Journal of Developments in Sustainable Agriculture 5: 82–95 (2010)

Utilization of Biomass and Its Environmental Impact in Lake Kasumigaura Basin from the Viewpoint of Nutrient Flow and Greenhouse Gas Emissions

Yoshiro Higano[1] and Shintaro Kobayashi[2]

[1] Doctoral Program in Sustainable Environmental Studies, Graduate School of Life and Environmental Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan

[2] Development Research Division, Japan International Research Center for Agricultural Sciences, 1-1 Owashi, Tsukuba, Ibaraki, 305-8686, Japan

In this paper, we focus on the risks to human health that may be directly and indirectly caused by food production. A typical example is the inappropriateness of the material balance of nitrogen and phosphorous in the Lake Kasumigaura Basin. Agricultural production and fishery activities prosper in the basin. Nitrogen and phosphorous overflow into the lake due to the industrial wastes as well as from other sources of water pollution such as household and manufacture wastewater even though they must be processed and treated following strict regulations on wastewater effluents into the lake set by the Prefectural Government. The water of Lake Kasumigaura is used for drinking even though inorganic nitrogen and phosphorous cause sudden growth of toxic Microcystis. Furthermore, underground water is contaminated with nitrogen nutrients and the contaminated water is hazardous especially if taken by children. Another example of contamination is the emissions of Greenhouse Gases (GHG) such as methane and dinitrogen monoxide due to improper or insufficient treatment of biomass wastes in the basin. In this paper, the material balance of nitrogen and phosphorous in the basin is shown and the potential of the biomass resources in the lake estimated. Feasibility and effectiveness of composting and methane fermentation technologies are analyzed from their impacts on GHG emissions in the basin and the flow of nutrients into the lake.

Key words: Nutrient flow, Material balance, Biomass wastes, Water pollution, Lake Kasumigaura

1. Introduction

Lake Kasumigaura, the second biggest lake in Japan, is located in the southern part of Ibaraki Prefecture, and is a valuable water resource for the region. The water quality in the lake had been deteriorated since the mid of 1960's and the environmental standard for drinking water has not been met in the lake notwithstanding many measures adopted by the prefectural government. Recently, water-bloom has been observed, which is different from the visible one so far observed several times every year since 1970's. It is called Mycrocystis bloom and highly hazardous to human health. If the toxic water-bloom so often grows in the lake in future, we have to face with many issues such as serious impact on the ecological system, decrease in productivity of fishery and agricultural industries in the basin, increase in cost of purification for drinking water, etc. since the water-bloom

Received: October 25, 2009, Accepted: December 18, 2009

Corresponding author:

[1] Doctoral Program in Sustainable Environmental Studies, Graduate School of Life and Environmental Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan. Tel: +81-29-853-7221, Fax: +81-29-853-7221,
E-mail: higano@jsrsai.envr.tsukuba.ac.jp

[2] Development Research Division, Japan International Research Center for Agricultural Sciences, 1-1 Owashi, Tsukuba, Ibaraki, 305-8686, Japan. Tel: +81-29-838-6344, Fax: +81-29-838-6342, E-mail: shinkoba@affrc.go.jp

is harmful for plants and animals. It is considered that the growth of toxic water-bloom is caused by the eutrophication of in-organic matters composed of nitrogen and phosphorous. Therefore, the amount of nutrients in the lake must be controlled in order to prevent the toxic water-bloom growing. As we will show, about 70% of nitrogen load in the lake or more than that is transported by the rivers. It is mainly due to imbalance of nitrogen between necessity for crop production and supply of composted livestock wastes in addition to chemical fertilizer.

On the other hand, greenhouse gas is emitted due to socio-economic activities in the basin. It is well known that we must face the risk that life and property of human will be seriously damaged in future because of climate change and rise in the sea level unless the amount of GHG emission is fairly decreased by 2050.

In order to avoid the risk, we must change the fossil-oriented energy system, on which the current social and economic activities are heavily dependent on, into the non-fossil and carbon neutral one. Also, we must change the current social and economic structure, in which most of material flows is one way from the production to the abolishment, into circular-oriented one. In this sense, biomass resource has attracted considerable attention.

In this paper, firstly we focus on potential utilization of biomass in the basin. We consider proper utilization and treatment of biomass resource would solve both of the problems as it contains energy and nutrients. Next, we estimate material flow of nitrogen and phosphorous in the basin. We show effectiveness of alternative measures including biomass utilization technology, which aim to control the amount of their flow into the lake as well as to decrease GHG emission in the basin.

2. Potential Utilization of Biomass in the Basin and its Effectiveness

The biomass potential in the basin is estimated based on social and economic data such as population, number of employees, production of manufacturing industries, heads of domestic animals cultivated by the livestock industries, land area of crops, etc. The potential utilization of biomass is a hybrid of methane fermentation and composting. The potentials of compost and biomass energy are compared to the potential demand for compost and energy, respectively (Fig. 1).

(1) Estimation of biomass

We consider that biomass that can be utilized as resources are kitchen wastes, sludge of sewage disposal plants, and livestock wastes. The amount of biomass is estimated using the following calculation:

(amount of biomass) = *(social/economic data)* × *(biomass resource estimation parameters)*.

The biomass resource estimation parameters (BREPs)

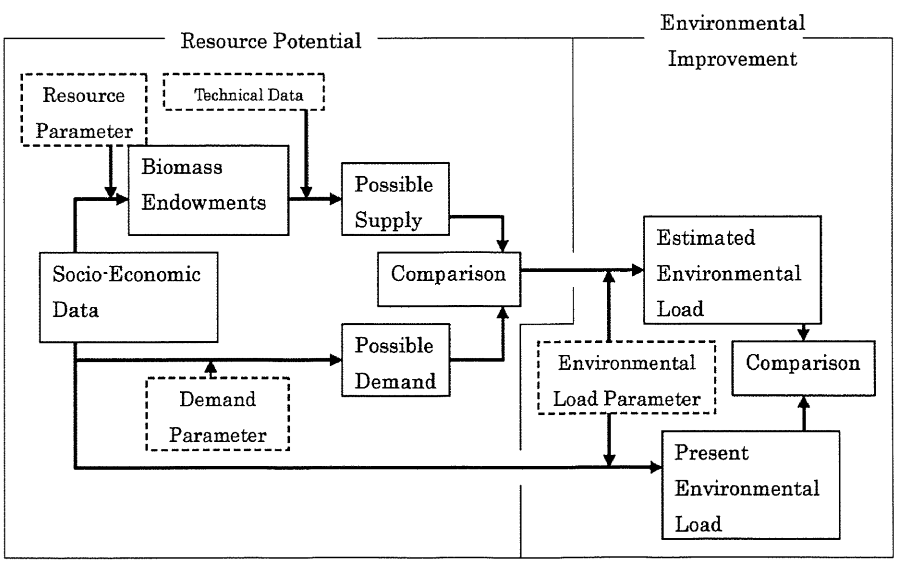

Fig. 1. Estimation of flow in this study.

