D5. SUMMARY AND CONCLUSION

(1) For the purpose of formulation of rehabilitation and expansion of existing sewage works in the Nakuru Municipality, a sewage generation mechanism was analyzed based on such data and records as the number of registrant for water supply and sewerage services, administration map of water supply and sewerage, source and metered public water supplies, sewage inflow into the sewage works, private water supply facilities, etc.

(2) In view of the water supply and sewerage systems, the municipal area of Nakuru could be divided into two areas, namely Town area and Lanet area. According to the water supply and sewerage administration map, the Town area is further sub-divided into 87 water supply sections. The existing public sewer network extends over 69 sections, covering an area of 12.85 km^2, which is divided into Town, Njoro and Central SDs.

In the Lanet area the sewerage system is furnished only to a limited military service area.

(3) There are two sewage treatment works at present in the Nakuru Municipality : one is Njoro STW with a treatment capacity of 3,600 m^3/day and the other is Town STW with a treatment capacity of 3,400 m^3/day. In addition a new sewage treatment works with a treatment capacity of 6,000 m^3/day is under implementation which is scheduled to be commissioned in 1994 in the vicinity of the existing Njoro STW by NWCPC.

(4) The water supply quantity was verified and it was concluded that the public water supply system implicates a great amount of un-accounted for water and metered water records are unsuitable for the analysis of the sewage generation. The source water supply quantity was 22,079 m^3/day on the average during a five year period from 1988 to 1992.

(5) The current sewage inflow is far exceeding the design treatment capacity of the existing sewage works. According to the sewage inflow records during a four-year period from 1989 to 1992, the average daily sewage volume is 5,897 m^3/day at Njoro STW and 3,469 m^3/day at Town STW. As a result, the quality of treated water is far below provisional effluent standards, resulting in a threat to ecology of Lake Nakuru.

(6) There are 14,904 registrants for the public water supply, of which 11,194 registrants fall in the area of the existing sewer network. The number of registrant for the public sewer service is 9,538 in total, of which 9,530 registrants are within the existing sewered area. A sewer connection ratio is therefore 85.1 % for the existing sewered area.

(7) A sewer generation factor was analyzed with the aid of a simple mathematical model for the period from December 1988 to February 1993 and it is defined as a multiple index of water distribution loss rate, sewage generation ratio, arrival rate of sewage to the sewage works and other pertinent factors. Under the present water supply and sewer connection, it is assessed to be 0.55 for a dry weather flow. The rate of rainwater mixture is also evaluated to be equivalent to 20 % of the dry weather flow.

(8) The water supply capacity will increase largely upon commissioning of the Greater Nakuru Water Supply Project, Eastern Division , Stage 1, which is capable of supplying treated water amounting to 13,300 m^3/day. It is evident that the sewage quantity will eventually increase immediately upon its commissioning. It is therefore necessary to augment sewage treatment capacity to cope with the increasing sewage.

(9) The dry weather flow is forecast under conditions of the augmented water supply and increased sewer connection conditions by applying the sewage generation factor obtained. The forecast dry weather flow is 16,186 m^3/day assuming the sewage connection ratio and generation factor at 0.92 and 0.60 respectively.

(10) It is proposed to expand only Town STW by 3,200 m^3/day from the technical, financial and environmental viewpoints. With the proposed plan, ultimate sewage treatment capacity of Njoro and Town STWs are 9,600 m^3/day and 6,600 m^3/day respectively, totaling 16,200 m^3/day.

(11) The amount of the rainwater mixture are estimated at 1,920 m^3/day and 1,320 m^3/day for Njoro STW and Town STW respectively.

E : PRELIMINARY POLLUTION LOAD ESTIMATE

E: PRELIMINARY POLLUTION LOAD ESTIMATE

TABLE OF CONTENTS

		Page
E1.	INTRODUCTION	E-1
E2.	SOURCES OF POLLUTION	E-2
E3.	POLLUTION PROCESS AND ESTIMATION METHOD	E-6
	E3.1 Pollution Process	E-6
	E3.2 Methods of Estimation	E-6
	E3.2.1 Point Source	E-10
	E3.2.2 Stormwater Pollution (Point and Non-point Source	E-10
	E3.2.3 Non-point Source	E-11
E4.	ESTIMATE OF BOD LOADS	E-12
	E4.1 Sewered Area	E-12
	E4.1.1 Population	E-12
	E4.1.2 Sewage generation	E-14
	E4.1.3 BOD Loads	E-18
	E4.2 Unsewered Area	E-21
	E4.3 Others	E-22
	E4.3.1 Njoro River	E-23
	E4.3.2 Makalia River, Nderit River and Springs	E-26
	E4.4 Annual BOD Load into Lake Nakuru	E-29
E5.	ESTIMATE OF COD LOADS	E-30
E6.	ESTIMATE OF NUTRIENT (NITROGEN AND PHOSPHOROUS) LOADS	E-31
	E6.1 Sewered Area	E-31
	E6.1.1 Sewage Treatment Works	E-31
	E6.1.2 Town Stormwater Drainage Channel	E-31
	E6.2 Others	E-31
	E6.3 Annual Nitrogen and Phosphorous Loads Flowing into Lake Nakuru	E-34
E7.	CONCLUSIONS AND RECOMMENDATIONS	E-36

LIST OF TABLES

		Page
Table E-1	Classification of Pollution Sources	E-2
Table E-2	Type of Influents and Pollution	E-5
Table E-3	Population Distribution in Nakuru Municipality in 1979 and 1993 by Income Level	E-12
Table E-4	Sewered Area by Ward	E-13
Table E-5	Population in Sewered Area Served by Njoro and Town STW	E-15
Table E-6	Summary of Industrial Questionnaire Survey	E-16
Table E-7	Sewage Generation to Njoro and Town STWs	E-17
Table E-8	Annual BOD Load through Sewage Treatment Works	E-20
Table E-9	Population Distribution by Income Level and Sewage Generation in the Unsewered Area	E-21
Table E-10	Livestock Population Within the Lake Nakuru Catchment Area	E-22
Table E-11	Summary of Water Quality at Njoro River Mouth (UIV)	E-25
Table E-12	River Discharge, BOD and BOD Load along Njoro River	E-25
Table E-13	BOD Load at Points UII and UIII	E-26
Table E-14	BOD Concentrations and BOD Loads Measured at Springs and Rivers	E-27
Table E-15	Unit BOD Loads Utilized for Drainage Areas of Rivers (Preliminary)	E-28
Table E-16	Annual BOD Load through Makalia River, Nderit River and Springs	E-28
Table E-17	Annual BOD Load Flowing into Lake Nakuru (Preliminary)	E-29
Table E-18	Unit COD Loads Utilized for Drainage Areas of Rivers and Town Stormwater Drainage Channel (Preliminary)	E-30
Table E-19	Annual COD Load Flowing into Lake Nakuru (Preliminary)	E-30
Table E-20	Nitrogen and Phosphorous Loads Through Njoro, Makalia and Nderit Rivers	E-32
Table E-21	Average Unit Nitrogen Load from the River Drainage Area	E-32
Table E-22	Unit Nitrogen and Phosphorous Loads Reported in Japan	E-33
Table E-23	Unit T-N and T-P Loads Utilized for Drainage Areas of Rivers (Preliminary)	E-34
Table E-24	Nitrogen and Phosphorous Loads into Lake Nakuru (Preliminary)	E-35

LIST OF FIGURES

		Page
Fig. E-1	Pollution Process	E-6
Fig. E-2	Point Source Pollutant Load Estimation	E-7
Fig. E-3	Storm Water Pollutant Load Estimation	E-8
Fig. E-4	Non-point Source Pollutant Load Estimation	E-9
Fig. E-5	Measured Pollutant Loads at Sewage Treatment Works	E-19
Fig. E-6	Flow Diagram of Njoro River	E-23
Fig. E-7	Map of Sampling Locations and River Flow Gauging Stations	E-24

ANNEXES

Annex-1	Estimation of Unit Pollution Loads for Town Stormwater Drainage Channel
Annex-2	*Estimation of Nutrient Loads from Nonpoint Sources Based on Land Use*

E1. INTRODUCTION

This Supporting Report presents a preliminary estimate of pollutant load generation in the drainage area of Lake Nakuru and amount of pollutant load into Lake Nakuru. In order to achieve these objectives various surveys and investigation have been carried out by a joint operation of the Kenyan Counterpart and JICA Study Teams : The investigation and survey included (1) industrial questionnaire survey, (2) water and sludge quality analysis on sewage treatment works and industrial effluents including 24-hour continuos samplings , (3) water quality analysis of rivers and springs as well as stormwater drainage channel, (4) demographic reconnaissance survey, (5) reconnaissance survey on existing drainage and sewer network. Great effort and emphasis have been placed on Items (1) through (3) among the others and have continued during a 4-month periods from June to September 1993. Details and results of the analysis are presented in Supporting Report C, Water and Sludge Quality Surveys.

This preliminary estimate of pollutant loads estimation presented has been made based on the data and information collected during the field work in Nakuru and analytical work carried out in Japan. It should however be noted that the current survey, investigation and analytical work have been programmed to be completed within a various limited condition such as period, timing, frequency, climatological condition, equipment etc. Although the teams have made every efforts to complete the study within a given condition, it is recommendable that such survey and investigation as above-noted be continued to accumulate more qualitative and quantitative data than obtained through the current Study for further upgrading the pollutant load estimate presented by the Study. It should therefore be noted that an attempt made under the current study is a benchmark for future survey and investigation.

E2. SOURCES OF POLLUTION

Pollution sources, in general, are classified into two, depending on how pollution is emitted or discharged into the receiving body: (a) point sources that discharge pollutants in a discernible and discrete manner through any pipe, ditch, channel, tunnel, conduit, well, container, rolling stock, etc. and (b) non-point sources that discharge pollutants area-wide into the water body in a indiscernible manner. Further, pollution can be grouped into two whether it originates from human activities or not: (a) anthropogenic or man-made pollution and (b) others.

To assess intensity and mechanism of pollution that affects water quality of Lake Nakuru, it is fundamental to identify whether the pollution source is a point or non-point source. Pollution sources are summarized in Table E-1.

Table E-1 Classification of Pollution Sources

Pollution Sources	Point or Non-Point	Man-made or Others
1) Domestic	P	M
2) Industrial	P	M
3) Commercial	P	M
4) Public	P	M
5) Recreational	P	M
6) Stormwater Runoff	P&N	M
7) Agriculture	N	M
8) Livestock	N	M
9) Wild Animal	N	O
10) Natural Plant	N	O

(Data Source: Study Team)

Pollution from the sources 1) through 5) listed in Table E-1 closely relates to the water consumption. Following the operation of the water supply facilities completed in 1992, the water consumption will increase significantly from the present 22,080 m^3/day to 35,460 m^3/day and pollutant load generation will also increase. In this Supporting Report, pollutant loads for the present condition are estimated.

Inflow of the above pollutants to Lake Nakuru are mainly through rivers and channels, and their typical features are outlined below:

(1) Njoro River

The river has a catchment area of 293 km^2, gathering runoff from north-west area of Lake Nakuru. Njoro Town which has a population of about 15,000 as of 1993 lies at about 23 km from the mouth of the river. Egerton University is located further upstream of Njoro Town. The river has a perennial flow throughout the year. Most of the catchment area is mainly farm lands. At 3 km upstream from the river mouth, treated effluent from Njoro STW joins the stream.

(2) The Makalia River

Catchment area of the river is 315 km^2, covering south of Lake Nakuru. The area is composed of mainly grassland surrounded with mountains.

(3) The Nderit River

The river originates from Mt. Longonot and runs northwards towards Lake Nakuru. The river has a catchment area of 520 km^2 which consists mainly of hilly area and grassland.

(4) The Lamudiak River

The river is situated at south-west of Lake Nakuru. It has a catchment area of 116 km^2. Most of the area is cultivated farm land. The flow of the river disappears into ground at about 2 km from the lake. Most of the flow assumingly infiltrates into porous layer of land.

(5) The Ngosor River

The cathment area of the river is at the north-eastern side of the Lake, and estimated at 77 km^2. The area is a farm land. The flow disappears at a point, 3 km from the lake near Route A-104.

(6) Town stromwater drainage channel

The channel runs through the residential, commercial and administrative areas of the municipal center from north to south and finally reaches to the lake. The channel gathers storm water from a drainage area estimated at 374 ha, occupied by government offices, shops, restaurants, churches, schools and houses. In dry season, a flow of sludge discharged from the unsewered residential area is observed in the channel. Most of it is used for irrigation near Town STW. In built-up areas, even a little rainfall (>3 mm/day) results in surface run-off. During rainfall, brown and dark colored stormwater that contains garbage and oils enters into the lake through the channel. At about 500 m upstream from the influence to the lake, the flow rate increases gathering treated effluents from Town STW.

(7) Others

Several springs exist around the lake. They are those near the camp site, Lion Hill and Baharin Spring where infiltrated surface water appears again, discharging into the Lake throughout the year. Apparently, they are not related to man-made pollution. However, it is often that such spring water contains high concentration of pollutant loads because of organic matter from marshland.

In and around the lake side, a couple of hotels that accommodate more than one hundred tourists are conveniently located. They are Lion Hill Lodge on an eastern hill and Lake Nakuru Lodge in a south-east plain of the lake. The Team's survey conducted in July 1993, however, confirmed that effluents from the hotels do not affect the water quality of Lake Nakuru. Effluents from camp sites situated near the main gate to the national park were not observed.

From the above, all influent channels, rivers and springs are not necessarily identified as probable sources of pollution. They are summarized in Table E-2.

