3 FINANCIAL QUESTIONNAIRE SURVEY

3.1 OBJECTIVES OF THE SURVEY

Financial questionnaire survey is one of the bases of sewerage tariff setting. The survey aims to reveal sewerage users' willingness to pay (WTP) for the sewerage service charge.

Moreover, the income levels as well as miscellaneous expenses of sewerage users are asked in the questionnaires. These data are required to estimate affordability of households to pay sewerage service charge.

3.2 SURVEY DESIGN

Survey design is summarized as follows.

Sample design:	300 households/city, 3 F/S cities (Tulcea, Galati, Braila)
Sampling method:	Random sampling
Survey method:	Interviewing to household heads
Elicitation method of WTP:	Multiple choice method

The questionnaire is composed of a question concerning respondents' WTP and questions concerning attributes of samples, as shown in the attachment 2 at the end of this appendix.

3.3 FIELDWORK

The fieldwork was conducted during July 15 to 22, 1999. Well-trained surveyors visited each sample household and interviewed household heads based on the Romanian translation of the questionnaires.

In total surveyors visited 1,115 households and succeeded to interview 970 households. The number and rate of refusals are summarized below.

City	Number of visits	Number of available samples	Number of refusals	Refusal rate
Braila	349	322	27	7.7 %
Galati	375	322	53	14.1 %
Tulcea	391	326	65	16.6 %
Total	1,115	970	145	13.0 %

3.4 SAMPLING RESULTS

3.4.1 ATTRIBUTES OF RESPONDENTS

In this people's awareness survey, a household head is defined as the person who earns the most in the household.

The attributes of respondents' are summarized in the following table.

		Braila		Galati		Tulcea		Total	
		No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
Q1: Age	18-25	8	2.5%	8	2.5%	15	4.6%	31	3.2%
	26-35	37	11.5%	57	17.7%	49	15.0%	143	14.7%
	36-45	67	20.8%	50	15.5%	86	26.4%	203	20.9%
	46-55	53	16.5%	68	21.1%	76	23.3%	197	20.3%
	56-	157	48.8%	139	43.2%	100	30.7%	396	40.8%
Q2: Sex	Male	226	70.2%	221	68.6%	190	58.3%	637	65.7%
	Female	96	29.8%	101	31.4%	136	41.7%	333	34.3%
Q3: Marital status	Married	251	78.0%	233	72.4%	270	82.8%	754	77.7%
	Single	71	22.0%	89	27.6%	56	17.2%	216	22.3%
Q5: Occupation	Owner, manager	6	1.9%	2	0.6%	15	4.6%	23	2.4%
	Specialist, faculty graduate	28	8.7%	39	12.1%	23	7.1%	90	9.3%
	Technician, teacher	16	5.0%	19	5.9%	23	7.1%	58	6.0%
	Clerk	6	1.9%	3	0.9%	25	7.7%	34	3.5%
	Services employee, merchant	14	4.3%	8	2.5%	13	4.0%	35	3.6%
	Qualified worker, craftsman	66	20.5%	99	30.7%	74	22.7%	239	24.6%
	Worker	5	1.6%	10	3.1%	13	4.0%	28	2.9%
	Farmer	2	0.6%	3	0.9%	2	0.6%	7	0.7%
	Military	7	2.2%	1	0.3%	8	2.5%	16	1.6%
	Pensioner	149	46.3%	127	39.4%	106	32.5%	382	39.4%
	Housewife	5	1.6%	0	0.0%	4	1.2%	9	0.9%
	Unemployed	17	5.3%	11	3.4%	18	5.5%	46	4.7%
	Sailor	1	0.3%	0	0.0%	2	0.6%	3	0.3%
Q6: Education	University	41	12.7%	41	12.7%	39	12.0%	121	12.5%
	Post high-school education	43	13.4%	33	10.2%	24	7.4%	100	10.3%
	High school	63	19.6%	76	23.6%	97	29.8%	236	24.3%
	Professional school	75	23.3%	86	26.7%	65	19.9%	226	23.3%
	General school	93	28.9%	73	22.7%	95	29.1%	261	26.9%
	No schooling	6	1.9%	11	3.4%	5	1.5%	22	2.3%
	Other	1	0.3%	2	0.6%	1	0.3%	4	0.4%

A quite high ratio of female household head, more than 30%, may reflect the fact that females play important roles in Romanian society. It should be noted that ratio of housewives is less than 1% though that of female is high.

Similar to economic questionnaire survey, the distribution of age and occupation is characteristic. The ratios of more than 56 years old and pensioner are conspicuously high, and these two rations seem to be corresponding. The highest ratios are marked in Braila, and the lowest in Tulcea.

3.4.2 Attributes of Households

(1) Number of Family Member

The distribution of number of family member is as shown below.

		Braila		Galati		Tulcea		Total	
		No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
Q4: Number of family member	1 person	53	16.5%	55	17.1%	23	7.1%	131	13.5%
	2 persons	99	30.7%	83	25.8%	97	29.8%	279	28.8%
	3 persons	90	28.0%	88	27.3%	87	26.7%	265	27.3%
	4 persons	42	13.0%	51	15.8%	76	23.3%	169	17.4%
	5 persons	26	8.1%	25	7.8%	29	8.9%	80	8.2%
	6 persons	8	2.5%	10	3.1%	6	1.8%	24	2.5%
	7 persons	4	1.2%	4	1.2%	6	1.8%	14	1.4%
	8 persons		0.0%	3	0.9%	2	0.6%	5	0.5%
	9 persons		0.0%	2	0.6%		0.0%	2	0.2%
	10 persons		0.0%	1	0.3%		0.0%	1	0.1%

Ratio of 1-person household in Tulcea is low comparing to other two cities. It can be explained by the difference of city size between Tulcea, with around 70 thousand inhabitants, and other two cities, with more than 250 thousand inhabitants.

(2) Miscellaneous Household Expenses

To ask monthly households' expenses for household maintenance, electricity, and telephone, open-ended method was applied. The definition of household maintenance charge in the Study is the charges for water supply, garbage collection, gas supply, and operation and maintenance of elevators.

The following table shows the distribution of categorized data of the abovementioned expenses.

		Braila		Galati		Tulcea		Total	
		No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
Q8: Maintenance (=water, garbage, gases, elevator)	less than 50,000 lei	61	18.9%	49	15.2%	39	12.0%	149	15.4%
	50,000-99,999lei	86	26.7%	84	26.1%	30	9.2%	200	20.6%
	100,000-149,999lei	77	23.9%	77	23.9%	78	23.9%	232	23.9%
	150,000-199,999lei	38	11.8%	36	11.2%	84	25.8%	158	16.3%
	200,000lei -	60	18.6%	76	23.6%	95	29.1%	231	23.8%
Q9: Electricity	less than 50,000 lei	168	52.2%	113	35.1%	50	15.3%	331	34.1%
	50,000-99,999 lei	91	28.3%	127	39.4%	113	34.7%	331	34.1%
	100,000-149,999 lei	39	12.1%	54	16.8%	69	21.2%	162	16.7%
	150,000-199,999 lei	13	4.0%	13	4.0%	40	12.3%	66	6.8%
	200,000 lei -	11	3.4%	15	4.7%	54	16.6%	80	8.2%
Q10: Telephone	No answer	128	39.8%	91	28.3%	126	38.7%	345	35.6%
	less than 50,000 lei	11	3.4%	16	5.0%	4	1.2%	31	3.2%
	50,000-99,999 lei	84	26.1%	74	23.0%	70	21.5%	228	23.5%
	100,000-149,999 lei	45	14.0%	63	19.6%	51	15.6%	159	16.4%
	150,000-199,999 lei	27	8.4%	28	8.7%	25	7.7%	80	8.2%
	200,000 lei -	27	8.4%	50	15.5%	50	15.3%	127	13.1%

(3) Household Income

To ask monthly households' income, multiple choice method was applied. The distribution of household income is as shown below.

		Braila		Galati		Tulcea		Total	
		No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
Q11: Household income	No answer	2	0.6%	8	2.5%	5	1.5%	15	1.5%
	less than 500,000 lei	52	16.1%	50	15.5%	41	12.6%	143	14.7%
	500,000-999,999 lei	101	31.4%	93	28.9%	88	27.0%	282	29.1%
	1,000,000-1,499,999 lei	80	24.8%	48	14.9%	52	16.0%	180	18.6%
	1,500,000-1,999,999 lei	44	13.7%	27	8.4%	58	17.8%	129	13.3%
	2,000,000-2,999,999 lei	24	7.5%	35	10.9%	41	12.6%	100	10.3%
	3,000,000-3,999,999 lei	8	2.5%	18	5.6%	19	5.8%	45	4.6%
	4,000,000-5,999,999 lei	8	2.5%	12	3.7%	14	4.3%	34	3.5%
	6,000,000-7,999,999 lei	3	0.9%	13	4.0%	5	1.5%	21	2.2%
	8,000,000-9,999,999 lei	0	0.0%	12	3.7%	2	0.6%	14	1.4%
	10,000,000 lei -	0	0.0%	6	1.9%	1	0.3%	7	0.7%

3.4.3 Distribution of WTP for Sewerage Service

To ask monthly willingness to pay (WTP) for sewerage service, multiple choice method was applied. The distribution of WTP for sewerage service is as shown below.

		Braila		Galati		Tulcea		Total	
		No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
Q7: WTP for sewerage service	No answer	59	18.3%	75	23.3%	56	17.2%	190	19.6%
	less than 5,000 lei	129	40.1%	113	35.1%	141	43.3%	383	39.5%
	5,000-9,999 lei	83	25.8%	57	17.7%	54	16.6%	194	20.0%
	10,000-14,999 lei	12	3.7%	16	5.0%	23	7.1%	51	5.3%
	15,000-19,999 lei	6	1.9%	15	4.7%	15	4.6%	36	3.7%
	20,000-29,999 lei	12	3.7%	9	2.8%	15	4.6%	36	3.7%
	30,000-39,999 lei	5	1.6%	16	5.0%	8	2.5%	29	3.0%
	40,000-59,999 lei	10	3.1%	13	4.0%	8	2.5%	31	3.2%
	60,000-79,999 lei	2	0.6%	3	0.9%	0	0.0%	5	0.5%
	80,000-99,999 lei	2	0.6%	3	0.9%	4	1.2%	9	0.9%
	100,000 lei -	2	0.6%	2	0.6%	2	0.6%	6	0.6%

3.5 Estimation of WTP for Sewerage Service

3.5.1 Estimation Method

As the representative value of WTP for sewerage service, the mean value of WTP was estimated based on the sampling result. Procedure of estimation method applied in the Study is as follows:

- Eliminate "no answer" samples.
- Calculate a central value (X_i) of each category. The subscription "i" means the category. For example, the central value of category "5,000 – 9,999 lei" is 7,500 lei.
- Calculate a probability of acceptance to pay (P_i) at certain level of sewerage service charge. In this calculation it is assumed that the person who accept to pay a level of service charge will always agree to pay lower level of charge. For example, the respondent whose WTP is 50,000 lei will agree to pay 20,000 lei of service charge.
- Apply a logit transformation to P_i. Logit transformation can be written as follows.

$$Logit\ P_i = \ln\left(\frac{P_i}{1-P_i}\right)$$

- Optimize the following equation by the regression method.

  $Logit\ P_i = a + b * \log_{10}(X_i)$ ······· [2]

  where a, b are regression coefficients.

- Calculate the mean value of WTP by the following equation

  $$Mean = \int_0^{Max} xP(x)dx \quad \cdots\cdots\cdots\cdots [3]$$

  where,

  Max : Maximum level of sewerage service charge,

  x : level of sewerage service charge, and

  $P(x)$: probability of acceptance at the level x. $P(x)$ can be expressed as

  $$P(x) = \frac{\exp\{a + b * \log_{10}(x)\}}{1 + \exp\{a + b * \log_{10}(x)\}}$$

3.5.2 Result of Regression Estimation

The regression coefficients in the expression [2] are obtained by the regression method using the data below.

Xi (lei)		7,500	12,500	17,500	25,000	35,000	50,000	70,000	90,000
Pi	Braila	51.0%	19.4%	14.8%	12.5%	8.0%	6.1%	2.3%	1.5%
	Galati	54.3%	31.2%	24.7%	18.6%	15.0%	8.5%	3.2%	2.0%
	Tulcea	47.8%	27.8%	19.3%	13.7%	8.1%	5.2%	2.2%	2.2%
log (Xi)		3.875	4.097	4.243	4.398	4.544	4.699	4.845	4.954
LogitPi	Braila	0.0380	-1.4248	-1.7481	-1.9416	-2.4444	-2.7368	-3.7573	-4.1705
	Galati	0.1705	-0.7920	-1.1149	-1.4747	-1.7362	-2.3760	-3.3970	-3.8795
	Tulcea	-0.0889	-0.9555	-1.4333	-1.8401	-2.4224	-2.9061	-3.7842	-3.7842

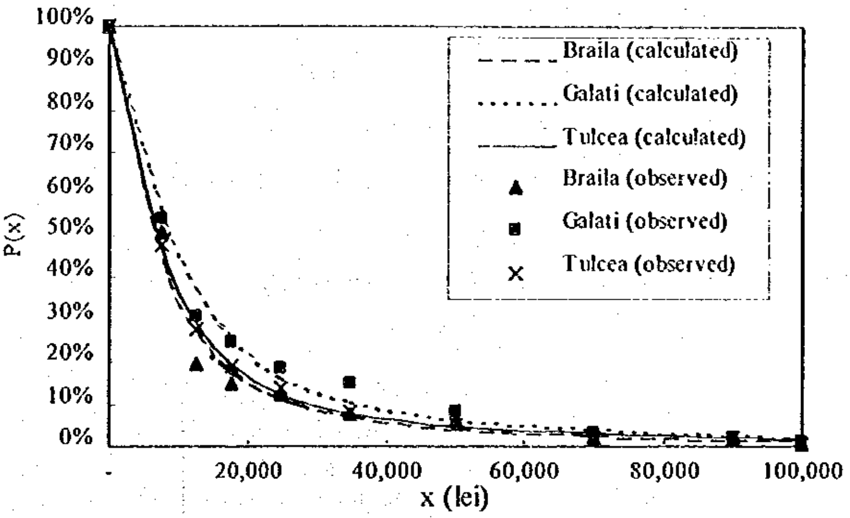
It is noted that the categories at both ends are eliminated from the above table because they don't have central values.

The result of regression estimate is summarized below.