Table 1. Biomass resource estimation parameters for household and industrial kitchen wastes

Source of Garbage		Variable	Parameter	Unit
Garbage from household		population	0.22	kg/(person・day)
Garbage from industry	Office	worker	57.00	kg/(person・day)
	Restaurant	produce	77.82	kg/million yen
	Hotel	produce	31.48	kg/million yen
	Department store, supermarket	produce	49.29	kg/million yen
	Food shop	produce	29.13	kg/million yen
	Other shop	worker	202.00	g/(person・day)
	Amusement	produce	21.36	kg/million yen
	School	student	16.17	kg/(person・year)
	Hospital	worker	267.00	g/(person・day)
	Manufacturing of food, beverage, tobacco and feedstuff	produce	29.25	kg/million yen
	Other manufacturing	worker	30.00	g/(person・day)

Table 2. Biomass resource estimation parameters for sludge from sewage disposal plants

Source		Variable	Parameter
Organic Sludge from Household	Combination treatment	population	160.37
	Independent treatment	population	51.46
Organic Sludge from Industry	Sewage management	population	25.85
	Excrement management	population	51.46

Table 3. Biomass resource estimation parameters for livestock wastes

Source		Variable	Parameter (kg/head/day)
Animal manure	Milk cow	number of farm animals	48.10
	Beef	number of farm animals	25.40
	Pig	number of farm animals	6.30
	Spawned chicken	number of farm animals	0.12
	Broiler	number of farm animals	0.13

for kitchen wastes are shown in Table 1. BREPs for sludge of sewage disposal plants are shown in Table 2. Those for livestock wastes are on Table 3.

(2) Potential supply of biomass energy and compost

The technology assumed is a hybrid system of methane fermentation with cogeneration and composting. Technology parameters of methane fermentation are shown on Table 4 and those of thermal efficiency are shown on Table 5. The system needs no energy input from outside. The potential supply of energy is calculated using the following:

(*potential energy supply* (kwh)) = (*potential of biomass*) × (*biogas generation unit*) × (*biomass heat capacity unit*) × (*thermal efficiency*).

The potential supply of compost is calculated in terms of nitrogen as follows:

(*potential supply of compost* (N・t)) = (*potential biomass*) × (*sludge rate by fermentation*) × (*content of nitrogen in sludge*).

Technology parameters of composting are shown in Table 6.

(3) Potential demand for biomass energy and compost

The potential demand for energy in the basin is

Table 4. Methane fermentation parameters

Waste Materials		Variable	Amout of Biogas		Quantity of Heat from Biogas	
			Parameter	Unit	Parameter	Unit
Sludge from Sewage and Human Waste Treatment		Weight of Dry Sludge	75.25	m^3/t/year	5500	kcal/m^3
Garbage		Weight of Dry Sludge	174.38	m^3/t/year	5000	kcal/m^3
Animal Manure	Pig	Weight of Dry Sludge	0.20	m^3/head/day	6000	kcal/m^3
	Milk Cow	Weight of Dry Sludge	0.99	m^3/head/day	6000	kcal/m^3
	Beef	Weight of Dry Sludge	0.99	m^3/head/day	6000	kcal/m^3
	Spawned Chicken	Weight of Dry Sludge	0.01	m^3/head/day	6000	kcal/m^3

Table 5. Thermal efficiency parameters

	Efficiency	Rate of inner consumption	Pure efficiency
Power generation	0.25	0.2	0.2
Heat supply	0.6	0.34	0.4
Total			0.6

Table 6. Compost production parameters

Waste materials		Fermentation residue rate (t/t)	Nitrogen concentration (t/t)
Sludge from sewage and human waste treatment		0.5	0.05
Garbage		0.11	0.06
Animal manure	Pig	0.5	0.0077
	Milk cow	0.5	0.0076
	Beef	0.5	0.0082
	Spawned chicken	0.5	0.0331

calculated as follows:

The potential demand for energy is calculated as follows:

(potential demand for energy(kwh)) = (production of each industry) × (direct energy input coefficient of each industry) + (population) × (direct energy input coefficient of final demand).

Energy input coefficients are given by Nanzai and Moriguchi (2002). In the above calculation, production of each industry in the basin is estimated as follows:

$$X = \mathrm{inv}\{(I-(I-M)A)\} \times ((I-M)F+E), \quad (1)$$

in which:

X: amount of production of each industry (vector);

inv{y}: inverse matrix of y;

I: identity matrix;

M: a diagonal matrix of which elements are ratios of import to total supply;

A: input-output coefficient matrix;

E: amount of export (vector); and

F: final demand (vector).

Intra-regional (-basin) final demand and export are separately estimated as utilization of biomass induces changes in the intra-regional final demand only. Export is estimated assuming constant trade coefficients between the prefecture and other region. The import is assigned to the basin following the shares of the basin in terms of social and economic data collected. The intra-regional consumption is estimated assuming households are homogeneous. The analysis developed in this paper is dependent on those assumptions. The demand for energy is calculated as the one for the first energy in terms of heat capacity (Fig. 2). To multiply it by thermal and electricity transmission efficiencies gives consumption of electricity in the basin.

Utilization of compost cultivates fertility of soil that is essential and basic to the agricultural production. On the other hand, farmers are apt to avoid it as it is of uneven quality and timing of fertilization and the production management are bothersome work. Therefore, the demand for compost is dependent on awareness of farmers and available technology. Assuming changes in the awareness and development of technologies, we estimated potential demand for compost with several cases. As we do not consider effect of price changes, we use terminology - potential demand. The estimation is made as follows (Aramaki and Suzuki, 2001):

(potential demand for compost) = (land area of each crop) × (standard fertilization of each crop) × (ratio of compost to the standard fertilization).

