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Comparison of greenhouse gas (GHG) reduction effects of decentralized wastewater treatment facilities

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Outline

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1. INTRODUCTION

Background

SDGs: Halve the proportion of untreated wastewater globally
Paris Agreement: Reduction of greenhouse gas (GHG) emissions
It also affects the spread of wastewater treatment facilities

※ High population density area→Centralized wastewater treatment facility
※ Low population density area→Decentralized wastewater treatment facility

Need for knowledge on the environmental impact of decentralized wastewater treatment facilities

Challenges for the diffusion of decentralized wastewater treatment facilities overseas

①Septic Tank (Widespread in the world)

➢effluent BOD: 145～912mg/L

cf: Small-scale sewage treatment facility (EU)
cf: Johkasou (Japan)
➢ Good effluent water quality

② Differences in domestic wastewater among countries and regions

➢Asian countries: 131 mg/L (low)
➢EU: 337 mg/L (High)

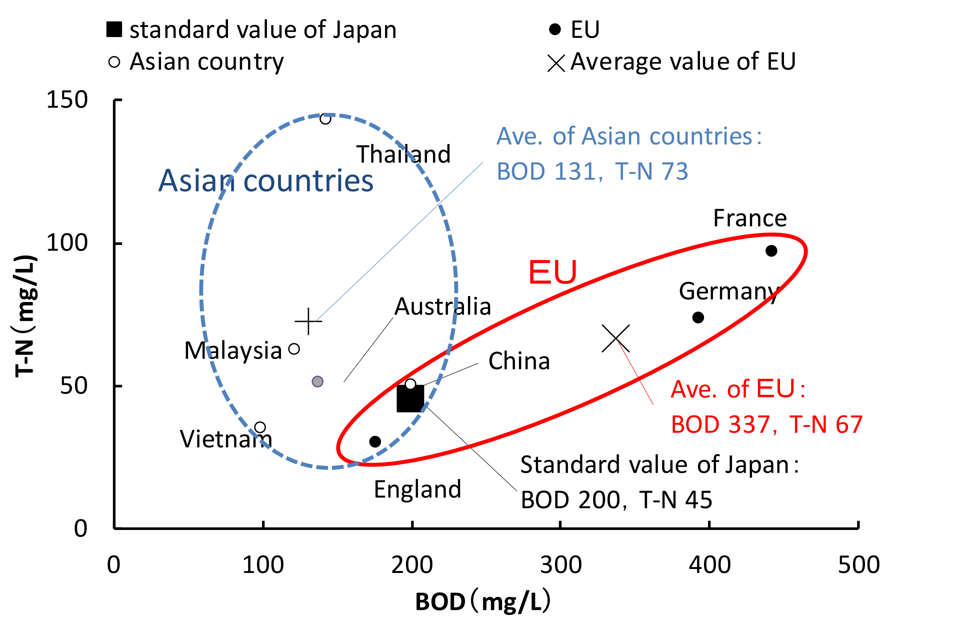

Figure -1 Characteristics of Domestic Wastewater in Japan and Overseas

1. Introduction

Necessary knowledge

- GHG emissions considering discharged pollutant load
- Environmental Impact of Decentralized wastewater treatment facilities by treatment method

Expected effect

- Widespread use of wastewater treatment facilities that aim to comprehensively reduce the environmental impact according to the region

➢ To contribute the achievement of the SDGs and the Paris Agreement

Purpose of this research

Promoting the spread of environmental load-reducing wastewater treatment facilities that both achieve the water environment conservation and prevention of global warming

Comprehensive comparison and analysis on the effect of reducing environmental impact under the same usage conditions as in the EU, where the concentration of pollutants in domestic wastewater is the highest.

➢ This makes it possible to apply it to Asian countries, etc.