- Braila : $Logit\ P_i = -3.4933\ \mathrm{Log}_{10}X_i + 13.296$ $R^2 = 0.9587$
- Galati : $Logit\ P_i = -3.5281\ \mathrm{Log}_{10}X_i + 13.899$ $R^2 = 0.9636$
- Tulcea : $Logit\ P_i = -3.5195\ \mathrm{Log}_{10}X_i + 13.534$ $R^2 = 0.9908$

Since all of three cities obtain very high correlation coefficients above 0.95, the estimation seems to be fully successful.

The below graph shows the observed value and calculated value of P_i.



3.5.3 Mean Value of WTP

The mean value of WTP was estimated by the equation [3]. Maximum level was set at ROL 200,000, double amount of the highest presented amount. The result is as follows.

- Braila : ROL 13,014.9 per household per month
- Galati : ROL 17,029.4 per household per month
- Tulcea : ROL 14,019.2 per household per month

3.6 Household Income and Miscellaneous Expenses

3.6.1 Estimation of Household Income

The abovementioned logit model method was applied for the estimation of mean value of household income.

The regression coefficients *a, b* in the expression [2] are obtained by the regression method using the data below.

Xi (1,000 lei)		750	1,250	1,750	2,500	3,500	5,000	7,000	9,000
Pi	Braila	83.8%	52.2%	27.2%	13.4%	5.9%	3.4%	0.9%	0.0%
	Galati	84.1%	54.5%	39.2%	30.6%	19.4%	13.7%	9.9%	5.7%
	Tulcea	87.2%	59.8%	43.6%	25.5%	12.8%	6.9%	2.5%	0.9%
log (Xi)		2.875	3.097	3.243	3.398	3.544	3.699	3.845	3.954
LogitPi	Braila	1.6397	0.0876	-0.9851	-1.8628	-2.7627	-3.3354	-4.6603	0.0000
	Galati	1.6639	0.1788	-0.4401	-0.8201	-1.4225	-1.8409	-2.2115	-2.8000
	Tulcea	1.9212	0.3977	-0.2569	-1.0697	-1.9212	-2.6094	-3.6668	-4.6634

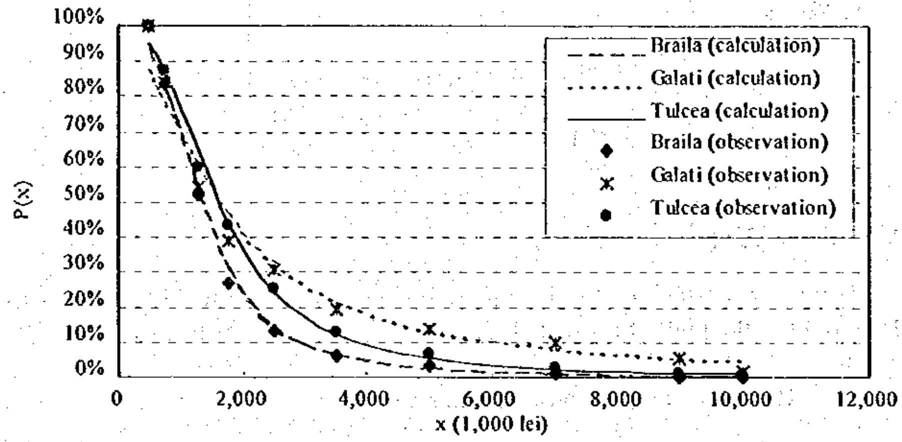
The categories at both ends are eliminated from the above table because they don't have central values. It is noted that the unit of X_i is 1,000 lei.

The result of regression estimate is summarized below.

- Braila : *Logit* P_i = -6.2471 $Log_{10}X_i$ + 19.455 R^2 = 0.9935
- Galati : *Logit* P_i = -3.7802 $Log_{10}X_i$ + 12.106 R^2 = 0.9732
- Tulcea : *Logit* P_i = -5.7913 $Log_{10}X_i$ + 18.537 R^2 = 0.9933

Since all of three cities obtain very high correlation coefficients above 0.95, the estimation seems to be duly successful.

The below graph shows the observed value and calculated value of P_i.



The mean value of household income was estimated by the equation [3]. Maximum level was set at 100,000,000 lei. The result is as follows.

- Braila : ROL 1,643,600.3 per household per month
- Galati : ROL 3,063,748.0 per household per month
- Tulcea : ROL 2,088,266.9 per household per month

3.6.2 Miscellaneous Household Expenses

Monthly households' expenses for household maintenance, electricity, and telephone are estimated by arithmetic mean of obtained data. The result is as follows:

Unit : ROL/household/month

	Maintenance	Electricity	Telephone	Total
1:Braila	126,534.2	61,807	79,624	267,966
2:Galati	133,593.2	81,804	115,932	331,329
3:Tulcea	151,911.0	119,718	104,212	375,840

The ratio of these expenses to household income is calculated as follows:

	Maintenance	Electricity	Telephone	Total
1:Braila	7.7%	3.8%	4.8%	16.3%
2:Galati	4.4%	2.7%	3.8%	10.8%
3:Tulcea	7.3%	5.7%	5.0%	18.0%

Table AI.2.1 Result of Parameter Estimation

	Variable	Estimated value	Standard error	Level of significance
Braila	α	3.9966	0.03531	***
	δ	-0.7129	0.01208	***
	σ	1.2458	0.07287	***
	Maximum log-likelihood		-376.4	
Galati	α	4.0768	0.03948	***
	δ	-0.3505	0.01445	***
	σ	1.0382	0.07226	***
	Maximum log-likelihood		-381.7	
Tulcea	α	4.0257	0.02942	***
	δ	-0.3258	0.00531	***
	σ	0.7344	0.04489	***
	Maximum log-likelihood		-377.9	
Constranta	α	4.0848	0.03666	***
	δ	-0.5579	0.02041	***
	σ	1.3188	0.08793	***
	Maximum log-likelihood		-355.0	
Brasov	α	3.9576	0.04011	***
	δ	-0.5035	0.02154	***
	σ	1.3656	0.09498	***
	Maximum log-likelihood		-357.7	
Bucharest	α	3.9715	0.03545	***
	δ	-0.5387	0.01542	***
	σ	1.1671	0.07604	***
	Maximum log-likelihood		-350.5	
F/S cities	α	4.0328	0.01972	***
	δ	-0.4396	0.00590	***
	σ	0.9786	0.03533	***
	Maximum log-likelihood		-1144.8	
National samples	α	4.0035	0.02151	***
	δ	-0.5333	0.01103	***
	σ	1.2828	0.04967	***
	Maximum log-likelihood		-1064.9	
As a whole	α	4.0204	0.01453	***
	δ	-0.4729	0.00569	***
	σ	1.0995	0.02907	***
	Maximum log-likelihood		-2213.6	

*** : Significant level is lower than 1.0%.

Attachment 1

The Questionnaires (Version E1)

Introduction

This questionnaire survey aims to estimate benefits of the project to construct wastewater treatment plants along the downstream reach of Danube River.

This questionnaire consists of 4 sections. First section is description of the Danube Delta. Second section is explanation of negative impacts on the Danube Delta. Third section is description of the project. The last section is a series of questions.

It is guaranteed that your personal information will never be disclosed.

Section I Description of the Danube Delta

(☛Surveyor! If necessary, show the pamphlet of Danube Delta.)

The Delta is located at the mouth of the Danube River. The river collects the water from 15 countries, and flows four capital cities, Vienna, Bratislava, Budapest and Belgrade.

The Danube Delta is the second largest Delta in Europe with about 4,200km². The Danube Delta has very rich variety of fauna and flora, eventually the 3rd richest bio-diversity in the world next to the Great Barrier Leaf in Australia and the Galapagos Islands in Chile.

There are 1,668 species of flora and 3,846 species of fauna. Among them, 277 species of flora and 1,921 species of fauna are endemic species and can not be found outside the Danube Delta.

Reeds cover around 1,700 km². Reedbeds provide safe spawning places for some fish. River water is filtered and purified by reedbeds. Decaying reeds form floating islands so called 'plaur' which provide suitable nesting places for birds and living places for animals.

White pelican is a symbol of the Danube Delta. 2,500 pairs of white pelicans are living here. The Danube Delta breeds also other very important species of birds, for example more than 60% of the world population of pygmy cormorants can be observed. The Danube Delta is a very important area for passage migrants and wintering birds, which breeds more than 300 species of the birds.

The Danube Delta is very important for fish with more than 45 species of fresh water, including high value species like pike and sturgeon.

Pike prefers clear water. However the water quality has been getting worse and worse because of the human activities, and as a result the number of pikes has declined severely.

Attachment 1

Action to Biosphere Reserve

The importance of bio-diversity is well recognized worldwide. To protect the highly important bio-diversity in the Danube Delta, the government of Romania has designated that territory as the Danube Delta Biosphere Reserve in 1990. Since 1990, the Danube Delta has been included in the International Network of Biosphere Reserves and registered to the World Heritage List of UNESCO. The Danube Delta is the only delta listed in the International Network of Biosphere Reserve in the world.

Section II Negative impacts on the Danube Delta

The Danube Delta has suffered deterioration of environment and loss of species caused by various human activities.

- Increase nutrient levels in the water (in part due to the domestic wastewater from households which is discharged into Danube River or tributaries of Danube River without proper or even any treatment) leading to dramatic losses of aquatic plants and changes in fish communities.
- Construction of dams upstream. Dams have altered fluctuation of water level and flooding frequency. It is said that dams also destructed spawning places of sturgeon.
- Creation of agricultural and fish polders in the Danube Delta which reduced the original natural area by over 20%.
- Extension of canals for navigation that carries polluted water all over the Danube Delta and reduces the overall drainage time during the flood period.
- Industrial pollution and effluents that accumulated in fish and then in the eggs of fish-eating birds like pelicans and cormorants, so reducing their breeding success.

Attempt toward protection and improvement of the biodiversity and environmental conditions in the Danube Delta

Although it is impossible to remove all of the above negative impacts, there are some attempts towards nature conservation of the Danube Delta. One example is a pilot project for ecological restoration by re-inundating abandoned agricultural polders. This pilot project is ongoing since 1994.

Attachment 1

Section III Project Description

Please assume that now Romanian Government and seven cities along the Danube River plan the following project.

The Aim of the Project

- To construct a sewage treatment plant with biological treatment process in each of the seven cities along the Danube River: Drobeta Turnu-Severin, Turnu M g urele, Giurgiu, C l ra i, Br ila, Gala i and Tulcea. After the completion of the project, wastewater from all the cities will be properly treated in compliance with Romanian Standards.

Reasons why the project must be implemented

- A total population of these cities is around 1,000,000 and daily wastewater generation in these cities is around 50,000 m^3. Wastewater from kitchen, bathroom and toilet is collected by sewer networks. The wastewater contains high pollution loads and needs to be treated before discharging.
- At present, all the seven cities discharge the wastewater with no treatment or insufficient treatment. Drobeta Turnu-Severin, Br il a, Gala i and Tulcea do not have sewage treatment facilities, and remaining three cities apply mechanical treatment process only. The water quality of discharge from all the seven cities does not meet the Romanian Standards.

Costs of the Project

The implementation of the project requires roughly one trillion lei (Lei 1,000,000,000,000) equivalent to eighty million US dollar (US$ 80,000,000).

Benefits of the Project

Though the project aims to improve the water quality of Danube River and to contribute to protection and improvement of the bio-diversity and environmental condition of Danube Delta, the project can not achieve tangible improvement of river water quality as a single project. Please regard this project as the first step to protect not only national but also international heritages, Danube River and the Danube Delta.

Attachment 1

Section IV Questions

Q1: Do you agree to implement this project ?

Yes	1	
No	2	*Surveyor! Skip to Q3.*

Q2a: Please assume the following situation For the implementation of the Project the State Government plans to collect your contribution of **5,000** lei per month. Your contribution is needed for five years. Your contribution will be used only for the Project.

Do you agree to implement the Project?

Yes	1	*Surveyor! Skip to Q2b.*
No	2	*Surveyor! Skip to Q2c.*

Q2b: Please assume the following situation For the implementation of the Project the State Government plans to collect your contribution of **10,000** lei per month. Your contribution is needed for five years. Your contribution will be used only for the Project.

Do you agree to implement the Project?

Yes	1	*Surveyor! Skip to Q3.*
No	2	*Surveyor! Skip to Q3.*

Q2c: Please assume the following situation For the implementation of the Project the State Government plans to collect your contribution of **2,000** lei per month. Your contribution is needed for five years. Your contribution will be used only for the Project.

Do you agree to implement the Project?

Yes	1
No	2

Q3: Do you know something about Danube Strategic Plan?

Yes	1
No	2

Q4: Do you know something about Agenda 21 or Rio de Janeiro Environment Summit?
If the respondent has heard about at least one of them, mark code 1.

Yes	1
No	2

Q5: Have you ever been to the Danube Delta?

Yes	1	*Surveyor! Continue with Q6!*
No	2	*Surveyor! Skip to Q8!*

Attachment 1

Q6: When was your last visit to the Danube Delta ? |__|__|__|__| Year

Q7: How often have you traveled in the Danube Delta?

Many times a year	1
Once a year	2
Once in three years	3
More rarely	4

Q8: In average, how many days did you spend there (during a trip)? |__|__| Days

Q9: How much did you pay for your household maintenance in the last month? (Maintenance costs = water, garbage, gases, elevator)

|__|.|__|__|__| thousand lei

Q10: How much was your household income in the last month?

|__|__|.|__|__|__|thousand lei.

Q11: What is your occupation ?

owner, manager;	1
specialist, faculty graduate;	2
technician, teacher	3
clerk	4
services employee, merchant	5
qualified worker, craftsman	6
worker	7
farmer	8
military	9
other (What?)	10

Q12: What is your age?

18 – 25 years	1
26 – 35 years	2
36 – 45 years	3
46 – 55 years	4
56 years and over	5

Q13: Sex

Male	1	Female	2

Q14: How many family members live together? |__|__| Persons

Thank you for your work! Please read the following sentence and then sign up.

I declare I realized this interview according to the interviewing door to door instructions with a respondent selected according to the sampling instructions.
Signature ____________________ Date ______________

☛*Surveyor!*

City :		Sample Code:	

Attachment 2

The Financial Questionnaire

Section I Identity of Household Head

Q1: What is your age?

18 – 25 years	1
26 – 35 years	2
36 – 45 years	3
46 – 55 years	4
56 years and over	5

Q2: Sex

Male	1	Female	2

Q3: Marriage Status

Married	1	Single	2

Q4: How many family members live together? |__|__| Persons

Q5: What is your occupation ?