We consider that the ratio of compost to the standard fertilization is dependent on awareness of

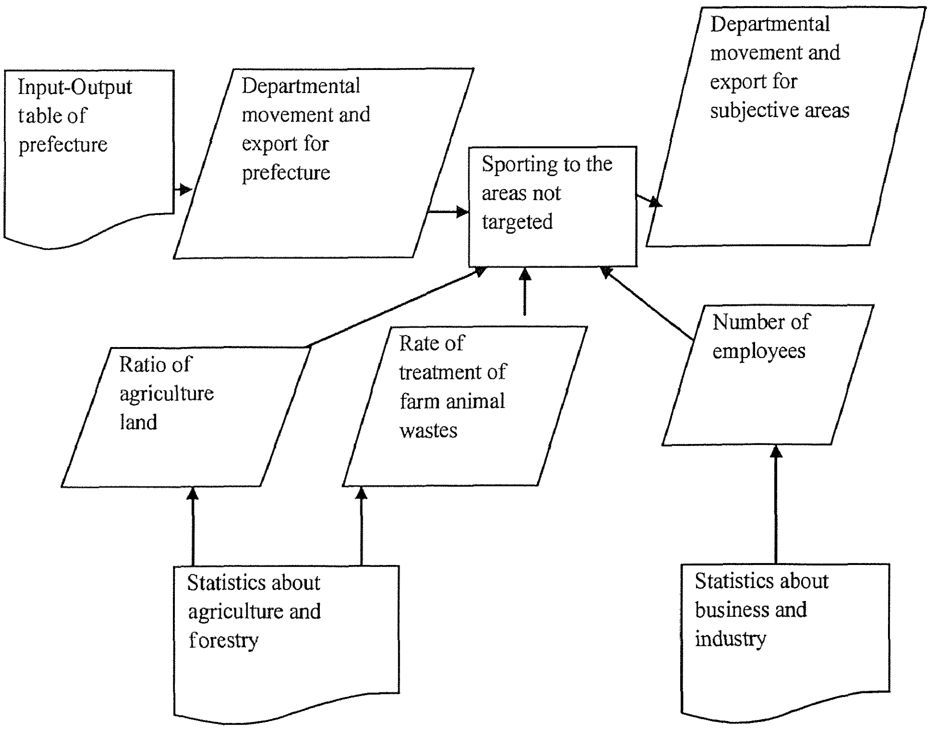

Fig. 2. Flow estimation.

farmers and development technology, and assume their several patterns.

(4) Current environmental loads

GHG emission is estimated by using the following calculation for each gas:

(GHG emission) = (production of industries)
× (direct emission coefficient of industries)
+ (population)
× (direct emission coefficient of final demand).

We use emission coefficient of carbon dioxide estimated by Nanzai and Moriguchi (2002). As for methane and dinitrogen monoxide we use those by Fujisawa and Higano (2000). Each coefficient of GHG is measured in terms of carbon dioxide by multiplying it with coefficient of global warming potential.

The amount of final disposal of wastes is estimated as follows:

(final disposal of domestic wastes originated in the basin) = (final disposal of domestic wastes originated in the prefecture) × (rate of population in the basin) + (final disposal of industrial wastes originated in the prefecture) × (rate of production in the basin).

(5) Change in environmental load by biomass utilization

Environmental load of biomass utilization is defined as follows:

(environmental load of biomass utilization) = (environmental load of existing way of biomass utilization) − (decrease in the environmental load by biomass utilization).

Reduction of the environmental load of biomass utilization is defined as follows:

(decrease in environmental load by biomass utilization) = (environmental load of existing way of biomass utilization) − (environmental load of biomass utilization) + (induced decrease in environmental load by biomass utilization).

Environmental load of existing way of biomass utilization means the current total environmental load in the basin. Environmental load of existing way of biomass utilization means environmental load of current way of processing biomass resources only. Induce decrease in the environmental load by biomass utilization means reduction of environmental load due to decrease in the demand for goods that can be substituted by biomass resource utilization.

3. Effectiveness of Biomass Utilization: Nutrient Flow Approach

Since input-output (I-O) structure of the industry must change that adopts technology of biomass utilization, environmental load of the biomass utilization cannot be estimated by I-O analysis only. It is estimated considering inflow and outflow of nutrients at processes of treatment and utilization of biomass resources.

(1) Frame of estimation

Frame estimation is shown in Figure 3. Nutrients are generated directly or indirectly after they are contained in organic wastes and wastewater. They are emitted into the environment through process of treating organic wastes and wastewater. Firstly, nutrients at the origin are estimated based on social and economic data (Table 7). After that, inflow into waste processing, inflow into transportation media such as soil and rivers, and inflow into the Lake are estimated one after another.

During staying at the process and the transportation media, chemical reaction occurs with organic wastes and wastewater, materials are emitted into the air and water area such as river and lake (Fig. 4). Amount of the emission are estimated based on

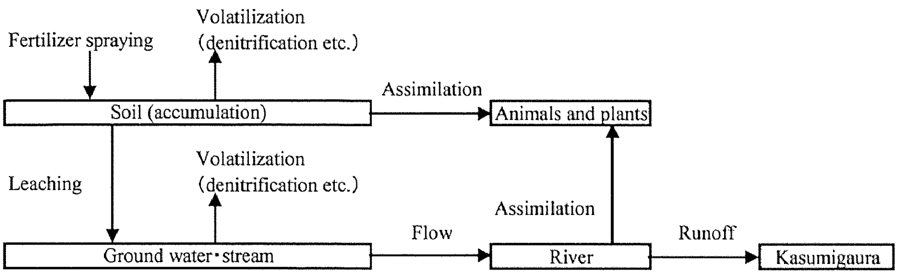

Fig. 3. Pathway of Nutrient salts in soil and river.