2. Methods

1. Setting conditions for the decentralized wastewater treatment facilities subject to environmental impact assessment

① Facility scale：Minimum PE for individual house (5 PE)
② Utilizing condition ： Equivalent to performance evaluation test by EU regional standard EN12566-3+A2

Table -1 Outline of each decentralized wastewater treatment facility assumed in this presentation

Category	Classification in this study	Process of treatment	Target of the wastewater
Septic tank	Septic tank	Solid-liquid separation process	Domestic wastewater (Both Black water and Gray water)
EU type wastewater treatment facility	BOD removal type	Combination of anaerobic and aerobic treatment	
	Nitrogen removal type		
Johkasou made in Japan	Applied to overseas usage		

2. Method

2. Condition to set up a calculation model of environmental load from each decentralized wastewater treatment facility

① EU - BOD removal type (Arithmetic Mean of 3 Models: from Literature)
② EU – Nitrogen removal type (Arithmetic Mean of 5 Models: from Literature)
③ Johkasou made in Jpan applied to overseas usage (Same BOD volume load as Japanese specification)
④ Vietnam Septic tank (5 years after desludging, average 4.9 years for 37 units: from Literature)

3. Evaluation method of effluent pollutant load to water environment and sludge discharge

① testing method: Performance evaluation test according to EU standard EN12566-3+A2. With regard to the septic tank the field survey conducted (inflow conditions equivalent to EU standards)
② Monitored pollutant amount in effluent: BOD and T-N (Johkasou made in Japan applied to overseas usage was monitored by Total Kjeldahl Nitrogen)

2. Method

4. Assessment of greenhouse gas emissions

Table -2 Types and main emission sources of GHG from wastewater treatment facilities focused in this study

Types of GHG	category	Main emission sources
CO_2	＜Energy-related＞	
	A	Emissions from fuel combustion (heavy oil, kerosene, gasoline, etc.)
	B	Emissions from the use and purchase of electricity (Not include in-house power generation etc.)
CH_4	＜Non-Energy-related＞	
	C	Emissions associated with wastewater treatment (domestic wastewater treatment facility: Johkasou)
	D	Emissions from wastewater treatment (domestic wastewater treatment facility: anaerobic treatment)
	E	Emissions associated with sludge treatment (night soil treatment facility)
	F	Natural decomposition of untreated wastewater
N_2O	＜Non-Energy-related＞	
	G	Emissions associated with wastewater treatment (domestic wastewater treatment facility: Johkasou)
	H	Emissions from wastewater treatment (domestic wastewater treatment facility: anaerobic treatment)
	J	Emissions associated with sludge treatment (night soil treatment facility)
	K	Natural decomposition of effluent
	L	Natural decomposition of untreated wastewater

