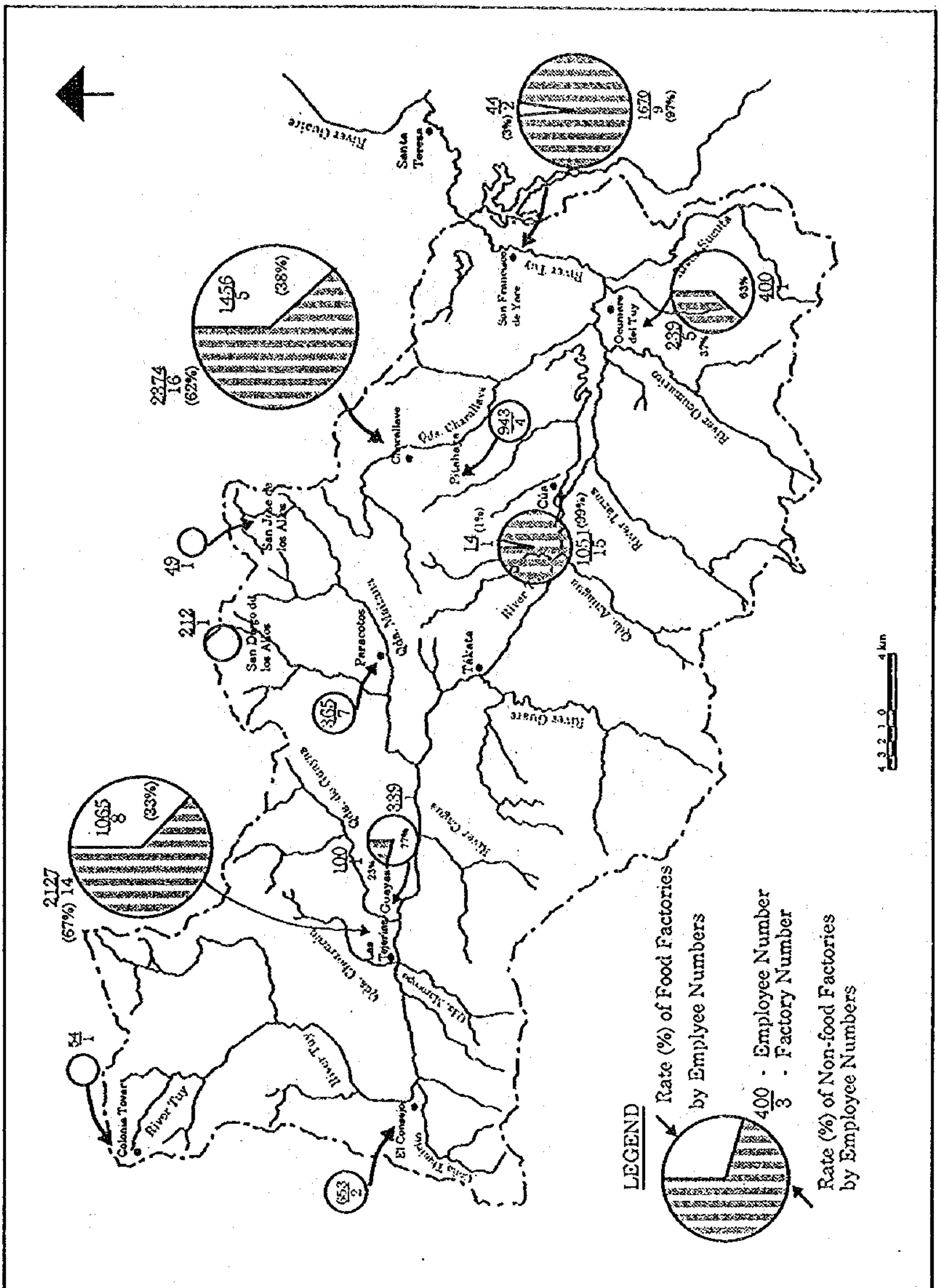
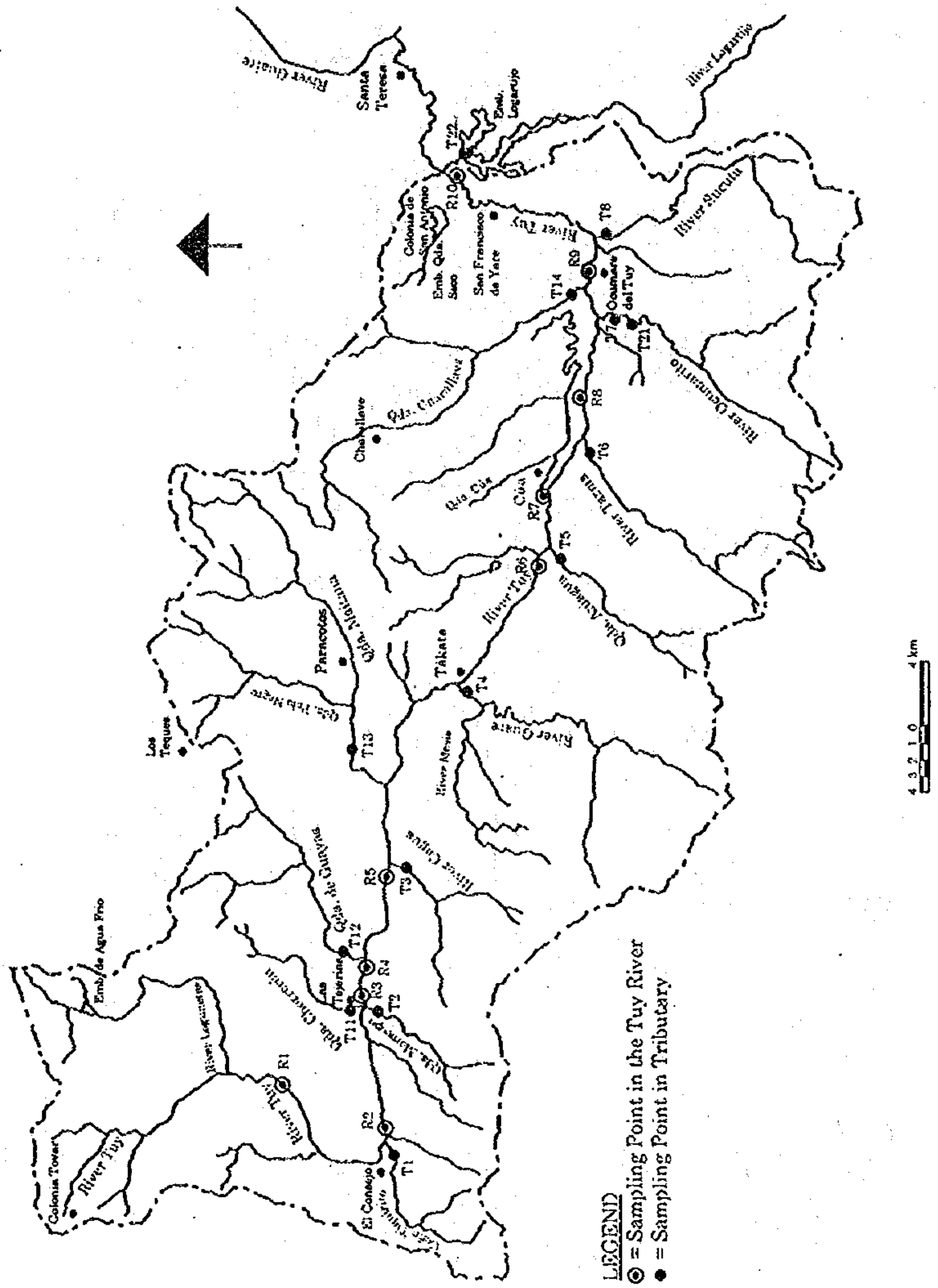
SECTOR C

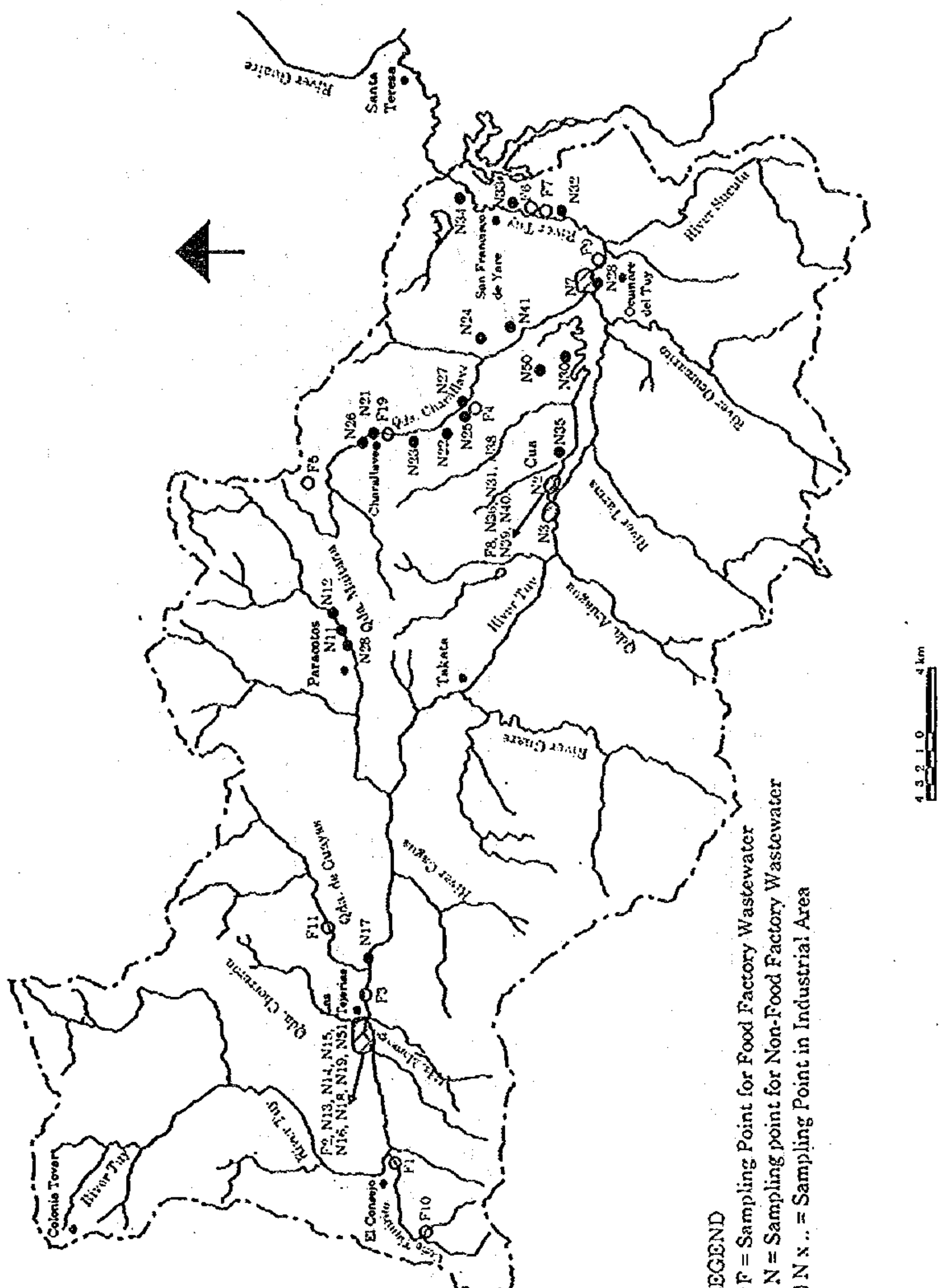
FIGURES



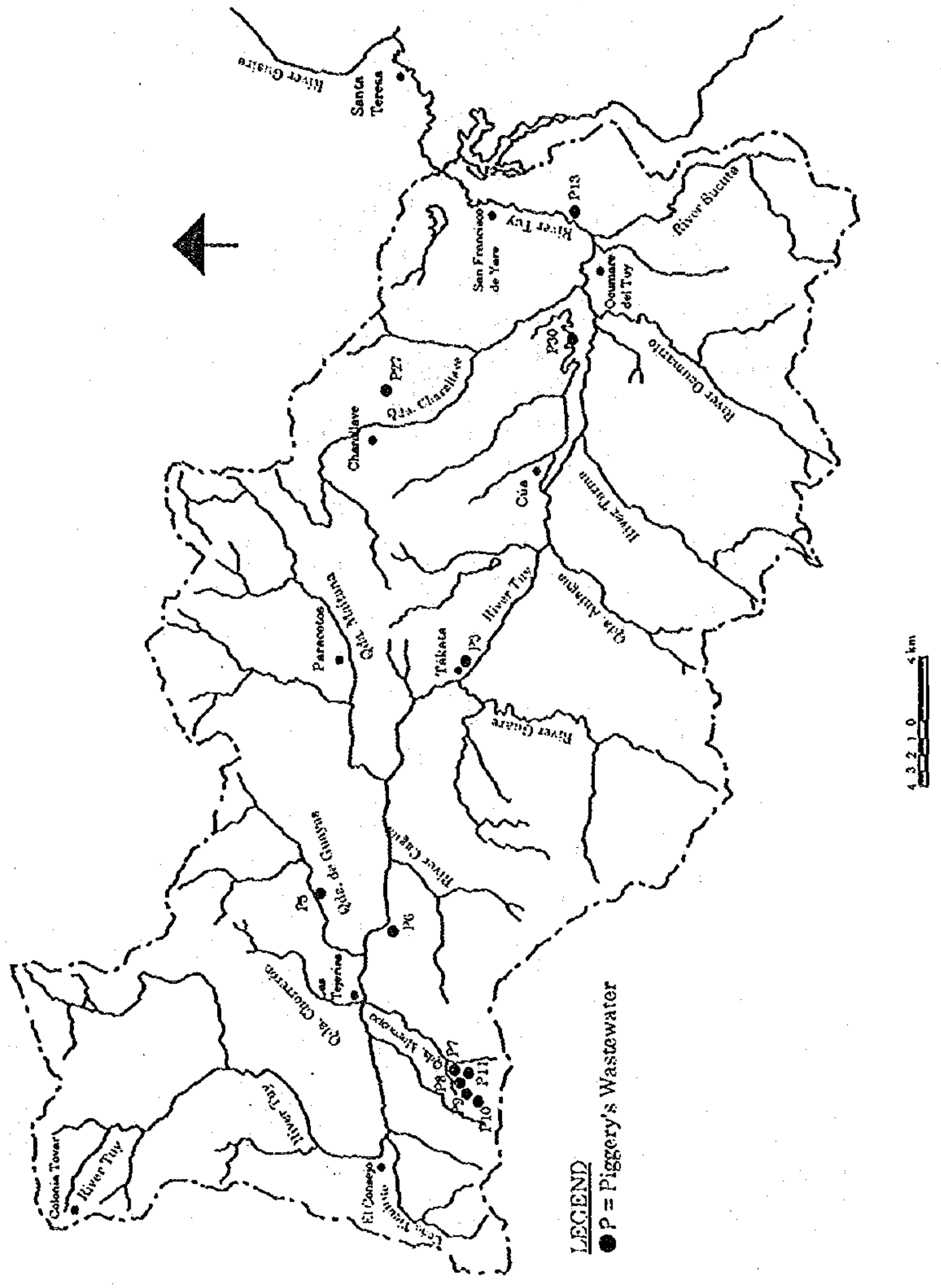
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.1-1	Distribution of Factory and Employee Numbers by Food and Non-food Factories
JAPAN INTERNATIONAL COOPERATION AGENCY		



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.1.2-1 (1/4)	Sampling Points on the Tuy River and Tributaries



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.2-1 Sampling Points on the Tuy River and Tributaries (2/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	



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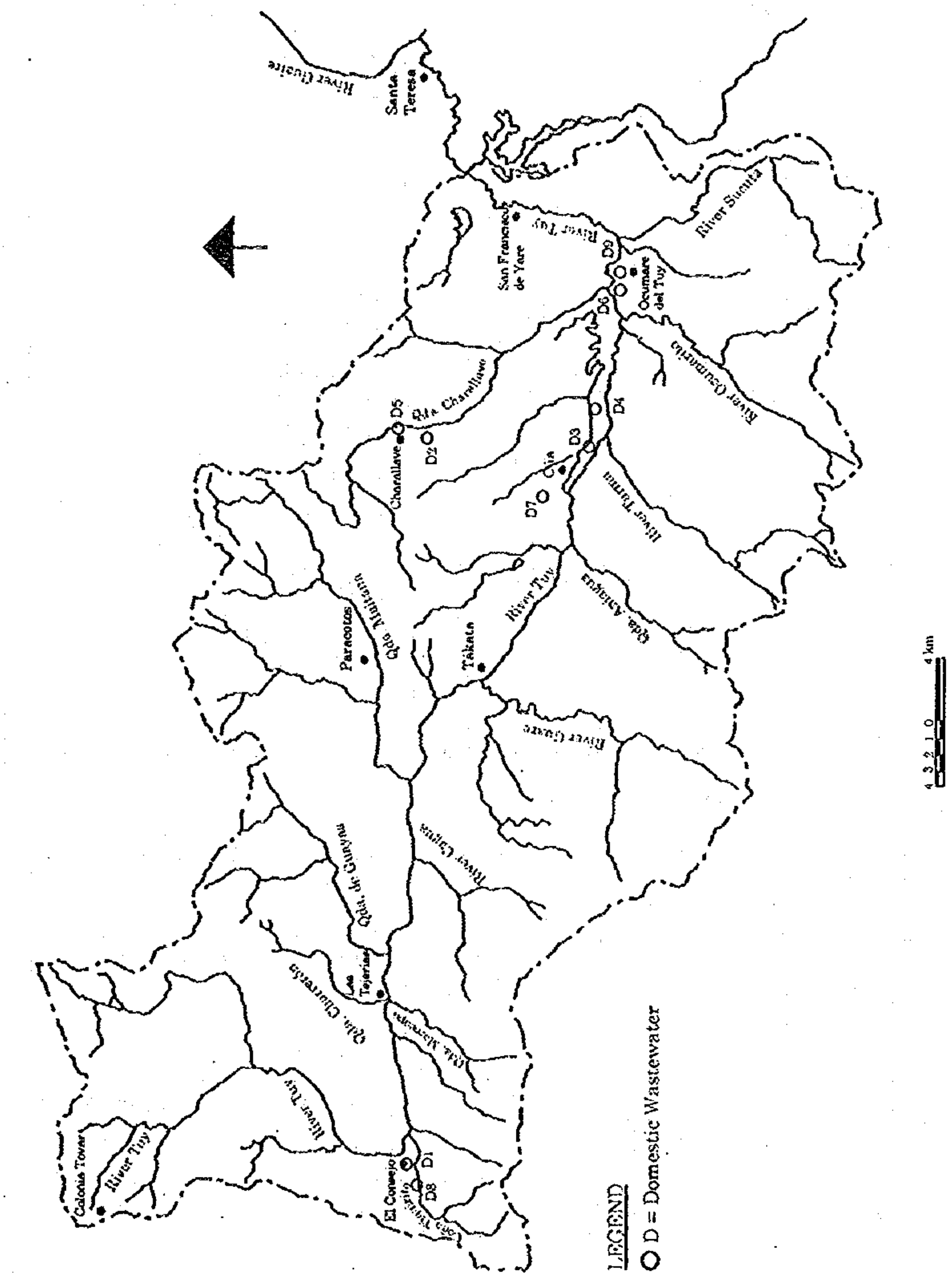

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Water Quality in Non-food Factory Wastewater