Table E-2 Type of Influents and Pollution

	Man-made Pollution	Others
The Njoro River	Yes	Yes
The Makalia River	No	Yes
The Nderit River	No	Yes
Town Stormwater Drainage Channel	Yes	No
Baharin Spring	No	Yes
Spring near Lion Hill	No	Yes
Spring near Camp Site	No	Yes

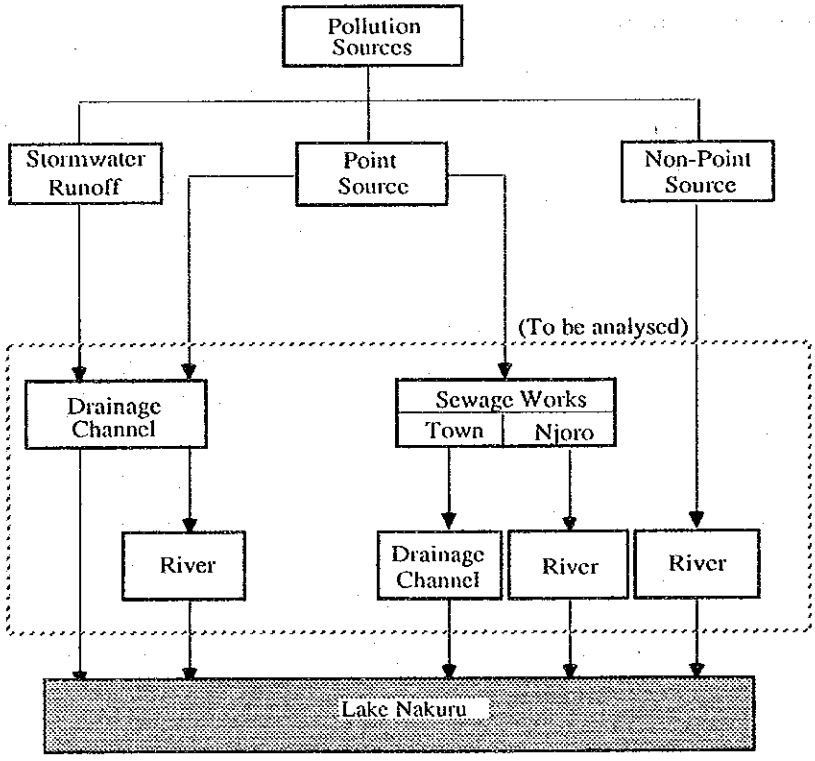
(Data source: Study Team)

E3. POLLUTION PROCESS AND ESTIMATION METHOD

E3.1 Pollution Process

Pollutants discharged from sources enter into rivers, storm channels and sewers in various forms of liquids and solids. Some of them are collected and treated at the existing sewage treatment works. Some are deposited and accumulated in the channels and river, and the remaining reaches Lake Nakuru. Fig. E-1 illustrates the typical process of pollution on the lake water. Present survey and study are focused on the process when pollutants discharge into rivers, channels, sewage facilities and the lake in a discernable manner.

Fig. E-1 Pollution Process

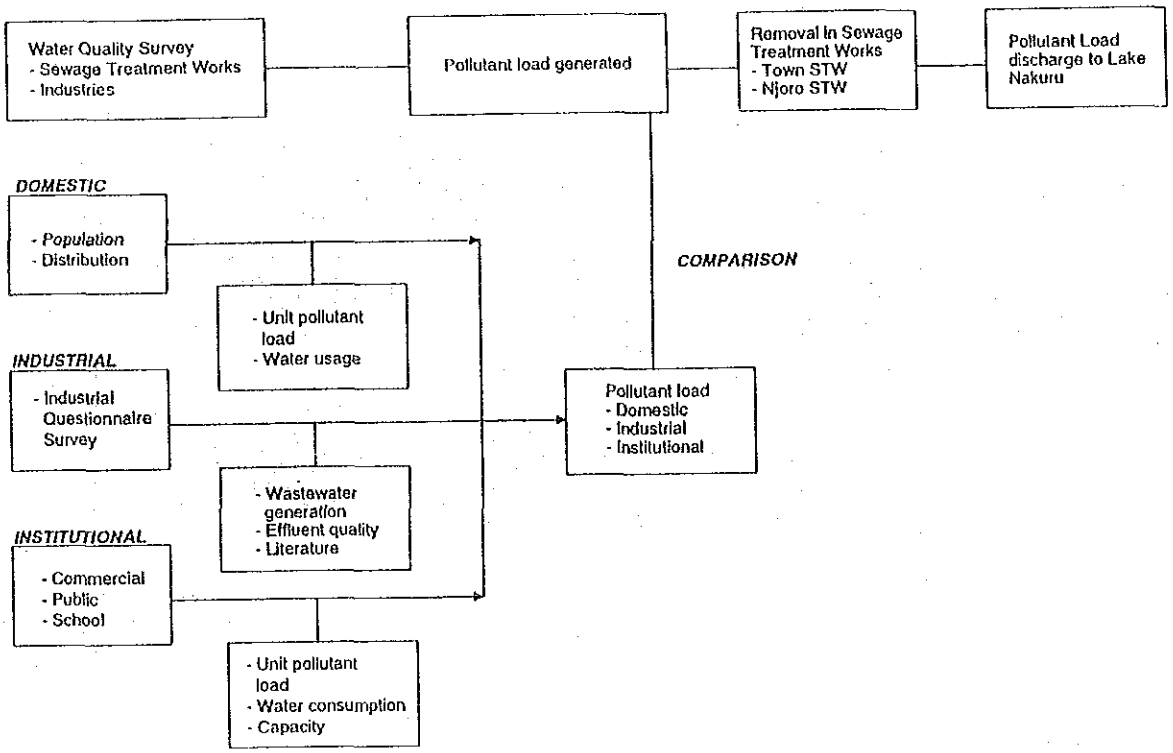


(Data Source: Study Team)

E3.2 Methods of Estimation

Under this heading, estimation methods of pollutant loads are discussed separately for point source pollution, stromwater pollution (point & non-point source) and non-point source pollution. They are schematically portrayed in Figs. E-2, E-3 and E-4 respectively and described below.

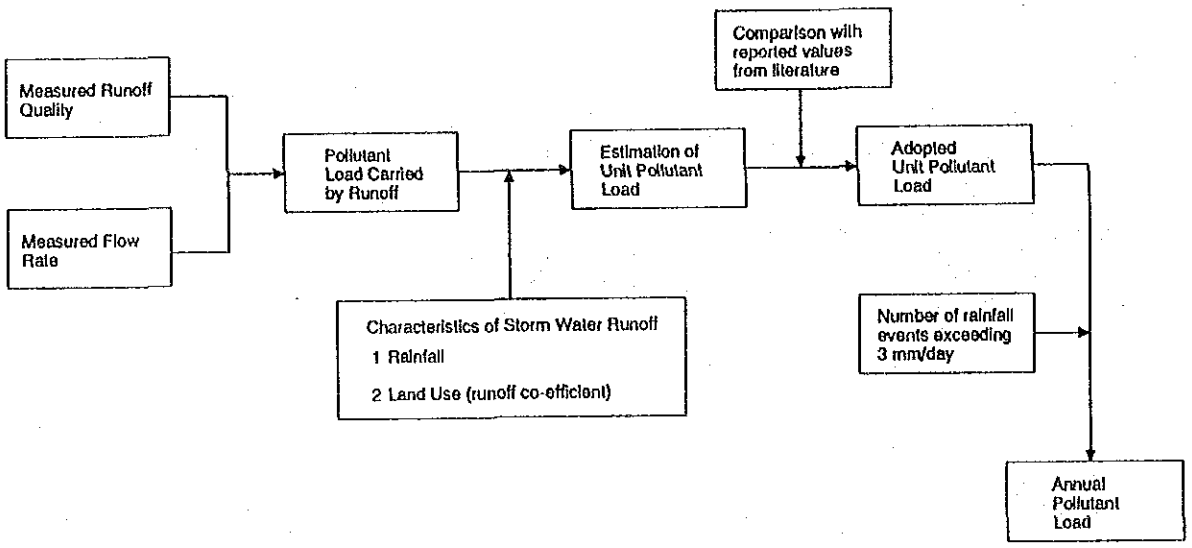
Fig. E-2



Data Source : Study Team

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE POINT SOURCE POLLUTANT LOAD ESTIMATION

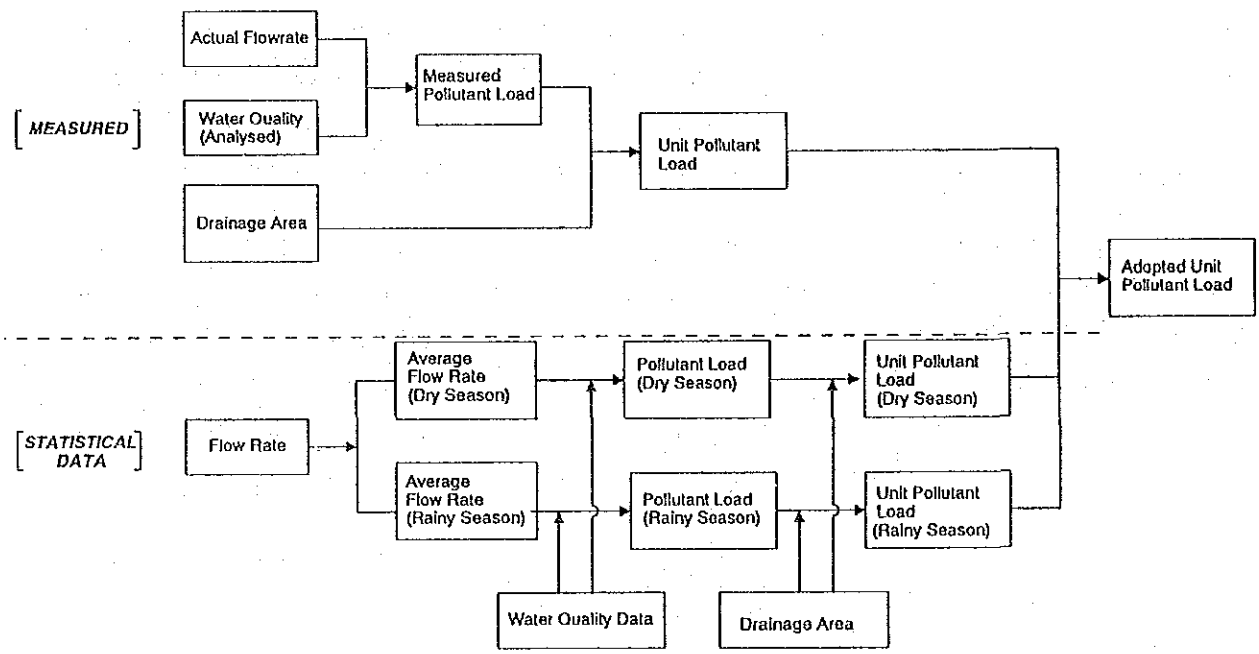
Fig. E-3



Data Source : Study Team

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE STORM WATER POLLUTANT LOAD ESTIMATION

Fig. E-4



NB : Non Point Pollutant Load = Drainage Area x Adopted Unit Pollutant Load

Data Source : Study Team

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE NON-POINT SOURCE POLLUTANT LOAD ESTIMATION

E3.2.1 Point Source

Waste, garbage, night soil and sullage discharged from residential, commercial, institutional, recreational and industrial areas in the sewered zone are recognized as point sources. Out of them, industrial pollution is dealt with separately because of its specific features of waste in terms of quantity and quality.

Except for the industrial waste, it is considered appropriate to apply unit loading method in estimating the total. To this end, population statistic for 1979 and 1987 are analysed to estimate the 1993 population. The estimated population are, then, distributed into two: sewered and unsewered area. Obtained data on the 1992 water consumption in the municipality are similarly distributed to each district, in consideration of large consumers such as hotels, hospitals, government offices, restaurants, etc. From these figures of the water consumption and population by zone, unit water consumption per capita per day is computed.

Apart from the water consumption, influent sewage flow rate and quality data provided by WSD. Data obtained through the field survey by the Team are utilized to compute pollutant load generated per day. Pollutant load are distributed to each zone and computed by water-use category. From the area-wise pollutant load and population, unit load (per capita per day) is estimated to ascertain its conformity with design values envisaged in previous plans and schemes developed by NMC.

As to the industrial wastes, water consumption data obtained from questionnaire surveys are utilized to estimate waste water discharge from each factory. The results of waste water testing and that reported from literature are reflected to compute total pollutant load from the industries.

From the influent and effluent quality, pollutant load to sewage treatment works and that discharged out can be estimated for Njoro and Town STWs. These values would be compared to that calculated from the population distribution and industrial and institutional effluents. Pollutant loads discharged out of the sewage treatment works are adopted from the water quality survey.

E3.2.2 Stormwater Pollution (Point & Non-point Source)

From the field reconnaissance, it is concluded that significant pollution is taking place when rainwater washes garbage, oils, grease, metals and other wastes accumulated on the municipal streets and yards. If the rainfall intensity is high, more pollutants will be washed-off. During storm runoff, concentation of pollutants will be high at the beginning of the flow and will decrease with elapsing time.

Fig. E-3 shows the flowchart for calculation of pollutant load in the stormwater runoff. Based on the measured run-off quality and flow rate, pollutant load is estimated. Using the characteristics of storm runoff, mainly rainfall amount and land use pollutant load per unit area is estimated. This value is compared with reported values from literature, and pollutant load per unit area is adopted.

