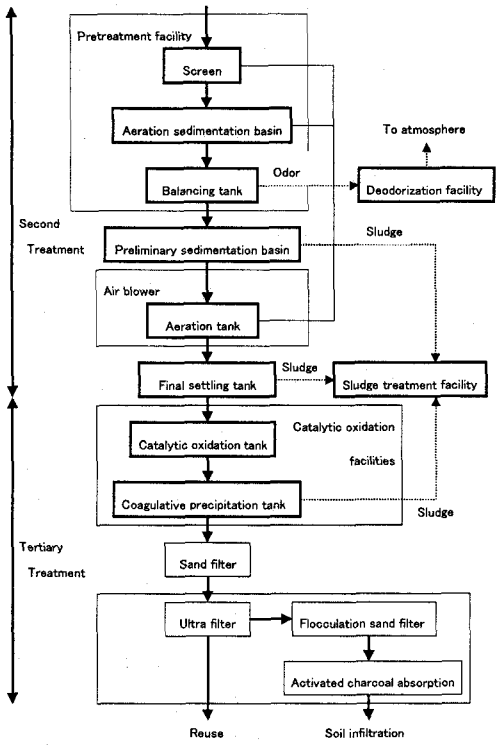

Fig.2 the information of treatment system in HTB

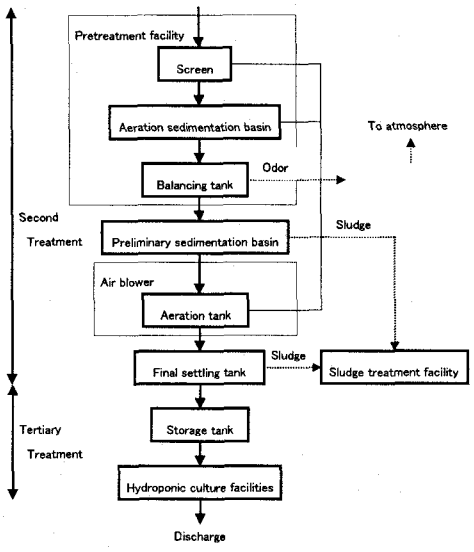

Fig.3 the information of treatment system in Moriyama town.

(2) Inventory analytical method

In this study, we attempted to look at and evaluate environmental impact of the tertiary treatment facilities through that facility's entire life, from construction, through use and disposal. However, the item of use and disposal assumed the condition in the inventory analysis, because two facilities of the evaluation object are being used as an effluent treatment facility at present. The use period of the concrete was made 30 years. The use of chemicals and electric power was figured out from the year average use from until now results, multiplied for the use period. The discharge in the disposal was calculated on the basis of the construction quantity in the construction, and it was also

similarly calculated on the disposal of the waste wood.

The inventory analysis fundamentally used the primary unit of Tsurumaki. On an item without a primary unit, the inventory analysis was carried out by the stacking method using NIRE- LCA Ver.2.1.

Table. 1 List and correspondence policy on the environmental loading item

environmental category	environmental loading item	unit	Effect with the waste water treatmen	Correspondence policy
Global warming	CO_2	kg−C	There is the discharge of CO2 in the exhaust gas as a result of the energy-consumption. And, there is the discharge as a reaction in the process stage.	○
Ozone layer depletion	CFC	kg−CFC	The discharge of the flon is limited to not direct and indirect load.	It is made to be the object outside, because it is difficult to be regarded as a direct impact.
Acidification	SO_X NO_X	kg− SO_2 kg− NO_2	There is the exhaust gas with the energy-consumption.	○
Air pollution	SO_X NO_X	kg− SO_2 kg− NO_2	There is the exhaust gas with the energy-consumption.	○
Eutrophication	COD T−N T−P	kg− COD kg− N kg− P	There is the discharge of the treated water. However, it is possible to make to be the effect of the environmental loading loss by the processing action in this case.	○
Water pollution	BOD COD	kg− BOD kg− COD	There is the discharge of the treated water. However, it is possible to make to be the effect of the environmental loading loss by the processing action in this case.	○
Consumption of resources	Consumption heat capacity	Mcal	The power plant such as the blower exists in great numbers, and they consumed energy and treated the waste water.	○
Waste discharge	Reclamation waste	t	There is the discharge as a disposal of excess mud.	○