2. METHOD

Types of target GHG and scope of emissions calculation

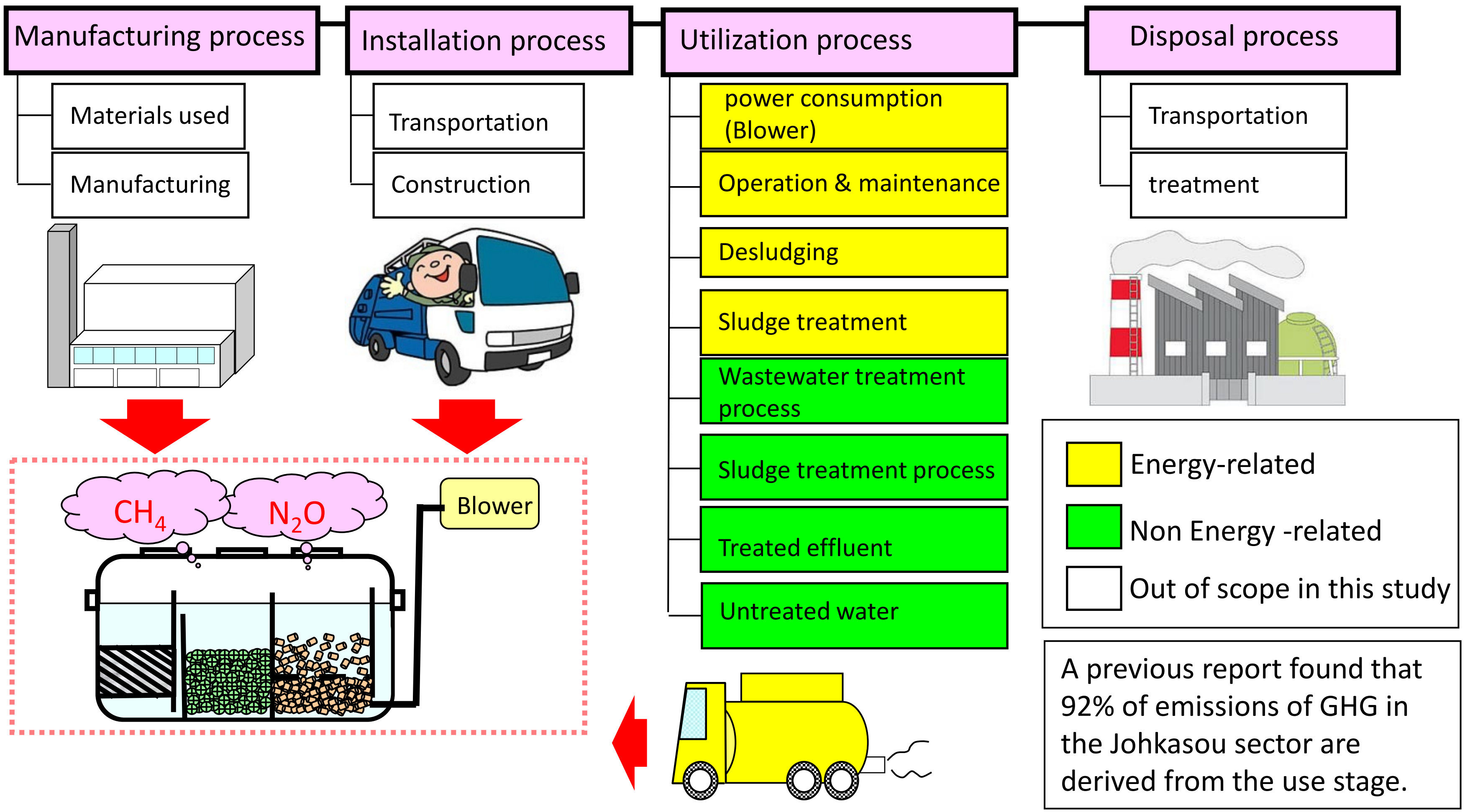

Figure -2　Activity classification by stage of decentralized wastewater treatment facility

2. Method

Table -3 Environmental load units and GHG emission factors used in calculations in this study

Item	Classification in Table 2	Environmental load unit		Unit	GHG factor
Energy -related	B	Power consumption by Blower		($kg\text{-}CO_2/kWh$)	0.555
	A	Vehicle fuel for maintenance inspection (private passenger car)		($kg\text{-}CO_2/PE\cdot km$)	0.188
	A	Vehicle fuel for desludging (vacuum vehicle)		($kg\text{-}CO_2/km$)	0.554
	A, B	Sludge treatment		($kg\text{-}CO_2/kL$)	86
Non Energy related	C, G	Wastewater treatment process	BOD removal type	($kg\text{-}CO_2/PE\cdot year$)	65.8
	C, G		Nitrogen removal type	($kg\text{-}CO_2/PE\cdot year$)	62.8
	D, H		Septic tank	($kg\text{-}CO_2/PE\cdot year$)	119.39
	E, J	Sludge treatment process	Night soil treatment plant	($kg\text{-}CO_2/m^3$)	0.551
	K	Natural decomposition of effluent		($kg\text{-}N_2O/kg\text{-}N$)	0.01
	K			($kg\text{-}CO_2/kg\text{-}N$)	2.354
	F	Natural decomposition of untreated wastewater		($kg\text{-}CO_2/kg\text{-}BOD$)	1.500
	L			($kg\text{-}CO_2/kg\text{-}N$)	2.354

① Global Warming Potential (GWP)
=> Compliant with IPCC Fourth Assessment Report（CH_4：25, N_2O：298）

