WASTEWATER TREATMENT BY LAND DISPOSAL ON SANDY GROUNDS

by
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ABSTRACT

Wastewater disposal on land can be considered as "appropriate" wastewater treatment technology for many less developed and developing countries. The main advantages of this technique are the low initial and maintenance costs involved, the effective reduction of the organic load as well as the removal of bacteriological pollution, reuse of nutrients such as nitrogen and phosphorus present in the wastewater through retention by soil and the increase of the productivity of the soil.

Treatment of wastewater by land application has not been practised so far in Turkey. The present study was conducted to investigate the applicability of this method in our country and to predict the results.

For this purpose, a 25 meter long channel was constructed and after it was filled with sand, domestic wastewater was applied. The variation of the wastewater and soil characteristics with time and distance were investigated through out the application period.

Removal efficiencies obtained are given below:

- Chemical oxygen demand (COD)	74-84 %
- Nitrogen (N)	65-75 %
- Phosphorus (P)	73-92 %
- Turbidity	75-80 %
- Total coliform	77.5-82.5 %

These results are in full agreement with the results of similar studies conducted elsewhere.

The conclusion of the present study is that land disposal on sandy grounds is a method which can be used effectively in many parts of Turkey.

ÖZET

Az gelişmiş ve gelişmekte olan birçok ülkede atıksuyu arazide uzaklaştırma uygun bir atıksu arıtma teknolojisi olarak düşünülebilir. Bu tekniğin önemli avantajları; yatırım ve bakım masraflarının düşüklüğü, bakteriyel kirliliğin uzaklaştırılmasının yanı sıra organik yükünün de etkili olarak azaltılması, atıksu'da bulunan ve toprak tarafından tutularak verimliliğini arttıran azot ve fosfor gibi besi maddelerinin geri kazanılmasını sağlamasıdır.

Türkiye'de, atıksuların arazide kullanılarak arıtılması bugüne kadar uygulanmamıştır. Önerilen bu çalışma da tekniğin ülkemizde uygulanabilirliğini araştırma ve sonuçlarını tahmin amacına yöneliktir.

Bu maksatla, 25 metre uzunluğunda bir kanal inşa edildi; kumla doldurulduktan sonra evsel atıksu kullanıldı. Uygulama süresince zaman ve mesafe ile atıksu ve toprak karakteristiklerinin değişikliği ölçülüp araştırıldı.

Arıtmada elde edilen arıtma verileri yüzde uzaklaştırma olarak aşağıda gösterilmektedir.

- Kimyasal Oksijen ihtiyacı (KOİ)	% 74-84
- Azot (N)	% 65-75
- Fosfor (P)	% 73-92
- Bulanıklılık	% 75-80
- Toplam koliform	% 77.5-82.5

Bu sonuçlar, diğer ülkelerde uygulanan benzer çalışmalarla uygunluk göstermektedir.

Atıksuların arazide arıtılması ve kumlu zemin vasıtası ile uzaklaştırılmasını amaçlayan bu yöntem, Türkiye'nin pek çok kesiminde etkili olarak uygulanabilir sonucuna varılmıştır.

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CHAPTER I

INTRODUCTION

Mankind realized the necessity of wastewater treatment after damaging the environment due to the disposal of wastes generated by human activies. Today, a wide variety of treatment processes are available for use in order to prevent the deterioration of the environment. Among these , one of the best alternatives is land disposal.

Land treatment systems involve the use of soil and plants to remove unwanted materials from the wastewater. This process is capable of achieving removal levels comparable to the best availeble conventional wastewater treatment technologies with some additional benefits such as the recovery and reuse of wastewater and nutrients for crop production. Thus, these systems accomplish far more than other known treatment and discharge alternatives (EPA, 1977; Billur and Siber 1982; Niyogi et al., 1982). So far, land treatment systems seem to be the most economic and natural way of purification of wastewater. In these processes the initial capital investment needed and the operation costs are reduced to a great extent compared with conventional wastewater treatment systems (Pound, Crites and Griffes, 1975; EPA, 1977; Metcalf and Eddy, 1979).

Although the concept of land application of wastewater is not new in the field of environmental engineering, a knowledgeable use of the system has not yet been developed in Turkey. Consideration of the fact that such an application would lead to successful results, mostly if applied in arid and semi-arid regions of Turkey, led us to develop a field model and to investigate the variation of wastewater and soil characteristics with time and distance under local conditions. This study was performed within the fields of Bogaziçi University.

An outstanding characteristic of the present study is the use of a model with a length of 25 meters resembling actual conditions. If it is considered that most of the studies conducted so far have used models considerably smaller in size; it is easy to understand that the results obtained in this study should be much more dependable.

CHAPTER II

LITERATURE SURVEY

This chapter, consisting of seven sections, emphasizes the processes and technologies so far in use, related to the application of wastewater on land. This chapter will hopefully give a general idea on the concept of purification of wastewaters, mainly of domestic origin, by infiltration through soil.

In the first part, the background and history of past applications will be reviewed followed by a section on land treatment processes. Section three mentions the factors affecting the efficiency of land treatment. These factors are location, soil characteristics, wastewater characteristics and plantation. The next section is on renovation processes of wastewater followed by a section on crop selection. Sections six and seven cover the subjects of public health implications and the social and economic aspects of land treatment of wastewater.

2.1 Background and History of Land Treatment of Wastewater

As depicted in the literature, the practice of applying municipal wastewaters and treated effluents to land is traced back to several centuries. Evidence of such systems dates back as for as ancient Athens (Metcalf and Eddy 1972; Metcalf and Eddy, 1979). A wastewater irrigation system in Bunzlaw, Germany, was reported by Hartman (1975) to have been in operation for over 300 years, beginning in 1559.

The greatest demand for use of land treatment systems occurred in Europe in the second half of the 19^{th} century (Pound an Crites 1973; EPA 1977). Pollution of many rivers had reached unacceptable levels, and disposal of sewage on land was the only feasible way of treatment achievable at that time. The practice of "Sewage Farming", in other words, transporting sewage into rural areas for irrigation and disposal purposes was commonly used by many European Cities (Kirkwood 1970;

EPA 1977). This practice resulted in an unintentional purification of wastewaters.

Early experiences in the United States date back to the 1870's (EPA 1977; Metcalf and Eddy 1979). As in Europe, sewage farming became a common practice for controlling water pollution. In the first half of the 20^{th} century, these primitive applications were generally replaced by either one of the following systems; a) Managed farms, where treated wastewater was used for crop production, b) landscape irrigation sites, c) groundwater recharge sites (Hammer, Clark and Viessman, 1977; EPA 1977) Today, these land treatment systems are still very common in many western countries.

The increasing use of land disposal and treatment in United States over the last few decades is shown in Table 2.1 (Thomas, 1973).

TABLE 2.1 MUNICIPALITIES USING LAND TREATMENT IN THE UNITED STATES (Thomas, 1973)

Year	No. of systems	Population Served, millions
1940	304	0.9
1945	422	1.3
1957	461	2.0
1962	401	2.7
1968	512	4.2
1972	571	6.6

On the other hand, in the east, mostly in rural and arid regions su as in Israel, modernized applications are in operation, and in coming yea the activity in the area of wastewater trensportation and disposal is expected to increase (Sullivan et al., 1973; Feinmesser 1070). In India, the necessity of finding alternatives for tradional waste management led to the development of a research project named "Ecologically Balanced Wastewater Renovation Systems" which was carried out between 1977-1979 (Niyogi et al., 1982). The results of this project put forth the feasibil of land intensive low-cost wastewater management systems in this country

Land disposal of wastewater has also been in use in Turkey for many years. This, however, has not been performed with the intention of purifying wastewater. The main reason of this practice was either the scarcity of pure water or the belief that the fertility of the soil will increase if crops are irrigated with wastewater.

2.2 Land Treatment of Wastewater

Land treatment is a reliable engineering process for wastewater management. Land application involves the recovery and beneficial reuse of nutrients and other elements present in wastewater through good agricultural practices.

This section covers the advantages and disadvantages of this treatment system; the types of land treatment processes, their capabilities and objectives.

2.2.1 Advantages and Disadvantages of Land Treatment of wastewaters

Hernāndez (1979) gives detailed information about the advantages and disadvantages associated with land treatment. The most important are given below;

Advantages:

- Lower energy costs in comparison with other treatment methods,
- High nutrient recycling capacity,
- Conservation of water resources,
- Increased crop yields,
- Efficient control of pollutant dispersion,
- Enlargement of greenbelt areas,
- Efficiency not effected by shock loadings,
- Lower initial capital investment and operation cost,
- Minimal need for pretreatment prior to use for irrigation,
- No necessity for skilled personnel.

Disadvantages:

- Exposure of large populations to hazardous materials,
- Potential for concentration of nutrients in the storm water run-off,
- Danger of concentration of nitrates in shallow groundwater,
- Loss of water through evapo-transpiration,
- Possible concentration of toxic substances in harvested crops and food chains,
- Danger of concentration of pollutants in groundwater and their uncontrolled migration,
- Use of the disposal site for another purpose not possible for a considerably long period,
- Difficulties of operation during cold and heavy rain periods.

2.2.2 Types of Land Treatment Processes, Their Capabilities and Objectives

The disposal of wastewater on land can be done by one of the following two distinct methods:

1- Irrigation - where sewage is utilized in production of crops by providing satisfactory hygienic disposal,
2- Infiltration - where wastewater is disposed of through infiltration without any intention for crop production (Mahida, 1981).

When sewage is used for irrigation purposes, wastewater must be applied only up to the optimum requirements of the crop otherwise it may have negative effects on the plantation.

Where suitable lands for irrigation are not available or where sewage irrigation is not practicable for some other reason, disposal of sewage on land by infiltration can be effectively used. The process of infiltration involves the existence of a free wastewater layer on land.

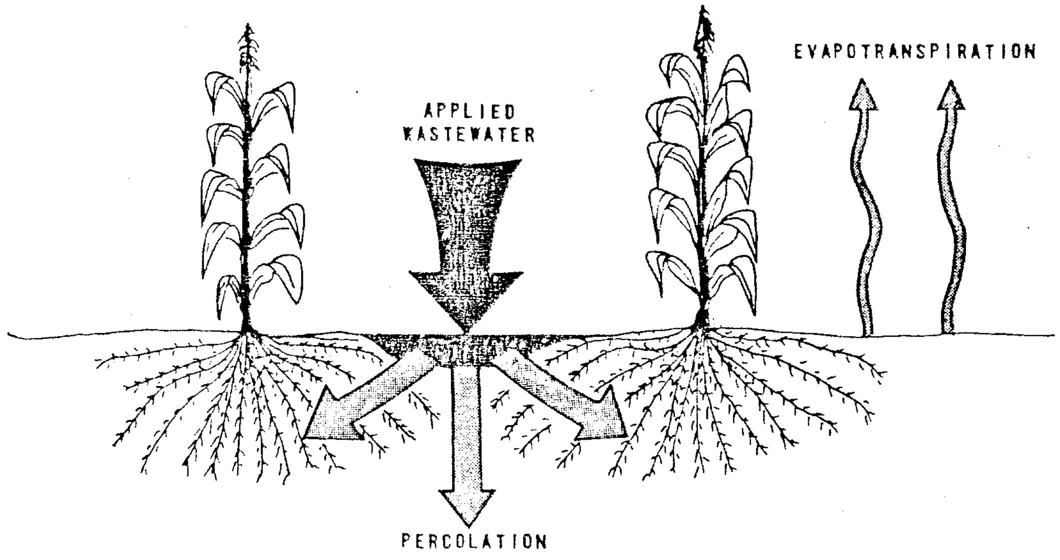
This is necessary only for a limited period as the wastewater is expected to infiltrate into the soil very rapidly so as to permit ready exchange of gases and free circulation of atmospheric air into the soils (Imhoff and Fair, 1959; Mahida 1981).

Wastewater may be disposed on land by one of the following processes;

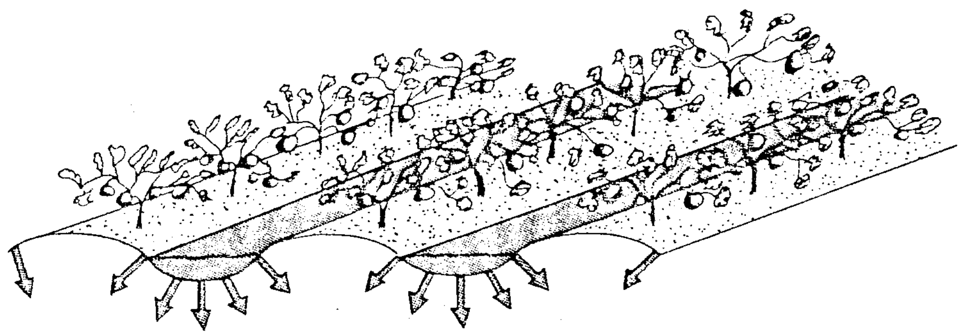
1- Slow Rate Process: In slow rate systems, crop production is the critical component. The applied wastewater is treated as it flows through the soil matrix and a portion of the flow percolates into the groundwater (EPA 1975 (b); EPA 1976). Surface run-off of the applied water is generally not allowed. Schematic views of the typical hydraulic pathway , surface distribution and sprinkler distribution are shown in Figure 2.1. The objectives of this process are purification of wastewater, economic recycling of nutrients, increase of soil fertility, enlargement of greenbelts, etc.

2- Rapid Infiltration Process: In rapid infiltration, most of the applied wastewater percolates through the soil and the treated effluent eventually reaches the groundwater. The wastewater is applied to soils which have high permeability, such as sands, by spreading in basins or by sprinkling. Usually, this land is not used for agricultural purposes, although there are some exceptions (Bouwer, Rice and Escarcega, 1974). Figure 2.2 shows the typical hydraulic pathway and the recovery of renovated water by underdrains and by wells (EPA, 1977). The most important objective of this process is the recovery of renovated water by wells. Removals of wastewater contaminants by the filtering action of the soil is excellent (Sanks and Asano, 1976).

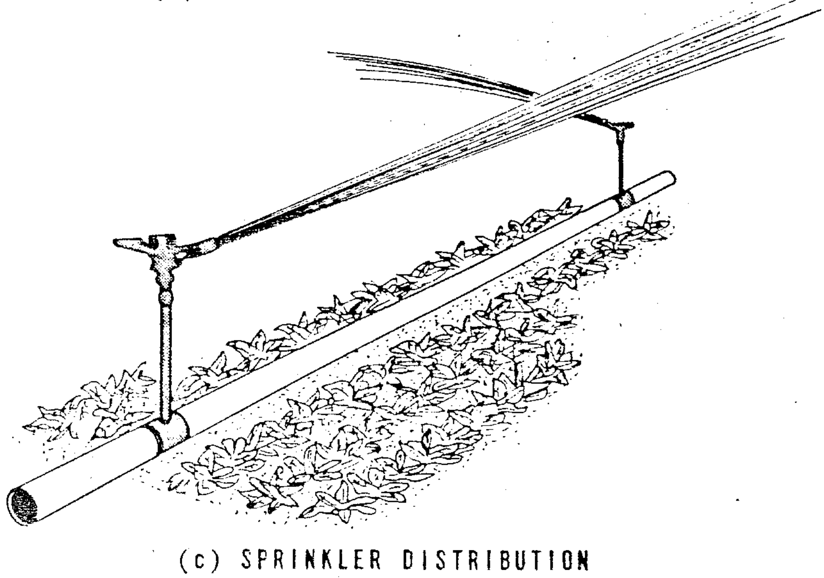
3- Overland Flow Process: Overland flow process is a recent one. Wastewater is applied over the upper parts of soil and allowed to flow accross the surface. The objectives are mainly wastewater treatment and to a minor extent crop production (Thomas, Jackson and Penrod, 1974; Metcalf and Eddy 1979). Figure 2.3 shows a typical schematic view of overland flow treatment and also a pictorial view of sprinkler application.



(a) HYDRAULIC PATHWAY



(b) SURFACE DISTRIBUTION



(c) SPRINKLER DISTRIBUTION

Figure 2.1 Graphical Representation of Slow Rate Land Treatment (EPA, 1977)

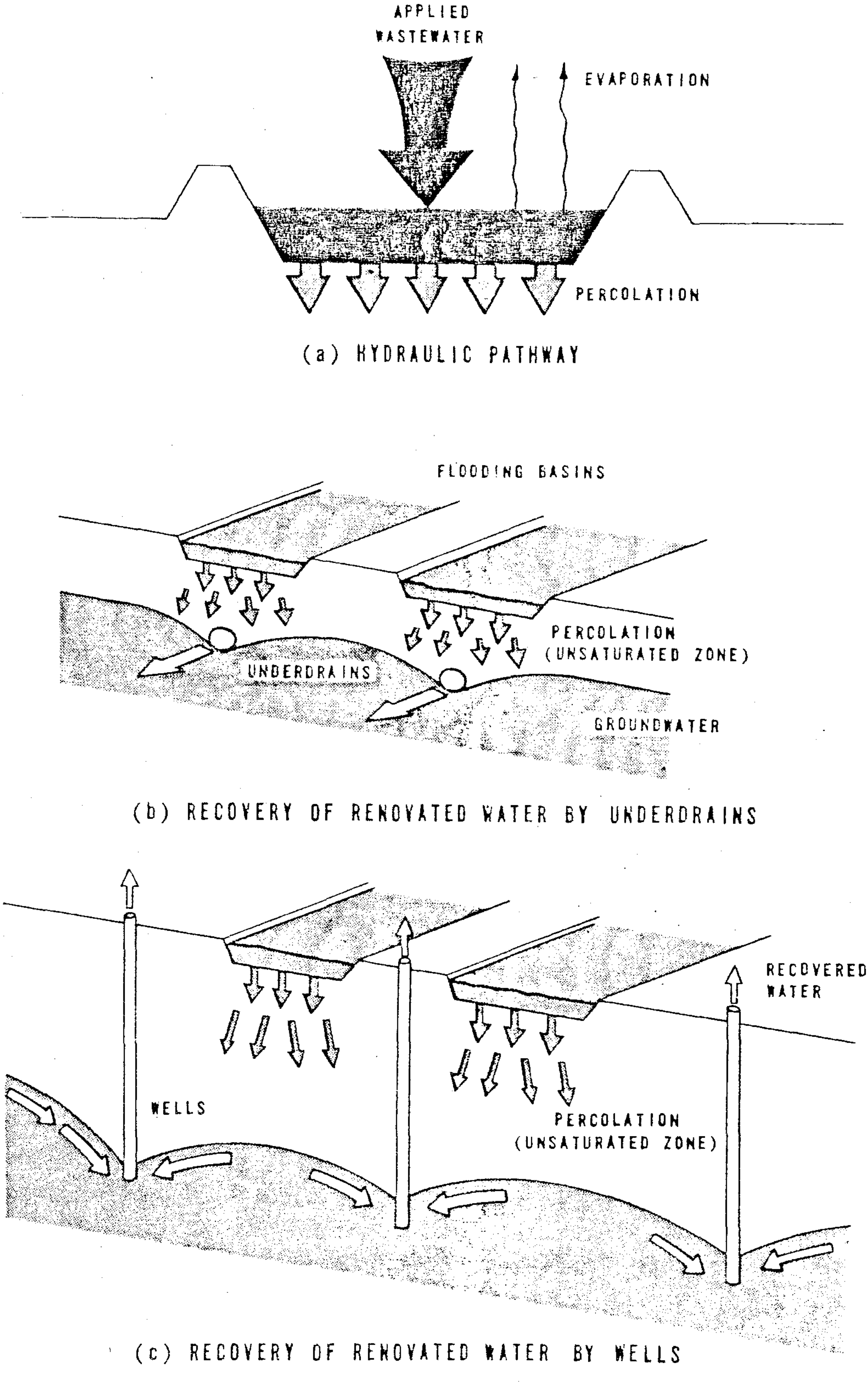
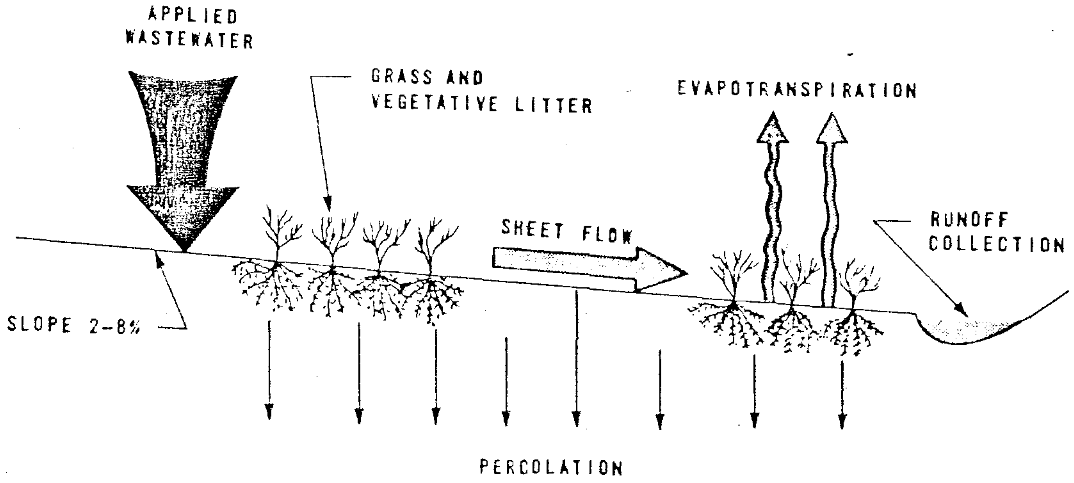
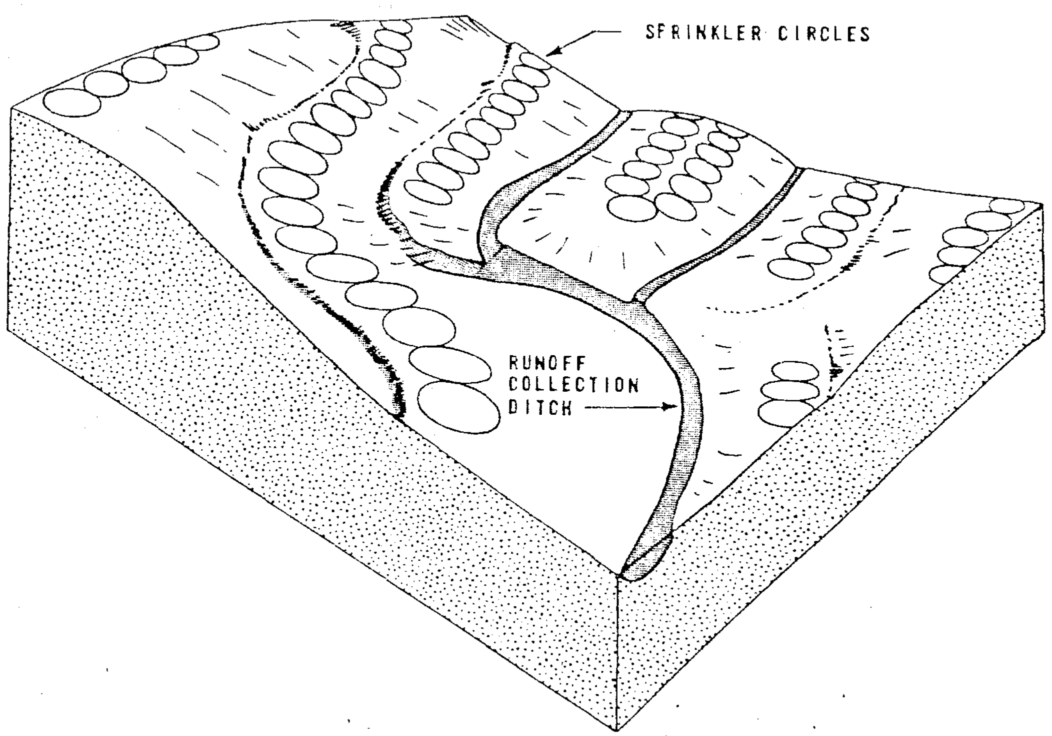


Figure 2.2 Graphical Representation of Rapid Infiltration (EPA, 1977)



(a) HYDRAULIC PATHWAY



(b) PICTORIAL VIEW OF SPRINKLER APPLICATION

Figure 2.3 Graphical Representation of Overland Flow (EPA,1977)

4- Wetlands process;

5- Subsurface process;

The details of these last two processes will not be given as they are not widely used and are less adaptable to large scale applications.

2.3 Factors Affecting the Efficiency of Land Treatment

The efficiency of land treatment of wastewater is affected by an interrelated series of factors, namely the site selected for land treatment, soil characteristics, the flow rate and corresponding chemical characteristics of the wastewater and the crops selected for production.

In the following sub-sections; each factor will be described in more detail. The determination of these factors constitute the preliminary design considerations for deciding on the most appropriate and suitable land treatment process.

2.3.1 Location (Site Selection)

Is the selected site sufficient and appropriate for the construction of the proposed treatment system? To answer this question public health considerations should be kept in mind. For example, a primary concern should be the probable pollution of a water supply through surface run-off of storm waters or percolation of toxic materials on land (Powell, 1975; Hernãndez 1979). Generally sites covered with good, deep soils should be selected for long term use (Knight, 1955).

2.3.2 Soil Characteristics

Today there is undeniable evidence that the soil-plant system or the "living filter" is a highly efficient physical, chemical and biological wastewater purification mechanism (Loehr, 1977). The nature of the over-lying soil blanket and the location of the groundwater table under the land are important factors in the applicability of the treatment process (Sullivan et al., 1973). In the surveys, sand, loam and silt were found to be the most suitable soil types for land application. Open-type soils, such as sandy-loam, sand and silt provided the best results so far (Da Costa and Novais, 1982).

The determination of the soil composition is one of the most important parameters that should be determined before the application of wastewater on land, as it's physical, chemical and hydraulic properties affect mainly the degree of treatment, the type of land treatment process and the kind of crops. The corresponding characteristics of soil are reviewed below.

a) Physical Characteristics of Soil:

The most important physical characteristics of soil are texture, structure and depth. The textural classes of soil are identified on the basis of the relative percentage of the three classes of particle size (Sand, silt, clay). Sand particles range in sizes from 2.00 mm to 0.05 mm, silt particles range in size from 0.05 to 0.002 mm and clay particles have size less than 0.002 mm (EPA, 1977).