（3） Selection of the environmental category

With existing literature and cases on the LCA, the single category of carbon dioxide emission and energy consumption occupies the most part on the environment category with the object of evaluation. There are small numbers on the case of the LCA in which multiple environment categories become an object. In short, the selection of the environment category seems to have not sufficiently been discussed until now. From until now research results, the environment category as an object contained

dimensional dispersion, and it became clear that unifying comparison was not possible. From the above fact, the environment category should attempt dimensional unification in this study. On the basis of the time-related background, unified dimension was divided and was expressed into 5 stages of 1) Driving force: D, 2) Pressure : P, 3) State : S, 4) Effect : E, 5) Response : R. Environment category grouped in the 5 stages correlates with adjoining environment category. In the base of the dimensional linkage, the global environmental problem has been formed. In this dimensional consideration, it is necessary to show criteria of each dimension. Thus, E was regarded as an effect on the object that maintains and should maintain it as an environment. Especially, the goal that the environment is maintained was made to be "human health", "ecosystem" and "resources" where the worldwide consensus approaches sustainable development. In addition, the concrete situation of E was defined as S. As a result, the objects in this study are the environmental category such as global warming, ozone layer depletion, acidification, air pollution, eutrophication, water pollution, consumption of resources and waste discharge.

The quantification of the environmental effect was evaluated in search of the size of the effect every object environment category. In this study, the weighting coefficient was set for each environmental loading item, as is shown in table. 1, since multiple environmental loading items exist in the identical category, and integration was attempted. To begin with, each environmental loading quantity of COD, T-N and T-P (the environmental loading item) is calculated, when it explains referring to the eutrophication of environment category which table. 1 showed. Next, it is integrated by the introduction of the weighting coefficient in the calculation formula which table. 2 showed, and it has been evaluated as eutrophication index (LEU). The following were also shown in table. 2 : Object of the evaluation and summary of the decision technique of the index-value.

Table. 2 Objects of the evaluation and summary of the decision technique of the index-value

environmental category	environmental loading item	unit	Effect with the waste water treatment	Quotation, etc.
Global warming	Warming index, GWP (CO_2= 1)	t−C	$L_{GW}=L_{CO2}+35L_{CH4}+260L_{N2O}$	IPCC
Acidification	Acidification index. AP (SO_2= 1)	t− SO_2	$L_{AC}=L_{SOX}+0.7L_{NOX}$	Univ. of Liden
Air pollution	Reciprocal of the emission standard	t− SO_2	$L_{AC}=L_{SOX}+1.112L_{NOX}$	Environmental standard
Eutrophication	Eutrophication index NP (PO_4^{3-})	t− PO_4	$L_{EU}=0.0221L_{COD}+0.42L_{T-N}+3.06L_{T-P}$	Univ. of Liden
Water pollution	Reciprocal of the emission standard	t− OD	−	Environmental standard
Consumption of resources	Higher order heat quantity of the fuel	Mcal	−	−
Waste discharge	Reclamation waste	t−DPW	−	−

3. RESULTS AND DISCUSSION

(1) Result of inventory analysis

The results of inventory analysis of two wastewater treatment systems are listed in Table. 3 and Table. 4.

In other environmental loading items except for land fill waste, the environmental loading in the use of HTB of the system increases. That is to say, the proportion of the environmental loading in the use was about 65~90%, and the proportion in the construction was 10−25%, and the proportion in the disposal was 5 −10%. In the meantime, the environmental loading in use increases on the system of the hydroponics in all environmental loading items. However, this proportion was lower in comparison with the case of HTB a little, and it is about 50−80%. There is no use of chemicals in the system using hydroponics. However, the proportion of environmental loading item that affects to the hydrosphere rises as well as HTB. And, the proportion of the environmental loading in the construction decreases, since the construction material quantity is little.