② Emission factor of wastewater treatment process with respect to influent pollutant load difference
=> Emission Factor of Johkasou x Inflow amount of pollutant load into each facility / Inflow amount of pollutant load into Johkasou

③ Effluent from Septic tank
=> Untreated wastewater（Higher concentration than untreated domestic wastewater in Japan, BOD 180mg/L ）

3. Result and Discussion

1. Establishment of an environmental load calculation model for decentralized wastewater treatment

Table -4 Environmental Load Calculation Model for Decentralized Wastewater Treatment Facilities

Item				Septic tank	BOD removal type	Nitrogen removal type	Johkasou made in Japan applied to overseas usage
Performance evaluation testing method				Field survey	EN12566-3+A2	EN12566-3+A2	EN12566-3+A2
Term of evaluation testing				4 days	38 weeks	38 weeks	63 weeks
Water temperature			(℃)	—	—	—	—
Population equivalent (PE) for treatment			(PE)	4	5	5	5
Volume of wastewater			(m^3/day)	0.451	0.750	0.750	0.780
			(L/PE・day)	112.8	150.0	150.0	155.9
Test results and specifications	BOD	Water quality of influent	(mg/L)	525	301	312	481
		Water quality of effluent	(mg/L)	378	9.0	9.7	10.7
		Inflow amount of pollutant load	(g-BOD/PE・day)	59.2	45.1	46.8	75.1
	T-N	Water quality of influent	(mg/L)	323	61	61	102
		Water quality of effluent	(mg/L)	238	54.2	7.9	20.2
		Inflow amount of pollutant load	(g-T-N/PE・day)	36.4	9.2	9.2	16.0
	Operation and maintenance	Interval	(day)	—	548	183	476
		distance travelled	(km/time)	—	11.9	11.9	11.9
	Desludging	Interval	(day)	1,825	791	365	476
		distance travelled	(km/time)	16.1	16.1	16.1	16.1
	Designed capacity		(m^3)	1.00	5.03	3.62	2.87
		Volume of removed sludge	(m^3)	1.00	2.84	2.43	2.31
	Designed power consumption		(W)	0	59	80	58
	Uptime of blower (standard)		(h)	0	20	14	24
	Annual power consumption		(kWh)	0	408	416	508

- Even in the same performance evaluation testing, the inflow BOD concentration varied from 301 to 481mg/L (concentration has not been adjusted)
- Unification of inflow water quality is difficult. The model shown above is based on the results of the same test method

3. Result and Discussion

2. Pollution load discharged into the water environment from wastewater treatment facilities

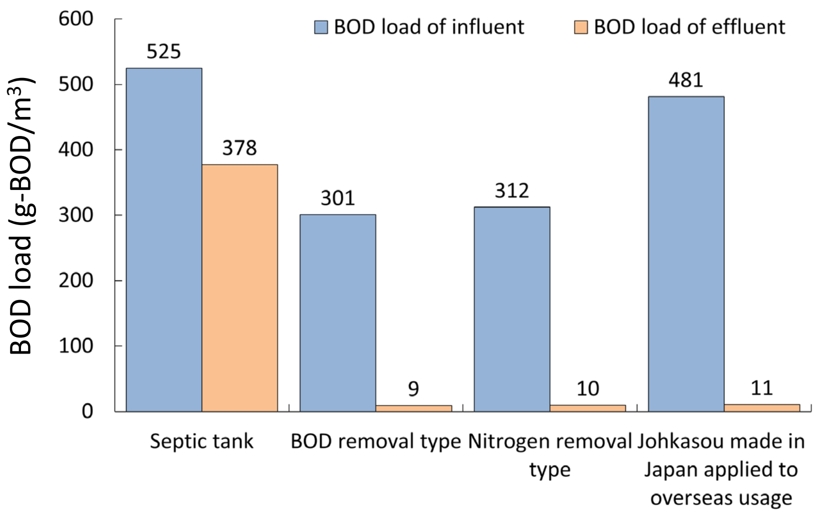

Figure -3 Amount of BOD load discharged from decentralized wastewater treatment facilities (per m^3)