Soil textural classes and the general terminology used in soil descriptions are given in table 2.2.

Fine textured soils do not drain well and retain large volumes of water for long periods of time. In other words, crop management is more difficult than with more freely drained soils such as loamy soils. Medium-textured soils show a good balance for wastewater renovation and drainage. Coarse-textured soils can accept large quantities of water but do not retain moisture very long (Alexander 1961).

The large pores in well-structured soils conduct water and air, making well-structured soils suitable for infiltration (NASU, 1973).

Soil depth is also important for root development, for retention of wastewater components on soil particles and for bacterial action (EPA, 1977). Plant roots can extract water from depths ranging between 0.3 to 2.7 meters.

TABLE 2.2 SOIL TEXTURAL CLASSES AND GENERAL TERMINOLOGY USED IN SOIL DESCRIPTIONS (Stone, 1976; EPA, 1977)

General terms Common Name	Texture	Basic Soil Textural Class names
Sandy soils	Coarse	Sand
		Loamy Sand
	Moderately coarse	Sandy Loam
		Fine sandy loam
Loamy soils	Medium	Very fine sandy loam
		loam
		Silt loam
		Silt
	Moderately fine	Clay loam
		Sandy clay loam
		Silty clay loam
Clayey soils	Fine	Sandy clay
		Silty clay
		Clay

b) Chemical Characteristics of Soil:

pH, cation exchange capacity, nutrient levels (e.g. nitrogen and phosphorus) and the adsorption and filtration capabilities for various inorganic ions are the most important chemical characteristics of soil.

The balance of chemical constituents in soil is important for plant growth and wastewater renovation (EPA, 1977). The chemical as well as the biological treatment mechanisms are affected by the soil pH. For example, the chemical removal mechanisms for phosphorus change with pH and biological activity is reduced as the pH drops below about 5 (Sanks and Asano, 1976).

The cation exchange capacity (CEC) is a quantitive indicator of the potential adsorption capacity for trace elements. The rest of the chemical characteristics are determined by conducting a series of tests. The results indicate the appropriate type of crops that should be planted and other suitable land application aspects.

c) Hydraulic characteristics of Soil:

Important hydraulic characteristics of soil are infiltration rate and permeability. The physical and hydraulic properties of soils are interrelated. For example, the depth of the profile, texture and structure are established for the determination of the infiltration rate. For high rate systems that depend on vertical water movement, the permeability of the most restricting layer in the upper several centimeters of soil usually determines the maximum hydraulic capacity (EPA, 1977). The most recent permeability classes for saturated soil are given in Table 2.3.

TABLE 2.3 PERMEABILITY CLASSES FOR SATURATED SOIL (Stone 1976; EPA 1977)

Soil Permeability (cm/h)	Class
0.15	Very slow
0.151 - 0.508	slow
0.508 - 1.524	Moderately slow
1.524 - 5.08	Moderate
5.08 - 15.24	Moderately rapid
15.24 - 50.8	Rapid
50.8	Very rapid

d) Nutrient Uptake Characteristics of Soil:

Okubo and his coaperators (1982) claim that soils play an important role in removing nutrients; especially nitrogen and phosphorus, from the wastewater in an efficient and economical manner. Apart from nitrogen and phosphorus, the major constituents essential to plant growth that are supplied by infiltration mechanisms are potassium, calcium, magnesium and sulphur (Ciaccio, 1971).

2.3.3 Wastewater Characteristics

The most important characteristics of wastewater are mainly the hydraulic loading rate (the flow rate of the raw sewage) and the organic and pollutant loading (the composition of the raw sewage). The preliminary design considerations also take these two factors into account while proposing an actual design.

2.3.3.1 Flow Rate of Raw Sewage (Hydraulic Loading Rate)

The flow rate of the raw sewage should be known in order to be able to calculate the required land area and the suitable crop, if the site will be used for agricultural purposes. It is known that different types of crops are tolerant up to certain limits of organic matter (nutrients) present in the wastewater; so there is a close relationship between the flow rate (hydraulic loading rate) and the organic loading of the raw sewage. The flow rate of the wastewater is determined by the following factors;

a) The composition of raw sewage,

b) The permeability of the soil media,

c) The depth and slope of the groundwater table of the selected site, which is usually determined by field tests,

d) The method of application of wastewater on land (i.e. rapid infiltration, slow sand, overland flow)

e) The local climatic conditions; the hydraulic loading rate must be chosen so as to prevent the surface run-off of storm water and wastewater when the site receives excess amount of rain and snow.

The lower rates of wastewater application on soil are the only ones that are safe for long-term use, where the typical range is from 2 cm/week to 10.2 cm/week (Sanks and Asano, 1976). Higher rates can be applied when the soil is sandy and when both the infiltration and percolation rates of the soil media are high. The typical range of high rates vary from 10.2 to 305 cm/week (Sanks and Asano, 1976). Usually when high rates are applied, a rest period of about two or three days follows the application period, to maintain aerobic conditions in the soil. During the resting time, water percolates downward through the soil allowing air to be drawn into it. The next application of water tends to force the captured air downward. Furthermore, a drying period is necessary to prevent the clogging of the soil surface (Sanks and Asano, 1976).

2.3.3.2 Composition of Raw Sewage (Pollutant Loading)

The wastewater to be disposed must be analysed so as to find out whether pre-treatment is necessary before land application or irrigation. This information is also required for the determination of the appropriat type of crop to be planted in this area.

Sewage containing hazardous wastes should not be applied on land without proper treatment. As stated by Dawson (1979) in the category of "hazardous wastes", the following are included:

a) "Wastes that are combustible at or below 60°C,

b) Wastes that have a vapor pressure lower than 78 mm Hg at 25°C,

c) Wastes that are corrosive (pH <3 or pH >12),

d) Wastes that are reactive by being thermally unstable, tending toward autopolymerization, explosion, or reaction to generate a toxic gas

e) Wastes that contain constituents that exceed the limits for safe drinking water by a factor of 10,

f) Wastes that are toxic to aquatic life or plants,

g) Wastes that tend to accumulate or concentrate in the food chain to levels that are toxic to human beings,

h) Wastes that contain pathogenic organisms, i.e, total coliform, counts in excess of 2000/L."

On the other hand, there are many substances present in wastewate which are considered as pollutants. Consequently, "pollutant loading" may be expressed in different ways. The most common are given below;

a) Sodium Adsorption Ratio (SAR);Exchangeable cations, particular sodium, calcium and magnesium ions, deserve special consideration as hig sodium concentrations decrease soil permeability. To determine the sodium hazard, the sodium adsorption ratio (SAR) is developed and is defined as follows; (Metcalf and Eddy 1979; Sanks and Asano, 1976; EPA, 1977).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

In this equation, the concentrations are in milliequivalents/L. As a general rule, a SAR of 15 or greater is considered unacceptable (Sanks and Asano, 1976). Higher SAR values (> 9) in soil can be toxic to plants and affect the permeability of the fine-textured soils adversely (knight, 1957; EPA, 1975(a)).

b) Salinity; is a measure of the total dissolved solids in the wastewater. The average salt concentration of the soil solution is usually three times higher than the concentration of the salts in the applied wastewater. High amounts of salt (electrical conductivity > 1 microohm/cm in the water body results in decreased crop yields and in some cases, no crop production is observed (Hernãndez, 1979). Natural processes like evaporation and evapotranspiration reduce the applied water content and thus increase salinity. In such cases, irrigation water is diluted to minimize the negative effects of salinity.

c) Chlorides; present in the wastewater body increases the total amount of dissolved solids. When the concentration of chlorides exceeds a value of 3 milliequivalents/L it tends to cause leaf burn (Hernãndez, 1979). Usually high concentrations cause similar negative effects like in salinity.

d) Nitrogen; Loadings may be limited, as different crops are tolerant to certain concentration limits. An important factor affecting the removal of nitrate present in the wastewater through plantation is that, the removal occurs only during the active growing season. Crops with a relatively short growing season do not absorb nitrate for long periods causing nitrate accumulation in the soil. This nitrate must, then be removed through the denitrification process, in the form of nitrogen gas, or else the degradation of crops take place due to the excess amount of nitrate present (EPA, 1977).

e) Phosphorus; compounds do not cause serious problems even at high concentrations. They are absorbed by soil colloids and can form insoluble complexes with calcium and iron compounds.

f) Toxic Ions; certain ions such as cadmium, chromium, mercury, zinc and copper may cause problems in food chains, mostly when they are in high concentrations (Hernàndez, 1979).

2.3.4 Plantation

Plants in land treatment systems are used to
-"take up nitrogen and phosphorus from the applied wastewater,
-maintain and increase water-intake rates and soil permeability, and
-reduce erosion" (Metcalf and Eddy, 1979).

The most important purpose of crop production (plantation) in irrigation systems is nutrient removal from the wastewater. The factors affecting the selection of the most suitable type of crop are described in section 2.5.

2.4 Renovation Processes of Wastewater

The nutrients taken up by soils from the wastewater media undergo a large number of processes, including adsorption on solid surfaces, plant and microbial uptake, microbial degradation, volatilization, leaching chemical breakdown and precipitation. The importance of each of these mechanisms in wastewater renovation in soils is a function of concentration of the material and soil properties (Sanks and Asano, 1976).

a) Microorganism Removal from Wastewater: Extensive field observations indicate that bacteria and viruses are efficiently removed from the wastewater as it percolates through the soil. Viruses are transported to greater depths in some instances than bacteria because of their smaller size (Drewry and Eliassen, 1968). Although several centimeters of soil appear necessary for nearly complete removal of bacteria, most of the organisms are removed in the upper centimeter of soil at the surface (Mathur and Grewal, 1972). Observations show that as much as 92-97% removal occurs in this one centimeter layer (Marculeseu and Drucan 1962; Sanks and Asano, 1976). Travel distances are also very important in microorganisms removal, as most types can travel in soil only for a restricted distance. These travel distances of microorganisms depend on the characteristics and type of wastewater application process. For example, Sanks and Asano (1976) State that "travel distances of 45.7 to 60.9 meters result in adequate organism removal from wastewater by rapid infiltration.

b) Biochemical Oxygen Demand Removal; The capacity of the soil and it's microflora to remove BOD is enormous. The BOD removal efficiency of soil can be affected by the amount and type of plantation and the infiltration capacity (Law, Thomas and Myers, 1969).

The particulate organic matter that is filtered by the soil as well as that dissolved in the percolating water is partially degraded by microorganisms.

Clogging may occur in the top ten centimeters or so and is usually a function of the high organic matter concentration. Allison (1947) demonstrated that soil clogging is due to biochemical processes of organisms within the soil and not due to filling soil spaces with organic matter added with the wastewater.

c) Nitrogen Removal; The efficiency of nitrogen removal varies from 0% to 91%, depending primarily on soil type, depth of soil,design and mode of application of wastewater and on the vegetation cover (Sanks and Asano, 1976). Removed nitrogen undergoes certain changes and therefore it is important to understand the complex and interrelated series of nitrogen transformations that may occur in soils. The predominant form of nitrogen in wastewater is usually ammonium. The conversion of ammonia nitrogen to nitrite and nitrate in soil and water systems is called the nitrification process. This process is accomplished by the activities of a few bacteria; nitrosomonas and nitrobacter being the most important ones (Okubo and Matsumoto, 1982).

The conversion reaction is a two-step mechanism. In the first step, reduction of ammonium to nitrite is carried out by nitrosomonas bacteria;

$$NH_4^+ + \frac{3}{2} O_2 \rightarrow NO_2^- + H_2O + 2H^+ \qquad (1)$$

The second step is accomplished by nitrobacter which involves the conversion of nitrite to nitrate.

$$NO_2^- + \frac{1}{2} O_2 \rightarrow NO_3^- \qquad (2)$$

These reactions do not need the utilization of organic matter as a source of energy.

The nitrification rate of ammonia nitrogen depends mainly on aeratic temperature and pH of the water body (EPA, 1977). The nitrification process is followed by denitrification which gives nitrogen gas and carbondioxide gas under the presence of carbon (Gilmour, Broadbent and Beck,1977). The presence of living plants stimulates denitrification (Woldendorp, 1963). Nitrogen is removed from the soil by crop uptake which varies with the type of crop grown and the crop yield.

d) Phosphorus Removal; Phosphorus, usually as orthophosphate, reacts with practically all soils resulting in an almost complete removal (up to 99%) from wastewater (Bailey, 1968; Sanks and Asano, 1976).The removal rate is governed primarily by the soil type and depth of the soil (Sanks and Asano, 1976).

Phosphorus is removed from the waterbody by fixation processes in the soil, such as adsorption and chemical precipitation. The removal efficiency generally depends on the soil properties as well as on the concentration of the applied phosphorus (EPA, 1977).

Removal mechanisms of phosphorus from wastewaters is accomplished by a) harvested crops, b) accumulation in the solid phase of the soil as organic compounds, c) Soil erosion removal as soluble phosphorus or phosphorus adsorbed or precipitated on soil particles, d) Leaching from the root zone in percolating water (Pratt, Jones and Chapman, 1956; EPA, 1977).

Apart from the above mentioned constituents, suspended solids, most of the organic toxicants and trace metals are also removed from wastewater passing through soil (Sanks and Asano, 1976).

2.5 Crop Selection

The selection of the most suitable type of crop is based on the factors described below.

a) Time of growth; Nitrogen uptake is closely related with the time of growth. Crops utilize nitrogen only during their growth period. Therefore; crops with a longer growth period are able to consume more nitrogen than crops with a shorter growth period.

b) The quantity of the wastewater available for disposal, in other words, the flow rate or the hydraulic loading of the wastewater; Different kinds of crops require different amounts of wastewater. For example; crops such as sugar cane, plantain and grasses require large quantities of water and need to be irrigated throughout the year. They are suitable for sewage irrigation in smaller farm areas.

c) Tolerance to harmful wastewater Constituents; Tolerances of the selected crops to salinity, acidity and other toxic nutrients are variable. In general, forage crops are the most tolerant, field crops (barley, corn, cotton, potatoes, wheat, etc.) are less tolerant and vegetable and raw crops are the least tolerant (EPA, 1977).

d) Nutrient Uptake Capacity of The Crop ;Different kinds of crops are tolerable to certain nitrogen, phosphorus and organic matter loadings, for example, higher concentration of total dissolved solids is considered suitable for irrigation of salt-tolerant crops (Niyogi et al., 1982).

e) Ease of harvesting;

f) Minimum netcost of production; The last two factors take into consideration the economic aspects of crop production (EPA,1977; Bahr 1979

The list of crops suitable for irrigation with wastewaters include varieties of beets, cotton, pasture and hay; egg-plant, white and sweet potatoes, okra, sweet corn, olive and dry onion; fruit trees like citrus, banana, nut, date; ornamental plants, nursery plants; sunflowers and corob, apple, pear and plants grown for seed. It is a general experience that almost any crop grown with ordinary irrigation at a selected site will thrive as well as or even better under sewage irrigation (Mahida, 1981) On the other hand, public health considerations in relation to crop production should be taken into account. The growing of vegetables likely to be eaten raw is usually forbidden by health authorities in most countries. Experiences in India show that, it is safer to use untreated wastewaters for irrigation of non-edible or other suitable crops which are eaten after cooking or which have a natural protective covering over the edible parts (Shende and Sundaresan, 1982). Among the many advantages of crop production by wastewater irrigation; the considerable saving of cost in the use of chemical fertilizers and in the use of ordinary water are of great importance to be mentioned.

2.6 Public Health Implication of the Application of Wastewaters on Land

A particularly good effluent with sanitary characteristics comparable to unpolluted surface waters is not safe as drinking water for human beings without further treatment. Apart from possible bacterial impurities, groundwater from land subject to sewage irrigation continuously for a long time may change its taste.

When sewage is used in broad irrigation, the nature of the various operations, involves direct contact of men and cattle with sewage. While carrying out these operations, this contact is generally unavoidable. So is it necessary to prevent direct application of sewage on land? So far, there seems to be no adequate evidence that wastewater application on land, if properly carried out, is bad to the health of humans and animals. Cattle wadinginto sewage channels do not suffer from any disease. In fact, cattle are known to drink sewage effluents without any injury to their health (knight, 1955; Mahida, 1981).

Bacterial infection from sewage does not travel into the tissues of living plants. There is teherefore no danger in the consumption of products raised on sewage farms. Grains like maize, barley, wheat; fruits like coconut and peach can be successfully grown without the least danger to the health of consumers. In general, bacteria penetrate into the just broken, bruised and unhealthy plants and vegetables (Rudolfs, Falk and Ragotzkie, 1950).

There is no reason why sewage irrigation, if properly conducted should give rise to unsanitary conditions, such conditions can only arise if the usual principles governing the distribution of water are neglegted. There can be little danger arising from unhygienic conditions or from the prevalence of mosquitoes (Shuval, 1969).

2.7 Social and Economic Aspects of the Application of Wastewater on Land

The social and economic aspects including relocation, aesthetics and general public acceptability are quite difficult to define and evaluate by the designer (Mc Harg, 1971; EPA, 1975 (b)).

If substantial purchase of land is proposed, relocation may be required of residences, farm buildings, etc.

What will be the public reaction to land treatment and reuse of renovated water? Although the recycling of animal wastes is encouraged and fully accepted, people are more anxious about the application of human wastes to land. They are generally thoughtful about potential publ health, odor, property values and nuisance problems related with land treatment. Yet it is now known that these problems should not arise in a well-planned, well-engineered and well-managed system (EPA, 1977).

The other aspect of public acceptability isreaction to reuse of renovated water. In areas, where both the farmers and civilians have no idea about the benefits of land treatment of wastewater, they refuse the application of such a process. It is apparent, then, that in areas where such applications take place the inhabitants must be trained well on the subject. Public participation programs must supply information o the advantages and utility of such processes. With time, public accepta will improve.

Wastewater treatment by land application is the most economic wa of wastewater purification compared with conventional treatment systems (i.e. activated sludge, trickling filter). Land application of wastewater needs lower initial capital investment and operation cost with respect to other treatment processes. As this method has a high nutrient recycling capacity, there is less or no need for chemical fertilizers compared with irrigation of lands with ordinary water. Water resources are concerved to a great extent through irrigation with wastewater. The wastewater recycling in agriculture does not aim simply to the production of crops but also to other savings. For example; considerable savings (30-40%) in energy can be achieved through recycling of wastewaters for crop production as against energy inputs in the production of chemical fertilizers, besides other costs involved (Mahida, 1981).

CHAPTER III

EXPERIMENTAL SET-UP AND WASTEWATER CHARACTERISTICS

3.1 Experimental Set-Up (Field Studies)

The purpose of this study, as mentioned earlier, is to purify domestic wastewater by infiltration through porous media (sand) while travelling horizontally along a channel and thus to observe the variation of wastewater and soil characteristics with time and distance. Utilization of the wastewater nutrients accumulated in soil for crop production is also proposed. Therefore, recycling of wastewater and its nutrient resources through crop production is to be realised.

In order to initiate the conditions dominating in land treatment, a model was constructed within the fields of Boğaziçi University. This model (Figure 3.1) consisted of three main parts, namely

a) The inlet tank (tank 1)
b) The channels
c) The outlet tank (tank 2)

The pair of similar channels are 25 meters long with a slope of % 2 in the direction of flow. Figure 3.1 (a), (b), (c) and (d) shows the top and the side views of the system. The cross-sectional view of one of the channels is shown in figure 3.2.

The length of the pair of channels are designed according to a well-known fact in environmental engineering. A septic tank is to be constructed at least 30 meters away from a well or a house indicating that wastewater is treated along a distance of 30 meters. In this study 25 meters distance is chosen as the optimum length necessary for treatment, thinking that 5 meter distance is used as a safety factor.