Table. 3 Result of inventory analysis of wastewater treatment system in HTB

		Energy	CO_2	SO_x	NO_x	Reclamation waste	COD	T−N	T−P	BOD
		Mcal	kg−C	g−SO_2	g−NO_2	kg	g−COD	g−N	g−P	g-BOD
In the construction	Construction work	1809498	153866	466096	942091	96279	141269	117874	12597	131371
	Civil engineering works	27413745	2798357	5007171	9940384	568165	357593	847717	81659	1294153
	Machine construction	598371	44619	99018	150376	5606	9995	16175	1458	24256
	Electrical work	128119	9570	28465	43972	1527	9469	7113	1025	9618
	Subtotal	29949733	3006412	5600750	11076823	671577	518326	988879	96739	1459398
In the use	Chemicals	43457004	1324318	5454698	7919484	70459	4929689	4297978	186352	3240768
	Use electric power	183165641	9000769	20101717	22501922	202517	452289	378782	49504	391533
	The maintenance	2809249	305295	480703	1030549	34248	58908	89192	8332	119987
	Subtotal	229431894	10630382	26037118	31451955	307224	5440886	4765952	244188	3752288
In the disposal		6889754	710815	2228125	3551242	3639864	322082	296506	31742	404704
Total		266271381	14347609	33865993	46080020	4618665	6281294	6051337	372669	5616390

(2) The calculation result on the quantification of the environmental effect

The result of comparing environmental loading quantity of both systems was shown in Figure. 4. From this figure, the difference of both systems is clear, and the environmental loading quantity of the system using hydroponics is shown to be less. Especially, the system using hydroponic culture system becomes about 10% of the Huis Ten Bosch' environmental loading quantity in resources consumption and global warming. In acidification and air pollution, the system by the hydroponic culture system becomes about 70% of the load in Huis Ten Bosch, and the proportion is bigger than other environment categories. From this fact, under this premise, it was indicated that the environmental loading of the wastewater treatment system by the hydroponics was lower than environmental loading of the Huis Ten Bosch' waste water treatment system.

Table. 4 Result of inventory analysis of wastewater treatment system at hydroponics

		Energy	CO_2	SO_x	NO_x	Reclamation waste	COD	T−N	T−P	BOD
		Mcal	kg−C	g−SO_2	g−NO_2	kg	g−COD	g−N	g−P	g-BOD
In the construction	Construction work	878432	62105	164079	243334	11275	86340	85087	4694	80714
	Civil engineering works	1063360	179100	166764	573089	15236	16167	34006	2309	34977
	Machine construction	90170	7567	17179	27307	1128	1128	2773	282	4771
	Electrical work	19466	1452	4387	6766	236	1524	1144	165	1524
	Subtotal	2051428	250224	352409	850496	27875	105159	123010	7450	121986
In the use	Use electric power	16952364	833040	1860456	2082600	18743	41860	35057	4582	36237
	The maintenance	1186561	53527	223400	279304	14364	241621	212701	9606	167510
	Subtotal	18138925	886567	2083856	2361904	33107	283481	247758	14188	203747
In the disposal		1300761	217576	950888	1332916	14486	118415	117106	8703	111549
Total		21491114	1354367	3387153	4545316	75468	507055	487874	30341	437282

Next evaluation was carried out from the viewpoint of environmental harmony, and it calculated environmental loading quantity per aquatic contaminant removal quantity. The comparison of environmental loading quantity per nitrogen and phosphorus elimination quantity. were shown in Figure. 5 and Figure. 6. Judging from both figures, on the removal of the phosphorus, there are many removal quantities of the system in Huis Ten Bosch than the removal quantity of the system of the hydroponics. On environmental loading quantity per removal quantity, the load of the system by the hydroponics is smaller than the load of the Huis Ten Bosch' system. On the nitrogen elimination, the removal quantity of the system in Huis Ten Bosch is more abounding than removal quantity of the hydroponics system, and it becomes about double. The system of the hydroponics gives large effect for acidification and air pollution. This fact seems to be the effect by the construction, maintenance and disposal, since the installation of the large-scale plastic greenhouse becomes a condition in the system of the hydroponics. And, it seem that the setting of the displacement in the system of the hydroponics was made to be the unreal