1	owner, manager;	6	qualified worker, craftsman
2	specialist, faculty graduate;	7	worker
3	technician, teacher	8	farmer
4	clerk	9	military
5	services employee, merchant	10	other (What?)

Q6: What is your final education ?

1	university;	4	general school
2	post high-school education	5	no schooling
3	high school	6	other

Section II Project Description

It is planned to construct a wastewater treatment plant in your city. The wastewater treatment plant applies biological treatment process in order that wastewater from your city will be properly treated in compliance with Romanian Standards.

The reasons why the project must be implemented are as follows:

- Wastewater from kitchen, bathroom and toilet is collected by sewer networks. The wastewater contains high pollution loads and needs to be treated before discharging. However, at present your city does not have any treatment facility and collected wastewater is discharged into Danube River directly.
- According to Romanian regulations, the city discharging wastewater without proper treatment should pay penalty to the state government.

Attachment 2

- To become EU member it is necessary to respect EU regulations (Directives). EU regulations requests all settlements with population more than 2000 to install wastewater treatment facility until 2005.

Section III Questions

Q7: What will be the maximum limit you are willing to pay monthly (at present value) for sewerage service, taking account of the importance of the construction of the sewerage treatment plant in your city?

1	less than 5,000 lei	6	30,000 ~ 39,999 lei
2	5,000 ~ 9,999 lei	7	40,000 ~ 59,999 lei
3	10,000 ~ 14,999 lei	8	60,000 ~ 79,999 lei
4	15,000 ~ 19,999 lei	9	80,000 ~ 99,999 lei
5	20,000 ~ 29,999 lei	10	more than 100,000 lei

Q8: How much did you pay for your household maintenance in the last month? (Maintenance costs = water, garbage, gases, elevator)

|__|.|__|__|__| thousand lei

Q9: How much did you pay for electricity in the last month?

|__|.|__|__|__| thousand lei

Q10: How much did you pay for telephone in the last month?

|__|.|__|__|__| thousand lei

Q11: How much was your household income in the last month ?

1	less than 500,000 lei	6	3,000,000 ~ 3,999,999 lei
2	500,000 ~ 999,999 lei	7	4,000,000 ~ 5,999,999 lei
3	1,000,000 ~ 1,499,999 lei	8	6,000,000 ~ 7,999,999 lei
4	1,500,000 ~ 1,999,999 lei	9	8,000,000 ~ 9,999,999 lei
5	2,000,000 ~ 2,999,999 lei	10	more than 10,000,000 lei

Thank you for your work! Please read the following sentence and then sign up.

I declare I realized this interview according to the interviewing door to door instructions with a respondent selected according to the sampling instructions.
Signature ____________________ Date __________

☛*Surveyor!* | **City :** | | **Sample Code:** | |

APPENDIX- 3 SELECTION OF TREATMENT PROCESS

1. GENERAL

The wastewater treatment plants (WWTP) of the seven cities studied under this feasibility study are required to produce the wastewater effluents that meet the effluent quality standards as set forth by the Romanian Standards (NTPA 001) "Load Limits of Pollutants in Wastewater Discharged in Water Resources."

In view of the prime importance of the river protection, it is possible that more stringent wastewater effluent discharge quality control requirements will be set in the future for the Danube River and its tributaries, for which additional treatment processes beyond the secondary level may be required.

In selecting the most appropriate WWTP system that will meet with the present standards and possible more stringent effluent requirements in the future, a variety of alternative combinations of treatment processes have been prepared and evaluated for accruing advantages and disadvantages.

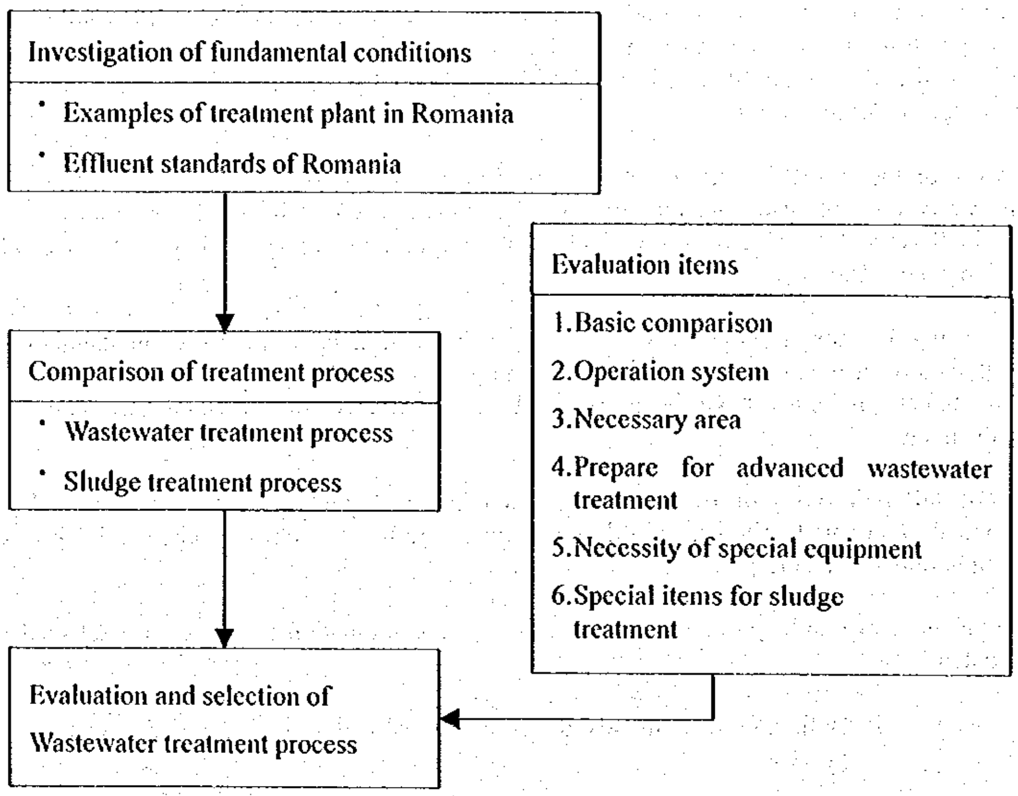
Various different types of treatment methods can be applied for the treatment, including biological (activated sludge, biofilm systems, etc.) and physical-chemical processes (precipitation, ozone, etc.).

Among these available processes, four scenarios of combination processes are selected and evaluated:

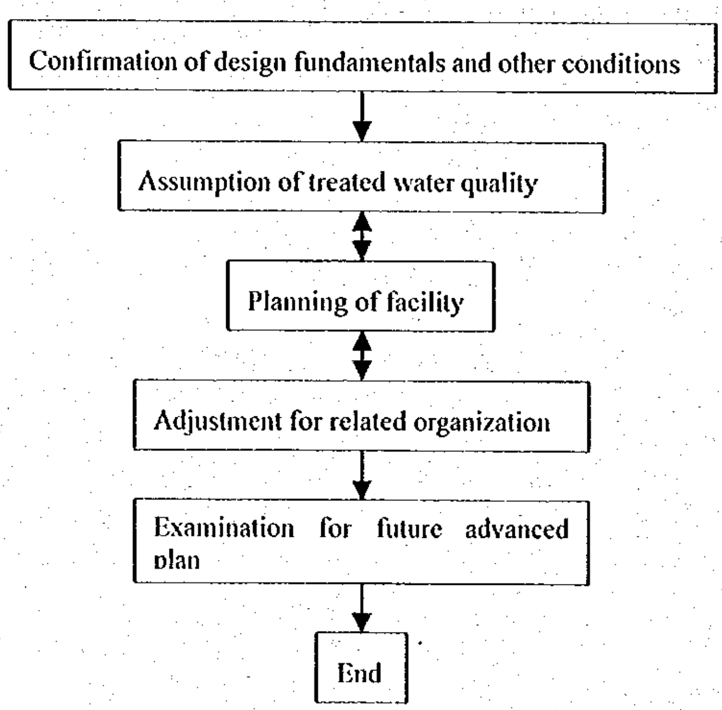
- Scenario 1: BOD and SS removals, the conventional activated sludge and oxidation ditch processes;
- Scenario 2 : BOD, SS, T-N removals, the recirculation nitrification-denitrification process, and step inflow multi-stage nitrification-denitrification processes;
- Scenario 3 : BOD, SS and T-P removal, Anaerobic-aerobic activated sludge process; and
- Scenario 4 : BOD,SS, T-N and T-P, Anaerobic-anoxic-aerobic process.

2. PROCEDURES FOR EVALUATION OF TREATMENT PROCESSES

A sequence for the process selection methodology is shown below:



WWTP of the three cities are selected by the following steps:



3. PLANNING BASIS

The two major wastewater discharge quality standards concerned with the wastewater management programs are "(NTPA 001) Load Limits of Pollutants in Waste Water Discharged In Water Resources (NTPA 002) 1997"and "Quality Indications of Wastewater Discharged into Municipal Sewage Systems."

The standard values for wastewater effluent quality limits discharging to the receiving water bodies are as follows:

- BOD = 20 mg/l,
- SS = 60 mg/l,
- T-N = 10 mg/l, and
- T-P = 1 mg/l

4. STUDY ON TREATMENT PROCESS

4.1 PRELIMINARY TREATMENT SYSTEM

All of the existing WWTPs have screening facilities ahead of pumps to protect the equipment from clogging by large floatable obstacles, followed by gravity or aerated grit chambers and grease removal devices.

The water quality data obtained from the water quality survey under the present study show that the concentrations of grease and oil are generally high, ranging from 3~4 to 50 times higher than the normal quality value (1 mg/l). The high grease and oil contents are detrimental to proper operation of wastewater treatment processes, and that grease and oil must be removed ahead of the primary and secondary treatment processes.

Aerated grid chambers and grease removal facilities are generally placed after pumping process in order to reduce construction costs and for easy operation and maintenance of the system. The WWTPs are provided with disinfection process to kill coliform bacteria.

4.2 BIOLOGICAL WASTEWATER TREATMENT SYSTEM

4.2.1 BASIC PROCESS MECHANISMS

The wastewater enters a reactor basin where preformed microbial floc particles are brought into contact with the organic components of the wastewater. The organic matter serves as a carbon and energy source for microbal growth and is converted into microbial cell tissue and oxidized end products (mainly CO_2).

When the air is supplied into the wastewater, the number of microorganisms increase, being fed with organic matters from wastewater and producing floc. This product is called activated sludge, based on bacteria, protozoa, microorganisms, and inorganic and organic compounds.

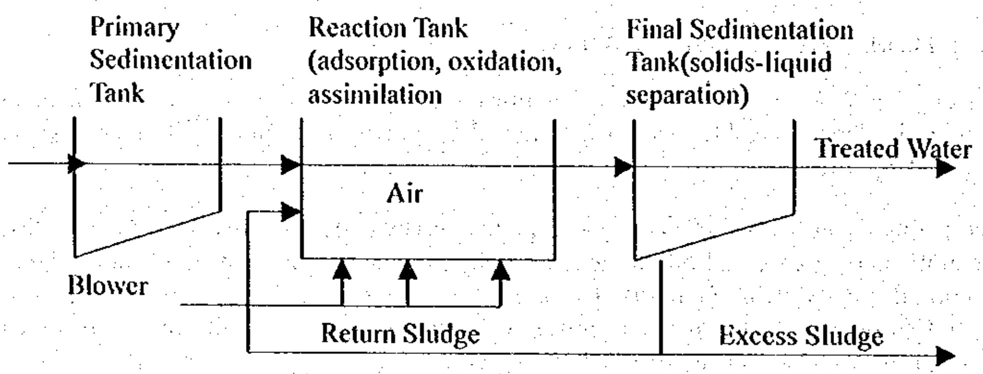
Mixing the activated sludge with the wastewater which contains dissolved oxygen, organic matters from the wastewater will be adsorbed by the activated sludge, and oxidized or assimilated by metabolism of microorganisms which produces aerobic sludge, and some part of microorganisms change to aerobic sludge.

In the activated sludge process, air is supplied by either mechanical or submerged devices (mechanical aeration and diffuser aeration). Mechanical devices agitate the sewage in a reactor basin so as to entrain the air from the atmosphere. Diffuser aeration induce the air or pure oxygen into the sewage by special devices which produce bubbles.

Mechanical and/or diffusersubmerged aeration maintain activated sludge in suspended growth status. Mixed liquor of activated sludge which goes out from the reaction tank, is separated to solids and liquid by gravity settling into the final settling tank, and supernatant liquor is discharged as a treated water.

Activated sludge which is settled and thickened, is returned to reaction tank to use for wastewater treatment by mixing with wastewater, and some part of the activated sludge is withdrawn as excess sludge.

The process of wastewater pollutants removal by the activated sludge system can be summarized in two components: one is pollutant removal in reaction tanks by microorganisms activity (such as adsorption, oxidation, assimilation), producing activated sludge, and the second is separation of biological solids from the treated wastewater in final settling tanks.

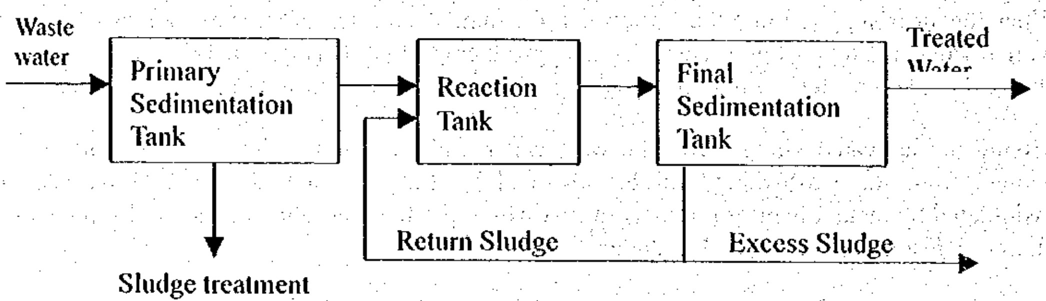


Two processes that are most widely used for the biological wastewater treatment are:

- Conventional activated sludge process
- Oxidation ditch treatment process

4.2.2 CONVENTIONAL ACTIVATED SLUDGE PROCESS

There are many differences in planning the conventional activated sludge process depending on localities and surrounding conditions, such as sludge retention time in reaction tanks, densities of MLSS, depth of tanks, shape of tanks, etc.