BOĞAZİÇİ ÜNİVERSİTESİ KÜTÜPH

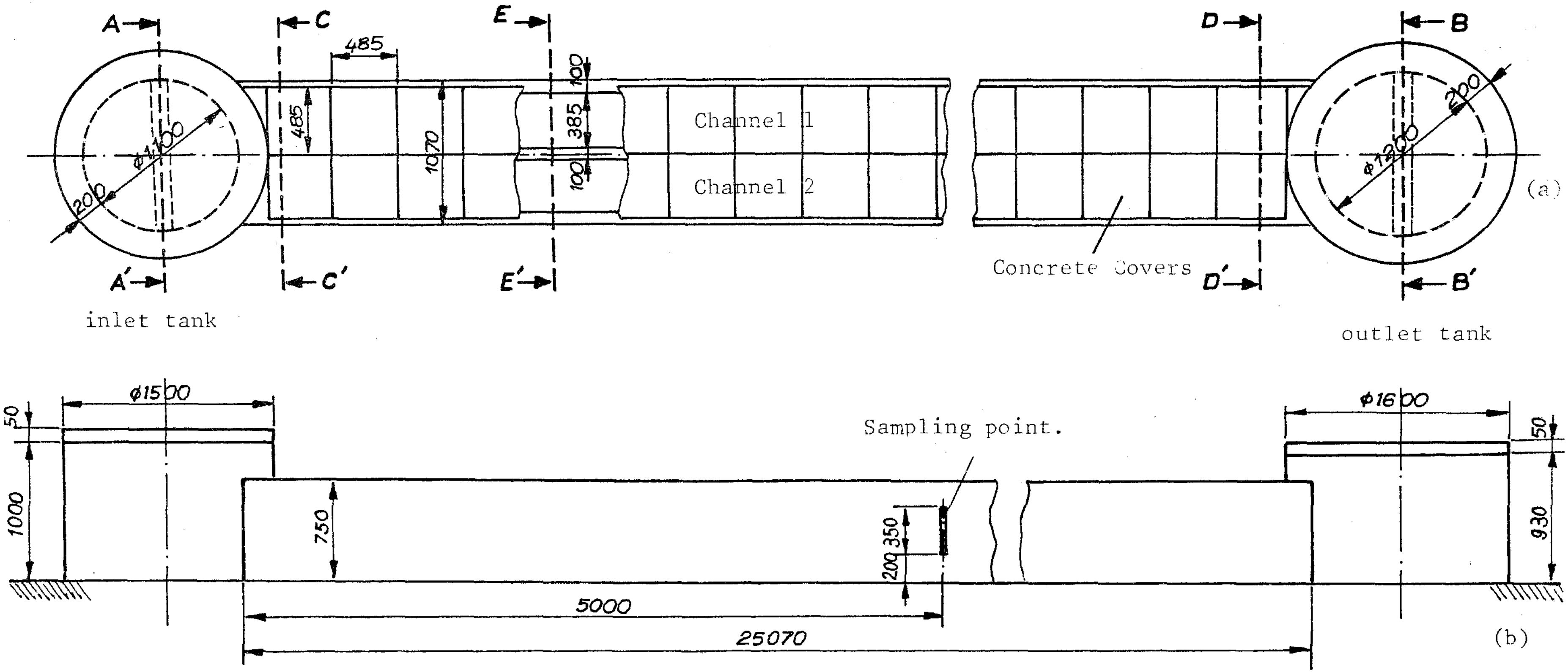


Figure 3.1 a) Top View of the System
b) Side View of the System

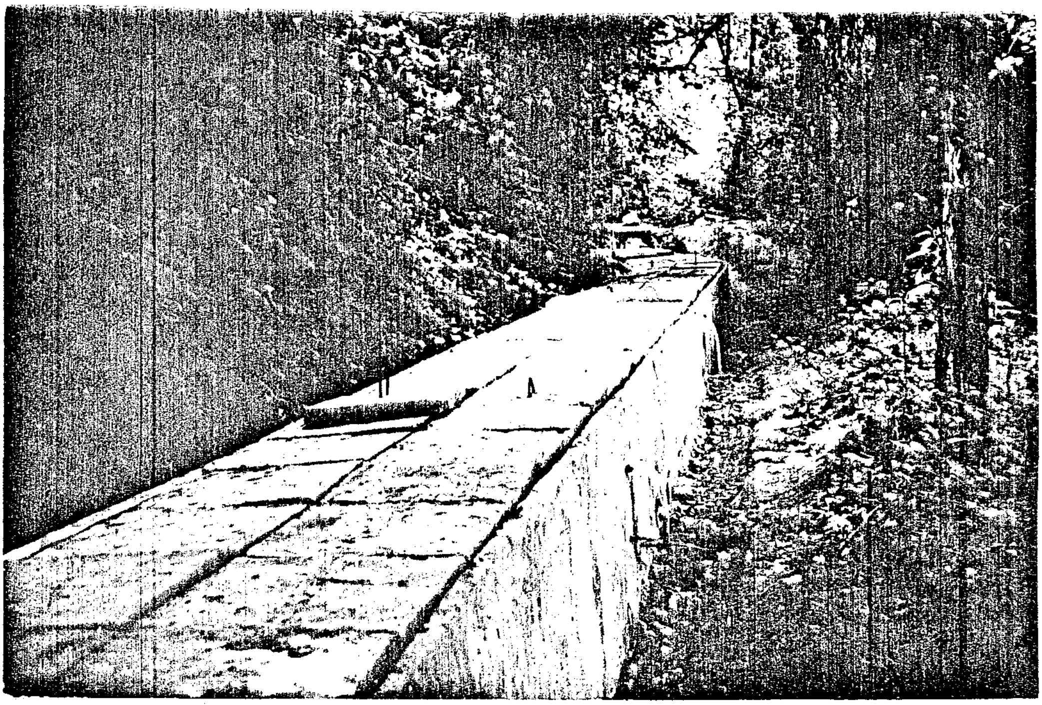


Figure 3.1 (c) Photograph of the Top View of the Channels

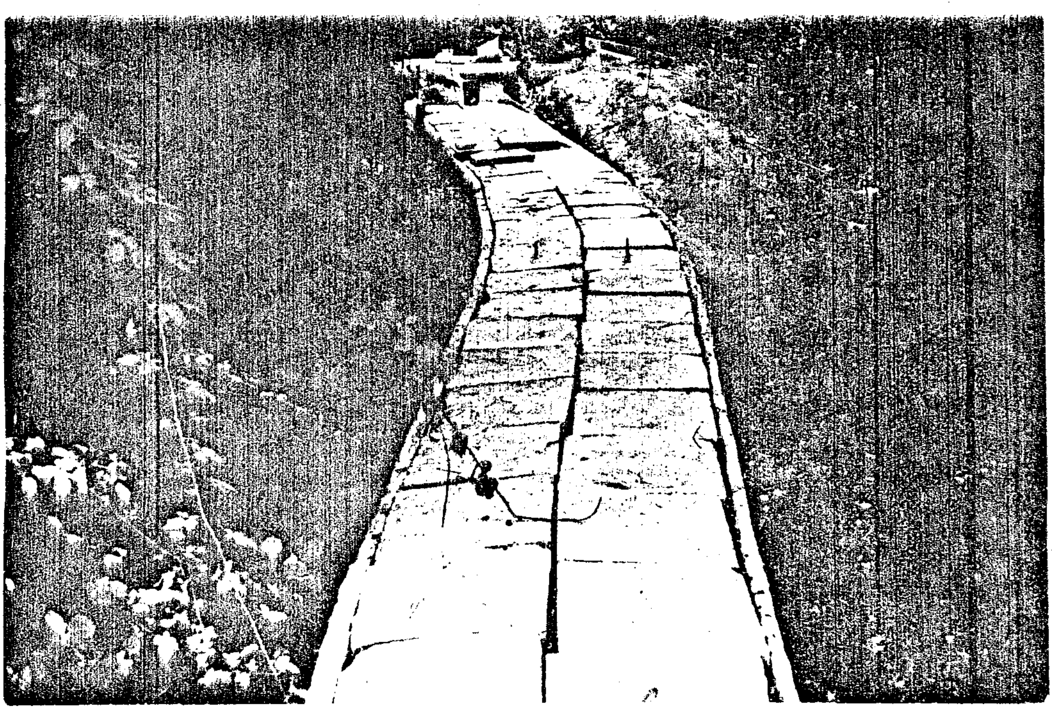


Figure 3.1 (d) Photograph of the Top View of the Channels and The Inlet Tank

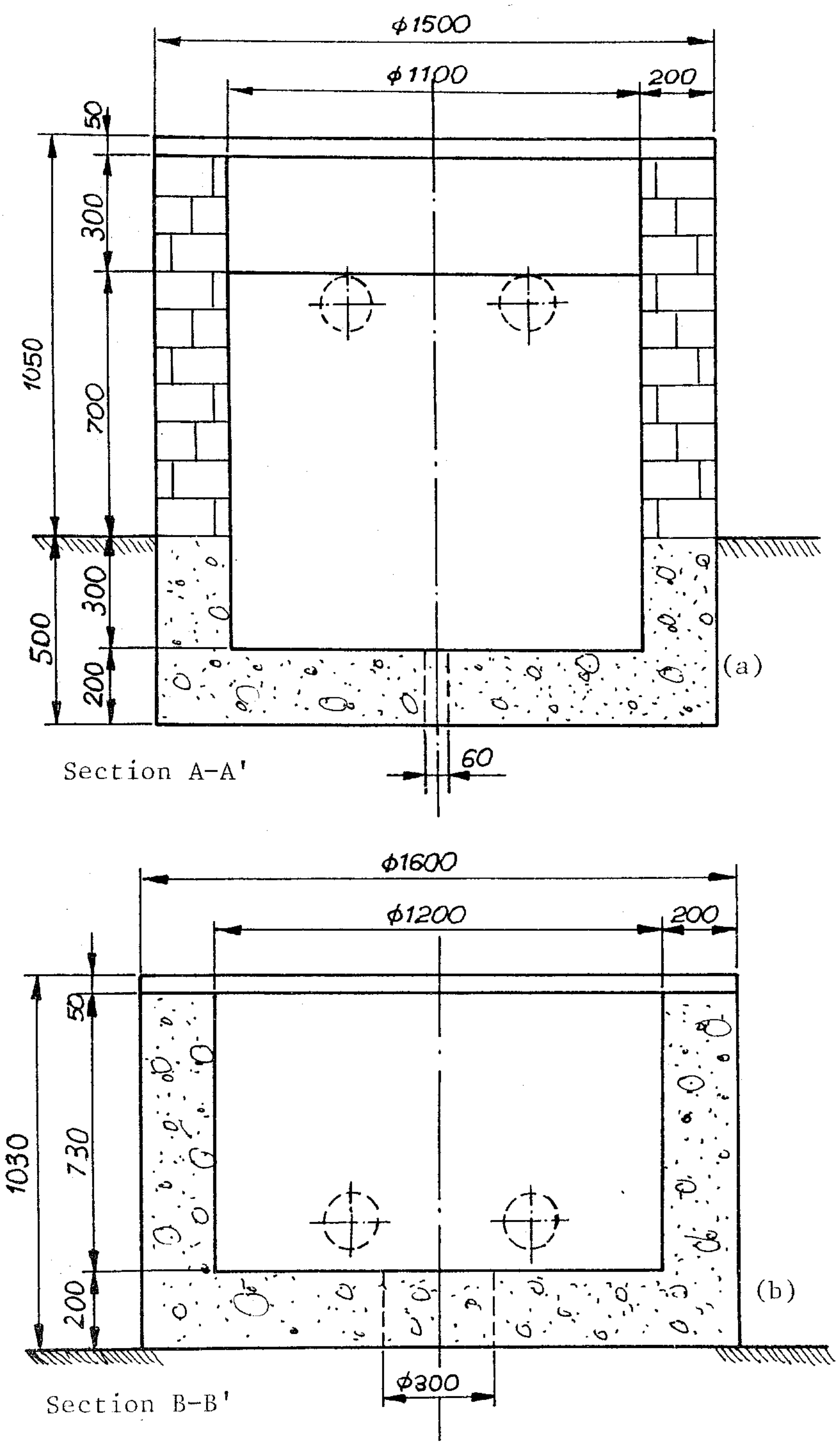


Figure 3.2 a) Cross-Sectional View of the Inlet Tank
b) Cross-Sectional View of the Outlet Tank

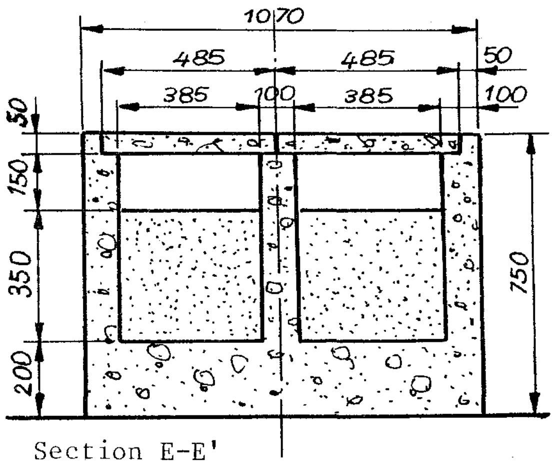
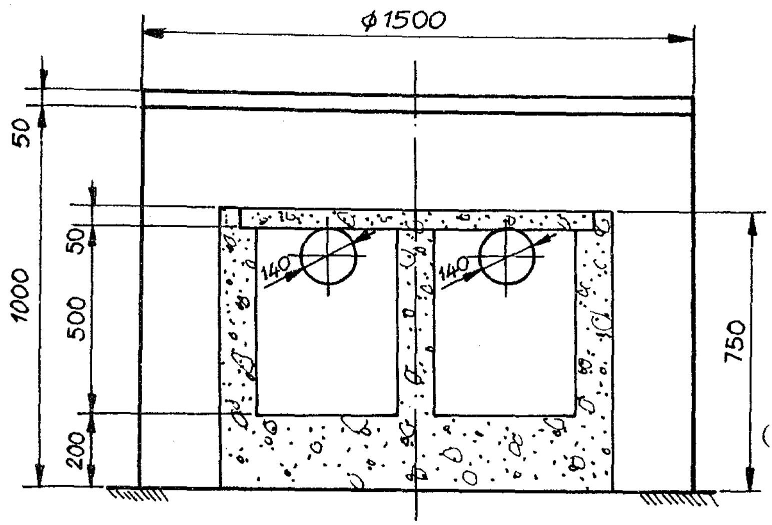


Figure 3.3 Cross-Sectional View of the Channel

The details of the different units are given below.

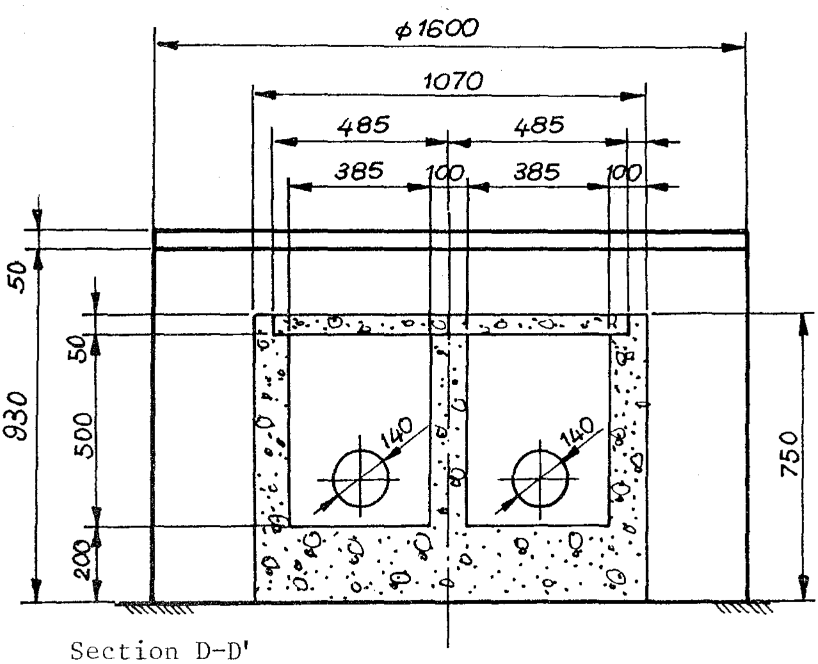
3.1.1 The Inlet Tank (Tank 1)

The inlet tank was constructed so as to continuously and uniformly supply raw sewage to the system. Part of this tank was already been present at the beginning of the study quite undestroyed, remaining from Robert College times. The main sewage line of the university passes under this tank. The cross-sectional view of the tank, that was repaired, is shown in Figure 3.3 (a). As can be seen from this figure, the tank has a height of 1.30 meters, out of which 0.30 meters is constructed below the soil surface and is made of concrete. The rest of the tank which is above the soil surface is made of fire-bricks. The thickness of the tank surface is 0.20 meters. The outer diameter of the tank is 1.50 meters, whereas the inner diameter is 1.10 meters. A separation wall was constructed in the inner side of the tank so as to decrease the amount of wastewater accumulated in it. This wall is made of concrete. Its height is 1 meter and its thickness is 0.10 meters. The wastewater was given to the channels through two openings constructed about 70 centimeters above the soil surface. These openings have a diameter of 14 cm. The inlet cross-sectional view of the channel is shown in Figure 3.4 (a) and a photograph of the inlet view of the channels is given in Figure 3.4 (c).



(a)

Section C-C'



(b)

Section D-D'

Figure 3.4 a) The Inlet Cross-sectional View of the Channel
b) The Outlet Cross-sectional View of the Channel

Figure 3.4 (c) Photograph of the Inlet View of the Channels

By clogging at a downstream point of the sewer line, which passes below the inlet tank wastewater was forced to flow into the inlet structure.

The top of the tank was covered with circular covers to prevent any external disturbances (e.g. to prevent the leakage of rain water)

The outer and the inner surfaces of the tank was well plastered so as to avoid the seepage of sewage.

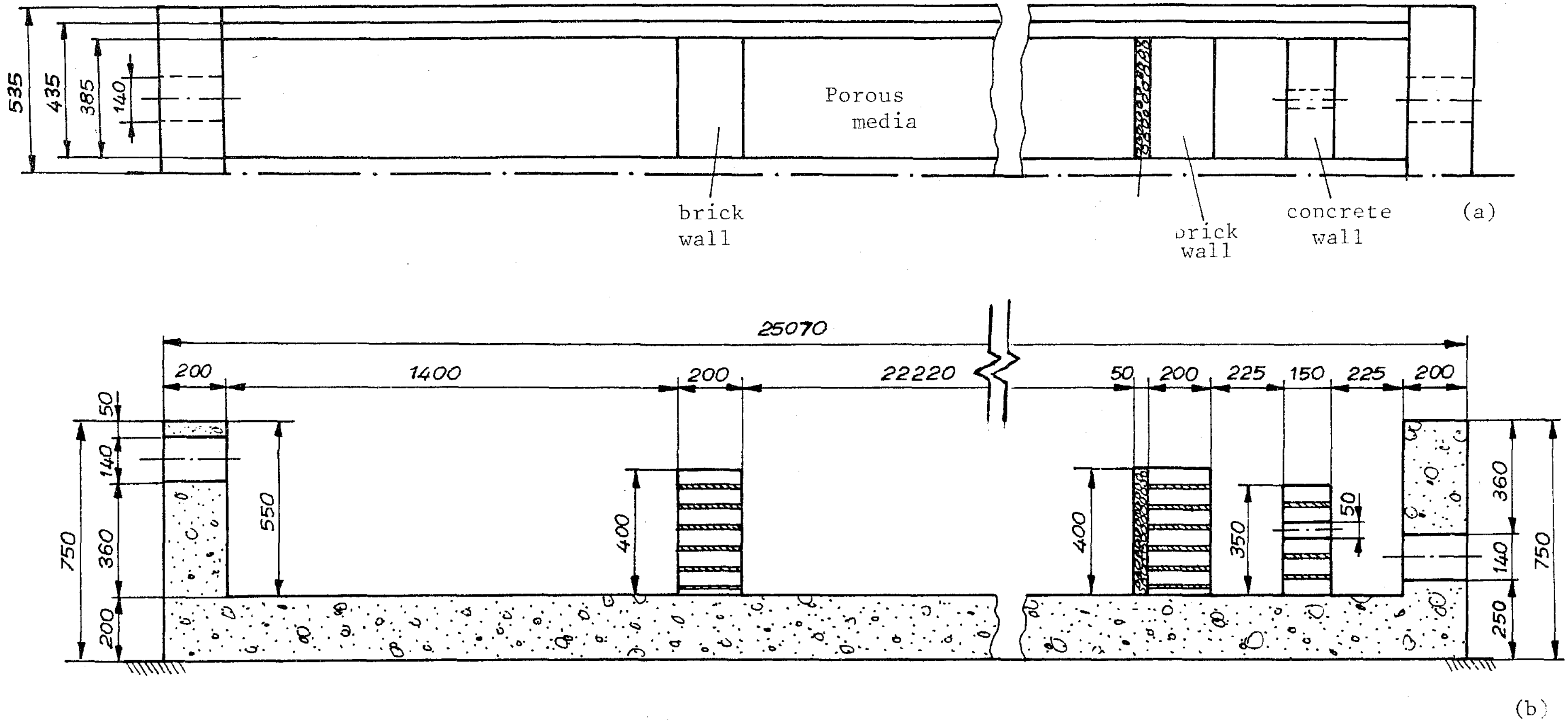


Figure 3.5 a) Top View of the Channel
b) Longitudinal Cross-section of the Channel

3.1.2 The Channels

The two infiltration channels where the main part of the study took place are ~25 meters long. Each contains one equalization chamber at the beginning and an outlet chamber at the end. Between these two chambers, the porous media is located. Fig 3.5 (a) shows the top view of one of the channels and Fig 3.5 (b) gives the longitudinal cross-section of it.

The Equalization Chambers

The equalization chambers were constructed to avoid turbulence and drag forces during the operation of the system. These chambers, located at the beginning of each channel have a length of 1.40 meters. The chambers end with a wall made of two lines of four perforated bricks (0.10 m.x 0.20 mx 0.10m) located in such a way that the holes permit uniform entrance of the wastewater into the porous media (Fig. 3.6)

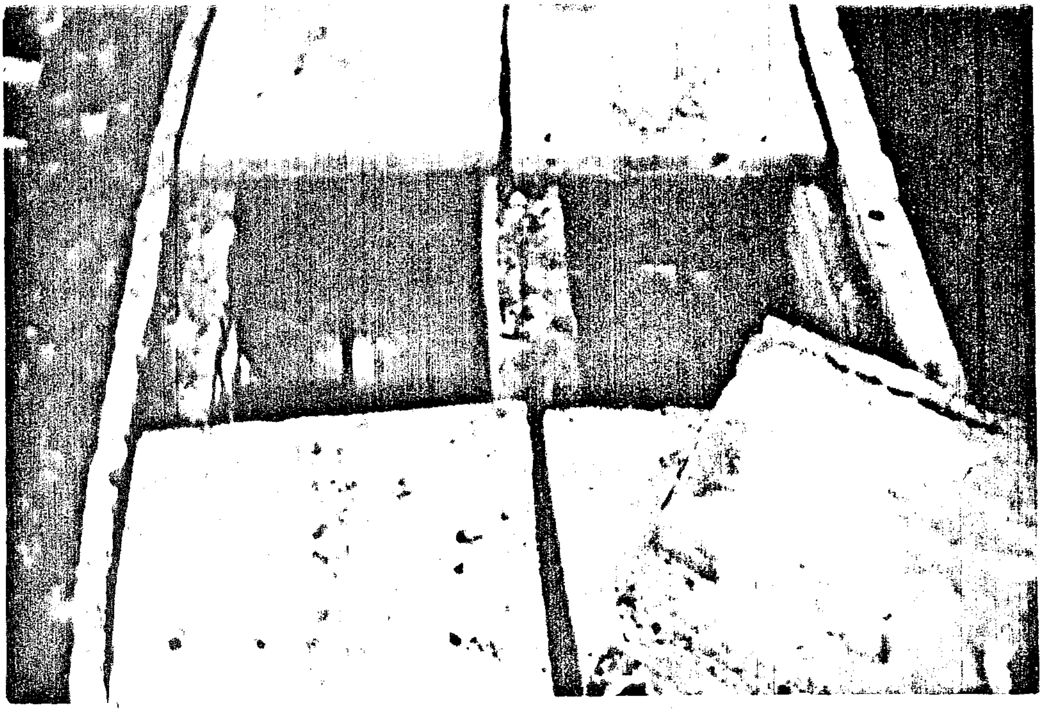


Figure 3.6 Photograph of the Channels Showing the Brick Wall

Outlet Chambers

A similar perforated wall is located at the end of the porous media. In this case, the block contains a sieve layer located between the media and the brick block to prevent dragging of sand particles into the outlet chamber. Figure 3.7 shows the photograph of the termination of the channels. The outlet chambers are near the end of the channels having a length of 0.60 m (Figure 3.5 (a), (b). At exactly the middle of this cavity, a concrete block is located. At about 0.18 meter from the bottom a hole was opened. The treated water reaching the first half

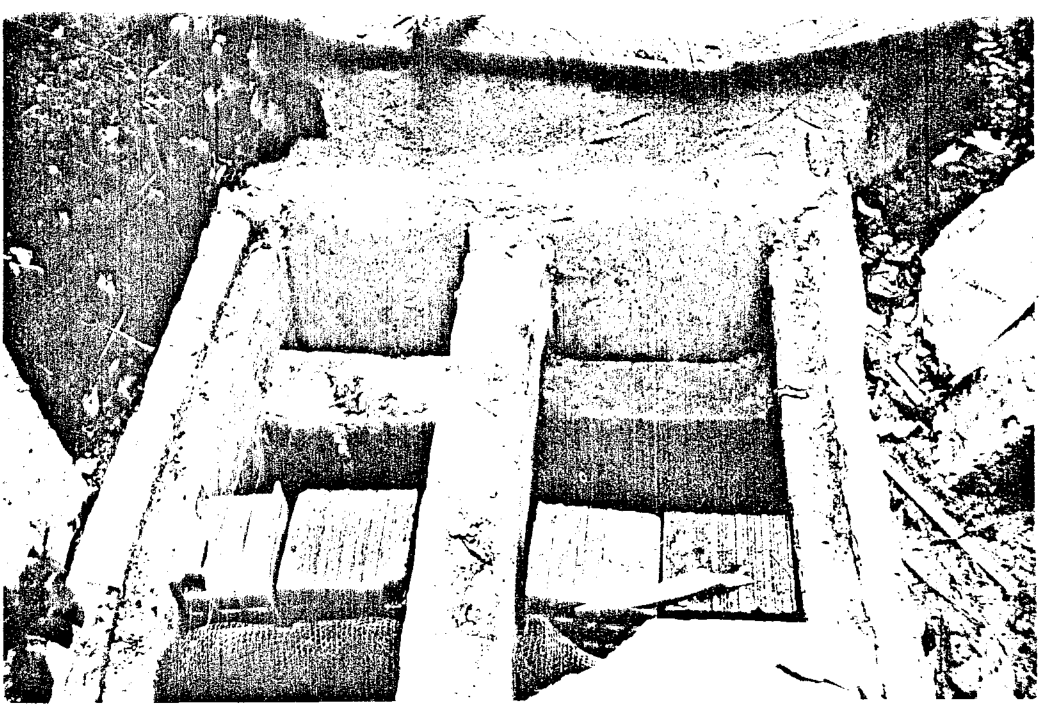


Figure 3.7 Photograph of the Termination of the Channels

of the chamber passes to the outer side as soon as the water level reaches the height of 0.18 meter.

Channels

The outer and the inner surfaces of the channels were plastered twice to prevent seepage of wastewater. Rectangular concrete covers were placed at the top of the channels to avoid possible disturbances during the experiment as well as problems of odor (Figures 3.8 (a), (b)). At

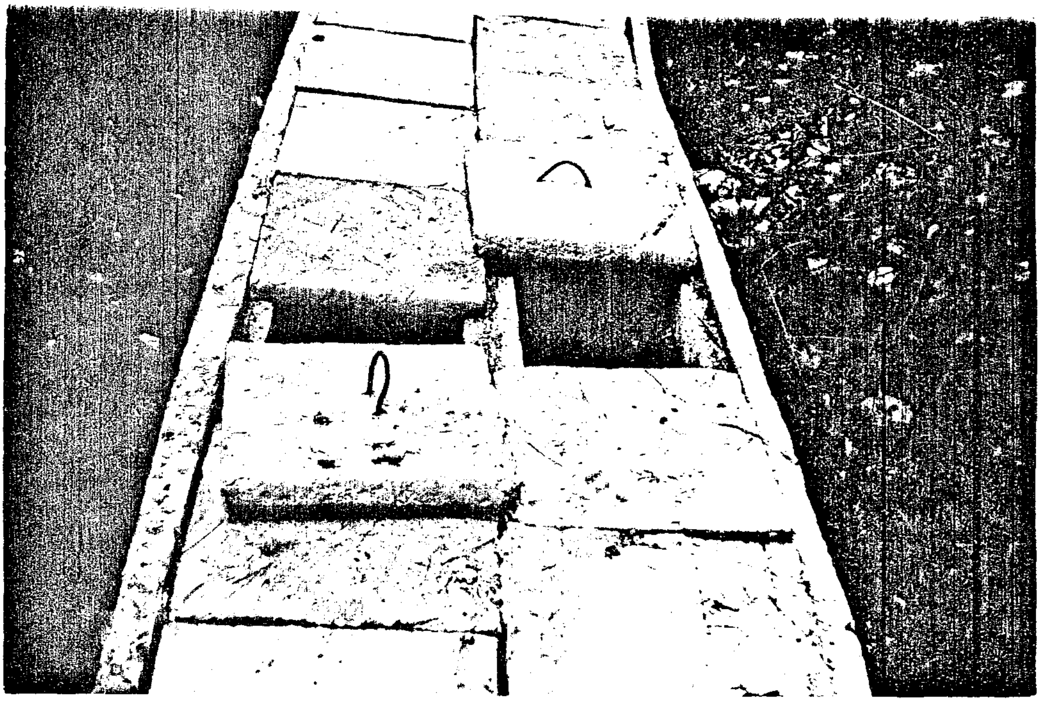


Figure 3.8 (a) Photograph of the Top View of the Channels

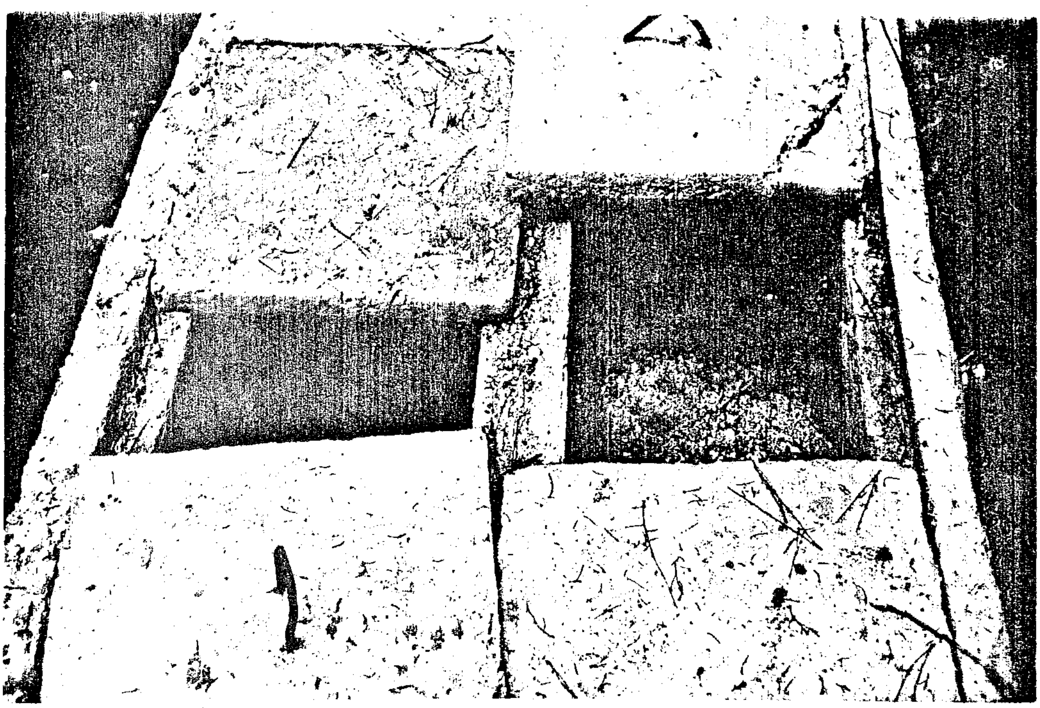


Figure 3.8 (b) Photograph of the Porous Media and the Iron Handles of the Covers

every five meters distance along the channels, the covers have iron handles to enable easy removal of the covers while collecting sand samples (Figures 3.8 (a), (b)).