displacement. However, the system in Huis Ten Bosch shows the result over the

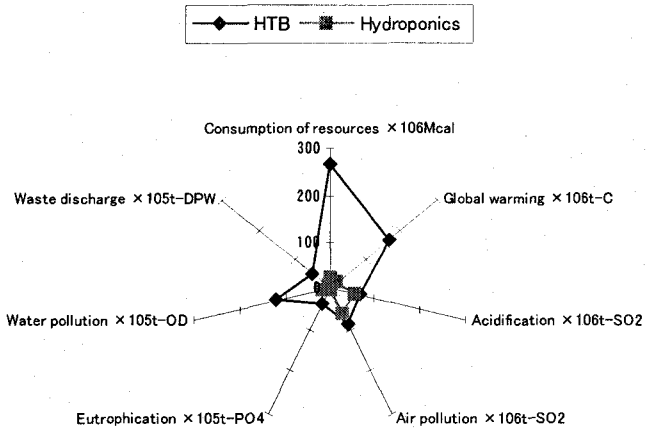

Fig.4 The result of comparing environmental loading quantity of both systems

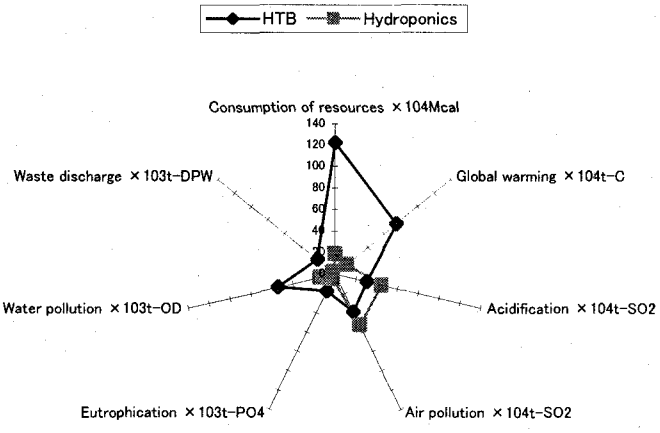

Fig.5 The comparison of environmental loading quantity per nitrogen elimination quantity.

standard on the water purification, when it is synthetically judged. The effect to each environment category is big for the system in Huis Ten Bosch, when the effect from the life cycle environment is evaluated. And, the system of the hydroponics seems to be more effective than the system in Huis Ten Bosch, when it is evaluated from the viewpoint of the environmental harmony of the system.

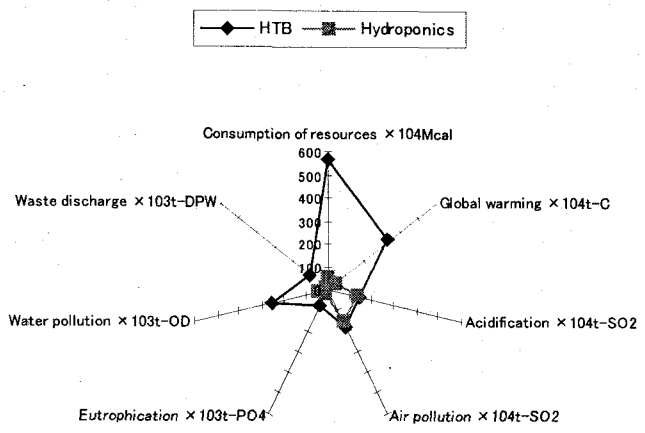

Fig.6 The comparison of environmental loading quantity per phosphorus elimination quantity.

4. CONCLUSION

This study evaluated the environmental effect of two wastewater treatment systems using the LCA technique. It was proven that set condition of the wastewater treatment system with hydroponics was smaller than that of the wastewater treatment system in Huis Ten Bosch on the load to the environment. And, it was shown that the degree of the environmental effect of the wastewater treatment system with hydroponics was smaller than that of the wastewater treatment system in Huis Ten Bosch, when the environmental loading quantity per removal quantity of

phosphorus and nitrogen were compared. However, the reuse of the treated water in Huis Ten Bosch is not considered in set condition. And, in the system of the hydroponics, an enormous installation area would be required so that the processing may enable Huis Ten Bosch' quantity of water to be treated, and this point is not considered either. In addition, the process efficiency of the drainage is an important factor, because treated water of the drainage is discharged to Omura Bay. It is necessary to also consider this point. As studied above, present examination cannot reach the conclusion that the environmental loading of the wastewater treatment system in Huis Ten Bosch is high only with these results. Our research group is aiming at the establishment of evaluation technique which can express the regionality of the foregoing as a future goal.

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