The characteristics of conventional activated sludge process are shown below:

- Required treatment area is smaller than oxidation ditch process;
- Consumption of energy is not quite high;
- Operation and maintenance are rather difficult; and
- More excess sludge production.

Design bases of the conventional activated sludge process (Japanese standards) are shown below:

MLSS Density	1,500 ~2,000 mg/l
BOD – SS Load	0.2 ~ 0.4 kg BOD/ kg SS・day
Water depth of Reaction Tank	4 ~ 6 m (Width of Tank is one to twice of depth)
Shape of Reaction Tank	Rectangular
H.R.T	4 ~ 6 hour
A.S.R.T	4 ~ 6 days

4.2.3 STUDY ON AERATION TIME OF CONVENTIONAL ACTIVATED SLUDGE PROCESS

Design standards of the conventional activated sludge method in Romania and Japan are summarized in *Table AI.3.1*.

There are no significant differences between the two standards as to primary and final sedimentation tanks, however, as to aeration tank the differences are rather significant.

The Study applies 6-hour aeration time to the aeration tank design, which follows the Japanese standards, based on the following reasons.

(1) Comparison of Design Standards

In the Romanian Standards, the sludge return ratio is set as high as 100 %, because the mixed liquor suspended solids concentration (MLSS, that is concentration of suspended solids in activated sludge mixed liquor) in aeration tank is set rather high side. Under the Romanian Standards, the aeration tank size becomes rather small, as the set aeration time of 3 hours in the aeration tank is relatively short. Consequently, the increased number of return sludge pumps and the accompanying energy makes the cost higher.

By the Japanese Standards, the aeration tank volume will be larger than that by the Romanian Standards as the hydraulic retention time in the aeration tank is about 6 hours. The return sludge ratio is at the maximum 50 % to maintain BOD-SS loading level of 0.3 kg/kg-day that is as same as the Romanian Standards. Although the proposed criteria in the Japanese Standards will make the civil construction expenses more costly, there are some advantages including:

- As the return sludge ratio is set as low as 50 %, expenses for return sludge pumps and operation are less costly; and
- This system makes operation easy because of the low MLSS concentration. Should bulking occurs in aeration tanks, the return sludge ratio can be increased as a remedial measure to as high as 100 % to recover the aeration function to normal.

Essential criteria of the two design standards are as show in table below. Installation and operation costs are compared in the following sections to establish the reasonable treatment process from financial viewpoint.

Comparison of Design Standards of Aeration Tank

	Unit	Romanian Standard Case	Japanese Standard Case
BOD-SS Loading	BOD kg/(MLSS kg x day)	0.3	0.3
Concentration of return sludge	mg/L	6600	5000
Return sludge ratio	%	100	50
MLSS	mg/L	3300	1667
Hydraulic retention time (HRT)	Hour	3	6
Return sludge ratio for equipment capacity	%	200	100
Return sludge ratio for normal operating	%	100	50

(2) Cost Comparison

Cost comparisons are made with the Romanian Standards and the Japanese Standards for a WWTP of 43,000 m^3/day capacity (same size as the Tulcea WWTP). The costs for comparison include civil works, return sludge pumps, and operation of return sludge pumps.

Life periods of the civil structure and equipment are assumed to be 50 years and 15 years respectively, and costs are calculated for over a 50-year period.

The concrete volume of aeration tanks with 6-hour aeration time is calculated to be 4,300 m^3, whereas that for the aeration tanks of 3-hour aeration time is 2,300 m^3.

In planning the return sludge pumps are assumed that 4 small pumps will handle 50 % of the sludge, and 2 large pumps will handle the remaining 50 % sludge. Specifications of the two types of pump are shown in the table below.

Specifications of Return Sludge Pumps

Kinds of Pump	Small Pump	Large Pump
Pump Type	Centrifugal	Centrifugal
Diameter	150 m	200
Capacity	1.9 m3/min	3.8 m3/min
TDH	10 m	10 m
Number of Pump	4 units	6 units (including 4 standby)
Motor Output	7.5 kW	11 kW

The required number of the return sludge pumps is selected based on the above specifications.

As the life period of the pump equipment is 15 years, 4 units of the return sludge pumps are required over the 50-year period.

Operation and maintenance cost is represented by the cost of electric power. The electric power requirement by the return sludge pumps based on the Japanese Standards is estimated as follows,

- 7.5 kW × 4 + 11 kW × 2 = 52 kW
- 52 kw × 24 hours × 365 days/year = 455,520 kWh/year

The electric power requirement of RO case is twice as much the JA case. The electric power costs are estimated by the required electric power and electric tariff of the Romania which is about US$ 0.05 /kWh.

The construction and operation costs of the two alternative cases are summarized in the table below.

Cost Comparison of Alternative Cases

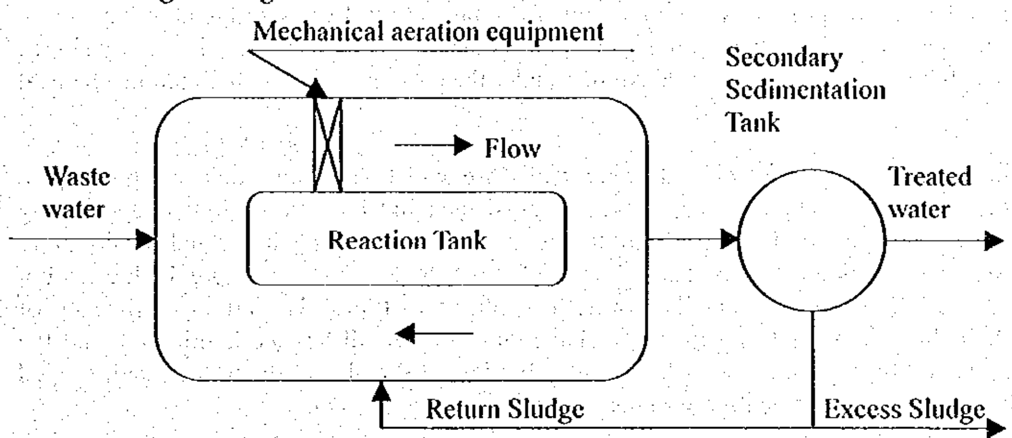
		Romanian Standard Case		Proposed F/S Case	
		HRT: 3 hours		HRT: 6 hours	
	Unit cost	Quantity	Cost(US$)	Quantity	Cost(US$)
Civil Construction					
Concrete work	100 US$/m³	2300 m³	230,000	4300 m³	430,000
Pump Equipment					
Romanian standard case	1,400,000 US$/unit	3 units	4,200,000		
Proposed F/S case	700,000 US$/unit			3 units	2,100,000
Total Installation Cost			4,430,000		2,530,000
Electric power cost	0.05 US$/kW				
Romanian standard case	911,040 KWh/year	50 years	2,277,600		
Proposed F/S case	455,520 kW/hyear			50 years	1,138,800
Total Required Cost for 50 years			6,707,600		2,530,000

The result of the cost comparison indicates that only the civil works by the Romania Standards is less costly than that by the F/S standards, but the equipment and operation cost by the F/S standards is lower than the Romanian Standards. The total cost of the system over the 50-year period by the Japanese Standards is apparently lower than that by the Romanian Standards, consequently, the 3-hour aeration are adopted in the Study.

4.2.4 OXIDATION DITCH TREATMENT PROCESS

Oxidation ditch treatment process is a system which generally omit primary sedimentation, and uses endless channels as reactor basins, which are provided with mechanical aeration equipment for aeration. Oxidation ditches are used to treat the wastewater by low-load activated sludge, and solids-liquid separation will be made in secondary settling tanks.

Mechanical aeration equipment is not only for supplying the air to biological process, but also for mixing of wastewater and activated sludge in ditches, recirculation of mixed liquor, and prevention of sludge settling.



Treatment of wastewater in a low-load condition (BOD-SS load is 0.03 ~ 0.05 kgBOD /kgSS,day), oxidation ditch treatment process is characterized by long solids retention time and by nitrifying reaction increasing, it is also possible to remove nitrogen by providing an anoxic zone.

Characteristics of oxidation ditch treatment process are shown below:

- Treatment of wastewater under low-load condition makes it possible to achieve stable treatment performance against the fluctuations of inflows, changes of quantity and quality, and low temperature (-5℃) of wastewater;
- It is possible to obtain a 70% efficiency for nitrogen removal;
- Mixed liquor in oxidation ditch, because of dissolved oxygen density has a slope to flow direction but density of MLSS and alkalinity are uniform;
- Excess sludge is has about 75% of SS which enters the treatment plant, and is less than that from conventional activated sludge process;
- Excess sludge is decomposed at high level in aerobic conditions, and becomes more stable than conventional activated sludge process; and
- Because of long retention time and shallow depth of reaction tank, oxidation ditch needs wide site.

Design fundamentals of oxidation ditch (Japanese standards) treatment process are as follows:

MLSS Concentration	3,000 ~ 4,000 mg/l
BOD - SS load	0.03 ~ 0.05 kg BOD/ kg SS・day
Water depth of reaction tank	1.0 ~ 3.0 m
Width of reaction tank	2.0 ~ 6.0
Hydraulic retention time (H.R.T)	24 ~ 48 hour
Activated sludge retention time (A.S.R.T)	8 ~ 50 days
Return sludge ratio	100 ~ 200 %
Oxygen demand	1.4 ~ 2.2 kgO_2/kgBOD

4.3 SLUDGE TREATMENT

Gravity sludge thickening method has in general low sludge thickening performance than other processes, but the structure of equipment is simple and has less mechanical failure. Hence, capital and O/M costs are generally low.

Mechanical sludge thickeners, such as centrifugal and floatation thickeners, fully rely on mechanical dewatering processes, with the higher capital and O/M costs and tend to have more chances of mechanical failures than the gravity thickeners. In view of these, the gravity sludge thickener will be used for the sludge thickening under the present project rather than mechanical processes.

Three different types of anaerobic digester tanks are widely applied, such as egg-shaped, tortoiseshell-shaped and cylinder-shaped types. Egg-shape tanks have the highest sludge mixing performance, but capital costs are the highest among the three different shapes and require more complicated construction methods. The capital costs for cylinder-shape tanks are the lowest, but sludge mixing efficiency is generally lower than other two types. The mixing efficiency of tortoiseshell-shape tanks is lower than egg-shape tanks but the difference is minimal, and the capital costs are lower than the egg-shape tanks. In view of the above, the tortoiseshell-shaped type is preferred for anaerobic digester tanks under the present project.

For sludge dewatering, a mechanical dewatering is proposed because the required area is relatively small, dewatering efficiency is high, and can produce stabilized sludge cake. Two different types of mechanical dewatering equipment, centrifuges and belt filter press systems, are most widely used for the digester sludge dewatering. Centrifuges generally consume more power and need more O/M costs than filter press type. The belt filter equipment has rather complicated dewatering mechanism, and requires wider floor areas and more capital costs, but operation and maintenance costs are generally low compared with the centrifuges. For these reasons, belt filter press system will be applied under the present project.

If the wide site area were available, the capital and O/M costs for dewatering could be significantly reduced by providing simple sand-drying beds instead of the mechanical dewatering system.

4.4 ADVANCED WASTEWATER TREATMENT

4.4.1 GENERAL

(1) Removal of T-N

T-N removal measures of conventional activated sludge and oxidation ditch processes include the following:

- Extension of facilities;
- Use a Bio-N-Cube in order to decrease a extension of facility; and
- Design WWTP facilities taking into account future upgrade, such as preparation of deep aeration tanks and two-story final sedimentation tanks at the initial stage, and easy improvement of the facilities easily in the future.

(2) Removal of T-P

For T-P removal, coagulant may be used except for the biological process. If anaerobic zones (retention time of 1.5 hour) can be provided in the first half of the activated sludge aeration tanks, it is possible to remove a phosphorus in the conventional activated sludge process.

(3) Removal of T-N, T-P

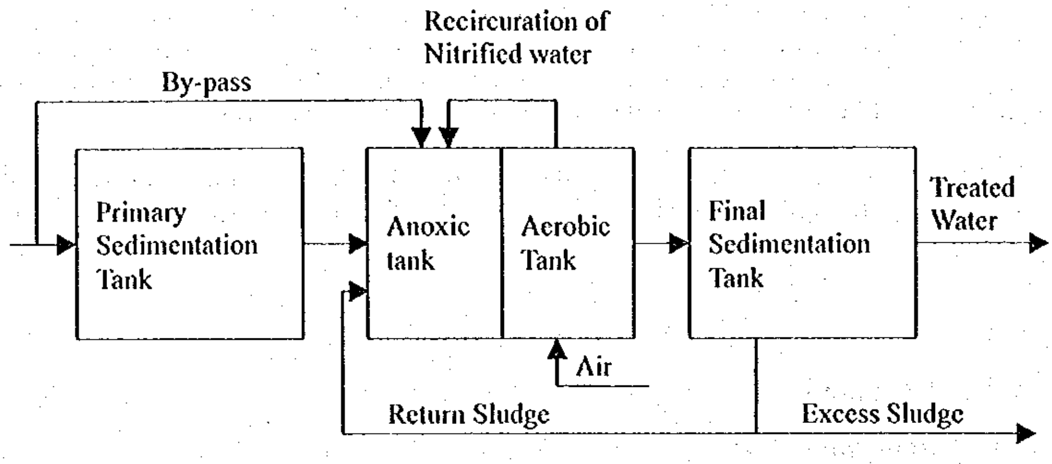
Necessity special equipment to make sure a high removal efficiency are examined. In case of biological process for T-P removal, phosphorus may need to be removed from the sludge under anaerobic condition.

4.4.2 TOTAL NITROGEN REMOVAL PROCESS

(1) Recirculation Nitrification-denitrification Process

Recirculation nitrification-denitrification process consists of the reaction tanks divided into two separate zones: anoxic(denitrification) and aerobic(nitrification). The wastewater and the return sludge go over the anoxic zone, and also a part of nitrified mixed liquor in the aerobic zone is recirculated to the anoxic zone.

In the aerobic zone, ammonia nitrogen that enters in it, is oxidized to form nitrite nitrogen and/or nitrate nitrogen. Then, in the anoxic zone, oxidized nitrogen is converted to nitrogen gas by oxidation reaction of organic matters from influent wastewater.