The part of the channel where the porous media is located has dimensions of 22.22 meters (length) x 0.35 meter (height) x 0.385 meters (width). Details of the porous media are given in section 3.2.

Sampling Points - Piezometers

At about every five meters distance along the outer sides of each channel, four plastic pipes of 0.35 meter length extend upwards parallel to the side surface of the channels (Figure 3.9). All of them contain plastic stoppers. When the samples were to be collected, these stoppers were removed and by gravity, the water samples were easily taken. Each channel contains four intermediate sampling points.

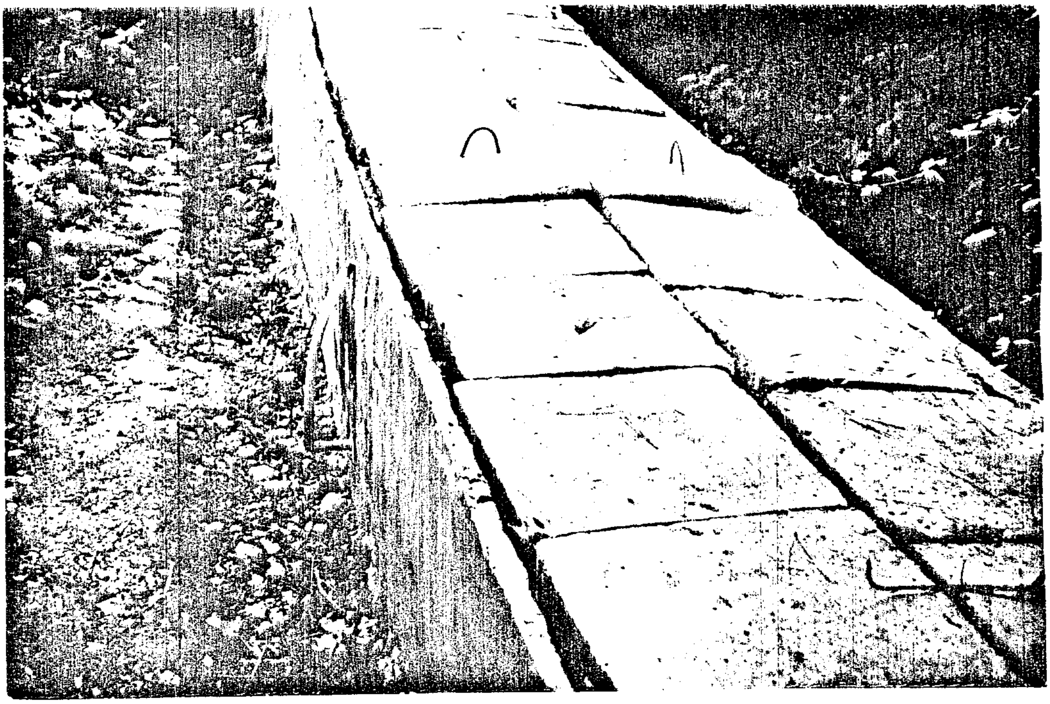


Figure 3.9 Photograph Showing one of the Sampling Points (Piezometer)

3.1.3 The Outlet Tank (Tank 2)

The height of this tank is 0.93 meters. The outer diameter is 1.60 meters, where as the inner diameter is 1.20 meters. The cross-sectional view of the tank is shown in figure 3.3 (b). The inner side is divided into two sections by a concrete block to avoid clogging of the piping system leading to the main sewer line with sand particles that may escape through the perforated wall.

The channels join the outlet tank through two openings (Figure 3.4 (b)), each having a diameter of 14 centimeters. The outlet tank, like the inlet tank is covered with circular covers on top and the inner and outer surfaces of it are well plastered.

<u>Alteration Made to the System:</u>

After the first experimentation, the following difficulties were encountered;

a) The regular flow rate of the sewage was quite higher than expected; even though equal flow rates were maintained in both channels, overflow was observed,

b) Overflow caused the wastewater to flow over the porous media instead of flowing through it. This situation was against the idea of infiltration,

c) It was quite difficult to decrease the flow rate as the design of the inlet structure seemed inconvenient to make the necessary alterations to the system, related to the return of the excess amount of wastewater back to the main sewer line.

At the beginning, the aim of the study was to use both channels filled with different grain sized sand, But, to overcome the above stated difficulties only one of them was used after making the following alterations to the system. The main opening to the channel to be used, was choked and all the wastewater was given to the other channel which was not used. The wastewater was supplied to the channel in which the study was supplied to the channel in which the study was conducted by a plastic syphon of 1 centimeter diameter and 1.60 meters length. The transfer of wastewater to the channel was continued until the water levels in each equalization chamber reached an equilibrium. As soon as the water level reach to 25 centimeters in the channel, flow through the porous media was observed. Thus, continuous and uniform flow of wastewater was obtained in this channel.

3.2 The Porous Media

Sand was used as the porous media in the present study, it is sea-sand and brought to the university by a lorry from a nearby sand depot. The granulometric curves of the sand used are given in Figure 3.10. As can be observed in Figure 3.10 the sand is uniform. The two curves represent the analysis of the sand samples collected from the 5^{th} and 20^{th} meter distances along the channel. The effective size of the sand, the uniformity coefficient and the coefficient of concavity determined from the above mentioned figure are given in Table 3.1 The texture of the soil can be classified as coarse to medium sand.

Other characteristics of the porous media observed before the operation of infiltration started are summarized below. It is important to note here that the related analyses were conducted just after the cleaning and washing process (section 3.3.1) of the sand.

TABLE 3.1 THE PHYSICAL CHARACTERISTICS OF THE POROUS MEDIA

Physical Characteristics	Samples collected at 5 m. distance	Samples collected at 20 m. distance	Average Values
Effective size (mm)	0.51	0.60	0.555
Coefficient of uniformity	3.13	3.00	3.065
Coefficient of concavity	1	0.93	0.965

- The total volume of the sand distributed in the channel ⇒ 29941 m^3 ≃ 3 m^3

- The depth of the sand media along the channel ⇒ 0.35 meters

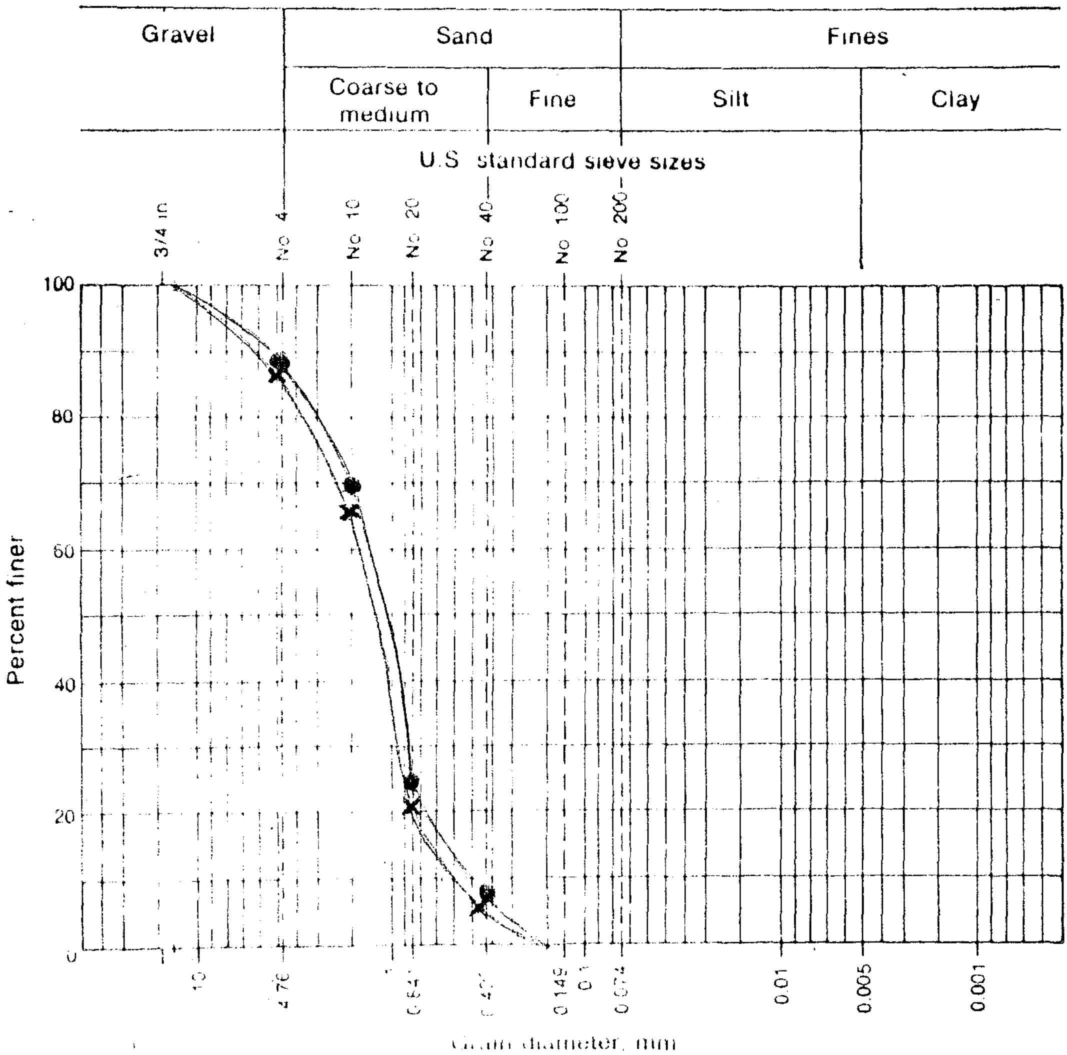
- The length of the sand media along the channel ⇒ 22.22 meters.

- The depth of the sand from which wastewater flows ⇒ 0.25 meter. (The 10 centimeter layer is left as a safety layer.)

- The porosity (n) of the sand ⇒ 42.8%

- The specific yield of the sand ⇒ 27.1%

The detailed characteristics of the porous media are given in Appendix A.



• sample from 5^{th} meter

x sample from 20^{th} meter

Figure 3.10 The Granulometric Curves of the Sand Used in the Study

3.3 The Wastewater Characteristics

Before the actual operation of the system, the experimental set-up was prepaired for the operation. It was then that the wastewater is given to the system and the experimental studies started after reaching stable conditions. The preliminary studies conducted before the experimentation and the procedure of the foregoing laboratory studies are mentioned in this section.

3.3.1 Preparation of the Experimental Set-Up

The sand after being sieved was placed uniformly through out the channel. Then, in order to remove impurities as well as salts present in the sand, the media was washed thoroughly with tap water. This process was repeated many times till the impurities were removed and clean water was was observed at the outlet tank. Clean sand samples were collected from the 5^{th} meter and from the 20^{th} meter distances along the channel from mid-depths.

The sieve analysis was conducted using these clean samples. Samples of sand were also kept for comparison with other soil samples collected at different times during the operation of the system.

3.3.2 The Experimental Procedure

The wastewater was given to the channels after the washing process of the sand is terminated. The first few experimentation showed the necessity of making alterations to the system (see section 3.1). The flow rate of the wastewater was maintained constant and continuous in the channel. The flow rate was recorded and the velocity of the wastewater in the soil was also calculated (See Appendix A). The sampling points were controlled once more, to check whether water flowed by gravity in the pipes or not. Details of the flow and the characteristics of the sand media are given in Appendix A.

The wastewater samples were decided to be collected from six sampling points, four intermediate points as well as the influent and the effluent samples were collected from the point of entrance (equalization chamber) and from the end (outlet chamber).

Experiments were conducted on the influent wastewater in order to determine its characteristics. The results are given in Table 3.2. The results obtained lie within typical medium concentrations of untreated domestic wastewater. Table 3.2 compares the typical composition of untreated wastewater with the influent characteristics of the wastewater used in this study.

TABLE 3.2 WASTEWATER CHARACTERISTICS AND COMPARISON WITH VALUES REPORTED BY METCALF AND EDDY (1979)

Parameters	Influent Characteristics		Metcalf and Eddy Concentrations (mg/L)		
	minimum (mg/L)	maximum (mg/L)	Strong	Medium	Weak
Chemical Oxygen Demand	32.0	747	1000	500	250
Nitrogen	12.88	23.83	35	15	8
Phosphorus	4.4	7	15	8	4
Suspended Solids (total)	42	232	350	220	100

The experimental studies were performed in the Environmental Engineering Laboratory of Boğaziçi University. The aim of this study was to determine the variations of wastewater characteristics with time and distance as it travels through the sand bed. The experiments were repeated twice and/ or thrice a week at the beginning of the study. Then, for a period of two months, the analyses were conducted once a week. The total experimental period was two and a half months (from the beginning of August till the third week of October) after steady conditions were reached. On the other hand, every three weeks during the study, a pair of soil samples (from the 5^{th} and 20^{th} meter distances) were collected from the mid-depth of the sand media. Analyses on soil samples were also conducted to determine the variations of soil characteristics with time and distance.

Apart from these studies; wheat, corn and bean seeds were sowed in the collected soil samples to observe their growth rate with time.

3.3.3 The Laboratory Studies

The wastewater and soil characteristics were determined on the basis of certain parameters. The parameters that were used in order to characterize the wastewater are pH, turbidity, Chemical Oxygen demand, phosphorus, nitrogen, solids and total coliform. The corresponding experiments were conducted according to the methods given in Standart Methods (1981). In the determination of phosphorus, the Stannous Chloride Method; for nitrogen, the kjeldahl nitrogen; for coliform; the Membrane Filter Technique were used.

The soil characteristics were determined on the basis of the following parameters; pH, volatile matter, organic matter and phosphorus (utilizable by crops). The determination of pH and volatile matter were conducted in the University's Laboratory, where as the organic matter and the phosphorus concentration in soil were conducted at TOPRAKSU, Toprak Tahlil Laboratuvarı, in İstanbul.

CHAPTER IV

EXPERIMENTAL RESULTS AND DISCUSSION

The experimental study mainly covered

- the variation of wastewater characteristics with time and distance,
- the variation of soil characteristics during infiltration process with time and distance, and
- the variation of crop production efficiency of sand (filter media) with time and distance.

The results of the experiments are given in the following sections.

4.1 Variation of Wastewater Characteristics With Time and Distance

Filtration is a dynamic process; it's efficiency depends on its depth, size of media, rate of flow and duration of filtration. The removal efficiency is usually proportional to the concentration of the influent parameters (Onaral, 1973).

The variation of wastewater characteristics with time and distance are observed by taking samples from different sampling points (section 3.1.2) and determining the following parameters: chemical oxygen demand, nitrogen, phosphorus, solids, turbidity, pH and coliform.

The raw data obtained are given in Appendix B.

4.1.1 Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a parameter that measures the pollutional strength of the wastewater. Since this parameter is one of the most important ones in determining the treatment efficiency of a process, the variation of this parameter was investigated.

The variation of COD values with time is given in Figure 4.1. Figure 4.2 gives the variation of the percent COD removal efficiency while figures 4.3 and 4.4 give respectively the COD removal and percent COD removal with distance. Examination of these figures results in the following conclusions;

- COD decreases with distance. The COD values of the intermediate points as well as of the effluent depend on the influent values. Large fluctuations in influent values range between 320-747 mg/L. This range varies between 267-690 mg/L at 5 meters distance, 187-586 mg/L at 10 meters distance, 160-426 mg/L at 15 meters, 104.5-267 mg/L at 20 meters and 78-200 mg/L at 25 meters distance.

- Percent COD removals are almost constant with distance, with slightly higher values at the beginning.

- The overall percent removal achieved is on the average around 84%. If it is considered that the removal efficiency of the activated sludge process varies from 65 to 90%, the trickling filter process within 65-85% and of sand filtration with crops grown within 90-95% (Fair, Geyer and Okun, 1968). The results obtained in this study are very satisfactory.

Niyogi et al., (1982) in India in a similar study, conducted on a sandy loam media of 120 centimeters depth and 240 centimeters width covered with hybrid Napier grass obtained 83.67% removal efficiency.

4.1.2 Nitrogen (N)

Nitrogen, if present in high amounts is considered as a source of pollution. Consequently, removal of nitrogen is generally desired.

In the present study, the removal of nitrogen was examined and the results are presented in figures 4.5 to 4.8 Results are expressed as Kjeldahl nitrogen. As can be observed from these figures:

- Nitrogen values decrease or removal efficiency increases with length of infiltration (distance travelled),

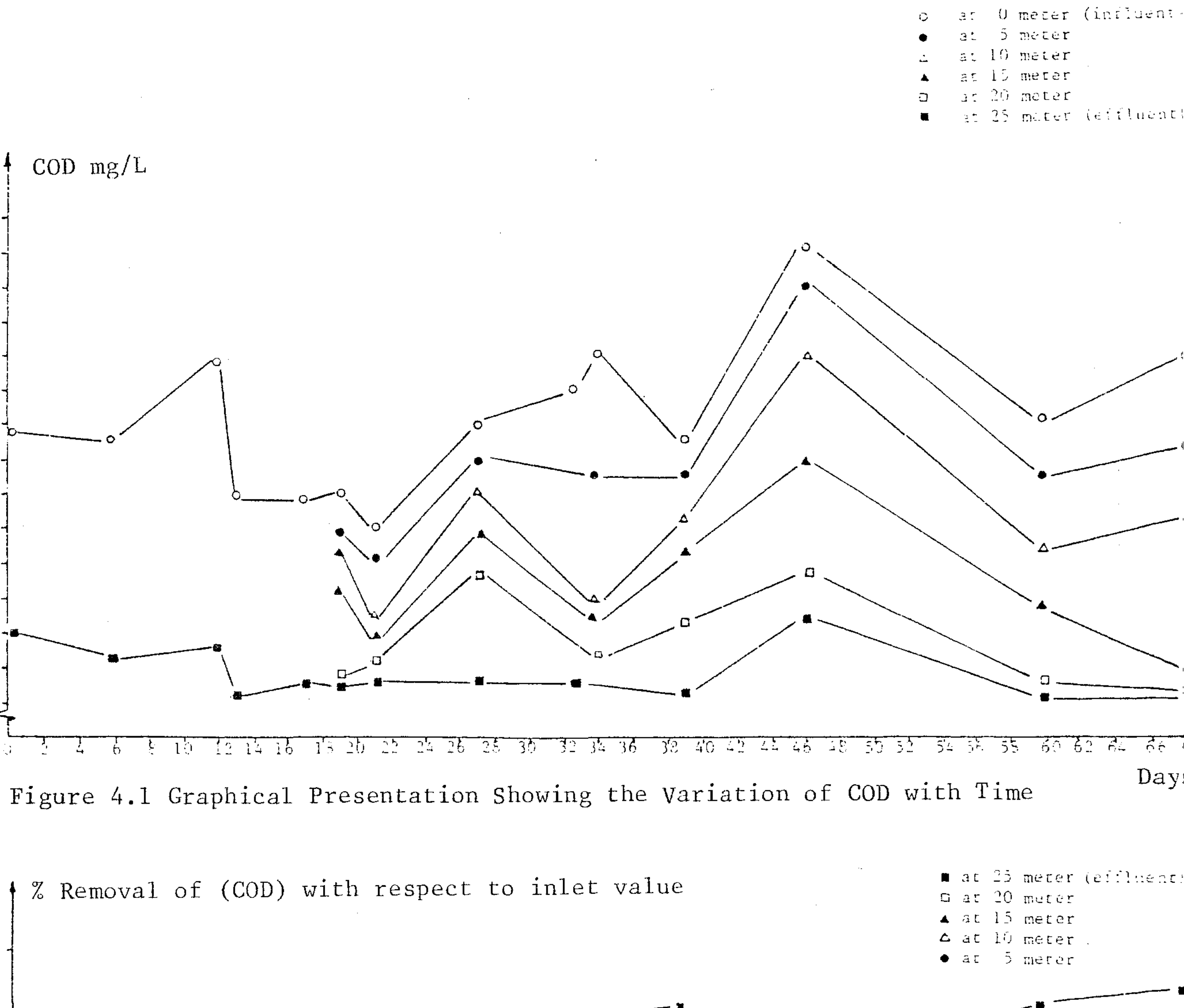


Figure 4.1 Graphical Presentation Showing the Variation of COD with Time

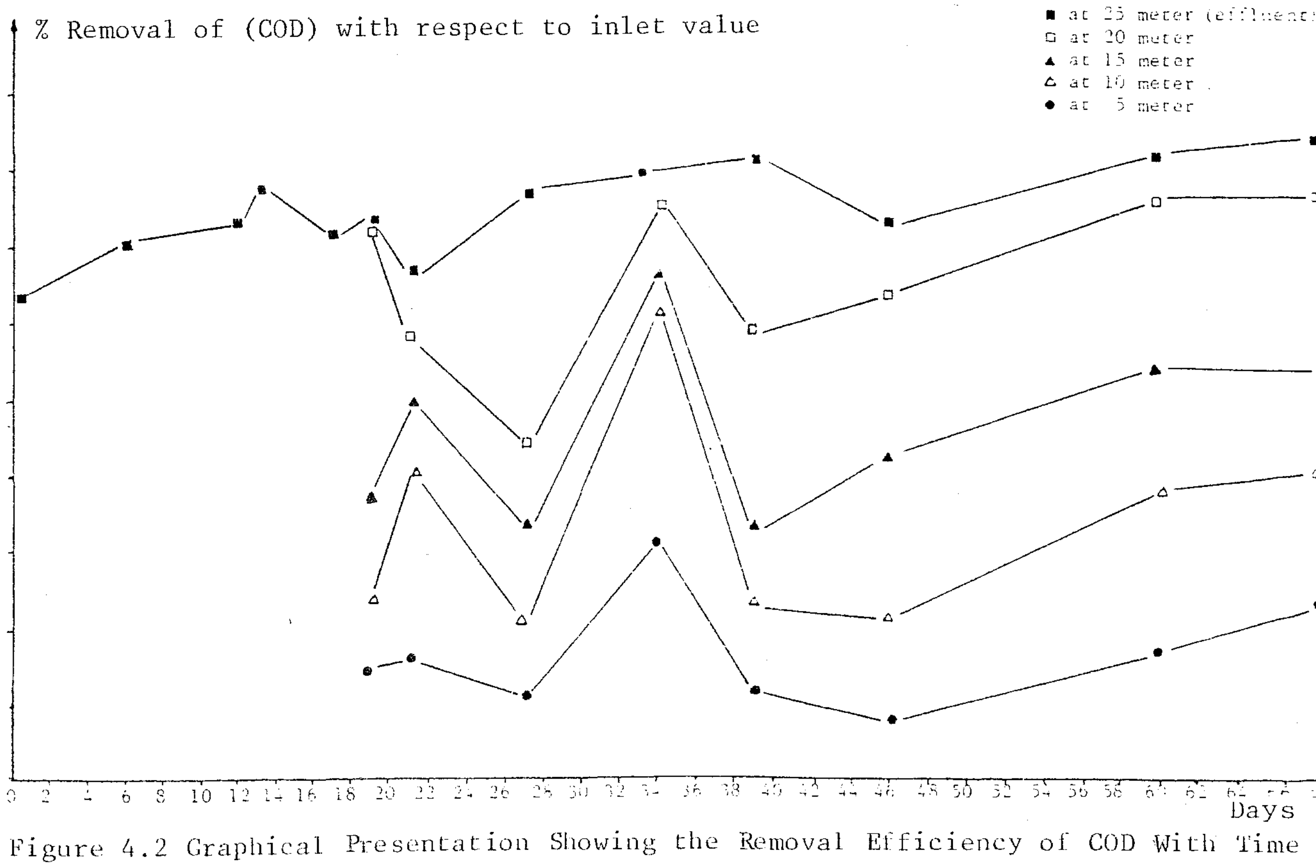


Figure 4.2 Graphical Presentation Showing the Removal Efficiency of COD With Time

