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CHARACTERIZATION, TREATMENT AND DISPOSAL OF SEWAGE OF DHAKA CITY

A Thesis

by

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ABSTRACT

This study investigates the characteristic quality of sewage of Dhaka city. The variation in physical, chemical and biological characteristics as well as the flow rate of sewage with time and also the seasonal effect both in volume and characteristics are studied and an attempt is also made to investigate the most effective method of sewage treatment.

This study attempts to determine the effect of discharging partially treated or untreated wastewater on the quality of water of the Buriganga river. The pollution load and self-purification process of the river are also discussed in this study.

Considering the established characteristics of sewage, climatic and meteriological factors, number of people utilizing present sewerage facilities and other socio-economic factors some alternative methods of sewage treatment are studied in details. An attempt is made to select the most appropriate method of sewage treatment for Dhaka city based on both engineering and economic analysis.

A detail study and survey on the existing sewerage system is done and some present and future problems with the existing sewerage system are identified. The remedeal measures of such problems are also investigated and discussed in this study.

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CHAPTER 1

INTRODUCTION

1.1 General

The aim of sewage treatment is to protect health and well being of the community. It is conventional to say that better environment for better health. Good sanitation is an index of civilization and sound society. Without characterization and proper treatment of sewage, the health and well being of the community and downstream water users will suffer. The physical and chemical characteristics of domestic sewage as well as its volume are different and vary significantly with time. This diversity affects not only the types of treatment processes used but also their method of operation.

The population of Dhaka city is increasing at a high growth rate of about 12% per year[18] for which the existing sewerage system in Dhaka city is not able to satisfy the rapidly increasing demand by the expanding population. Consequently the treatment of sewage is insufficient and the quality of effluent is not satisfactory. As a result, problems such as pollution of rivers and streams, deterioration of environmental and health sanitation have become serious.

The high fluctuations of both quality and quantity of sewage are observed in Dhaka city[25] due to ground and rain water infiltration. Infiltration occurs when existing sewer lines undergo material and joint degradation, as well as when new sewer lines are poorly constructed. Inflow normally occurs when rainfall enters the sewer system through direct connections such as roof leaders, catch basins and manhole covers. The elimination of inflow by sewer system rehabilitation can often substantially reduce the cost of wastewater collection and treatment.

The discharge of industrial wastes is one of the major reason for the degradation of water environment. A gradual deterioration of water quality and occasional upset of the balance mechanism of pollution recovery system have been observed.[2] Hence, it is necessary to evaluate the industrial wastewater production and disposal system in order to determine the effects of industrial wastewater discharges on receiving water or public sewer or on any proposed treatment process and to explore possible pretreatment process requirements to eliminate such effects.

In Bangladesh, the sewage is not treated properly and sometimes is disposed off in untreated condition which is dangerous for public health. Most of our urban centres do not have an acceptable sewerage system. Recently, government has taken a decision to provide sewerage facilities in all major cities and towns and low-cost sanitation in rural areas. To select the most effective and economical method of sewage treatment in our climatic condition based on modern engineering and technology, the sewage is needed to be characteristized first. The appropriate method of sewage treatment is greatly influenced by the nature and volume of influent, required effluent quality, population utilizing the sewerage facilities, climatic and meteriological factors and socio-economic conditions.

The most serious effect of the wastewater discharge to the river or adjacent areas is the contamination of the water supply system downstream of the river. The cases of communicable diseases for the year 1984 in Bangladesh were 6,99,891.[9] If the sanitary condition and sewerage system is upgraded and rehabilitated, a significant reduction in the cases of diarrhoeal attack is expected.

1.2 Need for the Study

The population and the needs for improvement of the living conditions in the most of major cities in our country have rapidly increased and will further increase. The service facilities of these cities have not expanded to cope with the rapid population growth and urbanization. As a result it has not been possible to meet the minimum service facilities for the citizen. Even in the city of Dhaka continous deterioration of service facilities is being experienced by the dwellers.

The most needed service facility such as sewerage needs special attention due to its importance and priority in maintaining sanitary condition which is an essential component of primary health care. The history of sewerage system of Dhaka city is old, dating back to 1923. Since then, the sewerage system has been expanded as the city has grown. The present population of Dhaka city is approximately 4,320,000.(17) Among these people, approximately 1,150,000 are serviced by the sewerage system and the rest of the people do not have adequate sewerage facility.(17)

The existing sewerage system is insufficient and also unsatisfactory which created serious unsanitary problems at many locations in the city. The waste stabilization ponds system installed for the treatment of sewage in Dhaka city is overloaded and produces an effluent which does not satisfy the minimum requirement to prevent contamination of the receiving waters. The river water contamination caused by unsatisfactory treatment of sewage has already become a deplorable level requiring immediate actions to prevent degradation of the sanitary conditions in the area. Narayanganj city, located a few kilometers downstream from the outfall, is planned to rely on river water as a source to supply drinking water to 120,000 residents and large number of industries, and therefore, the city has been in the chronic danger with the contaminated river water.(9)

These deteriorated sanitary conditions have further been aggravated due to various economic and social reasons associated with unplanned growth of the city. The present sewerage problems include insufficient capacities of sewers, clogging of pipe line by sand deposit or broken manholes, insufficient capacity and degree of treatment of sewage of the existing sewage treatment plant at Pagla. A properly designed sewage treatment plant is the vital element in sewerage system. In the context of sewerage problems in the city of Dhaka, it is essential to characterize the sewage and analyze the existing system to identify the deficiencies and to suggest improvements in the existing system. The study is expected to outline a rational sewage treatment system suitable for Dhaka city.

1.3 Objectives of the Study

The above discussion of the study essentially focuses on the greater importance of analysis and design of an effective and economic rational sewage treatment system for Dhaka city. The present sewerage problems of Dhaka city sets the following objectives of this study:

i) To characterize the combined sewage of Dhaka city and the the sewage collected from industrial and residential areas.

ii) To study the Dhaka WASA sewerage system including existing sewage treatment and disposal facilities and its effect on the quality of river water.

iii) To evaluate the alternative sewage treatment system based on characteristics of sewage and select a method suitable for the existing environmental, economical and social conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 History and Development of Sewerage Engineering

Sewerage Engineering has its history, archeology, literature and science as there was not real sign of civilization and culture without good sanitation. Therefore, a knowldge of historical development of sewerage engineering is highly desirable.

In fact, the needs for proper sewerage system seem to have been felt long before i.e., even in ancient times. The efficient sewerage system is known to have existed in Babylon, Greece, Rome and Egypt several centuries before chirst. And also, the efficient sewerage system have been discovered in excavation of ancient Indian towns or mederal towns notably Mohen-Jo-Daro and Harappa.[15] It is strange to note that no progress in sewerage engineering seems to have been made for nearly a thousand years. But in the 18th century the renaissance began and attention began to be paid to sanitary engineering and cities started improving in accordance with modern ideas of convenience. Sewage treatment and disposal based on science and technology is of recent origin.

The men who prodded the social conscience and aroused the sanitary consciousness of the people and their representatives in government included engineers, doctors, lawyers and many others. Sir Edwin Chadwick, by training a lawyer in Britain (1842) raised the slogan "the rain to the river and the sewage to the soil" and the general public accepted the slogan whole-heartedly.[1] British people are indebted to him for his general contribution to the advancements of public health. Engineers for their specific interest in sanitary works including advocacy of the small tile sewers and seperate system of sewers. Notable among doctors were Sir John Smith, first medical officer of health of London (1860), Dr. Lemuel Shattuck of Boston (1860), Dr. Stephen Smith of New York (1869), Dr. John Snow, Britain (1849) and Dr. Willium Budd, Britain (1857) who were responsible for the great sanitary awakening of the people of the world.[1]

Among engineers, Sir Robert Rawlinson, Superintendent Inspector of the General Board of the Health (1848), conducted engineering studies for sanitary works in industrial Britain, Sir John Bazalgette started the main sewerage scheme of London in 1850. John Roe accepted the Chadwick's suggestions to construct sewer lines of vitrified tile pipe. Julius W. Adams in 1857, designed the first comprehensive system of sewerage for Brooklyn, New York, U.S.A. and Hiram F. Mills in 1886, as the engineer member of the Massachussetts State Board of Health, gave direction to its newly formed engineering division and caused its work to be supported and advanced by the sanitary researches of the Lawrence Experimental Station of the Board.(1)

Therefore, it is seen that the present stage of development of sewerage engineering is the result of the combined efforts of engineers, doctors, lawyers, chemists, microbiologists and others.

In our country, sewerage engineering in modern line has just started. Many of our cities are without sewerage system. But the government has taken up plans to construct sewerage facilities in all the cities and towns.

2.2 Sewage and its Characteristics

2.2.1 General

Sewage is largely the water supply of a community after it has been fouled by various uses. The constituents of sewage are:

i) Domestic waste which includes human excreta as well as discharges from kitchens, baths, lavatories etc. from private public buildings.

ii) Industrial waste from manufacturing process such as tanneries, paper and pulp mills, slaughter houses, distilleries, textile processing mills, chemical plants etc.

iii) Groundwater entering to sewers through manholes and leaks and

iv) Rain water from houses, roads etc.

Sewage pollutes the various phases of human environment like air, water, food, land and shelter and thereby endangers public health in general. Sewage contains pathogenic microorganisms which causes most of vital diseases. To prevent the creation of intolerable nuisance, spread of diseases and creation of unhealthy environment in a community, proper treatment and disposal of sewage is essential.

2.2.2 Need for Characterization

Sewage characterization is essential in the design and operation of collection, treatment and disposal facilities and in the engineering management of environmental quality.

The following are the objectives of sewage characterization:

i) To determine the physical, chemical and biological characteristics of sewage in order to know the type and degree of treatment required.

ii) To determine the various matters and their quantity present in the sewage.

iii) To determine the informations required for operation and maintenance of sewage treatment works.

An important aspect of formulating a wastewater treatment plant is to characterize the wastewater. This is not only indicates likely methods of treatment but also provides a reliable means of evaluating on a continuing basis, the effectiveness of the planned water pollution control measures.

2.2.3 Characterization of Wastewater

Wastewater is characterized in two major ways: by origin and by enumeration of physical, chemical and biological characteristics.

Characterization of wastewater by origin: Wastewater is generally classified as being of domestic, industrial or storm origin.

Domestic wastewater is derived principally from residential, business and industrial users. It may or may not contain storm water or surface water. However, because of infiltration, groundwater is always present in water bearing ground. Domestic wastewater refers to the waste flow that originates mainly from the kitchen, bathroom and laundry. Kitchen wastewater may contain waste from food preparation, dish washing, garbage grinding etc. Bathroom wastes include those from toilets, baths, showers, hand and face washing, tooth brushing and shaving water. Laundry waste consists primarily of soil and detergent.

The domestic wastewater of a country tends to be uniform in character. Considerable variation is possible between individual communities, however because of differences in such factors as geographic location, climate and social and economic conditions.

Industrial wastewater may be thought of as that waste flow not originating from domestic sources. Each individual wastewater is unique. It generally reflects the raw material components, the intermediate products and the end products and by-products of a particular manufacturing or production process.

Storm wastewater is that portion of liquid resulting from precipitation runoff that flows in combined sewers during or after a period of rainfall.

Characterization of wastewater by physical, chemical and biological characteristics: Characterizing a wastewater by origin is limited in usefulness because only "grouped" parameters are considered. Considerably more insight into the quality of the wastewater is derived from a description of its specific physical, chemical and biological characteristics.

Physical characteristics commonly used to describe wastewater quality include temperature, odor, color, solids and flow variations. The chemical characteristics of wastewater are determined by the chemical properties of the suspended, colloidal or dissolved inorganic materials in the wastewater and their relative concentrations.

Biological constituents include all forms of living organisms present in wastewaters. A wide variety of microorganisms are found in most wastewaters, with concentrations ranging from 10^5 to 10^8 organism/ml. Most are free living single or clustered cells that are capable of independently carrying out life processes of growth, metabolism and reproduction.

The bacteria present in a wastewater treatment plant are the key to secondary biological unit process efficiency. In the presence of sufficient oxygen, aerobic bacteria convert the soluble organic matter in the wastewater into new cells and inorganic elements. These matters, in turn, provide the foods for other organisms and/or permit removal via other treatment processes. Bacteria also provide a means of evaluating effluent quality. The number and types of microorganisms present before and after a unit process are an indication of process efficiency.

2.3 Formulation of the First Stage BOD Curve

2.3.1 First Stage BOD Reaction Equation

The rate of BOD reaction is proportional to the amount of oxidizable organic matter remaining at any time. Once, the population of organisms has reached a level where only minor variations occur, the reaction rate is controlled by the amount of food available to the organisms and may be expressed as follows:

$$-\frac{dC}{dt} \propto C \qquad \text{or} \qquad \frac{dC}{dt} = kC$$

where 'C' represents the concentration of oxidizable organic matter at the start of the time interval 't' and 'k' is the rate constant for the reaction. This means that the rate of reaction gradually decrease as the concentration (C) of organic matter (food to micro-organism) decreases.

In BOD consideration it is customary to use L in place of C, where L represents the ultimate BOD (shown in Fig. 2.1). Because BOD is directly proportional to the organic substances present in sewage, the expression can be written as follows:

$$\frac{dL}{dt} \propto L \qquad \text{or} \qquad \frac{dL}{dt} = -k'L \qquad (1)$$

representing that rate at which organic polluting matter is destroyed.

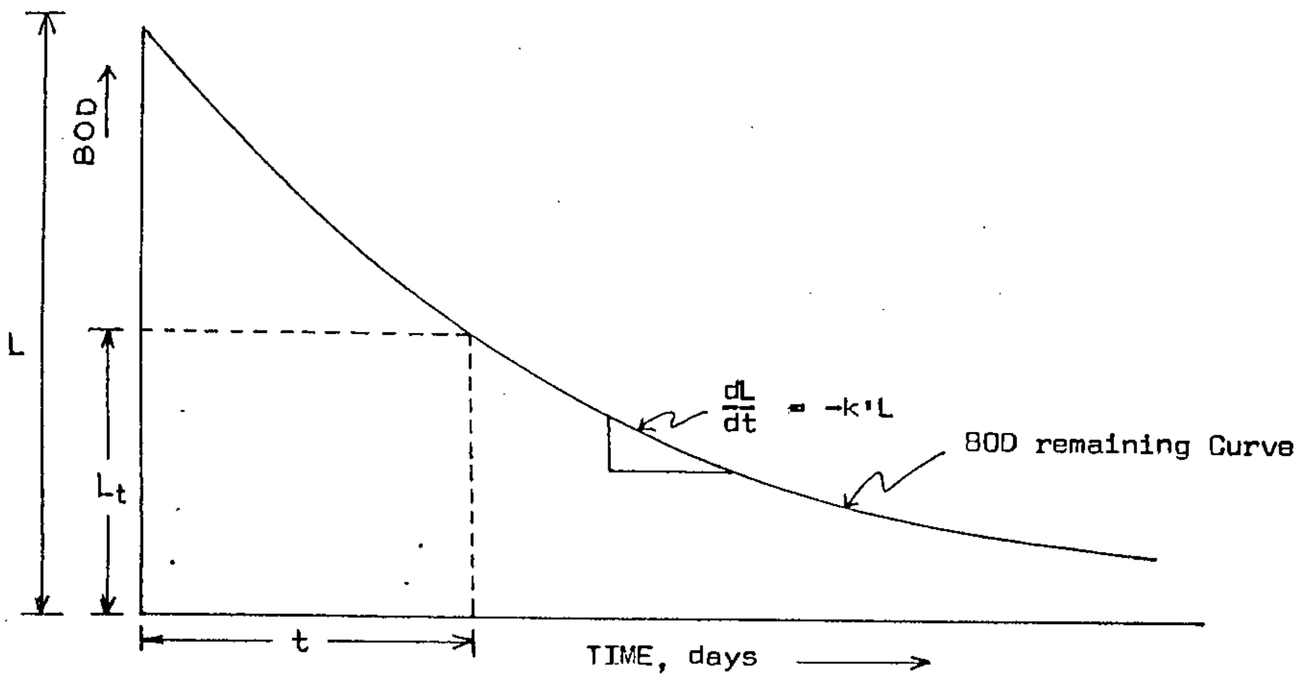


Fig. 2.1 BOD Satisfaction Curve

Since oxygen is used in stabilizing the organic matter in direct ratio to the amount of organic matter oxidized, it is possible to interpret L in terms of organic polluting matter or in terms of oxygen used, as preferred.

Integrating equation (1),

$$\int_{L=L_L}^{L_t} \frac{dL}{dt} = -\int_{t=o}^{t=t} k' dt$$

$$\text{or} \quad \left[\log_e L \right]_L^{L_t} = -k' \left[t \right]_o^t = -k't$$

$$\text{or} \quad \log_e (L_t - L) = -k't$$

$$\text{or} \quad \log_e \frac{L_t}{L} = -k't$$

$$\text{or} \quad \log_{10} \frac{L_t}{L} = -\frac{k't}{2.3026}$$

$$\text{putting } K = \frac{k'}{2.3026}$$

$$\log_{10} \frac{L_t}{L} = -Kt \quad \text{i.e.,} \quad \frac{L_t}{L} = 10^{-kt} \qquad (2)$$

in which K is termed as the BOD reaction rate or biochemical oxygen rate constant. It is the reciprocal of time unit.

It is to be mentioned that L_t/L is the remaining fraction of oxidizable matter and, therefore, $(1 - L_t/L)$ is the fraction oxidized in time t.

If Y_t is the amount oxidized in 't' days, then

$$Y_t = (1 - \frac{L_t}{L}).\ L = (1 - 10^{-kt}).\ L$$

i.e., $Y_t = L(1 - 10^{-kt})$ (3)

By the help of equation (3), the BOD of sewage at any time can be determined. This equation is termed as First Stage BOD reaction equation. It is represented by the curve A in Fig. 2.2.

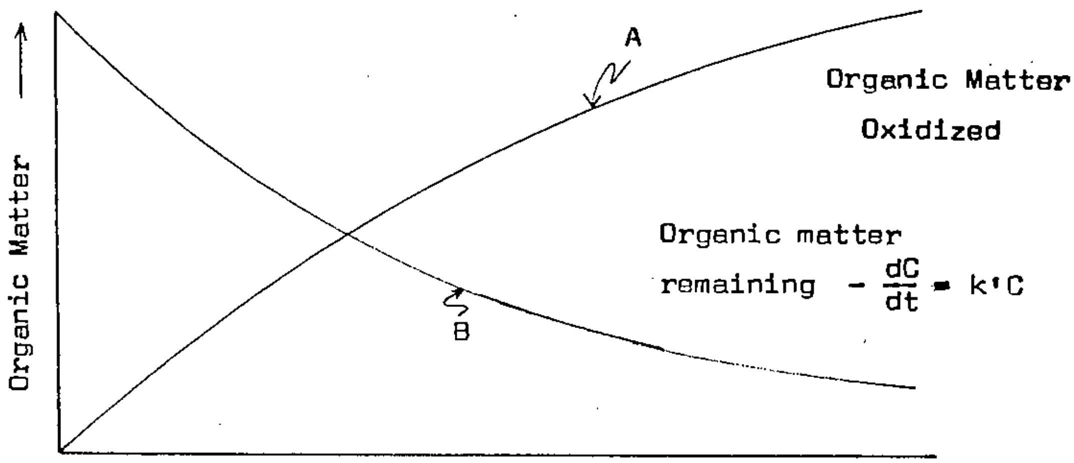


Fig. 2.2 Changes in organic matter during Biochemical Oxidation of sewage under aerobic condition

2.3.2 Variation of BOD Reaction Rate Constant (K) with temperature

As mentioned, the temperature at which the BOD of a wastewater sample is determined is usually 20°C. It is possible, however, to determine the reaction rate constant K at a temperature other than 20°C. The following approximate equation, which is derived from the Van't Hoff-Arrehenius relationship, may be used:

$$K_T = K_{20}\ \emptyset^{(T-20)} \qquad (4)$$

The value of Ø (the thermal coefficient) has been found to vary from 1.056 in the temperature range between 20°C and 30°C to 1.135 in the temperature range between 4°C and 20°C. A value of Ø often quoted in the literature is 1.047, but it has been observed that this value does not apply at cold temperature i.e., below 20°C.[1]

2.3.3 Variation of BOD with temperature

The BOD also varies with temperature as follows:

$$L_T = L_{20}\ (0.02T + 0.6) \qquad (5)$$

in which L_T is the BOD value at T°C. Fig. 2.3 shows the effect of temperature on BOD.

With the help of equation (3), (4) and (5) it is possible to determine quickly the BOD at any temperature or at any incubation period if it has been observed at other experimental conditions.

BOD satisfaction is achieved in two stages, first stage and second stage as shown in Fig. 2.4. During the first stage, only the carbonaceous organic matter is oxidized by bacteria. But during the second stage, both the oxidation of carbonaceous and nitrogenous organic matter takes place but the oxidation of nitrogenous matter is predominant.

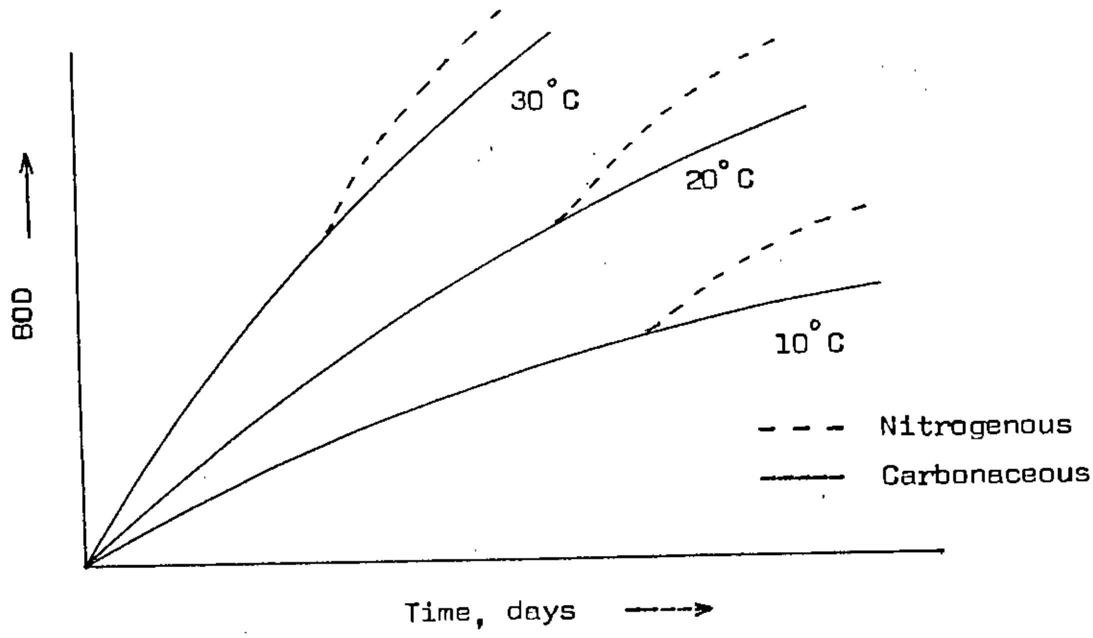


Fig. 2.3 Effect of temperature on BOD

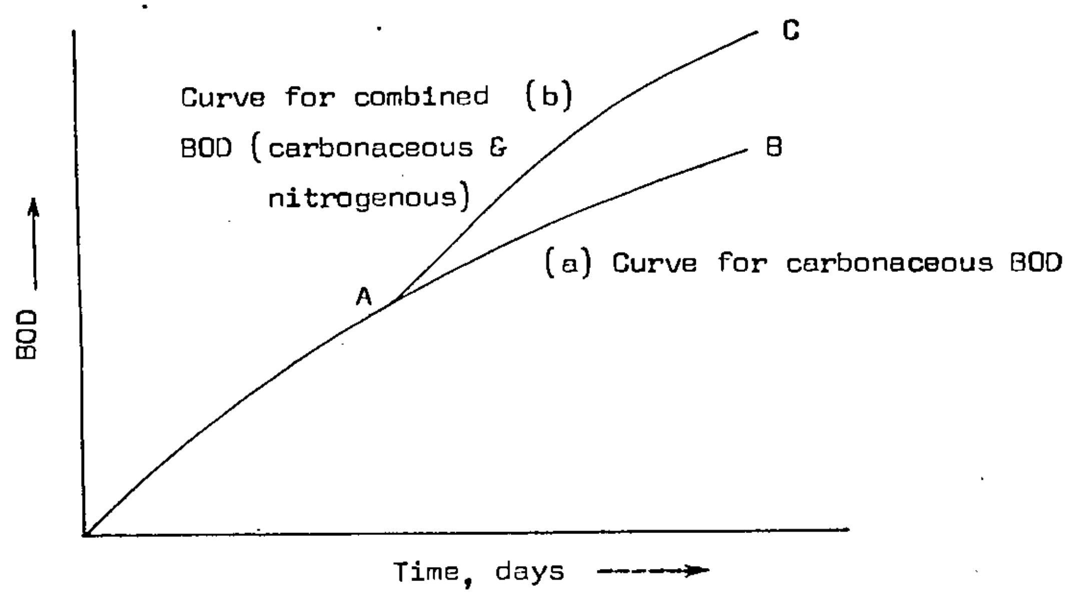


Fig. 2.4 BOD Curve : (a) Carbonaceous BOD curve
(b) Combined BOD curve

2.3.4 Rate of Biochemical Oxidation

BOD reaction rate constant value was established by extensive studies on polluted river waters and domestic sewage in the United States and England. As application of the BOD test spread to the analysis of industrial wastes and the use of synthetic dilution waters became established, it was soon noted that K value considerably in excess of 0.10 per day were involved and that an appreciable variation occured for different waste materials. In addition, it was found that K values for sewage varied considerably from day to day average about 0.17 per day rather than 0.10 per day as originally determined.(1) The importance of the reaction rate K with respect to BOD developed at any time is shown in Table 2.1.

Table 2.1 Significance of Reaction Rate K upon BOD[1]

Time(days)	Percent of total BOD exerted			
	K = 0.10	K = 0.15	K = 0.20	K = 0.25
1	20.6	29.2	36.9	43.8
2	37.0	50.0	60.0	68.0
3	50.0	64.0	75.0	82.0
4	60.0	75.0	84.0	90.0
5	68.0	82.0	90.0	94.0
6	75.0	87.0	94.0	97.0
7	80.0	91.0	96.0	98.0
10	90.0	97.0	99.0	99.0
20	99.0	99.0_+	99.0_+	99.0_+

From Table 2.1, it is noted that the course of the BOD reaction varies greatly, depending upon the reaction rate. The 5 day BOD values represent about 68 percent of the total BOD when K = 0.1 per day and as much as 94 percent when K = 0.25 per day. From this it may be concluded that K values must be known if a proper evaluation of ultimate BOD, or L is to be calculated from 5 day values.

2.4 Philosophy of Biological Treatment of Sewage

In the removal of carbonaceous BOD, the coagulation of nonsettleable colloidal solids and the stabilization of organic matter are accomplished biologically using a variety of microorganisms, principally bacteria. The microorganisms are used to convert the colloidal and dissolved carbonaceous organic matter into various gases and into cell tissue.[21] Because cell tissue has a specific gravity slightly greater than that of water, the resulting tissue can be removed from the treated liquid by gravity settling.

It is important to note that unless the cell tissue that is produced from the organic matter is removed from the solution, completed treatment has not been accomplished because the cell tissue, which itself is organic will be measured as BOD in the effluent. If the cell tissue is not removed the only treatment that has been achieved is that associated with the bacterial conversion of a portion of organic matter originally present to various gaseous end products.

Bacteria are the most influencial organisms in sewage treatment processes. The decomposition of organic matter in sewage is directly linked to the presence of bacteria and other organisms. Although some bacteria are responsible for causing diseases most of them are beneficial in the decomposition of sewage organic matter and convert it into energy and new cells. This is shown schematically in Fig. 2.5.[1] Bacteria can continously remove organic matter from liquid wastes under favourable conditions of temperature, P^H and nutrient substances.

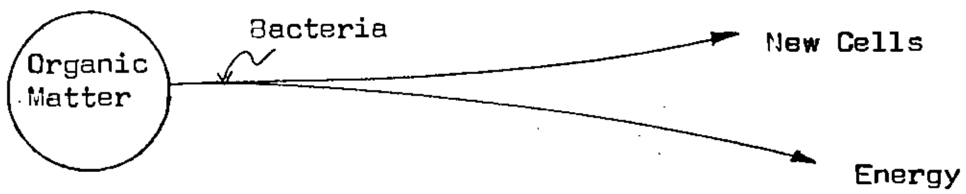


Fig. 2.5 Conversion of organic matter into energy and new cells by Bacteria

The conversion of organic matter to gaseous end products and cell tissue can be accomplished aerobically, anaerobically or facultatively using suspended growth or attached growth system. The aerobic conversion of the organic matter in the batch culture can be explained in terms of the sketch shown in Fig. 2.6.[21]

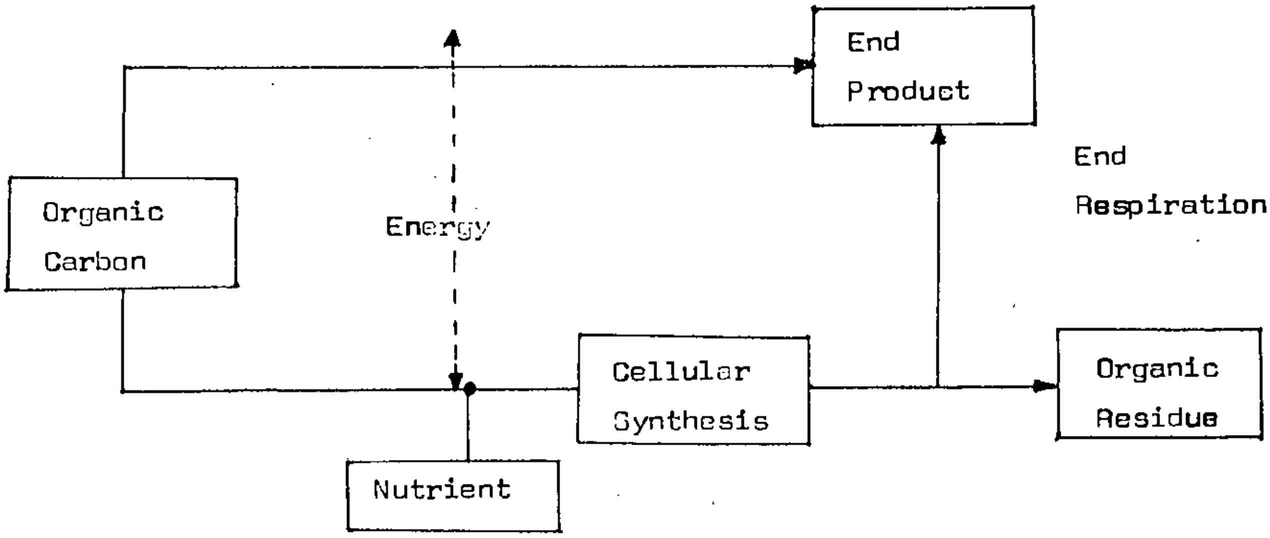


Fig. 2.6 Schematic representation of heterotrophic bacterial metabolism

As shown in Fig. 2.6, a portion of the organic material is oxidized to end products. This process is carried out to obtain the energy necessar for the synthesis of new cell tissue. In the absence of organic matter, the cell tissue will be endogenously respired to gaseous end products and a residual to obtain energy for maintenance. In most biological treatment system, these three processes may be represented as follows for an aerobic process:

Oxidation (Dissimilatory process)

$$\underset{\text{(Organic matter)}}{COHNS} + O_2 + \text{Bacteria} \longrightarrow CO_2 + NH_3 + \text{Other end products} + \text{energy} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Synthesis (Assimilatory process)

$$COHNS + O_2 + \text{Bacteria} + \text{Energy} \longrightarrow \underset{\text{(New bacterial cell)}}{C_5H_7NO_2} \ldots\ldots(2)$$

Endogenous Respiration (Autoxidation)

$$C_5H_7NO_2 + 5O_2 \longrightarrow 5\,CO_2 + 2H_2O + \text{energy} \quad \ldots\ldots\ldots (3)$$

In these equations, COHNS represents the organic matter in wastewater. The formula $C_5H_7NO_2$, which represents cell tissue, is a generalized value obtained from experimental studies and was first suggested by Hoover and Porges in 1952.[21] Although the endogenous respiration reaction is shown as resulting in relatively simple end products and energy, actually stable organic end products are also formed.

2.5 Sewage Treatment Processes

There are three major groups of biological processes used for wastewater treatment. These are as follows:

i) Aerobic process
ii) Anaerobic process
iii) Facultative process

The aerobic processes are biological treatment processes that occur in the presence of oxygen. Certain bacteria that can survive only in the presence of dissolved oxygen are known as obligate (restricted to a specified condition in life) aerobes.

The anaerobic processes are biological treatment processes that occur in the absence of oxygen. Bacteria that can survive only in the absence of any dissolved oxygen are known as obligate anaerobes.

The facultative processes are biological treatment processes that occur both in presence and absence of oxygen. The microorganisms involved in these processes are known as facultative microorganisms.

The individual processes are further sub-divided, depending on whether treatment is accomplished in suspended-growth system, attached-growth systems or combinations thereof. The classification of treatment process is shown in Table 2.2[21].

Table 2.2 Classification of Treatment Process (21)

- Aerobic Processes
  - Aerobic Suspended-Growth Treatment Process
    - Activated Sludge Process
    - Suspended Growth Nitrification Process
    - Aerated Lagoon
    - Aerobic Digestion Process
    - High Rate Oxidation Pond
  - Aerobic Attached-Growth Treatment Process
    - Trickling Filter
    - Roughing Filter
    - Rotating Biological Contactor
    - Fixed Bed Nitrification Reactor
- Anaerobic Processes
  - Anaerobic Suspended-Growth Treatment Process
    - Anaerobic Digestion Process
    - Anaerobic Contact Process
  - Anaerobic Attached-Growth Treatment Process
    - Anaerobic Filter Process
- Facultative Processes
  - Facultative Lagoons
  - Maturation Ponds
  - Anaerobic Facultative Ponds
  - Anaerobic Facultative Aerobic Lagoons
  - Nitrification - Denitrification

2.6 Previous Studies

In 1959-1961, a sampling programme was done by Ralph M. Parsons company under the sponsorship of the United States Agency for International Development to characterize the sewage for Dhaka city. Table 2.3 is a summary of data for the raw sewage feed data and Table 2.4 is a summary of the activated sludge effluent data. While good BOD and COD removals were obtained, trouble was experienced in the begining in obtaining a good activated sludge.[22]

The BOD/COD ratio was low, near 0.3, which indicates that the sewage samples were approximately three days old. A fresh domestic sewage will have a BOD:COD ratio of approximately 0.6. The 5-day BOD test is a measure of mostly the carbonaceous demand, while the COD test is a measure of approximately 90 to 99% of the total organic matter.

Approximately 20% of the total remaining BOD will be satisfied each day. Therefore, if sewage had been three days old when the sample was taken, approximately 49% of the total BOD would have been satisfied.

Then BOD of fresh sewage was calculated approximately as follows:

$$BOD = \frac{300}{1.00 - 0.49} = 590 \text{ mg/l}$$

$$BOD:COD \text{ ratio} = \frac{590}{1000} = 0.59, \text{ the ratio for fresh sewage.}$$

The sludge volume index varied between 22 and 60 mg/l with a median of 29 mg/l. This indicates that the sludge was over oxidized, however, no problem were encountered with the sludge settling characteristics. For example, suspended solids in the effluent had a median of 42 mg/l.

While BOD loadings were not high, (averaged 20 lbs BOD per 1000 cft. of aeration volume) a maximum loading of 100 lbs BOD per 1000 cft. of aeration volume did occur on occasions with no problems. The percentage of BOD and COD removals averaged 93.6% and 93.9% respectively. This indicates the high degree of treatment is possible with the activated

Table 2.3 Summary of Raw Sewage Quality for Dhaka 1960 and 1961

	p^H	BOD_5 (mg/1)	COD (mg/)	$\frac{BOD}{COD}$	Total solids (mg/1)	BOD loading (lbs/cf)
Minimum	6.3	50	160	0.31	450	0.0021
Average	6.8	480	1780	0.27	1650	0.0200
Maximum	7.2	2370	10400	0.23	6460	0.1000

Table 2.4 Data from Activated Sludge Process in treatment of Raw Sewage

	p^H	BOD_5 (mg/1)	COD (mg/1)	$\frac{BOD}{COD}$	Total Solids (mg/1)	% BOD Removal
Minimum	6.9	7	10	0.70	320	86.0
Average	7.8	31	110	0.28	600	93.6
Maximum	8.5	94	320	0.29	780	96.1

sludge process even when handling a strong septic sewage that fluctuated widely in strength.

An adequate sewage works serving majority of the population of Dhaka would greatly change the characteristics of the raw sewage. The sewage would be less septic and more dilute than when sludge is dumped into the sewers and pumping occurs intermittently. Because of this no further attempt was made to evaluate the sewage characteristics as they might affect a sewage treatment plant. It was found that the sewage is treatable

In 1980, a study on selection of sewage treatment method for Dhaka city was conducted by RMP International Ltd. and James M. Montgomery.[24] The following four types of treatment system were considered:

i) Trickling Filters
ii) Oxidation Ditch
iii) Stabilization Pond
iv) Aerated Lagoon

All four systems possess the virtue of relative simplicity in operation.