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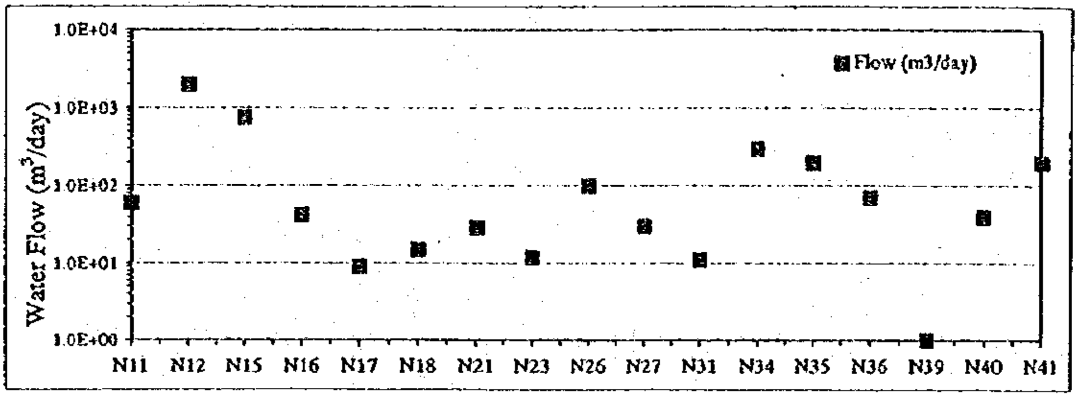

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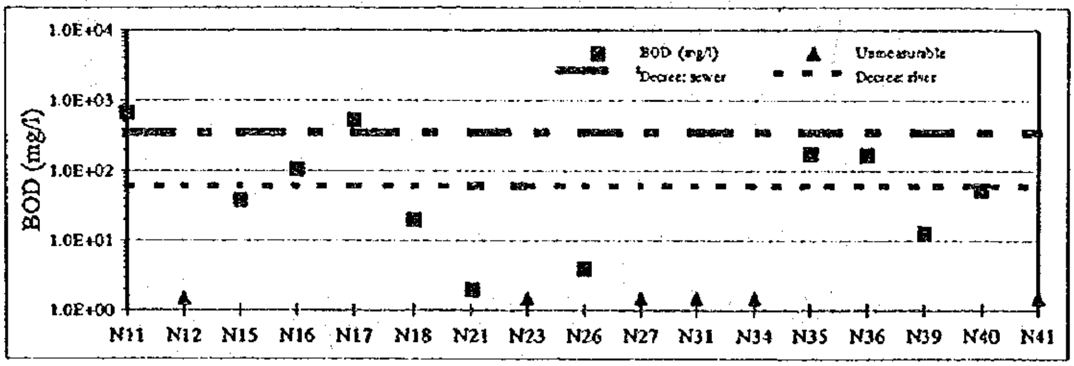

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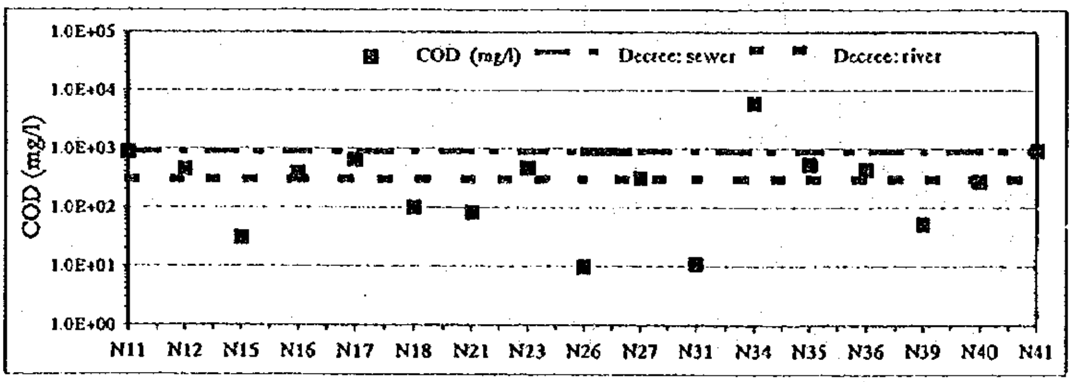

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Water Quality in Non-food Factory Wastewater

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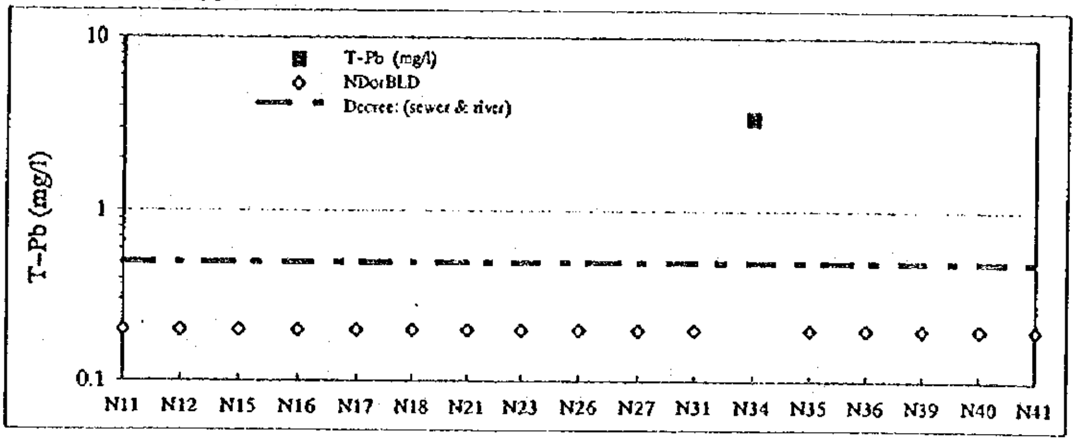

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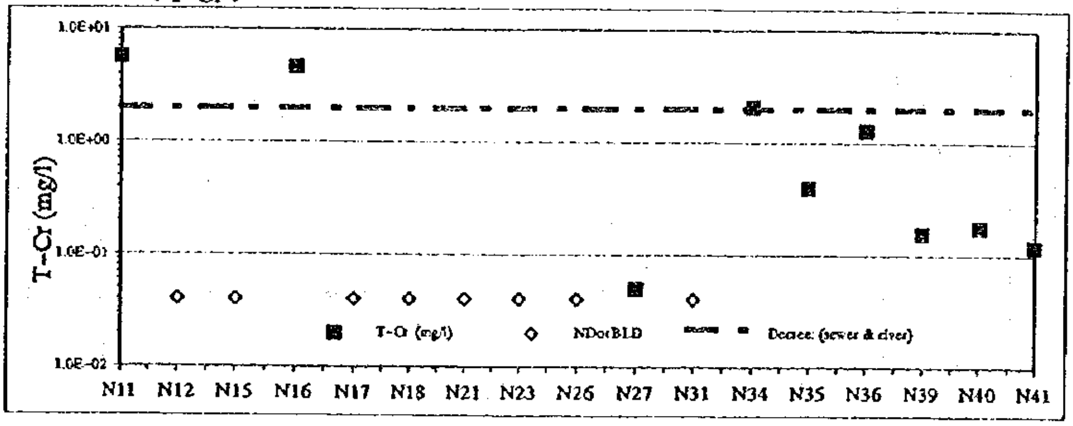

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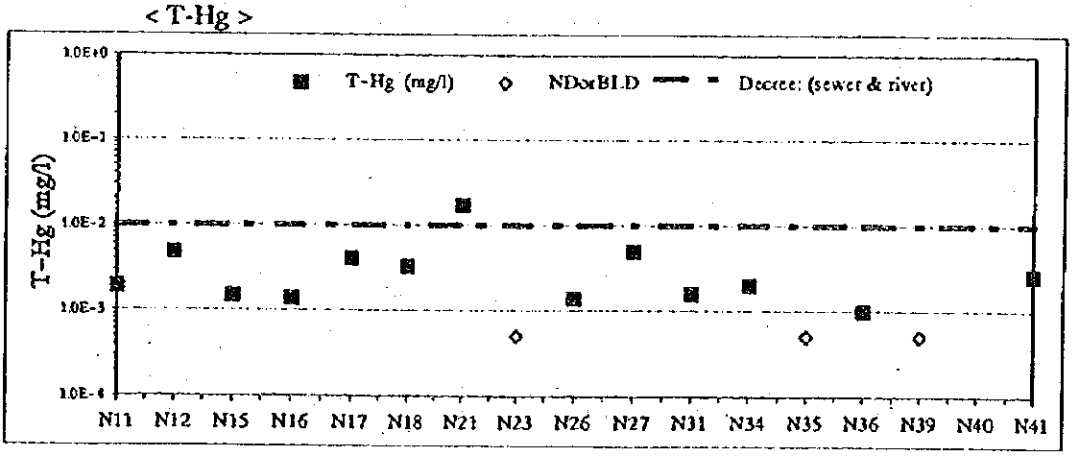

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.2-2 (2/4) Pollution from Non-food Factories
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Non-food Factory Wastewater

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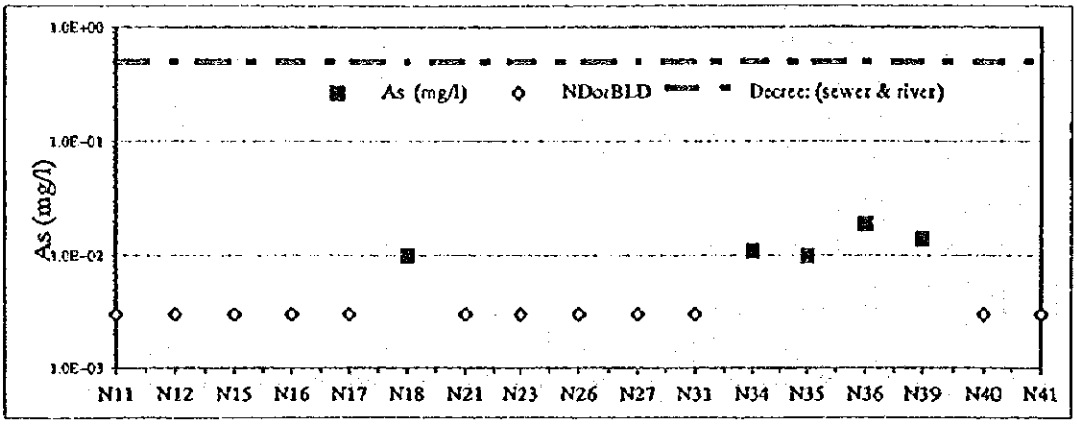

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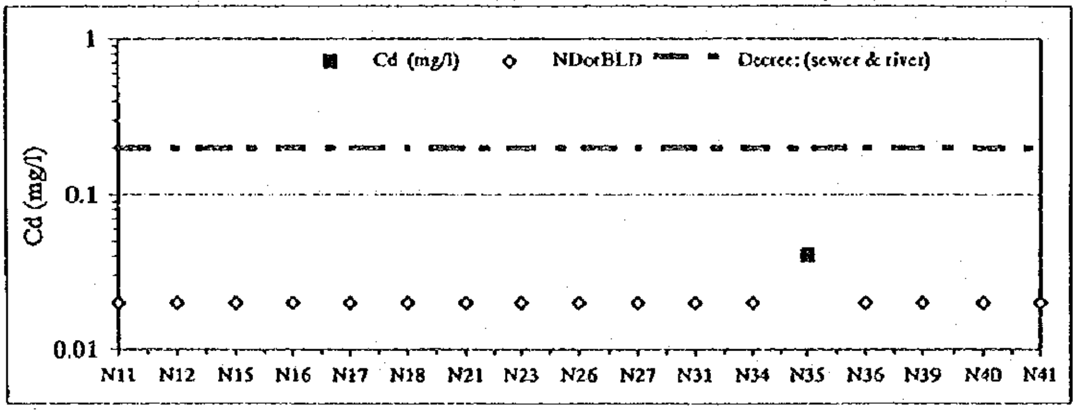

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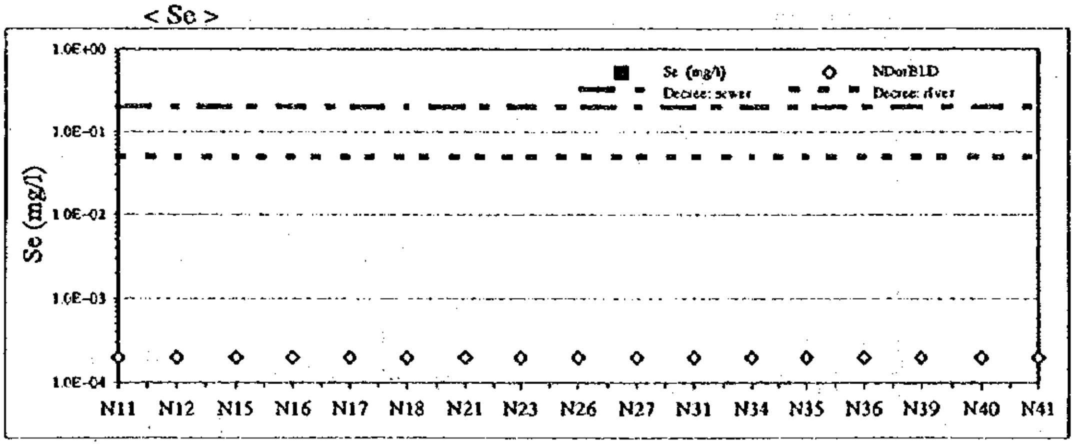

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.2-2 (3/4) Pollution from Non-food Factories
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Non-food Factory Wastewater

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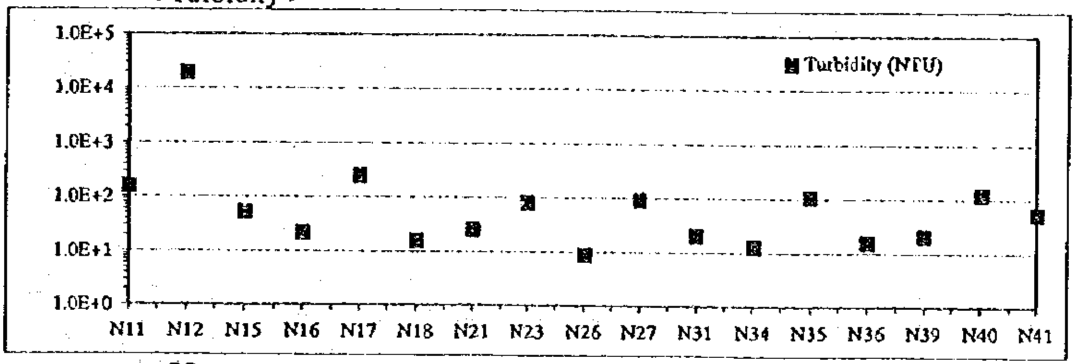

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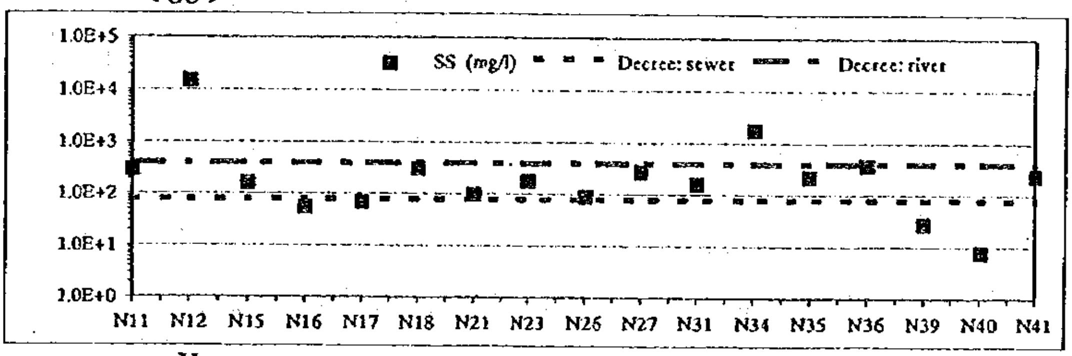

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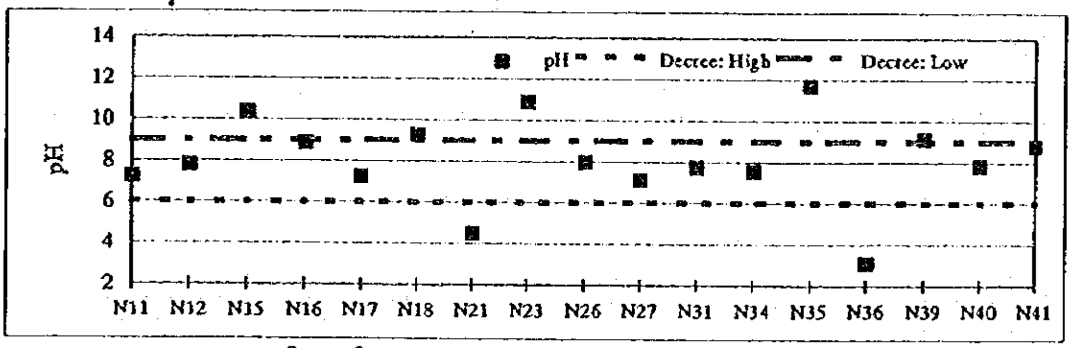

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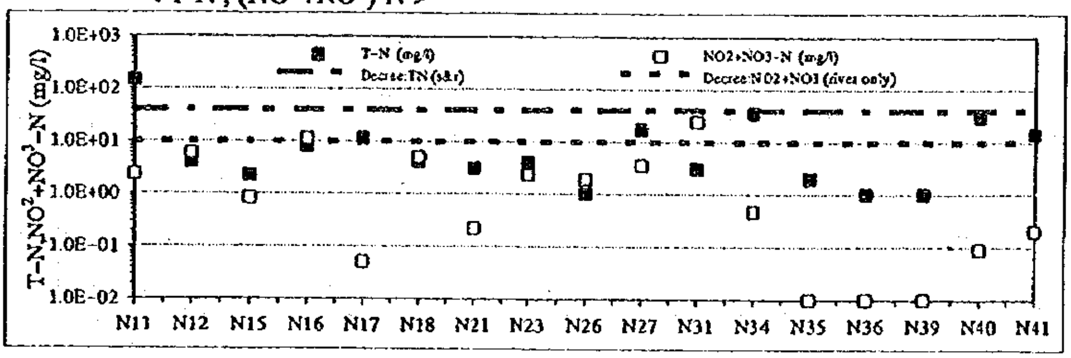

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.2-2 (4/4) Pollution from Non-food Factories
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Food Factory Wastewater

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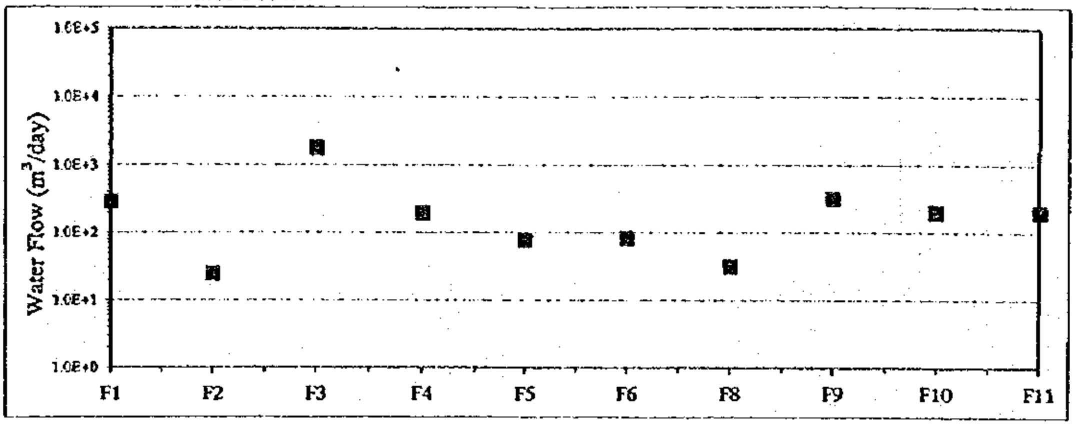