Table 7. Amount and rate of nutrient inflow in Lake Kasumigaura

Source		Wastewater	Emission unit Nitrogen	Emission unit Phosphorus	Unit	Explanatory parameter	Reference
Household		Excrement	3.281	0.312	kg/person/year	Population	Kunimitsu (1989)
		Graywater	0.930	0.130	kg/person/year	Population	Sakurai(2003)
		Kitchen refuse	0.456	0.088	kg/person/year	Population	Setting value
Office		Wastewater	0.233	0.033	kg/person/year	Population	Kunimitsu (1989)
	Office	Kitchen refuse	0.118	0.023	kg/person/year	Number of workers	Setting value
	Restaurant		0.442	0.085	kg/million yen	Production value	
	Hotel		0.179	0.035	kg/million yen	Production value	
	Department store, supermarket		0.280	0.054	kg/million yen	Production value	
	Food shop		0.165	0.032	kg/million yen	Production value	
	Other shop		0.419	0.081	kg/person/year	Number of workers	
	Amusement		0.121	0.023	kg/million yen	Production value	
	School		0.092	0.018	kg/person/year	Number of students	
	Hospital		553.279	107.021	kg/person/year	Number of workers	
	Manufacturing of food, beverage, tobacco and feedstuff		0.166	0.032	kg/million yen	Production value	
	Other manufacturing		0.062	0.012	kg/person/year	Number of workers	
Agricultural land		Chemical fertilizer	90.000	37.500	kg/ha	Area	Setting value
Livestock industry	Milk cow	fece	42.413	11.196	kg/head/year	Number of heads	Kobayashi (*2005)*
	Beef cattle		23.757	5.262	kg/head/year	Number of heads	
	Pig		3.152	2.502	kg/head/year	Number of heads	
	Layer		1.056	0.182	kg/head/year	Number of heads	
	Broiler		0.956	0.106	kg/head/year	Number of heads	
	Milk cow	urine	42.158	0.621	kg/head/year	Number of heads	
	Beef cattle		26.974	0.256	kg/head/year	Number of heads	
	Pig		10.001	0.949	kg/head/year	Number of heads	
Factory		Effluent	0.125	0.017	kg/million yen	Production value	Kunimitsu (*1989)*
	Food manufacturing	Animal and plant residue	0.397	0.077	kg/million yen	Production value	Setting value
	Beverage, tobacco and feedstuff		0.473	0.091	kg/million yen	Production value	
	Chemistry		0.006	0.001	kg/million yen	Production value	
	Food manufacturing	Sewage	0.191	0.044	kg/million yen	Production value	Setting value
	Beverage, tobacco and feedstuff		0.112	0.026	kg/million yen	Production value	
	Pulp, paper and paper converting		1.919	0.443	kg/million yen	Production value	

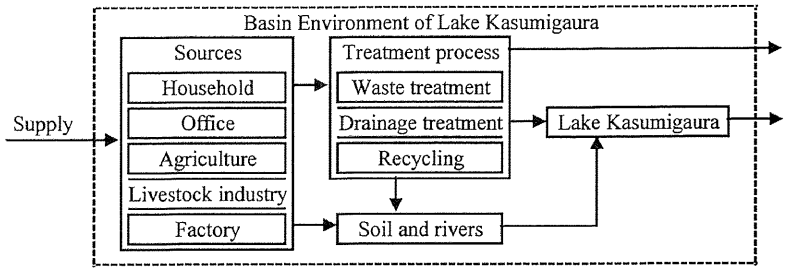

Fig. 4. Estimation frame for nutritive salt.

technology and chemical data (Table 8). The supply of nutrients to the origin is estimated backward by considering the estimated generation of nutrients. Outflow of nutrients from the lake into outside the basin is estimated considering official average water quality and amount of the outflow of water. In this paper, we only focus on anthropogenic nutrients and not those are given constants in the analysis.

(2) Parameters with generation

In Table 7, nutrients generated by kitchen wastes are estimated with emission coefficient of household in Table 1 and standard content of nutrients by percentage (Kobayashi *et al.,* 2005; Sakurai, 2003; Japan Center for Construction, 1999). Those by business office are made similarly.

Nutrients generated by agricultural land are estimated as nutrients included in the fertilizer, which is calculated based on the fertilization ratio. Fertilizers are chemical one and compost. Input of nitrogen by fertilization is based on the result of Matsumoto (2000). As for phosphorous, almost same approach as nitrogen is adopted using standard fertilization of phosphorous guided by the prefectural government, assuming that fertilization ratios of nitrogen and phosphorous by chemical fertilizer are same. Livestock industries are major business in the basin and the wastes are treated by composting, liquid fertilizer, etc. It is considered that those are mostly put into the agricultural land as fertilizer as well as chemical one. Therefore, as for nutrients put into the agricultural land are estimated with the amount of livestock wastes generated and treated in the basin. Organic wastes generated by factories are estimated by using same approach to kitchen wastes.

(3) Parameters with processing

Parameters with processing organic wastes and wastewater are shown on Table 8. As shown in Figure 5, materials change through the process, and are emitted into the air and water area while remained becomes sludge. As for nitrogen and phosphorous, ratio of the material that is emitted into the air to the total input measured at the element level is defined as vaporization ratio. The one into water area is discharge ratio. The one remained is residue ratio.

(4) Parameters with transportation media

Procedure for the estimation of nutrient flow in the transportation media such as soil and river are shown in Figure 4 (Kunimitsu and Muraoka, 1989; Ibaraki Prefecture 2004). Nutrients that are put into the agricultural land (soil) as fertilizer are absorbed by crops (and taken out by harvesting) while a part of them vaporize into the air or seep into soil (eluviation in Fig. 4). Those leached into soil are transported into rivers through underground water and small streams (effluence in Fig. 4), and finally flow into the Lake (river flow in Fig. 4) while their amount are decreased via absorption of animals and plans on the way of transportation. The ratio of nutrients that leached into soil to the total input into the soil is named as eluviation ratio. The ratio of nutrients that reach to rivers to the total of eluviation is effluent ration. The ratio of nutrients that flow into the Lake to the total of effluence is ratio of river flow. Those figures are shown on Table 8.

4. Analysis of the Results

(1) Treatment and utilization of biomass resources

The estimated amount of biomass resources in the basin in 2002 is shown in Figure 6. Wastewater treatment sludge is calculated in terms of weight of dewatered sludge. Manure of pigs is beyond

Table 8. Volatilization, residue, and effluent ratios of nitrogen and phosphorus at treatment