Cost (January 1980 shadow costs) for the sewage treatment and sludge handling component systems had been developed for a typical case of 33.3 million imperial gallon per day (IMGD) average sewage flow. The total cost of the most feasible combinations of the component system was expressed on a present-worth basis for the purposes of comparision. From cost estimate it was apparent that with the high land prices and the anticipated large sewage flows, Aerated Lagoon was the most cost-effective treatment method.

In 1985, the pond effluent of Pagla Sewage Treatment Plant were collected at each pond outlet by the Japanese Study Team and analysed in the Environmental Pollution Control Laboratory for P^H, suspended solids, BOD_5 and others. The result of the analyses are shown in Table 2.5

Ahmed[2] mentioned that the average BOD of Dhaka city sewage is around 180 mg/l which requires 12 times reduction by a efficient treatment process for inoffensive disposal in the river water.

Another study work was done by some Japanese consulting engineers together with DWASA's engineering staff for selecting the suitable method of sewage treatment for Dhaka city in 1985. The following five alternative biological treatment processes have been evaluated to select the most desirable treatment method:

i) Anaerobic Pond
ii) Oxidation Ditch
iii) Aerated Lagoon
iv) Biological Filtration
v) Activated Sludge

The Study Team recommended that the Trickling Filter process should be adopted to the new sewage treatment system. It is understood that the system was selected mainly from the view point of land availability and energy cost required to treat sewage of 40 IMGD.

In order to improve the sewerage system of Dhaka city, the Government of Bangladsh prepared an emergency project to improve the existing system and requested the Government of Japan for granting aid co-operation for its execution. In response to the request, the Japanese Government dispatched a preliminary Study Mission to Bangladesh through Japan International Cooperation Agency (JICA). Based on the result of the study by the delegation, a basic design Study Team was sent in 1987. The following three systems were studied as possible alternatives by the study team:

i) Facultative Lagoon
ii) High Rate Trickling Filters
iii) Aerated Facultative Lagoon

After careful evaluation, the Study Team recommended the Facultative Lagoon system as the most suitable method of sewage treatment for Dhaka city.

The river Burigenga flows by the side of the city of Dhaka. The river directly receives partially treated sewage effluent from overloaded stabilization ponds and untreated storm drainage from the city. The river also directly and indirectly receives effluents from 151 tanneries cluste at the western perifery of the city, effluents from 53 small and big indus trial and commercial installation of Dhaka-Narayanganj industrial belt and leachate from a solid waste dumping site.

Table 2.5 Anaerobic Ponds Effluent Qualities (9)

Location	p^H	Temperature (°C)	Transparency (cm)	BOD_5 (mg/l)	Color	SS (mg/l)	Date
Lagoon No.1	7.2		2 - 3	104	Slightly darkgrey	328	27.2.'85
Lagoon No.3	7.2		5 - 6	118	"	31	"
Lagoon No.2	7.2	27.5	2.0	56	Light pink	111	3.3.'85
Lagoon No.3	7.2	27.5	5.0	76.5	Light green	39	"

The comparision of the important water quality parameters with previous studies by Parsons Corporation(1959-60), Kalam(1968), Ahmed(1974), WPCP(1973-75), Islam(1977), DWASA(1985), Mitsubishi Corporation(1987) and JICA(1987) reveals that the quality of water of the river Buriganga has tremendously deteriorated.

Ahmed mentioned that the effluents with very high pollution potentials are discharged in the river system around the city of Dhaka. The pollutant are inorganic, organic and toxic in nature and require extensive treatment before disposal to prevent physical and biological pollution of the receiving body of water. In any developed country, polluting effluents of this nature are not allowed to be discharged in natural water.(2)

CHAPTER 3

THE EXISTING SEWERAGE SYSTEM OF DHAKA CITY

3.1 Historical Development

On the 15th August 1923, after World War I, modern sewerage system was inaugurated in Dhaka. At that time first sewage lift station was established at Narinda. About 182 'gully pits' admitted surface drainage into the sewers to carry the sewage to Narinda where it was pumped to a large septic tank. After natural treatment of sewage effluent was then disposed to the nearby irrigated field. (23)

In 1950 two more sewage lift stations were constructed and 24-inch and 36-inch brick sewers were extended to the new part of the city. In 1954 attention was directed back to the old town where the sewerage system was expanded with the construction of storm drains and the Dholai khal. It was done by the Department of Public Health Engineering. Although these lines were constructed by the Department of Public Health Engineering, but Dhaka Municipal Corporation was mainly responsible for operation and maintenance of sewerage system. (25)

In 1958 the need and importance of water supply and sewage disposal system for the greater Dhaka city was identified. With the assistantship of International Co-operation Agency M/s. Ralph M. Parsons were engaged to prepare a comprehensive master plan for sewerage system of Dhaka. In 1960 the master plan for sewerage system of Dhaka Metropolitan area was presented. The comprehensive scheme comprised a sewage treatment plant consisting of a system of 90 acres waste stabilization ponds at Pagla, three large sewage lift stations, 21 miles of main sewers (24 to 96 inches and 150 miles of collectors (8 - 18 inches). (25)

3.2 The Sewerage Authority

The collection, treatment and disposal of sewage for Dhaka city is managed by Dhaka Water Supply and Sewerage Authority (DWASA), created in 1963 as a semi-autonomus government agency. It was enpowered to provide potable water supply and sewage disposal service to greater Dhaka. The authority falls under the aegis of the Ministry of Local Government, Rural Development and Cooperatives (LGRD). The storm sewerage system and surface drainage system are managed by the Department of Public Health Engineering (DPHE) and Dhaka Municipal Corporation (DMC) respectively under the same ministry. (14)

Dhaka WASA consists of three departments under the control of the Chairman: the Secretariat (administration), the Engineering Department and the Commercial Department (for commerce, accounts and revenues). In addition, there is a Training Institute under the direct control of the Chairman. A total of 2610 personnel are working with Dhaka WASA.[8]

The sewerage system of Dhaka city covers almost entire old area and a part of the new Dhaka. Since its construction started in the early 1920's, the sewerage system has gradually been extended and now serves approximately 80 to 85% of the old Dhaka city area and 30 to 40% of the new Dhaka city area with the served population of about 1 million. DWASA has a sewerage improvement programme to serve upto 80% of the city's population by the year 2010.[9]

3.3 The Sewerage System

3.3.1 Existing System

The existing sewerage system consists of laterals, trunk lines, interceptors, lift stations, sewage treatment plant and disposal facilities. Due to general flatness of the area in and around of the city of Dhaka, the sewage flows by gravity in collection pipes to a lift station where it is lifted by pumps about 25 to 40 ft. and then flows by gravity to the next lift station and so on until it reaches the treatment plant at Pagla. From treatment facility the effluent is discharged by pump to the Buriganga river (shown in Fig. 3.1). The outline of the existing sewerage system is as follows:[8]

Total sewer length = 300 miles.
Number of sewage lift station = 14.
House service connection = 27,058.
Sewage treatment plant = 1

3.3.2 Sewerage Service Area

At present, the existing sewerage system collects and treats only 40% of the total wastewater production, the rest being discharged to the nearby drains, ground and other water ways.[9] The presumed population utilizing the sewerage facilities is 1.15 million.[18] The entire sewerage service area is divided into five sewerage zones for administrative and managerial purposes as shown in Fig. 3.2.[25]

3.3.3 Sewer Network

The existing sewer system consists of laterals, interceptors and trunk lines. In the old city, the sewer range in size from 9 inches to 39 inches and in the new city it range from 8 inches to 54 inches. The sewage is collected from various areas through these sewers and transmitted to the Pagla sewage treatment plant through 54 inches main brick sewer. The sewers are made of PVC, VC, RCC etc.

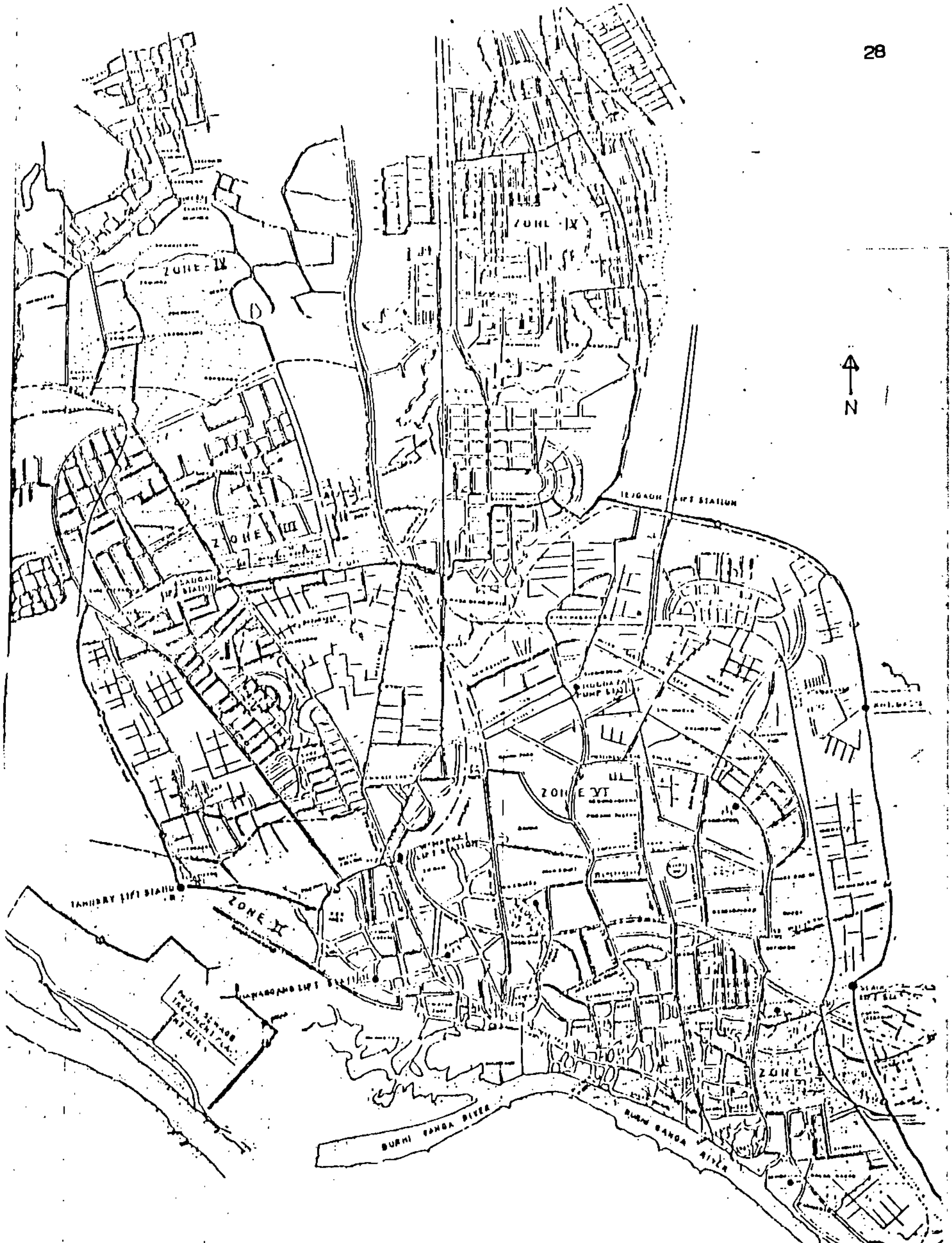


Fig. 3.1 Master Plan of Sewerage System of Dhaka city

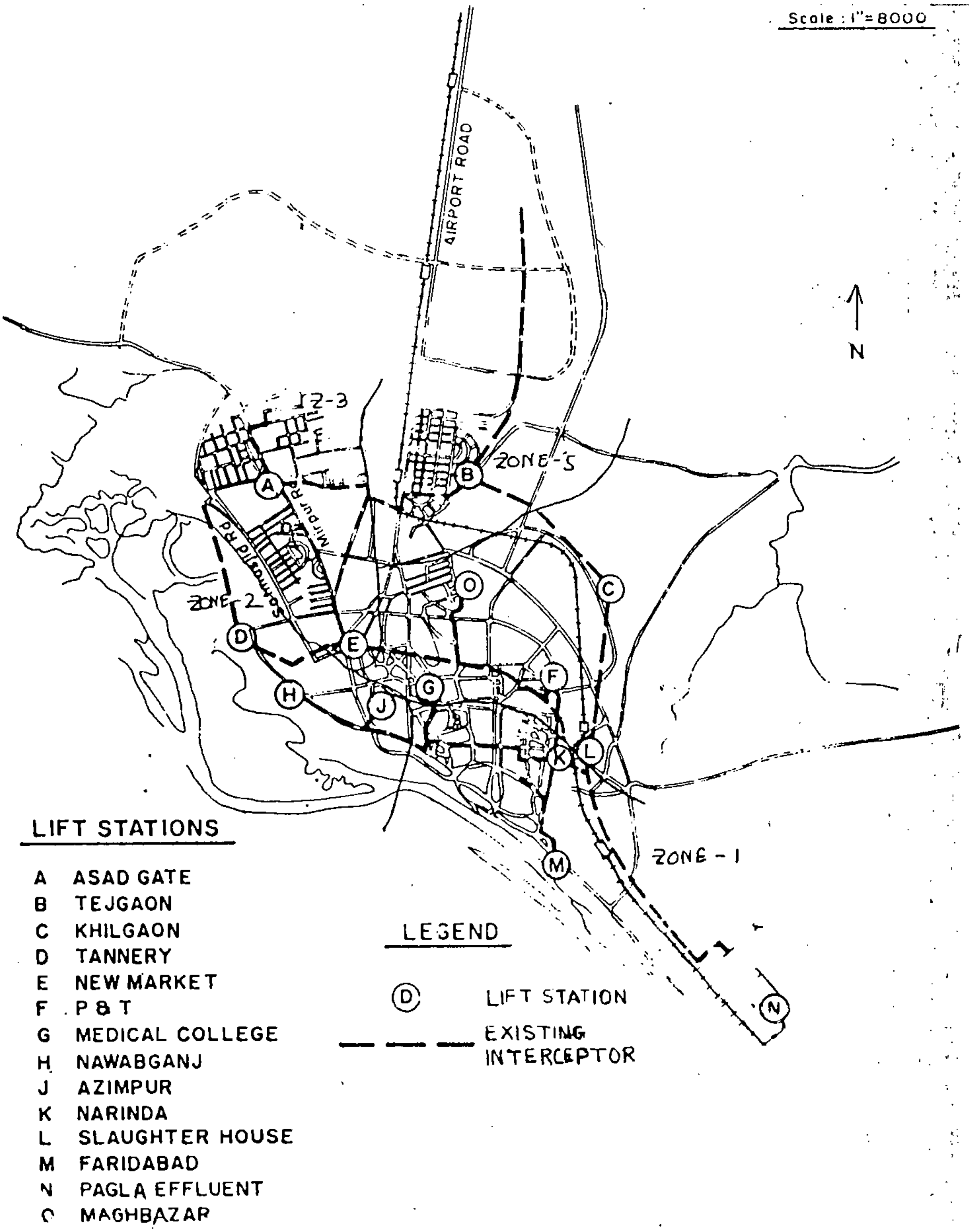


Fig. 3.2 Administrative Zones of the Sewerage System

3.3.4 Sewage Lift Station[23]

In each of five sewerage zones, the sewage pumping stations are provided to boost the sewage. Sewage from the sewerage zone 3,5 & 6 is conveyed to Swamibagh pumping station and transmitted to the treatment works, whereas that from the remaining zones is led to the treatment plant via Narinda central pumping station. Because of the general flatness of the existing service area in and around the city of Dhaka, the sewage collection system is constructed on minimum slopes that necessitate the frequent hydraulic assistance by pumps to transport the wastewater properly. There are 14 nos. sewage lift station in Dhaka at present. These are shown in Fig. 3.3 and Fig. 3.4 and the characteristics of all the stations are shown in tabular form in Table 3.1.

3.4 Sewage Treatment and Disposal

The existing sewage treatment and disposal facilities are the Pagla sewage treatment plant, its associated lift stations, as well as a 54 inch equivalent brick arch outfall discharging into the Buriganga river. This plant is the initial phase of a long-term plan to treat and dispose of sewage collected by Dhaka's expanding sewerage system.

3.4.1 Pagla Sewage Treatment Plant

The sewage from Swamibagh and Narinda central pumping stations is finally transmitted to the sewage treatment plant at Pagla. The treatment plant consisting of three waste stabilization ponds (two parallel ponds of 19 acres area each with a third 48 acres pond). The sewage first inflows into the partially anaerobic ponds (No. 1 & 2). The pond effluent is then led to the final pond (No.3). The effluent is chlorinated and pumped up at the Pagla outfall pumping station for the final disposal to the Buriganga river.

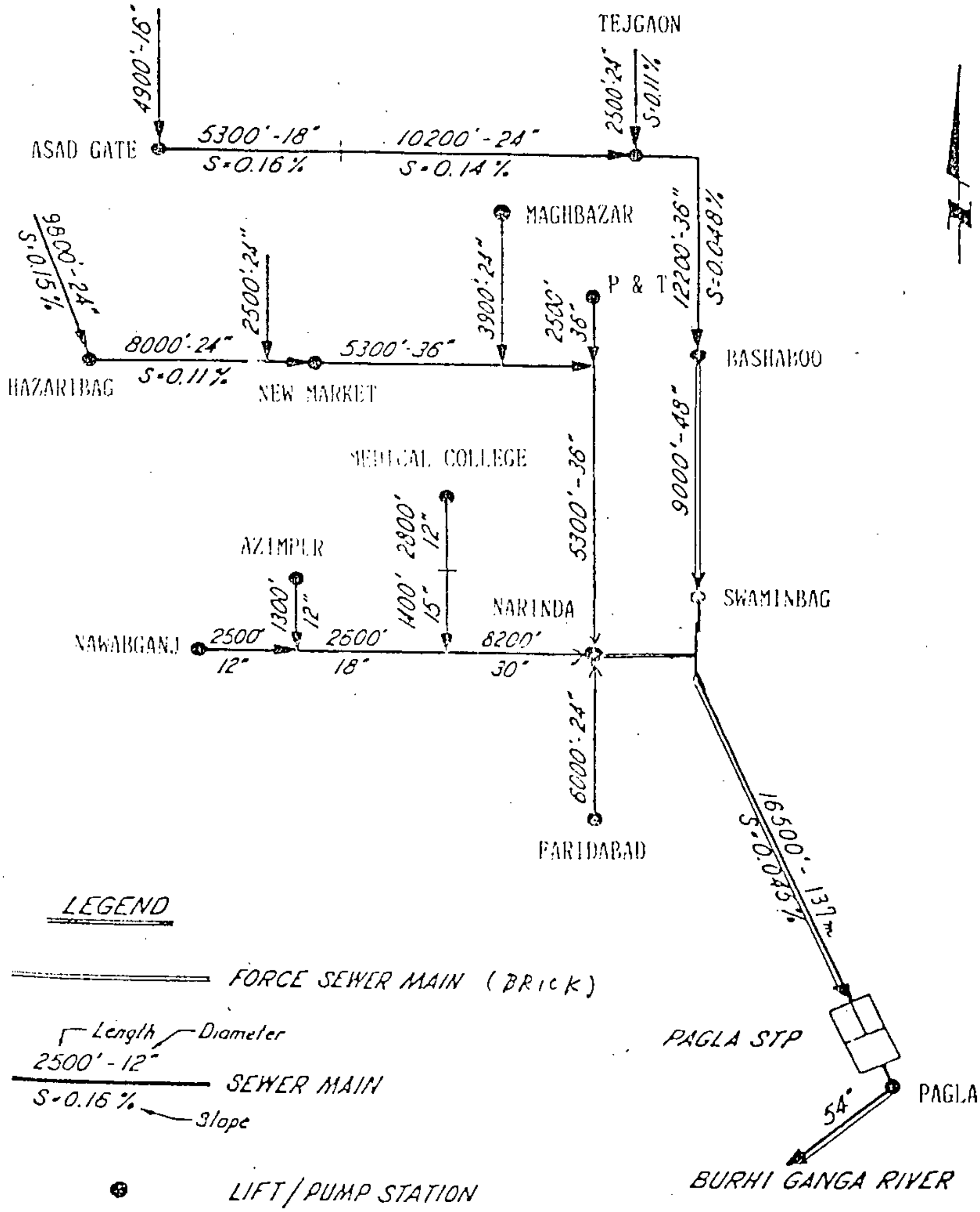


Fig. 3.3 Schematic Diagram of Dhaka Sewerage System

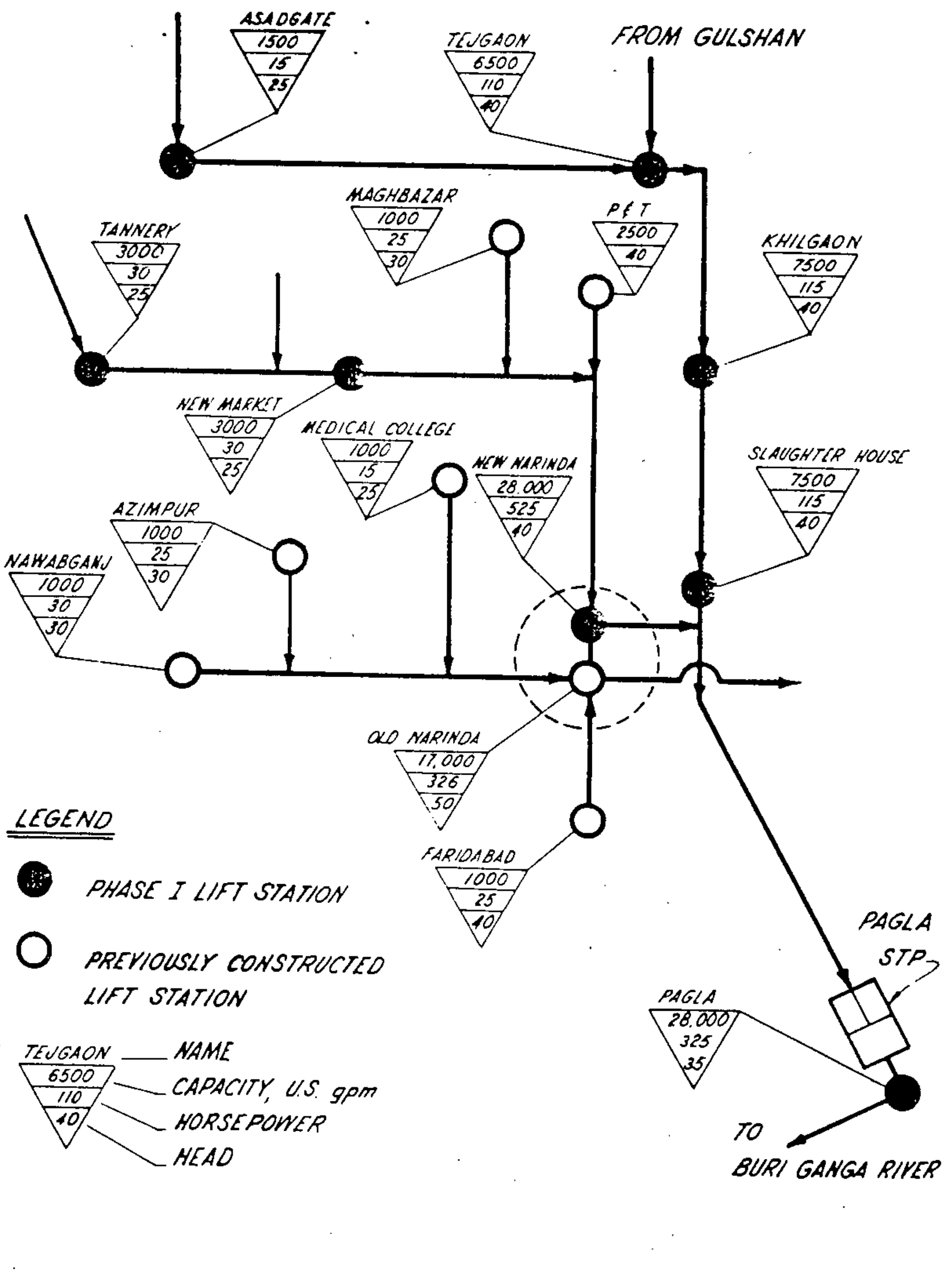


Fig. 3.4 Sewage Lift Station Pumping Details

Table 3.1 Details of Sewage Lift Stations

Sl. No.	Name of the pump	No. of pump	Flow, Q (US gpm)	Head (ft)	H.P.
1.	Asad Gate	3	1500	25	15
2.	Azimpur	2	1000	30	25
3.	Faridabad	2	1000	40	25
4.	Khilgaon	5	7500	40	115
5.	Maghbazar	2	1000	30	25
6.	Medical	3	1000	25	15
7.	Nawabganj	2	1000	30	30
8.	New Market	4	3000	25	30
9.	P & T	2	2500	40	40
10.	Swamibagh	5	7500	40	115
11.	Hazaribagh	4	3000	25	30
12.	Tejgaon	5	6500	40	110
13.	Pagla	7	28000	35	325
14.	Narinda (old)	4	17000	40	326
	Narinda (new)	7	28000	55	525

The total capacity of the ponds is estimated to be approximately 394,000 m^3, which retains the daily average inflow for about 2.5 days.[18] The treatment flow chart, the plot plan and the relevant facilities are shown in Fig. 3.5, Fig. 3.6 and Table 3.2 respectively.

In the stabilization process the sewage organic matters are oxidized and thereby stabilizing the sewage. Facultative ponds contain an aerobic layers near the water surface, where aerobic bacteria utilize dissolved oxygen to breakdown sewage organics and anaerobic bacteria convert settled organic material to methane gas and carbon dioxide (as shown in Fig. 3.7).

Stabilization ponds are being used extensively in tropical areas of the world because of their reliability, flexibility in operation and low installation and operating cost. The Pagla stabilization ponds are designed to be reliable under varying conditions of sewage strength and sewage load.

3.4.2 Outfall System

The final effluent from the Pagla plant is discharged via a 54 inch equivalent brick arch outfall to the Buriganga river, approximately 1 mile to the west.

3.4.3 Operation and Maintenance

The ponds require only routine weed control, dike maintenance, weir adjustment and periodic cleaning. The lift stations require routine operation and maintenance of pumps, valves, sluice gates, chlorination equipments and electrical motors.

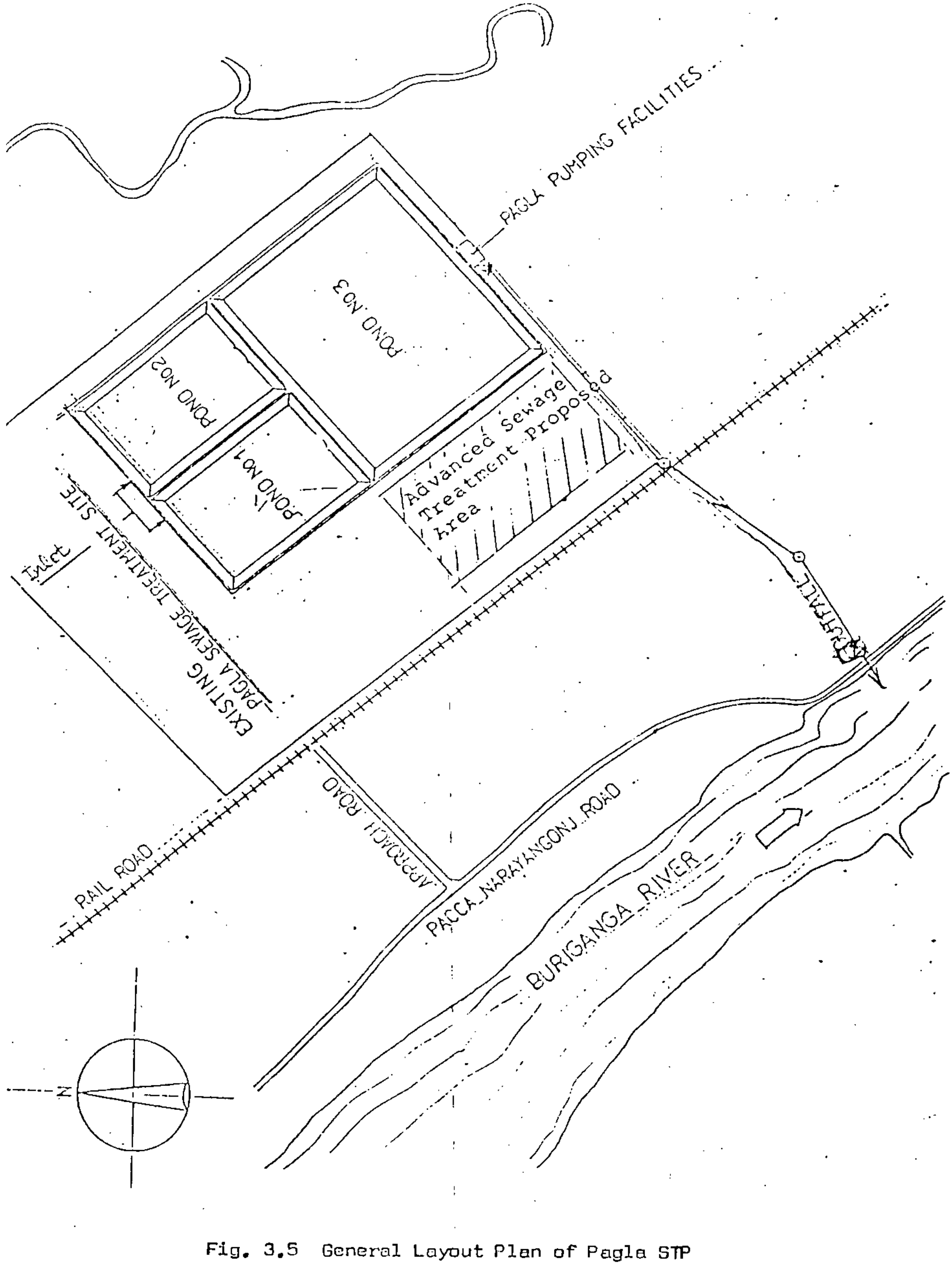


Fig. 3.5 General Layout Plan of Pagla STP

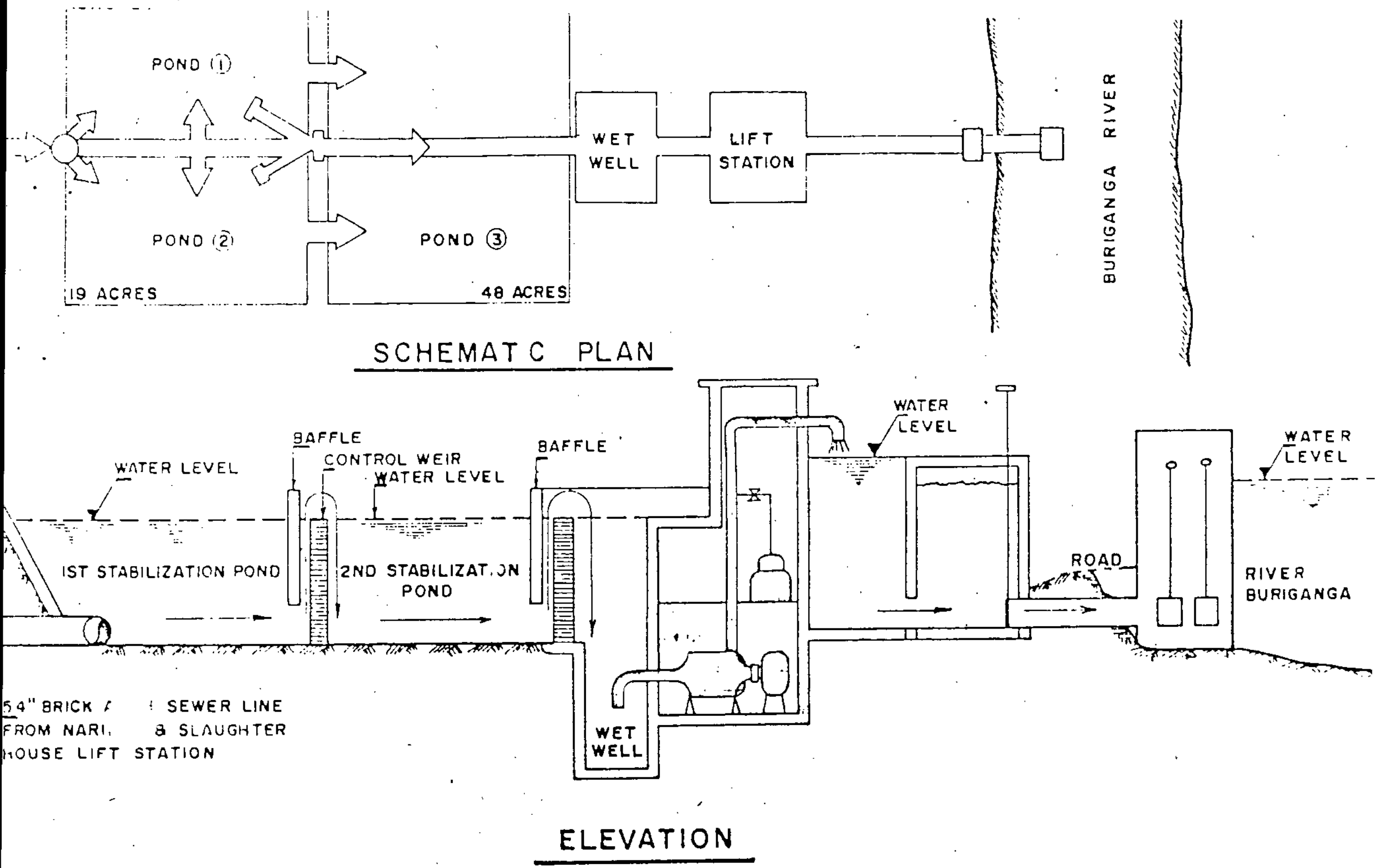


Fig. 3.6 Schematic Diagram of Pagla Sewage Treatment Plant

Table 3.2 Major Facilities of Pagla STP

Facility	Dimension, Specification	Q'ty	Capacity
Pond (1)	Solid banking type stabilization pond 19 acres (7.69 ha) Design depth: 1.5 m	1	Retention time: Approx. 0.46 days (*)
Pond (2)	(ditto)	1	(ditto)
Pond (3)	Solid banking type stabilization pond 48 acres (19.43 ha) Design depth: 1.5 m	1	Retention time: Approx. 1.18 days (*)
Outfall Pump	Horizontal-shaft volute pump 10"D x 1000 GPM x 35'H x 20 Hp 10"D x 2500 GPM x 35'H x 30 Hp 16"D x 7000 GPM x 35'H x 75 Hp	 2 2 3	Total lifting capacity: 28,000 GPM (127.3 m^3/min) or 183,000 m^3/day
Sterilization Unit	Liquid chlorine sterilization	1	With 68 kg cylinder
Influent Chamber	Brick-arch sewer line of 54" diameter	1	
Outfall Chamber	Brick-arch sewer line of 54" diameter	1	

Note (*): The retention time is indicated against 40 IMGD (183,000 m^3/day).