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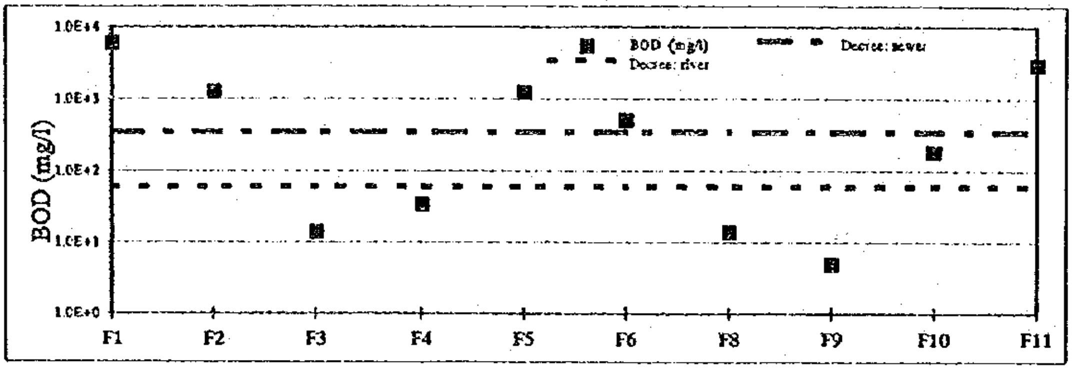

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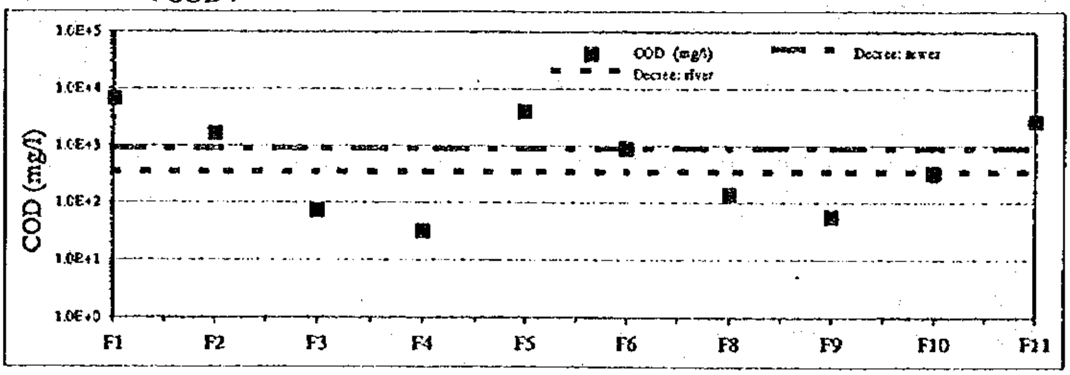

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Fig.1.2-3 (1/2) Pollution from Food Factories

Water Quality in Food Factory Wastewater

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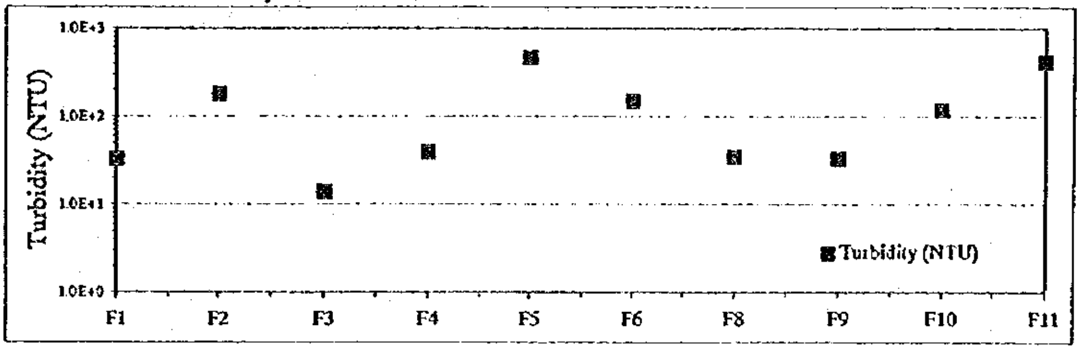

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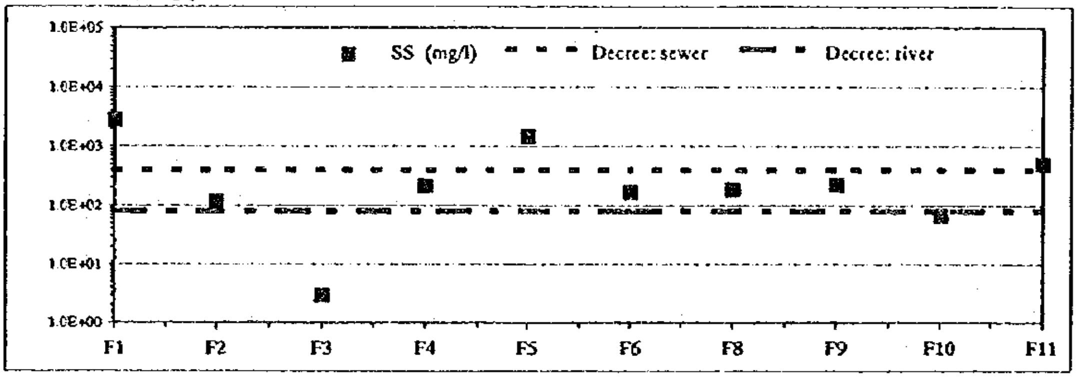

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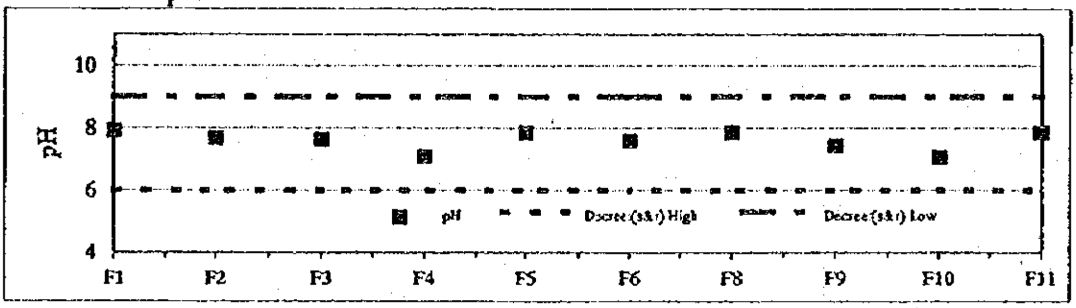

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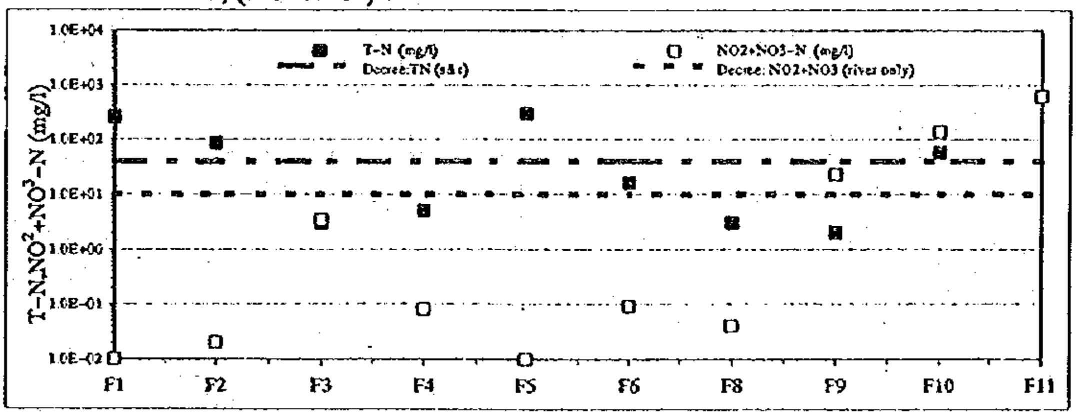

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.2-3 Pollution from Food Factories (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Water Quality in Piggery Wastewater

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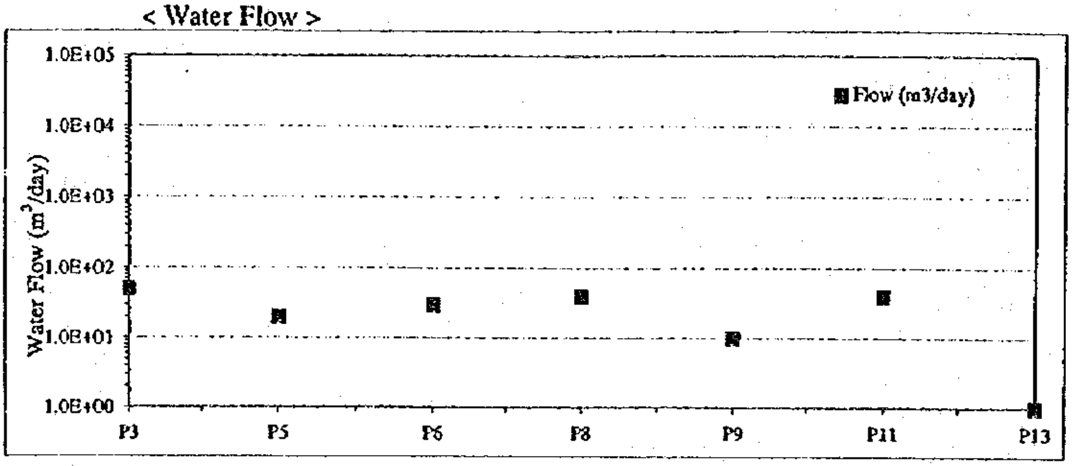

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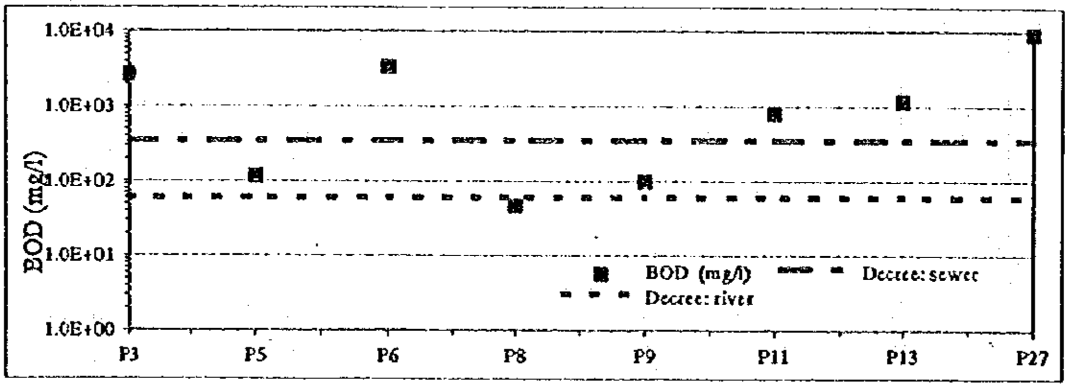

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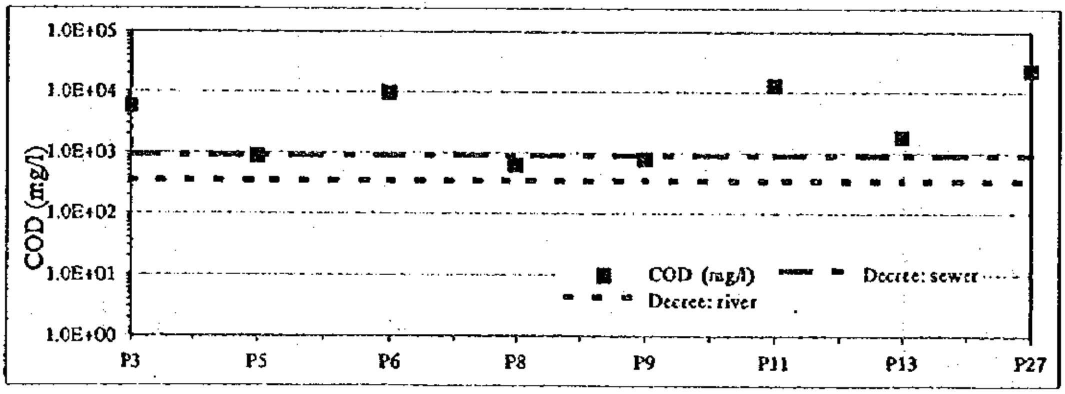

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Fig.1.2-4 (1/2) Pollution from Piggeries

Water Quality in Piggery Wastewater

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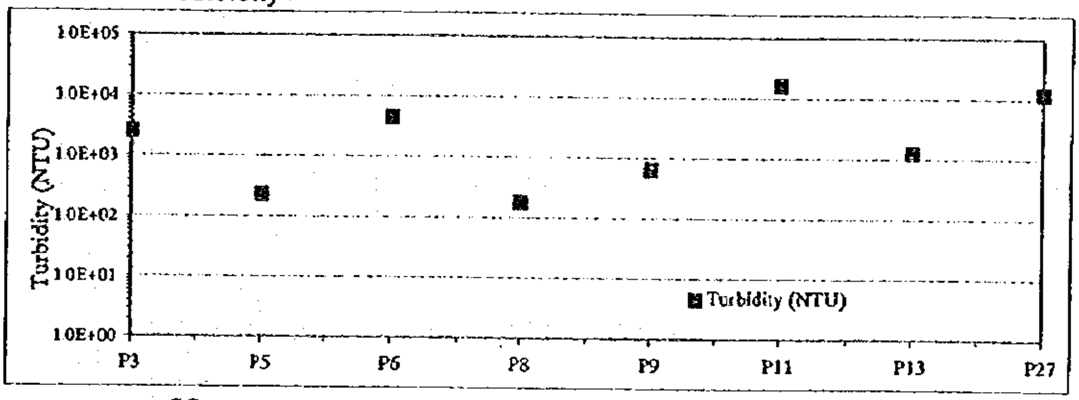

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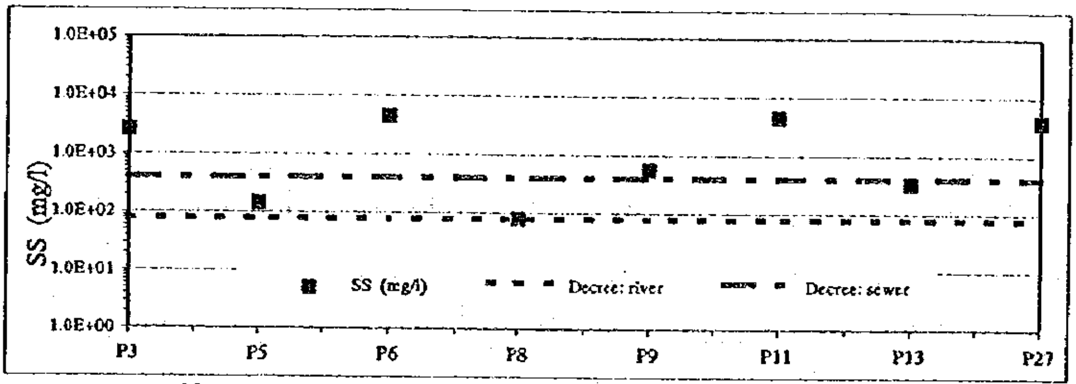

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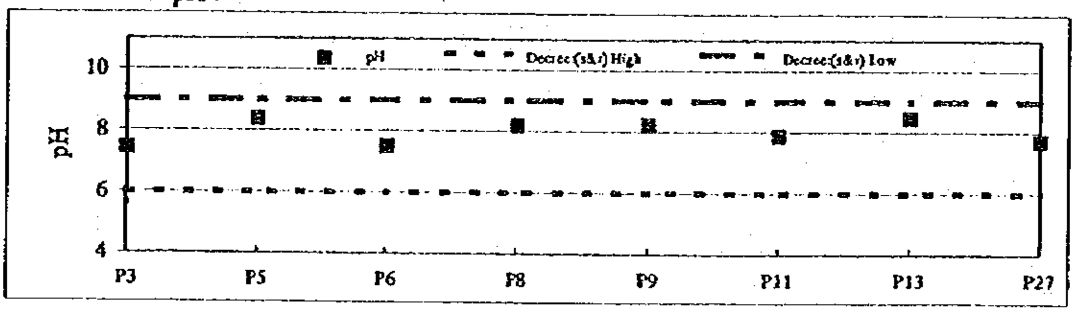
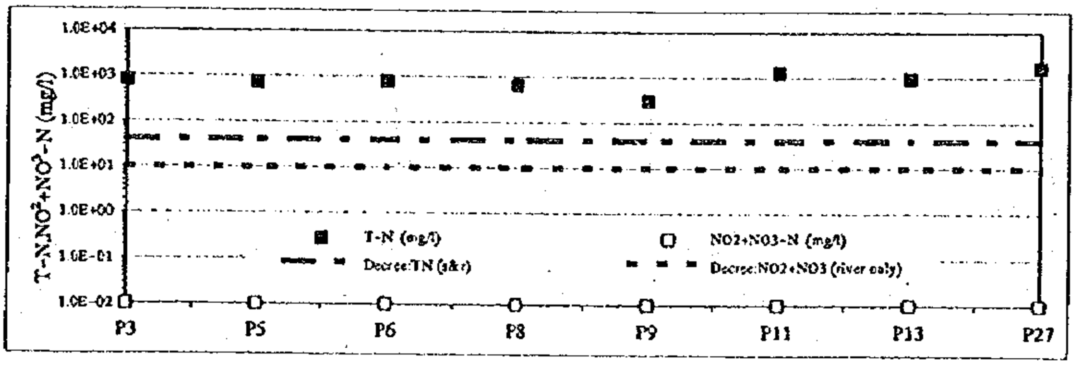
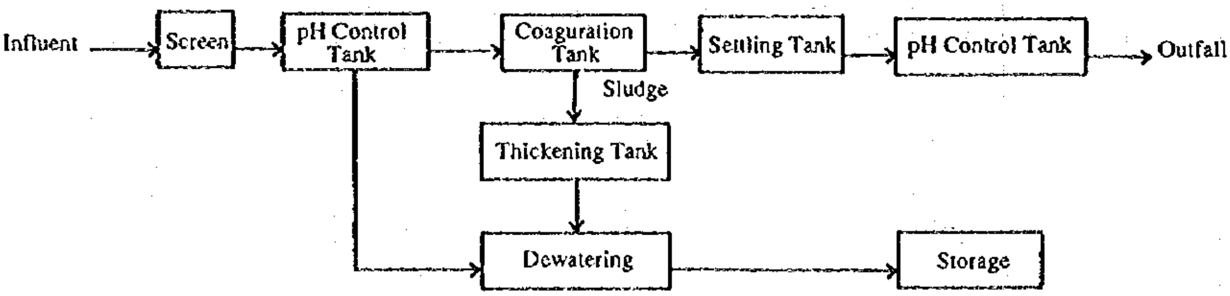


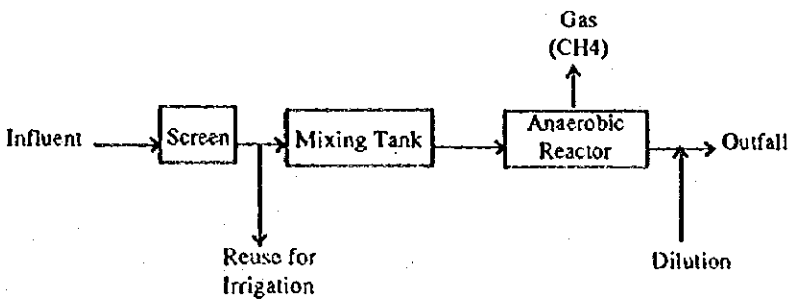


THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.1.2-4 (2/2)	Pollution from Piggeries
JAPAN INTERNATIONAL COOPERATION AGENCY		