Stormwater runoff will occur only when storm intensity exceeds 3 mm/day. Analysis of rainfall data between 1988 to 1992 showed that wash-out of pollutants have occurred more than 400 times in the past five years with an average of 80 times an year.

Total amount of pollutants washed-out from the sewered area is calculated by the following equation :

$$P = Pu \times Sr \times A \ / \ 1000$$

where,

P	:	annual pollutant load, ton/year
Pu	:	unit pollutant load, kg/ha
Sr	:	frequency of storm of more than 3 mm/day, number/year
A	:	area, ha

E3.2.3 Non-point Source

It is assumed that pollutants flow into the lake through stream water of the Njoro, the Makalia and the Nderit Rivers. Following method of estimation is proposed. It is based on the measurement of flow rate and quality of the river water for different flow conditions. From those data and drainage area of the rivers, unit pollutant loads is estimated. Generally, pollutant load varies depending on the season. It is assumed that a year consists of two seasons, namely a four-month wet season (1/3) and an eight-month dry season(2/3). Annual pollutant load is estimated using the unit pollutant loads for dry and wet season.

E4. ESTIMATE OF BOD LOADS

E4.1 Sewered Area

E4.1.1 Population

On the basis of the 1979 population statistic given in Greater Nakuru Water Supply Project, the Team assumed 1993 population distribution by income level as given in Table E-3.

Table E-3 Population Distribution in Nakuru Municipality in 1979 and 1993 by Income Level

	Ward	1979 Population	Estimated Population by Income Level (1993)					Remarks
			High	Medium	Low	Very Low	Total	
Nakuru Urban Center								
1.	Menengai	1,811	4,820	-	-	-	4,820	Northern Residential
2.	Misonge	3,542	-	5,200	2,200	-	7,400	
3.	Kisulisuli	2,075	-	-	2,400	800	3,200	
4.	Kivumbini	7,070	-	-	5,700	5,750	11,450	
5.	Shauyiyako	9,577	-	-	6,850	2,280	9,130	
6.	Bondeni	8,146	-	2,870	5,720	2,870	11,460	
7.	Baharin	8,116	-	3,590	10,690	10,390	24,670	
8.	Abraha	7,337	-	2,000	11,420	5,000	18,420	
9.	Central	3,393	-	4,720	1,570	-	6,290	Administrative
10.	Biashara	3,684	-	5,470	1,820	-	7,290	Commercial
11.	Hospital	7,125	5,480	8,950	-	7,510	21,940	Northern Residential
12.	Viwanda	2,085	-	-	4,440	-	4,440	Industrial
13.	Shabab	4,184	-	3,700	3,690	-	7,390	
	Sub-total	68,145	10,300	36,500	56,500	34,600	137,900	
14.	Nakuru East	11,717	-	400	24,300	16,200	40,900	
15.	Nakuru West	15,988	-	1,700	103,200	64,300	169,200	
16.	Langa Langa	2,440	-	5,500	7,500	-	13,000	
	Total	98,290	10,300	44,100	191,500	115,100	361,000	

(Data source: Final Design Report for Greater Nakuru Water Supply Project and Study Team)

A combined use of general plans of the existing piped water system, billing system map and sewer network shows the sewered areas contained in each ward and service area covered by water supply was made. Sewered area in each ward are further broken-down into that covered by three sewerage districts (SD) namely, Town sewerage District, Njoro Sewerage District and Central Sewerage District and are shown in Table E-4.

Table E-4 Sewered Area by Ward

Unit : km^2

Ward		Planned Area Served by Water Supply	Sewered Area			Unsewered	Sub-total	Others
			Town SD	Njoro SD	Central SD			
Nakuru Urban Center								
1.	Menengai	5.01	0.30	-	0.07	1.21	1.58	3.43
2.	Misonge	1.89	0.88	-	-	0.31	1.19	0.70
3.	Kisulisuli	1.23	0.27	-	-	0.12	0.39	0.84
4.	Kivumbini	1.08	0.28	-	-	0.12	0.40	0.68
5.	Shauyiyako	1.78	0.46	-	-	-	0.46	1.32
6.	Bondeni	0.42	0.42	-	-	-	0.42	-
7.	Baharin	0.91	0.30	0.33	-	0.28	0.91	-
8.	Abraha	1.60	0.91	0.69	-	-	1.60	-
9.	Central	0.89	0.34	0.19	0.36	-	0.89	-
10.	Biashara	1.62	0.03	0.39	1.20	-	1.62	-
11.	Hospital	5.86	-	0.58	0.54	1.42	2.54	3.32
12.	Viwanda	2.25	-	1.90	0.16	0.19	2.25	-
13.	Shabab	1.25	-	1.25	-	-	1.25	-
	Sub-total	25.79	4.19	5.33	2.33	3.65	15.50	10.29
14.	Nakuru East	10.40	-	-	-	0.89	0.89	9.51
15.	Nakuru West	7.18	-	0.41	-	6.62	7.03	0.15
16.	Langa Langa	0.74	-	0.66	-	0.08	0.74	-
	Total	44.11	4.19	6.40	2.33	11.24	24.16	19.95

(Data source: Study Team)

Table E-5 shows population distribution by income level for three sewerage districts namely Njoro Sewerage District, Town Sewerage District and Central Sewerage District. Interceptors located in the municipal center are functioning to collect the sewage from the municipal center and to distribute to NjoroSTW and Town STW.

Currently the interceptor is kept open by WSD and about 70% of the sewage from the Central Sewerage District flows into Njoro STW while the rest flows to Town STW.

E4.1.2 Sewage Generation

To estimate the sewage generation in the sewered area and to estimate the polutant load generated the folowing assumptions are made :

(1) Unit water consumption by medium income group ranges from 75 lpcd to 150 lpcd with an average of 100 lpcd,

(2) Unit water consumption by low income group is 50 lpcd on average,

(3) Unit water consumption by very low income group, all of whom are assumed not to be connected to sewer lines, is 20 lpcd on average,

(4) Water equal to water consumption less 10 lpcd enters into sewers as sewage,

(5) Wastewater discharged from commercial and governmental establishments, offices, schools and Lanet Base equal to 85% of the water consumption rate, and 60% for Kenya Railways, enters into sewer network.

Flow rate and quality of industrial waste are estimated based on the results of Industrial Questionnaire Survey (for details, refer to Databook on Questionnaire Surveys and Supporting Report C on Water and Sludge Quality Surveys). Table E-6 shows summary of industrial questionnaire survey. Total industrial wastewater generation is estimated at 838 m^3/day (including those major industries which have not returned the questionnaires).

Estimated sewage generation in the sewered area is summarized in Table E-7. From these estimates, it is concluded that Njoro and Town STWs receive sewage of 4,739 m^3/day and 3,484 m^3/day on average respectively. A total of 8,223 m^3/day corresponds to the dry weather flow recorded during the period from December 1992 to February 1993.

Table E-5 Population in Sewered Area Served by Njoro and Town STW

Ward	Town Sewerage District					Njoro Sewerage District					Central Sewerage District					
	High	Medium	Low	Very Low	Sub-total	High	Medium	Low	Very Low	Sub-total	High	Medium	Low	Very Low	Sub-total	Total
Nakuru Urban Center																
1. Menengai	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0
2. Misonge	-	3,850	1,630	-	5,480	-	-	-	-	0	-	-	-	-	0	5,480
3. Kisulisuli	-	-	1,660	550	2,210	-	-	-	-	0	-	-	-	-	0	2,210
4. Kirevubini	-	-	3,990	4,030	8,020	-	-	-	-	0	-	-	-	-	0	8,020
5. Shauyiyako	-	-	6,850	2,280	9,130	-	-	-	-	0	-	-	-	-	0	9,130
6. Bondeni	-	2,870	5,720	2,870	11,460	-	-	-	-	0	-	-	-	-	0	11,460
7. Baharin	-	1,180	3,530	3,430	8,140	-	1,290	3,850	3,740	8,880	-	-	-	-	0	17,020
8. Abraha	-	1,140	6,510	2,850	10,500	-	860	4,910	2,150	7,920	-	-	-	-	0	18,420
9. Central	-	1,790	600	-	2,390	-	1,030	340	-	1,370	-	1,900	630	-	2,530	6,290
10. Biashara	-	110	40	-	150	-	1,340	440	-	1,780	-	4,020	1,340	-	5,360	7,290
11. Hospital	-	-	-	-	0	-	-	-	4,700	4,700	-	350		-	350	5,050
12. Viwanda	-	-	-	-	0	-	-	4,080	-	4,080	-	-	360	-	360	4,440
13. Shabab	-	-	-	-	0	-	3,700	3,690	-	7,390	-	-	-	-	0	7,390
Sub-total	0	10,940	30,530	16,010	57,480	0	8,220	17,310	10,590	36,120	0	6,270	2,330	0	8,600	102,200
14. Nakuru East	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0
15. Nakuru West	-	-	-	-	0	-	100	5,900	3,680	9,680	-	-	-	-	0	9,680
16. Langa Langa	-	-	-	-	0	-	4,900	6,680	-	11,580	-	-	-	-	0	11,580
Total	0	10,940	30,530	16,010	57,480	0	13,220	29,890	14,270	57,380	0	6,270	2,330	0	8,600	123,460

(Data Source: Study Team)

Table E-6 Summary of Industrial Questionnaire Survey

Type of Industry	Number of Industries	Number of Employees	Water Consumption Rate, m3/d	Water Supply Source	Wastewater Discharge Rate, m3/d	Hours of Operation	Main processing chemicals used	Remarks
Textile industry (spinning, weaving and dyeing)	3	1530 ~ 1630	433	Boreholes and Public	258	24	Dyes, detergents caustic soda, magnesium chloride, sodium sulphite sodium metabisulphite	Acidic/Alkaline wastes containing dye stuff and detergents
Edible oil extraction	3	275	240	Public	113	24	Caustic soda, bleaching earth, solvent, sulphric acid	High organic with fat/oil
Soap manufacturing	2	122	102	Borehole	2.5	24	Caustic soda	One of the factory not connected to sewer. Alkaline waste with fat content
Tannery (hyde processing and chrome tanning)	1	82	100	Borehole	100	24	Lime, chromium sulphate, sodium sulphide	Heavy metal content, fats/suspended solids and sulphides
Milk processing and ghee making	1	162	167	Public	100	24	Acids, alkali and detergents	High organic, periodically contain high fat content from ghee making
Soft-drink bottling	1	90	246	Boreholes and Public	180	8	Lime, ferrous sulphate, calcium chloride, bleaching powder	High organic, alkaline
Steel machining and electroplating	2	54	5.5	Public	3	8		Not connected to sewer - comprehensive treatment
Bakery	1	90	17.5	Boreholes and Public	10	16	Acetic Acid	High organic from floor washing
Laundry (steam and dry cleaning)	2	49	5	Public	4	8~12	Perchloroethylene, starch, soda ash detergent	Alkaline wastes containing detergents. Occasional discharge from dry cleaners contain solvent
Dry cell manufacturing	1	484	100	Boreholes and Public	20	16	Zinc chloride, Tin, Zinc oxide, leadstrips, cadmium	Comprehensive treatment
Paint manufacturing	1	20	9	Public	1.5	8	Solvents, cobalt and lead driers and Titanium oxide	Floor washing, spills may contain solvents, heavy metals
Others	6	378	120	Boreholes and Public	9.5	8~24	Sodium lye, maleic anhydride, diatomite, perfumes and dyes	

Table E-7 Sewage Generation under Present Conditions to Njoro and Town STW's

Item		Town SD		Njoro SD		Central SD		Total	
		Population	Sewage Generation	Population	Sewage Generation	Population	Sewage Generation	Population	Sewage Generation
Domestic	Income Level								
	Medium (90 lcpd)	10,940	985	13,220	1,190	6,270	564	30,430	2,739
	Low (40 lcpd)	30,530	1,221	29,890	1,196	2,330	93	62,750	2,510
	Very Low (20 lcpd)	16,010	-	14,270	-	-	-	30,280	-
	Sub-total	57,480	2,206	57,380	2,386	8,600	657	123,460	5,249
Industrial			180		658				838
Institutional	Commercial		48		72		195		315
	Public		49		75		1,051		1,175
	School		200		195		30		425
	Sub-total		297		342		1,276		1,915
Lanet base			221		-		-		221
Total Sewage Generation, m3/d			2,904		3,386		1,933		8,223
Quantity of Sewage to each STW from Central SD, m3/d			580		1,353				
Total Sewage Quantity to each STW, m3/d			3,484		4,739				8,223

(Data Source : Study Team)

E4.1.3 BOD Loads

Pollutant load is estimated for sewage works and town drainage channel as described below :

(1) Sewage treatment works

Water quality survey was conducted at Njoro and Town STWs twice for each treatment works. Fig. E-5 shows the organic, nutrient and some heavy metal loads received at both sewage treatment works and those discharged out of the treatment works. Total BOD generated in the sewered area is 7,111 kg/d (3,644 kg/d to Njoro STW and 3,467 kg/d to Town STW). BOD load discharged out of the treatment works is 1,714 kg/d consisting of 876 kg/d from Njoro STW and 838 kg/day from Town STW. T-N (total nitrogen) and T-P (total phosphorous) loads generated were 1,659 kg/d and 192 kg/d respectively while that dischrged from the sewage treatment works are 1,344 kg/d and 414 kg/d respectively. Nitrogen removal was about 19% in the sewage treatment works. In case of phosphorous, effluent load was higher than that of the inflow. At both Njoro STW and Town STW, large amount of sludge is accumulated in the waste stabilization ponds. Anaerobic conditions resulting from the accumulation of sludge must have resulted in the release of phosphorous from the sediments and have caused the effluent phosphorous being higher than the influent. Complete removal of chromium (T-Cr) was observed in the Njoro STW, the source being the tannery. In case of zinc (Zn) which usually originates from deterioration of galvanized iron and brass and as well as from the effluent of domestic wastewater (zinc is an essential element for human growth) considerable removal was observed in the sewage treatment works. Since, potassium exists in soluble form its removal is negligible.