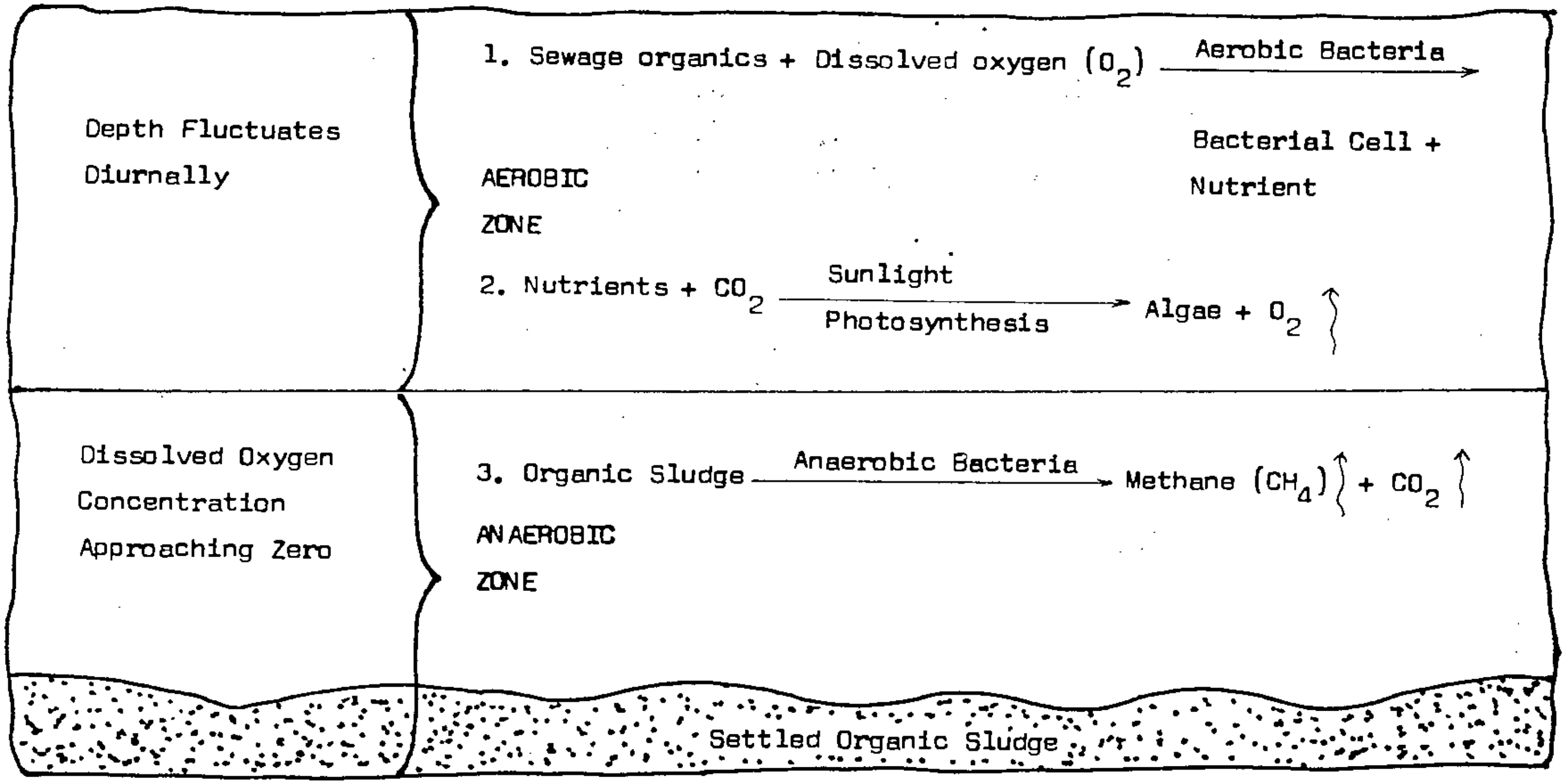


Fig.3.7 The Waste Stabilization Process

3.5 Problems in Existing Sewerage System

The following are the problems detected in the existing sewerage system of Dhaka city:

(1) Sewage line blockage and Manhole overflow: Blockage of sewers and manhole overflow are the main problems in the existing sewerage system. The following are the reasons of sewer blockage and manhole overflow:

i) Surface Drains: The sewerage system is designed only for domestic sewage. But now a days, it is common practice in the city to connect the surface drains to the sewers. Though a seperate system is adopted for the surface drains, intentionally or not, drainage is actually connected to the sewers.

ii) Rainwater: During rainy season, the surface drains and underground storm sewers become overloaded by rainwater because of their insufficient capacities. Most of the streets, lanes and by-lanes merged under water and water stagnancy is a common problem in the city. Then the city dweller open the manhole cover for disposing of these excess water through sewer and all street sweepings like sand, stone,papers etc. introduced into the sewer and.block the sewerage system.

iii) Road Level: Most of the places in Dhaka city, the level of house floor is below the adjacent road level. Moreover, the road level increased day by day by road carpeting. Then the sewage overflow appears in the house premices.

iv) Use of manhole and sewer-pit as dustbin: Household and kitchen waste like pieces of paper and cloth, skin of green vegetable, fruits and skin of green coconuts is directly dumped through manhole and sewer-pit into the sewerage system. The solid wastes thus discharged into sewers block the whole system and create overflow through manholes sewer-pits.

v) Dumping of Night-soil: Sometimes sweepers dump the night-soil from katcha latrines into the sewers through manholes and sewer-pits and thus block the sewerage system.

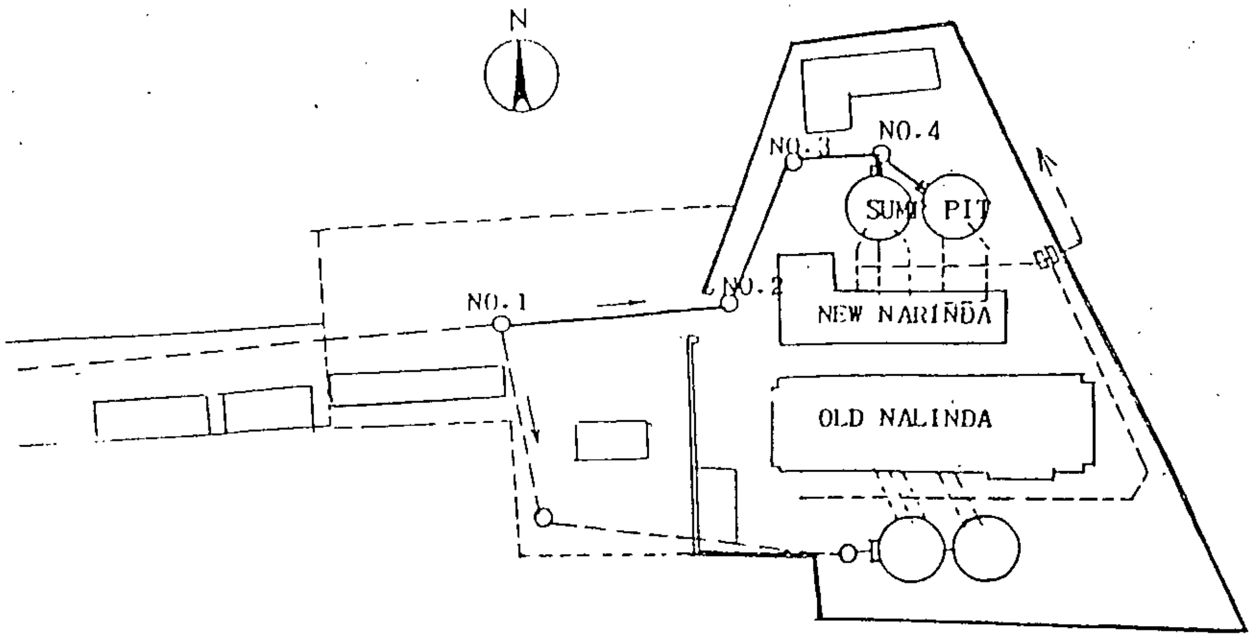
(2) Common problems among Sewage Lifting Pump Stations: There are no grit chamber or screen in sewage lift pump station for the protection of pumps. Because of absence of screen and grit chamber which are supposed to protect pumps, troubles often take place in the pumps due to clogging of foreign materials. There are also some deficiency of influent gate, level gauge, floor discharge pump and others.(16)

(3) Disposal of raw sewage: In some places the raw sewage is directly disposed to the adjacent low-lying areas through leakage and broken portion of sewers. Sewers are displaced in some places. Construction of sewers on clay or soft soil in low-lying areas without any base or foundation might be the reasons of such displacement. Sometimes, the raw sewage is disposed directly to the low-lying areas through by-pass line due to insufficient capacity of sewers and pumps. (16)

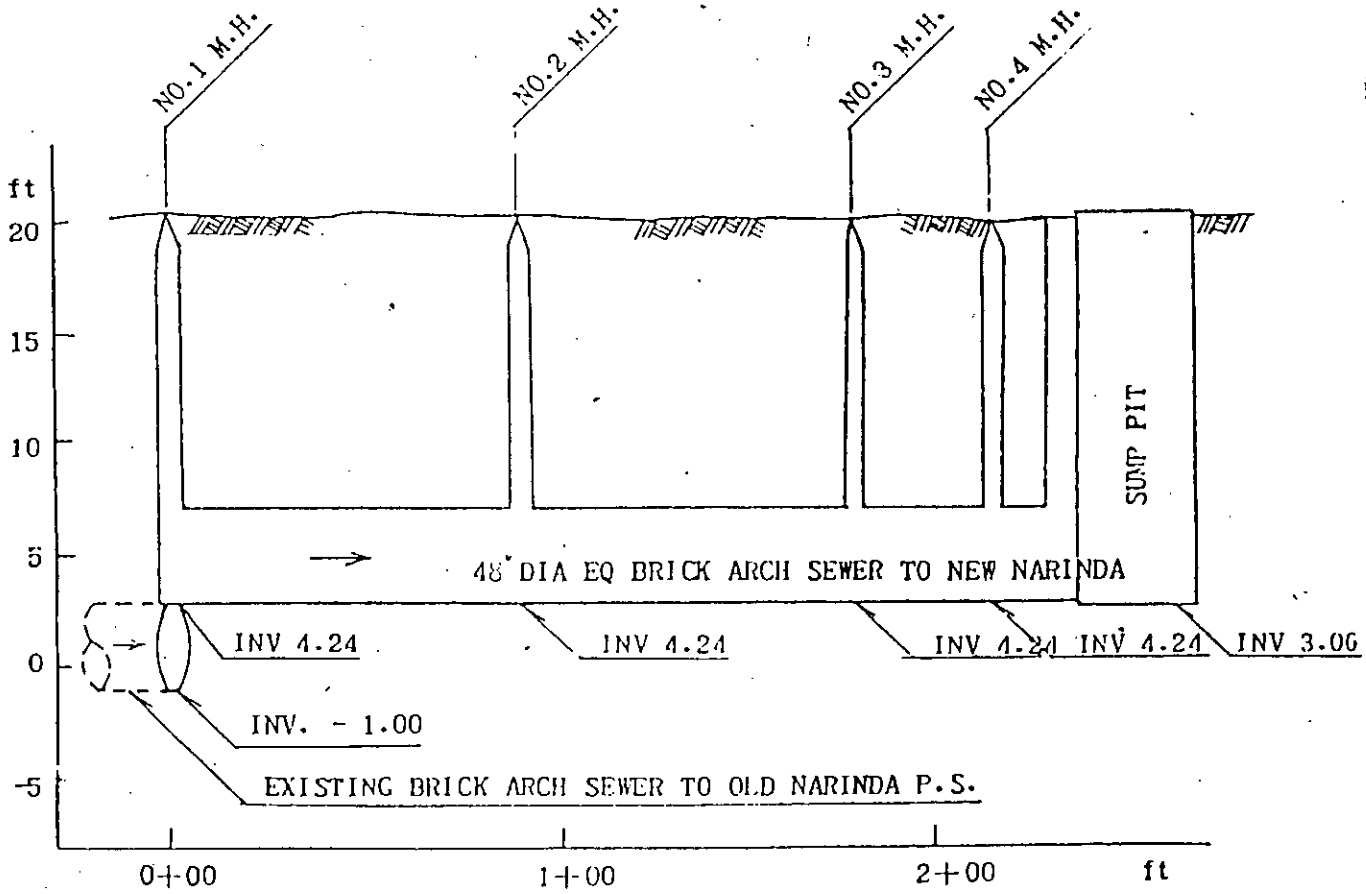
(4) Problem of influent to New Narinda Pump Station due to faulty construction: The influent pipe to New Narinda Pump Station constructed in 1978 was connected at a level higher than the top of the pipe to the old station (as shown in Fig. 3.8). The insufficient capacity of the pump pit interferes with a continous operation of the new station. (18)

(5) Countercurrent to Hazaribagh Lifting Pump Station: Due to faulty design and supervision of Hazaribagh sewage lift station by the Foreign Consultant it could not be operated since its construction. DWASA personnel reported that Hazaribagh lifting pump station had an adverse grade. (18)

(6) Insufficient capacity of Sewers: In the midst of nation-wide urbanization, density of the population into Dhaka city is increasing at a rapid pace. Such a steep population increase has put the old existing sewerage system under increasing stress and at many locations the system is overloaded. In many places, it was observed that the capacity of sewer is not sufficient. It was found that at many points 24 inch sewers have been combined and connected to another 24 inch sewer and that 36 inch sewer and 24 inch sewer have been combined and connected to another 36 inch sewer to which another 36 inch sewer is connected on its downstream side.



GENERAL PLOT PLAN



SECTION

Fig. 3.8 Explanation Drawing of Narinda Inflow Problem

Plate 3.1 Overflowing of sewage through manholes

Place: B.B.C. Road (above) and Azimpur Road (below)

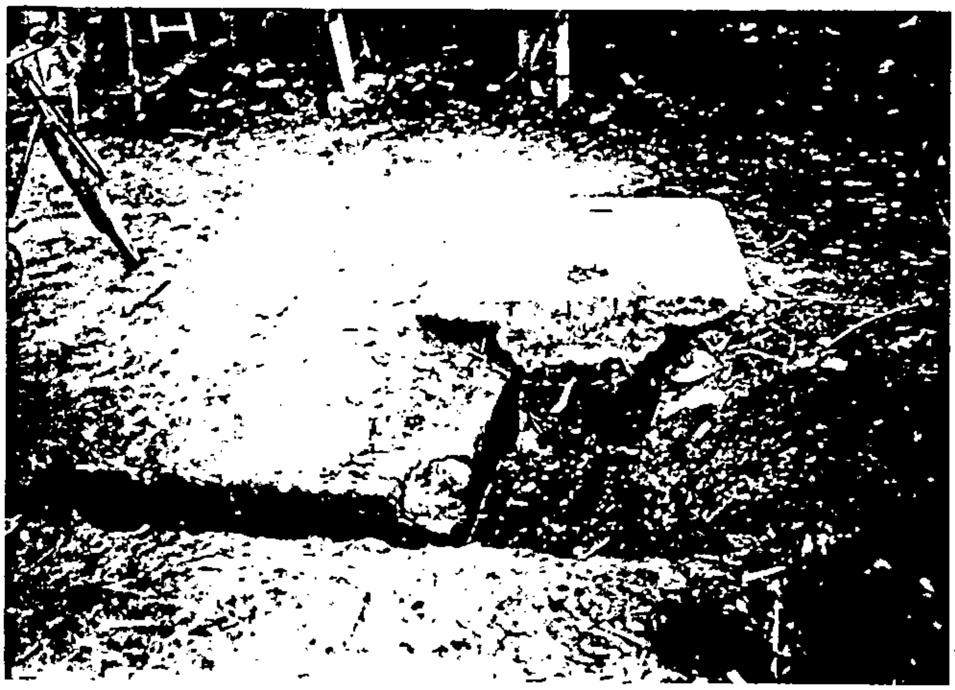


Plate 3.2 Connection of Surface Drain to Sewer
Place: Koratitola, Hatkhola Road

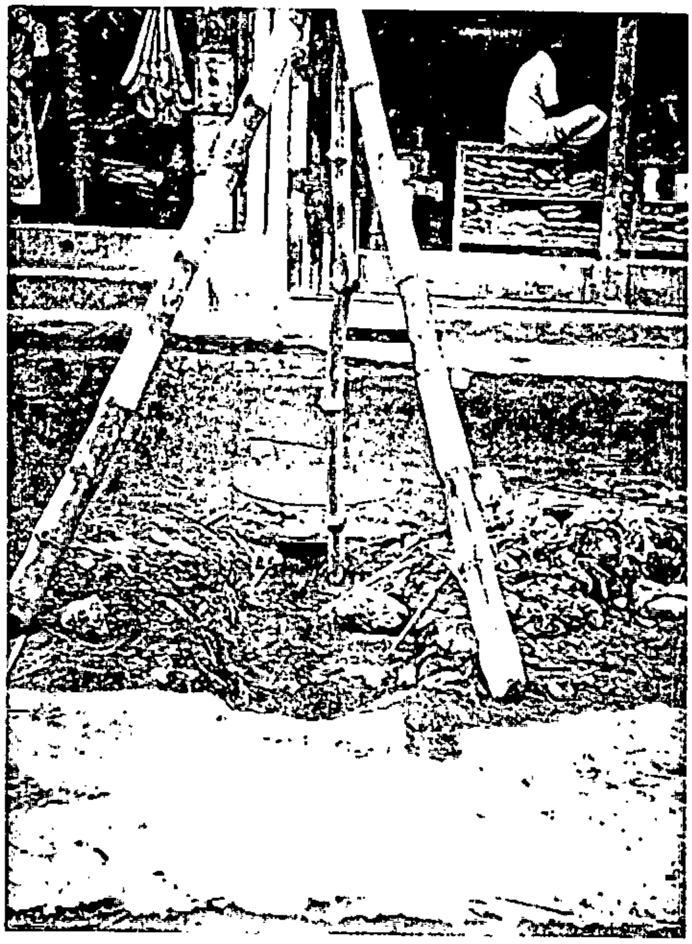


Plate 3.3 Connection of Sewer to Surface Drain
Place: Malibagh Bazar

Plate 3.4 Direct Discharging of Raw Sewage into the River
Place: Nawabganj Road, near Sewage Lift Station

Plate 3.5 Use of Manhole as Dustbin

Place: Rajnarayan Dhar Road

Plate 3.6 Deposition of Sludge in Pagla Lagoon

Plate 3.7 Removing of Sludge Manually from Pagla Lagoon

CHAPTER 4

LABORATORY ANALYSIS

4.1 General

Wastewater treatment facilities include chemical and biochemical processes. An understanding of the nature of wastewater is important in design and operation of collection, treatment and disposal facilities and in the engineering management of environmental quality. Laboratory data are therefore essential before a sound engineering design can be made. To obtain these data many sampling locations were selected in and around the city of Dhaka. Wastewater characterization studies were conducted to determine physical, chemical and biological characteristics and the concentrations of the constituents in the wastewater and the best means of reducing the pollutant concentrations. The nature, significance and purposes of the more important tests were discussed.

4.2 Sampling

A sample is a part or piece taken from a large entity and presented as being representative of the whole. The concept of 'being representative' is highly important because subsequent conclusions, decisions and action steps will depend to some degree on the validity of the samples initially collected.

Samples are generally defined and identified by type and the method of sampling. Grab (spot, catch, instantaneous, snap) samples were collected at a particular instant. To obtain and preserve the integrity of a representative sample the following general principles were considered during the collection of sample.

i) The sample should be taken at a place where the wastewater is well mixed, such as at a point of hydraulic turbulence.

ii) The sample should be taken in the centre of the channel of flow where the velocity is high and the possibility that solids have settled is minimum. Another sample point is at a top on the discharge side of a pump or at a free fall from the end of a pipe.

iii) Where it is necessary to avoid an excess of floating materials, the mouth of the collecting container should be held a few inches below the liquid surface. Where the liquid surface height varies, a float to position the mouth of the collector may be used. Care also should be taken to avoid solid accumulated on the bottom of a channel.

iv) Deposits or non-representative material at the sampling point, such as excessive grease and scum should not be included in the sample.

v) The volume of the sample obtained should be sufficient to perform all of the required analysis, with an additional amount obtained for repeating any doubtful analysis.

vi) The sample should be stored in a manner that the characteristics to be analyzed are not altered.

vii) When composite samples into other containers, the contents of each sample should be mixed vigorously before pouring.

viii) The sample container and sampling devices should be clean, uncontaminated and suitable for the selected analysis. Before the sample is taken, the container should be rinsed several times with the wastewater The possibility of adsorption of solutes from the bulk liquid onto the container surfaces, or the leaching out of a materials from the container itself also should be guarded against.

ix) Sampling points should be readily accessible, proper sampling equipments should be available and adequate safety precautions must be observed.

4.3 Sampling Locations

Dhaka is the largest metropolitan city and the capital of Bangladesh having population of 4.32 million. Different types of small and large industries have been developed in and around the city as well as major state offices and residential areas settled in the city. Tannery industries at Hazaribagh and rubber, soap, detergent, cosmetics, pharmaceuticals, paint & dye and textile industries at Tejgaon can be mentioned in this respect.

Chemicals and raw materials are used in the processes, which are toxic. Based on the data from the industrial survey, there is no current provision for the pretreatment of wastewater prior to discharge. On an average day in Dhaka about 6 million gallons of industrial waste are produced and discharged to the waterways, rivers, street drains etc.[25] Existing sewerage system in the city of Dhaka have been broached at many points to admit surface water. Some industrial wastewater find their way into the sewer system, presumably through illegal connections, manholes and sewer pipe joints. The characteristics of sewage collected from the system of industrial areas would be different from that collected from residential areas which needs different degree of treatment. Therefore, the sampling points, taking all the factors into account, were located in different areas as follows:

i) Hazaribagh Tanning Areas: The Hazaribagh area is situated on the southwestern periphery of Dhaka city. It is a mixed type of locality (both residential and industrial) with tanning industries scattered throughout the area. Samples were collected from Hazaribagh sewage lift station at the point of discharge side of pump where hydraulic turbulence occured.

ii) Tejgaon Industrial Areas: Tejgaon, also a mixed industrial zone, is situated north of Maghbazar extending to the southern portion of Mohakhali area. Among the different types of industries in Tejgaon are rubber, soap, detergent, cosmetics, pharmaceuticals, paint & dye factories, metal, fabricating and processing and textiles. All of these are potential pollution producing sources and therefore, require special attention. Samples were collected from Tejgaon lift station at the point of discharge side.

iii) Dhanmondi and Mohammedpur Residential Areas: Dhanmondi and Mohammedpur areas are situated on the west side of Dhaka city. There is no industr in these two areas. For representative sample of domestic sewage, samples were collected from Asadgate sewage lift station which collects sewage from these two residential areas.

iv) Pagla Sewage Treatment Plant: Samples were also collected from the inlet and outlet point of Pagla sewage treatment plant to assess the quality of the combined sewage, the degree of treatment and the efficiency of the sewage treatment plant.

v) Pagla STP Outfall Point: To determine the impact of treated sewage disposal on water quality, water samples were collected from upstream and downstream point of outfall of Pagla STP.

vi) Intake Structure of Dhaka Water Works at Chadnighat: To determine the river water quality, samples were collected from Buriganga river near the intake structure of Dhaka Water Works at Chadnighat.

vii) Different points on Buriganga river: To determine the assimilative capacity of the Buriganga river, six different sampling stations were established along a 10-mile stretch of the river.

The location of sample collection stations are shown in Fig. 4.1.

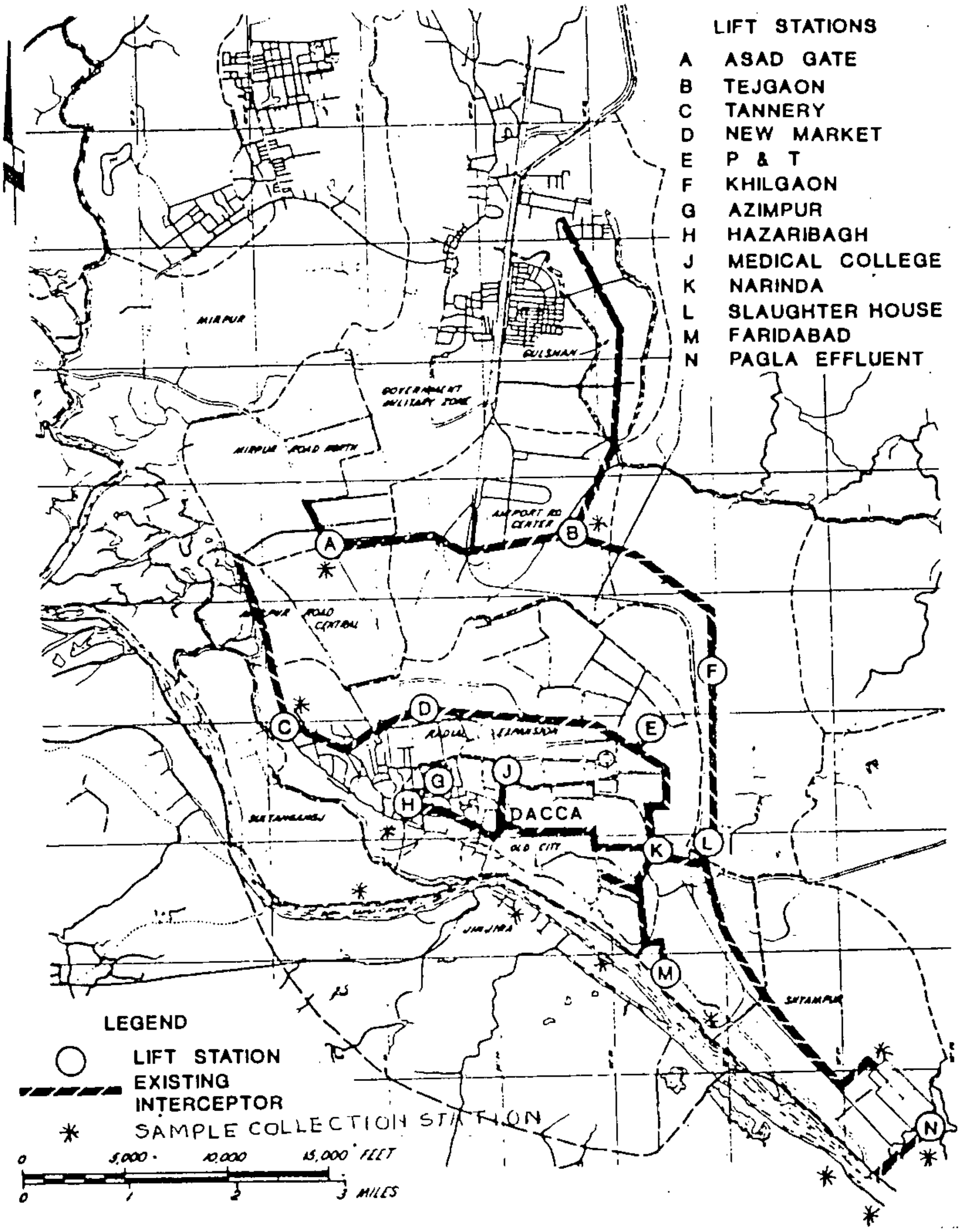


Fig. 4.1 The Location of Sample Collection Stations

4.4 Laboratory Tests

4.4.1 Parameters for Sewage

The characteristics of sewage include the physical, chemical and biological parameters. Laboratory tests were performed for the following characteristics:

i) Temperature
ii) P^H
iii) Color
iv) Turbidity
v) Total solids, Suspended solids and Dissolved solids
vi) Dissolved Oxygen
vii) Biological Oxygen Demand (BOD)
viii) Chemical Oxygen Demand (COD)

Temperature: Temperature represents the 'degree of hotness' of the wastewater in terms of arbitrarily established scale. Temperature is an important parameter in wastewater treatment plant operation because of its significant effect on biological and physical-chemical unit processes. The temperature of wastewater is usually higher than that of water because of the bacterial activity and addition of warm water from domestic, commercial and industrial sources.

P^H Value: P^H is a method of expressing the acid concentration (hydrogen ion concentration) of a wastewater. The P^H scale ranges from 1 to approximately 14, with a P^H of 1 to 7 considered the acid range and 7 to 14 the basic range. P^H 7 is defined as neutral. P^H is a vital tool of the wastewater treatment plant operator when determining unit operations.

Color: The general condition and color of wastewater is very important Fresh domestic sewage has a not unpleasant odour, the color being usually light to yellowish-grey. As the dissolved oxygen is used up and the sewage becomes stale, the color darkens, finally to dark grey or black, when the sewage smells of hydrogen sulphide and is called septic.

Turbidity: Turbidity is caused mainly by highly dispersed (but not soluble) suspended substances of particle size mainly in the colloidal range, and its degree is correlated with the strength of raw wastes such as sewage.

Solids in wastewater: The determinations of various forms of residue are useful in the control of a wastewater treatment plant. Total solids (TS), dissolved solids(DS) and suspended solids(SS) and their volatile and fixed fractions may be used to assess wastewater strength, process efficiency and unit loadings. Measurments of the various residue concentrations are necessary to establish and assure satisfactory operation control. The organic solids putrefy and thereby increase the strength of sewage. The inorganic solids are not of much importance. Total solids are important as indicators of the strength of sewage and the amount of treatment required.

Dissolved Oxygen: DO is the amount of oxygen dissolved in a sewage. The presence of dissolved oxygen in a sewage indicates that it is fresh or weak. Its presence in the effluent of a treatment works indicates good treatment. The concentration of oxygen dissolved in a running stream into which sewage effluents discharge must be such as not to deplet the level of DO concentration to a level as to endanger the life of aquatic animals. Besides, for maintaining aerobic conditions in water receiving pollutional matter so as to avoid anaerobic condition, resulting into the liberation of obnoxous gases and public nuisance. It is important that the DO concentration should be maintain to a level of 4-8 mg/l at all times.

Biochemical Oxygen Demand (BOD): BOD is the most important characteristics of sewage which is widely used to determine the pollutional strength of sewage and industrial waste. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of sewage.

The BOD test has been developed on the basis of a 5 day incubation period at 20°C. Therefore, 5 day BOD values represent only a portion of the total BOD. The exact percentage depends upon the character of the bacteria and the nature of the organic matter and can be determined only by experiment. In the case of domestic sewage and many industrial waste, it has been found that the 5 day BOD value is about 70 to 80% of the total BOD.

The BOD_5 of a wastewater is widely used as an indicator of the fractio of organic matter that may be degraded by microbial action in a given time period at a temperature of 20°C. BOD test results are used to:

i) determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present.

ii) determine the size of the wastewater treatment facilities.

iii) measure the efficiency of some treatment processes.

The limitations of BOD test are as follows:

i) a high concentration of active, acclimated seed bacteria is require

ii) pretreatment is needed when dealing with toxic wastes, and the effects of nitrifying organisms must be reduced.

iii) only the biodegradable organics are measured.

iv) the test does not have stoichiometric validity after the soluble organic matter present in solution has been used.

v) an arbitrary, long period of time is required to obtain results.

Perhaps the most serious limitation is that the 5-day period may or may not correspond to the point where the soluble organic matter that is present has been used. This reduces the usefulness of the test results. As a historical note, it was the British Royal Commission of sewage disposal that popularized the use of the BOD_5 test measured at 20°C. The temperature originally used was 18.3°C. The BOD_5 measured at 18.3°C was chosen because none of the river in England has a flow time to the sea of more than 5 days and the mean summer temperature is 18.3°C.

Chemical Oxygen Demand (COD): COD is another means of measuring the pollutional strength of wastewater. By using this method, most oxidizable organic compounds present in the wastewater sample may be measured. Generally, COD values will be higher than those determined with the BOD test. The reason for this difference is that the BOD_5 test measures only the quantity of organic material capable of being oxidized by microbial action, while the COD test represents a more complete oxidation, more organic compounds can be chemically oxidized than can be biochemically oxidized.

For many types of waste, it is possible to correlate COD with BOD. The COD test has a major advantage over the BOD analysis because of the short time required for performance - a few hours (3 hours) as opposed to 5 days for the standard BOD test. This advantage permits closer operational control of the treatment process. Typical COD values for a domestic waste range from 200 to 500 mg/l. As the industrial content of the wastewater increases, COD values may be 2 to 5 times (or higher) BOD_5 values. A fresh domestic sewage will have a BOD:COD ratio of approximately 0.6. The 5 day BOD test is a measure of mostly the carbonaceous demand, while the COD test is a measure of approximately 90 to 99% of the total organic matter.(2

4.4.2 Quality of river water

The river Buriganga flows by the side of the city of Dhaka. The river directly and indirectly receives partially treated or untreated sewage and storm drainage from the city. The common parameters involved in the pollution and self-purification process of a river were determined for the river Buriganga through extensive laboratory works. The analysis of these parameters are essential for the evaluation of assimilative capacity of the receiving water which is required to select and design wastewater treatment and disposal facilities.

4.5 Characteristics of Sewage

4.5.1 Laboratory Analysis

To characterize the sewage, samples were collected from five different places of the existing sewerage system as shown in Fig. 4.1 and laboratory tests were done for some important parameters. The test results of sewage are shown in Table44.1 The BOD of sewage for 1, 3, 5, 7, 10 & 15 days at 20°C were also determined as shown in Table 4.2.

BOD vs. time curve for different samples collected from different locations are shown in Fig. 4.2. From the curve for outlet point of Pagla sewage treatment plant it can be seen be that second stage BOD satisfaction is achieved after 8 days. In other points, second stage BOD satisfaction is achieved after 10 days. This indicates that outlet effluent contain much less carbonaceous organic matter.

4.5.2 Determination of K and L

The value of the BOD reaction rate constant (K) and Ultimate BOD (L) is important in designing the sewage treatment facilities. The value of K is needed if the BOD_5 is to be used to obtain L. The usual procedure followed when these values are unknown is to determine K and L from a series of BOD measurements. There are several ways of determining K and L from the results of a series of BOD measurements, including the least squares method, the method of moments, the daily-difference method, the rapid-ratio method and the Thomas method. The least-squares method and the Thomas method are illustrated in the following discussion:

The Least-squares method: The least-squares method involves fitting a curve through a set of data points, so that the sum of the squares of the residuals (the difference between the observed value and the value of the fitted curve) must be a minimum. Using this method, a variety of different types of curves can be fitted through a set of data points. For example, for a time series of BOD measurements on the same sample, the following equation may be written for each of the various n data points:

$$\left.\frac{dy}{dt}\right|_{t=n} = K'(L - y_n) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

In this equation both K' and L are unknown. If it is assumed that dy/dt represents the value of the slope of the curve to be fitted through all the data points for a given K' and L value, then because of experimental error, the two sides of equation (1) will not be equal but will differ by an amount R. Rewriting equation (1) in terms of R for the general case yields

$$R = K'(L - y) - \frac{dy}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Simplifying and using the notation y' for dy/dt gives

$$R = K'L - K'y - y' \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Substituting a for K'L and -b for K' gives

$$R = a + by - y' \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Now, if the sum of the squares of the residuals R is to be a minimum, the following equations must hold:

$$\frac{\partial}{\partial a}\Sigma R^2 = \Sigma 2R\frac{\partial R}{\partial a} = 0$$
$$\frac{\partial}{\partial b}\Sigma R^2 = \Sigma 2R\frac{\partial R}{\partial b} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

If the indicated operations in equation (5) are carried out using the value of the residual R defined by equation (4), the following set of equations result:

$$na + b\Sigma y - \Sigma y' = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$
$$a\Sigma y + b\Sigma y^2 - \Sigma yy' = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where, n = number of data points, K' = -b (base e), L = -a/b

The Thomas method:[21] This method based on the similarity of two series functions, is illustrated here. It is a graphical procedure based on the function

$$\left(\frac{t}{y}\right)^{1/3} = (2.3KL)^{-1/3} + \frac{K^{2/3}}{3.43L^{1/3}}\, t \qquad \ldots\ldots\ldots\ldots.(1)$$

where y = BOD that has been exerted in time interval t

K = base 10 reaction-rate constant

L = ultimate BOD

This equation has the form of a straight line,

$$Z = a + bt$$

where $Z = (t/y)^{1/3}$

$a = (2.3KL)^{-1/3}$

$b = K^{2/3}/3.43L^{1/3}$

and Z can then be plotted as a function of t. The slope b and the intercept a of the line of the best fit of the data can then be used to calculate K and L.

$$K = 2.61\,\frac{b}{a} \qquad \ldots\ldots\ldots\ldots\ldots.(2)$$

$$L = \frac{1}{2.3\,Ka^3} \qquad \ldots\ldots\ldots\ldots\ldots.(3)$$

To use this method, several observations of y as a function of t are needed. The data observations should be limited to the first of 10 days because of nitrogenous interference.

From the data obtained by laboratory tests the BOD reaction rate constant (K) and ultimate BOD (L) is determined by both Least squares method and Thomas method. The results are shown in Table 4.3 The graphical approach for determination of BOD reaction rate constant and ultimate BOD by Thomas method is shown in Fig. 4.3.