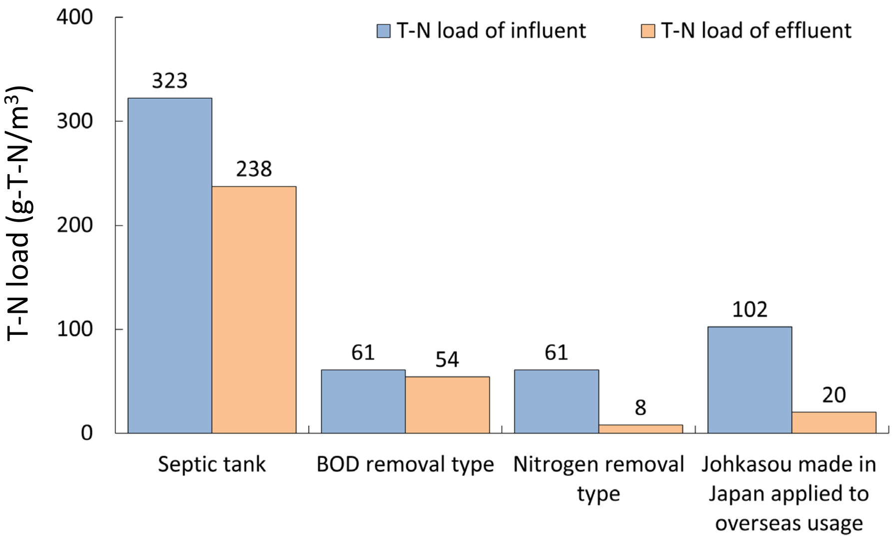

Figure -4 Amount of T-N load discharged from decentralized wastewater treatment facilities (per m3)

BOD load of effluent (per m^3)

- Septic tank ：378g-BOD/m^3
- 34 to 42 times higher environmental impact than other facilities
- other facilities：9～10g-BOD/ m^3

T-N load of effluent (per m^3)

- Septic tank ：238g-T-N/ m^3
- Large amount of load inflow but low removal ratio
- Nitrogen removal type and Johkasou made in Japan applied to overseas usage ：lower than 20g-T-N/ m^3

- The amount of BOD polluted discharged from the septic tank suggested the impact on the ecosystem and water environment.
- To reduce the amount of T-N load, Nitrogen removal type and Johkasou made in Japan applied to overseas usage are considered to be useful.

3. Evaluation of GHG emissions from decentralized wastewater treatment plant

Table-5 GHG emissions (CO2 equivalent) per 5 PE of decentralized sewage treatment facility

Item			Field survey	EN12566-3+A2		
			Septic taank	BOD removal type	Nitrogen removal type	Johkasou made in Japan applied to overseas usage
Water temperature		(℃)	―	―	―	―
Population equivalent (PE) for treatment		(PE)	5	5	5	5
Energy - related	Power consumption by Blower	(kg-CO_2/unit･year)	0.0	226.3	230.9	282.0
	Operation and Maintenance		0.0	1.5	4.5	1.7
	Desludging		1.8	4.1	8.9	6.8
	Sludge treatment		21.5	112.7	208.7	152.3
	Subtotal		23.3	344.7	453.0	442.9
Non Energy - related	Wastewater treatment process		597.0	362.3	339.4	570.6
	Sludge treatment process		0.1	0.7	1.3	1.0
	Natural decomposition of effluent		0.0	34.9	5.1	13.5
	Natural decomposition of untreated wastewater		231.7	0.0	0.0	0.0
	Subtotal		828.8	398.0	345.9	585.1
合計			852.0	742.7	798.9	1,028.0

- Septic tanks have a small amount of Energy -related GHG emission, however have the largest Non energy-related GHG emission.
- The BOD removal type (742.7 kg-CO2/unit/year) has the lowest GHG emissions, and Johkasou made in Japan applied to overseas usage has the largest GHG emission.

Inflow pollutant load and outflow pollutant load differ depending on the test.

↳ It is necessary to compare GHG emissions taking into account wastewater treatment capacity.