Fig. E-5

Unit : kg/d

Parameter	Total Load
BOD	7,111
COD	8,980
T-N	1,659
T-P	192
K	306
Zn	0.85
T-Cr	0.05-0.06

Unit : kg/d

Parameter	Load		Average Load
	23 - 24 June '93	21 - 22 July '93	
BOD	3,380	3,908	3,644
COD	4,111	5,141	4,626
T-N	1,272	505	889
T-P	120	58	89
K	195	157	176
Zn	0.93	0.20	0.66
T-Cr	ND	0.05-0.06	0.05-0.06

Unit : kg/d

Parameter	Load		Average Load
	30 June 1 July '93	28 -29 July '93	
BOD	4,302	2,646	3,467
COD	5,181	3,527	4,354
T-N	1,068	471	770
T-P	97	108	103
K	128	132	130
Zn	0.22	0.16	0.19
T-Cr	ND	ND	0

Unit : kg/d

Parameter	Sampling Date		Average Load
	23 - 24 June '93	21 - 22 July '93	
BOD	1,028	724	876
COD	1,263	923	1,093
T-N	970	441	706
T-P	200	141	171
K	237	158	198
Zn	0.13	0.03	0.08
T-Cr	ND	ND	0

Unit : kg/d

Parameter	Total Load
BOD	1,714
COD	2,210
T-N	1,344
T-P	414
K	329
Zn	0.35
T-Cr	0

Unit : kg/d

Parameter	Sampling Date		Average Load
	30 June - 1 July '93	28 -29 July '93	
BOD	372	1,305	838
COD	615	1,619	1,117
T-N	900	375	638
T-P	49	436	243
K	121	141	131
Zn	0.18	0.36	0.27
T-Cr	ND	ND	0

Data Source : Study Team

THE REPUBLIC OF KENYA	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT	*TITLE* MEASURED POLLUTANT LOADS AT SEWAGE TREATMENT WORKS
MINISTRY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPERATION AGENCY	

To estimate the annual BOD loads discharged out of the sewage treatment works, measured BOD loads (average) are used. Table E-8 shows the annual BOD loads received and discharged from both sewage treatment works.

Table E-8 Annual BOD Load through Sewage Treatment Works

Item	Influent (ton BOD/year)	Effluent (ton BOD/year)
Njoro STW	1,330	320
Town STW	1,265	306
Total	2,595	626

(Data Source: Study Team)

(2) Town Stormwater Drainage Channel

Based on the observation made for a storm event on 28 July 93 (see Supporting Report C for Details), pollutant loads are estimated. A hydrograph of 10 minutes interval constructed using land use and observation was utilized to estimate the pollutant loads for that storm event (see Annex E-1 for details). Unit pollutant loads are calculated for BOD, COD and nutrients (nitrogen and phosphorous). Calculated unit BOD loads are extremely higher. Comparing with the reported values elsewhere unit BOD load of 4.5 kg BOD/ha is adopted and the annual BOD load is calculated as follows:

$$P = Pu \times Sr \times A \times 365 / 1000$$
$$= 4.5 \text{ kg/ha} \times 80 \text{ times} \times 374 \text{ ha} / 1000 = 135 \text{ ton BOD/year}$$

Sullage from the unsewered population (corresponding to the very low -income group) although residing within the sewered area enters into the Town Stormwater Drainage Channel as well. Such population is estimated at 8,800 out of total 30,280. Annual BOD load is estimated as follows:

$$\text{Annual BOD load} = 8{,}800 \times 20 \text{ lcpd} \times 10^{-6} \times 400 \text{ mg/L} \times 365 \text{ days/year}$$
$$= 26 \text{ ton BOD/year}$$

From all the above, BOD load generated in the sewered area is 787 ton BOD/year in total, out of which 626 ton BOD/year or 80% and 161 ton/year or 20% are discharged through STW and Town Stormwater Drainage Channel respectively.

E4.2 Unsewered Area

As explained in Section E3, sullage and drain water from the unsewered area are not a possible pollutant source to the lake except through the stormwater runoff to the rivers. Therefore, pollutant load in the unsewered area are not computed here. Table E-9 shows salient features of the area such as population, income level distribution and sewage generation.

Table E-9 Population Distribution by Income Level and Sewage Generation in the Unsewered Area

Income Level	Population	Per capita sewage generation, lpcd	Quantity of sewage generated, m^3/d
High	10,300	-*	-*
Medium	13,670	70	1,230
Low	128,750	40	5,150
Very Low	84,820	20	1,696
Total	237,540		8,076

*High income group uses septic tanks for wastewater treatment

(Data Source : Study Team)

E4.3 Others

In this section, pollutant (BOD) loads flowing into Lake Nakuru through springs and river water are estimated with an emphasis on their water quality and quantity. Hydrological records on discharge are available as for Njoro River. Landuse in the catchment area of Lake Nakuru is described in detail in Supporting Report I on Environmental Study. Generally, livestock population within any catchment area is one of the major source of pollution and in case of Nakuru cattle, sheep and goat are brought up in farms as well as in individual houses.

According to Nakuru Development Plan (1988-1993), livestock population (cattle, sheep and goat) within the Nakuru District is given for the Nakuru District. Livesock population within the catchment area of Lake Nakuru is estimated in proportion to the area and is shown in Table E-10. Based on these data, population density of cattle within the catchment area of Lake Nakuru is about 100 heads/km^2. Most of the cattles are left to graze in the open pasture during day time. Rivers serve as water source for those cattle living near the rivers. Cattle urine and dung added along the river is considered to be the major source of pollutant load to the rivers and is included in the water quality measurements in the rivers.

Table E-10 Livestock Population Within the Lake Nakuru Catchment Area

	Nakuru District		Lake Nakuru Catchment Area	
Area, km^2	7,200		1,682	
Year	1988	1993	1988	1993
Dairy Cattle	251,300	318,000	58,700	74,300
Beef Cattle	153,300	201,400	35,800	86,200
Total Cattle Population	404,600	519,400	94,500	160,500
Sheep	207,800	260,000	48,500	60,700
Goat	114,700	143,500	26,800	33,500

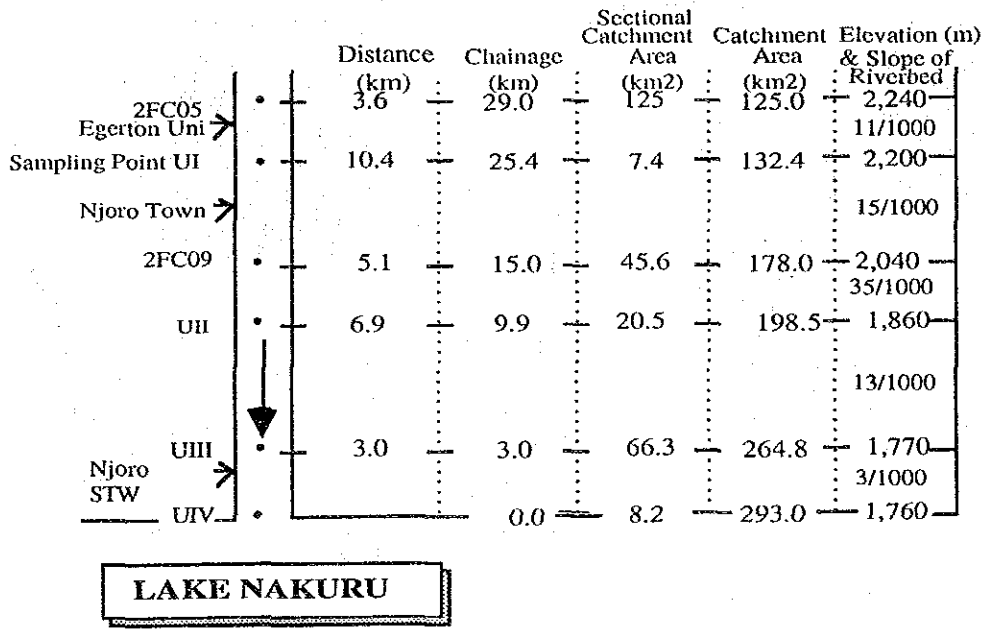
(Data Source : Ministry of Planning and National Development and Study Team)

Pollutant (BOD) loads are estimated for rivers and springs as described in the following sections.

E4.3.1 Njoro River

From the current land use, it can be said that the Njoro River may be affected to a large extent by wastewater discharge from cultivated lands and livestock. Along the river from its mouth to 25 km upstream, four locations (UI, UII, UIII and UIV) were selected for water sampling and flow rate measurement. Schematic diagram in Fig. E-6 illustrates typical features of the Njoro River and relative location of sampling points together with the gauging stations (2CF05 and 2CF09).

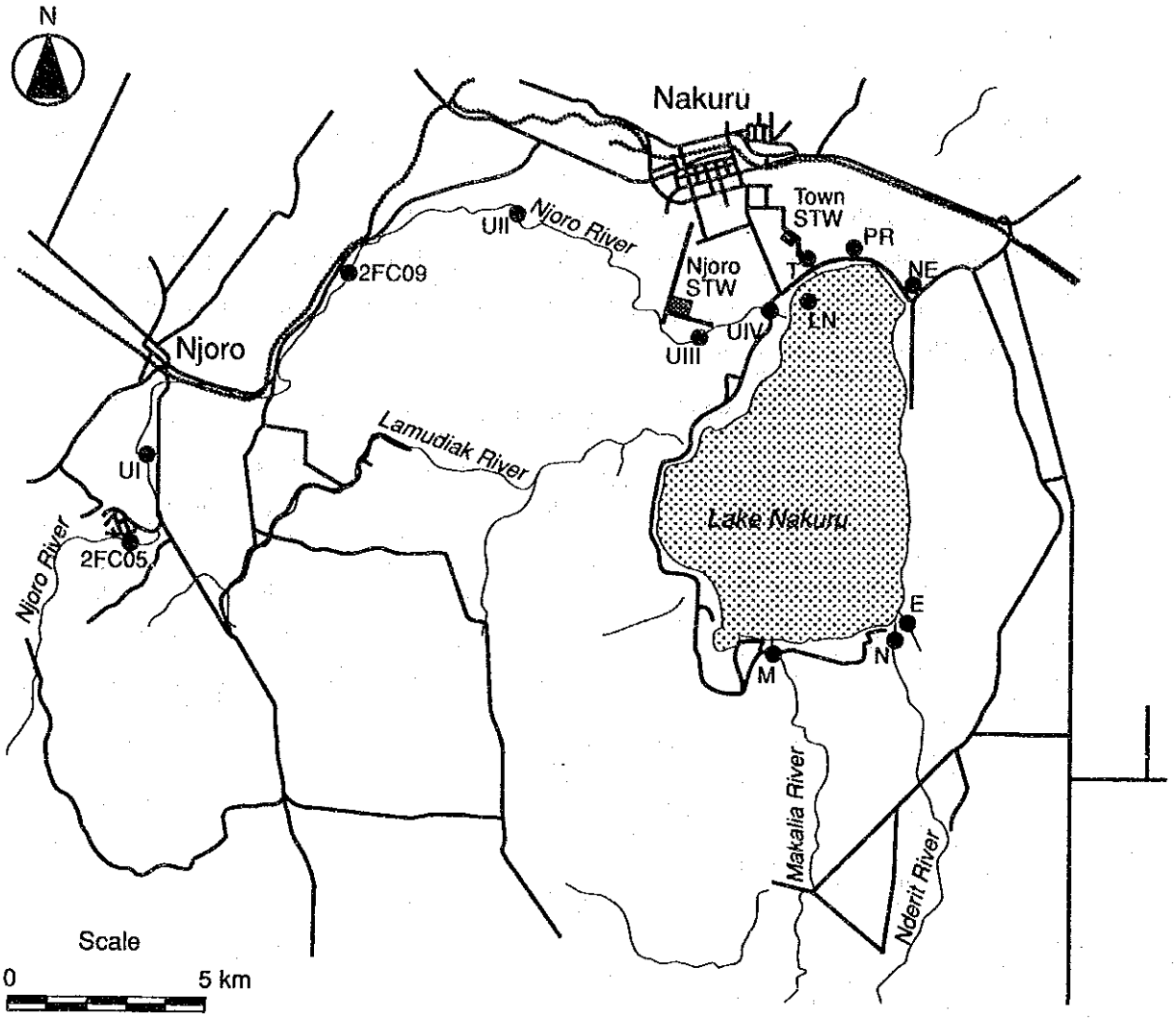
Fig. E-6 Flow Diagram of Njoro River



The river has two flow gauging stations under control of MOLRRWD, which are shown on Fig. E-7.

The first and second measurements were carried out by the Team on 7 July and 27 July 1993 respectively. BOD concentration of the river water sampled at UIV is compatible with the results of water testing conducted in 1992 by KWS. Table E-11 is a summary of water sampling and testing conducted in 1992 by KWS and in 1993 by Study Team.