Flowchart of Wastewater Treatment Process in Piggeries



Flowchart of Wastewater Treatment Process in Non-food Factories



Flowchart of Wastewater Treatment Process in Distilled Liquors Factories

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.2-1 Flow Chart of Treatment Plants of Factories and Piggeries
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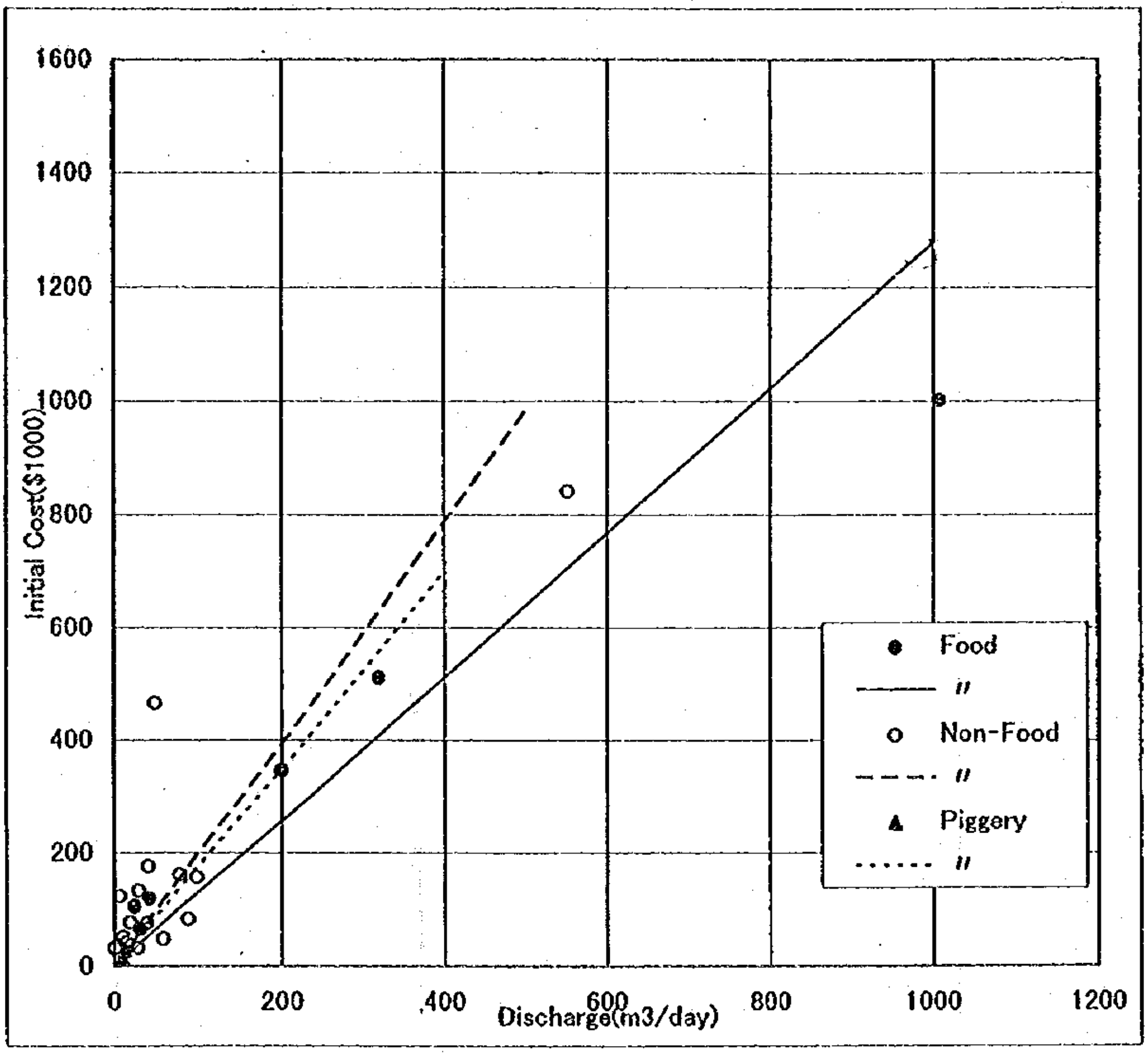

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.2-2 Treatment Plant Cost
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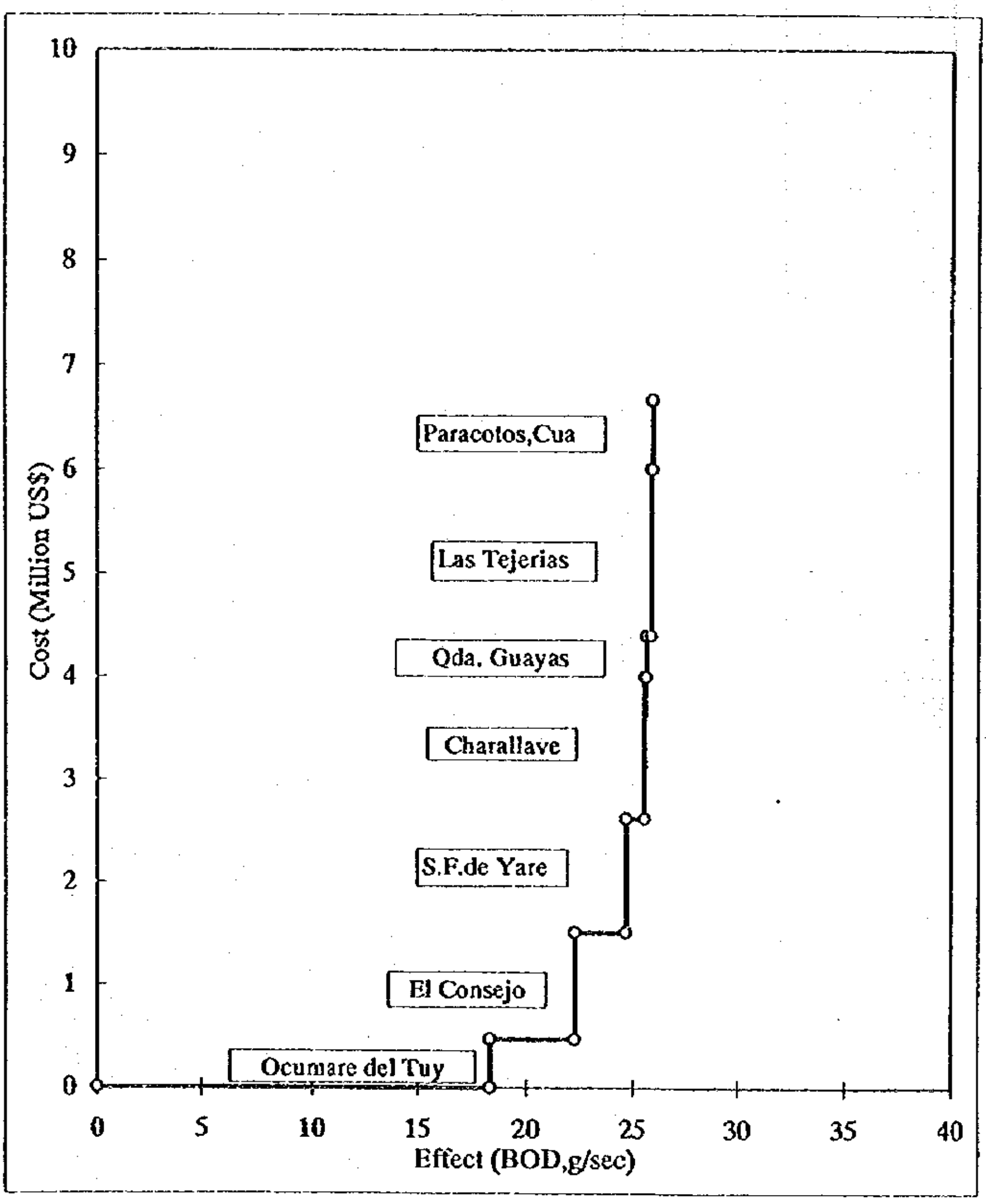
Factory: Effect and Cost of Factory Wastwater Treatment



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.3-1 Effect and Cost of Wastewater Treatment at Factories
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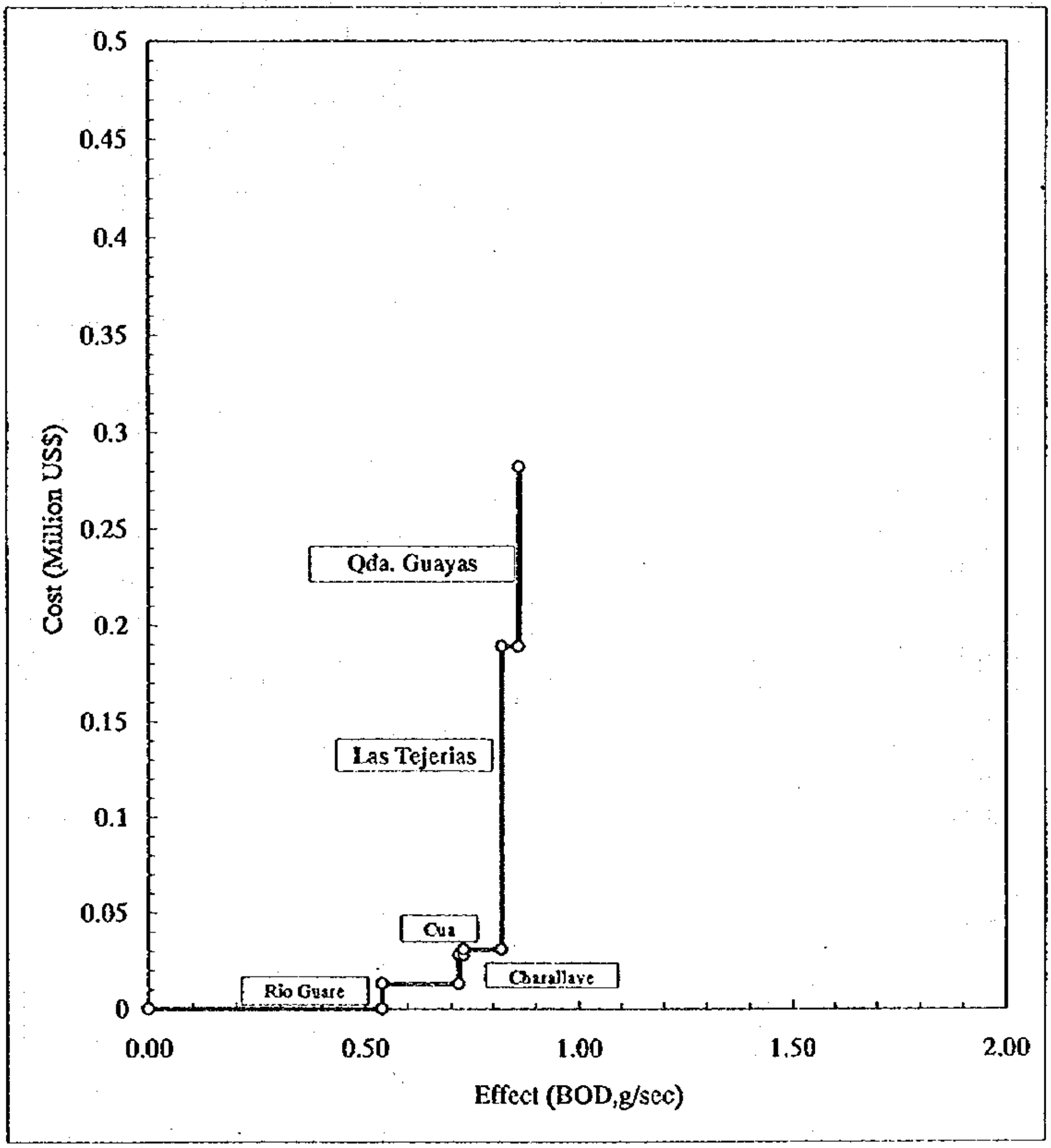
Piggery: Effect and Cost of Factory Wastwater Treatment



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.3-2 Effect and Cost of Wastewater Treatment at Piggeries
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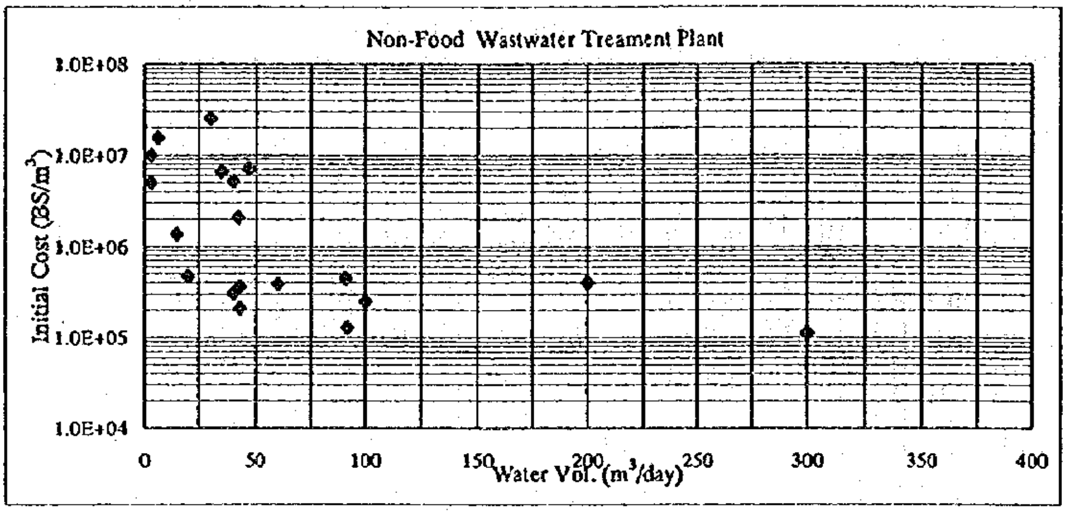