Table 4.1 Test results of Sewage collected from different locations of sewerage system of Dhaka city

Location	Temperature (C)	P^H	Color (ppm)	Turbidity (ppm)	BOD_5 (mg/1)	COD (mg/1)	$\frac{BOD}{COD}$	T S (mg/1)
Pagla STP Inlet point	30.4	7.10	480	212	260	394	0.66	672
Pagla STP Outlet point	30.4	7.95	400	180	81	240	0.34	497
Nawabganj SLS	31.8	7.60	1440	420	288	469	0.61	1203
Tejgaon SLS	31.8	7.80	480	172	275	481	0.57	2790
Asadgate SLS	32.0	7.20	460	200	270	400	0.68	780

Table 4.2 BOD of Sewage
at 20 C (mg/l)

Location	1d BOD	3d BOD	5d BOD	7d BOD	10d BOD	15d BOD
Pagla STP Inlet point	122	246	260	295	314	352
Pagla STP Outlet point	25	66	81	90	157	176
Nawabganj SLS	114	262	288	320	363	456
Tejgaon SLS	152	262	275	328	354	400
Asadgate SLS	160	258	270	323	357	410

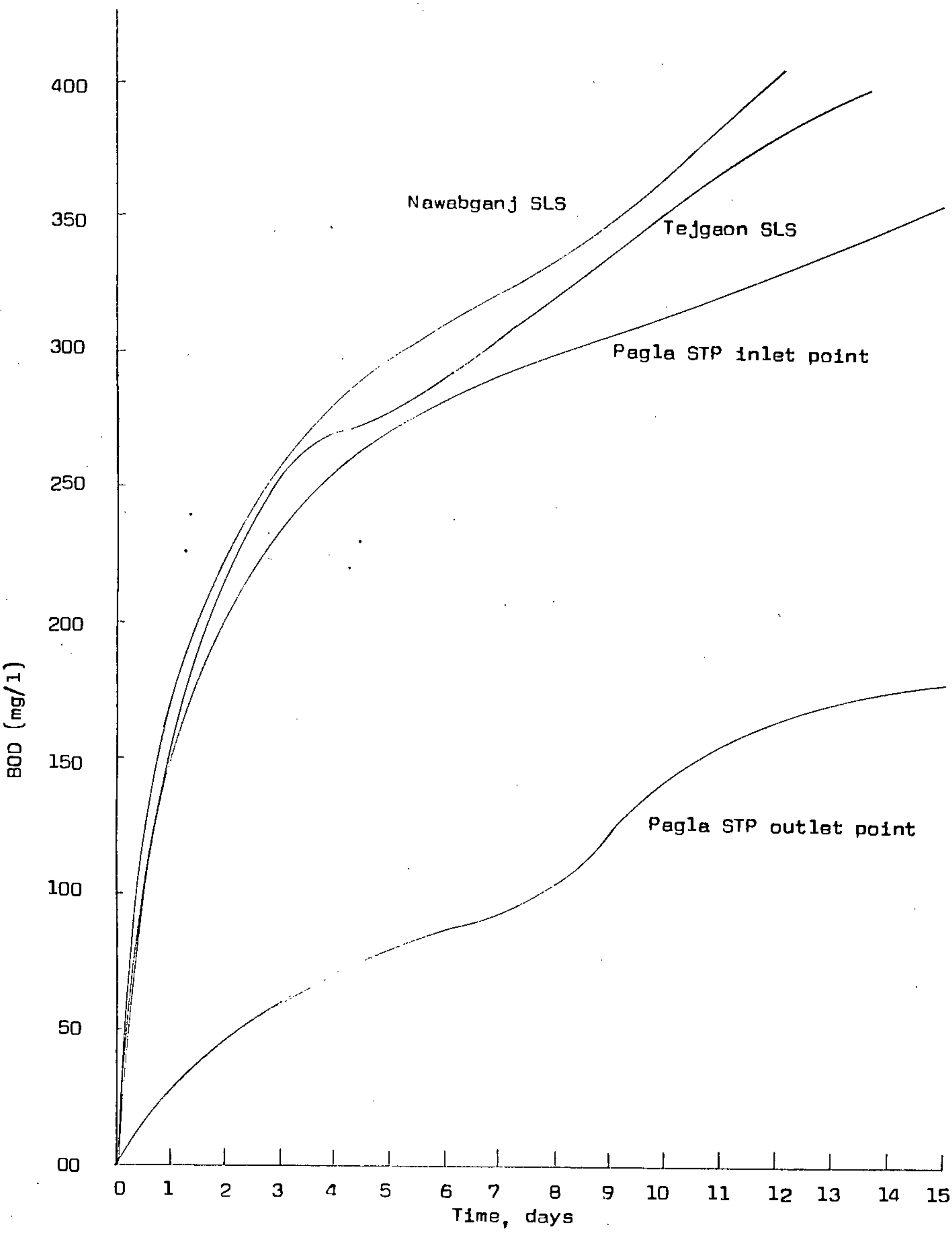
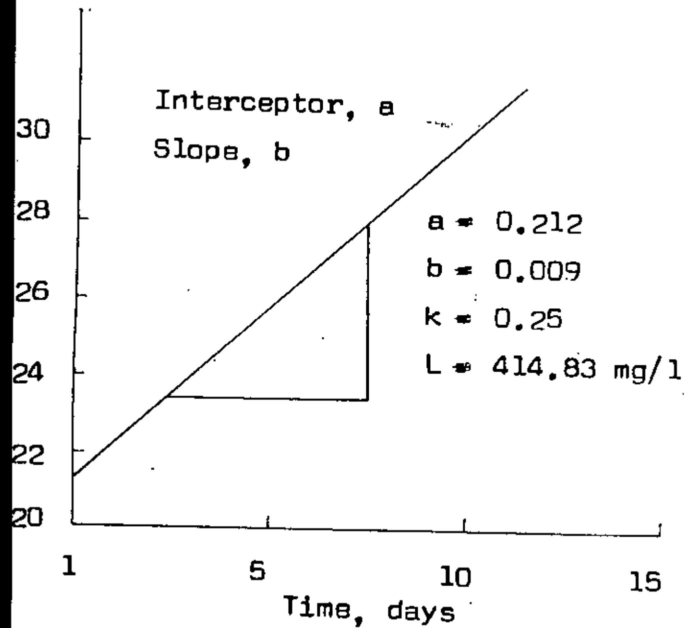
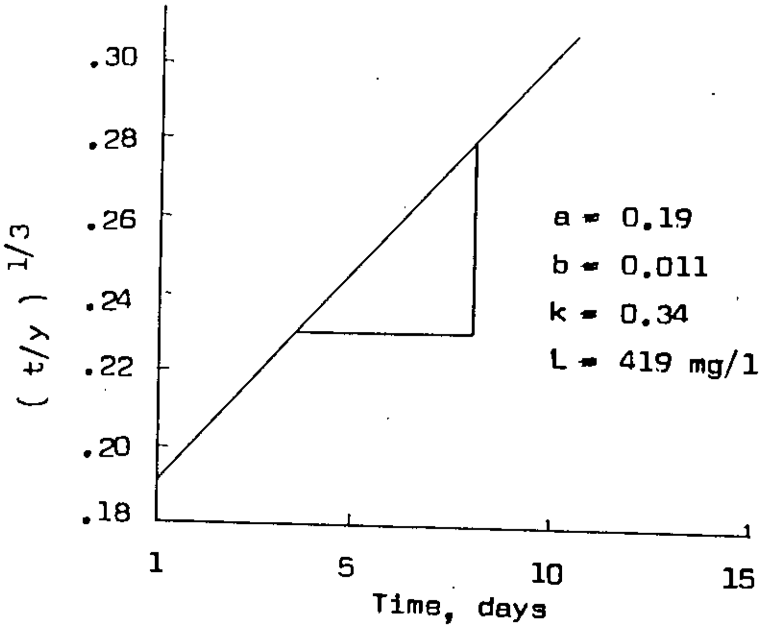


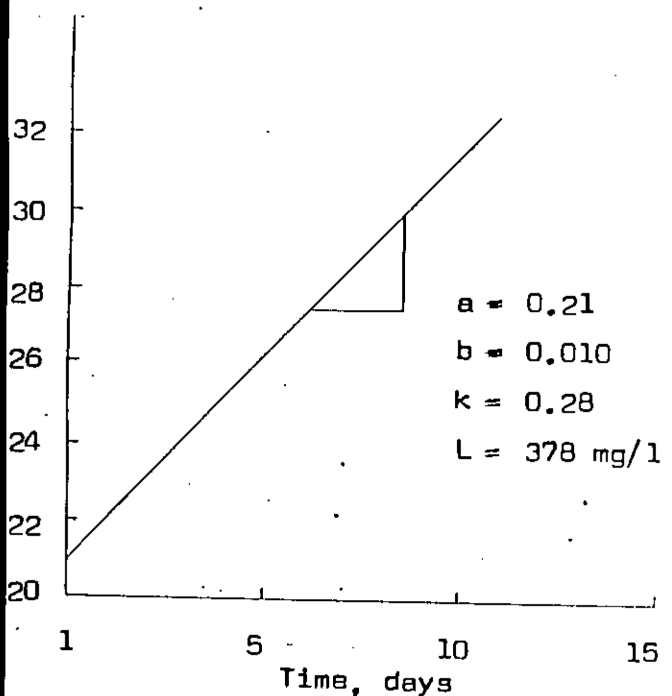
Fig. 4.2 BOD vs. Time curve for sewage collected from different locations of the existing sewerage system



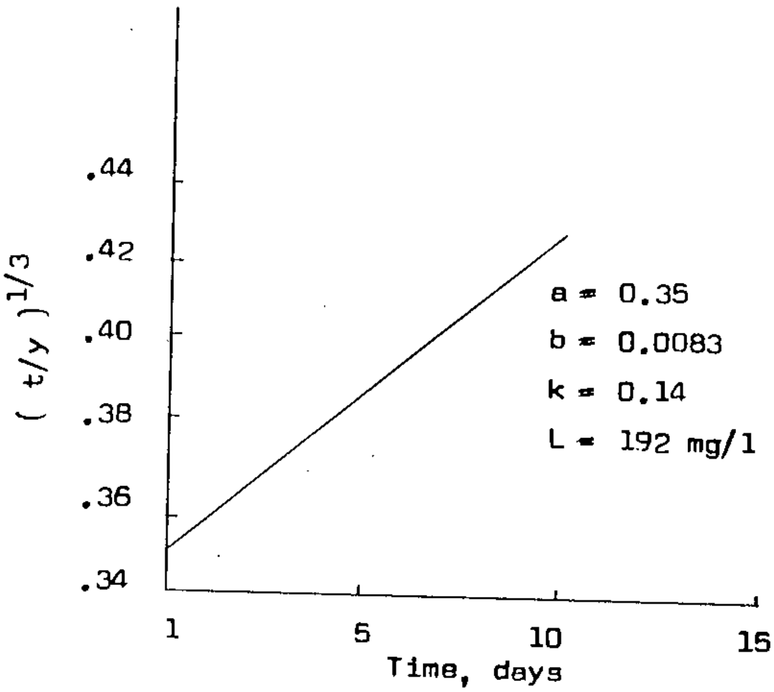
Location : Nawabganj SLS



Location : Tejgaon SLS



Location : Pagla STP inlet point



Location : Pagla STP outlet point

Fig. 4.3 Determination of k & L by Thomas Method

Table 4.3 The BOD reaction rate constant (k) and Ultimate BOD (L) of sewage of Dhaka city

Location	BOD reaction rate constant (K)		Ultimate BOD (L), mg/l	
	Least-squares method	Thomas method	Least-squares method	Thomas method
Pagla STP Inlet point	0.25	0.28	347.88	378
Pagla STP Outlet point	0.057	0.14	287.71	192
Hazaribagh SLS	0.232	0.255	398.27	414.83
Tejgaon SLS	0.29	0.34	366	419

4.5.3 Discussion

The ratios of BOD to COD are found 0.68 and 0.57 for the representative sewage of residential areas (Dhanmondi and Mohammedpur) and industrial areas (Tejgaon) respectively. The ratio of BOD to COD for the representative industrial sewage should be less in comparison to the representative domestic sewage, because the industrial sewage contains non-biodegradable organic matter which can be oxidized chemically. But the difference between these two ratios found very little. It indicates that the industrial sewage contains sufficient biodegradable organic matter that comes from domestic sewage of the adjacent residential areas.

The ratio of BOD to COD for the treated sewage at outlet point is found 0.34 which is less than that of untreated sewage. It indicates that the effluent contains the non-biodegradable organic matter and the biodegradable organic matters are already oxidized in the treatment process.

CHAPTER 5

FIELD OBSERVATION AND DATA ANALYSIS

5.1 Climatic Condition of Dhaka City

The climate over most of Bangladesh is more or less tropical with moderately warm temperature, high humidity and high annual rainfall. There are three seasons - summer, winter and monsoon (rainy season). Winter is from November to February, summer from March to May and the monsoon season starts in June and continues till October.

5.1.1 Rainfall[18]

The distribution of monthly average rainfall in Dhaka is shown in Fig 5.1. The maximum monthly rainfall is generally seen in June and July.

5.1.2 Temperature and Humidity[18]

The lowest temperature is recorded in January and the highest in June. The average lowest and highest temperatures in dry season are 10 C to 13 C and 24 C to 26 C respectively, while those in rainy season are 25 C to 26 C and 30 C to 32 C respectively. The average monthly humidity in dry season is 50% to 70%, and in rainy season it exceeds 80%. Annual temperature and humidity in Dhaka is shown in Table 5.1.

5.1.3 Hydrological condition

The water level of the Buriganga river, the major water source of Dhaka, is 0.6m to 1.8m during the dry season, but when the rainy season is in full swing, it exceeds 6 meters. The period when the water level exceeds 5 meters lasts for about two months with the surrounding area immersed in water for nearly 2 to 3 months. Seasonal variation in water level of the Buriganga river is shown in Fig. 5.2.

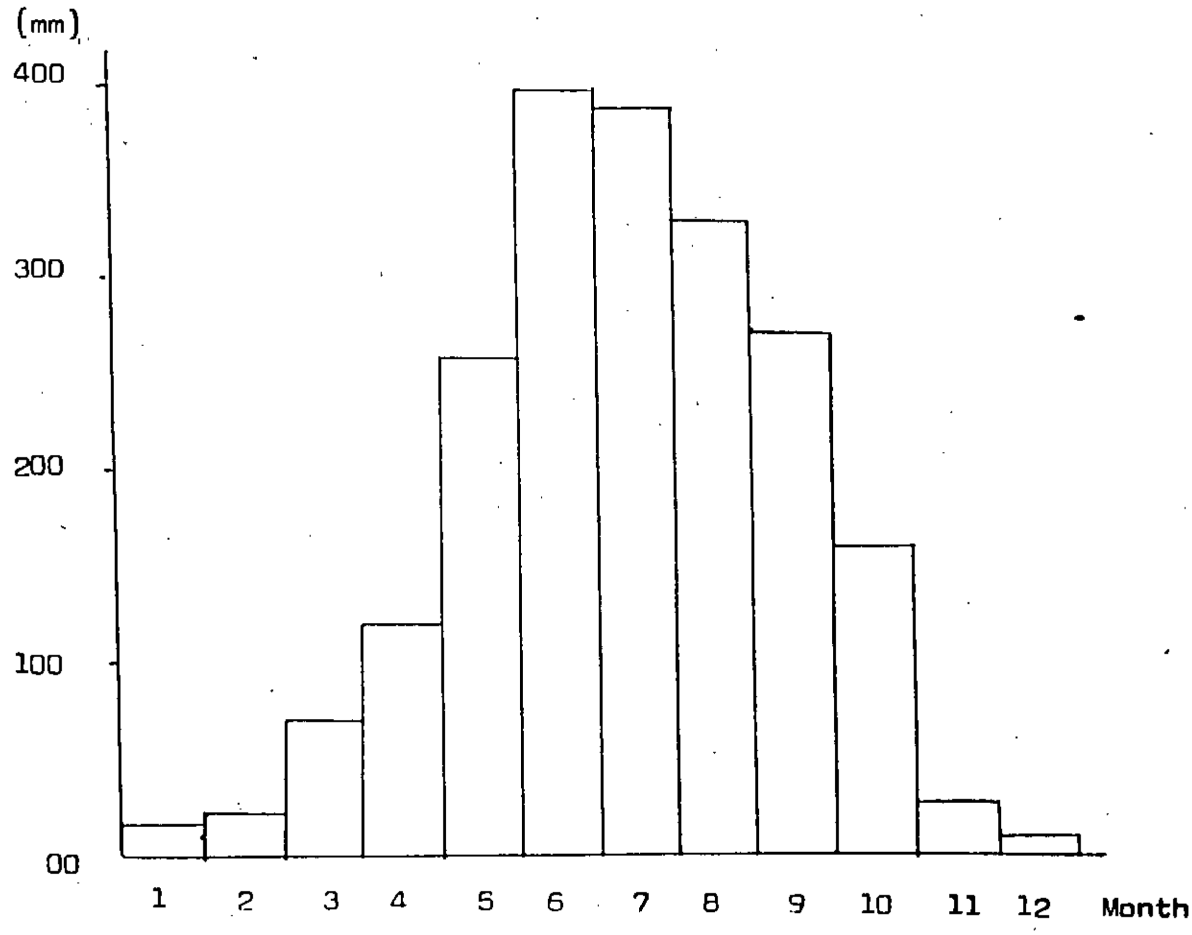


Fig. 5.1 Monthly Rainfall in Dhaka

Fig. 5.2 Seasonal variation of Buriganga river at Millbarrack station

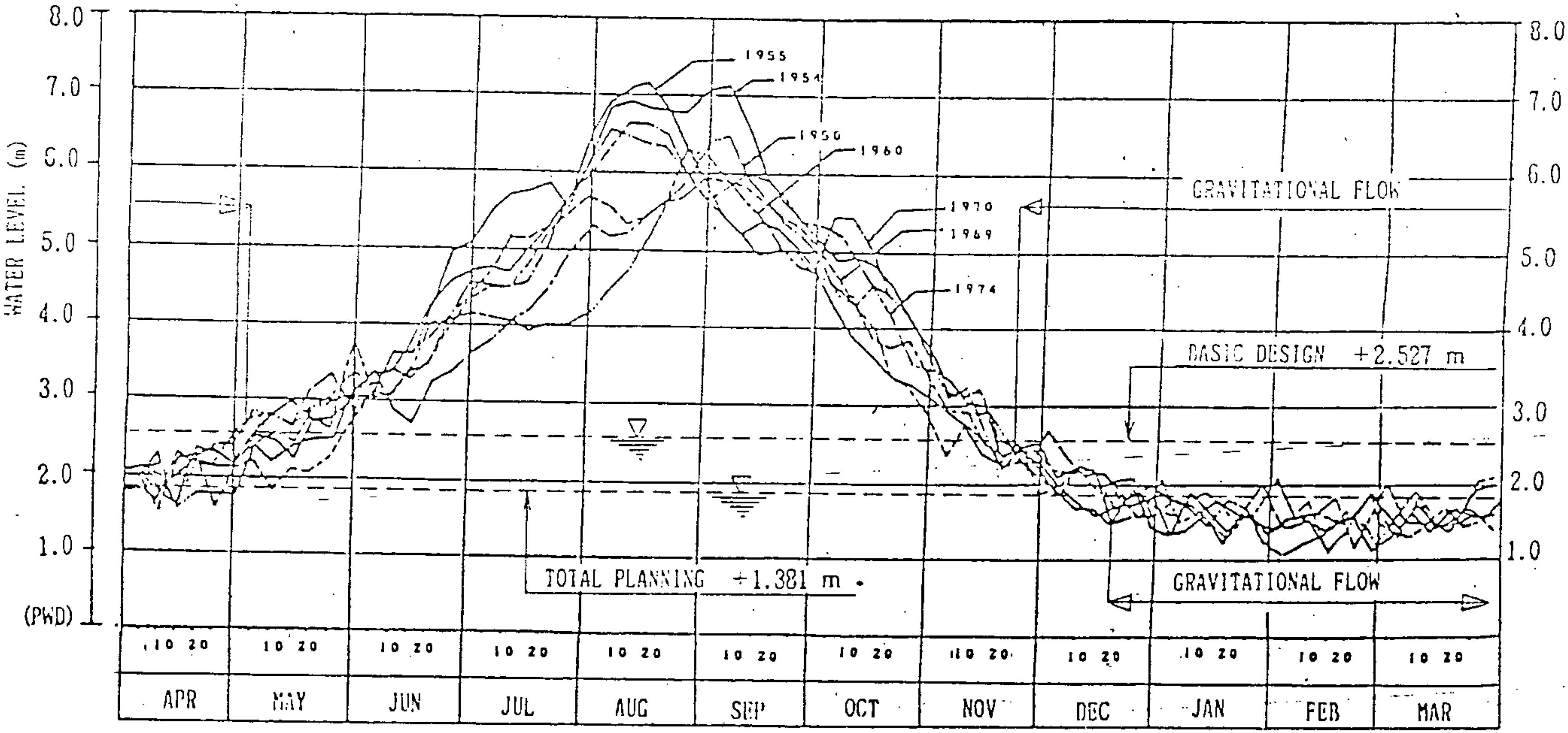


Table 5.1 Temperature and Humidity in Dhaka [18]

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tempt. (°C) Max.	25.5	28.0	32.5	35.0	33.7	31.7	30.7	31.0	31.0	30.9	28.6	26.2
Tempt. (°C) Min.	11.7	13.4	18.8	23.4	25.4	25.9	26.0	26.2	30.8	23.7	17.6	12.7
Humidity (%) at 6 AM	93	90	88	91	93	95	95	94	95	95	94	95
Humidity (%) at 6 PM	61	48	44	54	75	81	82	83	83	79	71	70

5.2 Population of Dhaka City

5.2.1 General

A combination of economic, social and other factors has created a high growth rate in Dhaka city and environs. Dhaka has experienced rapid population as a result of high rates of natural increase and massive in-migration from all regions of the country.[26] As of 1985, the Dhaka metropolitan area has a population of 4.2 million.[27] According to the United Nations 1984 assessment, Dhaka was the 31st largest city in the world in 1985 and is expected to be the 15th largest by the year 2000 (United Nations, 1987). The present population of Dhaka city is 4.32 million and the annual rate of population increase has reached as high as approximately 12%.[18] Out of 4.32 million people, 4.0 million people are in water service area and 3.3 million are receiving water service and approximately 1.15 million are serviced by the sewerage system.[18]

5.2.2 Population Forecasting

Any sewerage system must be planned to serve the present as well as the future needs of the community. Therefore, future population must be assessed while designing the sewerage system. Some of methods of forecasting population are discussed as follows:

Graphical Method:[4] The population during the past years is plotted against time. The graph was extended into the future in a manner which fitted the trend of population growth in the past. By means of such a graphical extrapolation, future population may be predicted. Using this graphical method, urban population of Dhaka city is predicted to be around 9.0 million by the year 2000. The graphical method of forecasting population is shown in Fig. 5.3

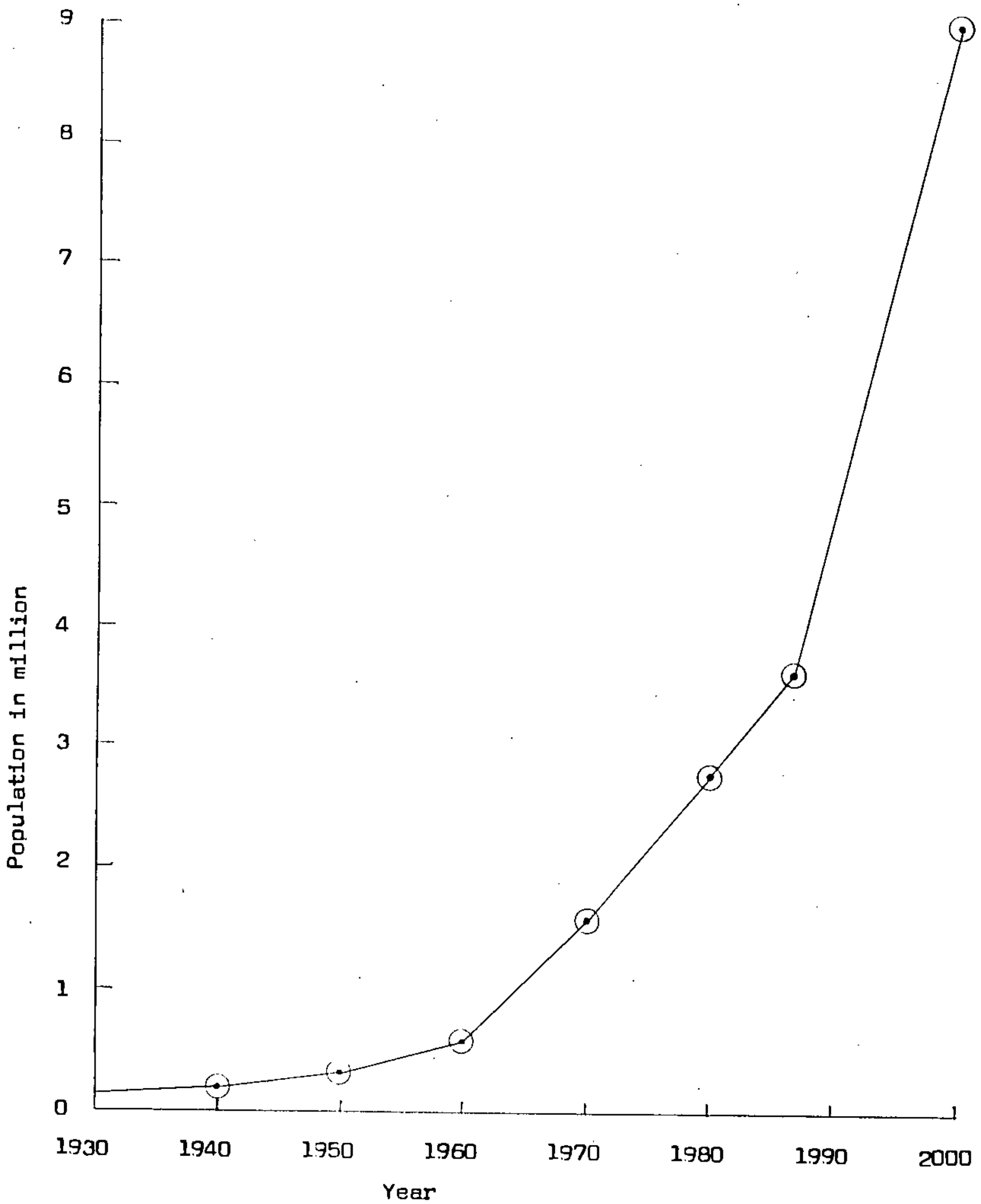


Fig. 5.3 Growth of population in Dhaka city

Arithmetical Method: (4) In this method it is assumed that the rate of population change has been and will remain constant. Expressing it mathematically,

$$\frac{dP}{dt} = K_a \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$dP = K_a dt$$

Here dP/dt represents the change in population P in unit time and K_a is an arithmetic constant.

Integrating between the initial population P_i at the initial year t_i and population P_f at the future year t_f,

$$\int_{P_i}^{P_f} dP = K_a \int_{t_i}^{t_f} dt$$

$$(P_f - P_i) = K_a (t_f - t_i)$$

or $$P_f = P_i + K_a (t_f - t_i) \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Therefore, $$K_a = \frac{P_f - P_i}{t_f - t_i}$$

$$= \frac{P_i - P_e}{t_i - t_e} \quad \ldots\ldots\ldots\ldots\ldots(3)$$

where P_e is the population in some earlier year t_e. From equation (2) it is clear that the relationship between time and population is a straight line and the slope of the line will give the value of K_a.

Using the Arithmetical method the population of Dhaka city is estimated to be 8.52 million by the year 2000 .

5.3 Sewage Flow for Dhaka City

Sewage flow rate was estimated on the basis of the results of the preliminary study and the supplementary data obtained from the recent field survey.

5.3.1 Water consumption of Dhaka WASA

As shown in Table 5.2 Dhaka WASA is supplying water to approximately 3.3 million out of the population of approximately 4.0 million living in the water service area whose water supply volume reaches 4, 21, 300 m^3/d (92.50 IMGD).[18]

According to the Dhaka WASA's Management Information Report, the average effective utilization is 65.05%. Thus the average daily water consumption per capita is

128 litres/head/day X 0.65 = 83 litres/head/day.

Table 5.2 Supplied water volume (per capita) for Dhaka city

Zone	Total population (1000)	Supplied population (1000)	Supplied water volume (m^3/day)	Supplied volume per capita (litre/head/day)
1	904	746	93, 600	125
2	387	319	53, 900	169
3	635	524	73, 800	141
4	764	700	44, 100	63
5	317	262	58, 400	223
6	993	819	97, 500	119
	4000	3300		128

5.3.2 Estimated sewage flow rate

(a) Presumed population utilizing the sewage is approximately 11, 51, 000. Sewage flow rate was calculated on an assumption that 70% of domestic water consuption would be discharged to the sewerage system. Table 5.3 shows the sewage flow rate for Dhaka city.

(b) Presumed water supply from non-governmental sources reaches 6.14 IMGD (28,000 m^3/day). The water from those sources is used as industrial water and commercial water. Although as a rule industrial sewer is not to be connected to the WASA's sewerage, many industrial sewers have been reportedly connected to it.(18) The ratio, however, has not been clarified.

On an assumption that the effective utilization of the water supplied from non-governmental sources is 80% and half of which is flowing into the sewerage, the sewage flow rate will be as follows:

$$28{,}000 \times 0.8 \times 0.5 = 11,\ 200 \text{ m}^3/\text{day}$$

(c) For the infiltration of groundwater (amount unknown), by applying the figure,8, 000 IGPD/mile,used in the Feasibility Report (RMP and J.M. Montgomery), the flow rate will be as follows:

$$300 \text{ miles} \times 8,\ 000 \text{ IGPD/mile} = 24,\ 00,\ 000 \text{ IGPD}$$
$$= 11,\ 000 \text{ m}^3/\text{day}$$

(d) The Feasibility Report presents illegal storm/infiltration = 65/35 as the figure for the penetrating rainwater volume from the results of pumping test at Narinda pump station. Using this figure in the calculation, the illegal storm volume will be as follows:

$$11,\ 000 \text{ m}^3/\text{day} \times \frac{65}{35} = 20,\ 000 \text{ m}^3/\text{day}$$

Table shows the sewage volume flowing into the sewerage calculated from the given conditions in the above (a) to (d).

Table 5.3 Sewage Flow Rate for Dhaka City

Zone	Supplied population (1000) (a)	Sewerage utilizing population (1000) (b)	+Unit actual consumption (l/hd/day) (c)	Consumption of sewerage utilizing population (d) = (b) X (c) m^3/day	Sewage Flow rate (e) = (d)xo.7
1	746	357	81	28,900	20,000
2	319	153	110	16,800	11,800
3	524	188	92	17,300	12,100
4	700	-	-	-	-
5	262	110	145	16,000	11,200
6	819	343	77	26,400	18,500
Total	3,300	1,151	92	105,400	73,800

+ Unit actual consumption = Unit consumption X Effective utilization (65%)

Table 5.4 Volume of sewage flowin
into the sewerage system

Type	Flow rate (m^3/d)	Remarks
(a) Sewage relating to WASA's water supply	73,800	
(b) Sewage relating to non-governmental water supply	11,200	
(c) Infiltration	11,000	
Subtotal: (a)+(b)+(c)	96,000	In dry season
(d) Illegal storm	20,000	
Grand total: (a)+(b)+(c)+(d)	116,000	In rainy season

Table 5.5 shows the sewerage flow rate by the zone where sewerage services are available on the basis of the above calculated rate.

Table 5.5 Estimated sewage flow rate
of Dhaka WASA by the zone with sewerage service available

Zone	WASA supply (a)	Other supply (b)	Infiltration water (c)	Illegal storm (d)	Flow Rate: Dry season (a+b+c)	Flow Rate: Rainy season (a+b+c+d)
1	20,200	2,500	3,000	5,400	25,700	31,100
2	11,800	600	1,700	3,300	14,100	17,400
3	12,100	600	1,800	3,300	14,500	17,800
5	11,200	3,000	1,700	3,000	15,900	18,900
6	18,500	4,500	2,800	5,000	25,800	30,800
	73,800	11,200	11,000	20,000	96,000	116,000

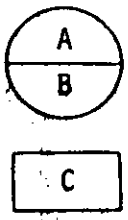
5.4 Collection of Sewage by Lifting Pumps

In the existing sewerage system, sewage flows by gravity. There are 14 number of sewage lifting stations in Dhaka city. The service area covered by each sewage lift station and the estimated flow rate of each sewage lifting pump is shown in Fig. 5.4

The sewerage system of Dhaka city is roughly divided into two lines, comparatively new Swamibagh line (Asadgate - Tejgaon - Bashaboo - Swamibagh) and the Narinda line covering the other areas. Fig. 5.5 shows the lifting capacity of Swamibagh lifting station and Narinda pumping station, both of which are located at the final destination of the above mentioned lines respectively. For comparision, the lifting capacity of Bashaboo lifting pump station, which is located on the upstream side of the Swamibagh line, is also shown. As the figure shows, the lifting capacity of Swamibagh lifting pump station is smaller than that of Bashaboo pump in spite of its location on the downstream side of the line. The reason for such arrangement could not be clarified by the field study.

5.5 Actual Sewage Flow Rate

A field survey is done for the whole area of existing sewerage system, it is supposed that the total amount of sewage coming at outlet point of Pagla sewage treatment plant will be equal to the sum of sewage discharged from Narinda sewage lift station and Swamibagh sewage lift station (with some limitations). But the field study shows that the sewage incoming Pagla sewage treatment plant is much less than the sum of sewage discharged by Narinda and Swamibagh sewage lift station. It indicates that some sewage are going out to the adjacent low-lying areas through leakage or broken of sewers and through by-pass line which create the unhygenic condition. Subtantial portion of the trunk sewers are exposed in the low marsh land, resulting in the egress of sewage from the joints and the damaged section in the dry season and the ingress of flooding water in rainy season.



A : Sewage flow rate (m^3/day) of the sewerage service area covered by a lifting pump station.

B : Total sewage flow rate (m^3/day) of the lifting pump station.

C : Sewage flow rate (m^3/day) of trunk sewers connected to Narinda Pump Station.

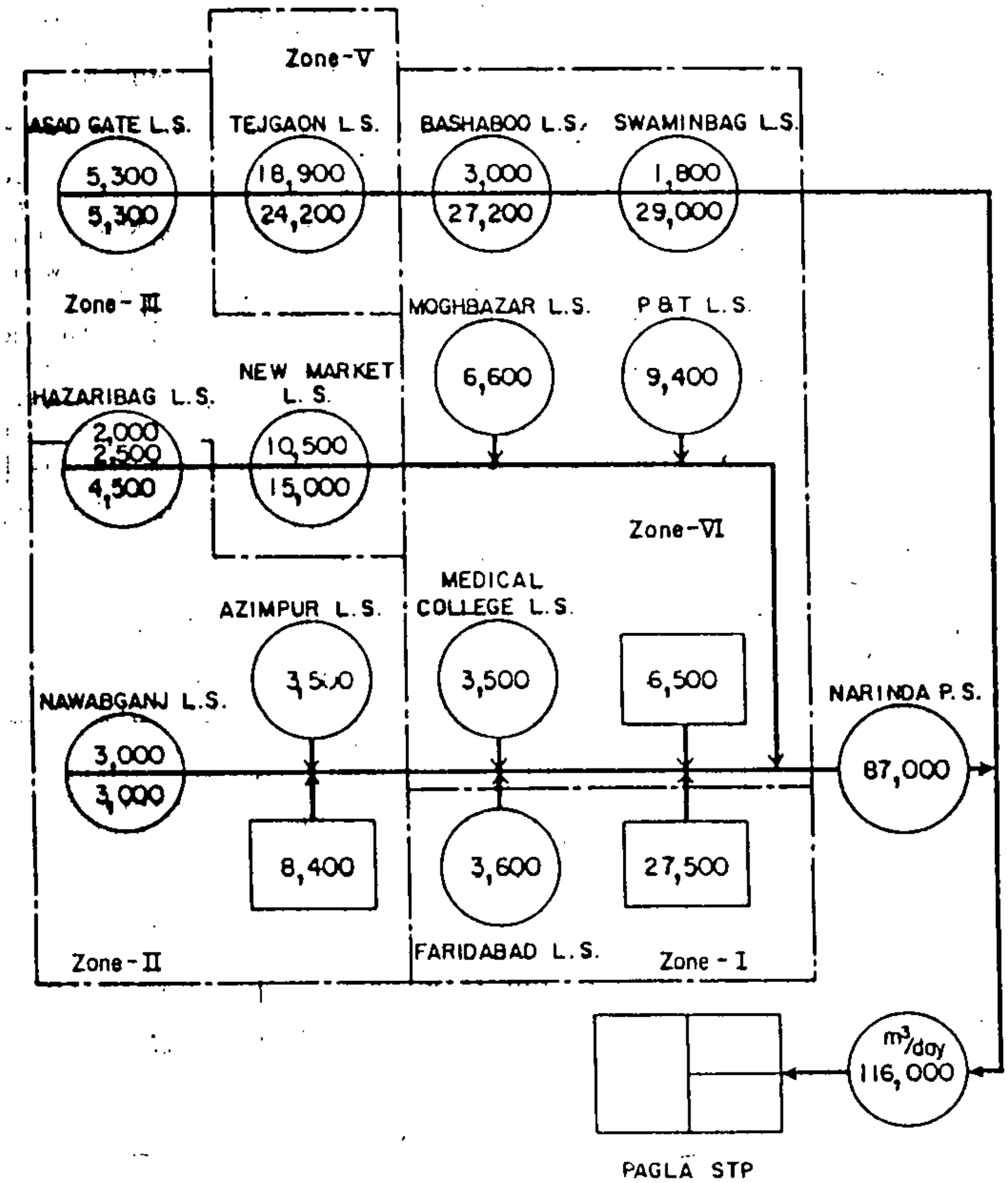


Fig. 5.4 Estimated sewage flow rate by the area with sewage service available

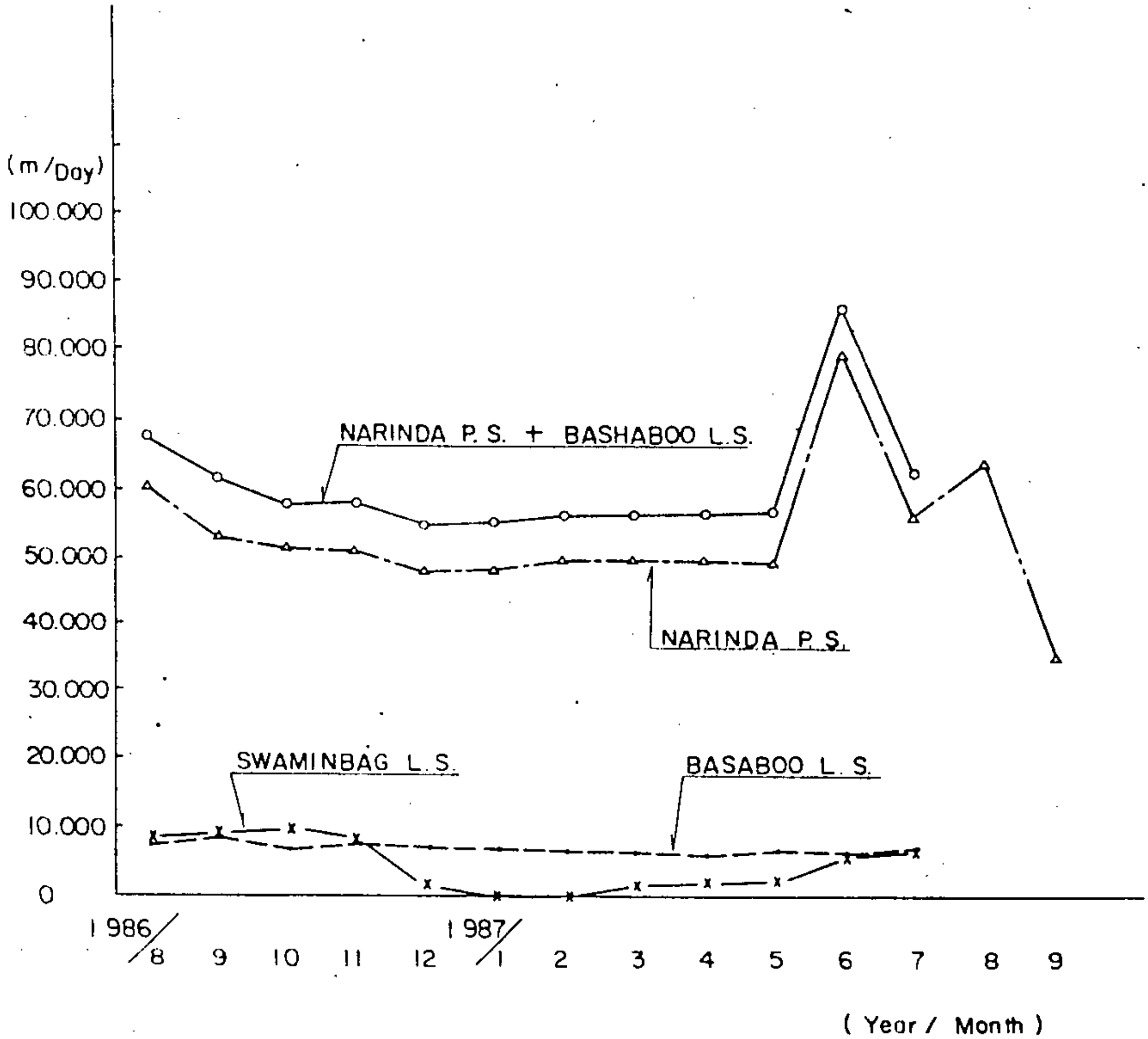


Fig. 5.5 Monthly lifting capacity of Narinda and Swamibagh stations based on the actual pump operation record

Based on the data of actual operation hour as shown in Table 5.6 and in Fig.5.6, 5.7 and 5.8 the discharges from Swamibagh SLS (Q_1), Narinda SLS (Q_2) and Pagla SLS(Q_0) were determined. It is seen that the total quantity of sewage from Swamibagh SLS and Narinda SLS is less than that of discharged by Pagla SLS.