3. Result and Discussion

Comparison of GHG emissions considering inflow/outflow water quality (per kg BOD removed)

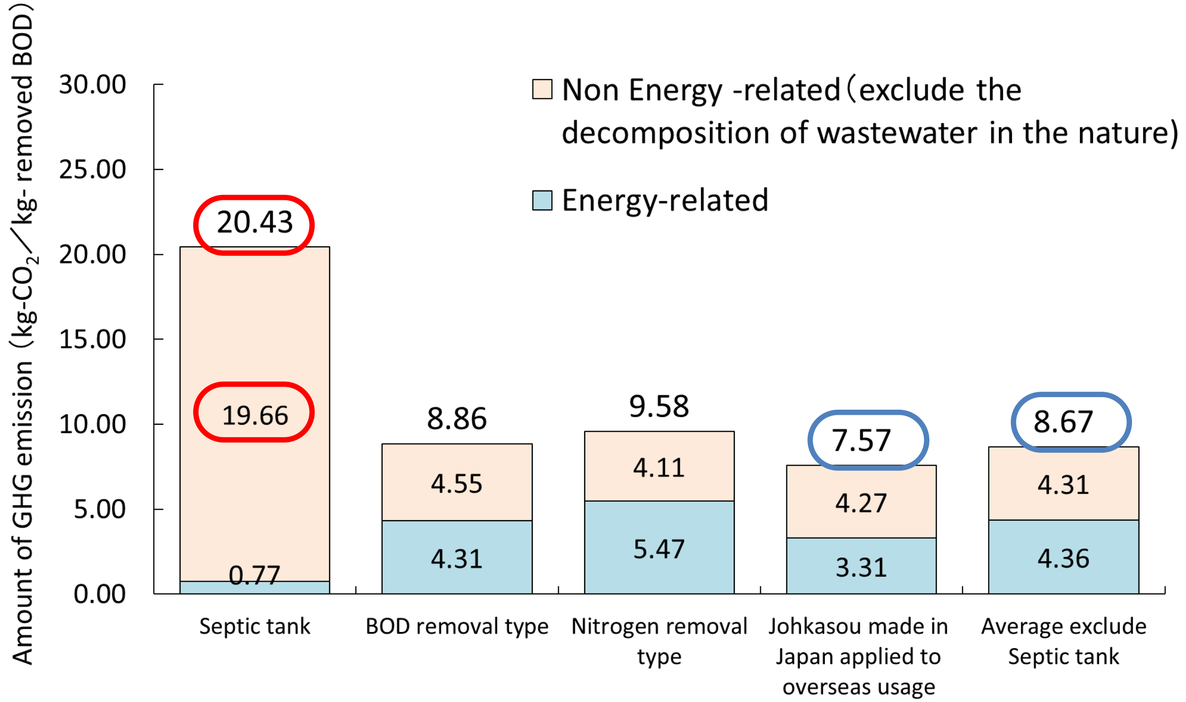

Figure -5 Greenhouse gas emissions per 1kg of BOD removed, excluding the decomposition of wastewater in the natural (CO2 conversion)

- Johkasou made in Japan applied to overseas usage has the smallest GHG emission(7.57 kg-CO2／kg-removed BOD)
- Septic tank has a 2.7 times higher GHG emission (20.43 kg-CO2/kg-removed BOD) compared with Johkasou made in Japan applied to overseas usage.
  - This might be due to the low BOD removal capacity and high GHG emissions in the wastewater treatment process.
- The average value of GHG emissions for BOD removal type, nitrogen removal type, and Johkasou made in Japan applied to overseas usage (exclude Septic tank) is 8.67 kg-CO2/kg-removed BOD.
  - It’s only 42% of septic tank emission when considering inflow/outflow water quality

3. Result and Discussion

Comparison of GHG emissions considering natural decomposition of effluent / untreated wastewater