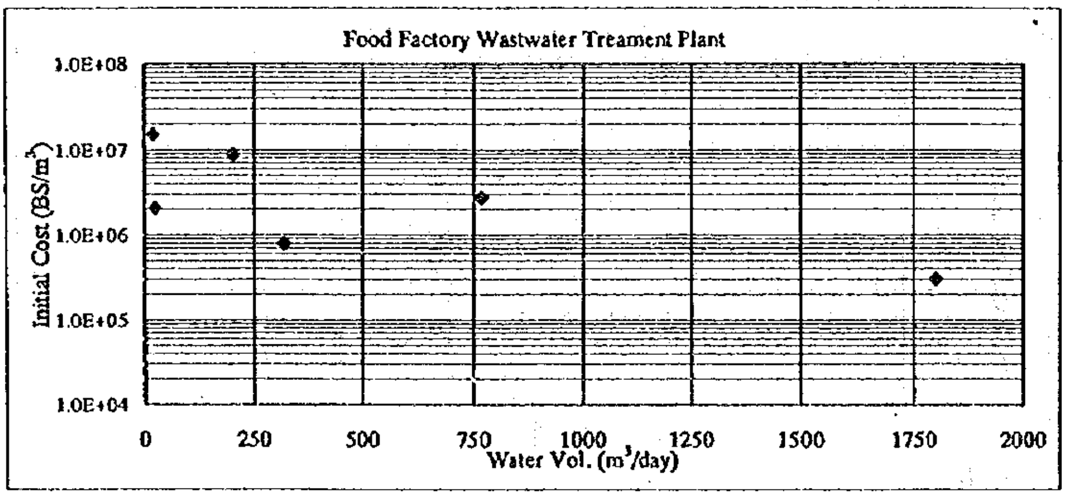

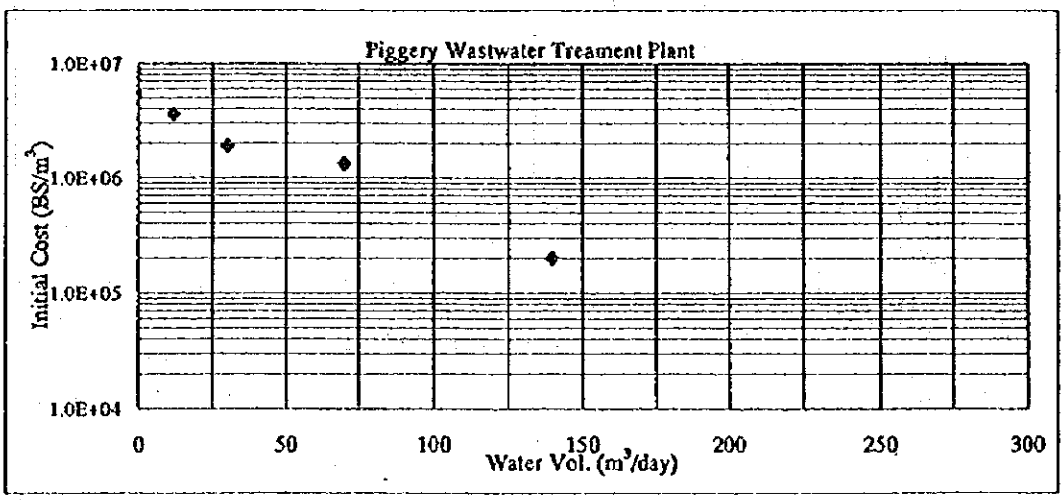

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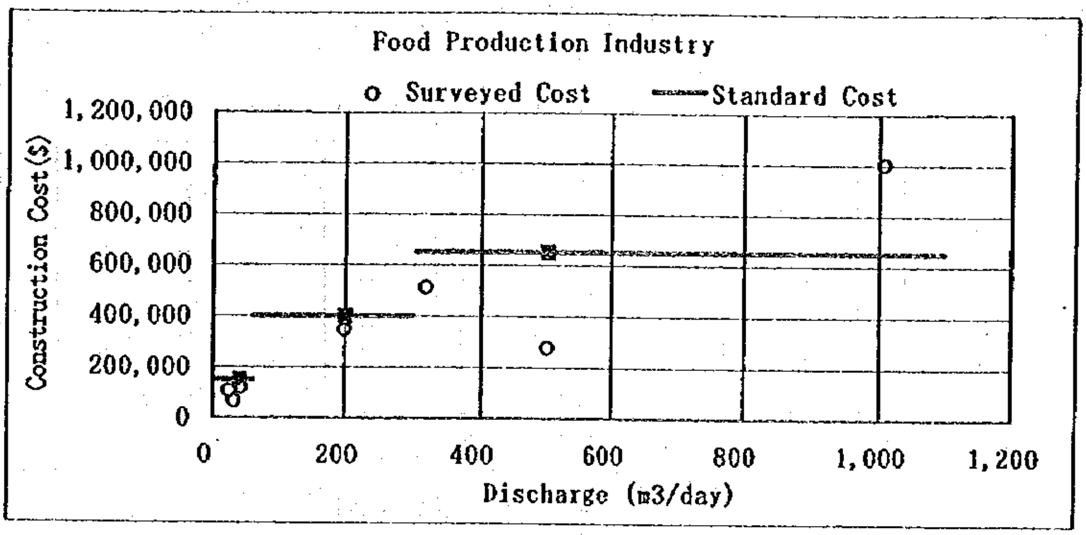
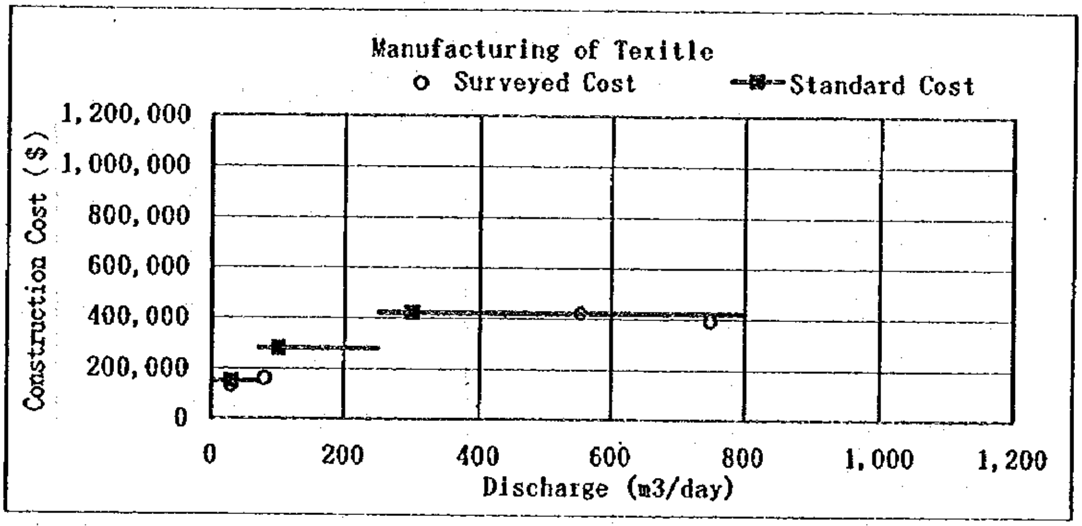
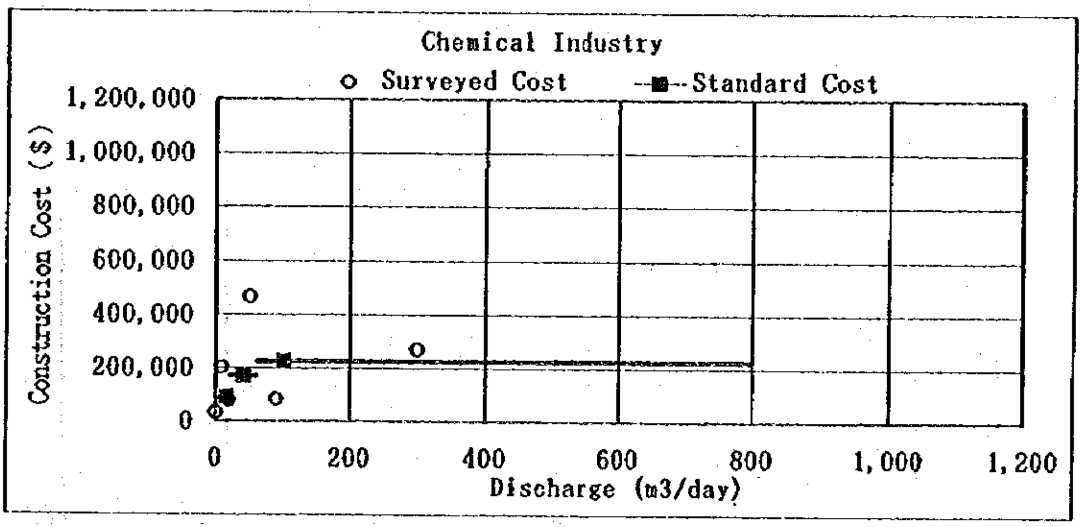
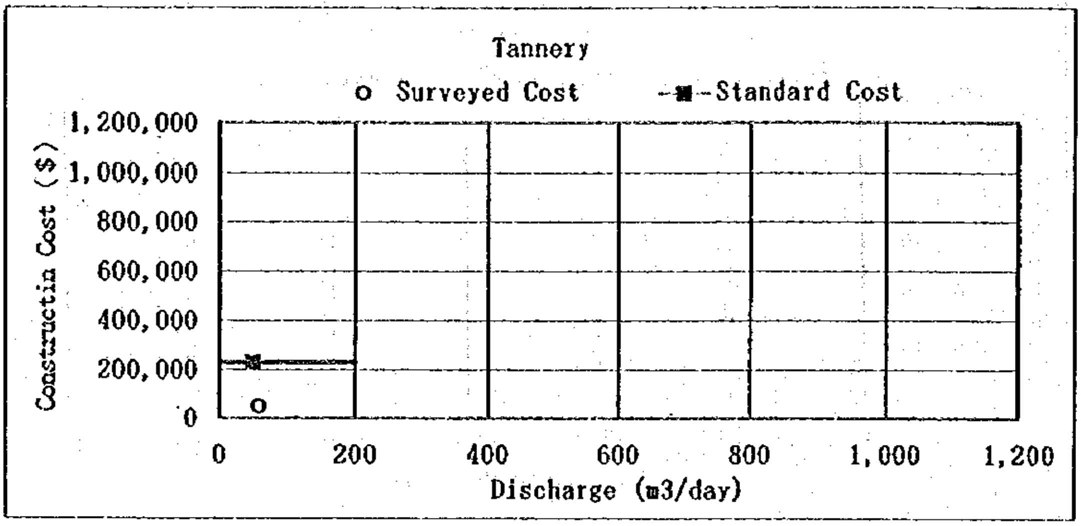
Fig.2.3-3 Unit Cost of Wastewater Treatment

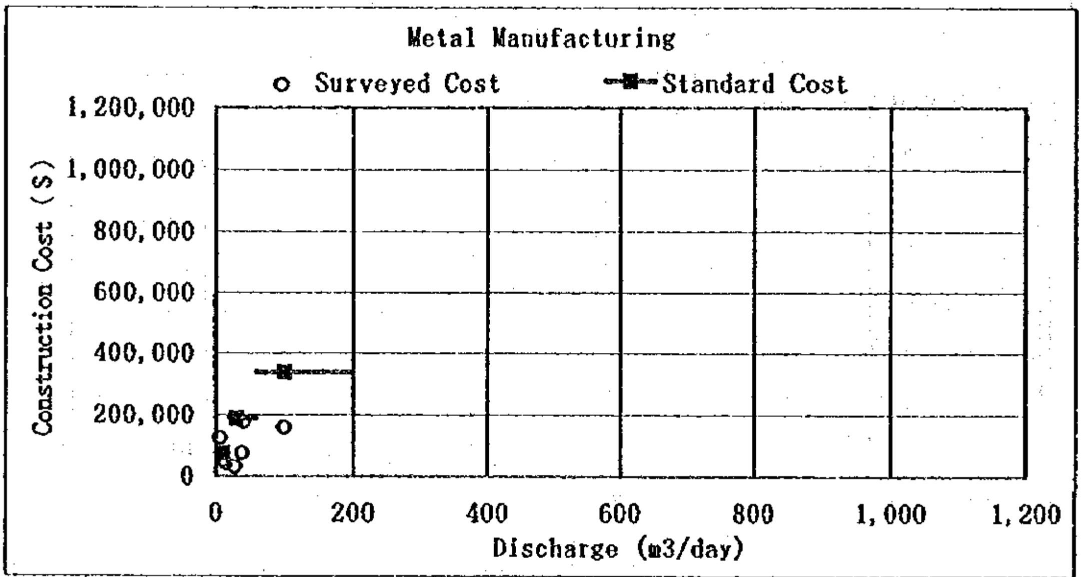


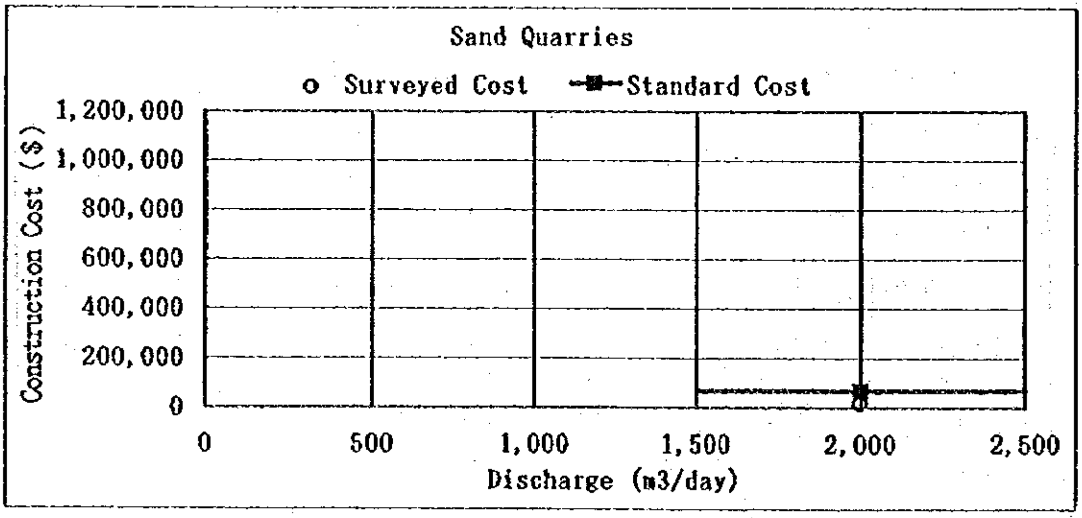




THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.3.3-1 (1/3) Relation between Cost and Discharge Volume of Treatment Plant







THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.3.3-1 (2/3) Relation between Cost and Discharge Volume of Treatment Plant
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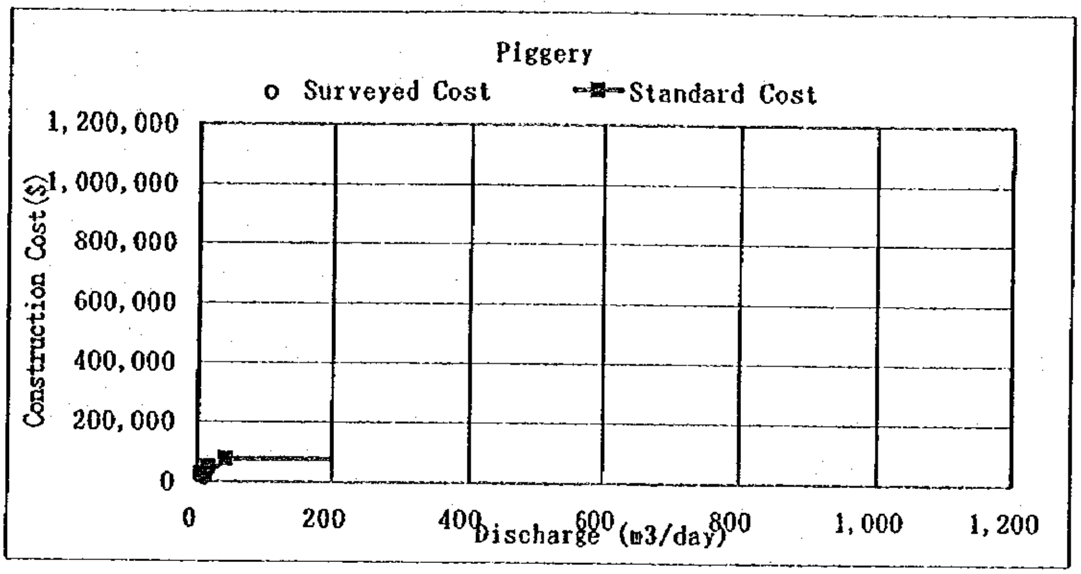

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.3.3-1 (3/3) Relation between Cost and Discharge Volume of Treatment Plant
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SECTOR D

SEWAGE TREATMENT

**THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF
THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN**

SECTOR D: SEWAGE TREATMENT

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1. GENERAL

1.1 Strategy of the Study

In the Tuy river basin, the production of organic pollutants and effluent pollution loads are brought mainly from factories and piggeries in the upper basin and from domestic wastewater in the middle basin. Pollution load from domestic wastewater is expected to increase in accordance with the population increase in urban areas.

In general, domestic wastewater treatment has been hardly promoted due to financial reasons, since effectiveness cannot be evaluated in monetary term. Even in developed countries, not much achievement on the treatment of domestic wastewater has been made. Recognizing the significance of preservation of better environment, the treatment of domestic wastewater is recently being promoted in urban areas in developing countries. In rural areas, treatment is minimal depending on individual efforts.

In the case of Tuy river basin, domestic wastewater from rural areas does not affect the pollution condition of the Tuy River at present, judging from the population ratio between rural and urban areas; i.e., only around 80% of the population in Las Tejerias, Cua , Charallave, Ocumare del Tuy and San Francisco de Yare live in urban areas. Therefore, the first priority should be given to the treatment of domestic wastewater from the urban areas. In this study it is assumed that treatment in rural areas will be undertaken after the sewage system in urban areas has been developed.

In this sector report, study is made putting emphasis on the treatment of domestic wastewater through the development of sewage network and construction of sewage treatment plant in the urban centers.

In the Master Plan study, the effectiveness of the sewage treatment plant in major urban areas was examined and priority was put on urban areas based on the cost effectiveness for reduction of pollution at the target poinst: Boca de Cagua and Toma de Agua. Furthermore, priority projects were selected to achieve the target set at the target points.

In the Feasibility Study, a more detailed study was conducted to identify the feasibility of the priority projects through preliminary design and cost estimate.

1.2 Consideration of Existing Sewage Treatment System

As shown in Sector A, 1.1.3, Population and Households, there presently exist the following sewage treatment system in the Tuy river basin.

Treatment System for Domestic Wastewater

No.	Location	Type of Treatment	Treatment capacity (m^3/day)	Water body (receiving)	Status
1	La Mora	Oxidation pond	800	C. Tiquirito	Not connected to sewer
2	El Consejo	Oxidation pond	600	C. Tiquirito	Not connected to sewer
3	Las Tejerias	Oxidation pond	800	Tuy River	Not connected to sewer
4	La Estrella (Charallave)	Biological Treatment	2,100	Qda.Charallave	Operating
5	Vallecito (Charallave)	Biological Treatment	500	Qda.Charallave	Operating
6	Ave Maria (S.F de Yare)	Biological Treatment	1,500	Tuy River	Stopped
7	Terraza de Cúa	Biological Treatment	800	Qda. Cúa	Operating

Among the seven treatment facilities, three are located in the upper basin and four in the middle basin. These systems consist of oxidation ponds to treat wastewater from neighboring residential areas. The collection rate of wastewater is low due to damaged pipes. Furthermore, ponds have been poorly maintained and therefore not functioning.

The remaining four areas are in the middle basin and are biological treatment plants. Although three of them are operating, the removal efficiency is not high because of the treatment method and poor maintenance. To secure the water quality discharged from these urban centers, these sewage systems should be replaced based on the results of this master plan study.

2. MASTER PLAN STUDY

2.1 Study on Sewage Treatment

2.1.1 Areas Covered by Public Sewerage System

A plan to provide a public sewerage-system for major urban areas with a population density of more than 40 persons/ha. in the Tuy river basin was studied by INOS in the 1970's. In this present study, the same areas are proposed to be covered by the sewerage system, as follows (refer to Fig. 2.1-1.

Urban Center	Area (ha)	Population (2010)	Density (person/ha)
El Consejo	710	39,000	54.8
Las Tejerías	619	31,000	49.8
Cúa	3,978	159,000	40.0
Charallave	4,736	199,000	42.1
Ocumare del Tuy	3,738	152,000	40.7
S. F. de Yare	680	30,000	44.4

2.1.2 Selection of Optimum Treatment Plant

<u>Sewage Treatment Plan</u>

The three most common types of treatment plant in Venezuela are (1) the Stabilization Pond System, (2) the Simplified Activated Sludge (Aerated) System, and (3) the Conventional Activated Sludge System. The comparison of factors to decide on the type to be introduced in this project are shown in the following table.

Factors	Stabilization Pond System	Simplified Activated Sludge (Aerated) System	Conventional Activated Sludge System
BOD Removal	*	**	**
System Stability	-	**	**
O&M	**	-	-
Land Acquisition	-	**	**
Sludge Removal	**	**	-
Cost	**	*	-

** Good * Fair - Poor

Judging from the table above, the second type is preliminarily selected as the optimum sewerage treatment plant in this study, though further study is required in the Feasibility Study stage. The flow sheet of these sewerage treatment plants is shown in Fig. 2.1-2.

<u>Individual Treatment System with Septic Tank</u>

In case of the individual treatment system, the septic tank is selected because it can be introduced at a low price, maintenance is easy and is commonly applied to the individual system.

2.1.3 Comparison between Independent and Integrated Systems for Urban Centers

Although distances among urban centers vary for the application of an integrated public sewerage system, it is necessary to examine the advantages and advantages of the following four cases for urban centers.

Case 1	One integrated sewerage system (Combination of all urban centers in the study area)
Case 2	Two integrated sewerage systems (One combination for all urban centers in the upper stream and another for all urban centers in the middle stream)
Case 3	Several integrated sewerage systems (Combination of several urban centers in the upper stream and in the middle stream)
Case 4	Independent sewerage system for each urban center

For economic comparison, the costs of land acquisition, sewage treatment plant and transmission pipe between urban centers are considered, while cost for the installation of sewerage pipe inside urban centers that is the same in all cases is disregarded. The comparison results are shown in the following table.

Case	Type of System	Cost (US$ Million)			
		Land Acquisition	Treatment Plant	Drainage Pipe between Urban Centers	Total
1	One Integrated System	2.40	27.30	29.83	59.55
2	Two Integrated Systems	2.66	30.35	18.75	51.76
3	Several Integrated Systems	2.98	34.00	15.45	52.43
4	Individual System	3.51	40.02	00.00	43.53

The cost comparison shows that Case 4 has an economic advantage; hence, it is applied to formulated the sewerage system plan.

2.1.4 Selection of Priority Area

The priority area to install a sewerage treatment plants is selected from the viewpoint of effectiveness to reduce pollution to the target point. As in the pollution reduction to factories and piggeries, the effectiveness to reduce pollution to the target point is examined on the following conditions:

(1) RIOS model is used to identify effectiveness.

(2) For pollution loan, that of the year 2010 is adopted.

(3) The pollution load after treatment including domestic wastewater and factory effluent is 350 mg/ltr.

(4) As the design wastewater, the following values are adopted: Design maximum daily wastewater of 388 liters and Design average daily wastewater of 272 liters (70% of design maximum daily wastewater) based of the report "Saneamiento del Río Tuy Venezuela PN 90.2241.9-01.100".

(5) The area for the construction of sewerage treatment plant is calculated assuming that the necessary area is 4 ha for 10,000 m^3/day of design wastewater volume.

(6) The construction cost is calculated by applying the unit cost of US$98/$m^3$ for wastewater based on the interview survey results.

(7) O&M cost is calculated by applying the cost of US$8/$m^3$ for wastewater.

Based on the above conditions, the effectiveness of the sewage treatment plant is evaluated by the reduction effect of pollution assuming that pollutants from each urban center are reduced by sewage treatment.

The study results are shown in Table 2.1-1. Judging from the table, the effectiveness of a treatment plant is the highest at Ocumare del Tuy, following by S. F. de Yare. Although the effectiveness at El Consejo and Las Tejerias is not so high, these areas are effective to improve the water quality at Boca de Cagua which is also a reference point to achieve the target.

The relation between effectiveness and cost is shown in Fig. 2.1-3. As the results, the following four areas are selected as the objective areas to develop the sewage system with sewage treatment plant: (1) Ocumare del Tuy, (2) San Fransisco de Yare, (3) Las Tejerias, and (4) El Consejo. The priority to install a sewage treatment plant is (1) Ocumare del Tuy, (2) Las Tejerias, (3) San Francisco de Yare, and (4) El Consejo.

2.1.5 Effectiveness Expected by the Construction of Sewerage System

This subsection presents the simulation results on the water quality betterment along the Tuy River, in case of the following two stages, probably generated by the realization of the sewage treatment plan established in Subsection 2.1.4.

<u>Year 2003</u>

(1) Water Quality Control in Factory Drainage: 350 ppm in terms of BOD at the outlets to the sewerage systems in El Consejo, Las Tejerías, Cúa, Charallave, Ocumare del Tuy and S. F. de Yare, while 60 ppm at the outlets to the rivers in the other areas.

(2) Water Quality Control in Livestock Drainage: 60 ppm in terms of BOD at the outlets to the rivers (The number of piggeries is assumed to be constant with time.)

(3) Sewage Treatment Plan: Two places at Ocumare del Tuy and Las Tejerías with a BOD value of 20 ppm to the rivers.