Fig. E-7



LEGEND

UI	: Njoro River, Upstream of Njoro Town
UII	: Njoro River, Upstream of Nakuru City
UIII	: Njoro River, Upstream of Njoro STW Discharge
UIV	: Njoro River Mouth
PR	: Baharin Spring
T	: Town Stormwater Drainage Channel
NE	: Spring near Special Camp Site
E	: Spring near Linon Hill
N	: Nderit River
M	: Makalia River
LN	: Lake Nakuru, near Njoro River Mouth
2FC05	: River Flow Gauging Station
2FC09	: River Flow Gauging Station

THE REPUBLIC OF KENYA	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT	TITLE MAP OF SAMPLING LOCATIONS AND RIVER FLOW GAUGING STATIONS
MINISTRY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPERATION AGENCY	

Table E-11 Summary of Water Quality at Njoro River Mouth (UIV)

Year	Data	pH	BOD(mg/L)	COD (mg/L)	Remarks
1993	7 July	7.85	100	140	
	27 July	7.88	45	56	
1992	4 March	7.9	100	520	No rainfall for 22 days
	8 April	8.0	70	271	Rainy season
	6 May	7.4	70	225	"
	13 July	7.4	70	150	"

(Data source: Study Team and KWS)

River discharge, BOD concentration and estimated BOD load are presented in Table E-12 for the two sampling conducted by the Study Team.

Table E-12 River Discharge, BOD and BOD Load along Njoro River

Sampling Points	7 July 1993			27 July 1993		
	Discharge	BOD	BOD Load	Discharge	BOD	BOD Load
	m^3/d	mg/L	kg BOD/d	m^3/d	mg/L	kg BOD/d
Upstream of Njoro Town [UI]	14,685	20	294	47,467	40	1,899
Upstream of Nakuru Municipality [UII]	7,843	60	471	45,892	35	1,606
Upstream of Njoro STW [UIII]	2,274	80	182	41,224	55	2,267
River Mouth [UIV]	7,896	100	790	41,497	45	1,867

(Data Source: Study Team)

Since, records obtained at UIV contains that of Njoro STW effluent, it will not be considered for estimating the unit pollutant loads for the Njoro River drainage area. Data obtained at UII and UIII are utilized to compute unit BOD load. Results of computation and conclusion is shown in Table E-13.

Table E-13 BOD Loads at Points UII and UIII

Date of Measurement	Measurements at UII	Measurements at UIII
7 July 1993	Unit BOD load per area is calculated as follows: [471 kg BOD/day] /198.5 km^2 = 2.40 kg BOD/(km^2.day) From the unit BOD load, BOD load of the river is computed as follows: 2.40 kg/(km^2.day) x 293km^2 =703 kg BOD/day	Submerged flow rate is considered. The BOD load per unit area is, 182/264.8 = 0.70 kg/(km^2.day) Therefore, BOD load of the river is computed as follows: 0.70 x 293 = 205 kg BOD/day
27 July 1993	Calculated Unit BOD load is 8.10 kg/(km^2.day), and the BOD load is computed as 8.10 x 293 = 2,373 kg BOD/day	Calculated BOD load is 8.60 kg/(km^2.day), and the BOD load is computed as: 8.60 x 293 = 2,520 kg BOD/day
Conclusion	Unit BOD load at UIII during dry weather is approximately one third of UII. Considering the submerged flow between UII and UIII and their location, unit load estimated at UIII is utilized for estimating the BOD load. In Japan, the unit BOD load varies from 0.5 to 1.0 kg/(km^2.day) . As to the unit BOD load during wet season, the estimate at UIII is selected for the same reason as above. Unit BOD loads selected are as follows dry season : 0.7 kg BOD/(km^2.day) wet season : 8.6 kg BOD/(km^2.day) Therefore, annual BOD load from Njoro River (excluding STW effluent) is calculated as follows: $(0.7 \times 365 \times 2/3 + 8.6 \times 365 \times 1/3) \times 293 \times 10^{-3}$ = 356 ton BOD/year	

(Data source: Study Team)

E4.3.2 Makalia River, Nderit River and Springs

Table E-14 shows result of water testing and flow measurements at springs and rivers.

It is appropriate to assume that BOD loads discharged daily from springs are constant throughout the year. BOD measured at the spring near Lion Hill is rather high because of high organic contents reflecting the nature of the adjacent marshland.

For Makalia River, unit BOD loads obtained during the survey are 0.54 kg BOD/(km^2.day) for the dry season and 2.1 kg/(km^2.day) for the wet season. From these unit pollutant loads, annual BOD load entering the lake is calculated as follows:

Annual BOD load

$$= (0.54 \times 365 \times 2/3 + 2.12 \times 365 \times 1/3) \times 315 \times 10^{-3}$$

$$= 122 \text{ ton BOD/year}$$

Table E-14 BOD Concentrations and BOD Loads Measured at Springs and Rivers

Measuring Points	7 July 1993			27 July 1993		
	Discharge	BOD	BOD Load	Discharge	BOD	BOD Load
	m^3/d	mg/L	kg BOD/d	m^3/d	mg/L	kg BOD/d
Baharin Spring	1,348	3	4	1,465	3	4
Spring near Camp Site	726	3	2	659	0	0
Spring near Lion Hill	224	640	143	324	550	178
River Nderit	259	280	73	181	70	13
River Makalia	5,651	30	169	8,350	80	668

(Data source: Study Team)

Nderit River, despite its large catchment area, has a small discharge varying from 200 m^3/day to 300 m^3/day during dry season. During the survey period, Nderit River bed was dry and a small flow appeared near the lake. This is mainly due to underground infiltration along the riverbed. From the results of the water quality measurement on 7th and 27th July '93, unit BODloads calculated for the catchment area are 0.14 and 0.025 kg BOD/(km^2.day). For estimation purposes, unit BOD load of 0.14 kg BOD/(km^2.day) is utilized. Due to lack of rainfall during the study period, BOD load discharged during the wet season could not be measured. However, to estimate the BOD load discharged during wet season, unit BOD load measured for Makalia River is used, since their catchment areas are relatively similar. Therefore, unit BOD load of 2.12 kg BOD/(km^2.day) is utilized. Annual BOD load is estimated as follows:

Annual BOD load

$$= (0.14 \times 365 \times 2/3 + 2.12 \times 365 \times 1/3) \times 520 \times 10^{-3}$$

$$= 152 \text{ ton BOD/year}$$

In summary, Table E-15 shows the unit BOD loads for dry season and wet season utilized for estimating the annual BOD loads from the respective drainage areas of rivers. Unit BOD loads for the Makalia River drainage area is slightly lower than that of Njoro River drainage area for both wet and dry seasons. During dry season, unit BOD load for the Nderit River is low because of drying-up of the river.

Table E-15 Unit BOD Loads Utilized for Drainage Areas of Rivers (Preliminary)

Name of Drainage Area	Unit BOD Load, kg BOD/(km^2. day)	
	Wet Season	Dry Season
Njoro River	8.60	0.70
Makalia River	2.12	0.54
Nderit River	2.12*	0.14

Note : * Unit BOD load for the Nderit River Drainage Area during wet season was not measured and is assumed to be the same as that of Makalia River Drainage Area.

(Data Source : Study Team)

Annual BOD load discharged through Makalia River, Nderit River and springs are estimated at 328 ton BOD/year as shown in Table E-16.

Table E-16 Annual BOD Load through Makalia River, Nderit River and Springs

	Catchment Area		BOD Load, kg BOD/year	
	km^2	Dry Season	Wet Season	Annual
Makalia River	315	41	81	122
Nderit River	520	18	134	152
Springs	Baharin	4 x 365/1000 = 1.46		
	near Camp Site	2 x 365/1000 = 0.73		
	near Lion Hill	143 x 365/1000 = 52.20		
	Sub-total			54
Total				328

(Data source: Study Team)

From these estimation, total BOD load discharged through rivers and springs including Njoro River are summed up to 684 ton BOD/year.

E4.4 Annual BOD Load into Lake Nakuru

Table E-17 shows the estimate of total annual BOD load into Lake Nakuru, i.e., 1,471 ton BOD/year, out of which 787 ton BOD/year (54%) is discharged from built-up sewered area through the two sewage treatment works and the Town Stormwater Drainage Channel, and 684 ton BOD/year (46%) through rivers and springs.

Table E-17 Annual BOD Load Flowing into Lake Nakuru (Preliminary)

Pollutant Source	Name	Annual BOD Load, ton BOD/year	Percentage of Total %
Sewered Area	Town STW	306	21
	Njoro STW	320	22
	Sub-total	626	43
	Town Stormwater Drainage Channel	161	11
	Sub- Total	787	54
Others	Njoro River	356	24
	Makalia River	122	8
	Nderit River	152	10
	Springs	54	4
	Sub-total	684	46
Total		1,471	100

(Data source: Study Team)

E5. ESTIMATE OF COD LOADS

Estimate of COD loads are obtained in a similar manner utilized for BOD loads. For sewered area water quality survey data at each sewage treatment works is used. Table E-18 shows the unit COD loads utilized for estimating the annual COD loads for Town Stormwater Drainage Channel, Njoro River, Makalia River and Nderit River. COD loads through the springs are assumed to be constant throughout the year. Table E-19 shows the estimate of annual COD loads flowing into Lake Nakuru.

Table E-18 Unit COD Loads Utilized for Drainage Areas of Rivers and Town Stormwater Drainage Channel (Preliminary)

Name of Drainage Area	Unit COD Load, kg COD/(km^2. day)	
	Wet Season	Dry Season
Njoro River	11.21	0.94
Makalia River	2.65	0.71
Nderit River	2.65*	0.18
Town Stormwater Drainage Channel	6.00†	

Note : * Unit COD load for the Nderit River Drainage Area during wet season was not measured and is assumed to be the same as that of Makalia River Drainage Area.
† See Annex-1 for details
(Data Source : Study Team)

Table E-19 Annual COD Load Flowing into Lake Nakuru (Preliminary)

Pollutant Source	Name	Annual COD Load, ton COD/year	Percentage of Total %
Sewered Area	Town STW	408	21
	Njoro STW	399	21
	Sub-total	807	42
	Town Stormwater Drainage Channel	215	11
	Sub- Total	1,022	53
Others	Njoro River	467	25
	Makalia River	156	8
	Nderit River	190	10
	Springs	81	4
	Sub-total	894	47
Total		1,916	100

(Data source: Study Team)

E6. ESTIMATE OF NUTRIENT (NITROGEN AND PHOSPHOROUS) LOADS

Nutrients namely nitrogen and phosphorous are important elements for the growth of living organisms. Similar to BOD loads, nutrients loads are discharged through man-made activities and natural processes. Estimate of nutrient loads will be based on water quality data and other considerations.

E6.1 Sewered Area

Similar to BOD and COD load estimates, nutrient loads will be estimated separately for sewered area and Town Stormwater Drainage Channel and are described in the following sections.

E6.1.1 Sewage Treatment Works

Annual nutrient loads will be estimated from the results of water quality survey conducted at the sewage treatment works. Average daily nutrient loads from each sewage treatment works are as shown in Fig. E-5.

E6.1.2 Town Stormwater Drainage Channel

T-N and T-P loads for the storm event of 28 July 93 are calculated to be 155 kg T N and 156.4 kg T-P (see Annex E-1 for details). Generally, T-P load is much less than that of T-N load. However, in the absence of any previous data the measured values are adopted and need to be be investigated in the future.

E6.2 Others

Table E-20 shows the results of water quality testing along the Njoro River and that for Makalia River and Nderit River for T-N and T-P. Unit T-N loads are calculated for each of the sampling locations. As discussed in Supporting Report C, sampling on 7 July 93 is considered to represent dry season and that on 27 July 93 is considered to represent wet season for Njoro and Makalia Rivers. Unit T-N load decreases along downstream of the Njoro River for both wet season and dry season. Unit T-N load calculated at sampling location UIII is utilized for estimating the T-N load of Njoro River drainage area.

In case of Makalia River, Unit T-N load on 7 July 93 is 0.15 kg T-N/(km^2.day) which is higher than that for UIII at Njoro River. However on 27 July 93, T-N was not detected and this is unusual. For estimation purposes, measured values are used.