Treatment process		Processing object	Nutrient salts	Volatilization ratio(%)	Residue ratio(%)	Effluent ratio(%)	Reference and note
Incineration		Kitchen refuse and sludge	Nitrogen	100.0	0.0	0.0	Setting value
			Phosphorus	30.0	70.0	0.0	
Drainage treatment	Sewage treatment	Mixed wastewater	Nitrogen	41.6	41.6	16.8	Setting value
			Phosphorus	0.0	93.2	6.8	
	Night soil treatment	Night soil	Nitrogen	21.0	21.0	58.0	Effluent ratio is quoted from Kunimitsu (1989), others are setting value
			Phosphorus	0.0	49.0	51.0	
	Treatment of rural agricultural wastewater	Mixed wastewater	Nitrogen	15.5	15.5	69.0	
			Phosphorus	0.0	28.0	72.0	
	Combined household wastewater treatment		Nitrogen	15.0	15.0	70.0	
			Phosphorus	0.0	8.0	92.0	
	Single type private sewage treatment	Night soil	Nitrogen	14.0	14.0	72.0	
			Phosphorus	0.0	12.0	88.0	
	Without treatment	Graywater	Nitrogen	0.0	0.0	100.0	
			Phosphorus	0.0	0.0	100.0	
Livestock waste treatment	Without treatment	Pig and poultry excrement	Nitrogen	0.0	0.0	0.0	Ibaraki Prefecture (2000)
	Composting		Nitrogen	32.0	0.0	0.0	
	Drying		Nitrogen	6.0	0.0	0.0	
	Liquid fertilizering		Nitrogen	22.0	0.0	0.0	
	without treatment	Pig and poultry feces	Nitrogen	0.0	0.0	0.0	
	Composting		Nitrogen	9.0	0.0	0.0	
	Drying		Nitrogen	6.0	0.0	0.0	
	without treatment	pig and poultry urine	Nitrogen	0.0	0.0	0.0	
	Liquid fertilizering		Nitrogen	22.0	0.0	0.0	
	without treatment	Cow excrement	Nitrogen	0.0	0.0	0.0	
	Composting		Nitrogen	25.0	0.0	0.0	
	Drying		Nitrogen	18.0	0.0	0.0	
	Liquid fertilizering		Nitrogen	22.0	0.0	0.0	
	without treatment	Cow feces	Nitrogen	0.0	0.0	0.0	
	Composting		Nitrogen	15.0	0.0	0.0	
	Drying		Nitrogen	18.0	0.0	0.0	
	without treatment	Cow urine	Nitrogen	0.0	0.0	0.0	
	Liquid fertilizering		Nitrogen	22.0	0.0	0.0	
	Cleanup	Pig excrement	Nitrogen	49.7	49.7	0.7	Setting value
			Phosphorus	0.0	99.7	0.3	
		Pig feces	Nitrogen	49.6	49.6	0.8	
			Phosphorus	0.0	98.9	1.1	
		Milk cow excrement	Nitrogen	49.7	49.7	0.6	
			Phosphorus	0.0	99.4	0.6	
		Milk cow urine	Nitrogen	49.6	49.6	0.7	
			Phosphorus	0.0	93.5	6.5	
		Beef cattle excrement	Nitrogen	49.6	49.6	0.8	
			Phosphorus	0.0	99.1	0.9	
		Beef cattle urine	Nitrogen	49.5	49.5	1.1	
			Phosphorus	0.0	85.2	14.8	
Fusion resource		Sewage treatment	Nitrogen	100.0	0.0	0.0	Setting value
			Phosphorus	50.0	50.0	0.0	

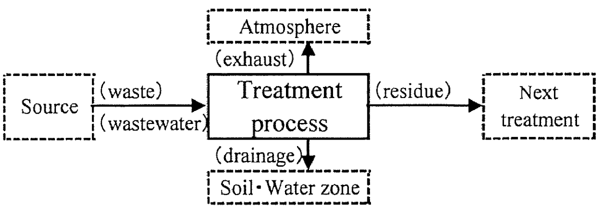

Fig. 5. Material flow at treatment.

700,000 tons/year, and is most. It is followed by manure of milk cows, and then by that of meat cows. Namely, ratio of livestock manure is overwhelming. The next to it is municipal organic wastes generated by business office and the amount is about 130,000 tons/year. Wastewater treatment sludge including sewage treatment sludge is about 90,000 tons/year. It is partially treated by com-

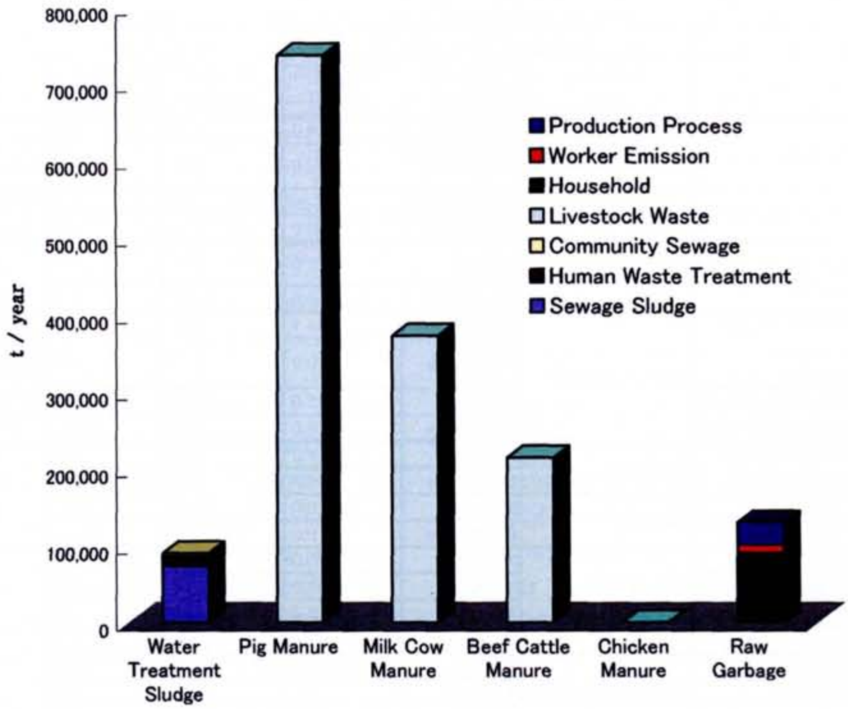

Fig. 6. Situation of the amount, treatment and utilization of biomass around Kasumigaura.

posting and most part is treated by incineration and the residue is utilized as building materials. Due to the regulation on food recycling, it is highly developed as for industrial organic wastes (generated by food industries) while it has not yet developed as for municipal organic wastes. Especially, those generated by households are incinerated and treated by landfill. As for livestock manure generated in the basin, its 90% is treated by manuring the fields and what remained is incinerated according to Higano (2005).

(2) Biomass resources and current environmental load

Environmental load is generated by utilization and treatment of biomass resources. Its ratio to the total environmental load generated in the basin is shown.

[Greenhouse gas]

The estimated GHG emission in the basin in 2002 is 25,530,000 tons. The amount of methane emitted by treatment and utilization of livestock wastes, organic wastes, and wastewater treatment sludge is 13,300 tons (CO_2 tons). That of dinitrogen monoxide is 125,400 tons. Their ratios to the total GHG emission in the basin are 0.05% and 0.49%, respectively. This amount is not negligible as there is no effective measure against GHG emission and it must be reduced little by little by various measures. Figure 7 shows details of the GHG emission (carbon dioxide originated from biomass resources is not counted as GHG since it id carbon neutral). Almost all the methane and 78% of dinitrogen monoxide are generated by treatment of livestock manure. The ration of GHG emission by treatment of livestock manure to the total emission in the basin is 0.44%. Reconsideration of the current treatment process of livestock manure is necessary as a measure against reduction of GHG emission.