<u>Year 2010</u>

(1) Water Quality Control in Factory Drainage: Same as in the year 2003.

(2) Water Quality Control in Livestock Drainage: Same as in the year 2003.

(3) Sewage Treatment Plant: Additional two places at S. F. de Yare and El Consejo with the same water quality to the rivers.

As the results of simulation, water quality (BOD) at the reference points along the Tuy River is as follows:

(Unit: BOD, ppm)

No.	Sub-Basin Area	Present (1996)	2003	2010
R-2	Tovar, El Consejo	720	147	69
R-4	Las Tejerías	570	108	50
R-5	Q. Guayas (Boca de Cagua)	690	113	57
R-6	R. Guare	32	6.1	4.6
R-8	R. Tarma (Cúa)	30	16	19
R-9	Qda. Charallave	8	7.8	10
R-10	Ocumare, S. F. de Yare	7	3.2	3.0

2.2 Study on Measures to Reduce Organic Pollution in River

2.2.1 Storage Ponds

Besides the sewage treatment plans for factories and piggeries and the sewerage systems for urban centers, organic pollutants in rivers can be reduced by providing storage ponds for oxygenation. The effectiveness of storage ponds is examined under the following conditions.

(1) Considering geographical and pollution conditions, the proposed sites of storage pond are Las Tejerías and Cúa.

(2) Area and size of storage pond (assuming one day of retention time and BOD load rate of 80 kg/ha):

Site	Area of Pond (ha)	Capacity (m3)	Depth (m)	BOD Load per ha. (kg/ha/m)
Las Tejerías	70.0	1,050,000	1.5	5,600
Cúa	9.5	142,500	1.5	760

(3) Pollution Load Condition

Site	Water Quality of Effluent (mg/ltr)	Water Quantity of Effluent (l/s)	Pollution Load (kg/day))	BOD Load per ha. (kg/ha/m)
Las Tejerías	208	469	8,428	5,619
Cúa	9.7	1,252	1,049	700

The construction costs of the storage ponds are estimated as follows:

(Unit: Bs. million)

Item	Las Tejerías	Cúa
Excavation	1,050	142.5
Land Acquisition	700	95.0
Intake Facilities	40	20.0
Total	1,790	252.5

The effectiveness of the storage ponds is as shown below.

(BOD mg/ltr: Year 2010)

Target Point	Without Storage Pond	With Storage Pond	
		Las Tejerías	Cúa
Boca de Cagua	205	152	-
Toma de Agua	9.5	9.5	9.4

Judging from the table, the effectiveness of the storage ponds to reduce pollution load at Toma de Agua is low compared with their costs. Hence, construction of storage ponds is not recommended.

2.2.2 Introduction of Diluting Water

Studied herein is the effect, in terms of water quality betterment along the Tuy River, of introducing deluting water from a newly constructed small dam in a tributary of the river. The study conditions are as follows:

(1) Dam Site: At the Guare River, a right tributary in the middle reaches of the Tuy River.

(2) Water Quality and Volume of Diluting Water: 2 ppm in BOD and 1.1 m^3/sec.

(3) Study Case: For the year 2010 with water quality control for factories and livestock industry activated.

The study results shown below indicate that the introduction of deluting water is of a certain effect to better the water quality in the river.

(Unit: BOD, ppm)

No.	Sub-Basin Area	Without Diluting Water	With Diluting Water
R-6	R. Guare	9.7	5.9
R-8	R. Tarma (Cúa)	21.9	12.3
R-9	Qda. Charallave	10.8	9.0
R-10	Ocumare, S. G. de Yare (Toma de Agua)	9.5	8.0

3. feasibility study on the construction of sewage treatment plant in ocumare del tuy

3.1 Objective Area Covered by Sewerage System

Ocumare del Tuy is situated on the right bank in the middle reaches of the Tuy River and about 20 km upstream of the municipal water intake at Toma de Agua. According to the urban development plan established by the Ministry of Urban Development (MINDUR), the Ocumare del Tuy urban area covers not only Ocumare del Tuy, but Sucuta, Las Yaguas on the right bank of the Tuy River and Piloncito and Santa Barbara on the left bank. The urban area is 4,660 ha in total. However, Sucuta and Las Yaguas are located downstream of the proposed sewage treatment plant with less population. The objective area covered by the sewerage system is hence limited to the area of Ocumare del Tuy, Piloncito and Santa Barbara. The total area is 3,636 ha as shown in Fig. 3.1-1, which represents 78% of the Ocumare del Tuy urban area.

3.2 Conditions of the Objective Area

3.2.1 Land Use

At present, on the highland along the right bank of the Tuy River there exists a high density commercial and residential area. On the opposite side of the river is the industrial area of Zona Industrial Pampero. Small villages, commonly flanged by farmland or forest, scatter in Piloncito and Santa Barbara.

On the other hand, MINDUR has delineated a land use plan (see Fig. 3.2-1) for the Ocumare del Tuy urban area at the year 2010 (the target year of this Study). The plan suggests that the Ocumare urban area will expand toward the south and the opposite bank (Piloncito and Santa Barbara).

The following table shows the area by land use in the objective sewerage system area, both at present and in future, based on Fig. 3.2-1.

Description		Commercial District *1	Residential District	New Residential District	Industrial District	Forest, Agriculture *2	Others	Total
At Present	Area (ha)	51	696	-	191	2,638	60	3,636
	Ratio (%)	1.4	19.2	-	5.2	72.5	1.7	100.0
In Future	Area (ha)	63	696	1,650	576	516	134	3,636
	Ratio (%)	1.7	19.2	45.4	15.8	14.2	3.7	100.00

*1 Commercial District: including high density residential districts.
*2 Forest, Agriculture: including protection areas.

3.2.2 Population

The population in 1990, 2003 and 2010 in the objective sewerage system area is tabulated below. Most of the population is concentrated in Ocumare del Tuy commonly in each year although in the other areas small villages lie along main roads.

Year	1990	2003	2010
Ocumare del Tuy	61,043	111,715	151,985
Piloncito	4,075	7,458	10,146
Santa Barbara	1,691	3,095	4,210
Total	66,806	122,268	166,341
Quoted from	OCEI	JICA (M/P)	JICA (M/P)

3.2.3 Existing Pipe Network

In the urban area of Ocumare del Tuy, there exists the main drainage network provided by MINDUR. The outline of the drainage network originally designed is as shown in Table 3.2-1.

However, most of the drainage network is composed of open channels which receive storm runoff and some portions of the network have been damaged. Judging from the condition, it is necessary to newly provide or replace the present drainage channel to establish the sewage system in the urban area of Ocumare del Tuy.

Table 3.2-2 shows the breakdown of the secondary drainage network. According to this table, the density of the secondary network is about 91 m/ha.

3.3 Basic Plan

3.3.1 Future Urban Development

The proposed Ocumare del Tuy sewage treatment plant is designed to treat domestic waste and industrial effluent for the target year 2003. Apart from this, it is also necessary that the sewerage system be gradually expanded to cope with the future increase of pollutant load due to increases of population and industry after 2003. Therefore, the sewerage system plan for the Mid-term target year of 2010 is examined as well.

3.3.2 Objective Sewage

The sewage to be collected by this sewerage system is composed of domestic and industrial wastewater. Infiltration from ground water is also expected. In the case of industrial wastewater, it is assumed that the sewerage system will collect wastewater that complies with the national water quality standards.

3.3.3 Population in the Objective Area

Population

The population in the objective area is calculated based on the percentage of households located in the urban centers. The number of households was calculated using 1/25,000 aerial photographs and 1/5,000 topographic maps. The percentages are as follows:

Name of Municipality	Percentage of Households	Population	
		2003	2010
Ocumare del Tuy	95	106,129	144,386
Piloncito	70	5,220	7,102
Santa Barbara	90	2,786	3,789

Spatial Distribution of Population

To decide the sewerage network, spatial distribution of the total population is determined in the following manner.

(1) Ocumare del Tuy

The population in Ocumare del Tuy is assumed to be distributed based on the following land use of the urban area: (1) commercial area, (2) present residential area, and (3) future residential area.

The population density according to land use is calculated as follows:

(a) The population in the commercial area is calculated by assuming that the population density is 300 persons/ha for 2003 and 350 persons/ha for 2010 in accordance with MINDUR's urban development plan.

(b) The population in the present residential area is calculated by assuming that the population density is 90 persons/ha in 2003 and 120 persons/ha in 2010.

(c) The population in the future residential area is calculated by deducting the population of commercial and present residential areas from the total population.

(2) Piloncito and Santa Barbara

Since land use is mainly residential in Piloncito and Santa Barbara, the population is broadly distributed to the present and future residential areas. In this connection, it is assumed that in the present residential areas the current population density will remain constant and the future increases in population will occur in the future residential areas.

Although there are inhabitants in the areas having other land uses such as industrial, forest, and agricultural, the population in these areas are not accounted for because of low density.

The following table shows the spatial distribution of population:

Land Use	Area (ha)	Year 1990		Year 2003		Year 2010	
		Population	Density	Population	Density	Population	Density
Commercial District	63	17,997	284	19,020	300	22,190	350
Residential District	696	44,368	64	54,189	78	70,794	102
- Ocumare del Tuy	553	39,994	72	49,815	90	66,420	120
- Piloncito	77	2,853	37	2,853	37	2,853	37
- Santa Barbara	66	1,522	23	1,522	23	1,522	23
New Residential District	1,650	-	-	40,927	25	62,293	38
Industrial District	576	-	-	-	-	-	-
Forest, Agriculture	516	-	-	-	-	-	-
Others	134	-	-	-	-	-	-
Total	3,636	62,365	17	114,135	31	155,277	43

3.3.4 Industry in the Objective Area

The number of factories in the present and future projections are studied in Supporting Report, Sector C. It is assumed that all the factories are located in the industrial zones and the discharge wastewaters are within the limits of the water quality standards and thus the sewerage system will collect all the wastewater from factories. The volume of industrial wastewater is calculated based on the number of employees in each industry. The number of employees are shown in Table 3.3-1.

3.3.5 Design Wastewater Discharge

The following three kinds of design wastewater discharge are set for designing the corresponding facilities:

(1) Mean daily discharge: for sludge treatment facilities
(2) Maximum daily discharge: for wastewater treatment facilities
(3) Maximum hourly discharge: for settling basin and pump facilities

Domestic Wastewater

(1) Wastewater Discharge per Capita

The wastewater discharge per capita from domestic origin is determined based on the past study results shown in Table 3.3-2. The following is the same applied in this study:

Year	Wastewater Discharge per Capita (l/day)	Remarks
1995	238	Study result in C applied
2003	287	Proportionately derived from the other two
2010	330	Average of the three study results (A, B and C)

(2) Wastewater Discharge

The design domestic wastewater discharge is calculated as: [Wastewater Discharge per Capita × Population]. The results are tabulated below.

Year	Population (person)	Mean Daily		Maximum Daily		Maximum Hourly	
		Per Capita Discharge (m^3/person/day)	Discharge (m^3/day)	Per Capita Discharge (m^3/person/day)	Discharge (m^3/day)	Per Capita Discharge (m^3/person/day)	Discharge (m^3/day)
1990	62,365	0.207	12,930	0.296	18,472	0.444	27,708
2000	99,186	0.269	26,648	0.384	38,068	0.576	57,103
2003	114,134	0.287	32,764	0.410	46,806	0.615	70,209
2005	124,100	0.299	37,147	0.428	53,068	0.641	79,602
2010	155,277	0.330	51,241	0.471	73,202	0.707	109,803

Note: Mean Daily : Maximum Daily : Maximum Hourly = 0.7 : 1.0 : 1.5, based on INOS data, Proyecto de los Colectores Generales de la Futura Poblacion, 1987.)

Industrial Wastewater

The design wastewater discharge is obtained from: [Wastewater Discharge per Capita × Number of Employees] (both are presented in Table 3.3-1 by industrial category). The calculation results are shown below.

Year	Mean Daily (m^3/day)	Maximum Daily (m^3/day)	Maximum Hourly (m^3/day)
1995	1,073	1,073	2,146
2000	1,342	1,342	2,684
2003	1,583	1,583	3,165
2005	1,743	1,743	3,487
2010	2,352	2,352	4,705

Note: Mean Daily : Maximum Daily : Maximum Hourly = 1 : 1 : 2.

Groundwater

Groundwater infiltrates into the sewerage system through joints and breaks. The volume of groundwater infiltration is assumed to be 15% of the domestic wastewater. The groundwater is considered only in the calculation of the maximum hourly wastewater discharge.

Total Wastewater Discharge

The total wastewater discharge consisting of domestic wastewater, industrial wastewater and infiltration is tabulated below.

(Unit: m^3/day)

Category	Year 2010			Year 2003		
	Mean Daily	Maximum Daily	Maximum Hourly	Mean Daily	Maximum Daily	Maximum Hourly
Domestic Wastewater	51,241	73,202	109,803	32,764	46,806	70,209
Industrial Wastewater	2,352	2,352	4,705	1,583	1,583	3,165
Infiltration	-	-	10,980	-	-	7,021
Total	53,594	75,554	125,488	34,347	48,389	80,395

3.3.6 Target Water Quality

Inflow Water Quality

(1) Water Quality of Domestic Wastewater

Inflow water quality from domestic wastewater is calculated in the following manner:

Water Quality (mg/ltr) = Pollution Load (mg/day) / Wastewater Discharge (l/day)

Herein, the pollution load is calculated applying BOD in the following equation:

BOD Pollution Loan = BOD pollution load per capita (g/person/day) × population

In this equation, BOD pollution load per capita is 54 g/person/day as used in previous studies.

(2) Water Quality of Industrial Wastewater

Water quality of inflow from industrial wastewater is assumed to be within the water quality standard for factories: BOD = 350 (mg/ltr).

(3) Water Quality of Inflow to Sewage Treatment Plant

Based on the total wastewater discharge and BOD load from domestic and industrial wastewaters, the water quality of inflow to the sewage treatment plant is calculated as below.

Category	Year 2010					Year 2003				
	Mean Daily Dis-charge	Pollutant Load (kg/day)		Water Quality (mg/ltr)		Mean Daily Dis-charge	Pollutant Load (kg/day)		Water Quality (mg/ltr)	
		BOD	SS	BOD	SS		BOD	SS	BOD	SS
Domestic Wastewater	51,241	8,385	8,540	164	167	32,764	6,163	6,277	188	192
Industrial Wastewater	2,352	823	941	350	400	1,583	554	633	350	400
Total/Average	53,594	9,208	9,481	172	177	34,347	6,717	6,910	196	201

Target Water Quality of Discharge from Sewage Treatment Plant

As shown in the table above, the water quality of inflow to the sewage treatment plant is estimated at about 170 mg/ltr in the year 2010. Moreover, to achieve the target water quality by the year 2010, it is required to reduce the BOD pollution load at Ocumare del Tuy by 90% in accordance with the results of the RIOS model water quality analysis. Consequently, the target water quality of the discharge from the sewage treatment plant is set at 20 mg/ltr of BOD, corresponding to approximately 12% of the inflow water BOD.

3.3.7 Sewage Treatment Plant

Site

The site of the sewage treatment plant is decided considering the availability of sufficient open space near Ocumare del Tuy and the geographical advantage for the collection of all sewage from the basin.

Area Available for Construction of Sewage Treatment Plant

The area of the site available for construction of the sewage treatment plant is roughly 40 ha. Since the site is low and inundation is possible, a flood protection dike surrounding the sewage treatment plant is proposed.

Method of Sewage Treatment

In the master plan study, three alternative methods of sewage treatment were examined: (1) stabilization pond system, (2) activated sludge/aerated system, (3) simplified activated sludge system. The simplified activated sludge system was selected because of the simplicity of maintenance, although this method requires a relatively large area.

In the feasibility study, this system's suitability was reexamined taking into account the future population increases and available land around the Ocumare del Tuy district for a sewage treatment plant. The reexamination provided the following conclusions:

(1) Judging from the future population projection for 2010, the population will be 2.5 times that of 1990. It is, therefore, desirable to apply a method that requires less space, even though the method requires more maintenance work. Thus, the activated sludge system is proposed to be applied in the future.

(2) However, in the initial stage, a low maintenance method is preferable because of the inexperience in the operation and maintenance of sewage treatment plants in Venezuela. At current population levels, need for space is not critical.

(3) Among low maintenance methods, the trickling filter method is preferred compared with the simplified activated sludge system, because of the flexibility with variable inflows and recovery from the accidental inflow of toxicants.

Consequently, it is proposed that the trickling filter method be applied from the beginning of the year 2003, and from then be gradually changed to the activated sludge system to cope with the future increases in population.

3.3.8 Drainage Pipe Network

In this study, the sewer network proposed by MINDUR is adopted with minor modifications due to the different locations of sewage treatment plants proposed.

3.3.9 Pumping Station

In general, gravity collectors are preferable, but geographical restraints often prevent this from practice. In this case, it is necessary to provide a pump to collect the sewage. In the case of Ocumare del Tuy, one pumping station is necessary to collect the sewage from the areas located on the opposite side of the river. The sewage collector is proposed to be placed under to cross the Tuy River and the sewage is pumped up to the treatment plant.