Table E-20 Nitrogen and Phosphorous Loads through Njoro, Makalia and Nderit Rivers

Sampling Location	Drainage Area km2	Date	Flowrate m3/day	T-N Concentration mg/L	T-N Load kg T-N/day	T-N Unit Load kg T-N/(km2.day)	T-P Concentration mg/L	T-P Load kg T-P/day	T-P Unit Load kg T-P/(km2.day)
Njoro River UI	132.4	7 July 93	14,685	5.3	78	0.59	6.4	94	0.71
		27 July 93	47,467	4.5	214	1.61	ND	-	-
Njoro River UII	198.5	7 July 93	7,843	8.7	68	0.34	ND	-	-
		27 July 93	45,892	7.3	335	1.69	5.7	262	1.32
Njoro River UIII	264.8	7 July 93	2,274	4.8	11	0.04	ND		
		27 July 93	41,224	1.1	45	0.17	2.4	99	0.37
Makalia River	315	7 July 93	5,621	8.4	47	0.15	ND	-	-
		27 July 93	8,350	ND	-		ND	-	-
Nderit River*	520	7 July 93	259	4.5	1	0.002	5.9	2	0.003
		27 July 93	181	14.0	3	0.005	ND	-	-

Note : * Nderit River was dry and a small flow appeared near the Lake and is affected by the adjacent marshland.
(Data Source : Study Team)

Table E-21 Average Unit Nitrogen Load from the Njoro River Drainage Area

Sampling Location	Calculation Method for Average Unit Load	Average Unit Nitrogen Load kg/(km2.day)	Average Unit Nitrogen Load kg/(ha.year)
UI	0.59 x2/3 + 1.62 x 1/3 = 0.93	0.93	3.4
UII	0.34 x2/3 + 1.69 x 1/3 = 0.79	0.79	2.9
UIII	0.04 x2/3 + 0.17 x 1/3 = 0.08	0.08	0.3

(Data Source : Study Team)

Table E-22 Unit Nitrogen and Phosphorous Loads Reported in Japan

Land Use	Unit Nitrogen Load T-N kg T-N/(ha.year)	Unit Phosphorous Load T-P kg T-P/(ha.year)	Ratio of Unit Phosphorous and Nitrogen Loads T-P/T-N kg T-P/kg T-N	Unit Phosphorous Load for unit nitrogen load of 0.3 kg T-N/(ha.year) kg T-P/(ha.year)	Adopted Unit Phosphorous Load kg T-P/(ha.year)
Forest Area*	1.46 ~ 3.36	0.336 ~ 0.9	1/10 ~1/1.6	0.03 ~ 0.19	0.005 kg/(ha.year) 0.0014 kg/(km2.day)
Mountainous forest area*	6.94	0.184	1/38	0.008	
Agricultural Area*	26.5	0.27	1/98	0.003	
Agricultural Area*	27.84	0.36	1/77	0.004	
Agricultural Area (rice field)#	52.56	0.33	1/159	0.002	
Agricultural Area (rice field)#	19.35	0.44	1/44	0.007	

Note: * Guidelines for Regional Sewerage System, Japan Sewage Works Association, 1977

Guidelines for Prevention of Eutrophication, Japan Sewage Works Association, 1983

(Data Source : Study Team)

Unit T-P load at UIII is 0.37 kg T-P/(km^2.day) as shown in Table E-20 for sampling on 27 July 93. However, this value is higher than the Unit T-N load (0.17 kg T N/(km^2.day). Generally, unit T-P load as well as T-P concentration is much less than the unit T-N load and T-N concentration respectively. To compare the ratio of Unit T-N load and Unit T-P load with those reported elsewhere for forest and farmlands, Annual Unit T-N loads are calculated and are shown in Table E-21. Annual unit T-N load for Njoro River is 0.3 kg T-N/(ha.year) [0.08 kg T-N/(km^2.day)].

As shown in Table E-22 reference is made to the reported values of unit T-N and T-P loads. By comparing the ratio of T-P/T-N and using the unit T-N load of 0.3 kg T-N/(ha.year) T-P value is estimated. An average value of 0.005 kg T-P/(ha.year) [0.0014 kg T P/(km^2.day)] is considered to be appropriate.

Table E-23 shows the unit T-N and T-P loads utilized for drainage areas of rivers.

Table E-23 Unit T-N and T-P Loads Utilized for Drainage Areas of Rivers (Preliminary)

Name of	Unit T-N Load, kg T-N/(km^2. day)			Unit T-P Load, kg T-P/(km^2. day)
Drainage Area	Wet Season	Dry Season	Annual	Annual
Njoro River	0.04	0.17	0.08	0.0014
Makalia River	0.15	-	0.10	0.0018
Nderit River	0.15*	0.005	0.10	0.0018

Note : * Unit T-N and T-P loads for the Nderit River Drainage Area during wet season was not measured and is assumed to be the same as that of Makalia River Drainage Area.
(Data Source : Study Team)

E6.3 Annual Nitrogen and Phosphorous Loads Flowing into Lake Nakuru

Estimate of Annual Nitrogen and Phosphorous loads flowing into Lake Nakuru is shown in Table E-24. Annual nitrogen load is estimated at 547.3 ton T-N/year consisting of 490.6 ton T-N/year (90%) from the sewered area and 44.3 ton T-N/year (8%) from rivers and springs. Similarly, T-P loads are estimated at 163.6 ton T-P/year (98%) and 2 ton T-P year (2%) from the sewered area and rivers/springs respectively. Unlike the BOD and COD loads major portion of the nutrient loads flows into Lake Nakuru from the sewered area.

Unlike the BOD concentration of rivers, previous data of nutrient concentrations are not available. Nutrient load estimates are made using measured values, one each for wet and dry periods. Generally nutrients are released from farmlands, forests etc. during heavy rainfall events. During the Study period, sampling of rivers during heavy rainfall could not be made. Therefore, it is worthwhile to estimate nutrient loads based on various land uses within the catchment area. Unit nutrient loads reported in the literature from long-term study and relatively similar land use conditions are used. Annex E-2 shows the details of estimation. Annual nutrient loads from the nonpoint sources (through rivers and springs) based on land uses are 447 ton T-N/year and 29 ton T-P/year which are one order higher than those estimated using the water quality survey results, c.f. 44 ton T-N/year and 3 ton T-P/year. From these results, it can be concluded that nutrient load estimates need to be improved with future monitoring.

Table E-24 Nitrogen and Phosphorous Loads into Lake Nakuru (Preliminary)

Pollutant Source	Name	T-N (Total Nitrogen)		T-P (Total Phosphorous)	
		Annual Load, ton T-N/year	Percentage of Total, %	Annual Load, ton T-P/year	Percentage of Total, %
Sewered Area	Town STW	232.9	43	88.7	53
	Njoro STW	257.7	47	62.4	37
	Sub-total	490.6	90	151.1	91
	Town Stormwater Drainage Channel	12.4	2	12.5	7
	Sub- Total	503	92	163.6	
Others	Njoro River	8.8	2.5	0.15	
	Makalia River	11.5	2	0.21	
	Nderit River	19.0	4	0.34	
	Springs	5	0.5	2.50	
	Sub-total	44.3	8	3.2	2
Total		547.3	100	166.8	100

E7. CONCLUSIONS AND RECOMMENDATIONS

As discussed in the Introduction, the observations for estimate of pollutant loads are made under various limited conditions especially the duration. For preliminary estimates of pollutant loads, some assumptions are made. They are:

(1) annual pollutant loads are obtained through a single measurement , each for wet and dry seasons.

(2) Nderit River was dry during the study period. Pollutant loads were estimated by assuming unit pollutant loads similar to Makalia River.

(3) Ratio of T-N/T-P is assumed from the reported values.

(4) For Town Stormwater Drainage Channel measured BOD and COD loads are extremely higher and unit pollutant loads are adopted from literature to estimate annual pollutant loads

These preliminary estimates need to be improved, since rivers and channels are subject to seasonal and chronological variation and pollutant loads are also expected to vary. A Monitoring Plan is proposed for Lake Nakuru in the Supporting Report H, Institutional Study.

ANNEXES

ANNEX-1

ESTIMATION OF UNIT POLLUTANT LOADS FOR TOWN STORMWATER DRAINAGE CHANNEL

As shown in Table EA-1, pollutant loads through Town Stormwater Drainage Channel was calculated using a summation method for storm event observed on 28 July 93. A hydrograph with regular intervals (10 minutes) and concentrations are interpolated linearly using the measured values. Pollutant load calculated for each time interval is summed up to obtain total pollutant loads for that storm event. Stormwater flow duration was 15:20 h to 18:00 h. Storm intensity was 11.8 mm as recorded at the Nakuru Meteorological Station.

Concentration of BOD and COD are extremely high compared to other cities. T-N and T-P concentration are similar, which also unusual. Generally T-N concentration is higher than the T-P concentration. Table EA-2 shows the unit loads calculated for the storm event. For BOD and COD unit loads are extremely high. In order to estimate, annual loads unit loads of 4.5 kg BOD/ha and 6.0 kg COD/ha are adopted based on the reported values. Table EA-2 also shows the adopted values used for estimation.

Table EA-2 Measured and Adopted Unit Pollutant Loads

Parameter	Measured Unit Load kg/ha	Adopted Unit Load kg/ha
BOD	70	4.5
COD	93	6.0
T-N	0.41	0.41
T-P	0.42	0.42

Table EA-1 Estimation of Pollution Load Variation During Storm Drainage Using Hydrograph Method

Time Interval	Flowrate	BOD		COD		T-N		T-P	
	m3/10 min	Concentration mg/L	Load kg/10 min	Concentration mg/L	Load kg/10 min	Concentration mg/L	Load kg/10 min	Concentration mg/L	Load kg/10 min
15:20~15:30	250	180	45	220	55	1.0	0.3	1.0	0.3
15:30~15:40	450	500	225	660	297	3.1	1.4	2.7	1.2
15:40~15:50	600	850	510	1,130	678	5.1	3.1	4.5	2.7
15:50~16:00	640	1,180	755	1,560	998	7.2	4.6	6.3	4.0
16:00~16:10	780	1,500	1,170	2,020	1,576	9.3	7.3	8.1	6.3
16:10~16:20	960	1,830	1,757	2,470	2,371	11.3	10.8	9.9	9.5
16:20~16:30	1,730	2,180	3,771	2,900	5,017	13.4	23.2	11.7	20.2
16:30~16:40	2,270	2,020	4,585	2,700	6,129	12.3	27.9	11.4	25.9
16:40~16:50	2,530	1,890	4,782	2,510	6,350	11.3	28.6	11.1	28.1
16:50~17:00	1,990	1,750	3,483	2,320	4,617	10.2	20.3	10.8	21.5
17:00~17:10	1,170	1,610	1,884	2,130	2,492	9.1	10.6	10.5	12.3
17:10~17:20	940	1,460	1,372	1,940	1,824	8.0	7.5	10.1	9.5
17:20~17:30	640	1,320	845	1,740	1,114	7.0	4.5	9.8	6.3
17:30~17:40	500	1,180	590	1,550	775	5.9	3.0	9.5	4.8
17:40~17:50	320	1,040	333	1,360	435	4.8	1.5	9.2	2.9
17:50~18:00	100	900	90	1,170	117	3.8	0.4	8.8	0.9
Total /Average	15,870	1,651	26,197	2,196	34,845	9.8	154.9	9.9	156.3

(Data Source : Study Team)

ANNEX-2

ESTIMATION OF NUTRIENT LOADS FROM NONPOINT SOURCES BASED ON LAND USE

Land use of the Lake Nakuru catchment are (1,682 km^2) consists mainly of agricultural area (808 km^2) and forest are (816 km^2). Corn and maize are the major crops grown in the agricultural area and depends on rain. Fertilizer application is minimal.

Table EB-1 shows reported unit nutrient loads for Pacific Northwest and Florida of USA which can be considered similar to the Study Area. Table EB-2 shows the selected unit nutrient load values for estimation. Either the lower values or mean values are chosen because:

1) Fertilizer application and irrigation is minimal.
2) Soils are highly permeable and evaporation is higher than rainfall. Surface runoff which is essential for nonpoint source pollutant transport occurs infrequently.

Table EB-3 shows the nutrient loads from nonpoint sources. Annual T-N load is 447 ton T-N/year and annual T-P load is 29 ton T-P/year which are one order higher than those estimated from the results of water quality survey. However, results from water quality survey are available once each for dry season and wet season and annual loads are obtained by extrapolation. Therefore, it is necessary to improve the estimates of nutrients in the future monitoring by conducting sampling during different storm events (different intensity).

Total annual nutrient loads estimated from both methods are shown in Table EB-4. Annual T-N load estimated based on land use is 950 ton T-N/year which is twice that obtained from water quality survey (547 ton T-N/year) while annual T-P load is of the same order.

Nutrient loads from different land uses depend on many factors. For example, topography, soil characteristics, amount and intensity of rainfall, vegetation, animal population etc. affect the nutrient load released from a forest area. For urban areas in addition to natural factors such as rainfall, human activities such as street cleaning practices, road/kerb length, ratio of built-up area etc. affects nutrient loads. In other words, nutrient loads are affected by local conditions and is illustrated in Table EB-5 by comparing unit nutrient loads reported for Japan and USA. Therefore further monitoring of rivers, channels and springs is highly recommended.