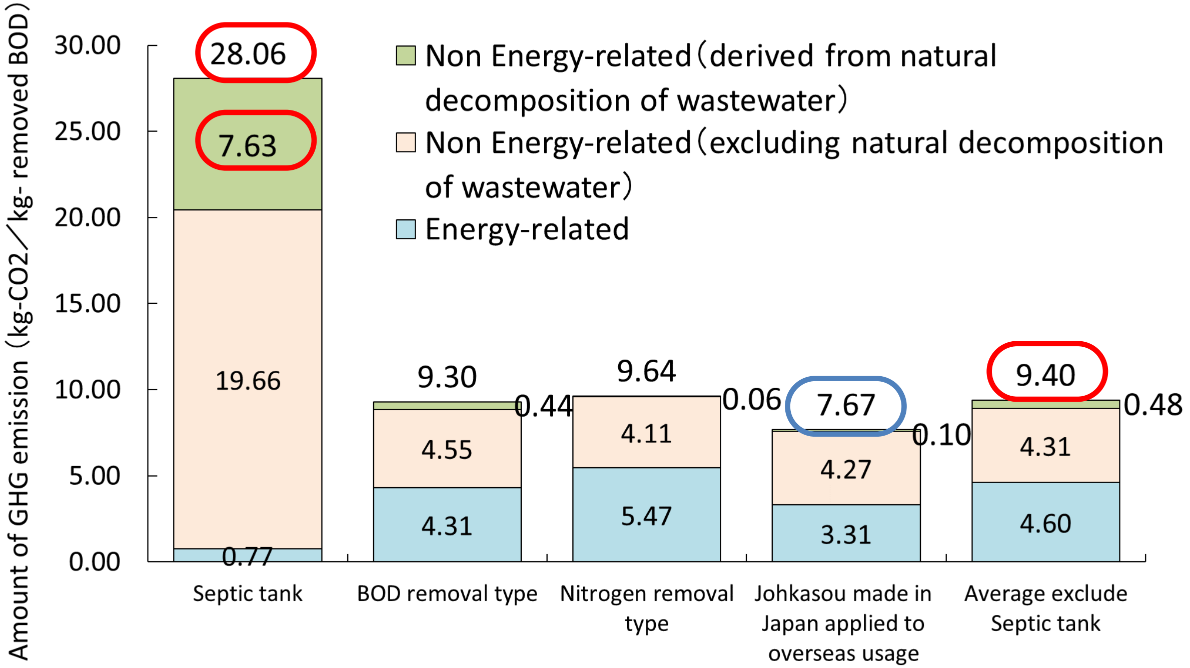

Figure -6 GHG emissions per 1kg of BOD removed considering natural decomposition of effluent / untreated wastewater (CO2 equivalent)

- Johkasou made in Japan applied to overseas usage has the smallest GHG emission (7.67kg-CO2／kg- removed BOD)
- Septic tank has a 3.7 times higher GHG emission (28.06 kg-CO2/kg-removed BOD) compared with Johkasou made in Japan applied to overseas usage.
  - ↳ It would be pollutant load contained in effluent from Septic tanks is high.
- The average value of GHG emissions for BOD removal type, nitrogen removal type, and Johkasou made in Japan applied to overseas usage (exclude Septic tank) is 9.40kg-CO_2／kg- removed BOD.
  - ↳ It's only 34% (1/3) of septic tank emission when considering inflow/outflow water quality.

4. Summary

From the perspective of the international wide spread of decentralized wastewater treatment facilities, with regard to the environmental impact, the amount of discharged pollutant load and the amount GHG emissions was studied in this research, and the following results were obtained.

1. The amount of BOD contamination in the effluent from the septic tank was 34 to 42 times higher than that of other facilities, giving a high environmental impact.
2. The amount of GHG emissions per unit was the lowest for the EU-BOD removal type.
3. Considering the wastewater treatment capacity of each facility, the amount of GHG emissions per removed BOD was the lowest for Johkasou made in Japan applied to overseas usage
4. The average value of GHG emissions per removed BOD for facilities applying combination of anaerobic and aerobic treatments was 42% of that of Septic tank, and 34% of that of septic tanks when considering natural decomposition of effluent / untreated wastewater

Thank you for your attention!