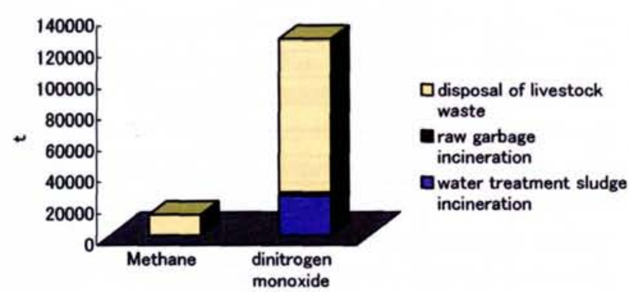

Fig. 7. Amount of GHG from biomass and the rate around Kasumigaura.

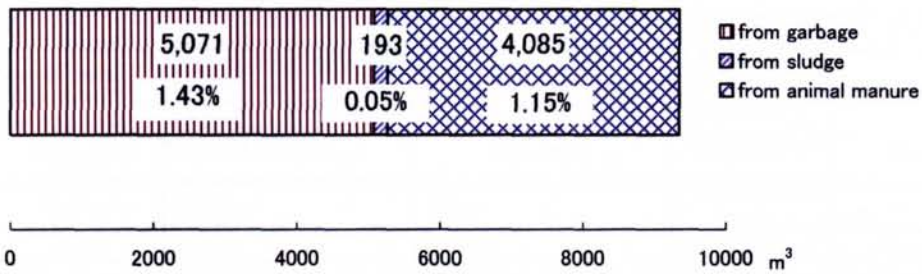

Fig. 8. Amount of sanitary landfill of biomass wastes and rate against the total amount around Lake Kasumigaura.

[Final disposal]

The total final disposal originated from the basin is 354,700 m^3. The final deposit originated from the three kinds of biomass resources, wastewater treatment sludge, organic wastes, and livestock manure are shown in Figure 8. The most is incineration ash of organic waste and its ratio to the total in the basin is 1.43%, which is followed by incineration ash of livestock manure. Its ratio is 1.15%. The wastewater treatment sludge and its landfill are very small since it is utilized as building materials. The sum of those three ash is 9,349 m^3 and its ratio to the total is 2.63%. This means we cannot expect drastic improvement in the shortage of final deposit land through recycling biomass resources.

(3) Evaluation of energy potential

We assume cogeneration system as alternative energy utilization and treatment system of biomass resources. Its fuel is methane generated by methane fermentation technology. Firstly we estimate potential electricity and heat capacity which can be generated by utilization of biomass resources ignoring restriction against location of the system. The result of estimation is shown in Figure 9. Sum of the potential energy is 89,000,000 kwh. The most is generated by livestock manure, and is 54,000,000 kwh. The next is by organic wastes, and is 26,000,000 kwh. Though the amount of livestock wastes is ten times as organic wastes (Fig. 6), its potential energy supply is two times, which means the potential of organic wastes is much higher. Electricity of 153,000,000 kwh was consumed in the basin in 2002, which means energy equivalent to 413,000,000 kwh must be produced as thermal and transmission of electricity is around 37%. The rate of self-sustenance by biomass energy is only 0.58%.

We cannot expect that biomass energy substi-

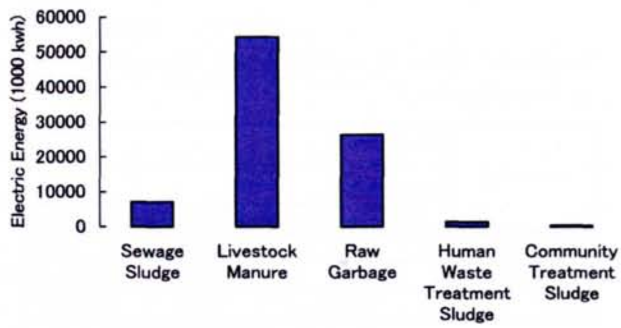

Fig. 9. Available electric supply from biomass and rate of self-support around Lake Kasumigaura.

tutes for the primal energy in the basin. However, we should pay attention to biomass resources of livestock wastes and sewage treatment sludge as they are concentrated at a several specific locations in the basin. If we could take an advantage of the concentration, energy utilization of those biomass resources may work well for management of livestock farmers and sewage treatment plants.

Table 9 shows self-sustenance of electricity in pig farmers when livestock wastes are utilized as energy source. Here it is assumed that the pig farm only uses electricity as energy source. So, the self-sustenance rate of electricity energy is that of energy. The table shows that the higher is the self-sustenance rate of electricity, the smaller the scale of production. With the scale of production less than 300 heads, it is more than 100%. Even with the scale less than 2,000 heads, it is more than 50%. It is considered that it is highly effective to utilize biomass energy in the pig farming.

Table 10 shows results for the sewage treatment plant. It is considered that biomass energy utilization in the sewage treatment plant is fairly prosper-

Table 9. Amount of self-sustainable electric power generated by pig farms from biomass

Production Scale (head)	Heating and Lighting expenses (A) (¥10000/year)	Electric Energy Demand (B) (kwh/year)	"Amount of Self-sustainable Electricity" and "Self-sustainability Rate" (C) (kwh/year)	Self Support Electric Rate (D) (%)
≦99	4	4,000	5,093	127
100～299	20	20,000	20,372	102
300～499	60	60,000	40,744	68
500～999	140	140,000	76,395	55
1000～1999	300	300,000	152,791	51

A:data of Higano et al.(2005); B=A/(average price of low voltage electricity);
C:estimated as shown in 2.(2); D=(C/B)*100

Table 10. Rate of self-sufficient energy power in households

Resources	Electricity Self-Sufficiency Rate (%)	Energy Self-Sufficiency Rate (%)	
		Only Electricity	Co-generation
Raw Garbage	1.3	0.4	3.9
Human Waste	2.0	0.6	6.1
Sum	3.3	1.0	10.0

Table 11. Potential reduction of GHG by using methane energy fermentation

Reduction Items		Reduction (t)	Reduction Rate (%)
Direct Reduction	Sewage Treatment Process	20,441	0.08
	Human Waste Treatment Process	3,823	0.01
	Raw Garbage Disposal Process	2,158	0.01
	Livestock Manure Disposal Process	117,731	0.46
Indirect Reduction	Electricity Use (Oil Substitution)	12,024	0.05
	Heat Use (Oil Substitution)	33,066	0.13
	Compost Use (Fertilizer Substitution)	113	0.00
Sum		189,357	0.74

ous. On the other hand, Table 11 shows biomass energy utilization is not efficient with households. The self-sustenance rate of 3.3% is too low as it could not cover initial cost for the facility.