Table EB-1 Reported Values of Nonpoint Source Loading for Various Land Uses

Location	Watershed Characteristics	T-N Load kg/(ha·year)	T-P Load kg/(ha·year)	Reference/Remark
Pacific Northwest USA	Cattle grazed	<1 ~ 4	0.1 ~ 1.3	The effect of Cattle Grazing on Nutrient Losses in a Pacific Northwest Setting, Jawson, M.D. Ellint, C.F., Saxton, K.E. and Fortier, D.H. (1982), Journal of Environmental Quality Vol. 11, No. 4, pp 628 ~ 632 Results of a three year study (1977 ~ 1979)
	non-grazed	<0.5	<0.1 ~ 0.7	
Florida USA	Urban	8.50 (3.2 ~ 18)	2.00 (1.0 ~ 5.01)	Estimation of Pre-and Post Development nonpoint water Quality Loadings, Shahane, A.N. (1982), Water Resources Bulletin, pp 231 ~ 237
	Pasture	5.30 (2.5.~ 8.5)	0.30 (0.24 ~ 0.66)	
	Cultivated	26.00 (15.0 ~ 37.0)	1.05 (0.18 ~ 1.62)	
	Woodland	3.10 (2.4 ~ 5.1)	0.10 (0.01 ~ 0.86)	

Table EB-2 Selected Unit Nutrient Load Values for Different Land Uses

Land Use	Selected Unit Nutrient Load		Explanation
	T-N kg T-N/(ha·year)	T-P kg T-P/(ha·year)	
Agricultural Area	2.5	0.2	Mean value of that reported for cattle grazed land use of Pacific Northwest since they are about 100 cattle/km2 in the Nakuru catchment
Urban Area	8.5	2.0	Mean value reported for urban area of Florida, USA
Forest	2.4	0.01	Lowest value reported for woodland of Florida

Table EB-3 Estimate of Annual Nutrient Loads from Nonpoint Sources

Land Use	Area km2	T-N		T-P	
		kg T-N/(ha·year)	ton T-N/year	kg T-P/(ha·year)	ton T-P/year
Agricultural Area	808	2.5	202	0.2	16
Urban Area	58	8.5	49	2.0	12
Forest	816	2.4	196	0.01	1
Total	1,682		447		29

Table EB-4 Estimate of Annual Nutrient Loads into Lake Nakuru

Source		T-N (ton T-N/year)		T-P (ton T-P/year)	
Sewage Treatment Works		491 (90%)	(52%)	151 (90%)	(78%)
Town Stormwater Drainage Channel		12 (2%)	(1%)	13 (8%)	(7%)
Rivers & Springs	Water quality survey	44 (8%)		3 (2%)	
	Land Use		447 (47%)		29 (15%)
Total		547 (100%)	950 (100%)	167 (100%)	193 (100%)

Table EB-5 Reported Values of Nonpoint Source Loadings for Various Land Uses in Japan and USA

Land Use			Japan*						USA**						Remarks	
			T-N			T-P			T-N			T-P			T-N	T-P
			Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.		
Agricultural area			8.2	76.0	238	0.0	0.68	2.43	15.0	26.0	37.0	0.18	1.05	1.62	Mean of Florida is 1/3 of the mean of Japan while min. is twice	Mean of Florida is 1.5 times that of mean of Japan
Urban area			4.5	19.7	34.2	0.9	2.7	6.5	3.2	8.5	18.0	1.0	2.0	5.01	Mean of Florida is 1/2 of the mean of Japan	Both values for Japan and Florida, USA are similar
Forest area (wood land)			0.3	3.6	8.8	0.01	0.30	1.27	2.4	3.1	5.1	0.01	0.10	0.86	Mean of Florida is slightly lower than that of Japan while min. is 8 times	Mean of Florida is 1/3 of that of Japan while min. is same
Pasture									2.5	5.3	8.5	0.24	0.3	0.66	* T-N/T-P ratio is almost 10:1 smaller than agricultural area but greater than that of forest area	
Pasture	Pacific Northwest	cattle grazed							<1 ~ 4			0.1 ~ 0.3			* min. and mean are similar to those of Florida * considered similar to agricultural area of Nakuru because minimal fertilizer application and cattle population of 100 head/km2	
Pasture	Pacific Northwest	non-grazed							<0.5			<0.1 ~ 0.17				

* Guidelines for Regional Sewerage System, Japan Sewage Works Association, 1993

** Values reported for Florida, USA unless otherwise noted. Source please refer Table EB-1.

F : EFFLUENT WATER QUALITY STANDARDS

F: EFFLUENT WATER QUALITY STANDARDS

TABLE OF CONTENTS

		Page
F1.	INTRODUCTION	F-1
F2.	WASTEWATER STANDARDS FOR DISCHARGE INTO LAKE NAKURU	F-2
	F2.1 Temperature	F-2
	F2.2 BOD_5 and COD_{Cr}	F-2
	F2.3 Nitrogen	F-4
	F2.4 Others	F-5
F3.	MUNICIPAL COUNCIL OF NAKURU (TRADE EFFLUENT) BY-LAWS (DRAFT)	F-6
	F3.1 Compliance Data	F-8
	F3.2 Parameters	F-8

LIST OF TABLES

		Page
Table F-1	Wastewater Standards for Discharge into Lake Nakuru	F-3
Table F-2	Effluent Quality Standards of West Germany (1989)	F-4
Table F-3	Concentration of Ammonium Nitrogen (NH_4-N) at Different pH Values for Free Ammonia Concentration at 25 °C	F-4
Table F-4	Draft Trade Effluent Standards for Discharge into Public Sewers	F-7
Table F-5	Comparison of Parameters Related to the Health (ie. toxic materials)	F-8
Table F-6	Comparison of Standards for Discharge into Public Sewers in Nakuru (Draft) and Japan	F-9

ANNEX

The Local Government Act (Draft)
(Cap. 265)

F1. INTRODUCTION

In this Suporting Report, Wastewater Standards for Discharge into Lake Nakuru and Draft Trade Effluent Standards for Discharge into Public Sewers are presented and discussed. Wastewater Discharge Standards are prepared and provided to the Study Team by the Government of Kenya in June 1993.

Trade Effluent Standards for Discharge into Public Sewers are being prepared (February 1994) by the Municipal Council of Nakuru for reducing the pollutant loads to its sewage treatment works and to safeguard the sewage treatment works from harmful materials.

Discussion and understanding on the purpose and meaning of the parameters are necessary. The following discussion is made from the viewpoint of sewage treatment.

F2. WASTEWATER STANDARDS FOR DISCHARGE INTO LAKE NAKURU

Table F-1 shows the "Wastewater Standards for Discharge into Lake Nakuru". A total number of 22 parameters are specified.

F2.1 Temperature

Maximum and minimum ambient temperatures in Nakuru are 27.2 and 7.8 °C respectively. Naturally, water temperatures will also vary between this range. During the two 24 hour sampling at Njoro STW and Town STW, effluents from sewage treatment works were as low as 18.2 °C. Further, river water temperatures as low as 16 °C was also recorded. It shall therefore be appropriate to enforce standards related to ambient temperature ie. effluent temperature shall not exceed ± 3 °C from the ambient temperature.

F2.2 BOD_5 and COD_{Cr}

BOD_5 and COD_{Cr} standards are specified as filtered values. Filtered values are suitable for waste stabilization pond, effluents to rivers and lakes because the algae in the effluent do not cause depletion of oxygen. However, water quality of Lake Nakuru is unique and supports the growth of algal species called Spirulina Platensis. Algae species generally found in the waste stabilization pond will not be able to survive within the lake environment and will die and degrade. In other words algae matter in the effluent are pollutant loads to Lake Nakuru. If other biological wastewater treatment processes are used, suspended water in the effluent will be biological matter which would consume dissolved oxygen. In addition these biological organisms may possibly be not able to survive in the Lake Nakuru water environment. Again this will also result as pollutant load to Lake Nakuru. If total pollutant loads entering the lake is to be curtailed, effluent standards shall be based on unfiltered sample.

The effluent standards for BOD_5 and COD_{Cr} values are 10 mg/L and 30 mg/L. Raw domestic wastewater contains organic mater which are biodegradable. The ratio of BOD_5/COD_{Cr} is in the range of 0.7 - 0.8. During biological treatment of sewage most of the biological matter are oxidized and broken down into simple compounds and converted into bacteria or algae which appear as suspended solids in the effluent. Dissolved matter remaining in the treated effluent is hardly biodegradable matter. Therefore, ratio of BOD_5/COD_{Cr} will decrease in the effluent.

Table F-1 Wastewater Standards for Discharge into Lake Nakuru

Parameter	Limit
pH	7.0 - 9.0
BOD_5 at 20 °C (filtered), mg O_2/L	10
COD_{Cr} (filtered), mg O_2/L	30
Temperature, °C	25±2
Total suspended Solids, mg/L	15
Oil/Grease	Trace
Nitrogen as nitrates, mg/L	5.0
Free Ammonia (NH_3), mg/L	1.0
Total Dissolved Solids, mg/L	1,500
Chloride mg Cl/L	1,000
Total phosphorous, mg/L	5.0
Sulphides, mg/L	0.5
Sulphates, mg/L	500
Pesticides, mg/L	0.05
Phenols, mg/L	2.0
Hexavalent Chromium (Cr^{6+}), mg/L	0.05
Total Chromium, mg/L	0.1
Copper, mg/L	0.05
Zinc, mg/L	0.5
Other metals in combination (except iron), mg/L	1.0

Note : In addition to the above limits, no toxic, or inflammable substances should be discharged into the lake.

(Data Source : MOLG)

The ratio can be as low as 0.2. This meansCOD_{Cr} value will be more than 50 mg/L, for a treated effluent BOD_5 of 10 mg/L. For example, Table F-2 shows effluent standards of West Germany enacted in 1989. Ratio of BOD_5/COD_{Cr} for an effluent BOD_5 of 40 mg/L is 0.27 while that for 15 mg/L is 0.2. These are for domestic wastes with an influent concentration of about 250 - 300 mg/L. For Nakuru, BOD_5 concentration of domestic wastes based on per capita BOD_5 of 40 g/d and 80 l/d water consumption would be about 500 mg/L. It means that the wastes are in a concentrated form and the concentration of non-biodegradable matter will also be higher. Further, these non-biodegradable matter will neither consume oxygen nor become pollutant load when discharged into the lake. Thus, the effluent COD_{Cr} standard of 30 mg/L is the most stringent and is beyond the limit that can be achieved by biological treatment assuming only domestic wastes are treated. The problem is aggravated when industrial water and night soil/septage are discharged into the sewerage system.

In Nakuru, night soil/septage emptied from cesspools and septic tanks are discharged into the sewer system. Night soil is in a concentrated form and septage contains more non-biodegradable matter, resulting in lower BOD_5/COD_{Cr} ratio. BOD_5/COD_{Cr} ratio of industrial wastes is highly variable. Most food processing industrial wastes contain more biodegradable matter while some chemical industrial wastes may contain hardly biodegradable matter.

In summary, COD_{Cr} standard of 30 mg/L is the most difficult to achieve even for domestic wastes. When industrial wastes and night soil/septage are discharged together with domestic wastes, the standard is impractical to achieve by biological treatment. Effluent COD_{Cr} standard of 30 mg/L is not compatible with the BOD_5 standard of 10 mg/L.

Table F-2 Effluent Quality Standards of West Germany (1989)

Item			BOD_5, mg/L	COD_{Cr}, mg/L	NH_4-N mg/L	Total-P mg/L
1.	Gemeinden, Villages					
1.1	Groveklasse less than	1,000	40	150	-	-
1.2	"	above 1,000	25	110	-	-
1.3	"	above 5,000	20	90	10	-
1.4	"	above 20,000	20	90	10	2
1.5	"	above 100,000	15	75	10	1

(Data Source : Study Team)

F2.3 Nitrogen

Standards for free ammonia and nitrogen as Nitrates are specified at 1 mg/L and 5 mg/L. Free ammonia concentration depends on the pH and temperature. Assuming effluent temperature of 25°C, Table F-3 shows the ammonium (NH_4-N) nitrogen concentration for pH values of 7 to 9 and 10.5 (pH of Lake Nakuru).

Table F-3 Concentration of Ammonium Nitrogen (NH_4-N) at different pH values for free Ammonia Concentration at 25°C

pH	7	8	9	10.5
Free Ammonia, mg/L	1	1	1	1
NH_4-N, mg/L	190.6	19	1.9	0.06

(Data Source : Study Team)

Average influent concentration of total nitrogen is about 273.4 mg/L, with an average influent NH_4-N concentration of 43.6 mg/L (Town), and 57 mg/L (Njoro). Highly efficient treatment methods are necessary, to achieve these standards.

However, the basis for the standards are not given. The only explanation given was that for the protection of Tilapia in Lake Nakuru from the toxicity of free ammonia. Toxicity of free ammonia to fish are researched for rivers and freshwater lakes. In case of Lake Nakuru, Tilapia grows in a high pH environment. Ammonium ion entering the Lake through River Njoro and Town Storm Drainage channel may possibly escape into atmosphere in the mixing zone with the lake water due to increase in pH and high surface area for gas transfer.

F2.4 Others

Since Lake Nakuru has no outlets and acts as a sink for its catchment area, its preservation requires control measures to reduce pollutant loads. Wastewater discharge standards is one of the tools. Application of this tool has to be based on step by step improvement of control measures. The effluent standards proposed are drastic. Its implementation has socio-economic impact to the city of Nakuru. Some revision are necessary especially for effluent COD_{Cr} and nitrogen concentrations.

F3. MUNICIPAL COUNCIL OF NAKURU (TRADE EFFLUENT) BY-LAWS (DRAFT)

A draft copy of the the abovenamed by-laws is attached in Annex F-1. Reduction of industrial wastewater loads into the sewerage system will reduce the pollutant loads discharged into Lake Nakuru and protect the sewage treatment works from harmful chemicals. Table F-4 shows the draft standards.

Maximum concentration of BOD_5 and COD_{Cr} are specified as 500 and 1,000 mg/L, requiring the pretreatment of those industries discharging above these concentration. A total of 35 parameters are specified. pH range is also specified between 6.5 - 8.0. In addition, discharge of the following material into public sewers are prohibited. They are :

(1) Calcium carbide
(2) Chloroform
(3) Condensing water
(4) Degreasing solvents of mono-di-trichloroethylene type
(5) Volatile petroleum products
(6) Inflammable solvents (e.g., carbon disulphide or any other products which produce inflammable vapors in the sewer
(7) Substances likely to interfere with the free flow in the sewers or to damage the sewers (refuse, glass, sand, solid waste, fibers, leather, textiles, plastic, cement, calcium hydroxide, bitumen).

Further, NMC determines the maximum concentration of substances and other matter.

By-laws vests powers for prosecution of defaulters. Following observations are made on the draft standards.