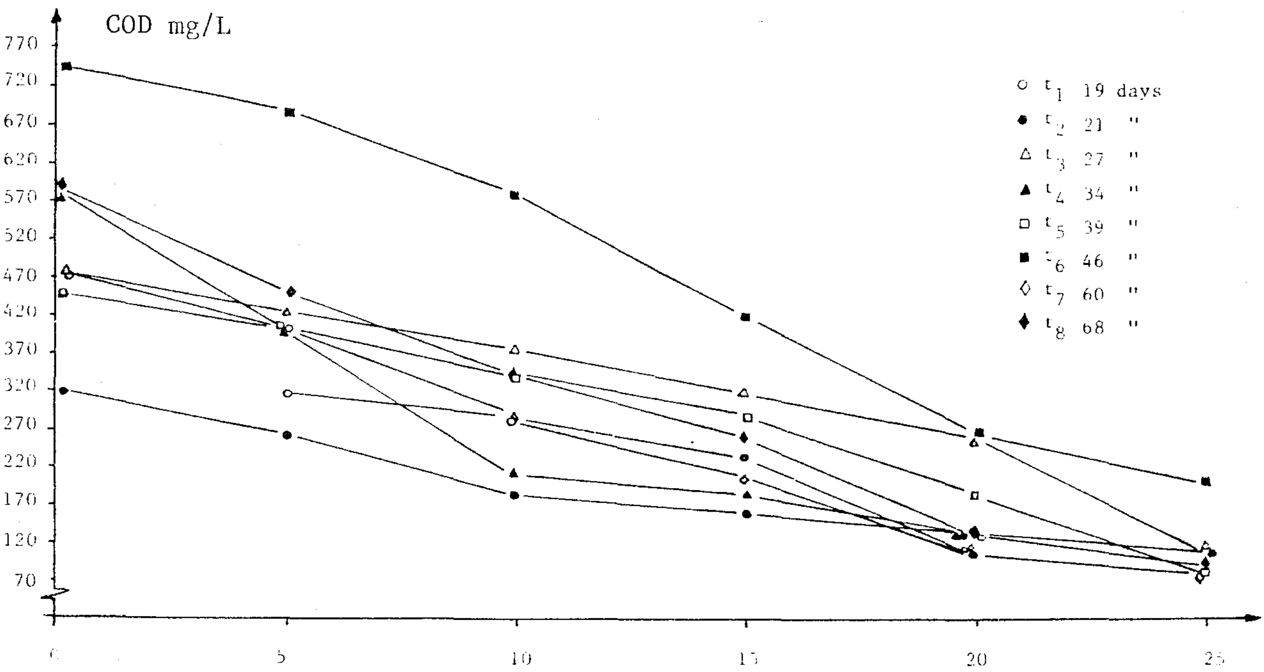


Figure 4.3 Graphical Presentation Showing the Variation of COD With Distance

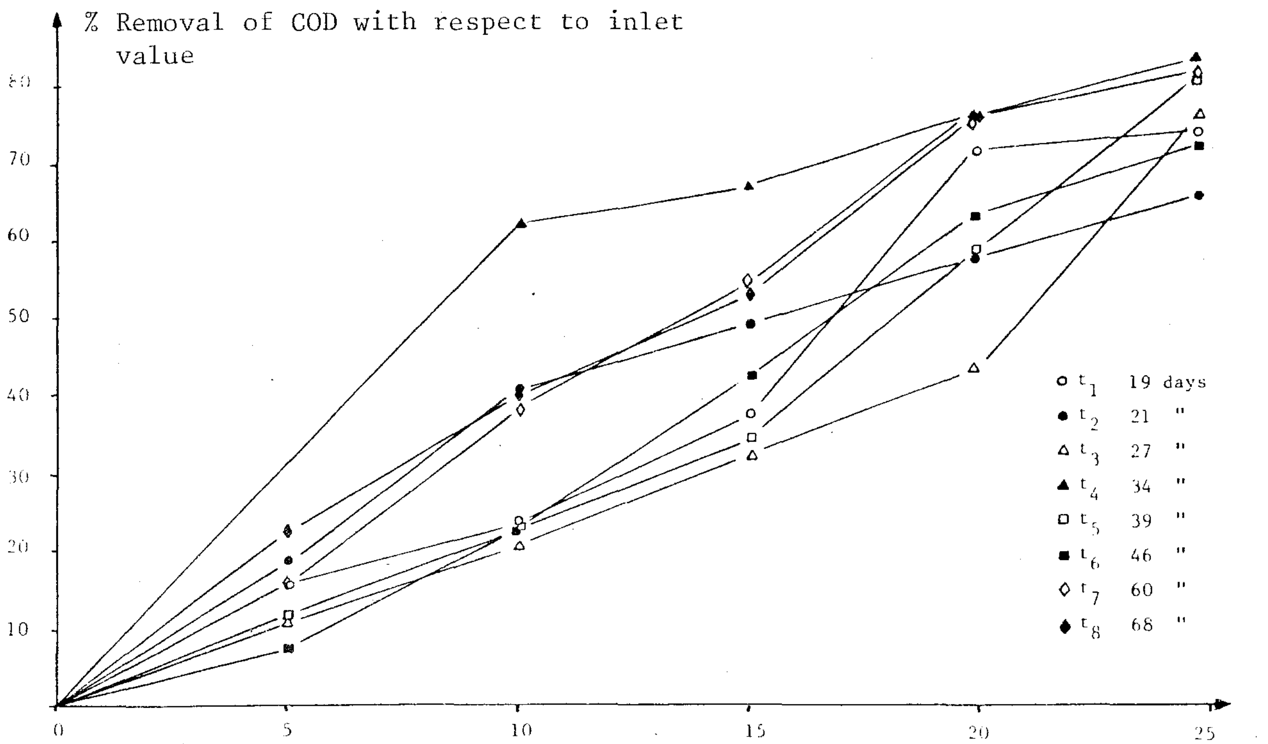


Figure 4.4 Graphical Presentation Showing the Removal Efficiency of COD With Distance

- Variation of efficiency with time did not follow a certain pattern,

- The nitrogen removal obtained at the effluent of the channel (a travel distance of 25 meters) is within a range of 65 to 75%. This value compared with the values reported by Sanks and Asano (1976) shows an agreement. It should be noticed, however, that in Sank's study the surface was covered with vegetation (Table 4.1). This, of course, had a further positive effect on the removal efficiency. Niyogi's (1982) study, where the surface of the sandy loam was covered with hybrid Napier grass gave similar results (Table 4.1).

TABLE 4.1 COMPARISON OF NITROGEN REMOVAL RATES

Type of Land Treatment	% Removals
Spray Irrigation [x] (Sanks and Asano, 1976)	70-90
Overland runoff[x] (Sanks and Asano, 1976)	60-90
Rapid Infiltration[x] (Sanks and Asano, 1976)	30-80
Sandy Loam Filtration (Niyogi et al., 1982)	67.74
Present Study	65-75

x with a vegetation cover

As mentioned previously in section 2.4, the presence of living plants stimulates denitrification. Thus, in this study, the denitrification rate is slightly low due to the lack of a vegetation cover on the system.

On the other hand, in conventional wastewater treatment system, the removal efficiency is quite lower than the efficiency achievable in any of the land treatment systems (30-60%).

In conventional activated sludge plants partial conversion of ammonia to nitrates takes place. In order to induce more complete nitrification, it is necessary to decrease the sludge loading factor (sludge age is to

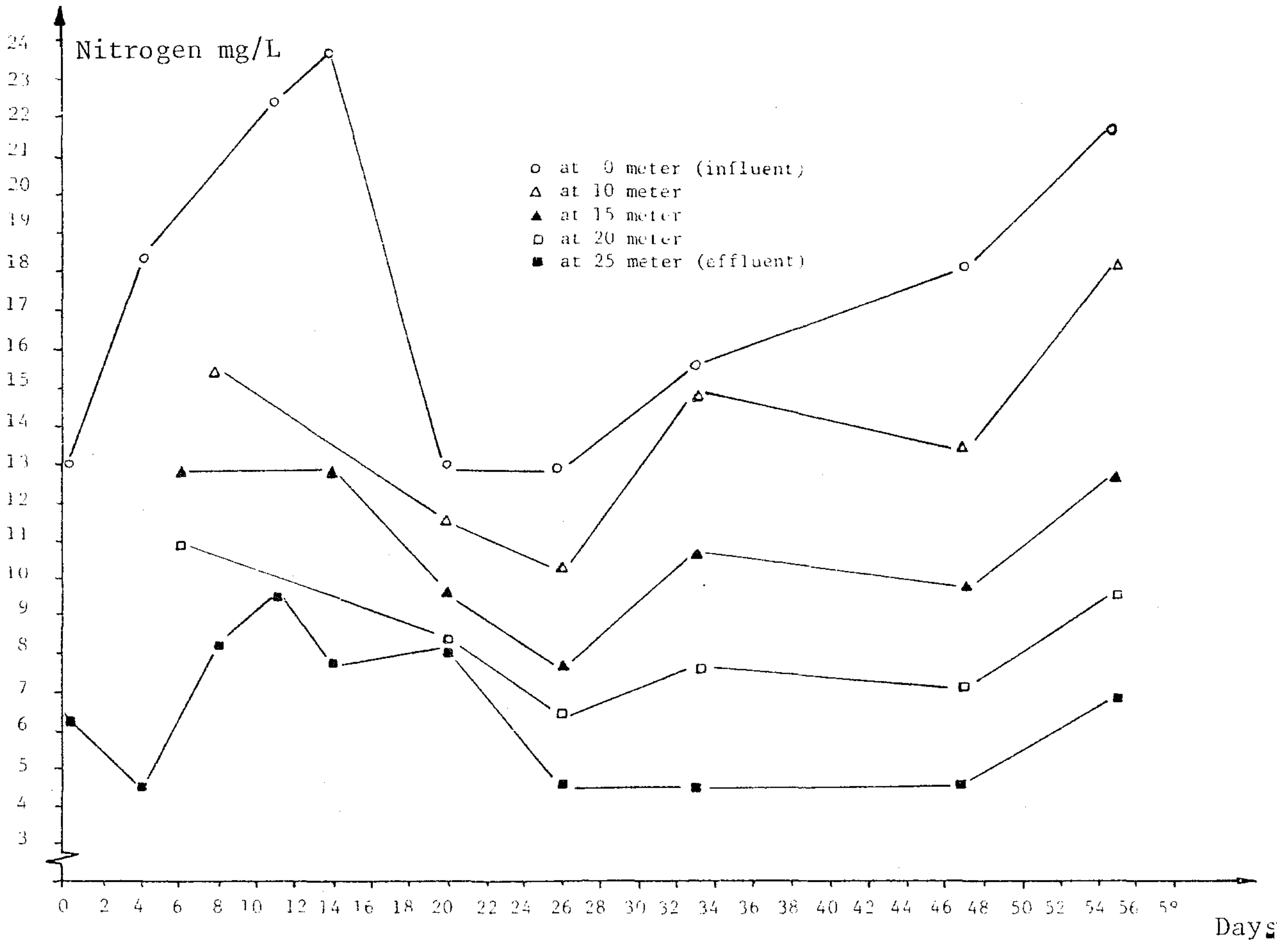


Figure 4.5 Graphical Presentation Showing the Variation of Nitrogen With Time

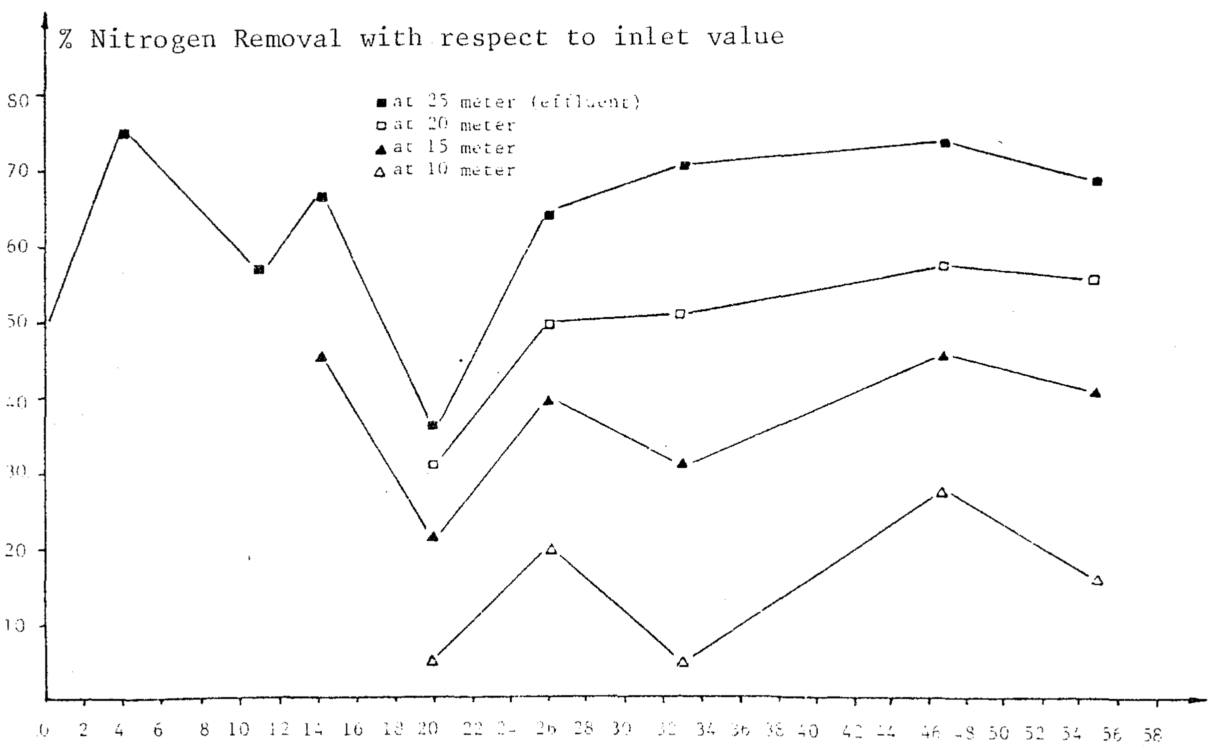


Figure 4.6 Graphical Presentation Showing the Removal Efficiency of Nitrogen With Time

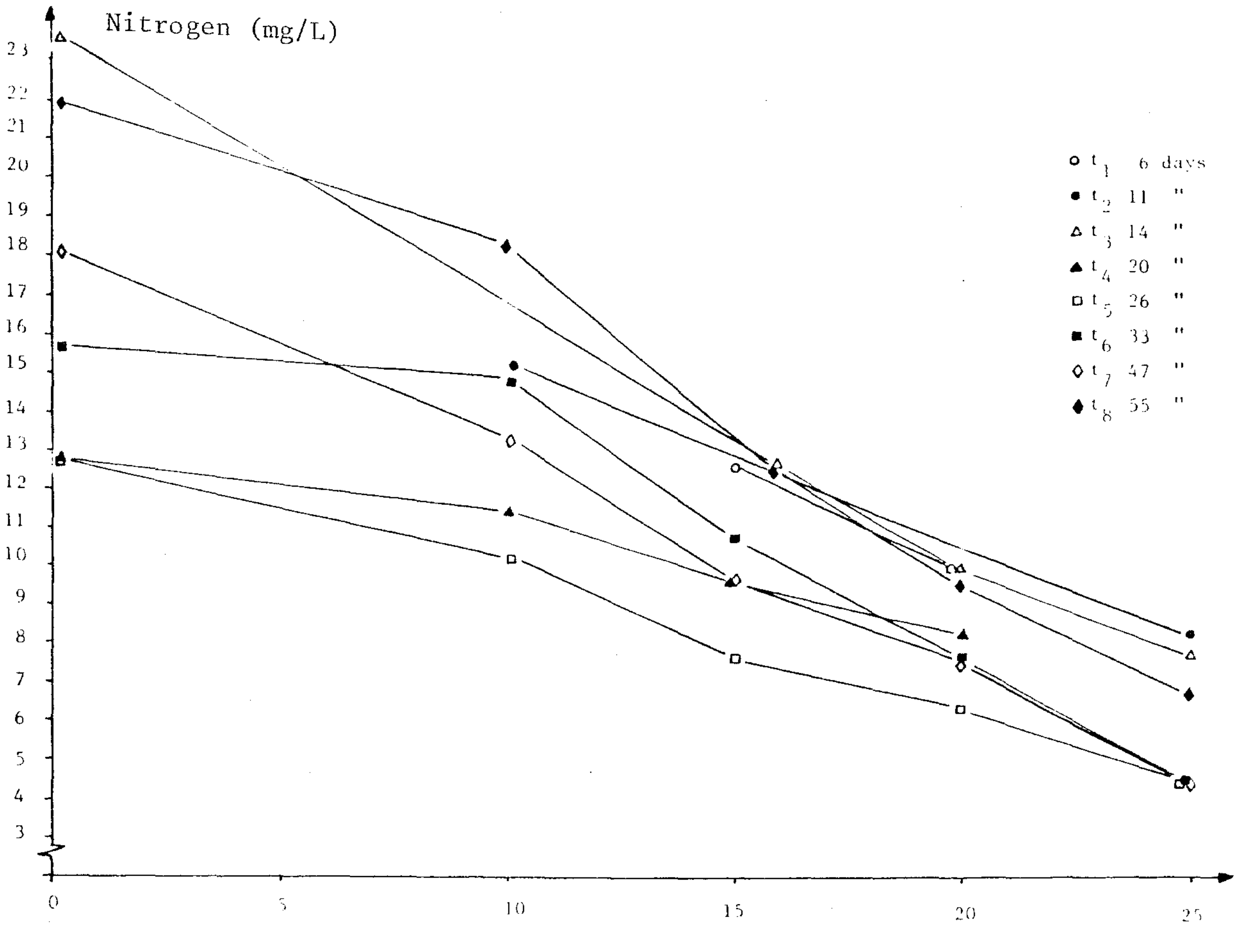


Figure 4.7 Graphical Presentation Showing the Variation of Nitrogen With Distance

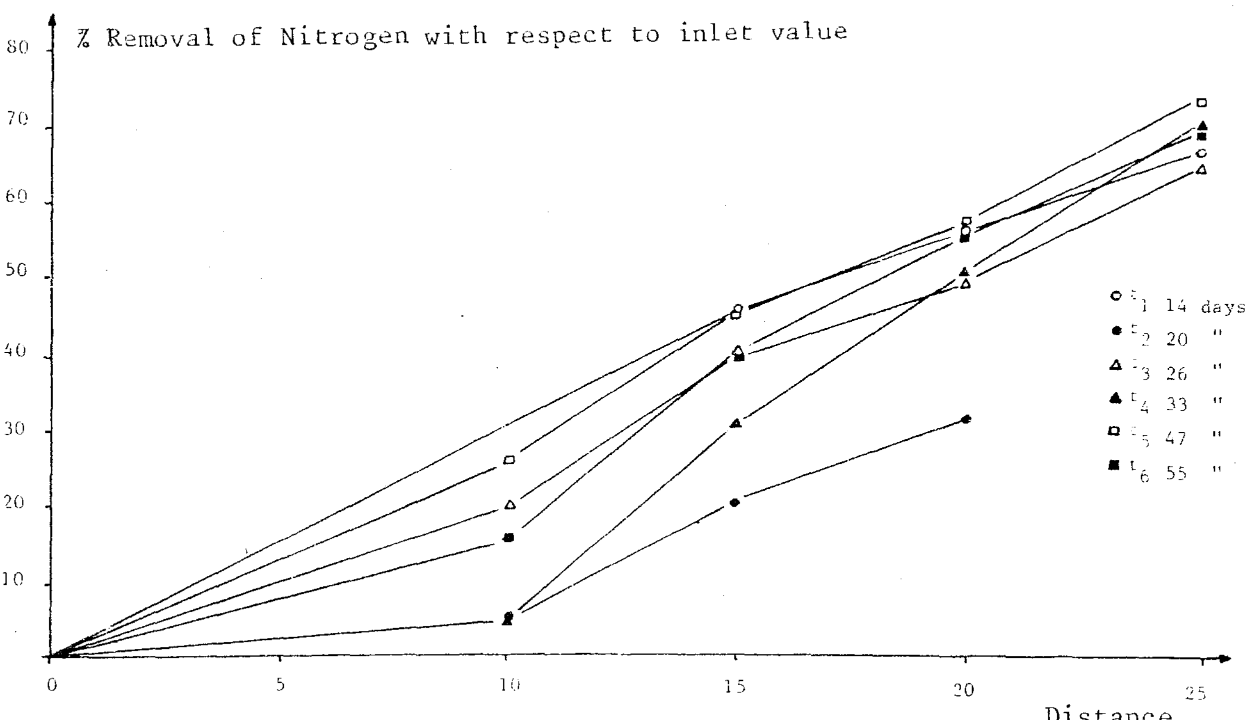


Figure 4.8 Graphical Presentation Showing the Removal Efficiency of Nitrogen With Distance

be increased) (Gehm and Bregman, 1976).

In conventional trickling filters, conversion of ammonia to nitrates occur in the lower sections. Nitrification however is not complete and part of the ammonia (30-60%) is discharged into the effluent (Gehm and Bregman, 1976).

4.1.3 Phosphorus (P)

Phosphorus, like nitrogen is also essential for the growth of plants. But, if it is present in high amounts, it causes pollution and thus it's removal from a wastewater body is usually required.

In this study, the variation of phosphorus (in the form of ortho-phosphate) values with time and distance was observed. The examination of the collected data are shown in graphical forms in figures 4.9-4.12. The stannous chloride method was used for orthophosphate determinations according to Standard Methods (1981).

The following statements summarize the observations made through the examination of the figures;

- The system shows steadily decreasing phosphorus values with increasing time, and most of the removal takes place within the first ten meters of distance,

- The effluent values converge at the end of the channel (0.5-1.5 mg/L) even though fluctuations are observed within the influent values (4.4-7 mg/L).

- The effluent removal percents increase with increasing time; the highest removal being achieved (92.5%) after 71 days of continuous filtration. This value, compared with the values given by Sanks and Asano (1976), show an agreement. It should also be noticed that in Sank's study the surface was covered with vegetation (Table 4.2). Niyogi's (1982) study show very similar results as well.

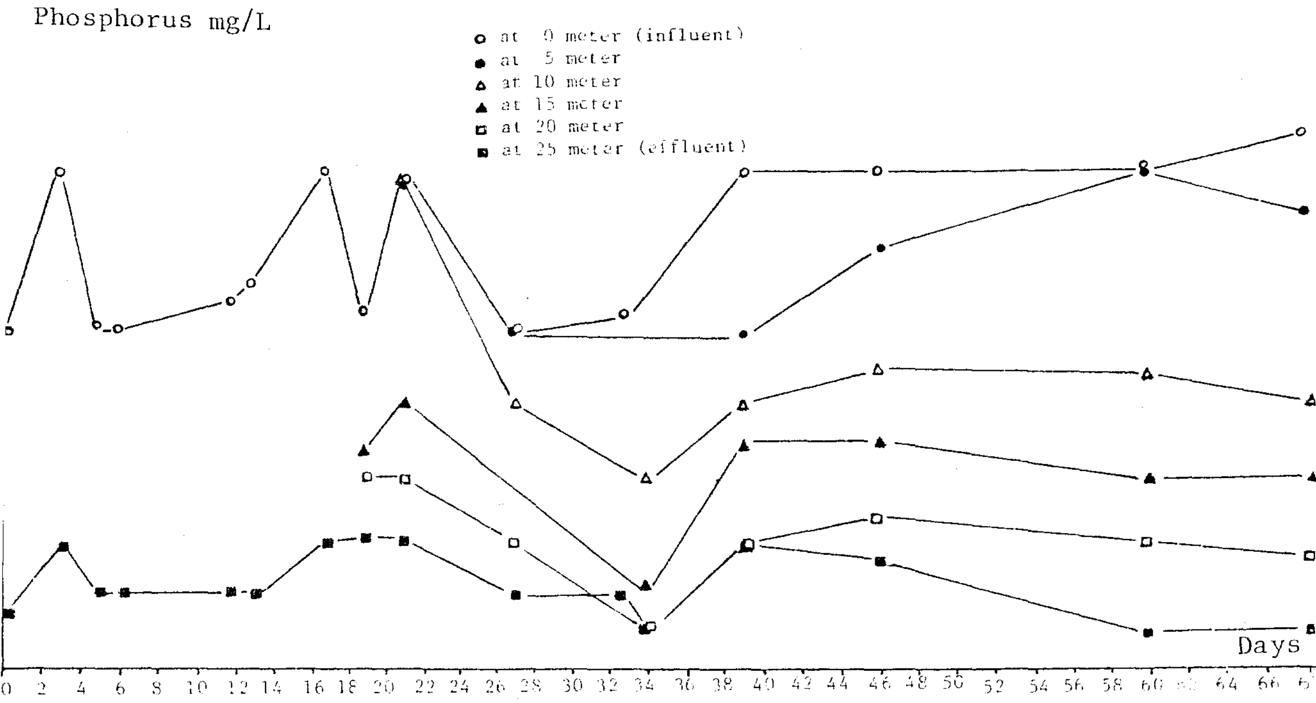


Figure 4.9 Graphical Presentation Showing the Variation of Phosphorus With Time

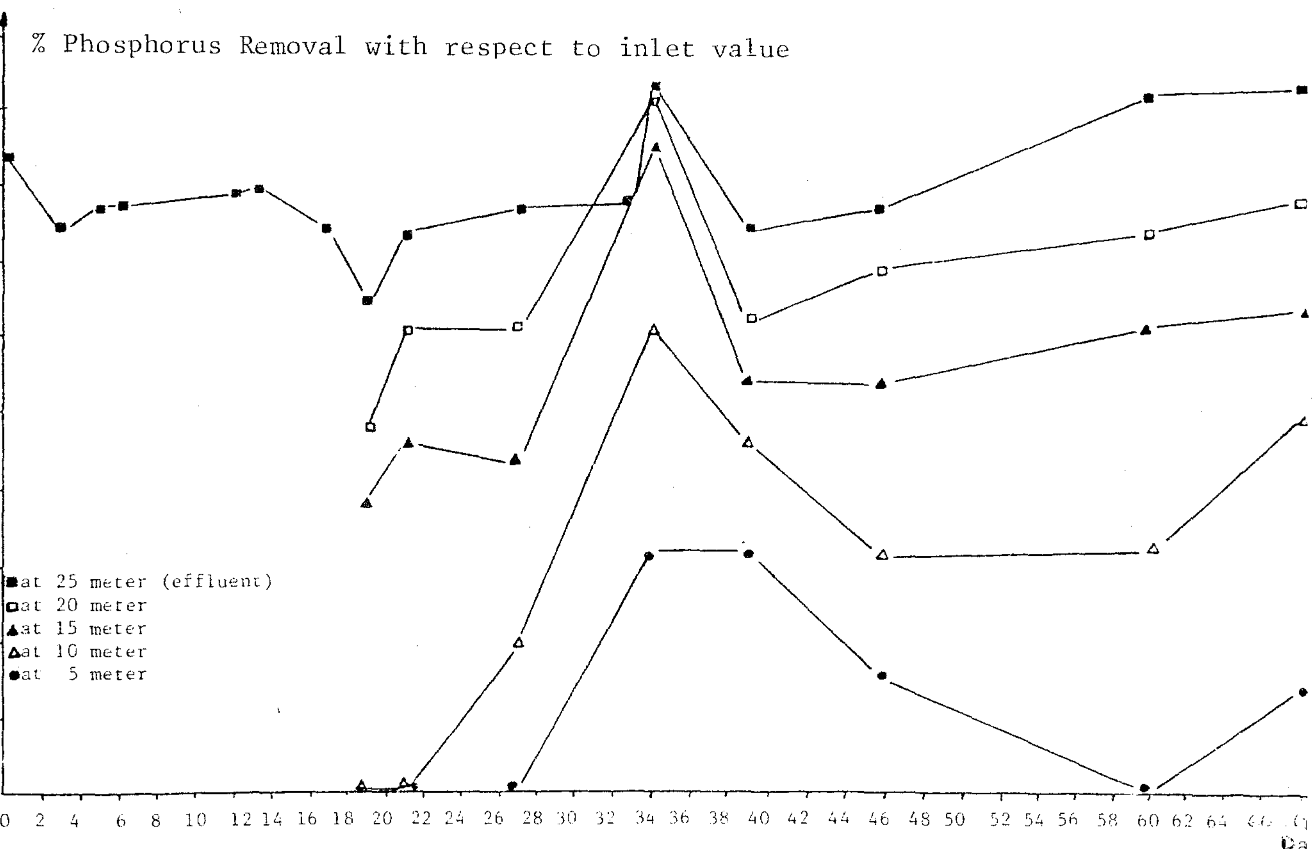


Figure 4.10 Graphical Presentation Showing the Removal Efficiency of Phosphorus With Time