(4) Demand and supply of compost

Figure 10 shows potential demand and supply of compost in the basin. The total potential supply is 8,100 tons, of which 62% is originated from livestock manure. Actual supply is around 5,000 tons, of which 91% is from livestock manure. This means that livestock wastes generated in the basin provide large quantities of nitrogen into the agricultural fields. Interesting result is that the actual supply of compost is 4,976 tons and it is almost equivalent to the total nitrogen which agricultural land in the basin demands −5,144 tons (case 3). According to Matsumoto (2000), chemical fertilizer of 4,000 tons is used in the basin and too much excessive amount of nitrogen is put into the agricultural land. It is considered that the composting is made based on the supply side reason that regulation on the treatment of livestock manure became stricter. Considering farmers attitude against compost, Case 1 has reality.

(5) Environmental effects of biomass utilization

Table 12 shows amount of reduction in GHG made by the biomass energy utilization with methane fermentation. Maximum 0.74% of the total GHG emission can be reduced. This figure cannot be negligible.

(6) Nutrient flow in the basin

Figure 11 shows current nutrient flows of nitrogen and phosphorous in the basin in 2002. The total inflow of nitrogen into the lake is 4,224 tons and it is almost same as estimated by the Ibaraki Prefectural government (Table 13 and 14). Using this figure, share of sources which finally emit nutrients into the lake are summarized in Table 15. The table shows that fertilizer and compost are too much made into the agricultural land in the basin, too. Table 16 shows accumulation of nutrients and their ratio to the inflow. About 20% of the inflow of nitrogen and 60% of phosphorous into the lake are accumulated in the lake. This means it is difficult to improve water quality in the lake only by controlling inflow of nutrients.

Figure 12 shows changes in the nutrient flows that are made when the cogeneration system of methane fermentation is introduced in order to treat livestock manure in the basin. Inflow of ni-

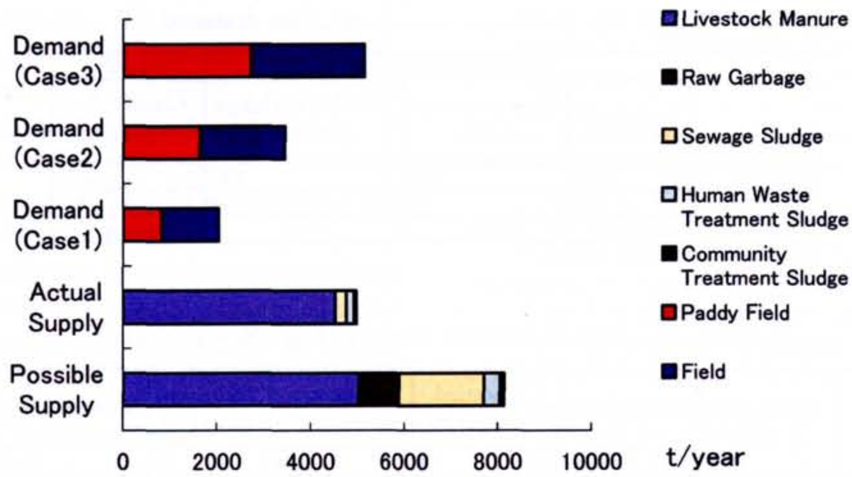

Fig. 10. Comparison about the amount of demand and supply for compost.

Table 12. Observed values of inflow material

	Inflow load per day		Inflow load per year (t/year)
	Irrigation season (t/day)	Non-irrigation season (t/day)	
Nitrogen	19	6.4	4226
Phosphorus	1.14	0.19	211.85
Note	Observed value		Supposing that Irrigation season was 150 days

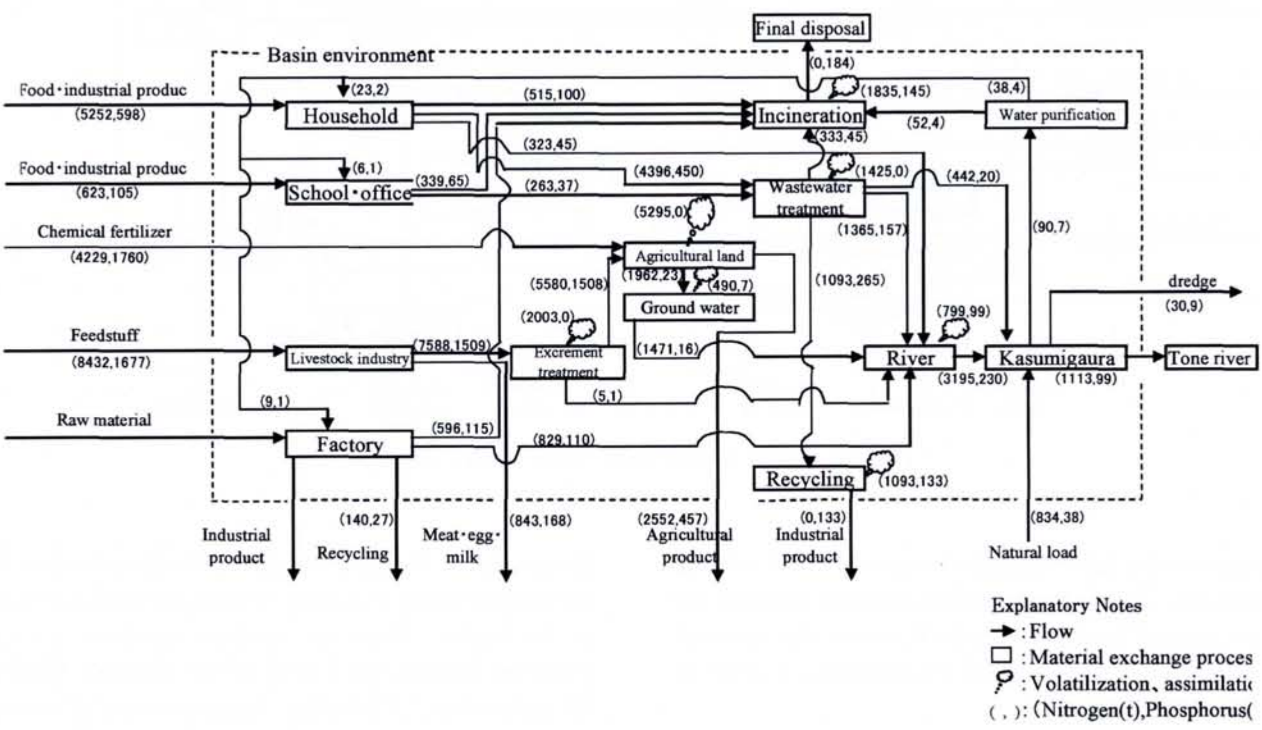

Fig. 11. Nitrogen and phosphorus flow around Kasumigaura Lake.