For average water quality of urban wastewater, removal efficiency of total nitrogen as annual average is expected to be 60 ~ 70% for primary sedimentation tank effluent, and also BOD and SS removal efficiency exceeds the conventional activated sludge process. Characteristics of recirculation nitrification-denitrification process are shown below:

- For total nitrogen design removal efficiency of 60 ~ 70%, the capacity of reaction tank is larger than conventional activated sludge process;
- It is necessary to divide the reaction tank;
- Some equipment (pumps) is required to recirculate a nitrified liquor;
- In order to ensure food to microorganisms in the aerobic zone, it is necessary to provide a channel to by-pass the primary sedimentation tank in case of rainfall or for initial operation;
- It is necessary to maintain MLSS concentration of 2,000 ~ 3,000 mg/l (higher than conventional activated sludge process). For final settling tank design, a small value for surface loading and a high effective water depth should be considered; and
- Scum breaker should be provided in the anoxic tank.

Design fundamentals of recirculation nitrification-denitrification process are shown bellow:

Items of water Quality	Reaction Tank Influent Water Quality	Design Quality of Treated Water
BOD (mg/l)	130	10
SS (mg/l)	70	5
T-N	36	12
Temperature (℃)	13℃	

Design Example

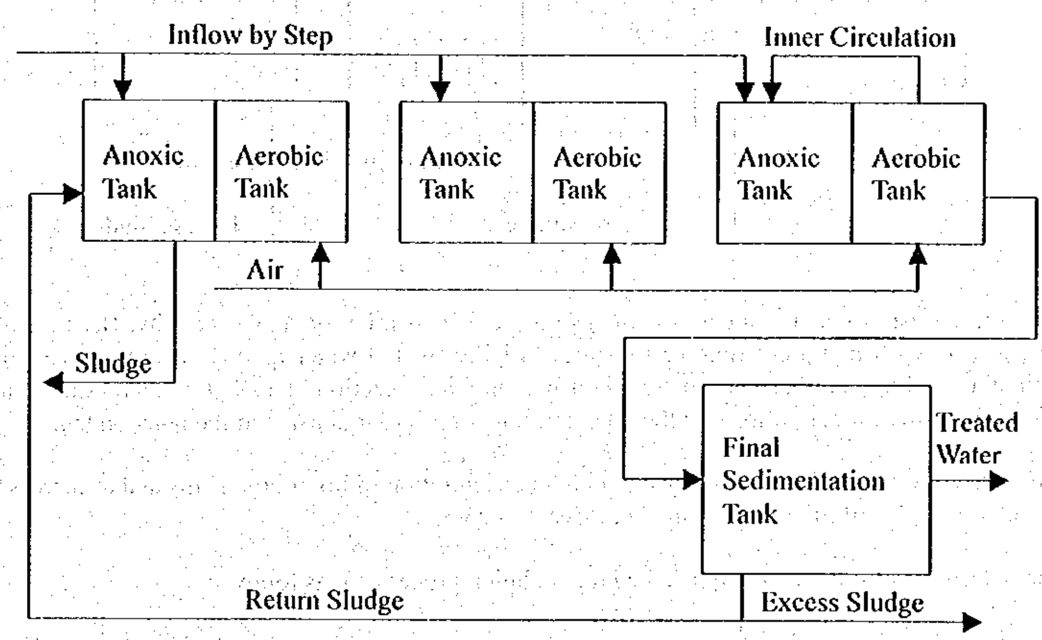
Items	Design Fundamentals
Reaction Tank	
Recirculation Ratio	150 (%)
Return Sludge Concentration	9,000 mg/l
Return Sludge Ratio	50 (%)
MLSS Concentration	3,000 mg/l
Hydraulic Retention Time(HRT)	12 hour
HRT of Anoxic Zone	4.8 hour
HRT of Aerobic Zone	7.2 hour
Activated Sludge Retention Time(ASRT)	14 days
Final Sedimentation Tank	
Surface Loading	20 m^3/m^2/day
Settling Time	4.2 hour
Effective Water Depth	3.5 m

(2) Step Inflow Multi Stage Nitrification-denitrification Process

In order to improve the removal efficiency of total nitrogen, step-inflow multi-stage nitrification- denitrification process consists of more than two tanks, each having two zones, an anoxic zone and an aerobic zone, connect in series. It is necessary to ensure a high concentration of MLSS and long Sludge Retention Time (SRT) and to divide the wastewater equally to each anoxic steps of tank.

Ammonia nitrogen from wastewater which enters to each step of anoxic zone is nitrified in aerobic zone of the same step, after that enters into anoxic zone of the next step, and finally is discharged to atmosphere as a nitrogen gas.

During the denitrification reaction, organic matters from wastewater is applied with the influent to each step of anoxic tank.



To add more steps to this process, air volume is increased because it is applied to denitrification reaction after the nitrification reaction, it is not necessary so many internal recirculation of mixed liquor. So it is not necessary to provide a circulation pumps, and also it is not necessary electric power for pumps.

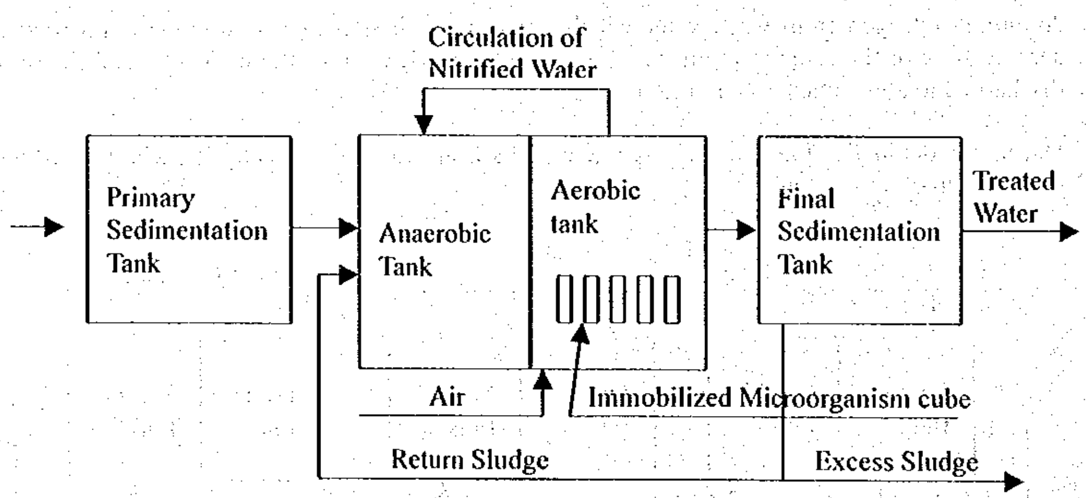
Removal efficiency of total nitrogen of this process is higher than recirculation nitrification - denitrification process, and wastewater which is divided equally to each steps is treated by activated sludge which is maintained equally at each tanks because each tanks is completely mixd type. So it is possible to control all aerobic zones by monitoring only one aerobic zone, if air volume is supplied equally to each aerobic zone, and it is also efficient for control the treatment plant.

Other characteristics are same as recirculation nitrification-denitrification process.

(3) Nitrification Quickened Recirculation Process Using Bio-N-cubes

This process is a nitrogen removal process where added cubes to aerobic zone (nitrification zone). It is also provided the recircuration nitrification-denitrification process in the same time with activated sludge process. The Bio-N Cubes have a size of 3 mm and are made by poly-ethylene glycol. During the process, the microorganisms are immobilized inside of cubes, and the nitrification time is shortened.

Generally, the recircuration process needs a high retention time compared with conventional activated sludge process (almost two times than the conventional activated sludge process) to maintain a nitrification bacteria, to produce enough nitrification in biological reaction tank and to produce enough denirification in anaerobic zone too. But Bio-N-Cubes process removes nitrogen for almost the same retention time as conventional activated sludge process.



Biological wastewater treatment systems use the effect of microorganism activity. Because of this, to shorten a treatment time or to achieve higher treated water quality, it is necessary to maintain usable number of microorganisms in the reaction tanks by increasing the microorganisms concentration and the retention time of microorganisms in the reaction tanks.

This process was developed to carry out a high concentration of microorganisms and to increase the retention time of microorganisms in the reaction tank.

Characteristics of nitrification quickened recirculation process are as follows:

- By adding immobilized microorganism cubes in the aerobic tank, which can maintain a high concentration of microorganisms in the reaction system, and reduce the anaerobic zone capacity too;

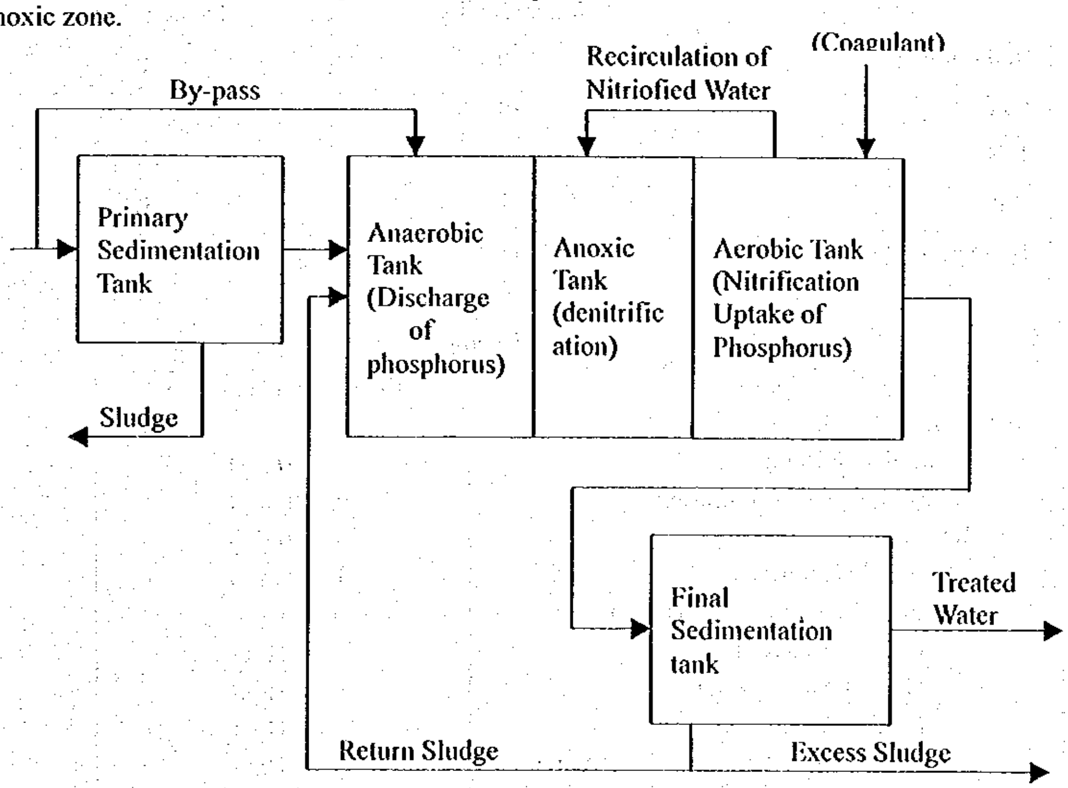
- By adjusting the quantity of immobilized microorganism cubes, a suitable nitrifying bacteria corresponding to nitrogen load can be maintained;
- By adding immobilized microorganism cubes to the aerobic zone, control SRT will become not necessary to maintain nitrifying bacteria into the treatment system; and
- Because of the high BOD-SS load, compared with the recircuration process, this process can have high denitrification rate and increase denitrification efficiency.

4.4.3 REMOVAL OF TOTAL NITROGEN AND TOTAL PHOSPHORUS

Anaerobic-anoxic-aerobic process is mixed process of biological phosphorous removal process and biological nitrogen removal process. It use a excessive uptake phenomenon of phosphorus and nitrification-denitrification reaction by microorganisms in activated sludge.

Phosphorus removal process which is applied to this process is anaerobic-aerobic activated sludge process, and nitrogen removal process is decircuration nitrification-denitrification process.

This is a process where it is provide an anaerobic zone-anoxic zone(denitrification)-aerobic zone(nitrification) tank step by step as reaction tank. The inflow of the anaerobic zone consists of wastewater and return sludge and mixed liquor from the aerobic zone is recirculated to anoxic zone.



For the average water quality of urban wastewater, it is expected for primary sedimentation tank effluent, that total nitrogen removal efficiency to be 60 ~ 70%, and total phosphorus removal efficiency to be 70 ~ 80%.

Removal efficiency of this process has a tendency to decrease, especially for phosphorus, and if it is necessary to ensure an appropriate phosphorus removal efficiency, in many wastewater treatments plant, this process is used together with with other methods, such as chemical precipitation.

Design fundamentals and important elements for operation of anaerobic-anoxic-aerobic process are shown in below.

- In order to ensure food to microorganisms in anoxic and anaerobic zones, in case of rainfall or for initial operation, it is necessary to provide a channel to by-pass the primary sedimentation tank.
- In case of low concentration of alkalinity, or the rainfall influence is high because of special quality of watershed, it is necessary to provide a source of alkali matter or methanol to support denitrification. For average water quality of urban wastewater, this source is not necessary.
- In order to obtain a high phosphorus removal efficiency, it is better to thicken a sludge from primary sedimentation tank and excess sludge in separate facilities. This can also be useful when it is selected the sludge treatment process for low-load return sludge coming from settling tank.

Design fundamentals of anaerobic - anoxic - aerobic process is shown in bellow.

Design Fundamentals

Items of water Quality	Reaction Tank Influent Water Quality	Design Quality of Treated Water
BOD (mg/l)	130	10
SS (mg/l)	70	5
T-N	36	12
T-P	3.2	1.0
Temperature(℃)	13℃	

Design Example

Items	Design Fundamentals
Reaction Tank	
Recirculation Ratio	150 (%)
Return Sludge Concentration	9,000 mg/l
Return Sludge Ratio	50 (%)
MLSS Concentration	3,000 mg/l
Hydraulic Retention Time (HRT)	13.2 Hour
HRT of Anaerobic zone	1.2 Hour
HRT of Anoxic zone	4.8 Hour
HRT of Aerobic zone	7.2 Hour
Activated Sludge Retention Time(ASRT)	14 Days
Final Sedimentation Tank	
Surface Loading	20 m^3/m^2/Day
Settling Time	4.8 Hour
Effective Water Depth	4.0 m

5. CONSIDERATION FOR LAND RESTRICTION

5.1 PREPARATION OF ALTERNATIVES

Two major different types of secondary wastewater treatment processes are biological and physical-chemical treatments. Physical-chemical treatment processes consume considerable amount of chemicals, produce large amount of waste sludge, and need strict control of chemical dosing rates.