5.6 Effectiveness of Treatment

Table 5.7 shows the past data concerning the water quality at each measuring point in the plant and the observation points on both upstream and downstream sides of the outfall point of the Buriganga river.

Both influent and treated water show fluctuation in quality, However, as far as the biological oxygen demand (BOD) is concerned, the influent has 180 to 260 mg/l which is reduce to 76 to 109 mg/l by the treatment. Accordingly, BOD reduction efficiency is roughly 50 to 60% at present.

Table 5.6 Actual pump discharge of various SLS calculated from operation hour[10,11,12]

Narinda $Q_1 (m^3/d)$	60000	54000	52000	52000	47000	48000	50000	50000	50000	49000	80000	57000
Swamibagh $Q_2 (m^3/d)$	8800	9600	10000	8000	1300			1700	2000	2000	6400	7000
Total $Q_0 = Q_1 + Q_2$	66800	63800	62000	60000	48300	48000	50000	51700	52000	51000	86400	64000
Pagla $Q (m^3/d)$	30000	55000	53000	38000	19000	29000	20000	25000	13000	16000	35000	43000
% of Q_0	43.6	86.20	85.5	60.0	40.4	60.4	40.4	48.4	25.0	31.0	40.5	67.0

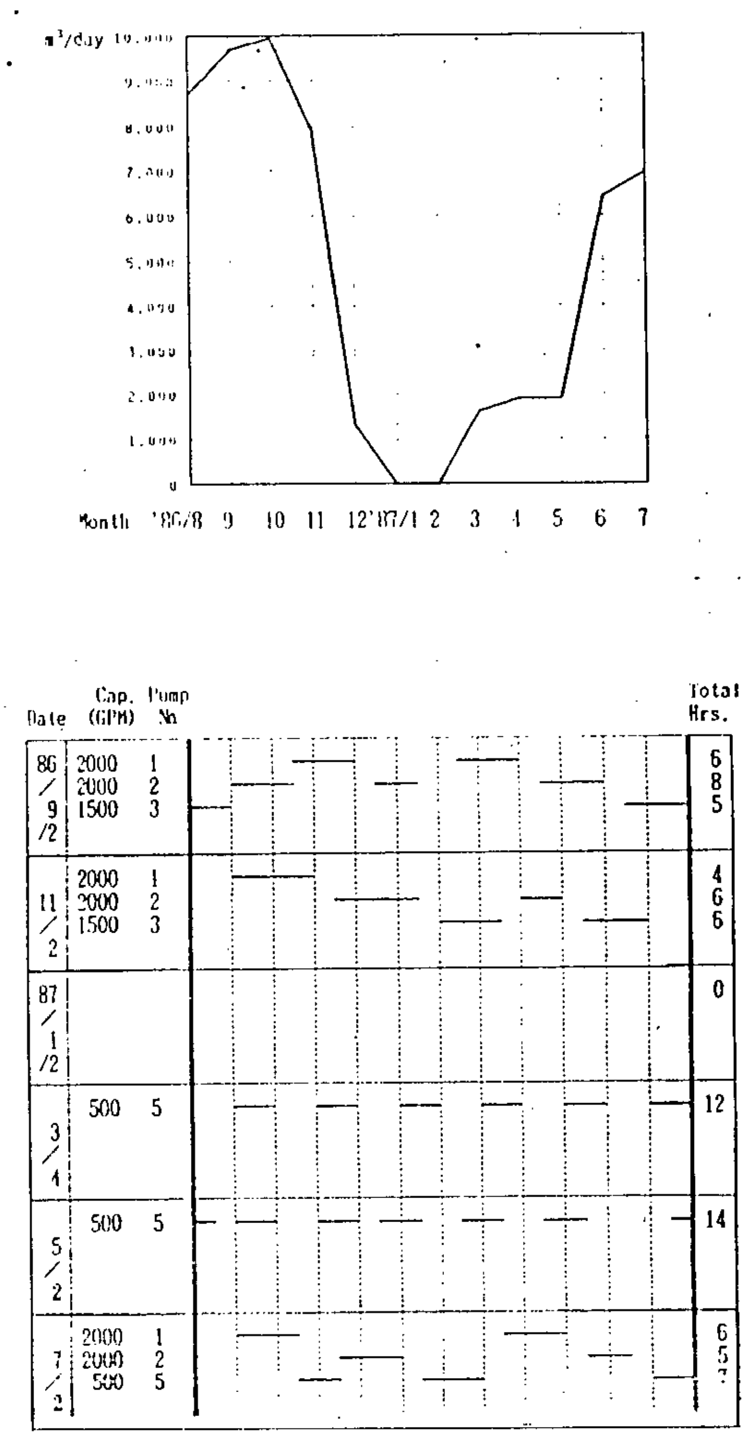


Fig. 5.6 Discharge from Swamibagh Sewage Lift Station (12)

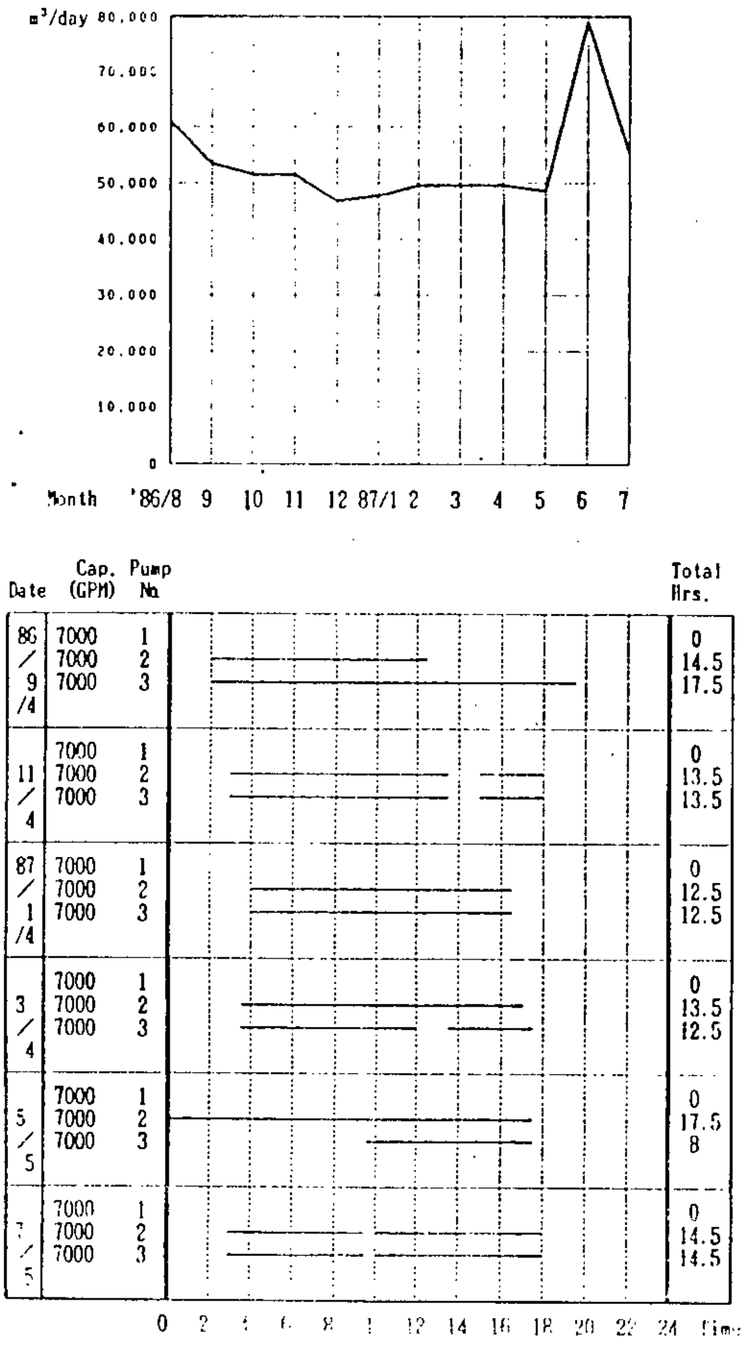


Fig. 5.7 Discharge from Narinda Sewage Lift Station[11]

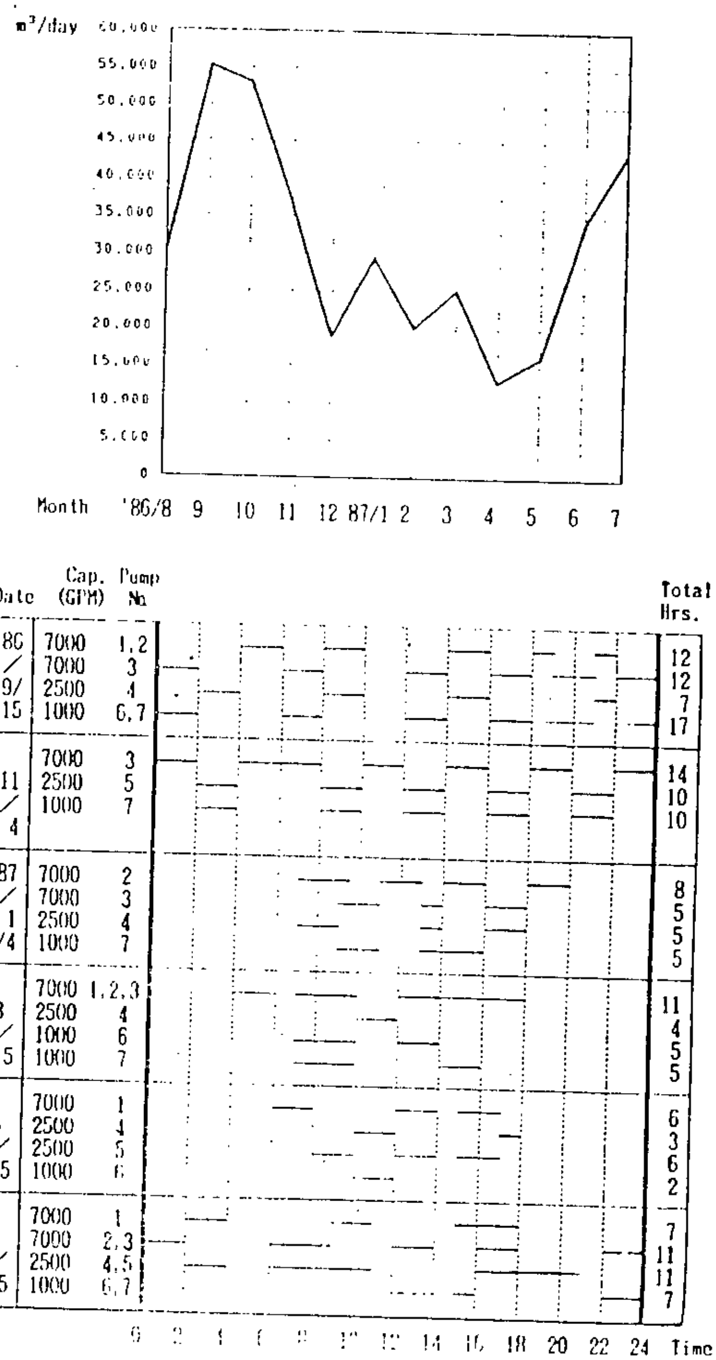
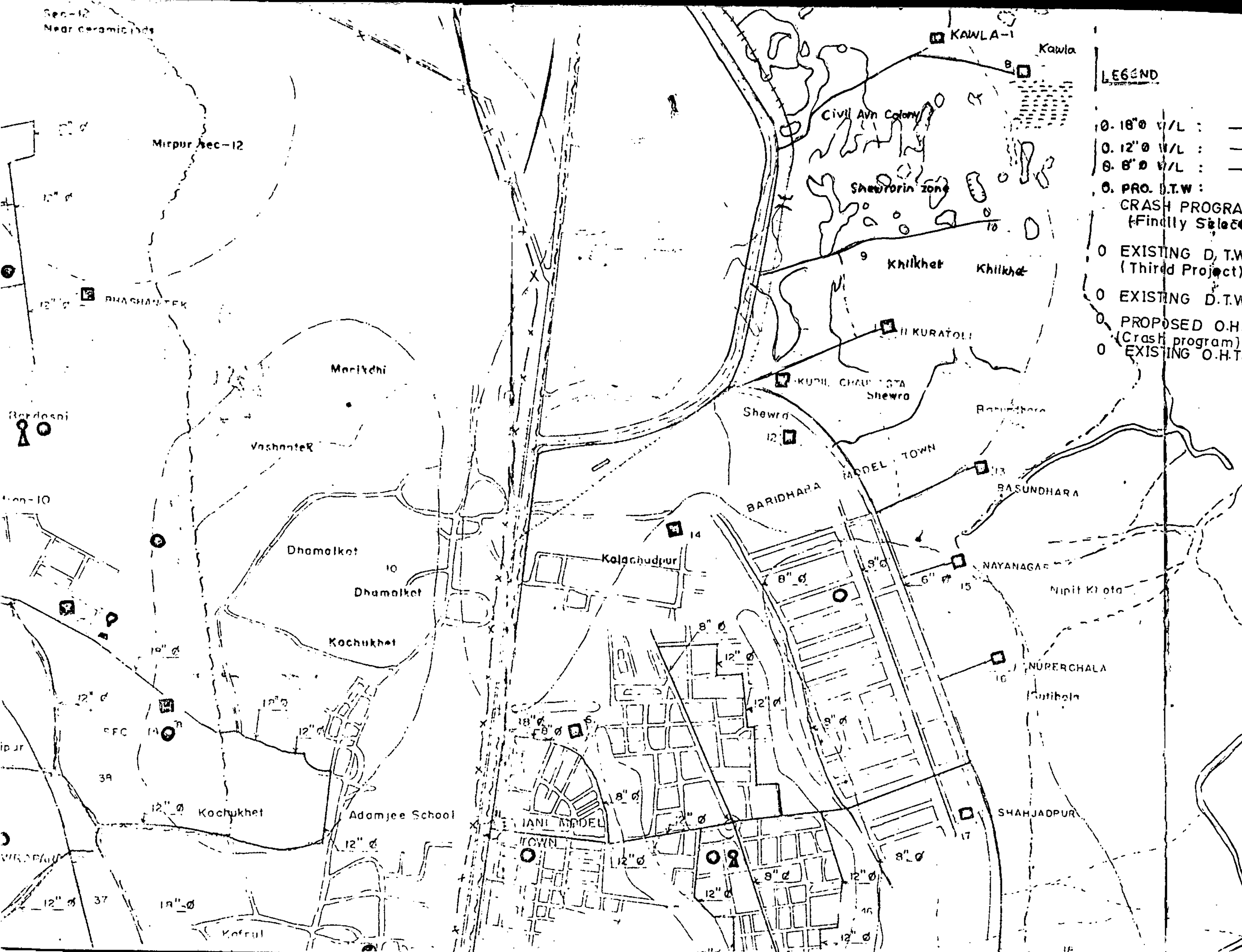


Fig. 5.8 Discharge from Pagla Sewage Lift Station (10)

OLIAN AREA

SYSTEM MAP


LEGEND
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0. 8"Ø W/L :
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CRASH PROGRA
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(Third Project)
0 EXISTING D.T.W
0 PROPOSED O.H
(Crash program)
0 EXISTING O.H.T
KAWLA-1
Kawla
Civil Avn Colony
Shewrorin zone
Khilkhet
Khilkhet
KURATOLI
Shewra
Shewra
MODEL TOWN
BASUNDHARA
BARIDHARA
Kalachudpur
NAYANAGAR
Nipit Khota
NURERCHALA
SHAHJADPUR
Adamjee School
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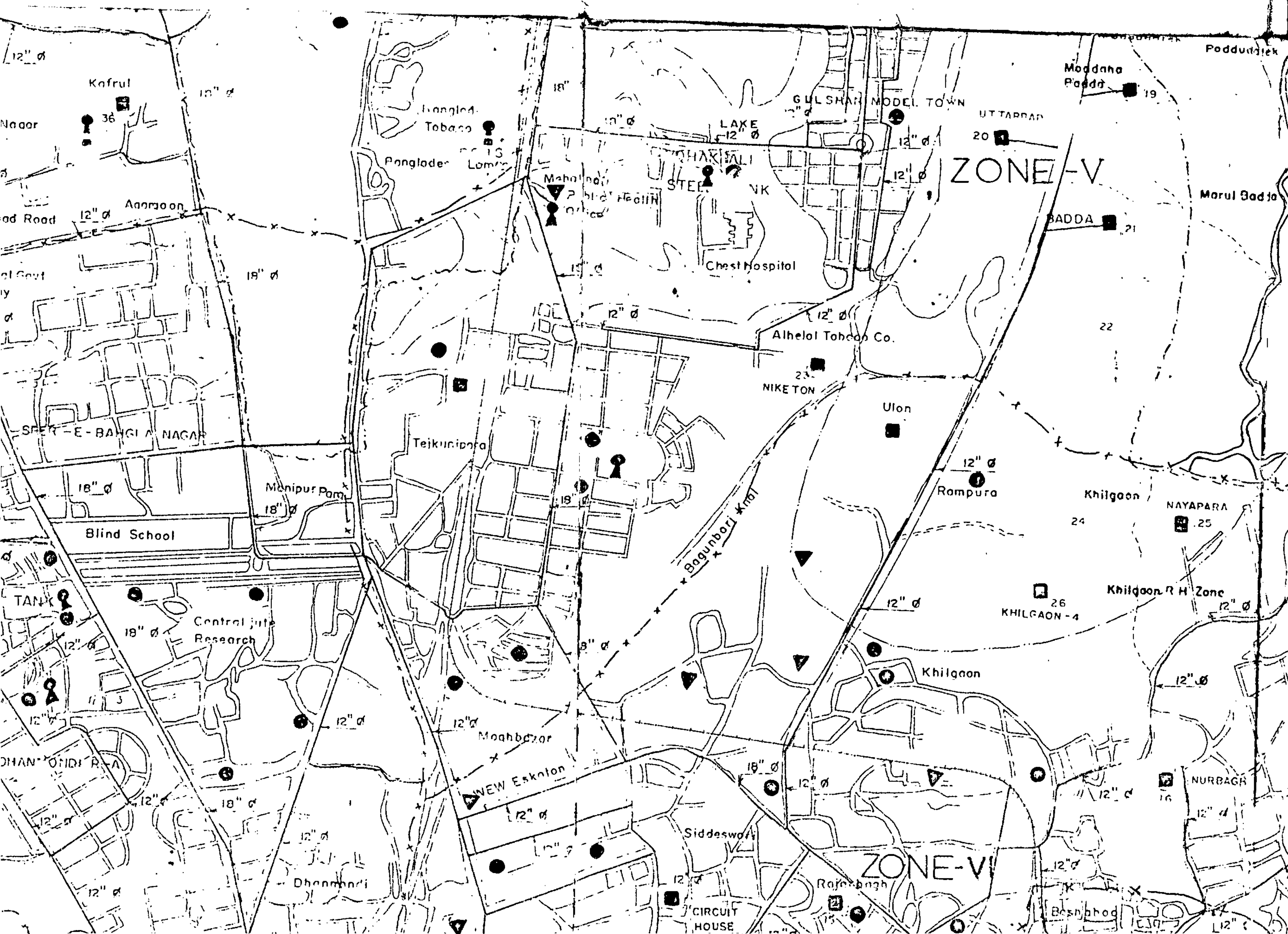
ZONE-V
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Podduddek
Moddana Paddo
19
GULSHAN MODEL TOWN
UTTARPAR
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Marul Badda
BADDA
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22
LAKE
Chest Hospital
Alhelal Tobacco Co.
23
NIKETON
Ulon
Rampura
Khilgaon
24
NAYAPARA
25
Khilgaon R H Zone
26
KHILGAON-4
Khilgaon
NURBAGH
Kafrul
36
Aagargaon
Tejkunipara
SHER-E-BANGLA NAGAR
Manipur Para
Blind School
Central Jute Research
Bagunbari Khal
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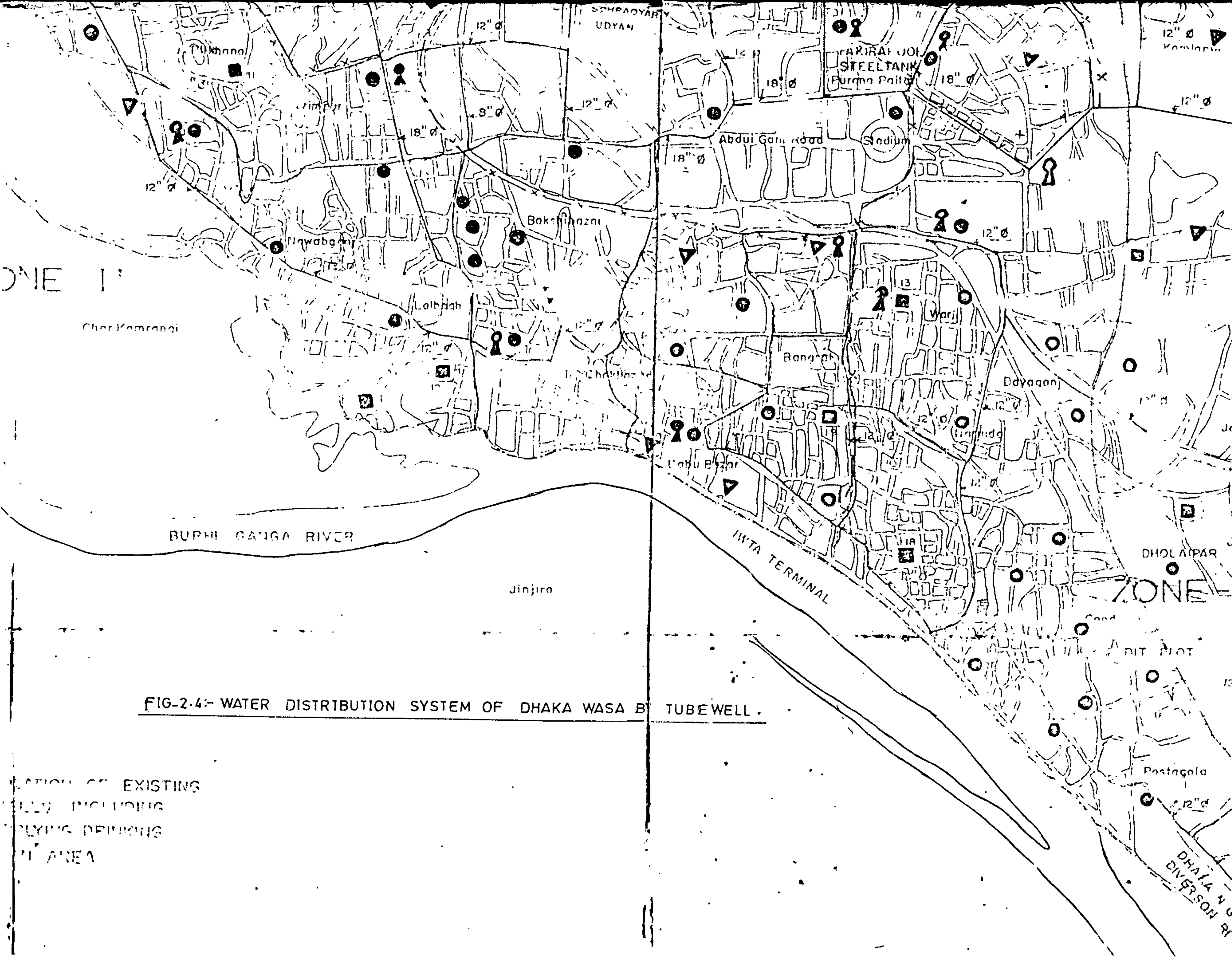


FIG-2.4:- WATER DISTRIBUTION SYSTEM OF DHAKA WASA BY TUBEWELL.

...ATION OF EXISTING
...LLS INCLUDING
...PLYING DRINKING
...N AREA

Table 5.7 BOD_5 at 20°C for Pagla STP and Buriganga river

Period	Influent	Effluent	Upstream of discharge point at Buriganga river	Downstream of discharge point at Buriganga river
In last wet season 7.10.1987	250	86	2.8	19.0
In last dry season 2.12.1987	210	76	2.2	17.0

(Unit: mg/l)

5.7 Discussion

The estimated sewage flow (Q_e) and the actual sewage flow (Q_a) based on operation hour of each sewage lift station is shown in Table 5.8. From the comparison of these two flows, it is observed that the actual flows are less than the estimated flows. The reason of such flow differences is due to the disposal of raw sewage to the adjacent low-lying areas through by-pass line, leakage and broken sewers, overflowing the manholes, connection of sewers to surface drains etc.

The actual flow (Q_a) of Swamibagh and Narinda sewage lift station and the incoming flow (Q_i) at inlet point of Pagla sewage treatment plant is shown in Table 5.9. The total amount of sewage coming at inlet point of Pagla treatment plant should be more or less equal to the sum of actual flow of Swamibagh and Narinda sewage lift station. But it is observed that the incoming flow is less than the sum of actual flow of these two lift stations. The leakage and damage of trunk sewers is the main reason of such flow difference. There are some flows into the trunk sewers by infiltration of ground and surface water, but the rate of exfiltration exceeds the rate of infiltration.

Table 5.8 Estimated sewage flow and Actual sewage flow of sewage lift station

Sl. No.	Name of the Sewage lift station	Estimated flow, Q_e (m^3/d)	Actual flow, Q_a (m^3/d)
1.	Asad Gate	5,300	5,034
2.	Tejgaon	24,200	4,934
3.	Bashaboo	27,200	6,835
4.	Swamibagh	29,000	7,400
5.	Hazaribagh	4,500	—
6.	New Market	15,000	7,670
7.	Moghbazar	6,600	5,000
8.	P & T	9,400	7,330
9.	Nawabganj	3,000	2,000
10.	Azimpur	3,500	2,000
11.	Medical College	3,500	2,200
12.	Faridabad	3,600	2,000
13.	Narinda	87,000	65,660
14.	Pagla	116,000	36,000

Table 5.9 Actual flow of Swamibagh and Narinda sewage lift station and Incoming flow to Pagla treatment plant

Sl. No.	Name of the sewage lift station	Actual flow, Q_a (m^3/d)	Incoming flow, Q_i (m^3/d)
1.	Swamibagh	7,400	--
2.	Narinda	65,600	--
3.	Pagla	--	36,000
Total		73,060	36,000

CHAPTER 6

WASTEWATER DISPOSAL IN DHAKA CITY

6.1 General

The disposal of wastewater in the rapidly expanding city of Dhaka has become a great concern in the face of increasing pollution problems. Wastewaters that are discharged throughout the Dhaka metropolitan area have both a regional and local impact on the water quality.[25] Therefore, an evaluation of assimilative capacity of receiving water is required to select and design the greater Dhaka wastewater treatment and disposal facilities and, in particular, the level of treatment required.

River pollution is now recognised as a world problem. The problem has become intensified by the technological and industrial revolution of this century. As a result, large volume of industrial wastes in addition to the domestic sewage and sewage plant effluents found their easy way to the nearest water courses and polluted their water.

In a normal stream there is a cycle which results in a balance between animal and plant life. When the amount of pollution is less, the river behaves as a balanced ecosystem. When sewage is discharged into a natural stream, a succession of changes in river water take place. The initial effect of pollution on a river is to degrade the physical quality of water. As decomposition becomes more active a shift to chemical degradation is biologically induced. The supply of dissolved oxygen may be completely exhausted if conditions allow for the active development of bacteria. In course of time and flow, the normal cycle of the river is gradually re-established. The river is returned to normal purity. This restoration is termed as the self-purification or natural purification of streams.[1]

When heavy sewage pollution occurs, fairly well defined zone of pollution recoverly can be observed. Each of these zones is characterised by physical, chemical and biological conditions. These zones are (1) zone of degradation (2) zone of active decomposition or septic zone (3) zone of active recovery and (4) zone of clear water. The pattern of pollution and the effects of pollution on the biological life in sewage polluted stream is schematically shown in Fig. 6.1.(1)

The degree of pollution caused by the waste depends upon the polluting load and the assimilation capacity of the body of water in which the polluting substances are discharged. The BOD exerted by the waste in water causes a depletion of dissolved oxygen which is replenished by reoxygenation through surface aeration and algael photosynthesis. Deoxygenation of the body of water by excessive polluting loads beyond critical limit discrupts the balance between animal and plant life and causes characteristic changes in physical, chemical and biological conditions of water. Dilution, sedimentation, current, sunlight and temperature are the major factors influencing water pollution and self-purification processes. The organic, inorganic and toxic wastes discharged in the stream within or beyond the assimilation capacity leave some residual pollutants in water. In tidal rivers, under certain conditions, a gradual deterioration of water quality with time by the accumulating residuals of naturally degraded wastes may occur.[1]

6.2 Waste Disposal in Dhaka

6.2.1 Domestic sewage

The ever-increasing population of Dhaka has rapidly increased the wastewater production and the city area has outgrown its sanitary system, particularly the sewerage extension. At present, the existing sewerage system collects and treats only about 40% of the total wastewater production, the rest being discharged directly to the nearby drains, ground and other water ways.[9] As a result, the wastewater is everywhere in evidence, and now, the sanitary condition and water contamination of public water bodies have become a deplorable level. A significant Water quality deterioration has also been observed in the Buriganga river and will progressively become worse due to accelerating growth of population and industry.

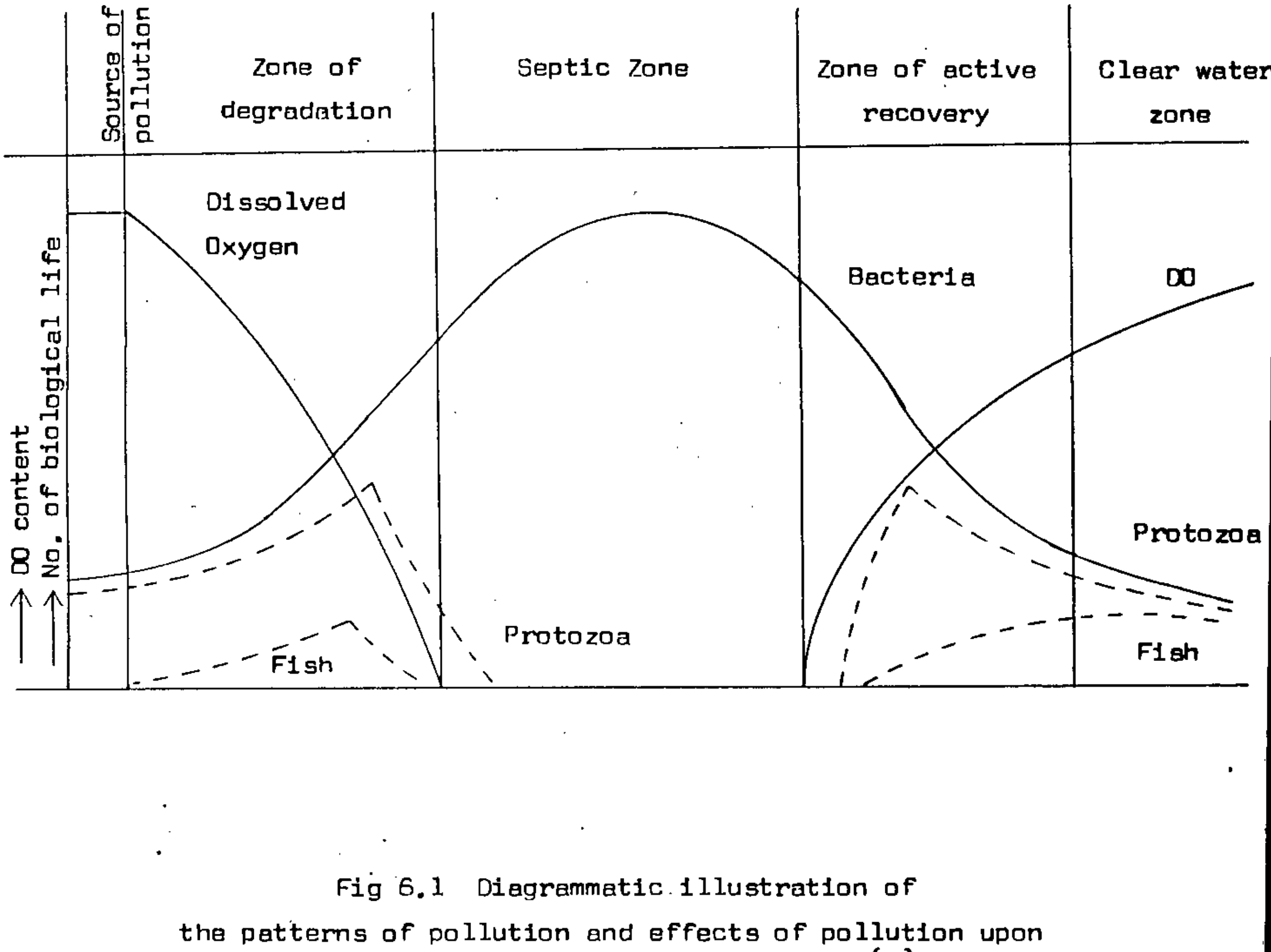


Fig 6.1 Diagrammatic illustration of the patterns of pollution and effects of pollution upon Do and biological life in rivers[1]

6.2.2 Industrial Wastewater

The industrial pollution within Dhaka city is concentrated primarily in the following locations:

i) Hazaribagh Tanning Area
ii) Tejgaon Industrial Area
iii) Dhaka-Narayanganj Industrial Belt (along the river Buriganga)

In and around the Dhaka city, there is no any particular aystem for industrial wastewater collection, treatment and disposal. Untreated or/and partially treated industrial wastewaters with very high pollution potentials are discharged to the adjacent low-lying areas, drains and other water-ways and ultimately with the river system around the city of Dhaka. The pollutants are inorganic, organic and toxic in nature and require extensive treatment before disposal to prevent the environment.

6.2.3 Solid Waste

The quantity of solid wastes produced in Dhaka varies between 700 and 800 tons per day in dry season and 900 and 1100 tons per day in rainy season.[2] The present dumping site in open area near Mirpur Bus Terminal is a focus of pollution. The leachate from open garbage dump produced in rainy season which is known to have extremely high pollution potential, reaches groundwater and surface water sources. Dumping of solid waste in river water by people living or working nearby is very common in Bangladesh.

6.3 Quality of Buriganga River Water

The volume of wastewater in Dhaka city is increasing with industrialization and the rapid growth of population. The river water contamination caused by unsatisfactory treatment system of wastewater has already become a deplorable level, requiring immediate actions to prevent degradation of the sanitary conditions in the area. Most serious effect of the wastewater discharge to the river is a potential high danger to contaminate the water supply system downstream of the Buriganga river. The comparison of the important water quality parameters of the Buriganga river with previous studies by Parsons Corporation (1959 – 60), Kalam(1968), Ahmed(1974), WPCP(1973 – 75), Islam(1977), WASA(1980) and JICA(1987) reveals that the quality of water of the river has tremendously deteriorated. Careful examination indicates that the water from the river is unsafe for many uses and needs extensive and costly management to achieve International Standard for drinking water.

In 1980, a sampling programme of the Buriganga river shown deteriorating water quality and Table 6.1 shows the comparison of the different sampling results.