Table 13. Estimated values of inflow material

	Inflow to Kasumigaura			Total
	From river	From treatment facility	Derived from nature without rain	Annual inflow load
Nitrogen	3195	442	587	4224
Phosphorus	230	20	28	278
Unit	t/year	t/year	t/year	t/year

Table 14. Rate of nutrient inflow to Lake Kasumigaura

	Factory (%)	Aguriculture (%)	Chemical fertilizer (%)	Livestock excrement (%)	School and office (%)	Household (%)	Total (%)
Nitrogen	18.2	32.5	14	18.4	1.2	48.1	100
Phosphorus	30.8	4.8	2.4	2.1	1.2	63.3	100

Table 15. Amount and rate of a nutrient accumulation in Lake Kasumigaura

	Inflow volume				Outflow volume				Net inflow volume (c) (t)	Volatilization (d) (t)	Sedimentation (e) (t)	Sedimentation ratio (%)
	Total (a) (t)	Treatment water (t)	River (t)	Nature (t)	Total (b) (t)	Water intake (t)	Dredge (t)	Runoff (t)				
Nitrogen	4471	442	3195	834	1233	90	30	1113	3238	2266.6	971.4	21.7
Phosphorus	288	20	230	38	115	7	9	99	173	0	173	60.1

Relation of estimated value: a - b = c, c - d = e

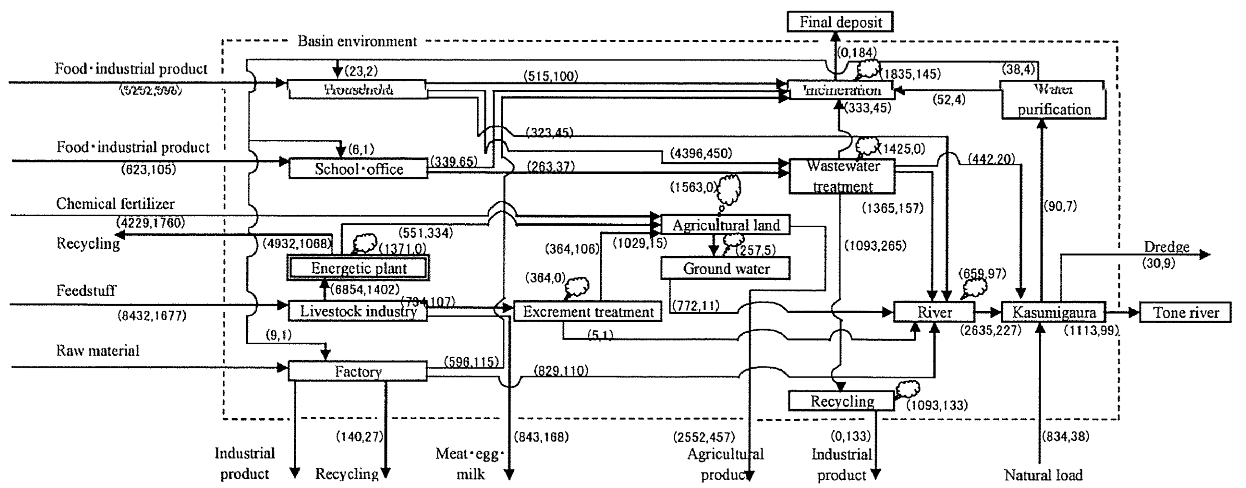

Fig. 12. Flow with animal urine energy system.

trogen to the lake through rivers is reduced around 800 tons. This is because that compost put into the agricultural land in the basin is drastically reduced. On the other hand, as for phosphorous almost no change is made.

5. Conclusion

Large amounts of nitrogen are imported into the basin as feed for livestock and the amount of nitrogen produced by composting is almost equivalent to the total amount necessary for the agricultural land in the basin. However, farmers continue to use chemical fertilizers for 80% of the nitrogen needed for agriculture. Therefore, large amounts of excess nitrogen flow into Lake Kasumigaura. This over use of nitrogen should be stopped because composting is sufficient to provide the necessary nitrogen for agriculture in the basin. Energy usage of the biomass wastes emitted by the livestock industry in the basin will improve the material balance and reduce GHG emissions. However, this alone is not enough to improve the water quality of the lake. It is also essential to reduce both usage of chemical fertilizers and import of feed by developing local circulation of nitrogen in the basin.

This is a typical hazard in which correspondence between cause and victim cannot be identified and a systematic approach is effective to find an overall solution.

References

Aramaki, S. and Suzuki. E., 2001. The supply and demand balance analysis for compost product to use usefully organic waste. J. Soc. Environ. Sci., Japan 14 (4), 367-371.

Fujisawa, K. and Higano, Y., 2000. Emission Control of Anthropogenic Nitrous Oxide. J. Japan Sect. RSAI 30 (1), 231-250.

Higano, Y., Central Research Institution for Feed and Livestock, National Federation of Agricultural Cooperative Associations, Mizuniya, T., and Piao, S., 2005. The development of spreading way for clean energy. The journal of project result for the biomass recycle development in Kasumigaura at the project to promote liaison between industry, learning, and government at a city, pp. 238-326.

Ibaraki Prefecture, 2004. The drawed paper for lakes and marshes water quality conservation plan in Kasumigaura, 221 pp.

Japan Center of Construction, 1999. Development of the Garbage Recycling System by Use of Disposer, p. 130.

Kobayashi, S., Sakurai, K., Mizunoya, T. and Higano, Y., 2005. Determination of unit resource generation and environmental load coefficients for evaluation of regional biomass-recycling systems. Planning Administration, 32 (4), 56-62.

Kunimitsu, T. and Muraoka, K., 1989. Analysis for river filth model. 266 pp.

Matsumoto, N., 2000. Development of Estimation Method and Evaluation of Nitrogen Flow in Regional Areas. Bull. Natl. Inst. Agro-Environ. Sci. 18, 81-152.

Nanzai, K. and Moriguchi, Y., 2002. Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables. 163 pp.

Sakurai, K., 2003. A study of comprehensive management for the environment of Lake Kasumigaura basin, Doctoral Dissertation submitted to the University of Tsukuba, p. 141.