In biological wastewater treatment processes do not use much chemicals, operation and maintenance costs are low, and are most widely applied to wastewater treatment processes throughout in Romania and elsewhere in the world. For these reasons, the biological treatment processes are considered in the study on alternative combinations of processes.

In view of the possible restrictions for acquiring the WWTP lands, the following two scenarios are considered in the study:

- No restriction for plant site area (normal type); and
- Available land is limited for the plant site (small area type)

For the both scenarios, various combinations of biological and physical-chemical processes are studied and advantages and disadvantages accruing to each process combination are evaluated.

Normal Type

For comparison of the WWTP processes, the following four scenarios of the process combinations are developed and evaluated:

- Removal of BOD, SS
  Conventional activated sludge process.
  Oxidation ditch process.
- Removal of BOD, SS, T-N
  Recirculation nitrification-denitrification process
  Step inflow multi-stage nitrification-denitrification process
- Removal of BOD, SS, T-P
  Anaerobic-aerobic activated sludge process
  (This process can be provided by adding anaerobic tanks within a conventional activated sludge process, thus the activated sludge plant could be upgraded to the advanced treatment plant).
- Removal of BOD, SS, T-N, T-P
  Anaerobic-anoxic-aerobic process

Coagulant dosing equipment for removal of T-P is required. Degrees of control and operation of the equipment considered for the above plans are moderate level, not fully automated process.

Small Area Type

This type is compared for T-N and T-P removals efficiencies. A coagulant dosing system is required for denitrification process from the experience obtained from other similar processes elsewhere. Also, Bio-N-Cube, deep aeration tank, and two-story sedimentation tank processes are compared for their appropriateness. Each of the processes is then compared in its land requirements, capital and O/M costs.

5.2 COMPARISON OF ALTERNATIVE SCENARIOS

5.2.1 REQUIRED LAND AREAS FOR WWTP FACILITIES

Necessary land areas are estimated for each of the wastewater treatment processes, comprising primary sedimentation tanks, aeration tanks, and final sedimentation tanks.

5.2.3 CONSTRUCTION COSTS

Construction cost for each process is estimated and compared each other by the ratio of construction costs.

5.2.4 OPERATION AND MAINTENANCE COSTS

The ratio of equipment cost in each scenario is shown in the ratios of return sludge quantity and air supply volume of each scenario. Cost for sludge treatment is estimated based on excess sludge volume.

5.2.5 COMPLEXITY OF OPERATION

Difficulties as to MLSS controls because of the type of mechanical equipment and process control etc. are checked.

5.2.6 NECESSARY LAND AREA FOR FACILITIES

WWTP land areas are estimated for buildings all other necessary facilities for treating the wastewater of 100,000 m^3/day.

The results of these evaluations are shown in *Tables AI.3.2 and AI.3.3*.

6. EVALUATION OF TREATMENT PROCESSES

6.1 EVALUATION OF NORMAL TYPE WWTP

Removal of BOD, SS: Oxidation ditch WWTP requires wider area than conventional activated sludge process plants. In addition, there have been no existing treatment plants or future construction plans with oxidation ditch process in Romania, according to the results of investigation on seven target cities and 17 other cities (treatment capacities ranging 1,400~30,400 m^3/day).

Because of its superior pollutants removal efficiencies to other processes and long operational experience gained elsewhere in Romania, the conventional activated sludge process is proposed for removal of BOD and SS.

Removal of BOD, SS, T-N, T-P: Advanced treatment process needs a significant capital costs as compared with the conventional activated sludge process. Construction costs and land area requirements of the advanced treatment process are about 1.5 times the conventional activated sludge process. Operation and maintenance costs are also about 1.8 times higher than the conventional activated sludge process.

Comparing the BOD removal efficiency cost (150mg/l to 20mg/l) and T-N (30mg/l to 10mg/l), the cost for T-N removal is higher. Therefore, removal of BOD seems to be more efficient from economical point of view.

The advanced treatment process involves more complex actions for operation and control than those required for the conventional activated sludge process.

From economical and technological view points and long experience in facilities operation and control available in Romania, it is prudent to design the treatment process mainly for BOD and SS removals as the first step, and the upgrading of the treatment process shall be made only when the situations become to required that.

Removal of T-N, T-P: It is difficult to remove phosphorus by the biological reaction in the anaerobic zone in the first half of reactor tanks, because aerated grit chambers and oil traps will be provided ahead of the primary treatment process and cannot maintain the influent under anaerobic conditions. Hence, biological removal of phosphorous is hardly achievable. For this reason, T-N removal will be achieved by the recirculation nitrification-denitrification method.

6.2 EVALUATION OF SMALL AREA TYPE WWTP

In planning the small area WWTP, the future upgrading by T-N removal is considered at the initial stage. Total WWTP land area, when upgraded in the future, will be almost equal to the conventional activated sludge process.

For the small area WWTPs, three combinations of processes are selected and compared in construction and O/M costs. Among the processes, "deep aeration tanks + two-story final sedimentation tanks" process has the highest capital cost and the "Bio-N-Cube + single-story final sedimentation tank" process is the lowest. While the process of "Bio-N-Cube + tow-story final sedimentation tank" is in between the other two processes.

The operation and maintenance difficulty increases in the order of the "deep aeration tank + two-story final sedimentation tank" process, "Bio-N-Cube + single-story final sedimentation tank" process and "Bio-N-Cube + tow-story final sedimentation tank" process.

The above discussions lead to the conclusions that if the available land is sufficient only for the conventional activated sludge process, it may be appropriate to consider the small area process as the first step, then leave the land space for the future expansion or additional advanced treatment process.

Table AI.3.1 Romanian and Japanese Standard Design Criteria for Conventional Activated Sludge Method

Institution	Item	Unit	Parameter	
			Japan	Romania
Primary sedimentation	Hydraulic Flow Rate			
Tank	-separate system	m^3/m^2.day	35-70	26,5
	-combined system		25-50	-64.8*)
	Settling time			1.5-2 (Qd)
*)suspended solid	-separate system	hour	>1.5 (Qd)	>1.0 (Qh)
initial concentration	-combined system		>0.5 (Qh)	>0.5 (Qh)
200-300mg/l	Effective water depth	m	2.5-4.0	
Qd :Max daily flow	- radial horizontal			1.6-2.5
Qh:Max hourly flow	-Longitudinal horizontal			1.8-2.95
	weir loading	m3/m.day	250 (Qd)	1440 (Qd)
Aeration reactor tank	MLSS	mg/l	1500-2000	3300
	BOD−SS Loading	BOD-kg/ MLSSkg-day	0.2-0.4	0.3
	Return sludge ratio	%	25-50	100
	Effective water depth	m	4-6	2-6
	Hydraulic retention time	hour	6-8	2-3
Romanian standard	A−SRT	day	3-6	
*)Discharge conditions	(Acrobic sludge retention			
BOD5<20mg/l	time)			
Finally settling tank	Hydraulic Flow Rate	m^3/m^2.day	20-30	16.8-28.8
	Settling time	hour	3-4 (Qd)	3.5-4.0 (Qd)
	Effective water depth	m	2.5-4.0	
	- radial horizontal			2.5-3.5
	-Longitudinal horizontal			2.4-3.3
				192 (Qd)
	weir loading	m^3/m.day	150 (Qd)	
Disinfection	Contact time	minutes	15	
	Chlorine dosing rate			
	-Biological treatment	mg/l	2-4	
	-Primary treatment		7-10	

Table AI.3.2 Comparison of Wastewater Treatment Process (Normal Type 1/2)

Items of Process	Removal of BOD-SS		Removal of BOD-SS, T-N		Removal of BOD-SS, T-N, T-P	Remark
	Conventional activated Sludge process	Oxidation Ditch Process	Recircuration Nitrification Denitrification process	Step Inflow Multi Stage Nitrification-Denitrification Proces	Anaerobic-Anoxic-Aerobic Process (A2O Process)	
1. General Comparison						
1.1 Design Fundamentals	PS 50 m3/m2/day RT 8 hr FS 25 m3/m2/day	– m3/m2/day 24 hr 10 m3/m2/day	50 m3/m2/day 12.5 hr 15 m3/m2/day	50 m3/m2/day 10 hr 15 m3/m2/day	50 m3/m2/day 13.5 hr 15 m3/m2/day	
Area of Facility(m2)	100% 12,100m2	413% 50,000m2	150% 18,200m2	135% 16,300m2	156% 18,900m2	
1.2 Operation and Maintenance Cost						
(1) Return Sludge and Circuration water ratio	100% 50	300% 150	300% 150	100% 50	300% 150	
(2) Amount of Air Blow	100%	100%	150%	150%	150%	
(3) Amount of Excess Sludge						
(BOD+P)	100% 20.3	93% 18.8	99% 20.1	88% 17.9	82% 16.6	Removal of T-P by Coagulant Pouring
(BOD)	100% 20.3	75% 15.3	82% 16.6	71% 14.4	82% 16.6	In Case of Removal of BOD, T-N
Total of 1.2	300	475	532	321	532	Except the Case of Using Coagulant
2. Condition of maintenance						
(1) Range of MLSS Dnsity	1,500 ~ 2,000mg/l	3,000 ~ 4,000mg/l	2,000 ~ 3,000mg/l	2,500 ~ 3,800mg/l	2,000 ~ 3,000mg/l	
(2) Return Sludge + Circuration Water	25 ~ 50%	100 ~ 200%	150	50	150	
a. Control of MLSS b. Pump for Return Sludge c. Anoxic Tank d. Anaerobic Tank e. Others	a. By control of return sludge amount e. Have the tendency to cause bulking, and to decrease the settling charasteristics of the sludge. It is necessary to provide an anaerobic tank in front of reaction tank or to by-pass the primary sedimentation tank.	a. To maintain a high MLSS concentration compared with other process, it is necessary to return a high amount of sludge. e. Maintaining a high MLSS concentration in the oxidation ditch, this process is not influenced by changes of influen wastewater quantity and quarity. Operate in a high MLSS concentration, it is better to use for design a small value for surface loading of final settling tank in order to ensure an efficieny sludge settling.	・A-SRT is an important factor to maintain nitrifying bacteria. a. Increasing of nitrifying bacteria deoends on water temperature, so, to maintain the A-SRT, it is necessary to operate during winter season with a high MLSS concentration. It is necessary to operate by taking out volume of excess sludge, in order to maintain a returan sludge volume under 50%. b. Pumping equipment is necessar to circulate a nitrifying liquor fro aerobic tank to anoxic tank. c. To maintain a dissolved oxygen concentration at low level in anoxic tank, it is necessary to take measures for outbreak of scum and surface layer of sludge by mechanical agitate or nitrification. e. It is necessary to consider a pouring system of methanol and natrium hydroxide.	・The same process as recircuration process, but in this process the influent wastewater is divided equally to each reaction tank, also it maintains a high MLSS concentration, recircuration by pumping from aerobic tank is not necessary. a. Sludge is returned by sludge pumping mximam 50% as same as recircuration process. b. Circulation by pumping is not necessary because nitrified liquor is coming from first aerobic tank or enters to anoxic tank as return sludge. c. It is necessary to operate each anoxic tank. e. The same as for recircuration process.	・This process is a removal process of nitrigen and phosphorus simultaneously, by providing an anaerobic tank in front of recircuration process to discharge pohosphorus from sludge in anaerobic tank and not to introduce too much phosphorus in aerobic tank. a. Sludge is returned by sludge pumping mximam 50% as same as in recircuration process. b. The same as for recircuration process. c. Ditto d. To maintain suitable condition for discharge the phosphorus in anaerobic tank, it is necessnry that structures of anaerobic tank to have a protecttion system for backflow from the anoxic tank, and also to operate the return sludge from aerobic to control the dissolved oxygen from the aerobic tank. e. In case of dissolved oxygen is high in influent wastewater, removal efficiency of phosphorus decreases.	
f. Conclusion	tIn order to maintain the MLSS concentration, it is necessary to control the taken out volume of excess sludge, and pumping for return sludge. And also to consider the bulking preventation.	Necessary operation is related to the amount of return sludge, retention time is high, so, maintenance and operation are more simple than conventional activated sludge process.	To maintain a high MLSS concentration compared with conventional activated sludge process, it is important to operate return sludge and running of sludge pump. Operation of circulation pump and mechanical agitator in anoxic tank are necessary for scum outbreak.	Circulation by pumping is not necessary but operation of return sludge pump is necessary. It is enough to operate only one aerobic tank, because solids in eac steps of aerobic tanks is the same. Tanks are increased but operation points are decreased and maintenance is simple compared with recircuration process.	Operation points are increased, such as control of machines of anaerobic tank, control of machines for scum. Process of simultaneously nitrogen and phosphorus removal. Operation of treatment is more difficult than recircuration process, such as control of SRT range.	