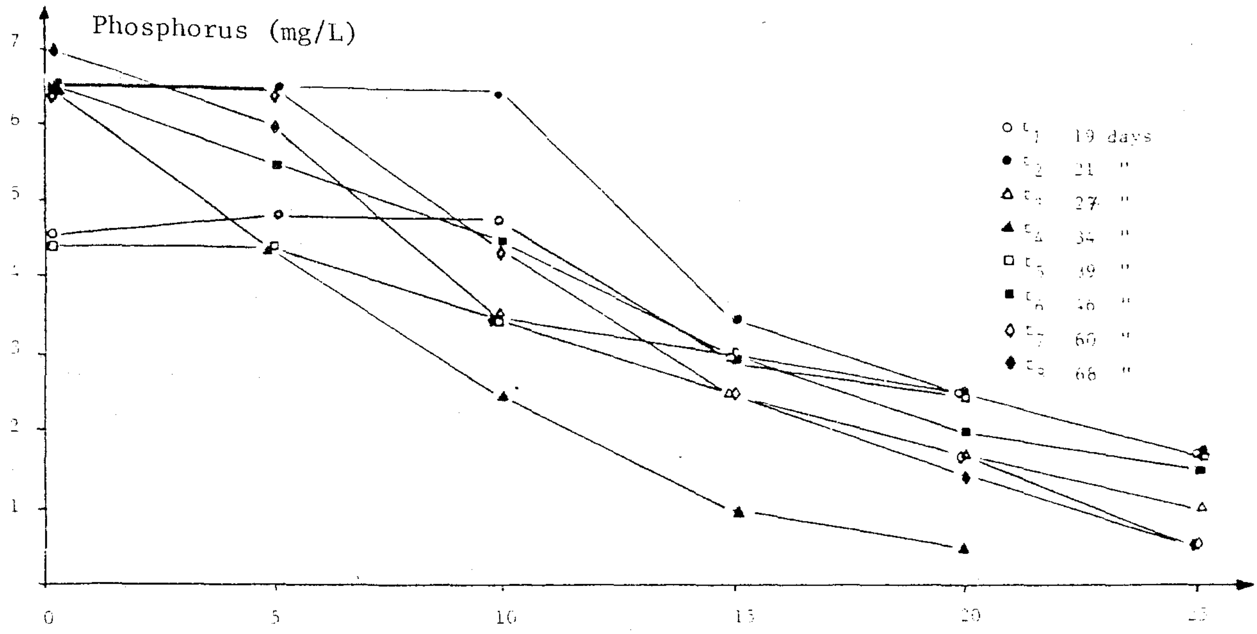


Figure 4.11 Graphical Presentation Showing the Variation of Phosphorus With Distance

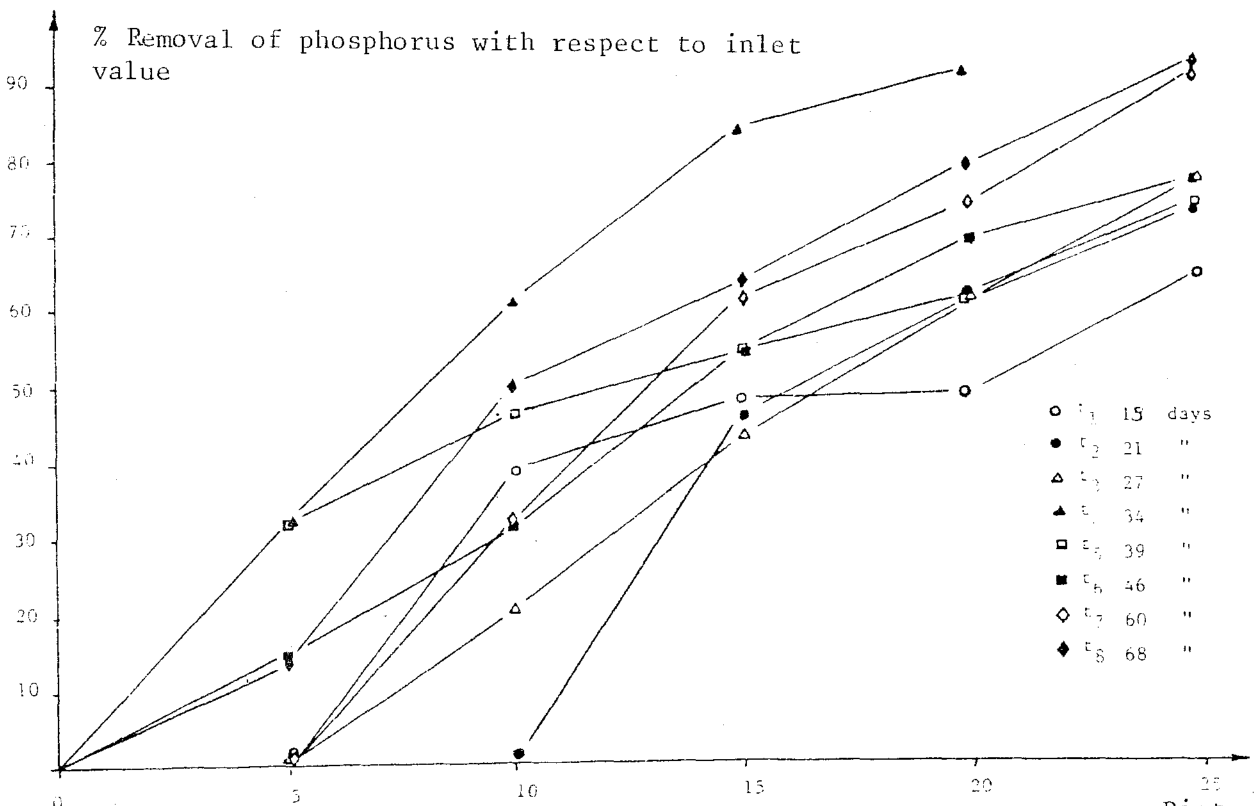


Figure 4.12 Graphical Presentation Showing the Removal Efficiency of Phosphorus With Distance

TABLE 4.2 COMPARISON OF PHOSPHORUS REMOVAL RATES

Type of Land Treatment	% Removals
Spray Irrigation x (Sanks an Asano, 1976)	95-99
Overland Runoff x (Sanks and Asano, 1976)	60-80
Rapid Infiltration x (Sanks and Asano, 1976)	50-90
Sandy Loam Filtration (Niyogi et al., 1982)	89.86
Present Study	65-92.5

x with a vegetation cover

As mentioned in section 2.4, the removal efficiency of phosphorus is generally dependent on the soil properties.

In conventional wastewater treatment plants (activated sludge, trickling filter) the phosphorus removals vary within the range of 30-60% depending on the type of process applied and again on the concentration of the phosphorus in the influent wastewater (Hammer, Viessman and Clark 1977).

4.1.4 Solids

Solids are another impurity present in wastewater which is desired to be removed during the treatment process.

In this study variations of total and suspended solids between influent and effluent are determined. The results obtained are plotted in figure 4.13.

As can be seen in this figure, the removal efficiency obtained is relatively low, if they are compared with values reported by other investigators or with values obtained in conventional treatment processes (table 4.3).

A possible reason of the low results obtained may be due to the

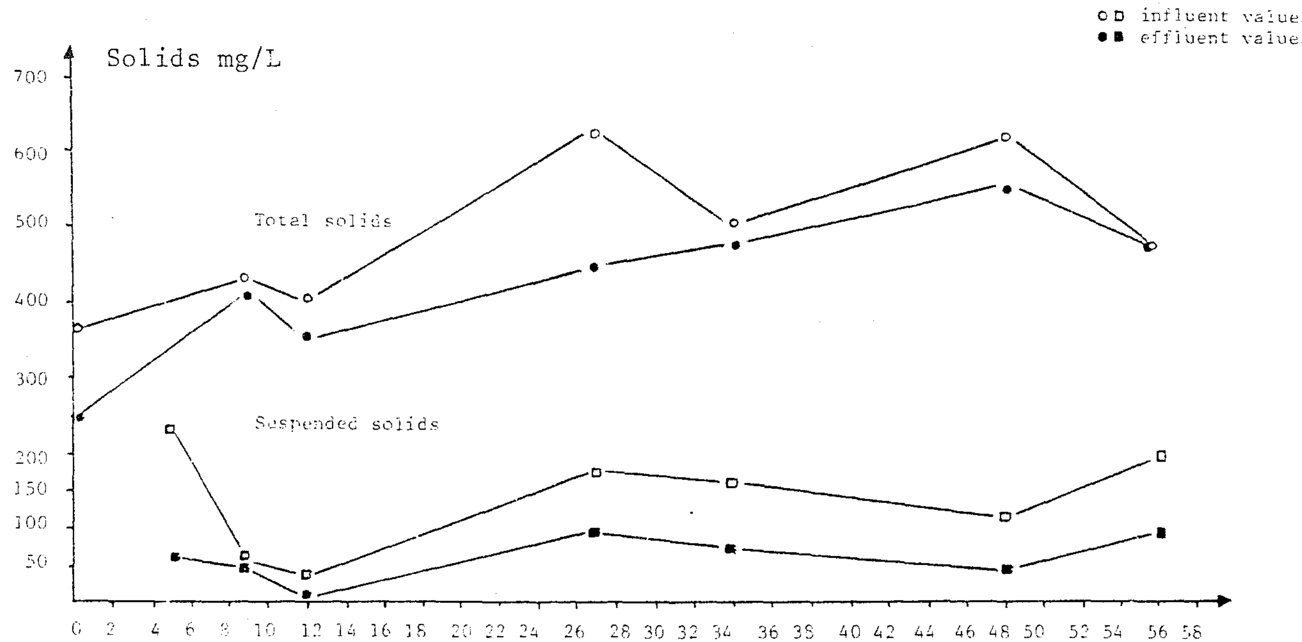


Figure 4.13 Graphical Presentation Showing the Variation of Solids With Time

removal of some solids present initially in the sand bed during the infiltration process.

TABLE 4.3 COMPARISON OF SUSPENDED MATTER (SOLIDS) REMOVAL RATES

Type of Treatment Process	% Removal
a) Land Disposal Systems	
Spray Irrigation [x] (Sanks and Asano, 1976)	99
Overland Runoff[x] (Sanks and Asano, 1976)	80
Rapid Infiltration[x] (Sanks and Asano, 1976)	99
Sand Filtration [x] (Fair, Geyer and Okun, 1968)	85-95
b) Conventional Treatment Systems	
Activated Sludge (Fair, Geyer and Okun, 1968; Vesilind 1978)	85-95
Trickling Filter (Fair, Geyer and Okun, 1968; Vesilind 1978)	80-90
c) Present Study	45-74

x Removal by harvest crop is also included.

4.1.5 Turbidity

Turbidity in a wastewater is caused by the presence of suspended matter (clay, silt, organic and inorganic matter) (Standard Methods, 1981).

The turbidity values in this study were determined by using a Hellige Turbidimeter where one unit of turbidity is accepted as equivalent to 1 $mgSiO_2/L$.

Figure 4.14 shows the variation of turbidity values with time and distance from the inlet. As can be observed from Figure 4.14 a great deal of decrease in wastewater turbidity takes place within the first ten meters. Even though, fluctuations of the influent turbidity are observed; the effluent turbidity values vary slightly. It can be concluded that regardless of the influent turbidity value, the bed is able to remove the turbidity up to a level that is more or less constant. Effluent turbidity values show a decrease with time. This result which was expected is most probably due to the fact that by the accumulation of material in the filter bed, the pore sizes decrease and thus better removal is achieved.

Figure 4.15 shows the percent removal efficiency of turbidity values with time with respect to the influent values. A stable increase of percent removal from the effluent is observed after a certain period of infiltration. As can be seen in all other parameters, the intermediate samples are not analysed for a certain time after beginning the infiltration process. This is due to the fact that the system is desired to be saturated with the wastewater and thus give stable results. In general, the percent removal increases with time and distance.

In vertical filtration systems, it is seen that most of the turbid matter are captured by the soil at the beginning of the system (Curi,1974). In horizontal systems the same facts hold true. As stated by Curi (1974), turbidity removal is directly proportional with the effective diameter (d_{10}) and with the flow rate of the incoming wastewater but inversely proportional with the height (distance) of the sand media. The results of the present study are in complete agreement with the above statements.

At the end of the channel, the maximum removal efficiency of turbidity reached is about 75-80%. This result is quite satisfactory as no pretreatment has been applied to the system.

In Figure 4.16, the variation of turbidity values with distance at different time intervals is given. The same pattern of decrease in turbidity values is observed in the figure no matter how the influent values varied. At first, the turbidity decreases sharply, then from the 10^{th} meter onwards, the curves decrease smoothly, indicating that most of the removal takes place within the first ten meters distance. This is in agreement with the results obtained by Curi (1974). Another observation which can be made from Figure 4.16 is that as the distance increase, the turbidity values approach each other regardless of the influent turbidity. Values obtained for the effluent-after the waste travels through the sand

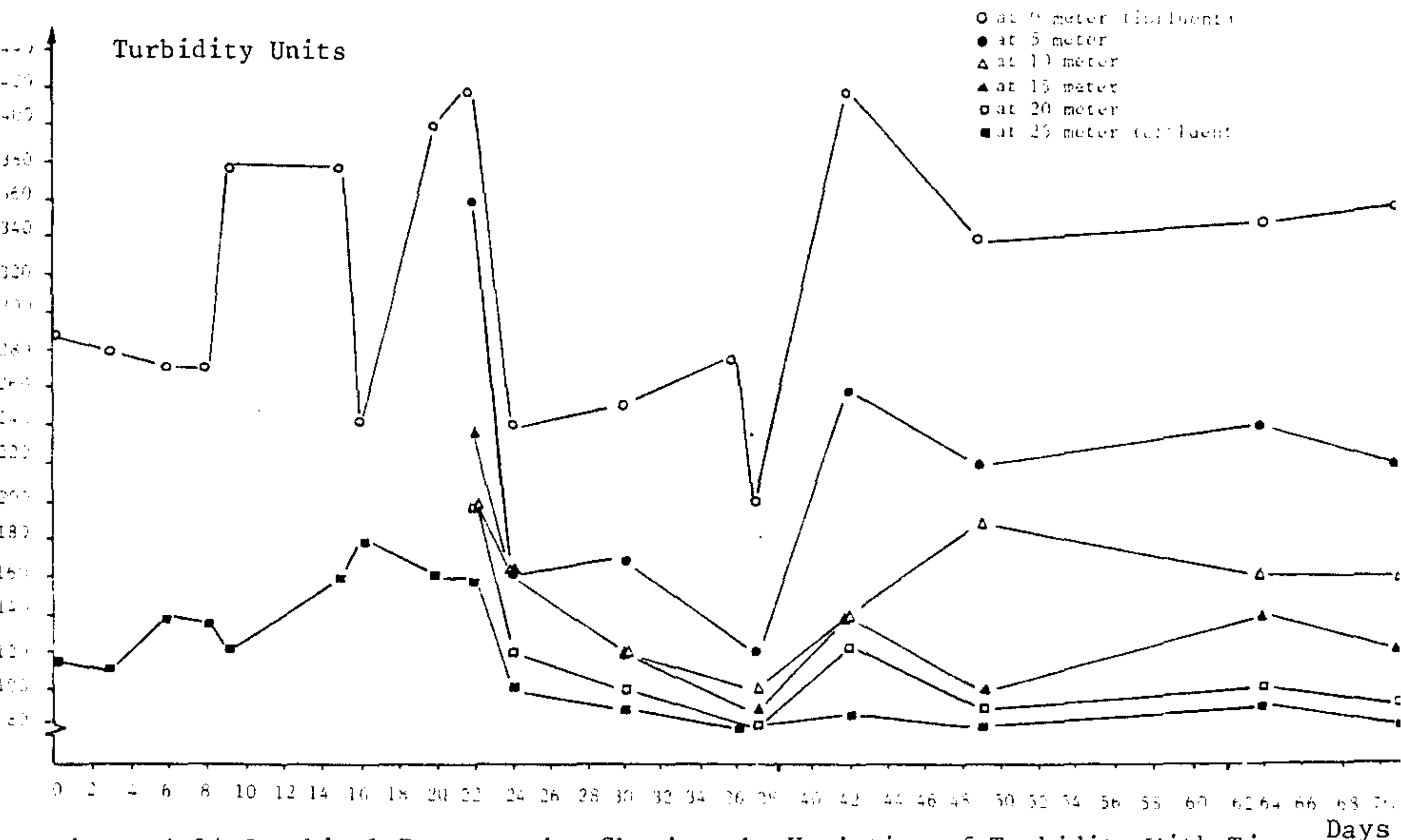


Figure 4.14 Graphical Presentation Showing the Variation of Turbidity With Time

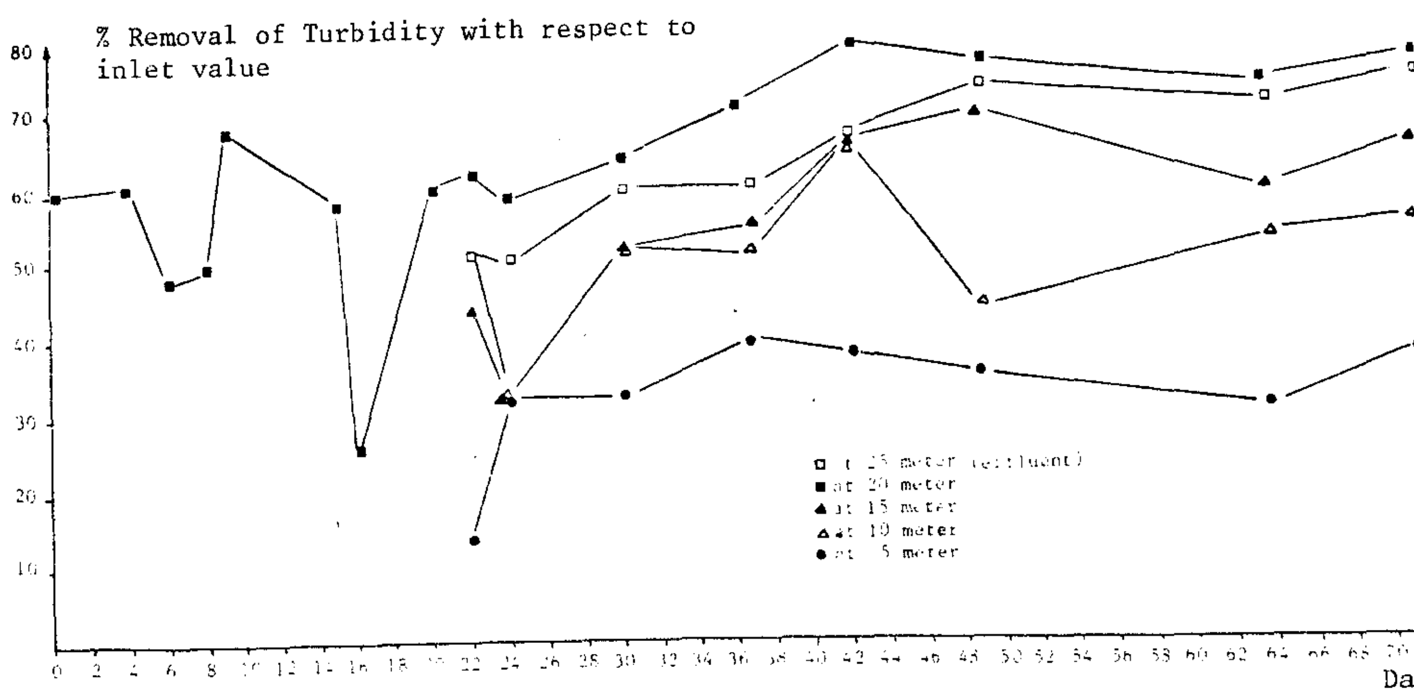
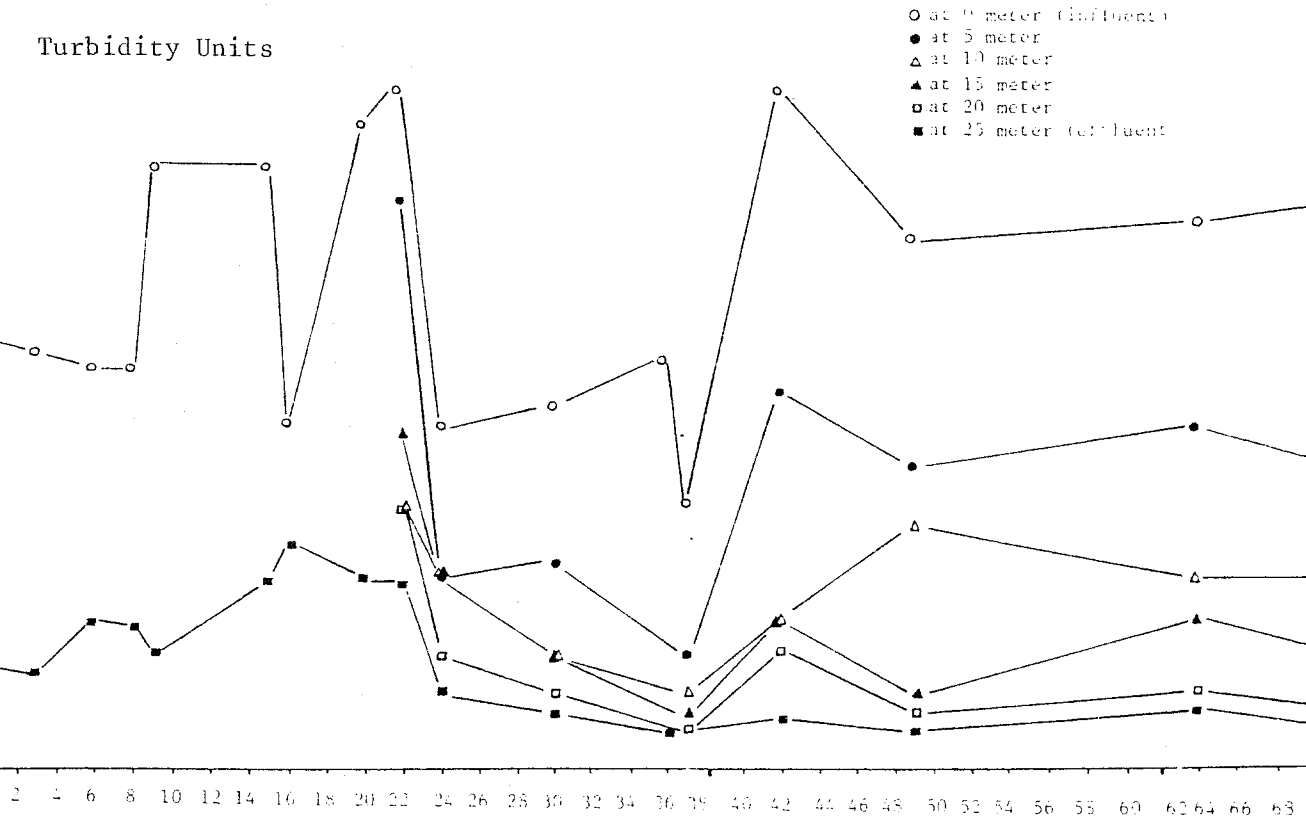


Figure 4.15 Graphical Presentation Showing the Removal Efficiency of Turbidity With Ti



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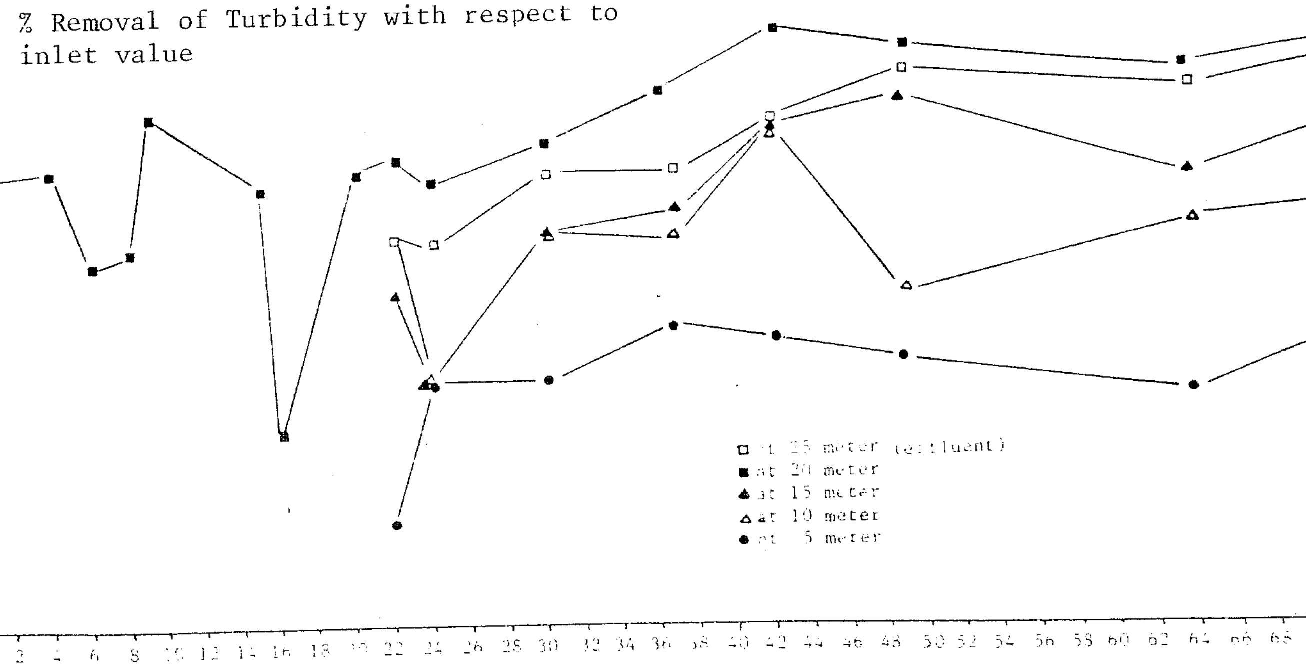

gure 4.15 Graphical Presentation Showing the Removal Efficiency of Turbidity With