3.4 Preliminary Design

3.4.1 Sewage Treatment Plant

<u>Treatment Method</u>

(1) Wastewater Treatment	• Trickling filter method by the year 2003 (see Figs. 3.4-1 and 3.4-2) • Activated sludge method after 2003 by 2010
(2) Sludge Treatment	• Non-heating non-mixing digestion method with drying bed

Treatment Capacity

Description	Year 2003		Year 2010	
	BOD	SS	BOD	SS
Water Quality of Inflow (mg/ltr)	200	200	170	180
Removal Rate of Primary Settling and First Filter (%)	55	50	-	-
Removal Rate of Final Settling and Secondary Filter (%)	80	70	-	-
Water Quality of Discharge (mg/ltr)	≅20	≅30	≅20	≅25
Treatment Process	Trickling Filter		Activated Sludge	

Requisite Water Quality in Receiving River (Tuy River)

(1) BOD	less than 60 mg/ltr
(2) SS	less than 80 mg/ltr

Features of the Sewage Treatment Plant

(1) First Stage Facilities by the Year 2003 (refer to Fig. 3.4-3)

(a) Design Flow Rates

Item	Unit	Flow Rate	Remarks
Mean Daily	m^3/day	35,000	
Maximum Daily	m^3/day	49,000	
Maximum Hourly	m^3/day	81,000	

(b) Pump

Item	Unit	Contents	Remarks
Real Head	m	18	
No. of Pumps	unit	5	with reserve of 1
Quantity of Pumping Water	m^3/sec	0.234	
Type		Vertical Volute Pump	
Caliber (ϕ)	mm	> 346	
Pump Shaft Power	kW	> 55.1	
Prime Motor Power	kW	> 63.4	

(c) Grit Chamber

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	0.938	Maximum hourly
Type		Horizontal longitudinal flow	
No. of Chambers		3	with reserve of 1
Size (W×L×D)	m	3×8×2	per chamber
Detention Time	min	1.5	
Effective Volume	m^3	84.4	
Real Volume	m^3	96.0	> 84.4 m^3
Volume of Sediment	m^3/day	1.62	
Screen before Grit Chamber		Type: Coarse screen	
/Mesh	mm	60~150	
/Angle	degree	45~60	
Screen after Grit Chamber		Type: Fine screen	
/Mesh	mm	60~150	
/Angle	degree	45~60	

(d) Primary Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	98,000	Maximum daily + recirculation flowrates > maximum hourly (81,000)
Type		Horizontal longitudinal flow	
Detention Time	hour	2.00	
Weir Loading	m^3/m/day	< 250	
Overflow Rate	m^3/m^2/day	35	
Required Volume	m^3	8,167	
Required Water Area	m^2	2,800	
Effective Depth	m	2.9	
Length of Weir	m	392	
Size (W×L×D)	m	13.5×54×2.9	Width: 3 lines × 4.5 = 13.5 m
Required No. of Tanks	unit	3.86 (4)	
Real Detention Time	hour	2.07	

(e) Sludge Hopper in Primary Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	35,000	Mean daily
Concentration of Inflow - SS	mg/ltr	201	
Removal Rate	%	85	
Quantity of Sludge Produced	t/day m^3/day	5.98 598	Water content of sludge: 99%
Sludge Hopper	m^3	> 120	Removal times per day

(f) First Step High Rate Filter

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	49,000	Maximum daily
Type		Rotary distribution	
No. of Beds		4	
Recirculation Ratio		1	
Diameter	m	32	
Depth	m	1.2	
Concentration of Inflow - BOD	mg/ltr	196	
Removal Rate of First Step	%	55	
BOD Loading to First Bed	kg/day	4,322	
BOD Loading	kg/m^3/day	1.12	< 1.2 kg/m^3/day
Hydraulic Loading	m^3/m^2/day	15.2	
Recirculation Pump			
/Design Flow Rate	m^3/day	49,000	Maximum daily
/No. of Pumps	unit	3	with reserve of 1
/Quantity of Pumping Water	m^3/day	0.284	
/Real Head	m	5	
/Caliber (ϕ)	mm	> 381	
/Pump Shaft Power	kW	> 18.5	
/Prime Motor Power	kW	> 21.3	

(g) Second Step High Rate Filter

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	49,000	Maximum daily
Type		Rotary distribution	
No. of Beds		4	
Recirculation Ratio		1	
Diameter	m	35	
Depth	m	1.2	
Concentration of Inflow - BOD	mg/ltr	196	
Removal Rate of First Step	%	55	
Removal Rate of Second Step	%	80	
BOD Loading to Second Bed	kg/day	5,186	
BOD Loading	kg/m^3/day	1.12	< 1.2 kg/m^3/day
Hydraulic Loading	m^3/m^2/day	25.5	
Recirculation Pump			
/Design Flow Rate	m^3/day	49,000	Maximum daily
/No. of Pumps	unit	3	with reserve of 1
/Quantity of Pumping Water	m^3/day	0.284	
/Real Head	m	5	
/Caliber (ϕ)	mm	> 538	538
/Pump Shaft Power	kW	> 37.1	
/Prime Motor Power	kW	> 42.6	

(h) Final Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	98,000	Maximum daily + recirculation flowrates > Maximum hourly (81,000)
Type		Horizontal longitudinal flow	
Detention Time	hour	2.00	
Weir Loading	m^3/m/day	< 150	
Overflow Rate	m^3/m^2/day	30	
Required Volume	m^3	8,167	
Required Water Area	m^2	3,267	
Effective Depth	m	2.5	
Length of Weir	m	653	
Size (W×L×D)	m	15×60×2.5	Width: 3 lines × 5 = 15 m
Required No. of Tanks		3.63 (4)	
Real Detention Time	hour	2.20	

(i) Sludge Hopper in Final Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	35,000	Mean daily
Concentration of Inflow - SS	mg/ltr	201	
Removal Rate of First Step	%	50	
Removal Rate of Second Step	%	70	
Quantity of Sludge Produced	t/day m^3/day	2.46 246	Water content of sludge: 99%
Sludge Hopper	m^3	> 41.0	Removal times per day: 6

(j) Chlorine Contact Basin

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	49,000	Maximum daily
Type		Rectangular detour flow	
Contact Time	min	15	
Required Volume	m^3	510	
No. of Ponds	m^3	2	6 channels each
Size (W×L×D)	m	4×6×2	per channel
Real Volume	m^3	576	> 510 m^3
Real Contact Time	min	16.9	
Chlorinator			
/Injection Concentration	mg/ltr	3~10	
/Quantity of Injection	kg/hour	6.1~20.4	

(k) Sludge Thickening Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	35,000	
Type		Gravity Thickening	
Concentration of Inflow - SS	mg/ltr	201	
Removal Rate of SS	%	85	
Sludge Volume	t/day	5.98	
Detention Time	hour	12	
Required Volume	m^3	299	
Solids Loading Rate	kg/m^2/day	45	
Effective Depth	m	2.5	
No. of Tanks		4	
Size (ϕ)	m	6.5	
Real Volume	m^3	332	> 299 m^3
Volume of Sludge Thickening	m^3/day	199.3	Water content of sludge: 97%
Removal Volume per Time	m^3	33.2	Removal times per day: 6
Operation Time	min	20	
Sludge Pump Capacity	m^3/min	> 1.66	

(l) Sludge Digestion Tank

Item	Unit	Contents	Remarks
Design Sludge Volume	m^3/day	199	
Type		Anaerobic	non-heating
Digestion Period	day	50	
Organic Matter	%	60	
Gasification, Liquefaction	%	70	
Water Content of Sludge	%	97	
Water Content of Sludge after Digestion	%	95	
Quantity of Digestion Sludge	m^3/day	69.4	
Required Volume	m^3	6,717	
No. of Tanks		6	
Size (ϕ)	m	12	
Height (H)	m	10	
Real Volume	m^3	6,786	> 6,717 m^3

(m) Gas Holder

Item	Unit	Contents	Remarks
Design Sludge Volume	t/day	5.98	
Organic Matter	%	60	
Gasification, Liquefaction	%	70	
Quantity of Gas Produced	m^3/day	2,511	
Detention Time	hour	12	
No. of Holders		4	
Required Volume per Tank	m^3	314	
Size (ϕ × H)	m	8×6.5	
Real Volume per Tank	m^3	327	> 314 m^3

(n) Drying Bed

Item	Unit	Contents	Remarks
Quantity of Digestion Sludge	m^3/day	69.4	
Detention Time	day	20	
Thickness of Injection	m	0.2	
Required Area	m^2	6,937	
No. of Beds		3	
Size (W×L)	m	70×100	Area: 7,000 m^2 × 3 beds
Real Area	m^2	7,000	> 6,937 m^2
Water Content of Sludge	%	95	
Water Content of Sludge after Drying	%	60	
Sludge Volume after Drying	m^3/day	8.7	

(2) Second Stage Facilities by the Year 2010 (refer to Fig. 3.4-3)

(a) Design Flow Rates

Item	Unit	Flow Rate	Remarks
Mean Daily	m^3/day	20,000	
Maximum Daily	m^3/day	28,000	
Maximum Hourly	m^3/day	46,000	

(b) Pump

Item	Unit	Contents	Remarks
Real Head	m	18	
No. of Pumps	unit	3	with reserve of 1
Quantity of Pumping Water	m^3/sec	0.266	per pump
Type		Vertical Volute Pump	
Caliber (ϕ)	mm	> 369	
Pump Shaft Power	kW	> 62.6	
Prime Motor Power	kW	> 72.0	

(c) Grit Chamber

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	46,000	Maximum hourly
Type		Horizontal longitudinal flow	
No. of Chambers		1	
Size (W×L×D)	m	3×8×2	per chamber
Detention Time	min	1.5	
Effective Volume	m^3	47.9	
Real Volume	m^3	0.92	> 47.9 m^3
Volume of Sediment	m^3/day	1.62	
Screen before Grit Chamber		Type: Coarse screen	
/Mesh	mm	60~150	
/Angle	degree	45~60	
Screen after Grit Chamber		Type: Fine screen	
/Mesh	mm	60~150	
/Angle	degree	45~60	

(d) Primary Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	56,000	Maximum daily + recirculation flowrates > maximum hourly (46,000)
Type		Horizontal longitudinal flow	
Detention Time	hour	2.00	
Weir Loading	m^3/m/day	< 250	
Overflow Rate	m^3/m^2/day	35	
Required Volume	m^3	4,667	
Required Water Area	m^2	1,600	
Effective Depth	m	2.9	
Length of Weir	m	224	
Size (W×L×D)	m	10.5×42×2.9	Width: 3 lines × 3.5 = 10.5 m
Required No. of Tanks	unit	3.63 (4)	
Real Detention Time	hour	2.19	

(e) Sludge Hopper in Primary Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	20,000	Mean daily
Concentration of Inflow - SS	mg/ltr	177	
Removal Rate	%	85	
Quantity of Sludge Produced	t/day m^3/day	3.01 301	Water content of sludge: 99%
Sludge Hopper	m^3	> 50.2	Removal times per day: 6

(f) Aeration Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	28,000	Maximum daily
Concentration of Inflow - BOD	mg/ltr	172	
Concentration of Inflow - SS	mg/ltr	177	
Concentration of Return Sludge	mg/ltr	7,000	
Ratio of Return Sludge	%	30	
Ratio of Loading between BOD and SS	kg/kg/day	0.3	
Air Volume	m^3/BOD-kg	50	3.5m^3/kg-O_2, Biological Reaction: 7%
Required Tank Volume	m^3	9,165	
Concentration of MLSS	mg/ltr	1,752	
No. of Tanks		6	
Volume per Tank	m^3	1,528	
Width	m	6	
Length	m	55	
Depth	m	5	
Volume	m^3	1,650	
Aeration Period	hour	7.9	
Sludge Age	day	3.2	
Loading Volume of BOD	kg/m^3/day	0.53	
Removal of BOD	kg/day	4,256	
Required Air Volume	m^3/min	148	
Ratio of Air-Volume against Inflow-Sewage		7.6	
Blower Type		Turbo blower	
Aeration Equipment: Diffuser		non-porous tube type	

(g) Final Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	56,000	Maximum daily + recirculation flowrates > Maximum hourly (46,000)
Type	-	Horizontal longitudinal flow	
Detention Time	hour	2.00	
Weir Loading	m^3/m/day	150	
Overflow Rate	m^3/m^2/day	30	
Required Volume	m^3	4,667	
Required Water Area	m^2	1,867	
Effective Depth	m	2.5	
Length of Weir	m	373	
Size (W×L×D)	m	12×42×2.5	Width: 3 lines × 4 = 12 m
Required No. of Tanks		3.70 (4)	
Real Detention Time	hour	2.16	

(h) Sludge Hopper in Final Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	20,000	Mean daily
Concentration of Inflow - SS	mg/ltr	177	
Removal Rate of First Step	%	50	
Removal Rate of Second Step	%	70	
Quantity of Sludge Produced	t/day m^3/day	1.24 124	Water content of sludge: 99%
Sludge Hopper	m^3	> 20.7	Removal times per day: 6

(i) Chlorine Contact Basin

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	28,000	Maximum daily
Type		Rectangular detour flow	
Contact Time	min	15	
Required Volume	m^3	292	
No. of Ponds	m^3	1	6 channels
Size (W×L×D)	m	4.5×6×2	
Real Volume	m^3	324	> 292 m^3
Real Contact Time	min	16.7	
Chlorinator			
/Injection Concentration	mg/ltr	3~10	
/Quantity of Injection	kg/hour	3.5~11.7	

(j) Sludge Thickening Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	20,000	
Type		Gravity thickening	
Concentration of Inflow - SS	mg/ltr	177	
Removal Rate of SS	%	85	
Sludge Volume	t/day	3.01	
Detention Time	hour	12	
Required Volume	m^3	150	
Solids Loading Rate	kg/m^2/day	45	
Effective Depth	m	2.5	
No. of Tanks		2	
Size (ϕ)	m	6.5	
Real Volume	m^3	166	> 150 m^3
Volume of Sludge Thickening	m^3/day	100.3	Water content of sludge: 97%
Removal Volume per Time	m^3	16.7	Removal times per day: 6
Operation Time	min	20	
Sludge Pump Capacity	m^3/min	> 0.84	

(k) Sludge Digestion Tank

Item	Unit	Contents	Remarks
Design Sludge Volume	m^3/day	100.3	
Type		Anaerobic	non-heating
Digestion Period	day	50	
Organic Matter	%	60	
Gasification, Liquefaction	%	70	
Water Content of Sludge	%	97	
Water Content of Sludge after Digestion	%	95	
Quantity of Digestion Sludge	m^3/day	34.9	
Required Volume	m^3	3,380	
No. of Tanks		3	
Size (ϕ)	m	12	
Height (H)	m	10	
Real Volume	m^3	3,393	> 3,380 m^3

(l) Gas Holder

Item	Unit	Contents	Remarks
Design Sludge Volume	t/day	3.01	
Organic Matter	%	60	
Gasification, Liquefaction	%	70	
Quantity of Gas Produced	m^3/day	1,264	
Detention Time	hour	12	
No. of Holders		2	
Required Volume per Tank	m^3	316	
Size (ϕ × H)	m	8×6.5	
Real Volume per Tank	m^3	327	> 316 m^3

(m) Drying Bed

Item	Unit	Contents	Remarks
Quantity of Digestion Sludge	m^3/day	34.9	
Detention Time	day	20	
Thickness of Injection	m	0.2	
Required Area	m^2	3,490	
No. of Beds		3	with reserve of 1
Size (W×L)	m	40×100	Area: 4,000 m^2 × 3 beds
Real Area	m^2	4,000	> 3,490 m^2
Water Content of Sludge	%	95	
Water Content of Sludge after Drying	%	60	
Sludge Volume after Drying	m^3/day	4.4	

3.4.2 Drainage Pipe Network

The proposed drainage pipe network is shown in Fig. 3.4-4. The total length is approximately 42 km, the breakdown of which is enumerated in Table 3.4-1. As for the secondary drainage pipes with an assumed diameter of 400 mm, the total length is estimated at about 181 km (refer to Table 3.4-2) by using the standard pipe density mentioned in Table 3.2-2.

3.4.3 Pumping Station

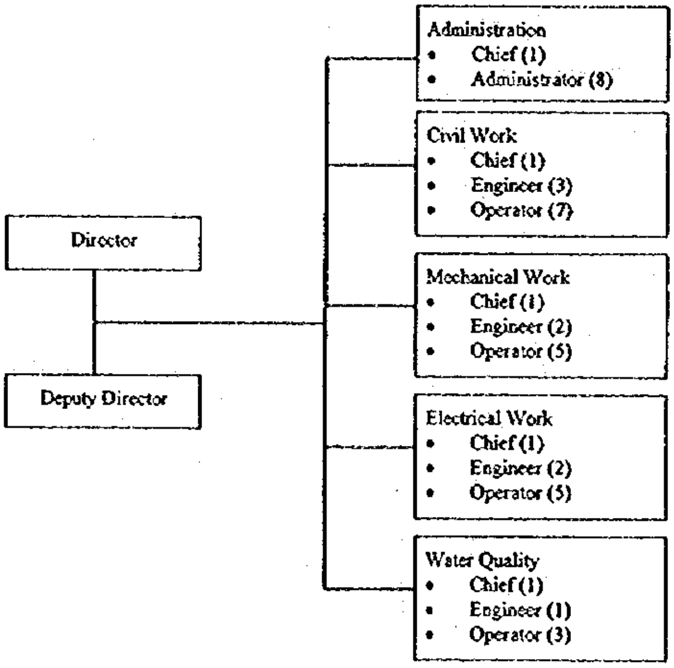
One pumping station will be provided to the north of the sewage treatment plant in order to pump wastewater from the west part of Ocumare and from the left (opposite) bank of the Tuy River through a siphon structure underneath the river.

3.5 Operation and Maintenance (O/M) Plan

3.5.1 General

Organization for O/M

An organization shall be set up for the operation and maintenance of the Ocumare del Tuy sewerage system. The organization may comprise of the following personnel:



Classification of Maintenance Work

The maintenance work for the sewerage system can be classified into daily, monthly and yearly maintenance depending on the nature of the objective facilities. Such results shall be recorded and compiled in forms.

3.5.2 Operation and Maintenance for the Sewage Treatment Plant

Sewage treatment plants are basically operated and maintained 24 hours without any interruption. Notable points for such O/M are enumerated herein for each of the facilities.

<u>Grit Chamber</u>

Sand deposit in the chamber shall be removed periodically. Should there be organic material found in such deposit causing difficulty in the removal of sand deposit, the flow velocity through the chamber shall be adjusted to avoid this. Screens shall be kept clean any time with manual raking.

<u>Pump Facility</u>

During pump operation, the operator shall watch on the control panel and gauges and confirm the normality of the operation. Anytime the operator notices heat, sound and vibration of facilities, if any, he shall stop the pump operation and proceed to necessary repair. Lubricants shall be changed at least once a year.

<u>Settling Tank</u>

Scum of the water surface shall be removed periodically. The training walls, side walls and overflow sections shall be cleaned with brush to prevent offensive odor and unevenness of the flow caused by sludge attached thereon.

<u>Trickling Filter</u>

The trickling filter, which requires less machinery except a re-circulation pump and a sludge pump, shall be operated continuously through re-circulation and maintained in accordance with the following remarks:

(1) Operate such that the BOD does not exceed the BOD limitation set for the facility by controlling the inflow of water and BOD load;

(2) Clean the nozzle and bearing parts of the rotary sprinkler everyday;

(3) Remove the bio-film and foreign matters from the filter surface and drainage channels;

(4) When fibrous substances or slime deposits on the filter surface, sprinkle the wastewater with about 5 ppm of chlorine; and

(5) When the filter is clogged, scrape the surface off, or wash the material with pressurized water, or change the whole material.

<u>Sludge Thickener</u>

(1) Prevent the occurrence of scum by continually introducing fresh sludge to avoid offensive odor; and

(2) Keep the side walls clean with pressurized water or brush.

Sludge Digestion Tank

(1) Cast the thickened sludge in the tank continuously such that the thickened sludge can sufficiently contact with the digested sludge to increase the digestion efficiency;

(2) When sand deposit or scum reaches a huge amount to clog the sludge drain pipe, clean up and/or take necessary repair after making the tank empty; and

(3) Do maintenance work inside the tank under sufficient fresh air supply measuring gas concentrations therein.

Sludge Drying Bed

The sludge shall be dried in the sun. The dried sludge shall be hauled to an adequate reclamation land for the time being.

3.5.3 Operation and Maintenance for the Pipe Network

The operation and maintenance for the pipe network comprise operation of equipment such as pumps, patrol, check, cleanup, repair and so on. The work itself is not difficult or sophisticated, but the most important in this effort is the preparation of the file compiling the dimensions, structure, capacity, conditions, drawings of each of the relevant facilities that can serve as the basic data for the operation and maintenance thereof.

3.5.4 Water Quality Management

The water quality management is composed of the surveillance of the outlet water quality from the sewage treatment plant and the water quality observation for the operation of the plant.

Sampling Point

(1) At the inlet of the plant (inlet water);
(2) At the outlet of the primary settling tank (settled water);
(3) At the outlet of the secondary settling tank (treated water); and
(4) Upstream and downstream of the outlet from the plant (river water).

Measuring Item and Frequency

(1) Daily Test: Weather, water temperature, transparency, color, odor, pH, DO;

(2) Biweekly Test: SS, BOD, COD, NH3-N, NO2-N, NO3-N, PO4-P, colon bacillus;

(3) Monthly Test: Total N, chlorine ion, Total P;

(4) Heavy Metal: Seasonally for heavy metals possibly discharging from factories;

(5) Sludge Test: Weekly and biweekly; and

(6) Activated Sludge Test: Daily and weekly.

4. FEASIBILITY STUDY ON THE CONSTRUCTION OF SEWAGE TREATMENT PLANT IN LAS TEJERIAS

4.1 Objective Area Covered by Sewerage System

Las Tejerías is located on the left bank of the upper Tuy River about 90 km upstream of the municipal water intake at Toma de Agua. According to the urban development plan established by the Ministry of Urban Development (MINDUR), the Las Tejerías urban area covers Las Tejerías itself and a part of Curiepe. However, the town of Curiepe is quite small in size and population, and it is located downstream of the proposed sewage treatment plant. Hence, this area is excluded from the sewerage system. The objective area covered by the Las Tejerías sewerage system is 495 has as illustrated in Fig. 4.1-1.