Table AI.3.2 Comparison of Wastewater Treatment Process (Normal Type 2/2)

Items of Process	Removal of BOD-SS		Removal of BOD-SS, T-N		Removal of BOD-SS, T-N, T-P	Remark
	Conventional activated Sludge process	Oxidation Ditch Process	Recirculation Nitrification Denitrification process	Step Inflow Multi Stage Nitrification-Denitrification Process	Anaerobic-Anoxic-Aerobic Process (A2O Process)	
3 All Necessary Area (m2)	100% 88,500m2	198% 175,100m2	116% 102,300m2	108% 95,900m2	119% 104,900m2	Treatment Capacity Q= 100,000m3
4. Prepare for Advanced Wastewater Treatment 4.1 Removal of T-N (In case of Recirculation Process)	1. Take measures by adding an aeration tank. It is necessary to modify or add an equipment to existing facility. (modify a structure of aeration tank, build a wall to divide an anoxic tank and aerobic tank, set up an agitator equipment at anoxic tank, set up an air diffuser and circuration pump and add a blower to supply an enough air for nitrification) 2. If there is no area to expand the facilities. 2.1 By adding a Bio-N-Cubes. 2.2 By building a two-storey or deep aeration tank.	· It is possible to add a small scale aeration tank. It is also possible to operate an intermittent aeration.	· Already prepared	· Already prepared	· Already prepared	
4.2 Removal of T-P	· It is possible to provide another anaerobic tank (retention time is 1.5hr) beside an aeration tank and to operate anaerobic-aerobic system. · Another measures is to add coagulant.	· To add coagurant into the effluent spot of oxidation ditch.	· To add a coagurant at outflow spot of reaction tank.	· To add a coagurant at outflow spot of reaction tank.	· Already prepared (Removal efficiency of T-P is not steady because of influent dissolved oxygen, in this case, it needs coagulant pouring system.)	
4.3 Removal of T-N, T-P	· Measures of 4.1 and 4.2 is necessary.	· It is necessary to add coagulant.	· It is necessary to add coagulant.	· It is necessary to add coagurant.		
5. Attention Items for Sludge Treatment	· Treatment of sidestreams and measures for leakage of T-P is necessary (*)	· Nothing special.	· Nothing special.	· Nothing special.	· Treatment of sidestreams and measures for removal of T-P is necessary (*)	(*)Pay attention to items in case of biological T-P removal.
6. Necessity of Special Equipment	· Nothing special.	· Nothing special.	· Air diffuser which has efficient dissolution. · Submerged agitator. · Subnerged mechanical aeration equipment.	· Submerged agitator. · Submerged mechanical aeration equpment.	· Air diffuser which has efficient dissolution. · Submerged agitator. · Subnerged mechanical aeration equipment.	
7. Overall Evaluation 1) Scale of Facility	100% • In the case of BOD + SS removal, conventional activated sludge process need a reduced area compared to oxidation ditch process.	413%	165% • In case of T-N removal, each process needs 1.5～1.8 times more of area compared to comventional activated sludge process, concidering T-N and T-P removal, A2O process requires large area and high construction cost. Step inflow multi stage process has the advantage of reduced facilities area and low construction cost.	147%	178%	
2) Operation and Maintenance Cost	300% •From operation and maintenance costa point of view, conventional activated sludge process is the most economical process and next process is step inflow multi stage process. Recircuration process and A2O process are the most expencive. From T-N removal point of view, step inflow multi stage process is just economic process.	475%	532%	321%	532%	
3) Operation of Facility	Standard (supposed)	•A little simpler than conventional activated sludge process.	•Control and survey points of machines and equipments are more than conventional activated sludge process. More difficult to operate than conventional activated sludge process	•Control and survey points of machines and equipments are not so many than recircuration process, so operation is more simple than for recircuration process.	•Anaerobic tank are many than in recircuration process, and operation range of SRT is narrow. Operation is more difficult than for recircuration process.	
4) Total Necessary Area	There is much difference of necessary area for wastewater treatment. All the necessary area for conventional activated sludge process is almost 9 ha. Necessary area for advanced treatment process is with 110～120% more than conventional activated sludge process. Oxidation ditch process need almost 2 times more area than conventional activated sludge process.					
5) Prepare for Advanced Wastewater Treatment	(Removal of T-N) Conventional activated sludge process needs an additional reaction tank, needs to modify the existing structure, and additional machines and equipments. So the investment for this process is quite high. Oxidation ditch process needs at least necessary aeration equipment to supply the air for nitrification. (Removal of T-P) Removal of T-P by biological process has not a stable removal efficiency, because dissolved oxygen from influent wastewater influences on the T-P removal efficiency. It also needs a measures for discharge of phosphorus from the sludge treatment system. Coagulant added to the system needs only pouring equipment and it has a stable removal efficiency. All process can be arranged for changing also for the phosphorus removal process.					
Overall Evaluation	For removal of BOD +SS, conventional activated sludge process which requires reduced area and operation and maintenance cost, seems to be the economic system. This system has the highest influence on investment because of reduced necessary area and economical cost. For advanced wastewater treatment, in case of priority given to T-N removal, step inflow multi stage process is the most economical process, because of reduced necessary area and low operation and maitenance cost.					

Table AI.3.3 Comparison of Wastewater Treatment Process (Small Area Type 1/2)

Items of Process	Removal of BOD-SS	Removal of BOD-SS, T-N, T-P			Remark
	Conventional activated Sludge process	Use Bio-N-Cubes + Single-Story Final Sedimentation Tank	Use Bio-N-Cube + Two-Storey Final Sedimentation Tank	Deep Aeration Tank + Two-storey Final sedimentation tank (Recircuration Nitrification-denitrification process)	
1.General Comparison 1.1Design Fundamentals Area of Facility(m2)	PS 50 m3/m2/day RT 8 hr FS 25 m3/m2/day 100% 12,100m2	50 8 15 Single-story 122% 14,800m2	50 Single-deck 8 15 Two-storey 102% 12,400m2	50 Single-deck 12.5 H = 10m 15 Two-storey 95% 11,520m2	
1.2 Operation and Maintenance Cost (1) Return Sludge and Circuration Water Ratio (2) Amount of Air Blow (BOD+P) (BOD)	100% 50 100% 100% 20.3 100% 20.3	300% 150 160% 99% 20.1 82% 16.6	300% 150 160% 99% 20.1 82% 16.6	300% 150 150% 99% 20.1 82% 16.6	In Case of Removal of BOD, T-N Removal of T-P by Chemocal precipitation.
Total of 1.2	300	542	542	532	Except Chemocal precipitation usage.
2. Condition of maintenance (1) Range of MLSS Dnsity (2) Return Sludge + Circuration Water a. Control of MLSS b. Pump for Return Sludge c. Anoxic Tank d. Anaerobic Tank e. Others	1,500 ~ 2,000mg/l 25 ~ 50% a. Controling of return sludge amount e. Have the tendency to cause bulking, and decrease a settling charasteristic of sludge. It is necessary to provide an anaerobic tank ahead of reaction tank or to by-pass the primary sedimentation tank.	2,000 ~ 3,000mg/l 150 a. It is easier to maintain the MLSS concentration than in recircuration process, because in Bio-N-Cubes process, MLSS is maintained into the cubes. b. Same as in recircuration process. c. Same as in recircuration process related to anoxic tank. e. It is necessary to provide a fine screen in front of reaction tank, because width of screen mesh for cubes separation from aerobic tank is too narrow and the cubes can block the screen easily. ・In order to prevent the cubes crushing, aeration area is limited to front part of awration tank. ・In order to maintain the cubes in suspension, it is necessary to blow more air than in other process.	2,000 ~ 3,000mg/l 150 a. The same as to the left. b. The same as to the left. c. The same as to the left. e. The same as to the left, but for scale down necessary area, final settling tank has a two-storey system, so operation is more difficult than single-story system.	2,000 ~ 3,000mg/l 150 a. The same as in recircuration process. b. The same as in recircuration process. c. Ditto e. The aeration tank is deep, so, it is necessary to ensure spiral-flow aeration or a mechanical aeration. ・Final settling tank has a two-storey system, so operation is more difficult than single-story sy6stem.	
f. Conclusions	To maintain the MLSS concentration, it is necessary to control the taken out volum of excess sludge, and pumping for return sludge. And also to consider the bulking prevention.	It is necessary to remove the fine screen in front of reaction tank for a fully cubes separation screen in aerobic tank. It is necessary to operate adequate air volume in order to maintain the cubes in suspension but also to prevent wear of cubes.	Bacically the same as for recircuration, but operation of final settling tank is difficult because of two-storey system.	Bacically the same as for recircuration process, but operation of final settling tank is difficult because of two-storey system.	

Table AI.3.3 Comparison of Wastewater Treatment Process (Small Area Type 2/2)

Items of Process	Removal of BOD-SS	Removal of BOD-SS, T-N (Recircuration nitrification denitrification process)			Remark
	Conventional activated Sludge process	Use Bio-N-Cube + Single-story Final Sedimentation Tank	Use Bio-N-Cube + Two-Storey Final Sedimentation Tank	Deep Aeration Tank + Two-Storey Final Sedimentation Tank	
3.All Necessary Area (m2)	88,500m2	·Almost same as to the left	·Almost the same as to the left	·Almost the same as to the left	Treatment Capacity Q= 100,000m3
4. Prepare for Advanced Wastewater Treatment 4.1 Removal of T-N (In case of Recircuration Process)	1. Take measures by adding an aeration tank. It is necessary to modify or add equipment to the existing facility. (modifing the structure of aeration tank, building a wall to separate the anoxic and aerobic zone, setting up an agitator equipment in anoxic zone, setting up air diffusers and circuration pump, add blowers to supply enough air for nitrification.) 2. If there is no area to expand the facilities. 2.1 Adding Bio-N-Cubes. 2.2 Building two-storey or deep aeration tank.	·Already prepared	·Already prepared	·Already prepared	
4.2 Removal of T-P	·It is possible to provide another anaerobic tank (retention time is 1.5hr) beside an aeration tank, and operate anaerobic-aerobic system. ·Another measures is to add chemical precipitation.	·Adding coagurant into reaction tank effluent.	·Adding coagurant into reaction tank effluent.	·Adding coagurant into reaction tank effluent.	
4.3 Removal of T-N, T-P	·Measures of 4.1 and 4.2 is necessary.	·It is necessary to add a coagulant.	·It is necessary to add a coagulant.	·It is necessary to add a coagulant.	
5. Attention Items for Sludge Treatment	·Treatment of sidestreams and measures for T-P removal is necessary. (*)	·Nothing special.	·Nothing special.	·Nothing special.	(*)Here areshown the attention items in case of biological T-P removal.
6. Necessity of Special Equipment	·Nothing special.	·Cubes, cubes separation equipment, fine screen. ·Air diffuser in front part of aeration tank with high oxygen transfer efficiency. ·Submerged agitator.	·The same as to the left, and sludge scraper for two-storey sedimentation tank.	·Air diffuser with high oxygen transfer efficiency. ·Submerged agitator. ·Submerged mechanical aeration equpment.(In order to supply enough air)	
7. Overall Evaluation 1) Scale of Facility	100%	122% * Bio-N-Cubes+single story final sedimantation tank needs the largest facility area. Generally speaking, deep structure need high cost for construction, so from the cost point of view, deep aeration tank + two storey final sedimentation tank is the highest and Bio-N-Cubes +single story final sedimentation tank is the lowest, and Bio-N-Cube + two storey final sedimentation tank is in the middle.	102%	104%	
2) Operation and Maintenance Cost	300%	542% * There is no big differrence in operation and maintenance cost. Treatment system which uses Bio-N-Cubes is costly because the price of cubes is high.	542%	532%	
3) Operation of Facility	Standard (supposed)	* Basic operation system is similar to recircuration process, but it needs a operation of Bio-N-Cubes in case of using Bio-N-Cubes system, and it needs operation of two storey sedimentation tank if the two storey system is used.			
4) Total Necessary Area		* There is no big differrence for necessary area of wastewater treatment, and all the necessary area is almpst the same.			
5) Prepare for Advanced Wastewater Treatment		* All system can be transformed for removal of T-N, and it is possible, for T-P removal, only to set up chemical precipitation system. If there is no additinal area for advanced wastewater treatment, one solution is to construct a facility structure taking into account from the biginning future advanced treatment, and change it in the future.			
Overall Evaluation		* It is possible to construct treatment facility equal or 20% exceed regarding to necessary facility area, compared with conventional activated sludge process, and it is also possible to construct facility structure taking into account future advanced treatment in scale-down a facility. Operation and maintenance process of Deep Aeration Tank + Two Storey Final Sedimentation Tank is similar to conventional activated sludge process and it is more simple than other process. Using Bio-N-Cubes process is depend on efficiency of special equipment, and it is not so common.			

PART AII-1: FEASIBILITY STUDY FOR TULCEA WWTP PROJECT

Table AI.3.3 Comparison of Wastewater Treatment Process (Small Area Type 2/2)

Items of Process	Removal of BOD-SS	Removal of BOD-SS, T-N (Recircuration nitrification denitrification process)			Remark
	Conventional activated Sludge process	Use Bio-N-Cube + Single-story Final Sedimentation Tank	Use Bio-N-Cube + Two-Storey Final Sedimentation Tank	Deep Aeration Tank + Two-Storey Final Sedimentation Tank	
3.All Necessary Area (m2)	88,500m2	･Almost same as to the left	･Almost the same as to the left	･Almost the same as to the left	Treatment Capacity Q= 100,000m3
4. Prepare for Advanced Wastewater Treatment 4.1 Removal of T-N (In case of Recircuration Process)	1. Take measures by adding an aeration tank. It is necessary to modify or add equipment to the existing facility. (modifing the structure of aeration tank, building a wall to separate the anoxic and aerobic zone, setting up an agitator equipment in anoxic zone, setting up air diffusers and circuration pump, add blowers to supply enough air for nitrification.) 2. If there is no area to expand the facilities. 2.1 Adding Bio-N-Cubes. 2.2 Building two-storey or deep aeration tank.	･Already prepared	･Already prepared	･Already prepared	
4.2 Removal of T-P	･It is possible to provide another anaerobic tank (retention time is 1.5hr) beside an aeration tank, and operate anaerobic-aerobic system. ･Another measures is to add chemical precipitation.	･Adding coagurant into reaction tank effluent.	･Adding coagurant into reaction tank effluent.	･Adding coagurant into reaction tank effluent.	
4.3 Removal of T-N, T-P	･Measures of 4.1 and 4.2 is necessary.	･It is necessary to add a coagulant.	･It is necessary to add a coagulant.	･It is necessary to add a coagulant.	
5. Attention Items for Sludge Treatment	･Treatment of sidestreams and measures for T-P removal is necessary. (*)	･Nothing special.	･Nothing special.	･Nothing special.	(*)Here areshown the attention items in case of biological T-P removal.
6. Necessity of Special Equipment	･Nothing special.	･Cubes, cubes separation equipment, fine screen. ･Air diffuser in front part of aeration tank with high oxygen transfer efficiency. ･Submerged agitator.	･The same as to the left, and sludge scraper for two-storey sedimentation tank.	･Air diffuser with high oxygen transfer efficiency. ･Submerged agitator. ･Submerged mechanical aeration equpment.(In order to supply enough air)	
7. Overall Evaluation 1) Scale of Facility	100%	122%	102%	104%	
		* Bio-N-Cubes+single story final sedimantation tank needs the largest facility area. Generally speaking, deep structure need high cost for construction, so from the cost point of view, deep aeration tank + two storey final sedimentation tank is the highest and Bio-N-Cubes +single story final sedimentation tank is the lowest, and Bio-N-Cube + two storey final sedimentation tank is in the middle.			
2) Operation and Maintenance Cost	300%	542%	542%	532%	
		* There is no big difference in operation and maintenance cost. Treatment system which uses Bio-N-Cubes is costly because the price of cubes is high.			
3) Operation of Facility	Standard (supposed)	* Basic operation system is similar to recircuration process, but it needs a operation of Bio-N-Cubes in case of using Bio-N-Cubes system, and it needs operation of two storey sedimentation tank if the two storey system is used.			
4) Total Necessary Area		* There is no big diffference for necessary area of wastewater treatment, and all the necessary area is almpst the same.			
5) Prepare for Advanced Wastewater Treatment		* All system can be transformed for removal of T-N, and it is possible, for T-P removal, only to set up chemical precipitation system. If there is no additinal area for advanced wastewater treatment, one solution is to construct a facility structure taking into account from the biginning future advanced treatment, and change it in the future.			
Overall Evaluation		* It is possible to construct treatment facility equal or 20% exceed regarding to necessary facility area, compared with conventional activated sludge process, and it is also possible to construct facility structure taking into account future advanced trteatment in scale-down a facility. Operation and maintenance process of Deep Aeration Tank + Two Storey Final Sedimentation Tank is similar to conventional activated sludge process and it is more simple than other process. Using Bio-N-Cubes process is depend on efficiency of special equipment, and it is not so common.			