A comparison of sampling data of the Buriganga river water near Chandnighat allows the following conclusion:

i) The DO levels decreased in comparison to the results of March,1975.
ii) The BOD_5 at 20 C values increased, but not substantially.
iii) Chloride concentration increased about 25% in 5 years (1975 –'80)
iv) The average coliform colonies increased threefold in 7 years (1968 – '75).

In May 1985, during SARC seminar on Protecting the Environment from Degradation, another study on the quality of Buriganga river water was done and presented by Ahmed,F. as shown in Table 6.2.

In July 1987, Mitsubishi Corporation of Japan conducted a study on water quality of the Buriganga river and the test results are shown in Table 6.3.

Table 6.1 Water quality changes
in Buriganga river (near Chandni ghat), 1968-1980 (25)

Parameters	BUET 1968			DPHE 1975			Study Team 1980		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
EC (μmho/cm)	950	332	207	325	650	-	282	512	-
p^H	7.1	8.2	-	7.1	8.5	-	7.1	7.7	-
Chloride (mg/l)	1.0	7.0	-	14	62	-	28	30	29
DO (mg/l)	5.4	8.0	6.7	1.55	10	-	2.4	4.6	3.3
BOD_5 at 20°C (mg/l)	0.0	1.5	0.8	1.4	6.5	-	1.6	8.4	3.0
Nitrate (mg/l)	0.1	0.6	0.3	2.6	6.2	-	0.1	1.9	-
Coliform colonies/ 100 ml	260	4600	1450	200	20,000		-	-	>20,000

Table 6.2 Quality of Buriganga river water (24)

Parameter	Minimum	Average	Maximum
Suspended solids	37	75	105
Turbidity	30	52	85
Color	25	32	45
Total alkalinity	15	75	230
Acidity	00	5	12
p^H	7.1	7.5	8.2
Total hardness	20	75	150
Dissolved oxygen	5.8	7.8	8.4
COD	0.9	2.2	5.0
BOD	0.7	1.8	4.3
Carbondioxide	1	7	13
Ammonia	1.2	2.6	3.8
Nitrate	0.6	2.2	7.0
EC (Elec. cond.)	120	260	490
Coliform count^{++} X 100/100 ml	1	36	125

Table 6.3 Water analysis of the Buriganga river, July, 1987 (26)

Parameter	Unit	Quantity
Turbidity		2.5 NTU
Color		14 degree
Total hardness	mg/l as $CaCO_3$	41.24
Calcium	mg/l as $CaCO_3$	26.90
Magnesium	mg/l as $CaCO_3$	14.34
Sodium	mg/l as Na	4.30
Potassium	mg/l as K	2.70
Iron	mg/l as Fe	1.06
Manganese	mg/l as Mn	0.029
Chloride	mg/l as Cl	2.60
Sulfate	mg/l as SO_4	9.10
Ammonia nitrogen	mg/l as NH_4	0.10
Nitrite nitrogen	mg/l as NO_2	0.025
Nitrate nitrogen	mg/l as NO_3	3.70
Silica	mg/l as SiO_2	12.38
Potassium permanganate consumed	mg/l	5.90
P^H value		7.25
Total alkalinity	mg/l as $CaCO_3$	47.00
Conductivity	s/cm	105.0
Total dissolved solid	mg/l as $CaCO_3$	75.0

The recent water quality survey conducted by Dhaka WASA and Environmental Pollution Control Board confirmed that the river water has been gradually polluted by the wastewaters. BOD concentrations at the selected monitoring points in the Buriganga river at the upstream of the treatment works ranged between 2.1 and 2.6 mg/l, whereas that of about 1.2 miles downstream of the outfall was 4 mg/l. The BOD concentrations at just downstream of the outfall were in the range of 14 to 18 mg/l.

In the recent field study by JICA, water quality of the river was analyzed. The results and sampling points are shown in Table 6.4 and in Fig. 6.2 respectively.

Table 6.4 Water quality of the Buriganga river [18]

Sampling date	Sampling point	BOD_5	SS	COD
13.11.1985	Outfall point (up)	2.0		
	Outfall point (down)	17.5		
12.4.1986	Outfall point (up)	1.8		
	Outfall point (down)	20.0		
7.10.1986	Outfall point (up)	2.8		
	Outfall point (down)	19.0		
1.12.1986	Outfall point (up)	2.2		
	Outfall point (down)	17.0		
2.7.1987	Outfall point (up)	4.3	57	14.4
	Outfall point (down)	18.3	66	43.2

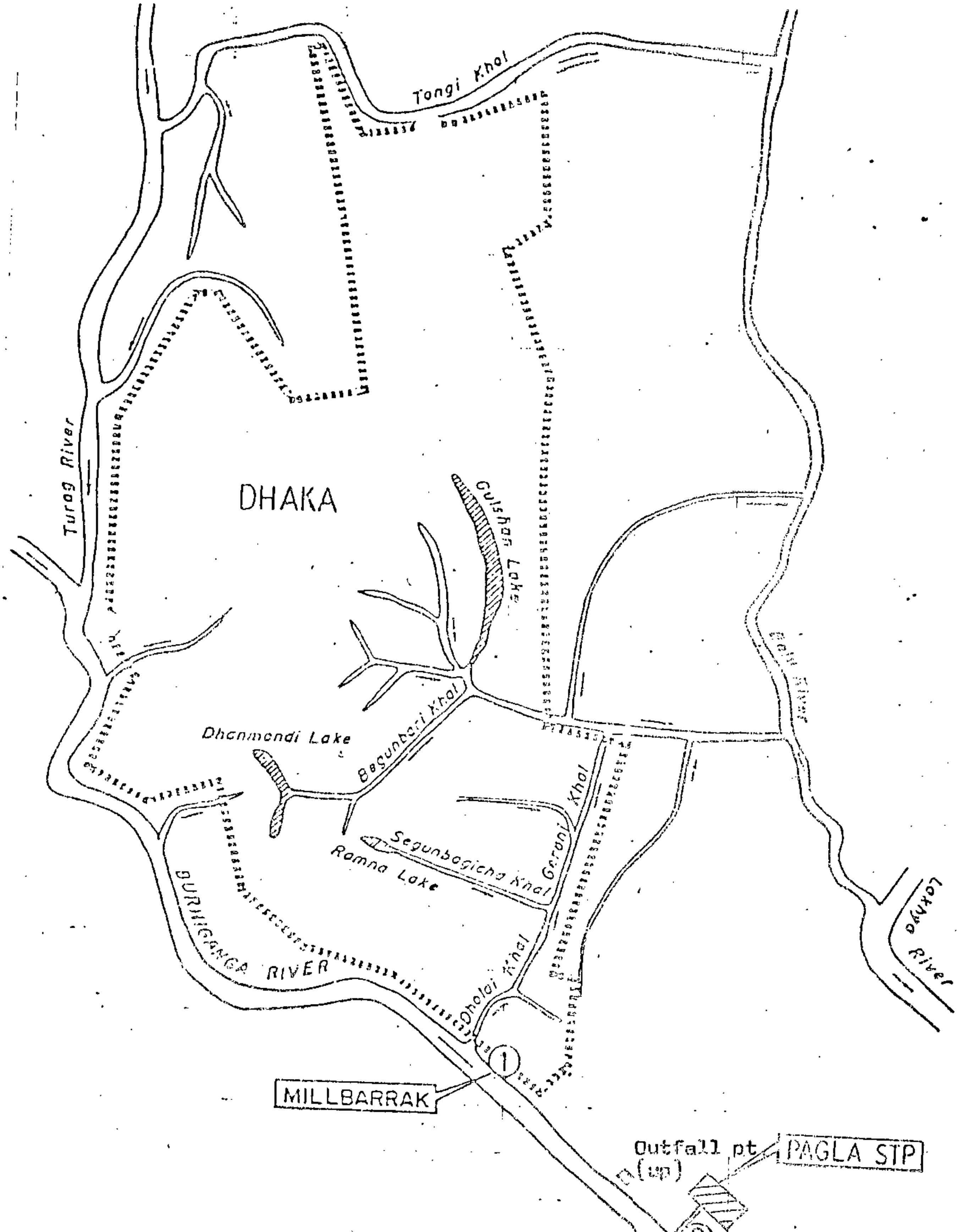


Fig.6.2 Sampling point for water analysis

6.4 Estimation of Pollution Load

6.4.1 Domestic sawage Pollution Load

Wastewater that are discharged throughout the Dhaka city have both a regional and local impact on the water quality. Considering the present and future population of Dhaka city and based on a 0.12 pound BOD per capita per day, the organic pollution from municipal sources is tabulated in Table 6.5. Fig. 6.3 shows the graphical form of the population and corresponding pollution load. Data from fig.6.3 reveals that the present organic pollution within the city area is 5,20,000 pounds BOD per day.

6.4.2 Industrial Pollution Load

On an average day in Dhaka, about 6 million gallons of industrial liquid wastes are produced and discharged to the waterways, rivers, st street drains etc. [25] Fig. 6.4 shows the location and daily quantity of pollution (5 day BOD) discharged from each area into the low-lying areas and/or receiving waters.[25] Industrial wastewater flows and pollution loads are as shown in Table 6.6 [25] Pollution potential of industrial wastes arises from high concentration of organic and inorganic loads, presence of toxic substances, acids or alkalis, oils and other floating substances.

Table 6.5 Pollution load of the Buriganga river

Year	Population	Pollution load (BOD_5 - 20°C) lb/day
1980	27,00,000	3,24,000
1985	35,00,000	4,20,000
1990	50,12,000	6,25,000
1995	60,75,000	8,30,000
2000	90,00,000	10,80,000

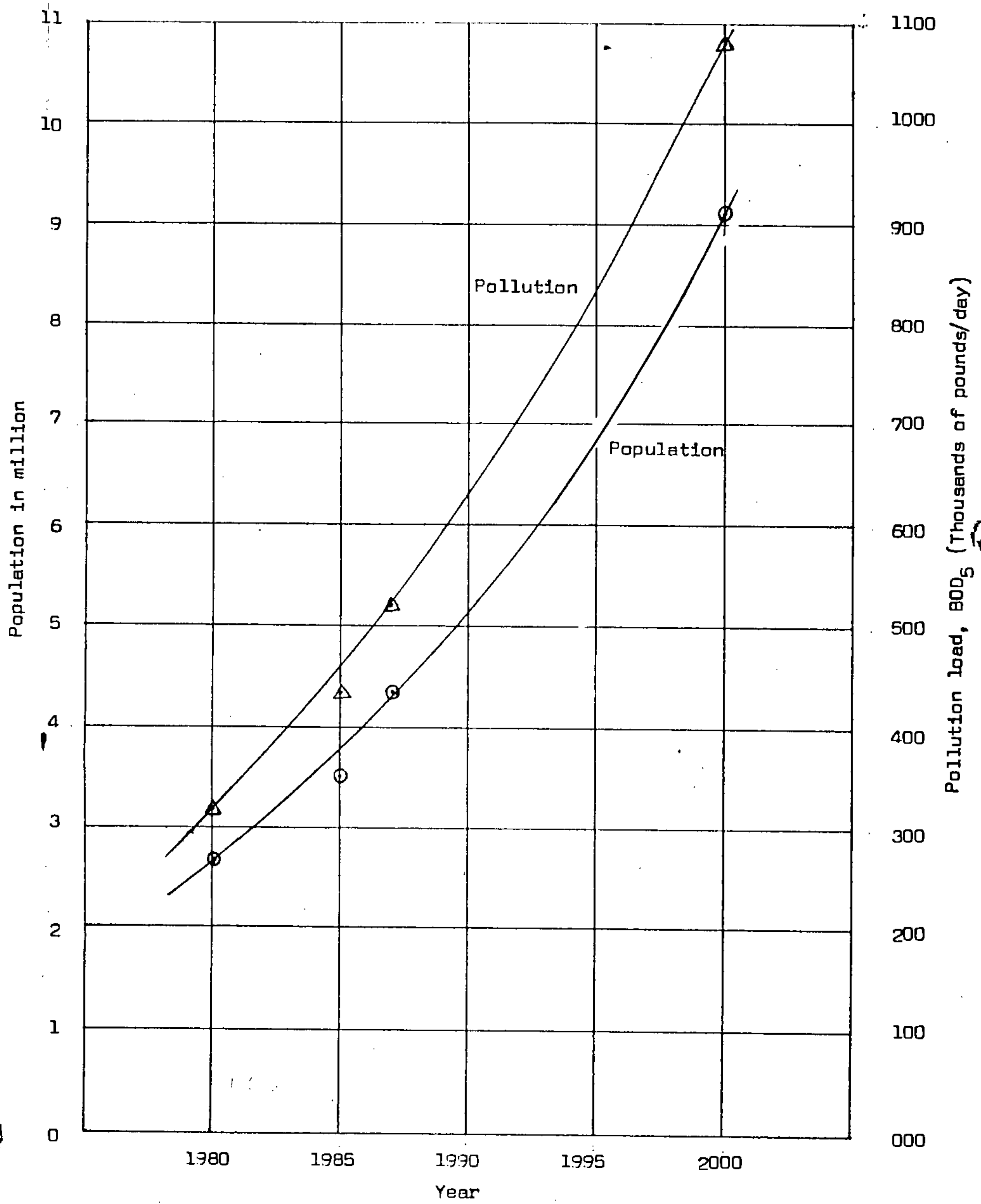


Fig. 6.3 Population and pollution projections

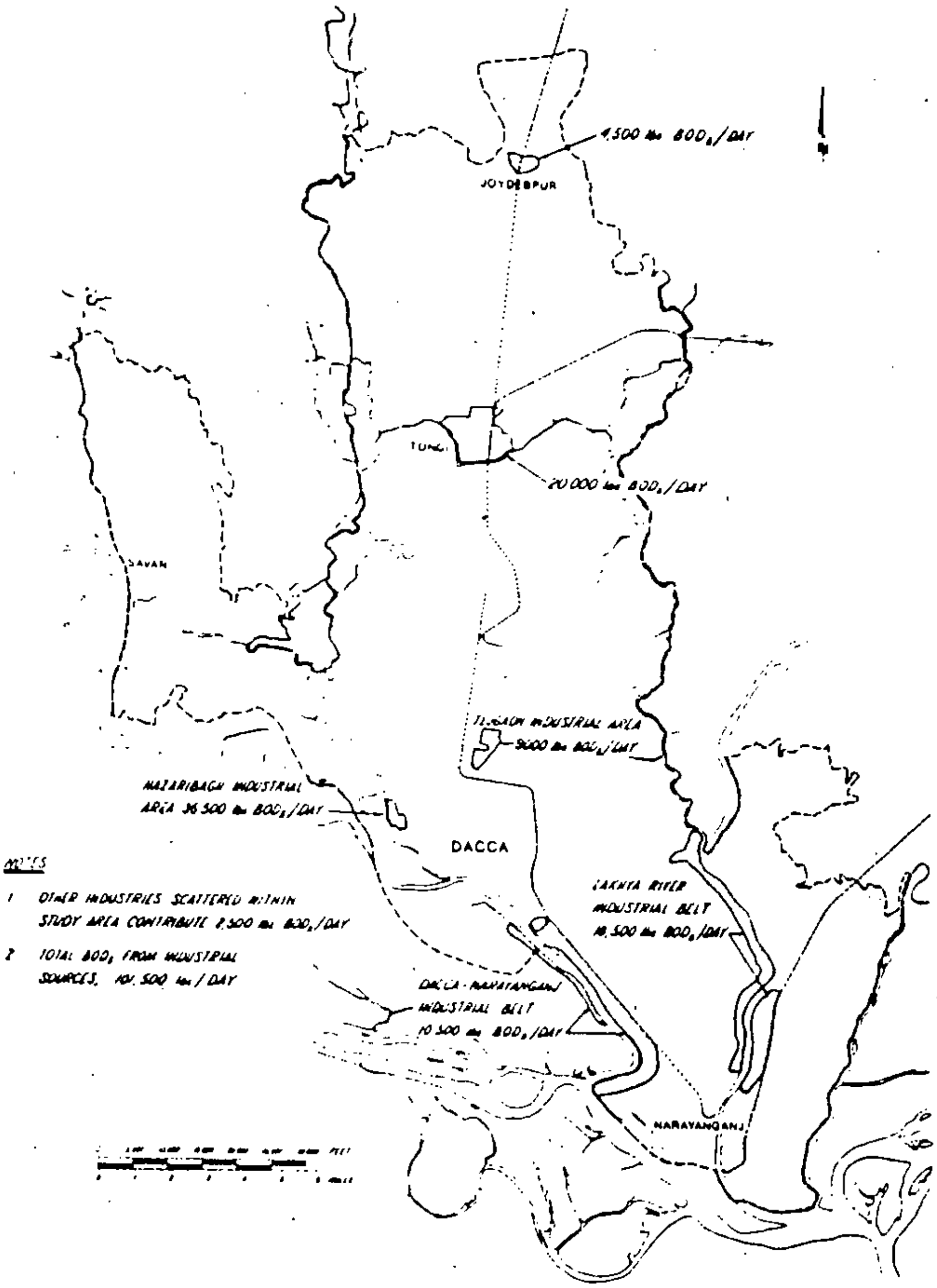


Fig. 6.4 Major sources of industrial pollution [25]

Table 6.6 Major industrial areas and pollution load [25]

Industrial area	Number of pollution producing industries	Industrial wastewater flow(MGD)	Pollution load 5-day BOD (pounds/day)
Hazaribagh	128	2.94	36,500
Tongi	29	0.96	20,000
Tejgaon	61	0.50	9,000
Lakhya river	29	0.96	18,500
Dhaka-N.Ganj	76	0.64	10,500
Joydevpur	3	0.05	4,500
Scattered	4	0.18	2,500
Total	330	6.23	101,500

6.5 Effect on the River of Buriganga

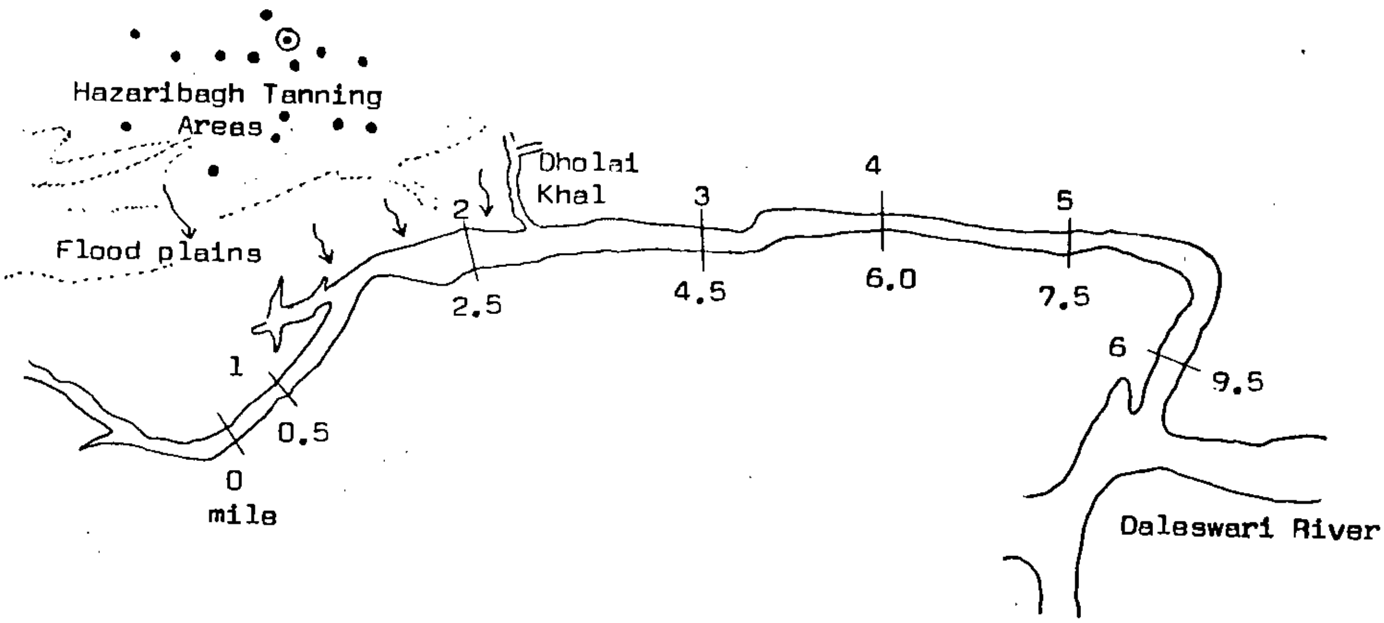
6.5.1 Dissolved Oxygen Sag Curve for Buriganga river

In February 1987, a sampling programme of the Buriganga river was done. Six different sampling stations were established along a 10-mile stretch of river starting from 6 miles upstream of Pagla outfall point upto 4 miles downstream side. Six samples were taken from different depths at each sampling station. Fig. 6.5 shows the location of the sampling station. It was assumed for this study that the flows, temperatures, BOD loads and rate constants at each point remain constant with time. It was further assumed that the concentration of BOD and DO is uniform over the cross-section of any river station. Since, in most cases, there will be daily variations in pollution loads, flows and temperatures, oxygen produced by photosynthesis throughout 24 hours etc., the assumption of steady state conditions will introduce some errors. However, for planning purposes, this simplified version of the DO sag curve determination is sufficient.

The result of the sampling programme of the Buriganga river are summarized in Table 6.7.

Table 6.7 Buriganga river assimilative study results of sampling programme

Sampling station	Av. DO (mg/l)	Av. BOD (mg/l)
1	3.4	5.7
2	3.1	2.6
3	3.0	3.2
4	4.2	2.1
5	6.7	2.2
6	7.8	1.4



1 Water quality sampling station
⊙ Glue factory
← Storm drainage

Fig. 6.5 Buriganga River Sampling Station

Fig. 6.6 shows the DO sag curve of the Buriganga river during the period of low-flows. It is apparent from the oxygen sag curve that the major pollutional impact is from the sources upstream of the direct municipal discharges at Pagla. These upstream pollution sources are principally uncontrolled industrial discharges (specially from Hazaribagh tanning areas), storm sewers and khals and runoff from agricultural land, city streets etc.

Another sampling programme is done in December, 1987. Three different sampling station were selected as shown in Fig. 6.7. The upstream and downstream point of Pagla sewage treatment plant outfall were selected 100 ft. upstream and 100 ft. downstream side respectively. The results of this sampling programme is summarized in Table 6.8.

Table 6.8 Result of sampling test of Buriganga river near Pagla STP out-fall

Sampling station	DO (mg/l)		BOD (mg/l)	
	10.9.1987	14.9.1987	10.9.1987	14.9.1987
Milbarak	4.9	6.7	12.5	9.1
Upstream point	5.6	7.1	1.8	1.5
Downstream point	3.7	4.1	19.0	20.0

From Table 6.7 and Table 6.8, it is seen that the DO and BOD_5 of river water 100 ft. downstream of Pagla outfall is 3.9 mg/l and 19.5 mg/l respectively, whereas the DO of the point 1.5 miles downstream of outfall is 6.7 mg/l and BOD_5 is 2.2 mg/l. These data indicate that a very high degree of mixing occurs in the Buriganga river. Any wastewater discharged into the river is dispersed very quickly. Mixing of the river water will also result in a relatively high degree of reaeration. Algae was found to play a small role in the river flow reaeration. This information and the associated computations lead to the conclusion that the river acts essentially as a large dilution and stabilization pond.

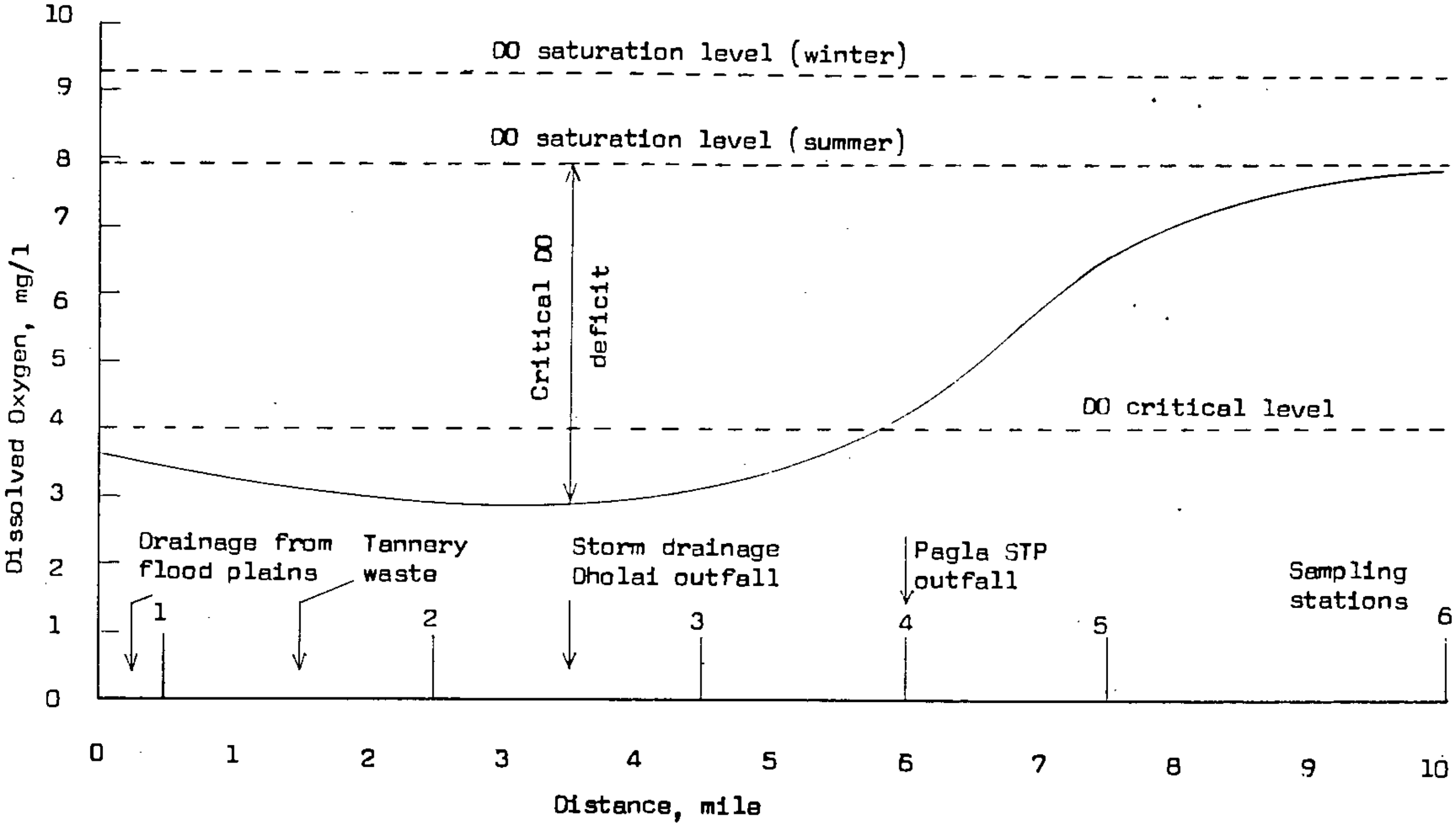


Fig. 6.6 Buriganga river DO sag curve

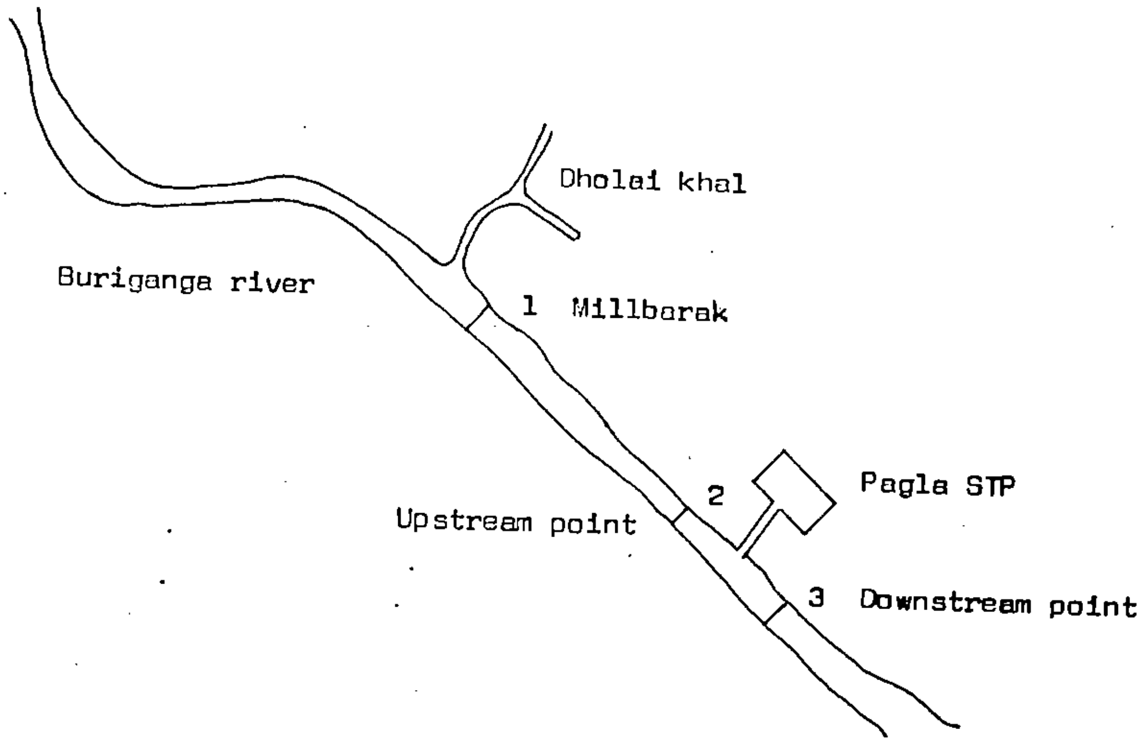


Fig.6.7 Buriganga river sampling station

6.5.2 Discussion

The principal objective of this study was to define a level of treatment for sewerage facilities that would be technically sound and economically viable and that will attain the level of environmental protection desirable for Dhaka city. In Fig. 6.6, from DO sag curve, it is seen that the critical zone is from 0 mile to 5.8 miles where DO is less than 4 mg/l which is required for fish and other aquatic life for their survival. Minimum DO concentration is observed at downstream point of Hazaribagh tannery waste discharge point. From 0 miles to 6 miles (Fig. 6.6), DO level is found less than the minimum DO required for aquatic life for the following reasons:

i) Discharging of Hazaribagh tannery waste: The Hazaribagh area is situated on the south-west periphery of Dhaka city alongside the Buriganga river. Upto 1987, 151 tanneries were identified in Hazaribagh and their locations is shown in Fig.6.8.[5] This industrial area is not served by sewer system. The area is provided with a system of open drains which discharges onto the floodplains of the Buriganga river. Unlined canal carries the wastewater from Hazaribagh to the river about 1.5 km. The average wastewater flow from Hazaribagh into the Buriganga amounts to about 400 m^3/h. Based on an average production day of 10 hours - the daily flow is estimated at 4000 m^3/d.[5]

The wastewater flow from the tanneries contains a very high BOD load in the form of suspended organic matter and various chemicals of which chromium and ammonium are the most toxic components. The discharge of tannery wastewater from Hazaribagh causes serious pollution in the receiving water of which the impact reached further than only the localities in and around Hazaribagh. Since the discharge is directly upstream of the densly populated areas of Dhaka alongside the Buriganga river, the health risks to hundred of thousand citizens have to be considered too. The high concentrations of organic materials, sulphides and organic or ammonium nitrogen rapidly deplete the DO in the receiving water and at the same time the sulphides are extremely toxic to fish.

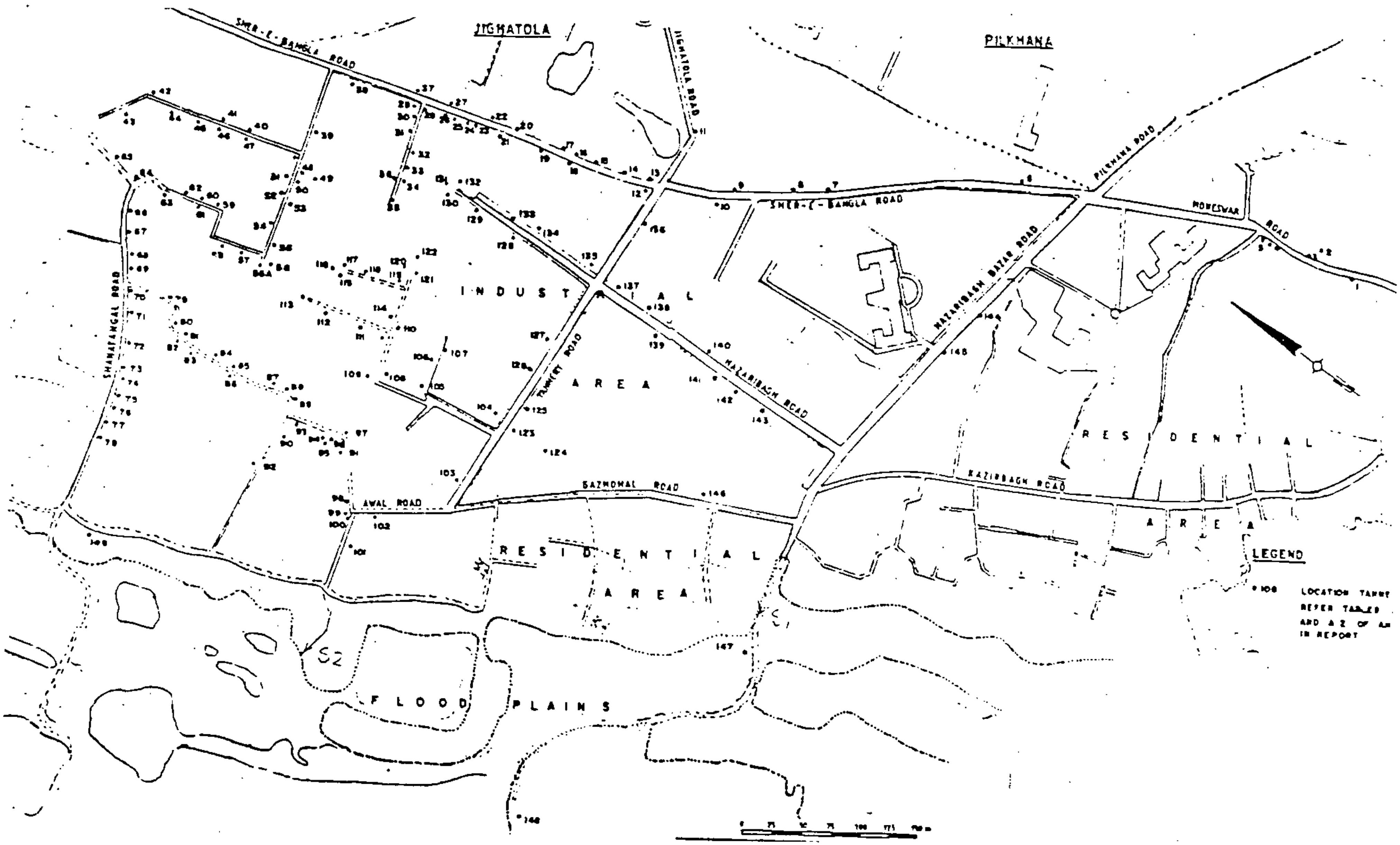


Fig. 6.8 Locations of Tanneries in Hazaribagh areas

ii) Discharging of wastewater by khals and storm drainage: Dhaka city is provided with storm drainage pipes, having a total length of 109 km and a diameter ranging from 0.3 m to 3.0 m. Location of trunk drainage pipes is also illustrated in Fig. 6.9. Wastewater is directly discharge onto the Buriganga river through the major four drainage pipes as indicated by S3, S4, S5 & S6 in Fig. 6.9. [17]

There are a number of khals in Dhaka city of which total length is 53 km. Major khals included are Dholai khal, Segunbagicha khal, Gerani khal and Begunbari khal. Location of khals is as illustrated in Fig. 6.10.[17]

6.6 Disposal of Effluent

6.6.1 Effluent Quality Standard

The average BOD of Dhaka city sewage is around 260 mg/l which requires 13 times reduction by a efficient treatment process for inoffensive disposal in river water. As the volume of wastewater is increasing with industrialization and rapid growth of population, therefore, it is required to formulate a standard effluent quality to control the pollution of river water. [17]

The Royal Commission adopted two basic effluent quality parameters, BOD and suspended solids and proposed that normal treated effluent should have a quality of 20 mg/l BOD and 30 mg/l SS or better. The Royal Commission's 20/30 standard has been widely adopted although sometimes a stringent standard may be required for streams receiving effluent with dilution factor less than 8. The tolerance limits suggested by Indian Standard Institution for industrial effluent discharged into inland water are 30 mg/l for BOD, 100 mg/l for suspended solids, 0.1 mg/l for hexavalent chromium and 5.5 to 9.0 for P^H. The magnitude of