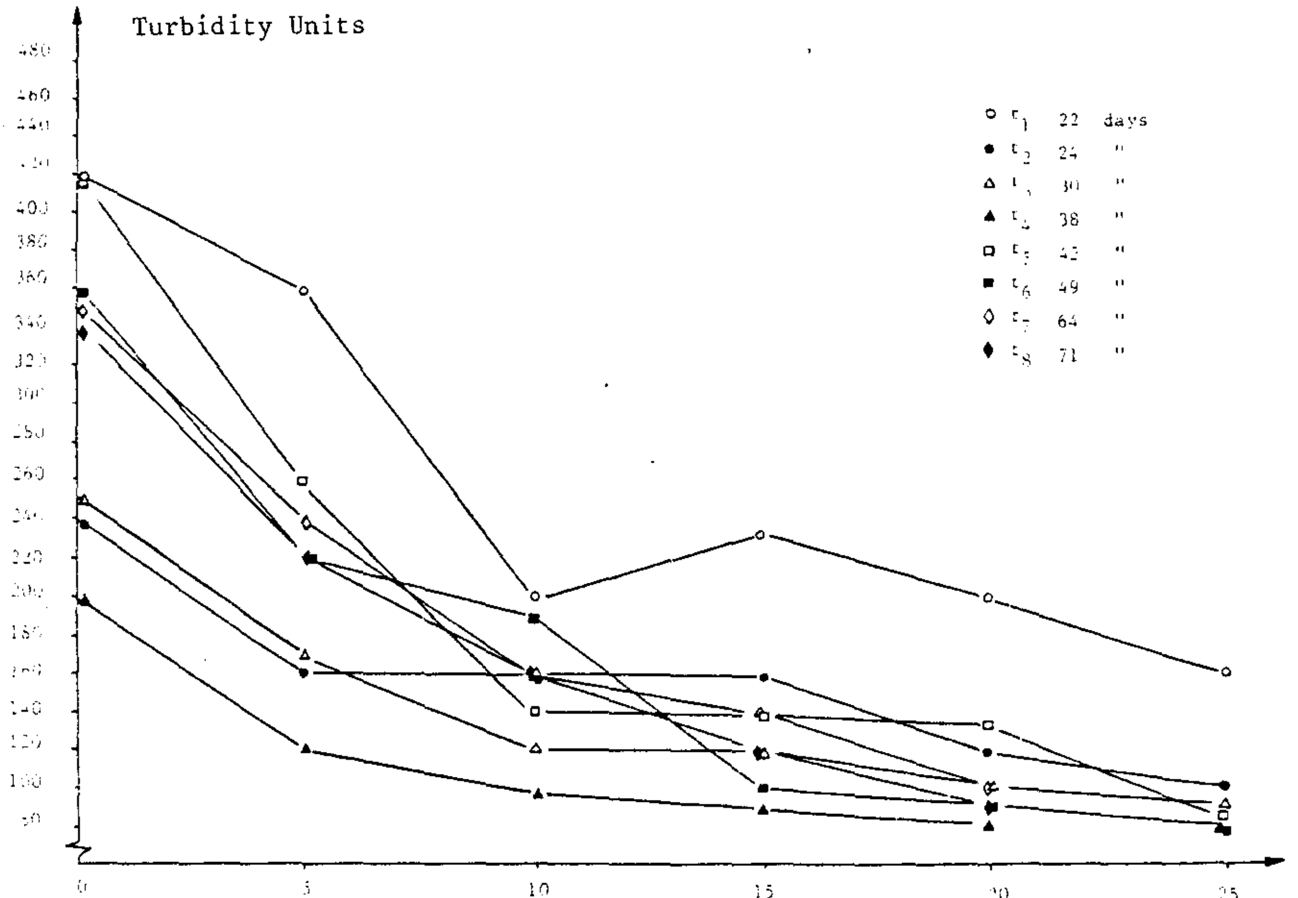

Figure 4.16 Graphical Presentation Showing the Variation of Turbidity With Distance

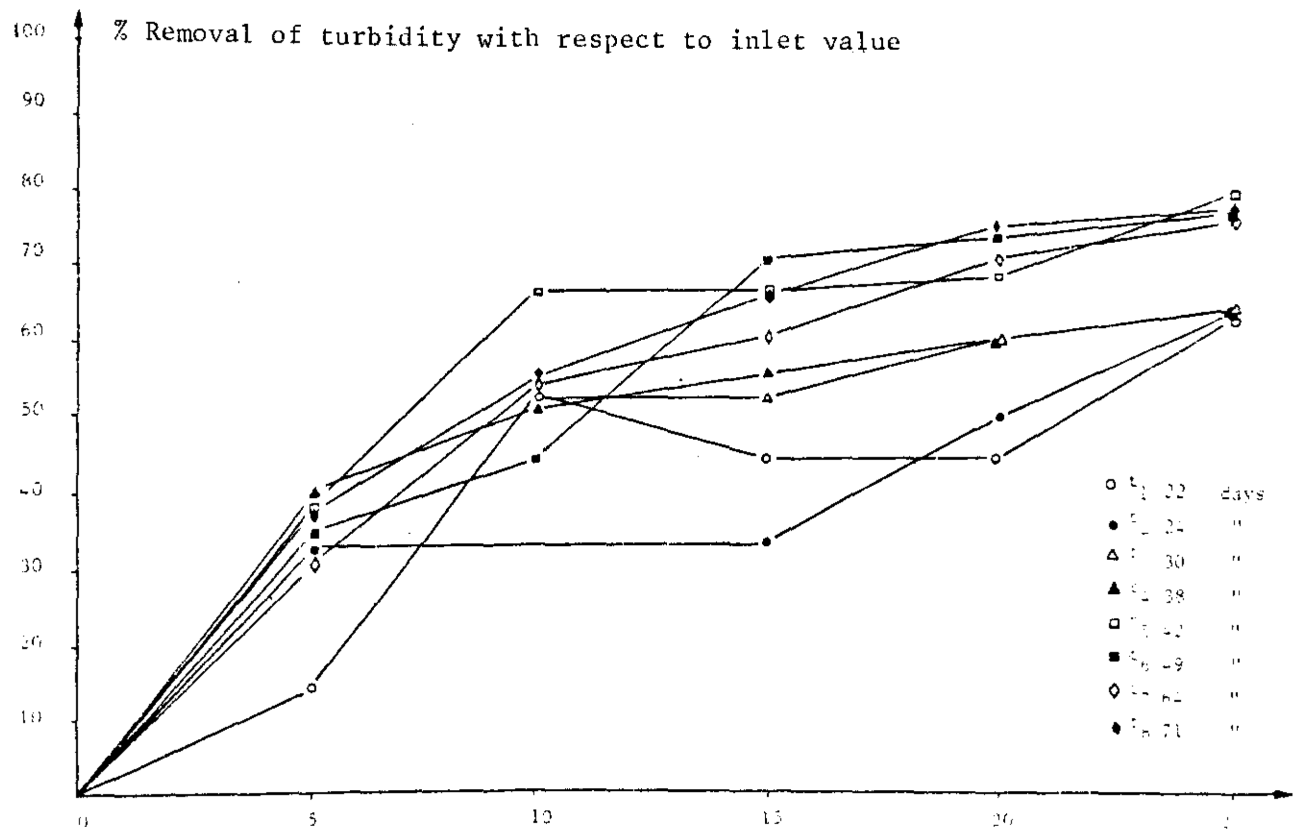

Figure. 4.17 Graphical Presentation Showing the Removal Efficiency of Turbidity With Distance

bed for 25 meters are almost the same; varying between 80-100 turbudity units, although the range of influent turbidity was rather large (200-420 turbidity units). The only exception to this observation is the values obtained for t_1 (≃ 22^{nd} day of infiltration period), however an explanation for this discrepancy may be that a longer time is required for the filter to reach the optimum conditions.

Figure 4.17 reinforces all previous observations. The percent removal increases sharply with distance in the first few meteres, then, reaches a constant state. Also, another observation is that turbidity removal efficiency increases with time.

4.1.6 pH

This paremeter indicates the intensity of the acid or alkaline condition of the wastewater. The majority of wastewaters are, usually, slightly basic because of the presence of carbonates and bicarbonates (Standard Methods, 1981).

Figure 4.18 represents the pH values determined during the study period. In general, it is recognised that, there is a slightly decreasing trend at all the points with time, and the effluent values are always higher than the influent values. This fact is probably due to the presence of certain salts in the soil media giving rise to basic conditions througthout infiltration of wastewater. The pH values varied only within a range of (6.8 to 8) which is accepted to be inbetween normal standards, at which biological treatment can easily take place (Sawyer and Mc Carty, 1967).

On the other hand, Figure 4.19 represents the variation of pH values with distance at different times. The most important observation in this configuration is that; even though there is no similar relation between the time curves with distance; a decrease is obtained with increasing time. The effluent values show more acid conditions with progress of time. This may be due to the fact that; bacterial decomposition takes place within the channel giving rise to CO_2; the continuous accumulation of CO_2 towards the end of the channel increases the acidity of the water body under its presence, producing H_2CO_3. For the same reason, the values of some of the intermediate points show more basic conditions than the effluent

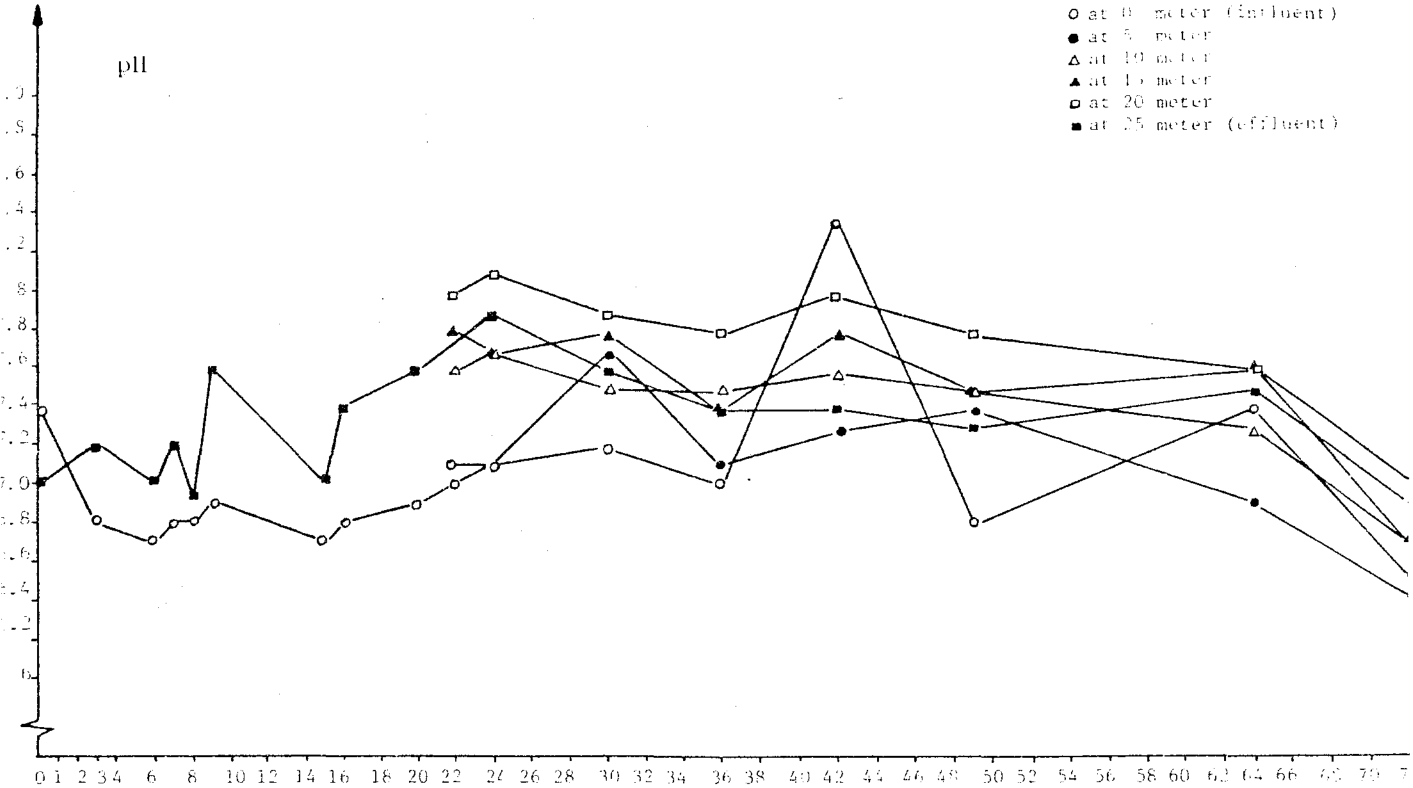

Figure 4.18 Graphical Presentation Showing the Variation of pH With Time

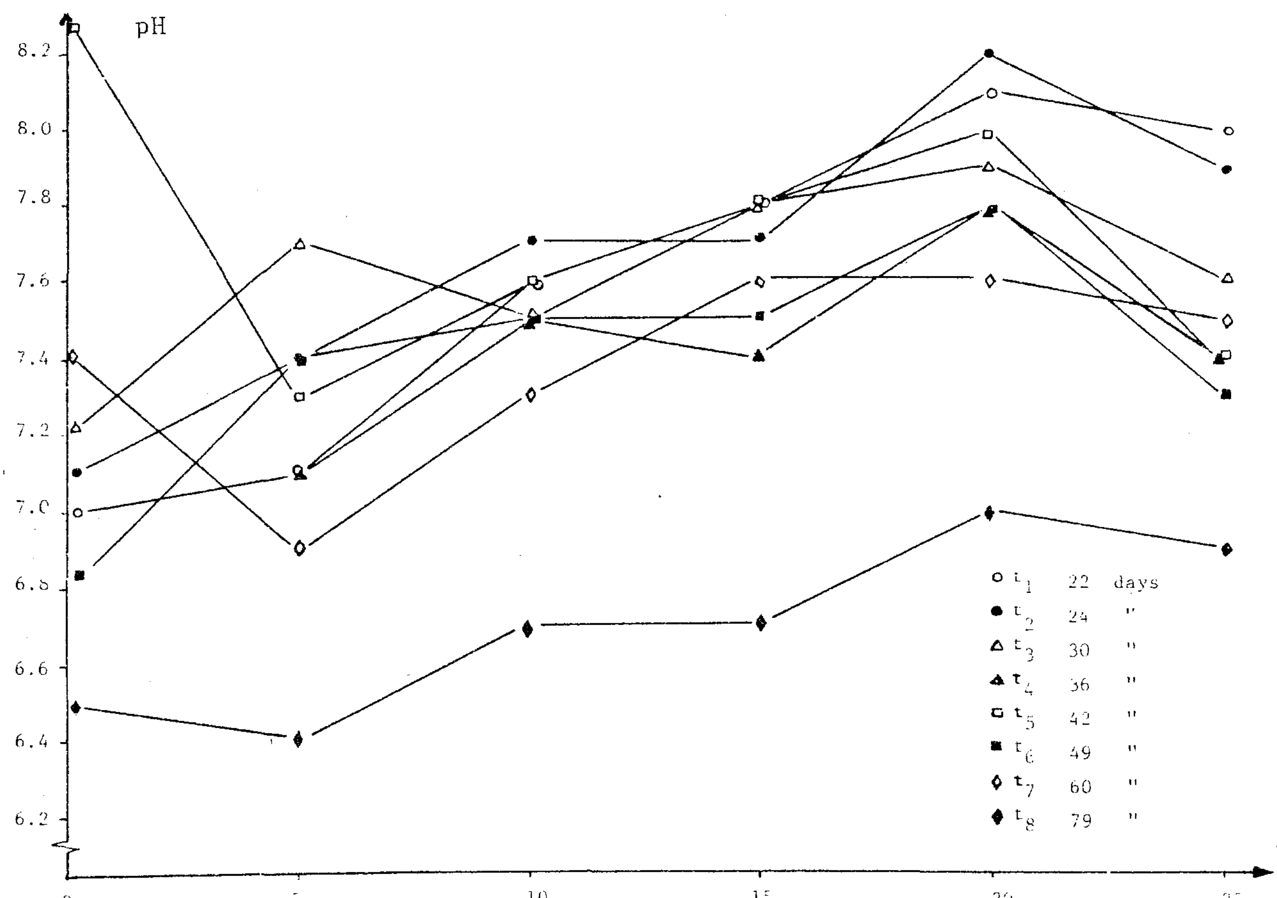

Figure 4.19 Graphical Presentation Showing the Variation of pH With Distance

value in Figure 4.18.

4.1.7 Coliform

A large variety of disease-causing microorganisms and parasites are present in domestic wasteweters.Coliforms are indicators of these organisms. Therefore, in this study and in similar researches, the removal of coliforms is investigated.

Figure 4.20 denotes the change of coliform counts with time. It is recognized that most of the removal takes place within the first ten meters and the removal descends as distance increases.

Figure 4.21 repsesents the percent removal of coliform with respect to time. It is seen that after a certain time of infiltration, a slightly varying (a constant) percent removal range is achieved (77.5-82.5%).

Figure 4.22 shows the number of coliforms with distance at different times. It is noticed, here, that there is a steady decrease in values with increasing distance and that the effluent values converge at the end of the channel (at a distance of 25 meters) even though the influent values fluctuate ($1x10^5$ - $2.2x10^5$ coliforms/100 mL).

Figure 4.23 on the other hand, represents the corresponding percent removal with time and distance. It is clearly seen that the removal increases with distance.

As mentioned previously in section 2.4, the bacterial removal from wastewaters depends largely on the type of the soil and on the horizontal travel distance. The results obtained in this study are compared with the result reported by other investigators (Table 4.4). The lower values are mostly due to the lack of more travel distance, type of the soil and on the lack of plantation.

In a similar study conducted by Onaral (1973) a similar presentation of percent removal is obtained with increasing depth (in vertical position). In this study the flow rate of the raw wastewater also varied to determine the optimum flow rate for the highest removal. At slower flow rates, a similar configuration seen in figure 4.23 is obtained and the highest removal

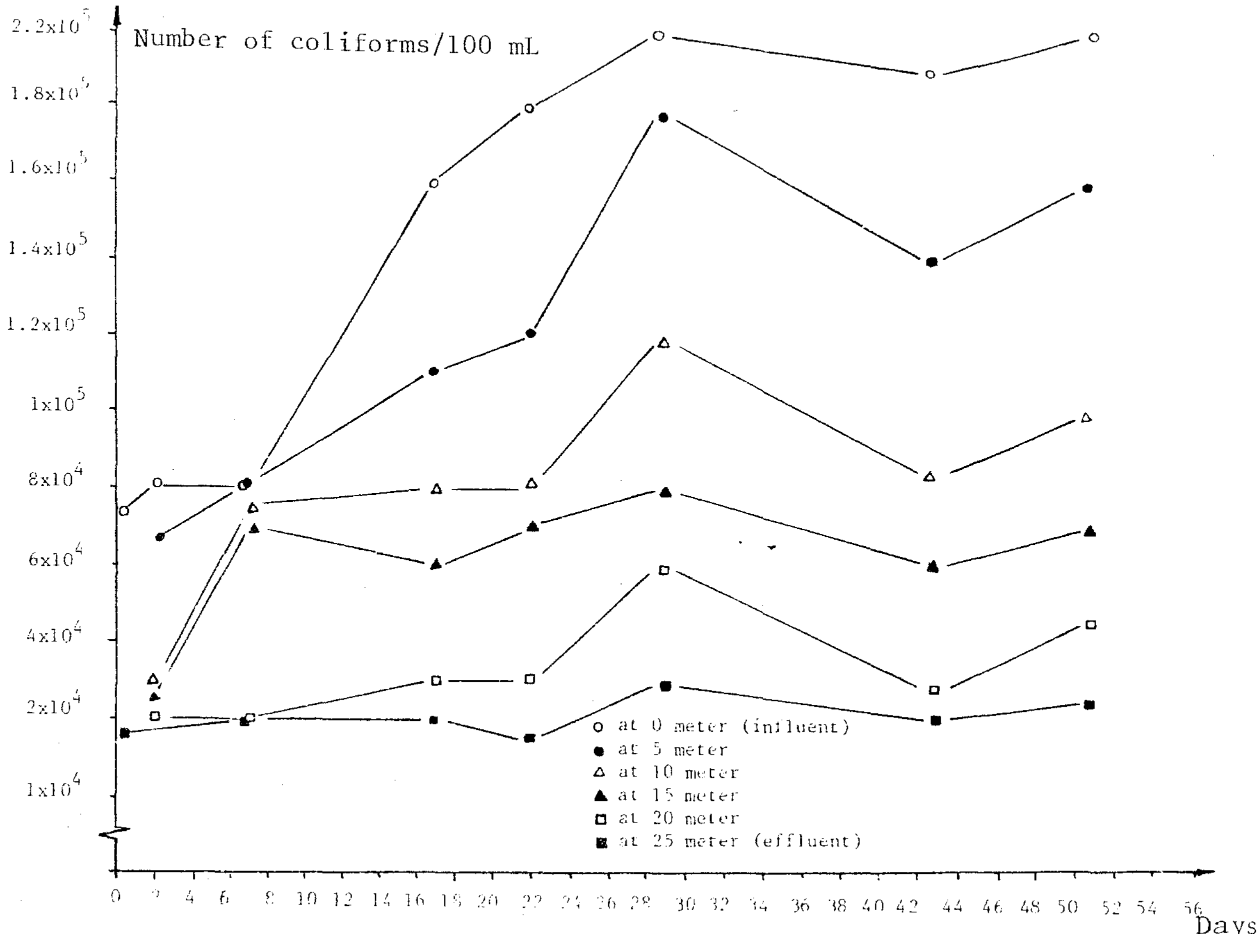

Figure 4.20 Graphical Presentation Showing the Variation of Coliform With Time

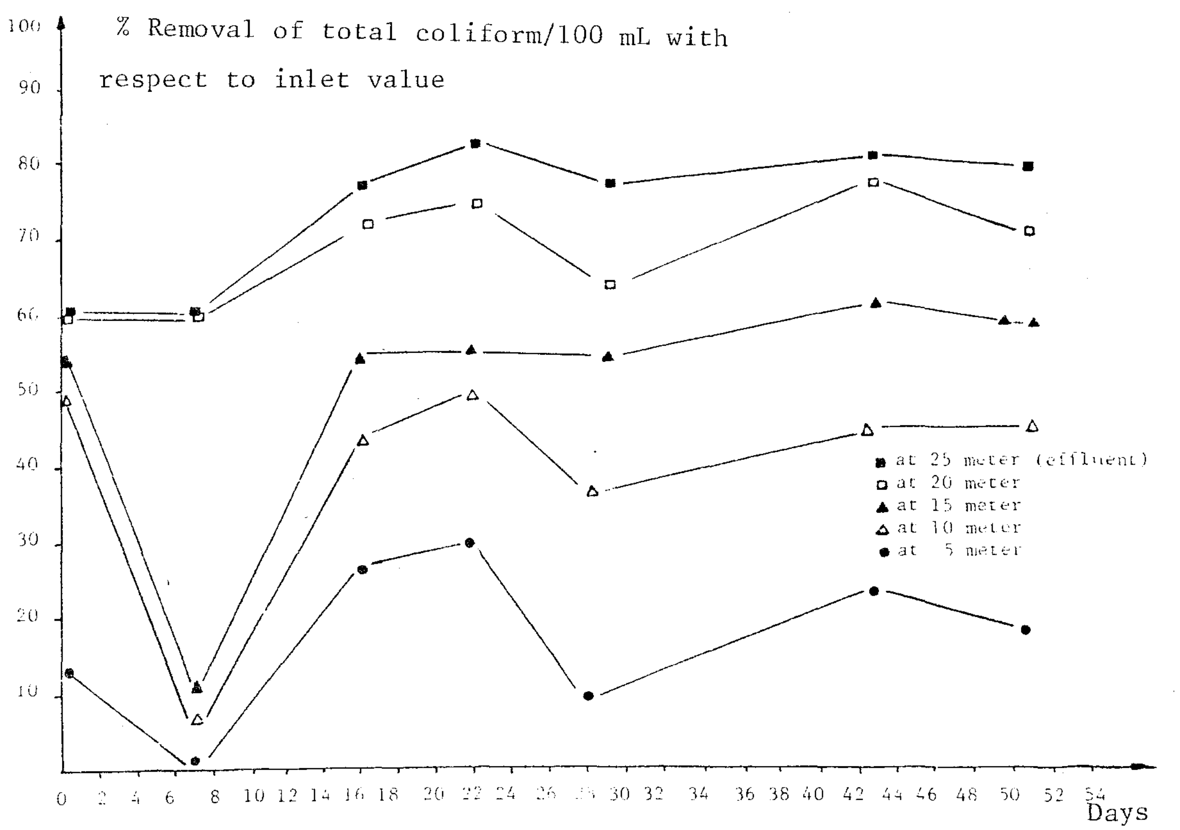

Figure 4.21 Graphical Presentation Showing the Removal Efficiency of Coliform With Time