4.2 Conditions of the Objective Area

4.2.1 Land Use

The urban center of Las Tejerías is on a terrace of the Tuy River's left bank, and villages develop along main roads running by the river. On the other hand, MINDUR has worked out the Las Tejerías urban plan, as shown in Fig. 4.1-1, for the year 2010 (the target year of this study). The following table shows the area by land use in the objective sewerage system area, both at present and in future, based on Fig. 4.1-1.

Description		Commercial District *1	Residential District	New Residential District	Industrial District	Forest, Agriculture *2	Others	Total
At Present	Area (ha)	35	189	-	103	129	40	495
	Ratio (%)	7.1	38.1	-	20.7	26.0	8.1	100.0
In Future	Area (ha)	35	189	89	103	40	40	495
	Ratio (%)	7.1	38.1	17.9	20.7	8.1	8.1	100.0

*1 Commercial District: including high density residential districts

*2 Forest, Agriculture: including protection areas.

4.2.2 Population

The population in 1990, 2003 and 2010 in the objective sewerage system area is tabulated below.

Year	1990	2003	2010
Las Tejerías	20,246	26,898	30,825
Quoted from	OCEI	JICA (M/P)	JICA (M/P)

4.2.3 Existing Drainage Network

In the urban area of Las Tejerias, there exists the main drainage network provided by MINDUR. The outline of the drainage network originally designed is as shown in Table 4.2-1.

However, most of the drainage network is composed of open channels which receive storm runoff and some portions of the network have been damaged. Judging from this condition, it is necessary to newly provide or replace the present drainage channel to establish the sewage system in the urban area of Las Tejerias.

Table 4.2-2 shows the breakdown of the secondary drainage network. According to this table, the density of the secondary network is about 91 m/ha.

4.3 Basic Plan

4.3.1 Future Urban Development

The proposed Las Tejerías sewage treatment plant is designed to treat domestic waste and industrial effluent for the target year 2003. Apart from this, it is also necessary that the sewerage system be gradually expanded to cope with the future increase of pollutant load and industrial wastewater. Also, infiltration from groundwater is expected. In the case of industrial wastewater, it is assumed that the sewerage system will collect wastewater complying with the national water quality standards.

4.3.2 Objective Sewage

The sewage to be collected by this sewerage system is composed of domestic and industrial wastewater. Infiltration from ground water is also expected. In the case of industrial wastewater, it is assumed that the sewerage system will collect wastewater that complies with the national water quality standards.

4.3.3 Population in the Objective Area

Total Population

The population in the objective area is calculated based on the percentage of households located in the urban area. The number of households was calculated using 1/25,000 aerial photographs and 1/5,000 topographic maps. It is determined that the ratio of population in the urban area of Las Tejerías is 95% of the total administrative area.

Spatial Distribution of Population

To decide the layout of the sewerage network, areal distribution of the total population is assumed in the following manner:

(1) The population density in new residential areas is assumed to be 50 persons/ha in 2003 and 70 persons/ha in the year 2010; and

(2) Future increase of population is assumed to be absorbed into the present residential area.

The following table shows the spatial distribution of population:

Land Use	Area (ha)	Year 1990		Year 2003		Year 2010	
		Population	Density	Population	Density	Population	Density
Commercial District	35	5,232	148	5,745	163	6,278	178
Residential District	189	14,002	74	15,377	81	16,802	89
New Residential District	89	-	-	4,431	50	6,203	70
Industrial District	103	-	-	-	-	-	-
Forest, Agriculture	40	-	-	-	-	-	-
Others	40	-	-	-	-	-	-
Total	495	19,234	39	25,553	52	29,284	59

4.3.4 Industry in the Objective Area

The number of factories in the present and future projections are studied in Supporting Report, Sector C. It is assumed that all the factories are located in the industrial zones and the discharge wastewater within the limits of the water quality standards. Thus, the sewerage system will collect all the wastewater from factories. The volume of industrial wastewater is calculated based on the number of employees in each industry. Table 4.3-1 shows the number of employees.

4.3.5 Design Wastewater Discharge

Domestic Wastewater

(1) Wastewater Discharge per Capita

The wastewater discharge per capita from domestic origin is determined based on the past study results shown in Table 3.3-2. Following are the same applied in this study:

Year	Wastewater Discharge per Capita (ltr/day)	Remarks
1995	206	Study result in C applied
2003	256	Proportionately derived from the other two
2010	300	Average of the three study results (A, B and C)

(2) Wastewater Discharge

The design domestic wastewater discharge is calculated as: [Wastewater Discharge per Capita × Population]. The results are tabulated below.

Year	Population (person)	Mean Daily		Maximum Daily		Maximum Hourly	
		Per Capita Discharge (m^3/person/day)	Discharge (m^3/day)	Per Capita Discharge (m^3/person/day)	Discharge (m^3/day)	Per Capita Discharge (m^3/person/day)	Discharge (m^3/day)
1990	19,234	0.175	3,370	0.250	4,814	0.375	7,221
2000	23,977	0.238	5,697	0.339	8,138	0.509	12,208
2003	25,553	0.256	6,550	0.366	9,357	0.549	14,035
2005	26,604	0.269	7,151	0.384	10,216	0.576	15,324
2010	29,284	0.300	8,785	0.429	12,550	0.643	18,825

Note: Mean Daily : Maximum Daily : Maximum Hourly = 0.7 : 1.0 : 1.5, based on INOS data, Proyecto de los Colectores Generales de la Futura Poblacion, 1987.)

Industrial Wastewater

The design wastewater discharge is obtained from: [Wastewater Discharge per Capita × Number of Employees] (both are presented in Table 4.3-1 by industrial category). The calculation results are shown below.

Year	Mean Daily (m^3/day)	Maximum Daily (m^3/day)	Maximum Hourly (m^3/day)
1995	3,480	3,480	6,960
2000	4,191	4,191	8,381
2003	4,826	4,826	9,653
2005	5,250	5,250	10,501
2010	6,860	6,860	13,719

Note: Mean Daily : Maximum Daily : Maximum Hourly = 1 : 1 : 2.

Groundwater

Groundwater infiltrates into the sewerage system through joints and breaks. The volume of groundwater infiltration is assumed to be 15% of the domestic wastewater. The groundwater is considered only in the calculation of the maximum hourly wastewater discharge.

Total Wastewater Discharge

The total wastewater discharge consisting of domestic wastewater, industrial wastewater and infiltration is tabulated below.

(Unit: m^3/day)

Category	Year 2010			Year 2003		
	Mean Daily	Maximum Daily	Maximum Hourly	Mean Daily	Maximum Daily	Maximum Hourly
Domestic Wastewater	8,785	12,550	18,825	6,550	9,357	14,035
Industrial Wastewater	6,860	6,860	13,719	4,826	4,826	9,653
Infiltration	-	-	1,883	-	-	1,404
Total	15,645	19,410	34,427	11,376	14,183	25,092

4.3.6 Target Water Quality

Inflow Water Quality

(1) Water Quality of Domestic Wastewater

Inflow water quality from domestic wastewater is calculated in the following manner:

Water Quality (mg/ltr) = Pollution Load (mg/day) / Wastewater Discharge (ltr/day)

Herein, the pollution load is calculated applying BOD in the following equation:

BOD Pollution Loan = BOD pollution load per capita (g/person/day) × population

In this equation, BOD pollution load per capita is 54 g/person/day that has been determined in previous studies.

(2) Water Quality of Industrial Wastewater

Water quality of inflow from industrial wastewater is assumed to be within the water quality standard for factories: BOD = 350 (mg/ltr).

(3) Water Quality of Inflow to Sewage Treatment Plant

Based on the total wastewater discharge and BOD load from domestic and industrial wastewaters, the water quality of inflow to the sewage treatment plant is calculated as below.

Category	Year 2010					Year 2003				
	Mean Daily Dis-charge	Pollutant Load (kg/day)		Water Quality (mg/ltr)		Mean Daily Dis-charge	Pollutant Load (kg/day)		Water Quality (mg/ltr)	
		BOD	SS	BOD	SS		BOD	SS	BOD	SS
Domestic Wastewater	8,785	1,581	1,611	180	183	6,550	1,380	1,405	211	215
Industrial Wastewater	6,860	2,401	2,744	350	400	4,826	1,689	1,931	350	400
Total/Average	15,645	3,982	4,354	255	278	11,376	3,069	3,336	270	293

Target Water Quality of Discharge from Sewage Treatment Plant

As shown in the table above, the water quality of inflow to the sewage treatment plant is estimated at about 260 mg/ltr in the year 2010. Moreover, to achieve the target water quality by the year 2010, it is required to reduce the BOD pollution load at Las Tejerías by 90% in accordance with the results of the RIOS model water quality analysis. Consequently, the target water quality of the discharge from the sewage treatment plant is set at 30 mg/ltr of BOD, corresponding to approximately 12% of the inflow water BOD.

4.3.7 Sewage Treatment Plant

Site

The site of the sewage treatment plant is decided considering the availability of sufficient open space near Las Tejerías and the geographical advantage for the collection of all sewage from the basin.

Area Available for Construction of Sewage Treatment Plant

A suitable area exists near the center of the town. The area has been proposed for a sewage treatment plant in previous studies. The available area measures approximately 20 ha facing the Tuy River. The area is so low that a flood protection dike surrounding the site is proposed.

Method of Sewage Treatment

In the master plan study, three alternative methods of sewage treatment were examined: (1) stabilization pond system, (2) activated sludge/aerated system, (3) simplified activated sludge system. The simplified activated sludge system was selected because of the simplicity of maintenance, although this method requires a relatively large area.

In Las Tejerías exist similar conditions to those in Ocumare del Tuy, therefore, in the feasibility study, the most suitable method is reexamined considering the future population and availability of land for the sewage treatment plant. The following conclusions are obtained:

(1) Similar to Ocumare del Tuy at the beginning, it is desirable to introduce a low maintenance method because of the inexperience in the operation of sewage treatment plants in Venezuela.

(2) Among low maintenance methods, the trickling filter method is preferred because of flexibility with variable pollution inflows and recovery from accidental inflow of toxicants.

(3) Judging from the increase in population to 2010 with only 14% from 2003, it is preferable to construct the entire treatment facility with the capacity of the wastewater volume at the year 2010 to avoid duplication of investment from the beginning.

Consequently, it is proposed that the trickling filter method is applied to the sewage treatment system in Las Tejerías.

4.3.8 Drainage Pipe Network

In this study, the sewer network proposed by MINDUR is adopted.

4.3.9 Pumping Station

In general, gravity collectors are desirable. However, geographical restraints often prevent this from practice. In this case, it is necessary to provide a pump to collect the sewage. The Las Tejerías site necessitates some form of pumping.

4.4 Preliminary Design

4.4.1 Sewage Treatment Plant

Treatment Method

(1) Wastewater Treatment	Trickling filter method (see Fig. 3-3)
(2) Sludge Treatment	Non-heating non-mixing digestion method with drying bed

Treatment Capacity

Description	BOD	SS
Water Quality of Inflow (mg/ltr)	255	278
Removal Rate of Primary Settling and First Filter (%)	55	50
Removal Rate of Final Settling and Secondary Filter (%)	80	70
Water Quality of Discharge (mg/ltr)	≅25	≅45

Requisite Water Quality in Receiving River (Tuy River)

(1) BOD	less than 60 mg/ltr
(2) SS	less than 80 mg/ltr

Features of the Sewage Treatment Plant (refer to Fig. 4.4-1)

(1) Design Flow Rates

Item	Unit	Flow Rate	Remarks
Mean Daily	m^3/day	16,000	
Maximum Daily	m^3/day	20,000	
Maximum Hourly	m^3/day	35,000	

(2) Pump

Item	Unit	Contents	Remarks
Real Head	m	7.5	
No. of Pumps	unit	3	with reserve of 1
Quantity of Pumping Water	m^3/sec	0.203	per pump
Type		Vertical Volute Pump	
Caliber (φ)	mm	> 322	
Pump Shaft Power	kW	> 19.8	
Prime Motor Power	kW	> 22.8	

(3) Grit Chamber

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	0.405	Maximum hourly
Type		Horizontal longitudinal flow	
No. of Chambers		2	with reserve of 1
Size (W×L×D)	m	4×6×1.8	per chamber
Detention Time	min	1.5	
Effective Volume	m^3	36.5	
Real Volume	m^3	43.2	> 36.5 m^3 effective volume
Volume of Sediment	m^3/day	0.7	
Screen before Grit Chamber		Type: Coarse screen	
/Mesh	mm	60~150	
/Angle	degree	45~60	
Screen after Grit Chamber		Type: Fine screen	
/Mesh	mm	60~150	
/Angle	degree	45~60	

(4) Primary Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	40,000	Maximum daily + recirculation flowrates > maximum hourly (35,000 m^3/sec)
Type		Horizontal longitudinal flow	
Detention Time	hour	2.00	
Weir Loading	m^3/m/day	< 250	
Overflow Rate	m^3/m^2/day	35	
Required Volume	m^3	3,333	
Required Water Area	m^2	1,143	
Effective Depth	m	2.9	
Length of Weir	m	160.0	
Size (W×L×D)	m	9×36×2.9	Width: 3 lines × 3 = 9 m
Required No. of Tanks	unit	3.63 (4)	
Real Detention Time	hour	2.26	

(5) Sludge Hopper in Primary Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	16,000	Mean daily
Concentration of Inflow - SS	mg/ltr	278	
Removal Rate	%	85	
Quantity of Sludge Produced	t/day m^3/day	3.78 378	Water content of sludge: 99%
Sludge Hopper	m^3	> 63	Removal times per day: 6

(6) First Step High Rate Filter

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	20,000	Maximum daily
Type		Rotary distribution	
No. of Beds		2	
Recirculation Ratio		1	
Diameter	m	30	
Depth	m	1.5	
Concentration of Inflow - BOD	mg/ltr	255	
Removal Rate of First Step	%	55	
BOD Loading to First Bed	kg/day	2,295	
BOD Loading	kg/m^3/day	1.08	< 1.2 kg/m^3/day
Hydraulic Loading	m^3/m^2/day	14.1	
Recirculation Pump		Vertical Volute Pump	
/Design Flow Rate	m^3/day	20,000	Maximum daily
/No. of Pumps	unit	3	with reserve of 1
/Quantity of Pumping Water	m^3/day	0.116	per pump
/Real Head	m	5	
/Caliber (ϕ)	mm	> 243	
/Pump Shaft Power	kW	> 7.6	
/Prime Motor Power	kW	> 8.7	

(7) Second Step High Rate Filter

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	20,000	Maximum daily
Type		Rotary distribution	
No. of Beds		2	
Recirculation Ratio		1	
Diameter	m	32	
Depth	m	1.8	
Concentration of Inflow - BOD	mg/ltr	255	
Removal Rate of First Step	%	55	
Removal Rate of Second Step	%	80	
BOD Loading to Second Bed	kg/day	2,754	
BOD Loading	kg/m^3/day	0.95	< 1.2 kg/m^3/day
Hydraulic Loading	m^3/m^2/day	24.9	
Recirculation Pump		Vertical Volute Pump	
/Design Flow Rate	m^3/day	20,000	Maximum daily
/No. of Pumps	unit	3	with reserve of 1
/Quantity of Pumping Water	m^3/day	20,000	
/Real Head	m	5	
/Caliber (ϕ)	mm	> 344	538
/Pump Shaft Power	kW	> 15.1	
/Prime Motor Power	kW	> 17.4	

(8) Final Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	40,000	Maximum daily + recirculation flowrates > Maximum hourly (35,000 m^3/sec)
Type		Horizontal longitudinal flow	
Detention Time	hour	2.00	
Weir Loading	m^3/m/day	< 150	
Overflow Rate	m^3/m^2/day	30	
Required Volume	m^3	3,333	
Required Water Area	m^2	1,333	
Effective Depth	m	2.50	
Length of Weir	m	267	
Size (W×L×D)	m	9.6×38.4×2.5	Width: 3 lines x 3.2 = 9.6 m
Required No. of Tanks		3.62 (4)	
Real Detention Time	hour	2.21	

(9) Sludge Hopper in Final Settling Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	16,000	Mean daily
Concentration of Inflow - SS	mg/ltr	278	
Removal Rate of First Step	%	50	
Removal Rate of Second Step	%	70	
Quantity of Sludge Produced	t/day m^3/day	1.56 156	Water content of sludge: 99%
Sludge Hopper	m^3	> 25.9	Removal times per day: 6

(10) Chlorine Contact Basin

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	20,000	Maximum daily
Type	-	Rectangular detour flow	
Contact Time	min	> 15	
Required Volume	m^3	208	
No. of Ponds	m^3	1	6 channels
Size (W×L×D)	m	4×5×2	per channel
Real Volume	m^3	240	> 208 m^3
Real Contact Time	min	17.3	
Chlorinator			
/Injection Concentration	mg/ltr	3~10	
/Quantity of Injection	kg/hour	2.5~8.3	

(11) Sludge Thickening Tank

Item	Unit	Contents	Remarks
Design Flow Rate	m^3/day	16,000	
Type		Gravity Thickening	
Concentration of Inflow - SS	mg/ltr	278	
Removal Rate of SS	%	85	
Sludge Volume	t/day	3.78	
Detention Time	hour	12	
Required Volume	m^3	189	
Solids Loading Rate	kg/m^2/day	48	
Effective Depth	m	2.5	
No. of Tanks		4	
Size (ϕ)	m	5	
Real Volume	m^3	196	> 189 m^3
Volume of Sludge Thickening	m^3/day	126.0	Water content of sludge: 97%
Removal Volume per Time	m^3	21.0	Removal times per day: 6
Operation Time	min	20	
Sludge Pump Capacity	m^3/min	> 1.05	

(12) Sludge Digestion Tank

Item	Unit	Contents	Remarks
Design Sludge Volume	m^3/day	126.0	
Type		Anaerobic	non-heating
Digestion Period	day	50	
Organic Matter	%	60	
Gasification, Liquefaction	%	70	
Water Content of Sludge	%	97	
Water Content of Sludge after Digestion	%	95	
Quantity of Digestion Sludge	m^3/day	43.9	
Required Volume	m^3	4,247	
No. of Tanks		4	
Size (ϕ)	m	12	
Height (H)	m	10	
Real Volume	m^3	4,524	> 4,247 m^3

(13) Gas Holder

Item	Unit	Contents	Remarks
Design Sludge Volume	t/day	3.78	
Organic Matter	%	60	
Gasification, Liquefaction	%	70	
Quantity of Gas Produced	m^3/day	1,588	
Detention Time	hour	12	
No. of Holders		4	
Required Volume per Tank	m^3	198	
Size ($\phi \times H$)	m	8×5	
Real Volume per Tank	m^3	251	> 198 m^3

(14) Drying Bed

Item	Unit	Contents	Remarks
Quantity of Digestion Sludge	m^3/day	43.9	
Detention Time	day	20	
Thickness of Injection	m	0.2	
Required Area	m^2	4,386	
No. of Beds		3	with reserve of 1
Size (W×L)	m	50×90	Area: 4,500 m^2 × 3 beds
Real Area	m^2	4,500	> 4,386 m^2
Water Content of Sludge	%	95	
Water Content of Sludge after Drying	%	60	
Sludge Volume after Drying	m^3/day	5.5	

4.4.2 Drainage Pipe Network

The proposed drainage pipe network is shown in Fig. 4.4-2. The total length is approximately 16 km, the breakdown of which is enumerated in Table 4.4-1. As for the secondary drainage pipes with an assumed diameter of 400 mm, the total length is estimated at about 43 km (refer to Table 4.4-2) by using the standard pipe density mentioned in Table 4.2-2.

4.4.3 Pumping Station

One pumping station will be provided to the north of the sewage treatment plant in order to pump wastewater from the left (opposite) bank of the Tuy River through a siphon structure underneath the river.

4.5 Operation and Maintenance (O/M) Plan

All the description in Section 3.5 is likewise applied to the operation and maintenance plan for the Las Tejerías sewerage system.