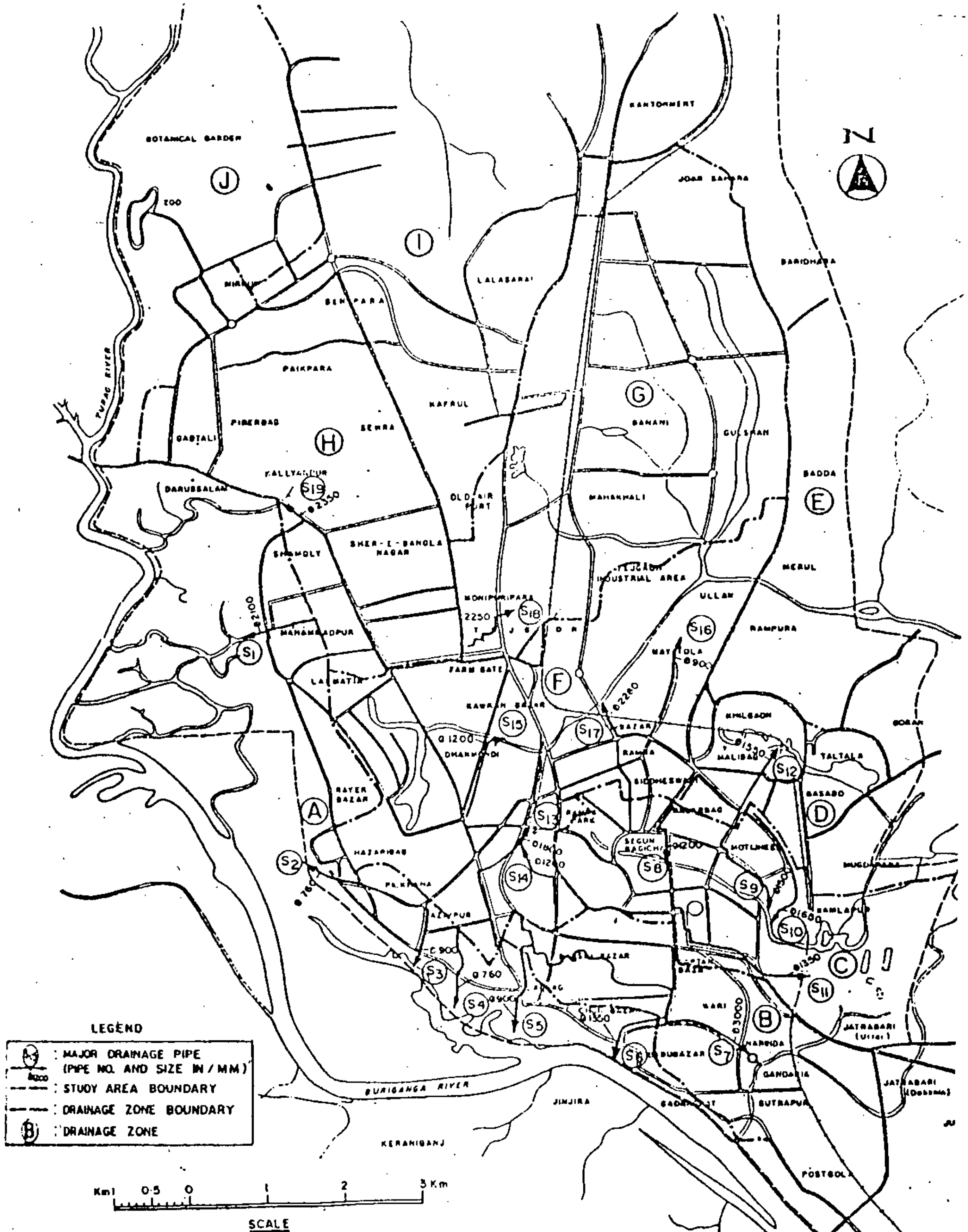


Fig.6.9 Existing drainage facilities of Dhaka city by drainage pipes (17)

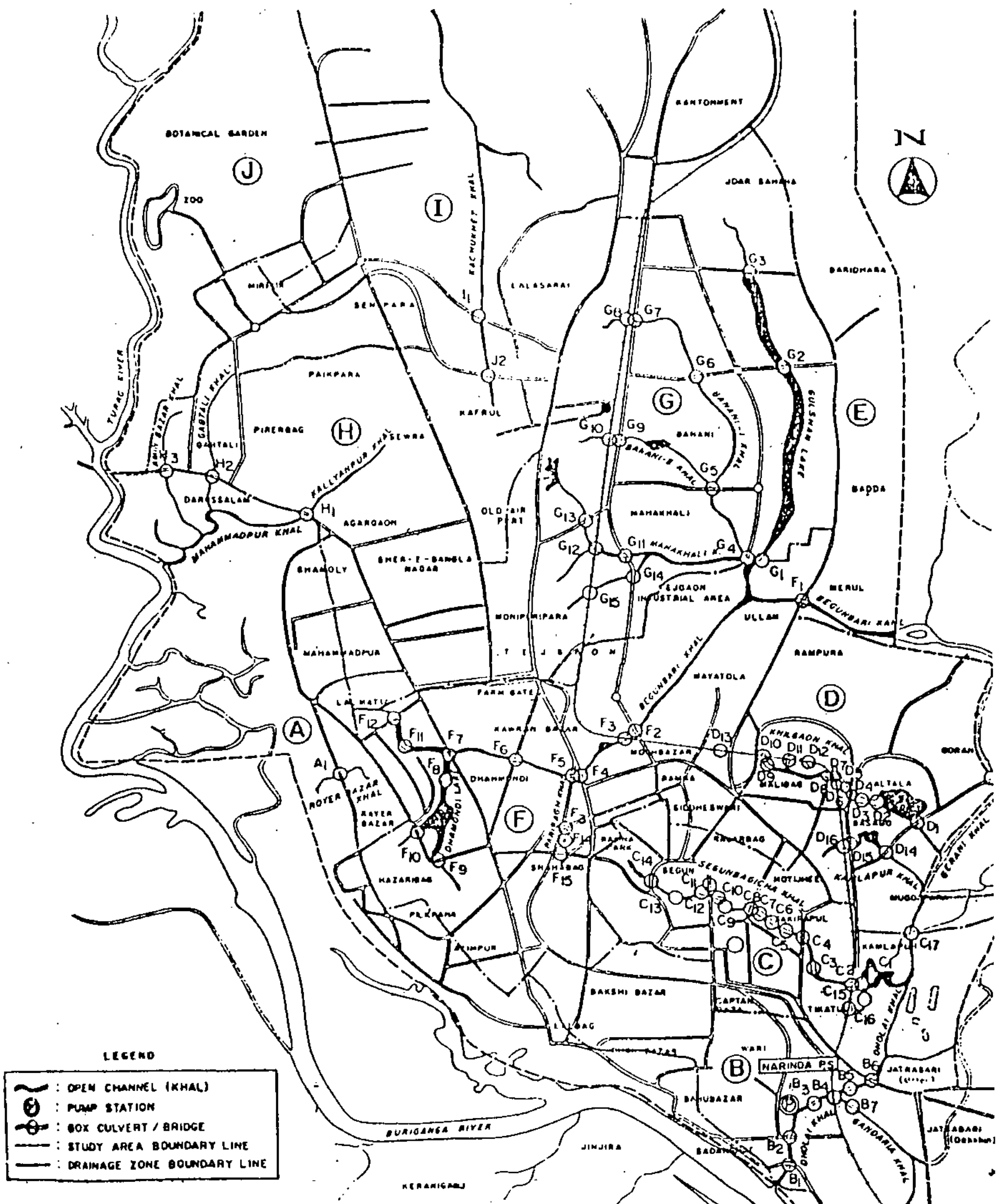


Fig.6.10 Existing drainage facilities by khals (17)

polluting loads received by the river system can be visualized by comparing the effluent quality parameters with the tolerance limits suggested by the Royal Commission and Indian Standard Institution.

Bangladesh does not have a effluent quality standard of its own to guide the design of treatment facilities and regulate the quality of effluents discharged in water. Considering the conditions exist in the country, Bangladesh should formulate a workable effluent quality standard to protect the environment of the natural water resources from degradation.

6.6.2 Determination of effluent standard

The design flow-rate of Pagla sewage treatment plant is 40 IMGD (183,000 m^3/day). The maximum lifting capacity obtained from the actual pump operation record for the past one year is 88,000 m^3/day. With the the addition of approximately 25,000 m^3/day which is apparently a by-pass outfall,caused by the failure of the pump or the outfall of some sewage, it will reach 113,000 m^3/day. On the other hand, estimated sewage flow rate calculated from the water consumption is 116,000 m^3/day. A master plan of the plant will be made to meet the capacity of 183,000 m^3/day. Therefore, outfall flow rate of Pagla treatment plant is considered as 183,000 m^3/day. (18)

According to the Feasibility Report (April, 1981), the flow rate of the Buriganga river seems to be approximately 570 m^3/sec. (18)

As the Buriganga river to which the treated water is discharged has sufficient water volume even in dry season, sufficient dilution of the outfall water and the river's spontaneous rehabilitating function are expected. Therefore, medium grade treatment (BOD = 60 mg/l or below) is selected as the target quality of the outfall water.

The average BOD_5 of the Buriganga river is considered as approximately 2 mg/l.

6.6.3 Influence on the water quality of the Buriganga river

The following shows a trial calculation for the expected water quality (BOD_5) on the downstream side of the outfall point in the case of medium grade treatment.

Conditions:

Flow rate of the Buriganga river:
Q_1 = Approximately 570 m^3/sec (dry season)

Average water quality of the river (BOD_5):
S_1 = Approximately 2 mg/l

Outfall flow rate of Pagla treatment plant
Q_2 = 183,000 m^3/day = 2.1 m^3/sec

Outfall water quality (BOD_5):
S_2 = 60 mg/l

If the outfall water is mixed up with the river water on the downstream side of the outfall point, the quality of the river water will be as follows:

$$S_3 = \frac{570 \times 2 + 2.1 \times 60}{570 + 2.1} = 2.2 \text{ mg/l} < 3 \text{ mg/l}.$$

From the preceding analysis of assimilative capacity and pollution sources of the Buriganga river, it is concluded that the level of treatment achievable by pond systems will be adequate to prevent significant degradation of river water quality due to treatment plant discharges. Thus an effluent quality of 60 mg/l BOD_5 will be considered the recommended treatment objective for sewage treatment facilities.

CHAPTER 7

THE METHODS OF SEWAGE TREATMENT

7.1 General

The large volume of sewage projected for Dhaka city during a planning period must be collected, transported, treated and disposed of properly to prevent disease transmission and adverse environmental impacts. Many systems have been developed to transport and treat sewage that are used successfully by the municipalities throught the world.

Based on the basic policy for selecting the method of treatment, different alternative biological processes have been studied and evaluated to select the suitable and most effective method of sewage treatment for Dhaka city. Sewage samples have been collected from the different locations of Dhaka city's sewerage system and it has been characterized. Field study, investigation and laboratory analysis shown that the BOD_5 of raw sewage is varying from 210 to 288 mg/l. Other characteristics of sewage like P^H, temperature, color, turbidity, TS, DS and SS are also considered in investigating the methods of sewage treatment and selecting the suitable one. A complete study was conducted for formulation of alternative sewage treatment schemes that will provide sanitary disposal of sewage without degrading the environment. Not all systems are well-suited to every set of climatic, topographic, economic and social conditions. To obtain the desired degree of treatment, in view of the conditions of Dhaka city, the climate, economy, population, habit of the people, topographical and geological condition, status of infrastructure and other socio-economic factors were considered.

7.2 Basic Policy for selecting Treatment Method

In selecting the method of sewage treatment for Dhaka city, the following points were taken as a guide line:

i) To employ a system which is effective in treatment and reliable in operation and maintenance.

ii) To employ a system whose power consumption is minimized as much as possible, because of the difficulties in electric power supply and economic situation.

iii) To employ a system which requires less construction materials that depend on the import and also minimizes the construction cost.

iv) To employ a system whose operation and maintenance are as easy as possible requiring little advanced technology.

v) To employ a system whose treatment level can be easily upgraded in future.

vi) To employ a system whose maintenance cost is minimized as much as possible.

vii) Target of the outfall water shall be placed upon the quality of medium grade treatment.

7.3 Basic Design Criteria and Data

The following are the basic design criteria and data which are considered in selecting the suitable method of sewage treatment for Dhaka city:

i) Physical, chemical and biological characteristics: Table 7.1 shows the physical, chemical and biological characteristics of sewage of Dhaka city.

ii) Population: The present population of Dhaka city is 4.32 million. Dhaka WASA is supplying water to approximately 3.3 million people whose water supply volume is 92.50 IMGD. Presumed population utilizing the sewerage facilities is approximately 1.151 million.

iii) Quantity of sewage: Sewage flow rate was calculated on an assumption that 70% of domestic water consumption would be discharged to the sewerage system. According to the consumption 83 litres/head/day sewage flow rate is 73,800 m^3/day. Considering other sources of supply, infiltration water, illegal storm, the flow rate is as follows:

Q_d mean = 96,000 m^3/day in dry season

Q_d max = 116,000 m^3/day in rainy season

Q_h max = Q_d max X 1.7 = 147,000 m^3/day

Seasonal variation of flow is 20.83% of the dry season flow.

Table 7.1 Characteristics of Sewage of Dhaka city

Parameters	Values	
	Minimum	Maximum
Temperature	11.0 C	35°C
p^H	7.2	8.0
Color	400	1440 ppm
Turbidity	180	420 ppm
Total solids	497	2790 ppm
BOD_5	210	288 mg/l
COD	320	481 mg/l
BOD reaction rate constant (k)	0.25	0.28
Ultimate BOD (L)	420 mg/l	

iv) Target quality of outfall water: Buriganga river to which the treated water is discharged has sufficient water volume even in dry season, therefore, sufficient dilution of the outfall water and the river's spontaneous rehabilitating function are certainly expected. To provide a better environment for the residents along the left bank on the downstream side of the outfall point. Therefore, medium grade treatment is determined as the target quality of the outfall water.

Medium grade treatment:

BOD :	60 mg/1 or below
SS :	120 mg/1 or below
Colony of Colon Bacillus :	3,000 pcs/m^3 or below

v) Availability of land: Land is available around Dhaka city for sewage treatment plant at a reasonable price. There is a flexibility in utilizing the land.

vi) Indegenous materials: In selecting the suitable method of sewage treatment, importance is given in using the locally available materials on priority basis.

7.4 Selection of alternative sewage treatment method

A variety of processes have been introduced and used as wastewater treatment system. Considering the desired degree of treatment, technical feasibility, availability of the materials, simplicity of operation and maintenançe the following alternative systems are evaluated carefully and compared with each other on technical suitability (engineering analysis) and economy (cost analysis) to determine the suitable and economic method of sewage treatment:

i) Waste Stabilization Pond
ii) Oxidation Ditch
iii) Aerated Lagoon
iv) Biological Filtration

All four systems posses the virtue of relative simplicity in operation. Other systems were rejected either because they involved excessively sophisticated technology, highly skilled operators, were very sensitive to electrical power failure or were so similar to one of the selected systems that further analysis appeared redundant.

Waste Stabilization Pond: The stabilization pond consists of a large land area with earthen dikes similar to the one at the present Pagla treatment facility. Algae growing in the sewage near the pond surface produce oxygen that is used by other microorganisms throughout the pond depth (up to about 5 ft.). These microorganisms ingest organic matter, therby stabilizing the sewage.

Stabilization ponds require very little care and maintenance in their operation and are the simplest of the systems studied. No clarifiers are required, and the sludge is built up in the ponds very gradually, requiring cleaning only once in 5 - 10 years. The effluent quality is generally acceptable although it is not as good as the other systems. The major drawback of stabilization ponds is the requirement of a large land area.

Oxidation Ditch: This ditch is a modification of the conventional activated sludge process, which has the advantages of not requiring primary clarification and of being less sensitive to changes in its operation. The oxidation ditch is a large, circular concrete-lined channel in which wastewater circulates, impelled by brush rotors that function to bring the sewage in concrete with oxygen in the air. Sludge returned from the secondary clarifier to the channel contains large quantities of microorganisms that ingest organic matter in the sewage, reproduce and grow, and are then separated in the secondary clarifier. A portion of the sludge that is settled in the clarifier must be disposed of, the remainder is returned to the oxidation ditch.

Oxidation ditches are capable of achieving a very high level of treatment. However, as with the trickling filter, they have the disadvantage that the large quantities of sludge produced must be properly disposed of.

Aerated Lagoon: Aerated lagoons function similarly to stabilization ponds, except that oxygen is provided by mechanical aerators rather than by algae. As a result, the depth can be increased to 10 - 20 ft. and the land area reduced proportionately. The treatment capacity of an existing stabilization pond can be expanded greatly by increasing the liquid depth and by adding mechanical aerators, thereby converting it to an aerated lagoon. Aerated lagoons require no clarification units and cleaning is required only once in 5 to 10 years.

Biological Filtration (Trickling Filter): The trickling filter is a large tank that is filled with rocks or other similar media. Clarified sewage is sprayed over the top of the filter, whereupon it trickles through the rocks to a collection chamber at the bottom. As the sewage passes through the rock bed, microorganisms growing on the surface of the individual rocks ingest the dissolved and suspended organic matter in the sewage, using the organic matter as food to support their further growth. Eventually the microorganisms become so numerous that some are unable to remain attached to the rock surfaces, these are sloughed off with the passing wastewater and must be seperated in a subsequent clarifier.

Trickling filter are relatively insensitive to large fluctuations in flow and organic loading and are fairly simple to operate. However, one drawback of trickling filters is that they must be preceded and followed by clarifiers, and the sludge produced must be treated and disposed of daily.

Before going to the selection of a suitable method of sewage treatment of Dhaka city, an extensive literature on the same issue was reviewed to determine the most appropriate method of sewage treatment.

7.5 Previous Recommendations for selection of Sewage Treatment Method

In 1981, RMP International Ltd. & James M. Montgomery, Consulting Engineers, Inc. conducted a study on selection of sewage treatment method for Dhaka city. They evaluated the following four types of treatment systems:

i) Trickling Filter
ii) Oxidation Ditch
iii) Stabilization Ponds
iv) Aerated Lagoon

The most feasible combinations of the component of sewage treatment systems are shown in Fig. 7.1 and Fig. 7.2. Cost (January 1980 shadow cost)

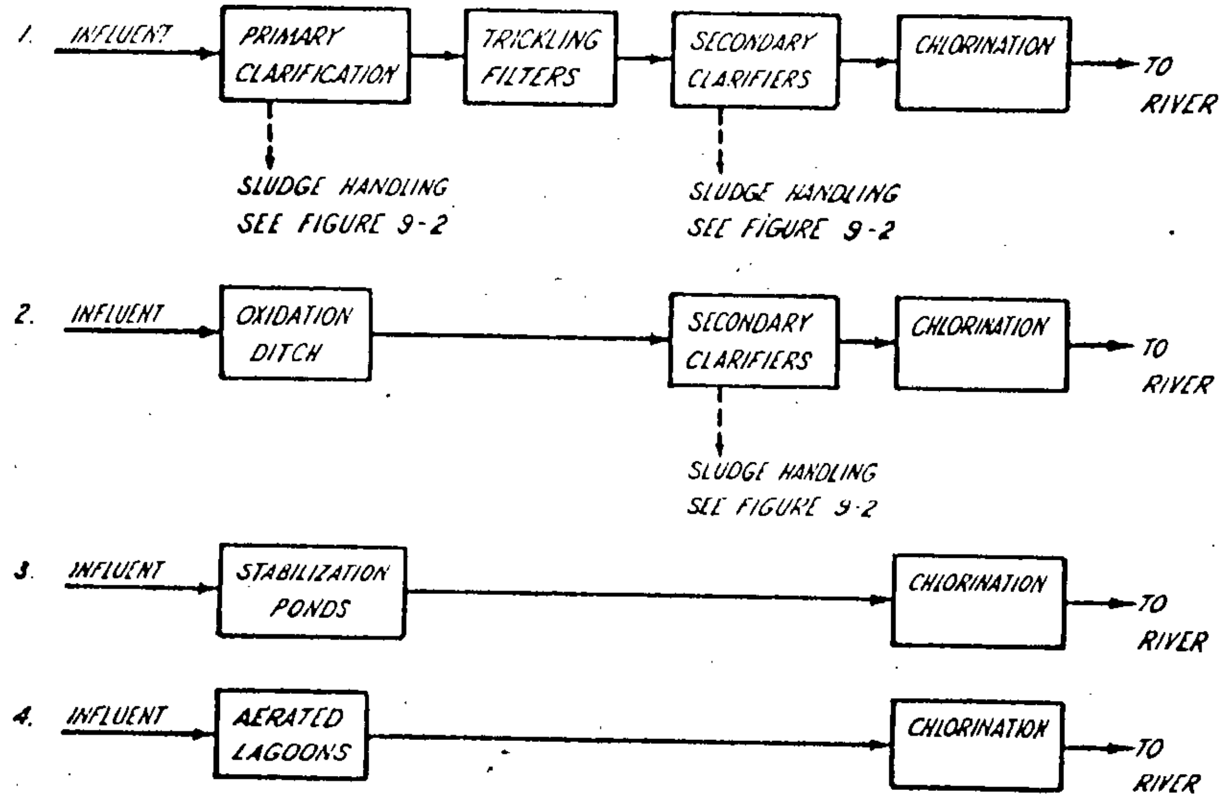
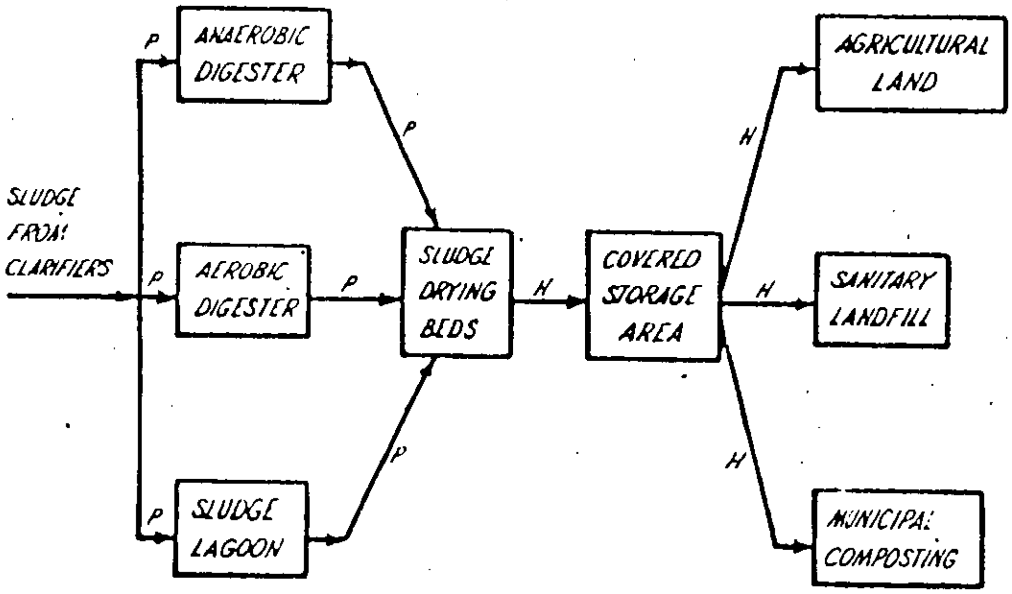


Fig: 7.1 Sewage Treatment Plant, Alternative Process Trains[25]



P = PIPED TRANSPORT OF LIQUID SLUDGE
H = HAULED TRANSPORT OF DRIED SLUDGE

Fig. 7.2 Sludge Handling, Alternative Process Train [25]

Table 7.2 Replcement Interval and Component Costs for (25)
Conventional Sewage Treatment Plants[a,b] (Million Takas)

Component	Replacement Interval (years)	Initial Cost	Replacement		O&M		Salvage		Tota Prese Wort
			Cost	Present Worth[c]	Yearly	Present Worth[c]	Yearly	Present Worth[c]	
Influent pumping	15	18.0	9.0	2.2	1.3	12.4	-	-	32.6
Primary clarifier (& sludge pumping)	15	84.2	9.4	2.2	2.2	21.1	-	-	107.5
Trickling filter (and pumping)	15	168.7	42.4	10.1	9.3	87.4	-	-	266.2
Secondary clarifier (& sludge pumping)	15	168.5	18.7	4.5	4.46	42.1	-	-	215.1
Oxidation ditch	15	290.2	114.1	27.3	30.0	282.9	117.0	6.8	593.6
Aerated lagoons	15	244.8	27.5	6.6	14.8	139.4	80.0	4.6	386.2
Stabilization ponds	30	602.6	-	-	7.6	71.0	320.0	18.2	655.4
Effluent pumping and outfall	15	40.7	9.0	2.2	1.32	12.4	7.6	0.4	54.9
Aerobic digester	15	128.0	44.2	10.6	24.3	229.1	-	-	367.7
Anaerobic digester	30	192.0	-	-	3.8	36.2	-	-	228.2
Sludge lagoon	30	45.4	-	-	0.6	5.4	16.0	1.0	49.8
Sludge drying beds	30	371.2	-	-	6.1	57.9	89.6	5.1	424.0
Sludge pumping	15	16.6	16.6	3.8	1.3	12.5	-	-	32.9
Sludge storage	30	63.4	-	-	1.0	9.0	16.0	1.0	71.4
Spreading on agricultural land (and hauling)	NA	-	-	-	12.2	114.6	-	-	114.6
Sanitary landfill (and hauling)	100	96.0	96.0	51.2	20.2	190.1	144.0	8.3	329.0
Municipal composting (and hauling)	NA	-	-	-	24.3	229.1	-	-	229.1

[a]Assumed average flow capacity of 33.3 IMGD for comparison purposes, January 1980 shadow costs.
[b]The raw sewage BOD_5 value used in the Draft Interim Feasibility Report has been modified in this report, and the component costs have been revised.
[c]30-year planning period; 10 percent discount rate.

for the sewage treatment and sludge handling component systems have been developed and are presented in Table 7.2 for a typical case of 33.3 million imperial gallons per day (IMGD) average sewage flow. The total cost of the most feasible combinations of the component systems (Fig. 7.1) are listed in Table 7.3, expressed on a present-worth basis for purposes of comparison.

From the cost estimates presented in Table 7.3, it was apparent that only treatment system having little or no sludge handling would be the cost effective, i.e., system (iii) & (iv). The choice between Stabilization ponds and Aerated lagoons was primarily a matter of land cost and sewage flow, since aerated lagoons cost more to construct and operate but use less land to treat the same flow. The flow above which aerated lagoons are more economical than stabilization ponds was analyzed for various land prices and the results of the analysis are shown graphically in Fig. 7.3. It was apparent that with the high land prices found in most of the study area and the anticipated large sewage flows, aerated lagoons would be the more cost-effective treatment method.

In 1985, another study work was conducted by Japanese Study Team together with DWASA for selecting the suitable method of sewage treatment for Dhaka city. The following five alternative biological treatment processes have been evaluated to select the most desirable treatment method:

i) Anaerobic Pond
ii) Oxidation Ditch
iii) Aerated Lagoon
iv) Biological Filtration
v) Activated Sludge

Each of the five alternatives had been evaluated for four major features, namely: a) cost effectiveness b) simplicity of process c) ease of process operation and maintenance and iv) treatment effeciency, reliability of process operation and maintenance.

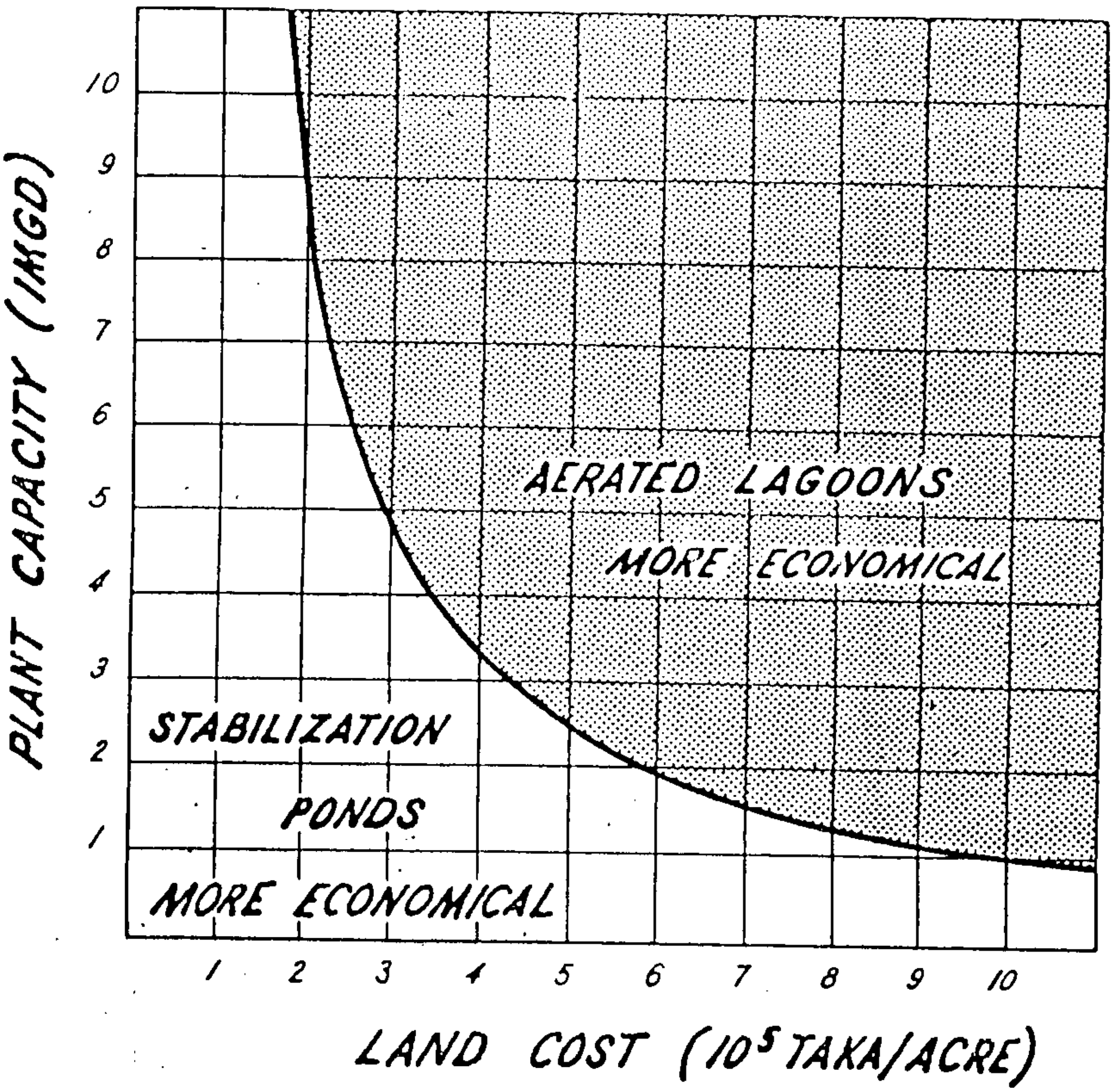
The study team reported that both anaerobic pond and oxidation pond systems were the least expensive among the alternative plans and easy to construct, operate and maintain. There were no mechanical equipment to

Table 7.3 Cost Summary of Complete Sewage Treatment System (25)

Components	Present Worth[a] (million takas)
System 1: Trickling Filter	
Influent pumping	32.6
Primary clarifier	107.5
Trickling filter	226.2
Secondary clarifier	215.1
Effluent pumping and outfall	54.9
Anaerobic digester	228.2
Sludge pumping	32.9
Sludge drying bed	424.0
Sludge storage	71.4
Spreading on farmland	114.6
Total present worth	1,547.4
System 2: Oxidation Ditch	
Influent pumping	32.6
Oxidation ditch	593.6
Secondary clarifier	215.1
Effluent pumping and outfall	54.9
Sludge lagoon	49.8
Sludge pumping	32.9
Sludge drying bed	424.0
Sludge storage	71.4
Sanitary landfill	329.0
Total present worth	1,803.3
System 3: Stabilization Ponds	
Influent pumping	32.6
Stabilization pond	655.4
Effluent pumping and outfall	54.9
Total present worth	742.9
System 4: Aerated Lagoons	
Influent pumping	32.6
Aerated lagoons	386.1
Effluent pumping and outfall	54.9
Total present worth	473.6

[a] 30-year planning period; 10 percent discount rate.

Fig. 7.3 Cost of Aerated Lagoons versus Stabilization Ponds (as a function of plant capacity and land cost) (25)



maintain, however, the large space requirement was the governing factor to rules out these processes from further consideration. The team also mentioned that the available land space for the expansion of the existing treatment works was not sufficient to provide facilities to treat the sewage inflow in future. They have shown that the required land space for treating the sewage from the 8 million inhabitants in the year 2010 would be about 1300 ha for oxidation ponds (if the BOD loading of 300 kg/ha is applied). Also, the present anaerobic ponds system can not reduce the BOD below 20 mg/l within the detention time of a few days, and therefore, can not produce a high quality effluent to prevent further pollution of river water.

The aerated lagoons system required less land space than the oxidation ponds and anaerobic ponds, and had various other advantages, however, the energy consumption was the highest among the alternatives. Although many advantages were realized, the high energy requirements did not overcome the advantages and therefore, this process cancelled out from further study.

The activated sludge process had many such advantages as small space requirements, reliability of operation, high quality of effluent etc., however, the power requirements were high. The overall costs were also high compared with other alternatives. In view of the facts that both capital and recurrent costs were prohibitively high and operation and control of the process were complicated, this process was screened.

The biological filter process required energy only for lifting up the sewage to the biofilters but no other power is required for the sewage aeration, thus the power consumption was the lowest among other mechanically aerated methods. Besides, this process was stable under condition of fluctuating hydraulic and organic loads, requiring simple operation and control. Maintenance of the units was also simple, because the main mechanical components were those to distribute the sewage, and because no drive units were provided for each set of the distributor. The minimum number of moving components make the servicing very easy, only occasional checking or greasing would be required.

According to the Japanese team, the above discussion had led to the conclusion that the trickling filter process should be adopted to the new sewage treatment system. The new biological filters by rotary distributors would treat the sewage effluent from the existing anaerobic ponds, thus the costs were considerably saved. The excess sludge is to be introduced to the sand sludge drying bed.

The proposed treatment plant flow diagram and plot plan are shown in Fig. 7.4 and Fig. 7.5 respectively.