PART AII-1: FEASIBILITY STUDY FOR TULCEA WWTP PROJECT

APPENDIX-1

PLANNING BASIS

1. INTRODUCTION

The following design basis for the Tulcea WWTP is studied and determined, based on analysis of data and information provided by the Tulcea City, the public water company "SC ACET SA", and related organizations. The survey results of wastewater quantity and quality conducted by JICA Study Team are also used to analyze the present conditions of wastewater generation and pollutant loads.

- Population

  Total Administrative Population

  Service Population of Public Water Supply and Sewerage System

- Design Flow

  Wastewater Generation, Average Daily Flow, Maximum Daily Flow, Maximum Hourly Flow, and Wet Weather Flow

- Wastewater Characteristics

  Wastewater Pollutant Loads

  Design Influent Quality for the WWTP

2. POPULATION

2.1 ADMINISTRATIVE POPULATION

The present administrative population of the Tulcea City is 96,278 in 1998. *Figure AII.1.1* shows the statistical data of population from 1982 to 1998 provided by the Tulcea City. It indicates that there are two growth patterns before and after the year of 1992. Before 1992, the population was increased with high annual growth rate at 2.26%, but after 1992, the population is nearly constant about 97,000 but is slightly decreased.

The statistical data of population includes the floating population who is registered but actually not living in the city. The city estimates that the floating population is about 10,000. Therefore, the present actual population living in the city is about 86,000.

One of the most important industries in the Tulcea City is tourism, because tourists come to the city to enjoy the natural environment of the Danube Delta. Therefore, the number of tourists is also studied to determine whether or not the sewerage plan should consider the tourist wastewater generation.

Because any statistical data on the number of tourists is not available, the Tulcea City and SC ACET SA survey the number of tourist stayed in three major hotels in the Tulcea City.

Figure AII.1.2 shows the monthly number of tourists stayed in those three major hotels during 13 months from June 1998 to June 1999. About 46,500 tourists stayed in the hotels and the average monthly was about 3,600. The figure shows a seasonal variation, during high seasons of four months from June to September, the monthly tourist number is more than 4,000. The highest monthly tourist number is 5,502 in August 1998 and the second highest one is 5,283 in June 1999. If it is assumed that the tourist stay three nights and four days in the highest month, the daily tourist number is estimated about 750 (5,502/30*4=734). The daily tourist number is only less than 1% of the present total population of 96,000.

As a conclusion of review on the administrative population of the Tulcea City, it is proposed that the administrative population in the target year of 2010 is 100,000, giving some allowance of 4,000 to the present population.

2.2 SERVICE POPULATION

At present the public water company "SC ACET SA" provides the water supply and sewerage services. The following table shows the present service population in 1998. The city and the water company do not have any expansion plan of water supply service. Therefore, the present service population is applied for the sewerage plan of 2010.

Table AII.1.1 Service Population by the Public Water Supply and Sewerage Systems

Category (Norm)	Per Capita Water Consumption (lpcd)	Present Service Pop. (As of 1998)	Service Pop. In the year 2010 (Proposed)	Remarks
1	65	0	0	
2	110	* 27,000	27,000	
3*	170	0	0	
4*	295	9,000	9,000	
5*	380	60,000	64,000	
Water Supply		96,000	100,000	
Sewerage		69,000	73,000	

Note: * indicates the population of 15,000 provided by groundwater source.

3. DESIGN FLOW

3.1 INTRODUCTION

The sewerage system of the Tulcea City is separate, thus the sanitary sewers installed collect and convey the wastewater and finally discharge off to the Danube River. The wastewater shall be treated at a new wastewater treatment plant.

To make a design of the wastewater treatment plant, it is necessary to determine the wastewater flows such as Average Daily Flow, Maximum Daily Flow, and Maximum Hourly Flow.

The Average Daily Flow is used as the basis for the estimation of pollutant loads, sludge volume generation, and O/M requirements. The Maximum Daily Flow is used for the design of wastewater treatment units. The Maximum Hourly Flow is used for the design of pipes and channels in wastewater treatment plant.

In order to estimate the present wastewater generation and to determine the design flows, the following Romanian Standards are used in principle, STAS 1343 (Water Supply – Determination of water supply volumes) and STAS 1846-90 (Sewerage – Calculation of the wastewater flow). Because the standard methods are judged be appropriate for a planning purpose. Per capita water consumption is reviewed briefly in the following section.

3.2 Domestic, Commercial and Institutional Wastewaters

3.2.1 Wastewater Generation

Table AII.1.2 shows a summary of the estimated present domestic, commercial and institutional wastewater generation provided by the water company "SC ACET SA". The consumers of category 3, 4, and 5 have access to the public sewerage system. The total wastewater generation is estimated about 18,500 m^3/d, and the amount of 16,600 m^3/d is collected by the public sewerage system, i.e. about 90% of the wastewater generated is collected by the existing sewerage system.

Table AII.1.2 Present Wastewater Generations except Industrial Wastewater

Category (Norm)	Per Capita Water Consumption (lpcd)	Present Service Population (1998)	Water Consumption (m^3/d)	Water Demand at Source *** (m^3/d)	Wastewater Generation **** (m^3/d)
2	110	12,000	1,320	1,782	860
2	110	**15,000	1,650	1,935	1,070
3*)	170	0	0	0	0
4*)	295	9,000	2,655	3,584	1,730
5*)	380	60,000	22,800	30,780	14,820
Total		96,000	28,425	38,081	18,480
Sewerage		69,000			16,550

Data Source: SC ACET SA

Note: * : the category includes sewerage services

**: Water is groundwater source and provided by public water supply system

*** : Water Demand at Source = Kp x Ks x Water Consumption

where, Ks=1.08, Kp=1.25, Kp x Ks=1.350 for the surface water taken from Danube River

and Ks=1.02, Kp=1.15, Kp x Ks=1.173 for the groundwater source

**** : Wastewater Generation = K x Water Consumption,

where K=0.65

The estimated water requirements at water sources and the estimated water consumption are compared with the data of water intake volume and water consumption. It indicates the domestic water consumption is the same as the metered water.

Table AII.1.3 Water Supply Conditions in 1998

	Daily Volume (/30 days) (m³/d)	Estimated Daily Water Volume in Table AII.1.2 (m³/d)	Remarks
Water Intake Volume			
Surface Water	95,000		
Groundwater	8,640		
Total	103,640	*38,100	
Water Treatment Plant			
Capacity	108,000		
Treatment Loss	20,700		20% of intake volume
Water to the Distribution Network	82,940		
Non-metered Water	53,940		
Metered Water	29,000	*28,430	

Data Source: SC ACET SA

Note: * is the domestic water only, any industrial water is not included

3.2.2 WASTEWATER TO BE COLLECTED BY SEWERAGE SYSTEM

Before estimating the wastewater generation in the year 2010 by the Romanian Standard Method or guideline for the design, the per capita water consumption for domestic, commercial and institutional purposes in the standards is reviewed briefly in the followings:

The per capita water consumption for each category already contains domestic, commercial and institutional water consumption as shown in Table AII.1.4 below. The domestic water consumption is reasonable for the design basis, taking into account the living standard and easy access to the surface water source, the Danube River. A ratio of commercial and institutional water consumption to domestic water consumption is set about 21% to 40% for consumers of house connections. The ratios are appropriate for the level of urban development of the city. The standards also give some allowance to add some commercial and institutional water consumption up to 15 or 25% depending on local conditions and population size of municipalities.

Table AII.1.4 Per Capita Consumption of Domestic, Public and Commercial Water (STAS 1343)

Category No.	Classification	Domestic Consumption q_g (lcd)	Public and Commercial Consumption q_p (lcd)	Total q (lpcd)	q_p to q_g Ratio
1	Water distributed through street taps	40	25	65	0.625
2	Water distributed through yard taps	80	30	110	0.375
3	Houses with plumbing and sewer pipes	140	30	170	0.214
4	Houses with plumbing and sewers, with in-house water heating system	210	85	295	0.405
5	Houses with plumbing and sewers, with provisions of central water heating	280	100	380	0.357

Note: The value of q_p can be increased depending local conditions, but not exceeds the followings by the size of the city;

- up to 15% for cities ranging in population from 300,000 to 1,000,000
- up to 25% for cities having the population more than 1,000,000

Table AII.1.5 shows the average flows of domestic, commercial and institutional wastewaters to be generated and to be collected by the public sewerage system in the year 2010. The Romanian Standard Method is applied to estimate the average flow.

Table AII.1.5 Wastewater Generation except Industrial Wastewater Estimated by the Romanian Standards

Category (Norm)	Per Capita Water Consumption (lpcd)	Service Population (2010)	Water Consumption (m^3/d)	Water Demand at Source *** (m^3/d)	Wastewater Generation **** (m^3/d)
2	110	12,000	1,320	1,595	1,280
2	110	**15,000	1,650	1,935	1,550
3*)	170	0	0	0	0
4*)	295	9,000	2,655	3,210	2,570
5*)	380	64,000	24,320	29,380	23,500
Total		100,000	29,945	36,120	28,900
Sewerage		73,000			26,070

Data Soource: JICA Study Team

Note: * : The category includes sewerage services
** : Water is groundwater source and provided by public water supply system
*** : Water Demand at Source = Kp x Ks x Water Consumption
where, Ks=1.05, Kp=1.15, Kp x Ks=1.208 for the surface water taken from Danube River
and Ks=1.02, Kp=1.15, Kp x Ks=1.173 for the groundwater source
**** : Wastewater Generation = K x Water Demand at Source,
where K=0.80

Table AII.1.6 shows the wastewater generation at present and in the target year of 2010. In the present wastewater generation estimated by ACET's, 65% of water consumption is used. While the future generation estimation, 80% of water demand at source (consequently, 96% of water consumption) is used for the estimation.

Table AII.1.6 Average Daily Flow of Wastewater in the year 2010

Category (Norm)	Per Capita Water Demand (lpcd)	Service Population (2010)	Average Flow (m^3/d)		Remarks
			Present	Year 2010	
2		27,000	(1,930)	2,830	
4*	295	9,000	(1,730)	2,570	
5*	380	64,000	(14,820)	23,500	
Total		100,000	(18,480)	28,900	
Sewerage		73,000	(16,550)	26,100	

Note: * indicates the category includes sewerage services

Maximum Daily Flow and Maximum Hourly Flow of the domestic, commercial and institutional wastewaters are calculated with using the coefficients set forth in the Romanian Standard (STAS 1343/1) as follows. The results of calculation are summarized in *Table AII.1.7.*

Table AII.1.7 Design Flows for the Domestic, Commercial and Institutional Wastewaters

Wastewater Flow	Design Flow : JICA Study		Coefficient	Remarks
	(m^3/d)	(L/s)	STAS 1343/1	
Average Daily Flow	26,100	302	-	
Maximum Daily Flow	28,800	333	*1.10 to 1.15	
Maximum Hourly Flow	36,000	417	1.25	

Note: * indicates that the coefficient for category 4 is 1.15 and that for category 5 is 1.10.

3.3 INDUSTRIAL WASTEWATER

3.3.1 PRESENT CONDITIONS

According to the information provided from the SC ACET SA, the total amount of 6,560 m^3/d is discharged to public sewers by contracts between manufactures and the SC ACET SA.

Table AII.1.8 shows a list of the major manufactures and companies, which are discharging the wastewater, obtained through a questionnaire survey conducted by JICA Study Team with the cooperation of the SC ACET SA. The daily flow of industrial wastewater is about 15,000 m^3 in 1998; in which only 450 m^3/d is discharged through public sewers.

3.3.2 WASTEWATER TO BE RECEIVED BY THE SEWERAGE SYSTEM

The wastewater discharged from the listed manufactures and companies are hereinafter referred as "point-source" and others are referred as "non-point source" in the following discussion.

In Table AII.1.9, the following average design flow of industrial wastewater is proposed, giving 22% increase to the present wastewater discharge to the public sewers.

Table AII.1.9 Summary of Industrial Wastewater Daily Average Flow

Industrial Wastewater	Present (1998) (m^3/d)	In 2010 Ave. Daily (m^3/d)	Remarks
Point Source		5,700	
Non-point Source		2,300	
Total	6,560	8,000	22% increase

For the design of the sewerage facilities, the design flows of industrial wastewater are proposed taking into account of flow variations. The following coefficients of flow variation are proposed, taking into account the scale of manufactures and companies. The coefficients proposed are the same as the present coefficients used by SC ACET SA.

Table AII.1.10 Flow Variation Factors Set for Industrial Wastewater

Industrial Wastewater source	Average Daily	Maximum Daily	Maximum Hourly	Remarks
Proposed				
Point Source	0.75	1.00	1.25	Medium to small scale
Non-point Source	0.75	1.00	1.50	Small scale
Present	0.82	1.00	1.22	SC ACET SA

The design flows of maximum daily and maximum hourly flows are calculated using the above flow variation factors and the calculation results are summarized in the table below.

Table AII.1.11 Summary of Design Flow of Industrial Wastewater

Industrial Wastewater	Ave. Daily (m^3/d)	Max. Daily (m^3/d)	Max. Hourly (m^3/d)	Remarks
Point Source	5,700	7,600	9,500	0.75:1.00:1.25
Non-point Source	2,300	3,070	4,600	0.75:1.00:1.50
Total	8,000	10,670 => 10,700	14,100	

3.4 GROUNDWATER INFILTRATION

The most of urban area of the city is developed on hills, the groundwater infiltration might be small. However, the data obtained at two existing wastewater-pumping stations indicates the groundwater infiltration should be taken into account for the design. During four months, from March to June, additional wastewater of 180 m^3/h (4,320 m^3/d) is recorded at the pumping stations; SP-3 120 m^3/h and SP-1 60 m^3/h, respectively. If the additional wastewater is taken