Table F-4 Trade Effluent Standards for Discharge into Public Sewers

(Unit: mg/L)

Item	Concentration
Total Suspended Solids	600
Total Non-volatile Dissolved Solids	3,000
BOD_5 at 20°C	500
COD	1,000
Phenols (total at connection point)	10
Detergents	15
Soaping oils and fats	10
Hydro carbons	20
Silver (Ag)	0.02
Arsenic (As)	0.02
Barium (Ba)	0.5
Cadmium (Cd)	0.01
Chloride (Cl)	1,000
Cyanide (CN^-)	0.02
Cyanide (CN) total	1
Cobalt (Co)	0.05
Hexavalent Chromium (Cr^{6+})	0.05
Total Chromium	3
Copper (Cu)	0.5
Mercury (Hg)	0.01
Ammonical Nitrogen	20
Nickel (Ni)	0.5
Free Ammonia	10
Total Kjeldahi Nitrogen	Nil
Nitrite	0.5
Lead (Pb)	2
Total Phosphate	30
Selenium (Se)	0.5
Tin (Sn)	0.5
Sulphite (SO_3)	2
Sulphate (SO_4)	1,000
Zinc (Zn)	0.5
Total Nonferrous Metals	0.5
Total Soluble Nonferrous Metals	30
Pesticides	Nil
pH	6.5 - 8.0
Temperature	*Not exceeding 35°C*
In addition, effluent should not contain any toxic matter or any matter that will cause blockage and damage to sewers. Inflammable material and tar should not be present in the final effluent entering the sewer.	

(Data Source : NMC)

F3.1 Compliance Date

Draft By-laws have not specified any compliance date. Following measures would become necessary for the industries to comply with the proposed by-laws. They are effluent pretreament, process modifications for reducing waste generation and reuse-recycling of effluents. Pretreatment requires building of facilities, financial investment and land for pretreatment facilities. Some of the industries may not have enough land for building pretreatment facilities. For those which have land, building of facilities will require time. Process modifications and reuse-recycling will also require time and money.

Considering the above factors for compliance, it is recommended that an earliest possible compliance date be set considering the time necessary for design and construction of pretreatment facilities.

F3.2 Parameters

Table F-5 shows the comparison of the standards related to health (ie. toxic and carcinogenic materials), between draft standards for Nakuru and Japan.

Table F-5 Comparison of Parameters Related to the Health (ie. toxic materials)

Item	Limit	
	Nakuru	Japan
Cadmium (Cd), mg/L	0.1	0.1
Cyanide (CN^-), mg/L	0.2	1
Lead (Pb), mg/L	2	1
Hexavalent Chromium (Cr^{6+}) mg/L	0.05	0.5
Arsenic (As), mg/L	0.02	0.5
Mercury (Hg), mg/L	0.01	0.005
Alkyl Mercury, mg/L	N/A	not detectable
PCB, mg/L	Nil	0.003
Organo phosphorous Pesticides, mg/L	Nil	1

Note : Heavy metals, namely Silver (Ag), Barium (Ba), Cobalt (Co), Total chromium, Copper (Cu), Nickel (Ni), Selenium (Se), Tin (Sn), and Zinc (Zn) are also specified for Nakuru.

N/A : Not Available

(Data Source : NMC & Study Team)

Except for lead, all parameters are very stringent for Nakuru. Treatment of toxic materials are difficult in sewage treatment works. They interfere with the functioning of biological treatment processes and restrict the reuse or disposal of sewage sludge and effluent.

The proposed standards related to toxic materials will be beneficial from the viewpoint of safe operation of sewage treatment works and sewage sludge disposal.

On the other hand, pretreatment of industrial effluents might produce industrial sludges containing high concentration of toxic materials and adequate measures for their safe disposal is necessary.

Table F-6 shows the comparison of organic parameters between Nakuru and Japan. It should be noted that average concentration of domestic waste in Nakuru is about 600 mg/L while that of Japan is about 250 mg/L. Japanese standards for industries discharging more than one quarter of the sewage treatment capacity (case 2) is stringent than other industries.

Table F-6 Comparison of Standards for Discharge into Public Sewers in Nakuru (Draft) and Japan

Item	Limit		
	Nakuru	Japan	
		Case 1	Case 2
pH	6.5 ~ 8.0	5 ~ 9	7 ~ 8
SS, mg/L	600	600	300
BOD_5, mg/L	500	600	300
Oil (*n-Hexane extract*), mg/L			
a) animal/vegetable origin	10	30	N/A
b) petroleum origin	20	5	N/A
Total Nitrogen, mg/L	N/A	240[a]	150[b]
Ammonium nitrogen, mg/L	20	N/A	N/A
Nitrite, NO_2^-,mg/L	0.5		
Total Phosphorous, mg/L	N/A	32[a]	20[b]
Phosphate (PO_4^3)	30	N/A	N/A

Note : N/A : Not Available
(1) For industrial effluent below one fourth of the capacity of sewage treatment works and above 50 m^3/d
(2) For industrial effluents above one fourth of the capacity of sewage treatment works
(a) If effluent discharge standard is specified, the limit shall be 1.25 times that of the effluent discharge standard.
(b) If effluent standard is specified, the limit shall be twice that of the effluent discharge standard.

(Data Source : NMC & Study Team)

Trade effluent standards in Nakuru are stringent for all industries comparing the average domestic waste concentration of 600 mg/L. However, if the wastewater discharge standards for Lake Nakuru are considered ammonium nitrogen and total-phosphorous concentration have to be limited to 2 mg/L and 10 mg/L (i.e., twice that of wastewater effluent discharge standard to Lake Nakuru, refer Table F-1). Considering the wastewater discharge standards to be satisfied by Nakuru Municipal Council, investigation on the total nitrogen and phosphorous concentrations that can be accepted into the public sewerage system is necessary.

Limit for ammoniacal nitrogen is specified at 20 mg/L while total kjeldahl nitrogen is set at zero which is impossible (note: total kjeldahl nitrogen = organic nitrogen + ammonia nitrogen). Specifying zero concentration for total kjeldahl nitrogen (or organic nitrogen) is incompatible with BOD (500 mg/L) and COD (1,000 mg/L) values specified. Revision is necessary.

In summary, the proposed standards are very stringent especially for organic materials. Revision is necessary for some parameters. Specifying a target date for earliest possible compliance is recommended for smooth enforcement of Trade Effluent By-Laws.

ANNEX

Annex

THE LOCAL GOVERNMENT ACT (DRAFT)
(CAP. 265)

IN EXERCISE of the powers conferred by Section 201 of the local GOVERNMENT ACT, the Municipal Council of Nakuru makes the following by-laws :

THE MUNICIPAL COUNCIL OF NAKURU (TRADE EFFLUENT) BY-LAWS, 1992.

1. These by-Laws may be cited as the Municipal council of Nakuru (Trade Effluent) By-Laws 1992. — Citation

2. In these By-Laws unless the context otherwise requires - — Interpretation
   "Authorised Officer" means any person authorised by the council to inspect sewers and take samples of trade effluent or do any other act authorised by the Council ;
   "Average Sewage" means all sewerage (including trade effluent and sludge) received at the Council's Sewerage Treatment Works ;
   "Council" means the Municipal Council of Nakuru :
   "Suspended solids" means undissolved solids which are liable to settlement or form a surface scum and is measured by filtration.
   "Grossly contaminated waste liquids" means water, liquids or semi liquids sludge kept separate or separated from the main waste water stream of manufacturing processes.

Discharge of trade effluent

3. (1) No person shall discharge any trade effluent into any sewer except with the written permission of the Council

(2) Where the discharge of effluent under paragraph (1) is into a water course, the Council's permission shall be subject to pollution control regulations made by the Minister for the time being responsible for water development.

(3) The Council may attach such conditions as it does seem fit to any permission granted under Paragraph 91) and may at any time with 21 days notice revoke such permission.

(4) It shall be illegal to discharge trade effluent into any underground acquifer by well, borehole, adit or pipe within the Municipality without the consent of the Council.

Discharge of trade effluent into sewer prohibited

4. No person shall discharge into any sewer any trade effluent which is likely to

(a) damage any sewer into which it is discharged or any sewer through which it is conveyed or to interfere with the smooth flow of the sewer ;

(b) damage sewer purification works at which it is treated or any equipment installed thereat ;

(c) Interfere with any process of purification of sewage or trade effluent :

(d) Be a nuisance or injurious to health ; or

(e) Affect the effluent discharge from the sewage purification works ; or

(f) cause foaming problems

Temperature of trade effluent

5. No person shall discharge into any sewer any trade effluent the temperature of which at its point of entry into the sewer exceeds thirty degrees centigrade

pH value of trade effluent

6. (1) No person shall discharge into any sewer any trade effluent the pH value of which at its point of entry into the sewer is less than 6.0 or exceeds 10.0

(2) For the purposes of paragraph (1) "pH value" means the logarithm to the base 10 or the reciprocal of the concentration of hydrogen ions in an aqueous solution.

Prohibition on content of trade effluent

7. (1) No person shall discharge any of the substances listed under the first column of the schedule into the sewer concentrations exceeding those specified in the second column of the schedule

(2) No person shall discharge into any sewer any of the following substances

(a) Calcium Carbide

(b) Chloroform

(c) Condensing water

(d) Degreasing solvents of mono-di-trichlorethylene type

(e) Volatile petroleum products

(f) Inflammable solvents (eg carbon disulphide or any other products which produce inflammable vapors in the sewer ; or

(g) Substances likely to interfere with the free flow in the sewers or to damage the sewers (refuse, glass, sand, solid waste, fibers, leather textiles, plastic, cement, calcium hydroxide, bitumen)

(3) The Council shall determine the maximum concentration of substances or other matter which shall be permitted to be discharged into the sewer.

Charges

8. (1) Any person who discharges into a sewer any trade effluent shall pay a monthly charge for the disposal thereof calculated in a manner which shall take into account the following ;

(a) Volume of the trade effluent discharge measured in cubic metres based on total usage

(b) The bio-chemical oxygen demand (BOD) measure in milligrams per litre

(c) Chemical Oxygen demand (COD) measured in milligrams per litre and

(d) Transparency measured in centimeters (CM)

(2) Any trade effluent having over 700 mg/l BOD and/or 1200 mg/l COD in stretch or transparency of less than 30 cm (measured in turbidity meter shall not be discharged into the Council's sewer and the Council shall require pre-treatment of any such effluent before acceptance into the sewer.

(3) The monthly charge may be varied from time to time by resolution of the Council.

(4) For the Purpose of this regulation "bio-chemical oxygen demand' means the quantity of oxygen utilized in the biological oxidation of organic matter under standard laboratory procedure in five days at 20°C expressed in milligrams per litre

"COD" means the chemical oxygen demand which is a measure of the amount of oxidation undergone by chemical materials in effluent sample after boiling with acid and dichromate.

9. Any authorised officer of the Council may from time to time take samples of trade effluent for testing at any premises from which trade effluent is discharged into a sewer.

Authorised Officer to carry out tests

10. (1) The Council shall require the occupier of any premises from which trade effluent is discharged into sewer to submit for approval by the Council sewered plan of his premises and to construct and maintain an approved manhole on his premises connected to the pipe or channel conveying such effluent

(2) An Officer of the Council shall at all times have access to the manhole and may examine and collect samples of such effluent

Manholes or Inspection Chambers

11 The occupier of any trade premises from which trade effluent is discharged into a sewer shall notify the Council forth of

(a) Any change in the process of manufacture or in the raw materials used or of any other circumstances which are likely to alter the nature or composition of such trade effluent

(b) Any circumstances which may result in the permanent cessation of discharge of trade effluent.

Change in cessation of trade effluent

Powers of the Council in respect of sewers

12 The Council may prescribe

(a) The hours during which trade effluent may be discharged into a sewer :

(b) The maximum hourly rate at which trade effluent may be discharged into a sewer :

(c) The total volume of trade effluent discharged into a sewer between midnight and the following day

(d) The precaution measures to be taken in case of emergencies

Offenses and penalties

13 (1) Any person who contravenes or fails to comply with any of these by-laws or any of the conditions imposed by the Council shall be guilty of an offense and shall be liable

(a) In the case of a first offender, to a fine not exceeding ten thousand shillings or imprisonment for a term not exceeding six months or both ;

(b) In the case of a second or subsequent offense, to a fine not exceeding twenty thousand shillings or to imprisonment for a term not exceeding twelve months or to both

(2) (a) Where an offense is of continuous nature for a period not exceeding sixty days, the offender shall in addition to the penalties prescribed in paragraph (1) pay an additional fine of one thousand shillings for everyday during which the offense continues

(b) Where an offense is of continuous nature for over sixty days, the Council may revoke the license.

Trade Effluent Standards for Discharge into Public Sewers

(Unit: mg/L)

Item	Concentration
Total Suspended Solids	600
Total Non-volatile Dissolved Solids	3,000
BOD_5 at 20°C	500
COD	1,000
Phenols (total at connection point)	10
Detergents	15
Soaping oils and fats	10
Hydro carbons	20
Silver (Ag)	0.02
Arsenic (As)	0.02
Barium (Ba)	0.5
Cadmium (Cd)	0.01
Chloride (Cl)	1,000
Cyanide (CN^-)	0.02
Cyanide (CN) total	1
Cobalt (Co)	0.05
Hexavalent Chromium (Cr^{6+})	0.05
Total Chromium	3
Copper (Cu)	0.5
Mercury (Hg)	0.01
Ammonical Nitrogen	20
Nickel (Ni)	0.5
Free Ammonia	10
Total Kieldahi Nitrogen	Nil
Nitrite	0.5
Lead (Pb)	2
Total Phosphate	30
Selenium (Se)	0.5
Tin (Sn)	0.5
Sulphite (SO_3)	2
Sulphate (SO_4)	1,000
Zinc (Zn)	0.5
Total Nonferrous Metals	0.5
Total Soluble Nonferrous Metals	30
Pesticides	Nil
pH	6.5 - 8.0
Temperature	Not exceeding 35°C

In addition, effluent should not contain any toxic matter or any matter that will cause blockage and damage to sewers. Inflammable material and tar should not be present in the final effluent entering the sewer.

(Data Source : NMC)

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