The Japanese team summarized the advantages of trickling filter process as follows:

i) Low operation and maintenance cost
ii) Production of a high quality effluent, particularly in hot climate regions like Dhaka
iii) Simple structure of the facilities
iv) Easy operation and maintenance
v) Simple process and reliability of operation particularly against the fluctuation of hydraulic and organic loads
vi) Low excess sludge production
vii) Low power cost requirement
viii) Low capital cost requirement

In 1987, the Japanese Government dispatched a preliminary study mission to Bangladesh through Japan International Cooperation Agency (JICA). Based on the results of the study by the delegation, a basic design study team was sent. The following three systems were studied as possible alternatives by the study team:

i) Facultative Lagoon
ii) High Rate Trickling Filter
iii) Aerated Facultative Lagoon

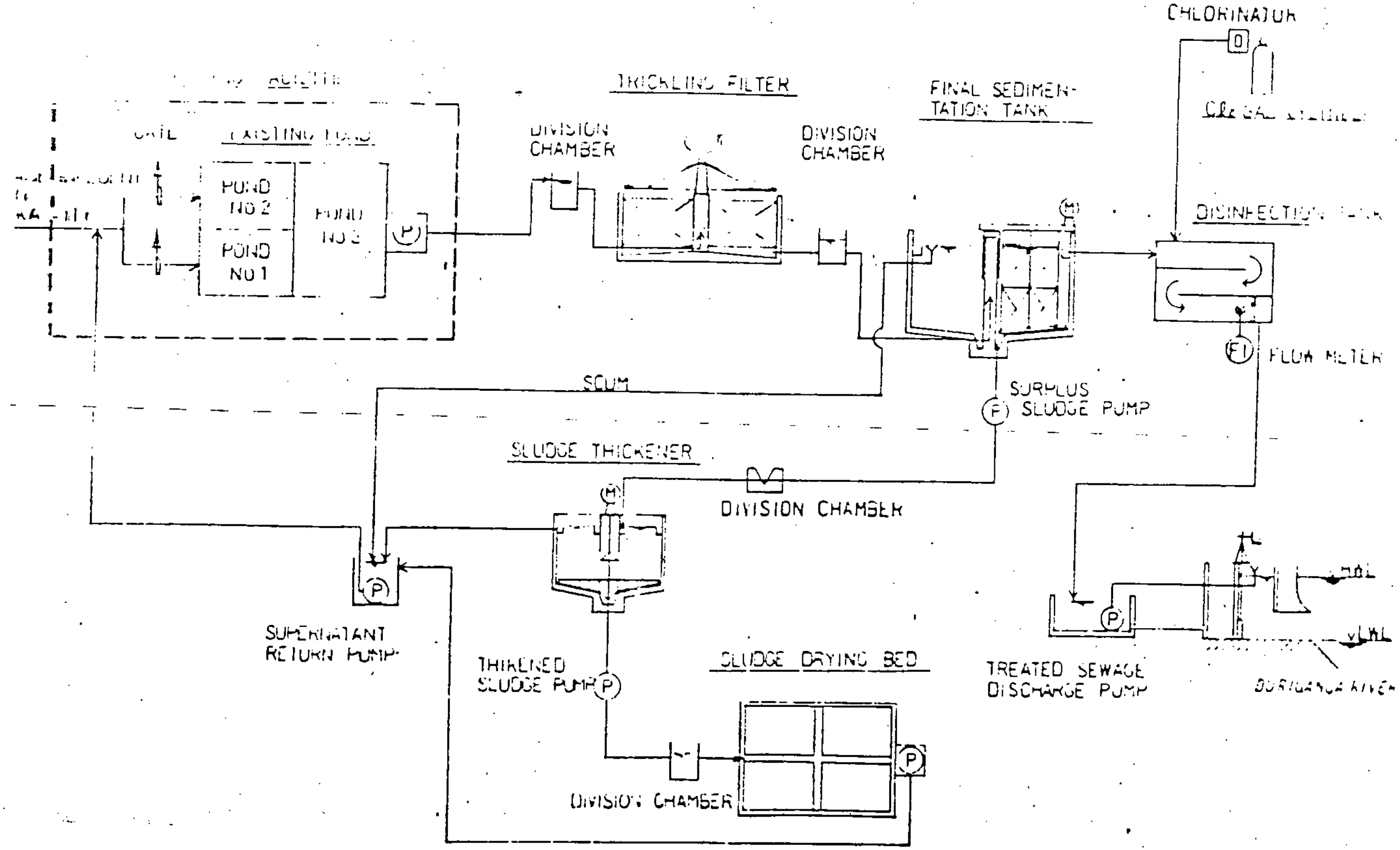
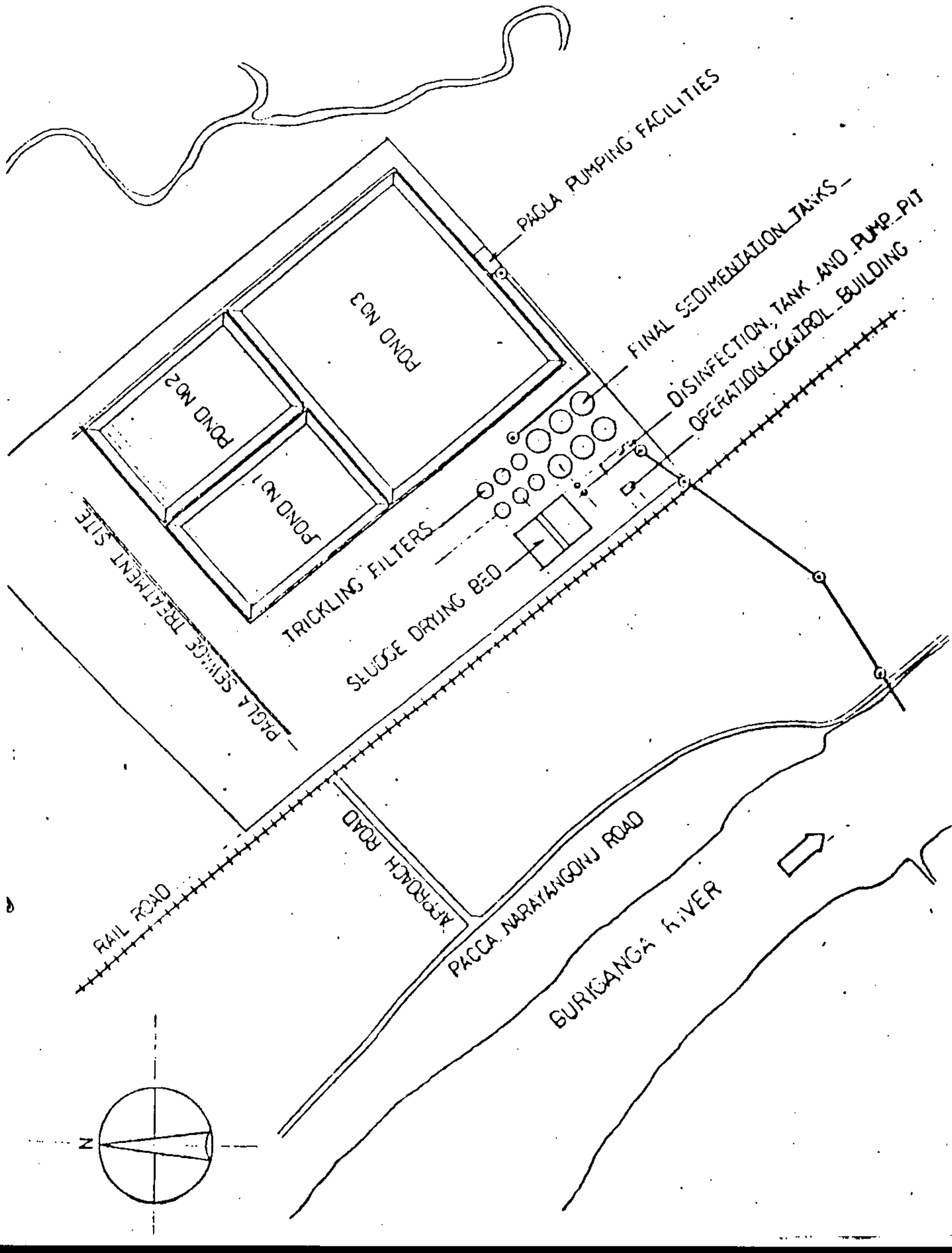


Fig. 7.4 Schematic Flow Diagram of Advanced Sewage Treatment Plant Proposed

Fig. 7.5 Plot Plan of Advanced Sewage Treatment Plant Proposed



In order to effectively utilize the existing facultative lagoon of the treatment plant and also to reduce the influent load on the secondary treatment facility by providing primary treatment facility as required, the following combinations were proposed as alternative:

i) Primary Sedimentation Tank + Facultative Lagoon (existing facility + new facility)

ii) Primary Sedimentation Tank + High Rate Trickling Filter + Sedimentation Tank (existing lagoon)

iii) Aerated Facultative Lagoon + Sedimentation Tank (part of the existing lagoon).

The flow diagram of the above three cases are shown in Fig. 7.6. Fig. 7.7 shows the flow and major facilities of each alternatives.

Case 1 gave priority to the improvement of the existing lagoon and the upgrading of treatment capacity of the plant. In order to secure the treatment and to reduce the influent load on the subsequent lagoon, primary treatment would be conducted in the primary sedimentation tank and secondary treatment would be managed by the facultative lagoons including the existing one. Although the quality of the treated water might be slightly fluctuated from season to season, especially by temperature, medium grade treatment will be achieved.

Case 2 aimed at the effective utilization of the space as well as the secure treatment. For the same reason as case 1, a primary sedimentation tank would be provided and the secondary treatment would be conducted by high rate trickling filter.

Existing lagoon would be used as a sedimentation tank. This alternative also could satisfy the medium grade treatment. In addition to sludge scraper and sludge pump, rotating trickler would be required.

Case 3 aimed at the expansion of the existing lagoon and the improvement of the treatment capacity by mechanical aerator. In order to improve the removal efficiency at the subsequent stage following the aerated lagoon,

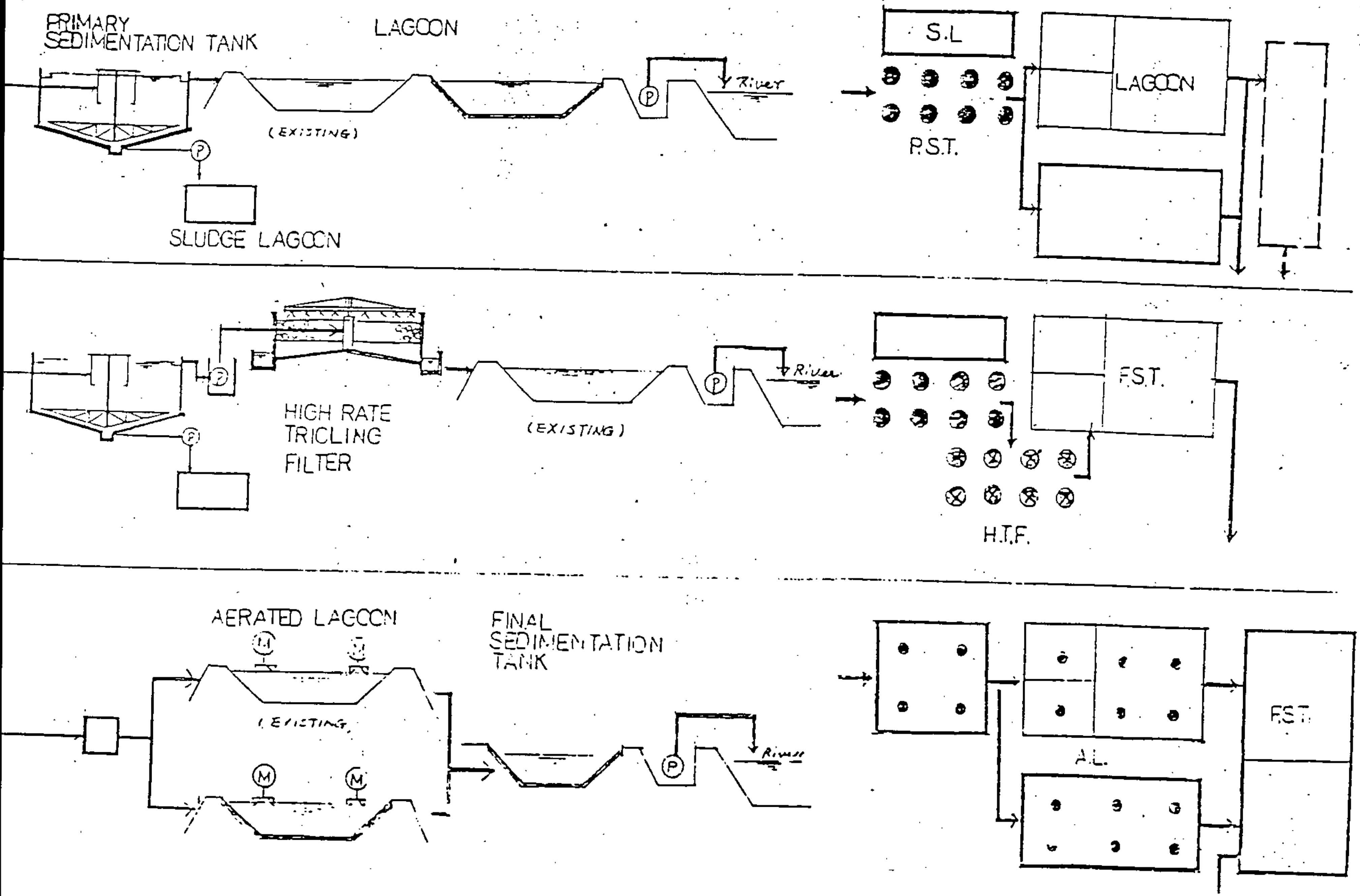
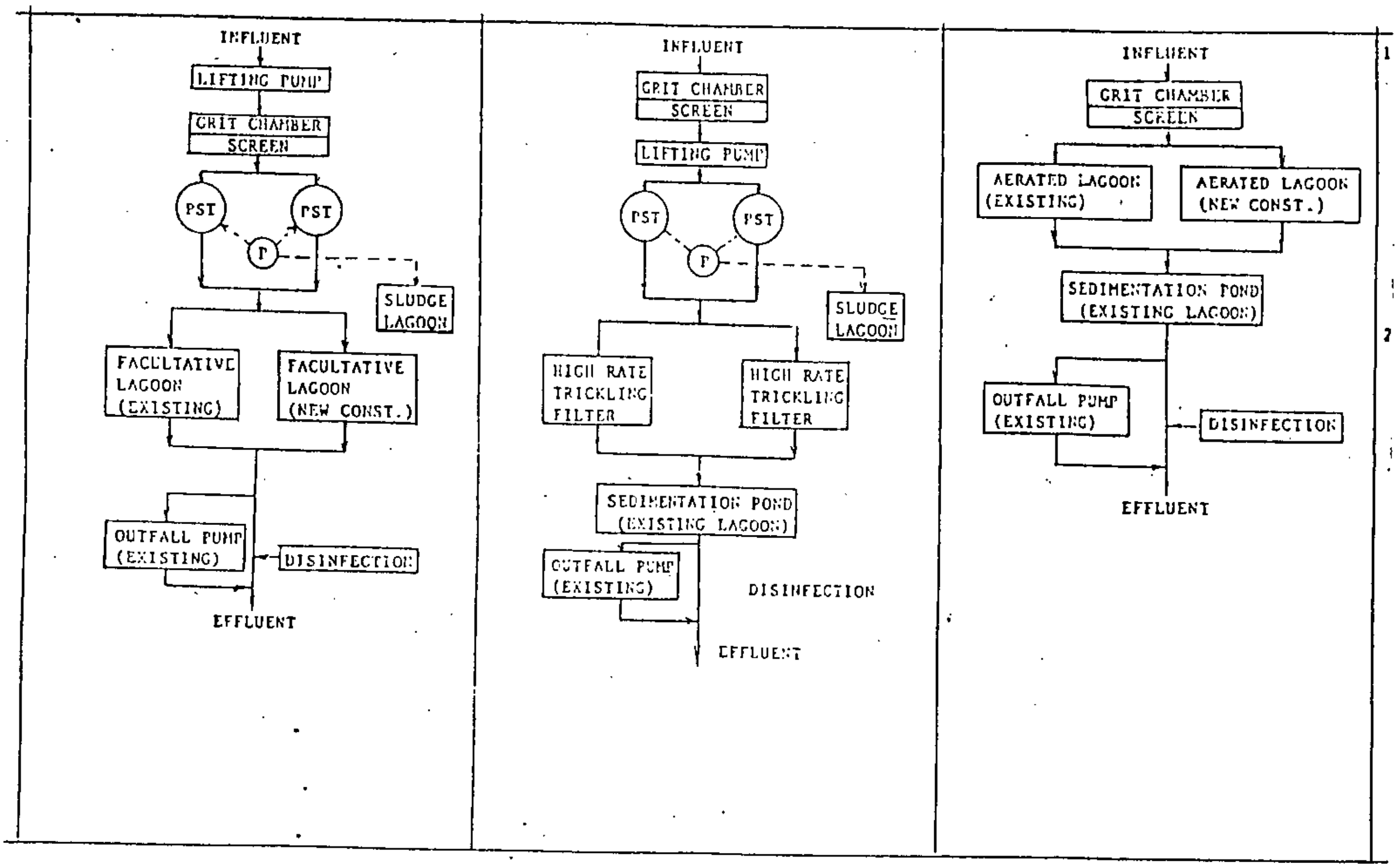


Fig. 7.6 Flow Diagram of the Alternatives

Fig. 7.7 Comparison of Treatment System (18)



part of the existing lagoon would be used as a sedimentation tank. Medium grade treatment could be achieved without requiring a lift pump because of a small level difference required for the system. The system component was only aerator but a large number was required. As the sludge accumulated on the bottom of the lagoon was exposed to the sun for drying whenever occasion arises and removed from the plant for disposal, it was not necessary to install additional sludge treatment facilities.

Each alternative had its positive and negative aspects in the features of treatment. However, high rate trickling filter system required biological control to a certain extent while aerated facultative lagoon demanded a lot of aerators to achieve the given treatment capacity and consumed time and effort in the maintenance . Accordingly, case 1, requiring fewer equipment seemed the most advantageous.

For the maintenance cost, case 1 was the least expensive because of its limited watt consumption.

From the view point of required construction area, case 2 and case 3 could be installed in the available land space of the plant. For case 1, the presently projected portion could be constructed in the plant, but expansion of the plant site by approximately 23 ha is required in the master plan.

In the high rate trickling filter system of case 2, some treatment conditions may require the returning of treated water (twice or three times recyling), resulting in a more watt consumption.

On the basis of the study and the comparison discussed above, "Primary Sedimentation Tank + Facultative Lagoon" system i.e., case 1 was recommended by the JICA study team as the treatment method for the following reasons:

i) Under the present plant operating conditions, a system with the minimum running and maintenance costs should take precedence.

ii) Unstability of treatment efficiency and egress of algal fungi are expected in case 1 because of seasonal influence but the situation of outfall river will not make them problematic.

iii) The system after the primary treatment can be easily expanded or modified to meet the increase in effluent volume and follow the progress in the treatment system in the future.

iv) With the cost for replacing equipment taken into consideration, it is desirable to minimize the number of equipment.

v) Although expansion of the plant site (by approximately 23 ha) is required in the master plan, the facilities subjected to this project (120,000 m^3/day) can be installed in the present available space.

7.6 Cost comparison of WSP and Aerated Lagoon

A cost comparison has been made between waste stabilization ponds system and aerated lagoon (Appendix-F) from which it is seen that the initiäl cost of wäste stabilization ponds is higher than that of aerated lagoon due to requirement of a vast area of the land. But considering total annual cost of operation and maintenance for an operation of 15 years, the waste stabilization ponds system is seems to be much more economical than that of aerated lagoon. Therefore, for the existing condition and the present situation the waste stabilization ponds system is recommended as the method of sewage treatment for Dhaka city.

7.7 Recommended Method of Sewage Treatment

The existing sewage treatment plant consisting of three facultative waste stabilization ponds. Two ponds are parallel with an area of 19 acres for each pond and the third pond is in series with an area of 48 acres.

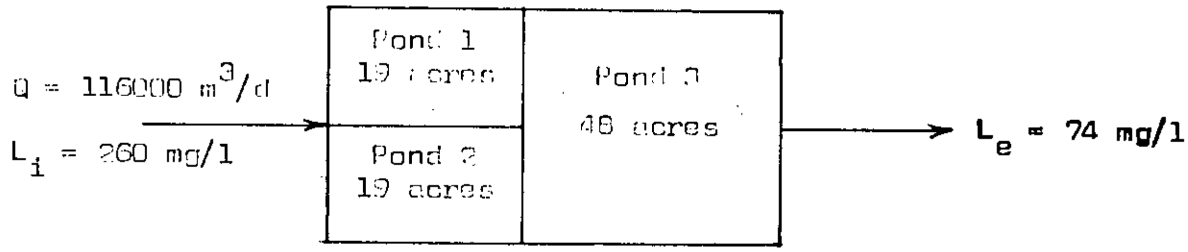


Fig. 7.8 Effeciency of the Existing Sewage Treatment Plant

When all the ponds are in operation, the existing treatment plant produces an effluent BOD_5 of 74 mg/l with a detention time of 4.5 days. To reduce the effluent BOD_5 to a level of 60 mg/l, a 4th pond of area 12 acres is to be constructed in series and the treatment system will require a detention time of 5.1 days. Thus the total area required for the system is 98 acres. (Appendix-A).

Considering desludging facilities, if one of the parallel pond is not in operation, then the existing treatment system will produce an effluent BOD_5 of 95 mg/l with a detention time of 3.5 days. To improve the effluent quality for 60 mg/l, another 4th pond of an area of 28 acres is to be constructed in series. Thus the total area required for the treatment system is 114 acres with a detention time of 5.0 days. (Appendix-B).

If one of the parallel pond is not in operation for desludging purpose the accumulated sludge in the other parallel pond will be 46,040 m^3/year which required desludging after every 1.25 years. Thus one of the parallel pond will not be in operational condition for 1.25 years which is not economical and acceptable. (Appendix-C):

When all the ponds are in operation, the sludge accumulated in the two parallel ponds will be 46,040 m^3/year which required a desludging frequency of 2.5 years. (Appendix-C). After every 2.5 years the capacity of the two parallel ponds will decrease and the treatment plant will produce an effluent of 95 mg/l. To obtain the target quality under critical condition, another 4th pond of an area of 28 acres is to be constructed in series for this system. (Appendix-D).

Thus for the present situation of Dhaka city and available sewerage facilities, the recommended method of sewage treatment is the facultative lagoon system with an area of 116 acres having desludging facilities after every 2.5 years. The recommended system of sewage treatment will produce the effluent with an acceptable BOD_5 less than 60 mg/l.

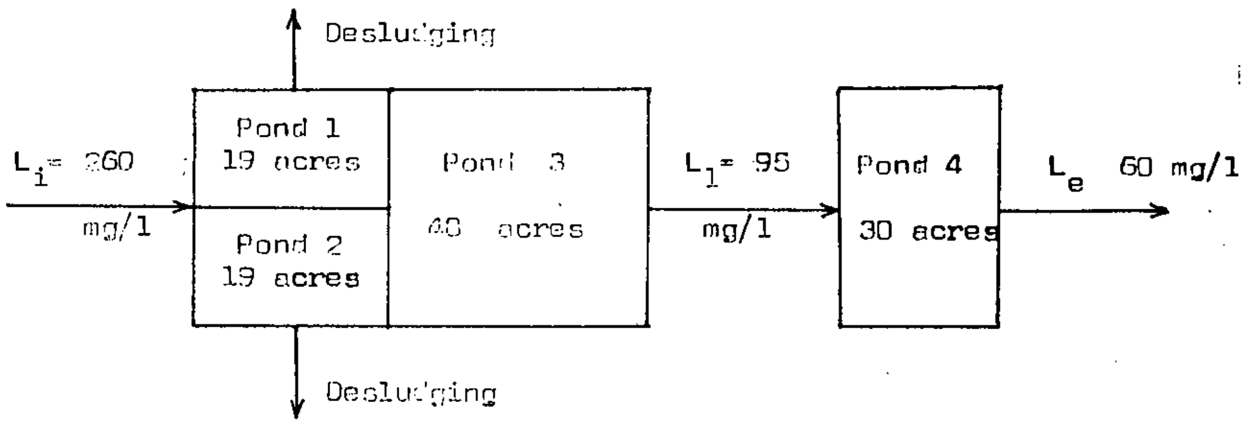


Fig. 7.9 Recommended System of Sewage Treatment

If a man is assumed to discharge 200X10^9 coliforms per day,[30] the average concentrations of total coliform in the sewage and in the effluent after treatment are expected to be about 2.5 X 10^8/100 ml. and 4.8 X 10^4/100 ml. respectively. (Appendix-E).

7.8 Discussion

Applying first order BOD removal kinetics equation the effluent BOD_5 from the first two ponds determined 145.73 mg/l. But from laboratory analysis and considering the third pond functioning as facultative pond, the effluent BOD_5 is calculated 160 mg/l. Again considering the first two ponds as anaerobic pond, the BOD removal would be 53% on the basis of empirical procedure (Appendix-G). These data indicate that the retention time in the first two ponds is less than the actual detention time (2 days) due to the sludge accumulation in the ponds.

The volumetric loading in the first two ponds is found 130 g/m^3d which is less than 400 g/m^3d. Therefore, there is no odor releasing problem. (appendix-G).

The third pond is not functioning as a complete facultative pond. No algae are observed near the inlet point of this pond, algae are observed near the outlet point. Thus the facultative condition is not maintained near the inlet point of the pond. The effluent BOD of the third pond is observed 81 mg/l which is more than the acceptable value (60 mg/l). So another pond is required to reach the allowable value of the effluent BOD. This pond will reduce the pathogens also. Although usually two ponds in series with a retention time of 5 days is required to remove the pathogens, for the limitations of land areas at least one maturation pond can be provided. For further reduction of pathogens disinfection process can be taken into the consideration.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The conclusions drawn from this study are summerized below:

i) The characteristic quality of sewage of Dhaka city is not uniform. The existing sewerage system collects sewage from residential, industrial and tanning areas. The BOD_5 values of sewage from residential, industrial and tanning areas are found to be 250 mg/l, 275 mg/l and 288 mg/l respectively. The BOD_5 of the combined sewage is found to vary from 180 mg/l to 270 mg/l. The lower BOD_5 values of combined sewage at final pumping stations are due to partial stabilization of sewage or infiltration of fresh water into the sewers during conveyance of the sewage.

ii) The ratios of BOD to COD are observed 0.68 and 0.57 for the representative sewage of residential and industrial areas respectively. A very little difference between these two ratios indicates that the industrial sewage contains sufficient biodegradable organic matter that comes from domestic sewage of the adjacent residential areas.

The ratio of BOD to COD for the treated sewage is observed 0.34 which is less than that of untreated sewage. It indicates that the effluent contains the non-biodegradable organic matter and the biodegradable organic matters are already oxidized in the treatment processes.

iii) The BOD reaction rate constant of the combined sewage is determined as 0.28 by Thomas method and the same is 0.25 by Least Square method. The ultimate BOD of the combined sewage is found to be 378 mg/l. The values are within usual range for domestic sewage and may be considered satisfactory for biological treatment of the sewage.

iv) The oxidation of nitrogenous organic matter starts after 10 days for untreated sewage and after 8 days for treated sewage. This is an indication that the sewage has been detained in the treatment plant for a period of not more than 2 days.

v) The Dhaka Water Supply and Sewerage Authority collects about 8 percent of the estimated BOD_5 load of sewage produced in greater Dhaka serving about 18 percent of the total population. It is obvious that a fraction of unaccounted BOD_5 load of the DWASA's share is destroyed in the sewers but a major fraction finds alternative routes.

vi) The actual sewage flows based on operation hour are observed much less than the estimated sewage flows for each sewage lift station. The reason of such flow difference is due to the disposal of raw sewage to the adjacent low-lying areas through by-pass line, leakage and broken sewers, overflowing the manholes, connection of sewers to surface drains etc.

vii) Applying first order BOD removal kinetics, the effluent BOD_5 has been determined 74 mg/l from the existing sewage treatment plant at Pagla with a detention time of 4.5 days. But practically, from laboratory analysis, the effluent BOD_5 is found 81 mg/l. In the context of the present situation, it has been determined that an effluent quality of 60 mg/l for BOD_5 may be considered as a treatment objective for the sewage treatment facilities.

viii) Effluent BOD_5 from the first two ponds has been determined 145.73 mg/l by applying first order BOD removal kinetics, but from laboratory analysis, it is found 160 mg/l. These data indicate that the retention time in the first two ponds is less than the actual retention time (2 days) due to the sludge accumulation in the ponds.

The third pond is not functioning as a complete facultative pond, facultative condition is maintained only near the outlet point. The The effluent BOD of the third pond is more than the acceptable value of 60 mg/l (5 day BOD9. Therefore, another pond is required to reach the allowable value of the effluent BOD which will reduce the pathogens also.

ix) In the river Buriganga, during dry season, the dissolved oxygen concentration in about a 6 miles stretch of the river at the western perifery of Dhaka city starting from 0.2 mile upstream of Pagla sewage treatment plant is found to be less than 4.0 mg/l. The DO sag curve indicates that the major pollutional impact on the river Buriganga is from sources upstream of the Pagla sewage treatment plant discharges. In fact sewage treatment plant at Pagla usually discharges 3000 kg/d of BOD_5 load in comparison to huge BOD_5 loads discharged upstream through large number of drains which include 19,000 kg/d of polluting load discharged by tanneries and glue factories.

x) A cost comparison has been made between waste stabilization ponds system and aerated lagoon from which it is seen that although the initial cost of waste stabilization ponds system is higher than that of aerated lagoon, considering a long period, the waste stabilization ponds system is seems to be much more economical than that of aerated lagoon. Therefore, for the existing condition and the present situation the waste stabilization ponds system is recommended as the method of sewage treatment for Dhaka city.

xi) For the present situation, the recommended method of sewage treatment is the facultative lagoon system with an area of 116 acres having desludging facilities after every 2.5 years. The recommended system of sewage treatment will produce the effluent with an acceptable BOD_5 less than 60 mg/l and the average concentrations of total coliform in the effluent after treatment are expected to be about 4.8×10^4/100 ml. For the future expansion of the existing treatment facilities, the intermediate management technology like aerated lagoons should be taken into consideration.

8.2 Recommendations for further study

i) To protect the environment of the natural water resources from degradation, guide the design of treatment facilities and to regulate the quality of effluent discharged in water, the study can be extended to formulate a workable effluent standard for Bangladesh.

ii) The study can be extended to establish a model on assimilation and DO sag curve for discharging the wastewater into the river Buriganga.

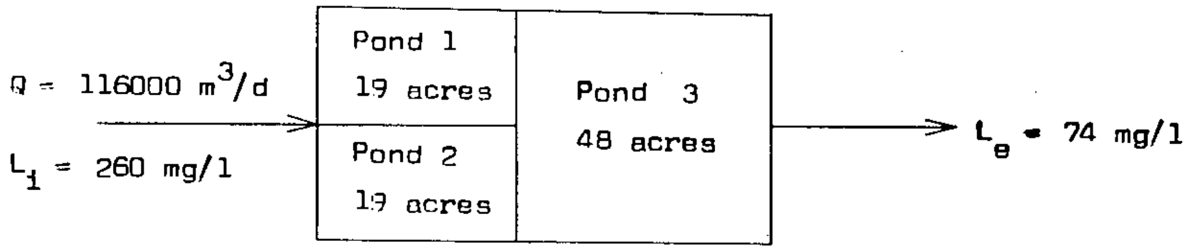
iii) The Mirpur area has not yet been brought under sewerage system. For the sewerage system of Mirpur area and a seperate small sewage treatment plant near the Mirpur bridge the study can be extended. Similarly, considering the system geometry, for geographically isolated areas installation of seperate sewage treatment plant can be studied for greater Dhaka city.

iv) The existing sewerage system has been designed only for the treatment and disposal of domestic sewage. Storm water and wastewater from surface drains are handled by other seperate system. A combined sewerage system may be studied for Dhaka city.

v) To discharge the wastewater from tanning and other industries into the existing sewerage system a study on pretreatment of tanning and industrial waste is to be required for combined sewerage system.

APPENDIX - A

(i) Efficiency of the existing Sewage Treatment Plant



Pond 1 : $A = 19 \text{ acres} = 76,893 \text{ m}^2$

$D = 1.5 \text{ m}$

$V = 76,893 \times 1.5 = 115,339.5 \text{ m}^3$

$t_1 = V/Q = 115,339.5/116000 = 1 \text{ d}$

Pond 2 : Same as pond 1.

Pond 3 : $A = 48 \text{ acres} = 194,256 \text{ m}^2$

$D = 1.5 \text{ m}$

$V = 194,256 \times 1.5 = 291,384 \text{ m}^3$

$t_3 = 291,384/116,000 = 2.5 \text{ d}$

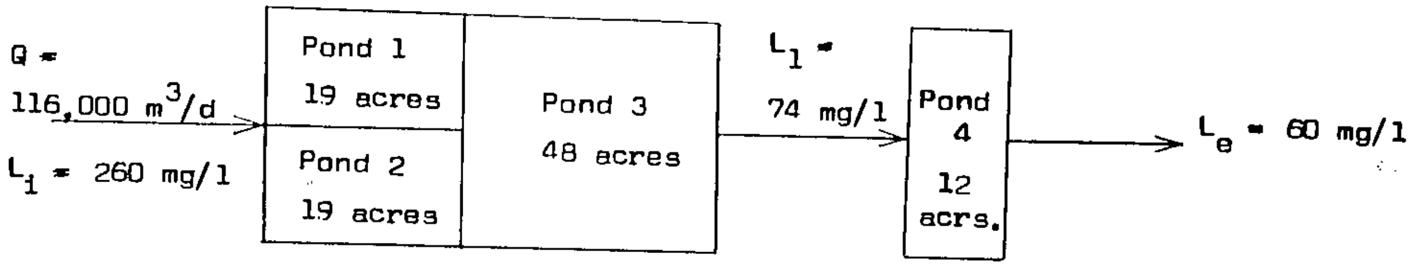
$$k_{28} = k_{20}\,(1.05)^8 = 0.265(1.05)^8 = 0.392$$

$$L_1 = \frac{L_i}{1 + kt} = \frac{260}{1 + 0.392 \times 2} = 145.73 \text{ mg/l}$$

$$L_e = \frac{145.73}{1 + 0.392 \times 2.5} = 74 \text{ mg/l} > 60 \text{ mg/l}$$

Therefore, another pond is to be constructed in series which will produce an effluent BOD_5 of 60 mg/l.

(ii) Improvement of the existing system



$$L_e = \frac{L_1}{1 + kt_3} \qquad \text{or,} \quad t_3 = \left(\frac{L_1}{L_e} - 1 \right) / k$$

$$\text{i.e.,} \quad t_3 = \left(\frac{74}{60} - 1 \right) / 0.392 = 0.6 \text{ d}$$

$V = Q.t = 116{,}000 \times 0.6 = 69{,}600 \text{ m}^3$

$A = 46{,}400 \text{ m}^2 = 12 \text{ acres}$

$D = 1.5 \text{ m}$

APPENDIX - B

(i) Efficiency of the system when one of the parallel pond is not in operation :

$t_1 = V/Q = 115,339.5/116,000 = 1d$

$$L_1 = \frac{L_i}{1 + kt_1} = \frac{260}{1 + 0.392 \times 1} = 186.8 \text{ mg/l}$$

$$L_e = \frac{L_1}{1 + kt_2} = \frac{186.8}{1 + 0.392 \times 2.5} = 95 \text{ mg/l} > 60 \text{ mg/l}$$

Therefore, another pond is to be constructed which will produce an effluent BOD_5 of 60 mg/l.

(ii) Improvement of the system

$$t_4 = \left(\frac{L_1}{L_e} - 1\right)/0.392 = \left(\frac{95}{60} - 1\right)/0.392 = 1.5 \text{ d}$$

$V = Q.t = 116,000 \times 1.5 = 174,000 \text{ m}^3$

$A = 116,000 \text{ m}^2 = 28 \text{ acres}$

$D = 1.5 \text{ m}$

APPENDIX – C

(i) When one of the pond is in operation :

The rate of sludge accumulation is approximately 0.03 – 0.04 m^3/hd per year and desludging is required when the pond is half-ful of sludge[7]

Volume of sludge = 0.04 X 11,51,000
= 46,040 m^3/year

n = ½ (pond volume) ÷ (volume of sludge accumulation)
= 0.5 (76,893 X 1.5) ÷ (46,040) = 1.25 years.

(ii) When both the ponds are in operation :

Volume of sludge = 0.04 X 11,51,000
= 46,040 m^3/year

n = 0.5 (1,53,786 X 1.5) ÷ (46,040)
= 2.5 years.

APPENDIX - D

Improvement of effluent quality :

After 2.5 years

$t_1 = V/Q = 230,679 \times 0.75 / (116,000) = 1\ d$

$L_1 = 260 / (1 + 0.392 \times 1) = 186.8\ mg/l$

$L_e = 186.8 / (1 + 0.392 \times 2.5) = 95\ mg/l$

For additional pond,

$t_4 = (95/58 - 1) / 0.392 = 1.6\ d$

$V = Q.t = 116,000 \times 1.6 = 185,600\ m^3$

$A = 124,000\ m^2 = 30\ acres$

$D = 1.5\ m$

APPENDIX - E

Coliform count :

Total coliform discharged per man per day = 200×10^{9}

Quantity of sewage per man per day

= 25 (gpcd of water) X 0.70 X 4.5

= 80 lpd

200×10^{9} coliform is to be mixed in 80 litres of sewage.

No. of coliform per litre = 2.5×10^{9} i.e., T.C. = 2.5×10^{8}/100 ml.

$k_b = 2.6\ (1.19)^{8} = 10.45$

$$N_e = \frac{2.5 \times 10^{8}}{(1 + k_b t_1)(1 + k_b t_2)(1 + k_b t_3)}$$

$$= \frac{2.5 \times 10^{8}}{(1 + 10.45 \times 1)(1 + 10.45 \times 2.5)(1 + 10.45 \times 1.6)}$$

$= 4.8 \times 10^{4}$ T.C. / 100 ml.

APPENDIX - F

Cost comparison of WSP and Aerated Lagoon

Sl. No.	Description of items	WSP System Quantity	WSP System Cost	Aerated Lagoon Quantity	Aerated Lagoon Cost
1.	Land	78 acres	Tk. 11,70,00,000/	38 acres	Tk. 5,70,00,000/
2.	Personnel cost				
	(a) Plant Manager	1	48,000/	1	48,000/
	(b) Technical Staff	2	72,000/	2	72,000/
	(c) Operation Staff	6	72,000/	8	96,000/
3.	Maintenance cost		200,000/		400,000/
4.	Mechanical Equipments	-		30 Aerators	1,95,00,000/
5.	Operation cost (power)	-		47,04,850 KW/year	98,80,185/
Cost for one year (initial)			Tk. 11,73,92,000/-		Tk. 8,69,96,185/-
Operation and maintenance cost for 15 years			58,80,000/-		15,74,42,775/-
Cost for 15 years			Tk. 12, 28,80,000/-		Tk. 23,39,42,775/-

APPENDIX - G

Performance of the existing Sewage Treatment Plant :

(i) Applying first order BOD removal kinetics in the first two ponds the effluent BOD_5 is determined 145.73 mg/l.

$$L_1 = \frac{L_i}{1 + kt} = \frac{260}{1 + 0.392 \times 2} = 145.73 \text{ mg/l.}$$

(ii) But from laboratory analysis and considering the third pond functioning as facultative pond, the effluent BOD_5 is calculated 160 mg/l.

$$\frac{L_e}{L_1} = \frac{1}{1 + 0.392 \times 2.5} \quad \text{i.e., } L_1 = L_e\,(1 + 0.392 \times 2.5)$$

$$= 81\,(1 + 0.392 \times 2.5) = 160 \text{ mg/l.}$$

(iii) The efficiency of the first two ponds were found

$$\frac{(260 - 160)}{260} \times 100 = 38\%$$

$$\text{Retention time} = V/Q = \frac{230679}{116000} = 2 \text{ days}$$

From empirical procedure basis the BOD removal would be 53% .

(iv) Volumetric Loading :

$$_v = \frac{L_i Q}{V} = \frac{L_i}{t} = \frac{260}{2} = 130 \text{ g/m}^3\text{d} \quad > \quad 400 \text{ g/m}^3\text{d}$$

Therefore, no problem of odor releasing.

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