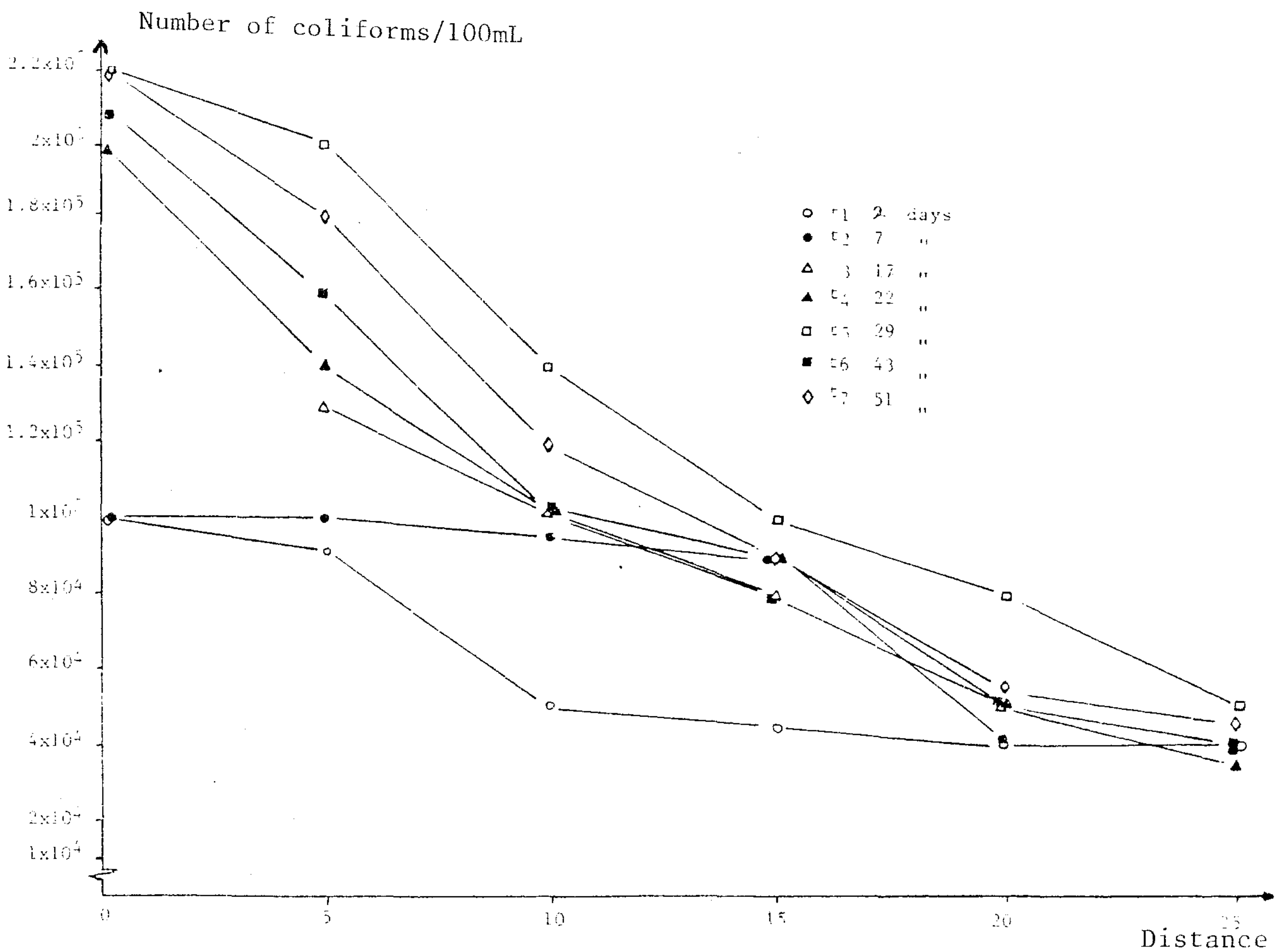

Figure 4.22 Graphical Presentation Showing the Variation of Total Coliform With Distance

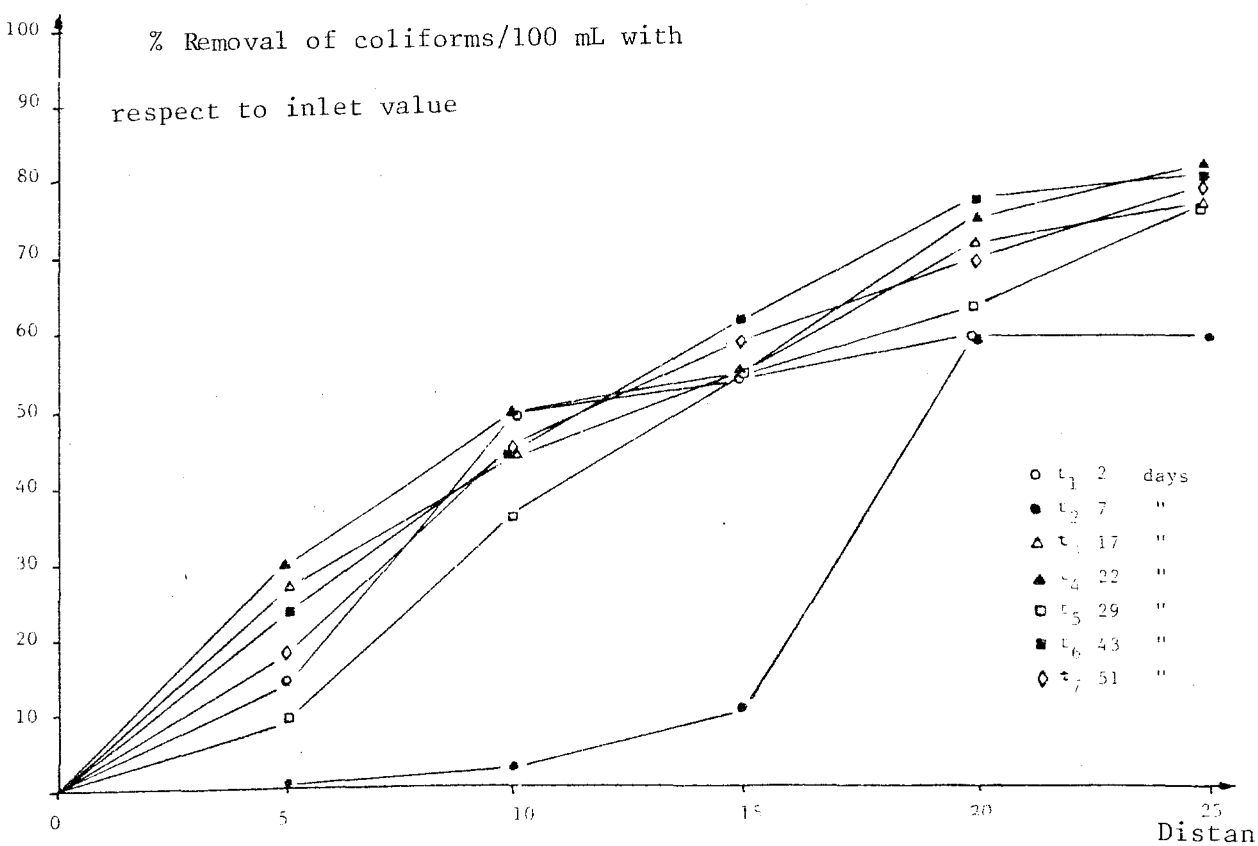

Figure 4.23 Graphical Presentation Showing the Removal Efficiency of Coliform With Distance

reached was about 75%. At higher flow rates a curve similar to the one plotted at t_2 time is obtained. This discrepancy is probably due to the unexpected increase of the influent flow rate as there was heavy rain during these days.

TABLE 4.4 COMPARISON OF THE COLIFORM REMOVAL RATES

Type of Treatment Process	% Removal
Plain Sedimentation (Metcalf and Eddy, 1979)	25-75
Chemical precipitation (Metcalf and Eddy, 1979)	40-80
Trickling Filters (Metcalf and Eddy. 1979)	90-95
Activated Sludge (Metcalf and Eddy, 1979)	90-98
Sand Filtration x (Fair, Geyer and Okun, 1968)	95-99
Sandy Loam filtration x (Niyogi et al., 1982)	99.67
Present Study	77.5-82.5

x with crop production

Studies by engineers of the United States Public Health Service have established the following empricical relation ship between the effluent concentration E_1 and the influent coliform, R_c, organisms in water that have been subjected to certain purification processes (Onaral, 1973; Fair and Geyer, 1958).

$$E_1 = CR_c^n$$

$$\text{Log } E_1 = \text{Log } C + n\text{Log } Rc \quad \text{where}$$

C and n are coefficients that reflect respectively the magnitude of effluent count for a given wastewater. A low value of C represents a high removal efficiency. This emprical formula conforms the curves in Figure 4.2 2. The value of C is quite low. Between times t_6 and t_7, C is found to be $2.86\text{x}10^{-8}$ and between times t_4 and t_5 as $2.96\text{x}10^{-11}$ whereas, the corresponding n values are 2.27 and 2.85 respectively.

4.2 Variation of Soil Characteristics with Time and Distance

Throughout the whole study, the variation of soil characteristics were determined at different time intervals. For thispurpose soil samples were collected simultaneously from the 5^{th} and 20^{th} meter distances of the channel. All samples were taken from a depth of 25 centimeters from the surface of the sand layer. The parameters that were analysed are pH, volatile matter, phosphorus utilizable by crops and organic matter. The analysis of phosphorus and organic matter were conducted at "Toprak Tahlil Laboratuarı of TOPRAKSU", in İstanbul, while the remaining ones were carried out in the Environmetnal Engineering Laboratory of Boğaziçi University. The determination of nitrogen in the soil was not possible due to the lack of the necessary chemical reagents both at the laboratory of Boğaziçi University and at any other related laboratory present in İstanbul.

In the following part of this chapter, the results of this study are given and discussed.

4.2.1. Variation of Volatile Matter in Soil

Figure 4.24 (a) shows the variation of percent volatile matter present in the sand bed with time.

At the beginning of the study, even though the channel and the sand media were washed many times, the results obtained from these experimentes indicate that it was not sufficiently cleaned. If the filter had been cleaned properly, the values both for the sample taken from the 5^{th} meter distance and the sample taken from the 20^{th} meter distance should have been the same. From the curves, it is understood that the volatile matter present at the beginning was dragged out along the channel and this matter was accumulated in the sand near the end of the channel during washing. As time progresses, the wastewater is continuously filtered by the sand media, thus the volatile matter present in the water body is removed by the sand grains. Therefore, increase in volatile matter with time is observed.

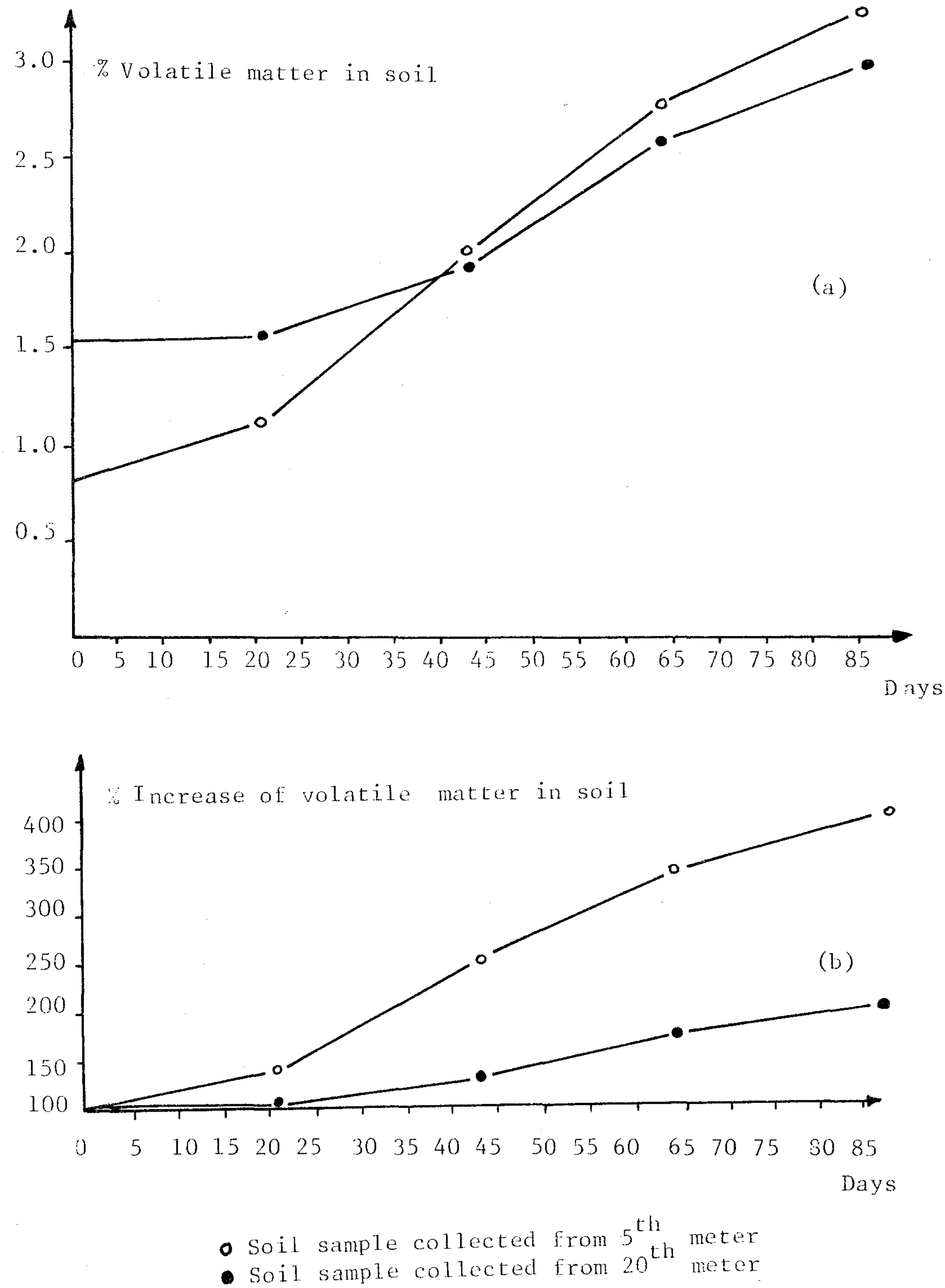

Figure 4.24 a) Graphical Presentation of the Variation of % Volatile Matter in Soil With Time
b) Graphical Presentation of the Variation of % Increase of the Volatile Matter in Soil With Time

As wastewater passes through the sand, most of the volatile matter is removed from the waterbody within the first five meters as seen more clearly from Figure 4.24 (b) which represents the percent increase of volatile matter in sand. Therefore; the increase in volatile solids in the sample taken from the beginning is considerably larger than those observed in the sample taken from the end.

4.2.2 Variation of pH of the Soil

The variation of pH values of the soil samples with respect to time are given in Figure 4.25 (a). In general, the pH of all Samples tend to increase as time progresses. pH values of samples collected from the 20^{th} meter distance were always higher than those collected from the 5^{th} meter distance. Something which should be noticed however is that most probably due to insufficient cleaning of the filter bed, the pH of the sand sample collected from the end of the channel is larger compared with the pH of the sand sample collected from near the beginning of the channel at time=0. If necessary cleaning had been realised, both samples should have had the same value at time=0 days. This variation in initial values may be due to the accumulation of saline particles present in the sand bed which were removed by the washing from the beginning towards the end of the filter bed.

The increase of pH values may be described by the concept of alkalisation of soils. The increase in pH values is due to the increase of percent exchangeable sodium percent in soil. Thus, through this increase, the soil becomes more alkaline (Mahida, 1981).

One of the most outstanding physiological characteristics of the soil solution is the pH, It influences many physical and chemical properties of soil, that govern the growth of plants (Table 4.5) as well as the activities of microorganisms in the soil (Mahida, 1981). The presence of salts like Ca, Mg and Na_2CO_3 raises the alkalinity of the soil. A pH range of 6-75 is about the most satisfactory biological environment. For example, nitrification starts at a pH above 6. As a result of biological decomposition, carbondioxide (CO_2) is produced and as soon as it is mixed with rainwater carbonic acid forms, increasing the acidity of the soil. Throughout this study, rainfall was insufficient to leach out the absorbed bases. Therefore, the

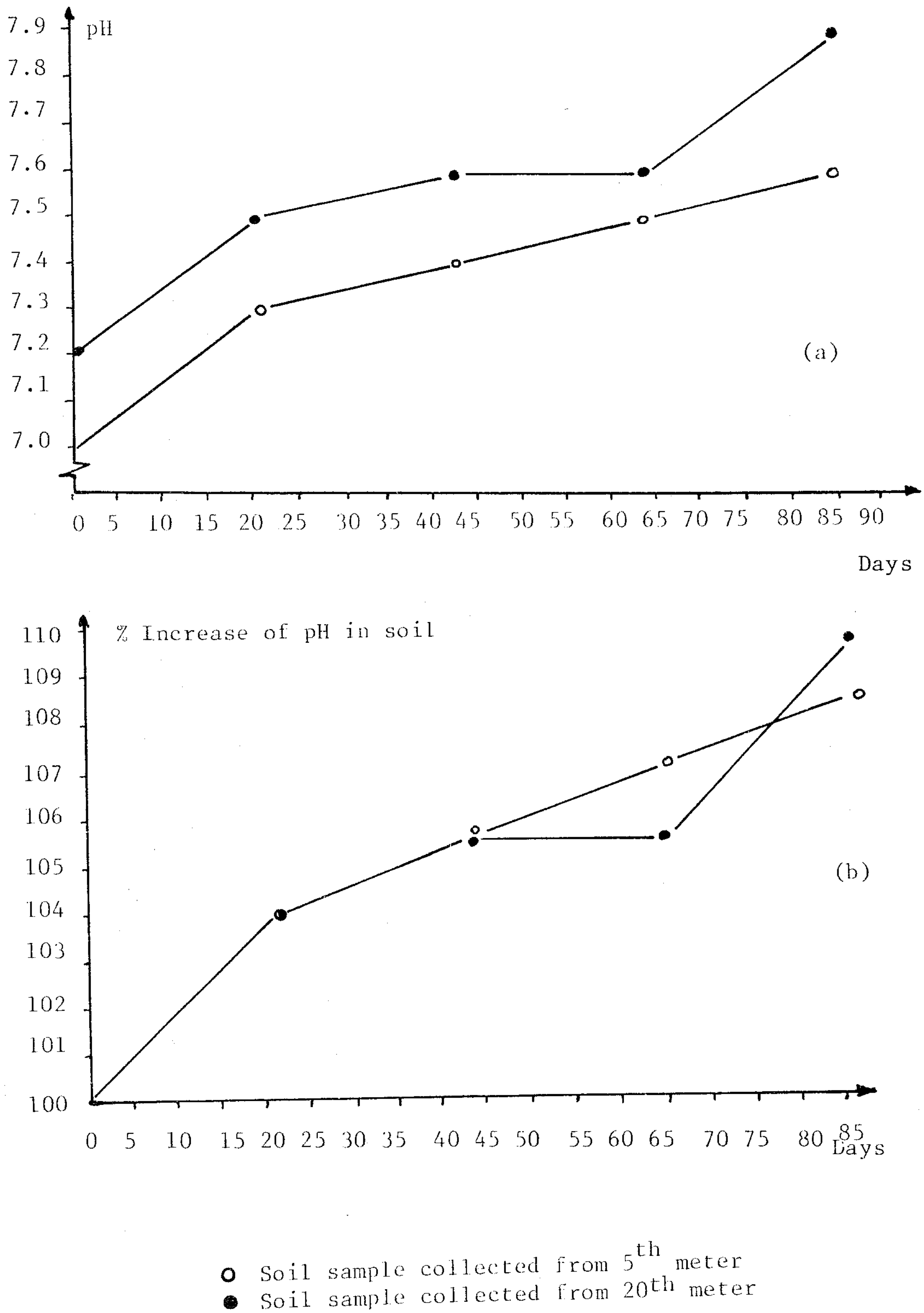

Figure 4.25 a) Graphical Presentation of the Variation of pH in Soil With Time
b) Graphical Presentation of the Variation of Percent Increase of pH in Soil With Time

alkalinity of the soil increased continuously, Table 4.5 shows the effect of certain pH ranges on crop production.

TABLE 4.5 THE EFFECT OF pH RANGES ON CROP PRODUCTION (EPA, 1977)

pH range	Effect on Crop Production
< 4.2	Too acid for most crops
4.2-5.5	Suitable for acid tolerant crops
5.5-8.4	Suitable for most crops
> 8.4	Too alkaline for most crops

Throughout the study, the pH values of soil varied between 7.0 and 7.9, indicating that the harmful limits were not reached during 85 days of continuous operation.

Figure 4.25 (b) represents the percent increase of pH in soil. For both cases the initial values (at time t=o) are accepted as 100 % and the other values were determined on this basis. It is seen that there is a very slight percent increase. For about 43 days, the same increase is attained. From then onwards a sudden but slight increase is observed in the sample set collected from near the end of the channel, due to the accumulation of the basic salts near the end of the channel rather than at the beginning.

4.2.3 Variation of Phosphorus Concentration in Soil

The variation of the amount of phosphorus utilizable by crops present in soil media was determined by TOPRAKSU with the Olsen and friends Method (Ülgen and Ateşalp, 1972 (a)). The results obtained are summarized in figure 4.26. An important fact to note is that the Olsen Method was adopted in such a way that the soil samples were passed through a 2 millimeter sized sieve and then the analysis is conducted using the soil that was sieved. Therefore; the results may not show the actual amounts of phosphorus.

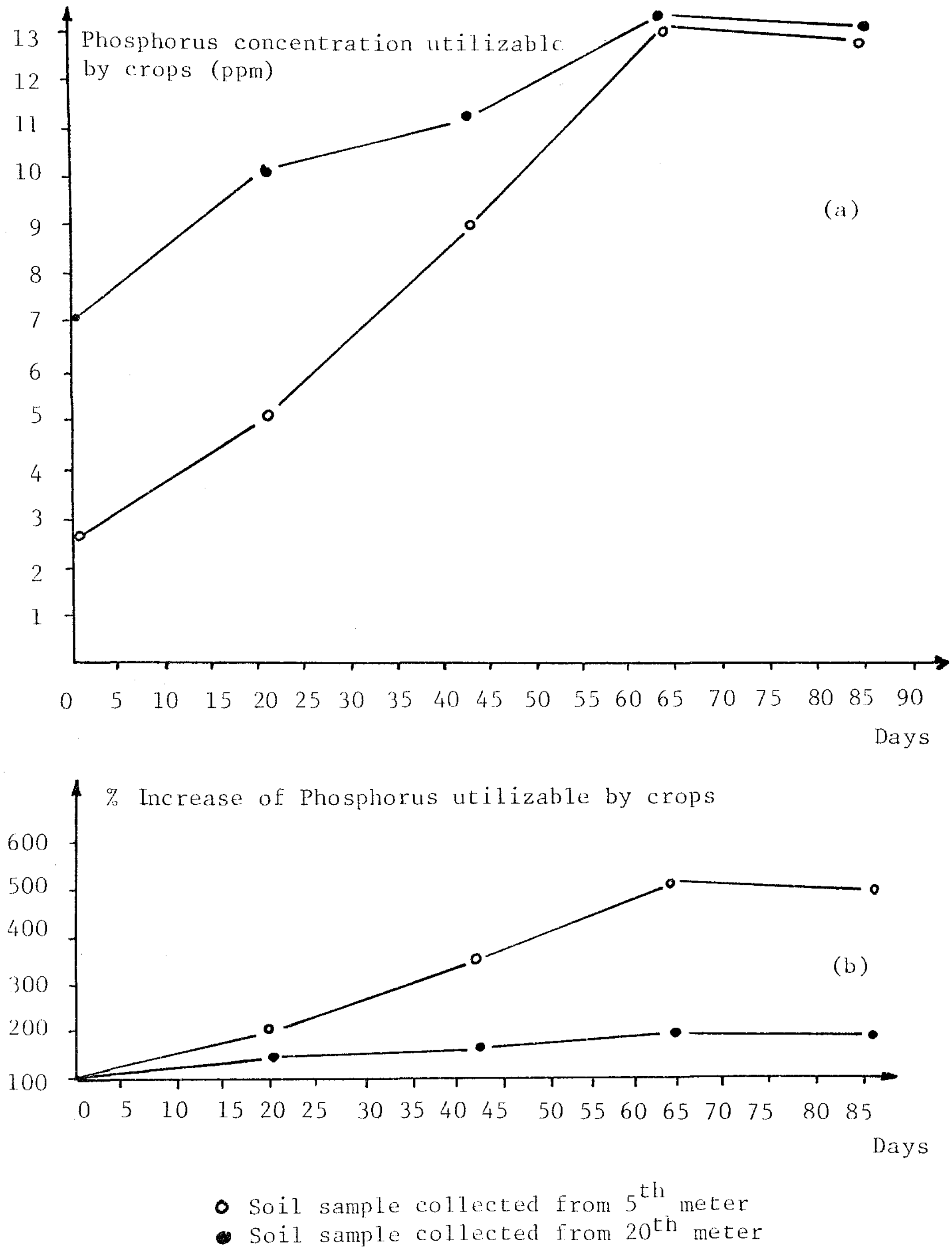

Figure 4.26 a) Graphical Presentation of the Variation of Phosphorus Concentration in Soil With Time

b) Graphical Presentation of the % Increase of Phosphorus Concentration in Soil With Time

Again, the insufficient washing and cleaning process caused the differences in values at t=o at the beginning and at the end of the filter bed. It is seen that the phosphorus utilizable by crops is accumulated towards the end of the channel.

Figure 4.26 (a) represents the increase of phosphorus concentration in soil with progressing time. It is seen that as time progresses, the soil is supplied with more phosphorus reaching values at the end, characteristic of productive soils. Table 4.6, on the other hand, gives information about the effect of phosphorus concentration on soil fertility.

TABLE 4.6 THE EFFECT OF PHORSPORUS CONCENTRATION ON SOIL FERTILITY (Ülgen and Ateşalp, 1972 (a))

Phosphorus Concentration range (ppm)	Effect on Soil Fertility
< 2.5	Soil very poor in phosphorus
2.5-6	poor
6-12	quite poor in phosphorus
>12	rich in phosphorus

Figure 4.26 (b) shows the percent increase of phosphorus concentration in soil. It is seen that the percent increase of the phosphorus in soil samples taken from the 5^{th} meter is higher compared with the percent increase in soil samples taken from the 20^{th} meter, indicating that most of the removal process during infiltration has taken place within the first five meters distance, even though, the phosphorus present initially is accumulated near the end of the channel.

4.2.4 Variation of Organic Matter in Soil

The percent organic matter is determined in the same way as phosphorus concentration in soil is determined. The soil samples were passed through a 2 millimeter sized sieve and then analyzed. Thus, the results presented in Figure 4.27 (a) do not actually indicate the true values.

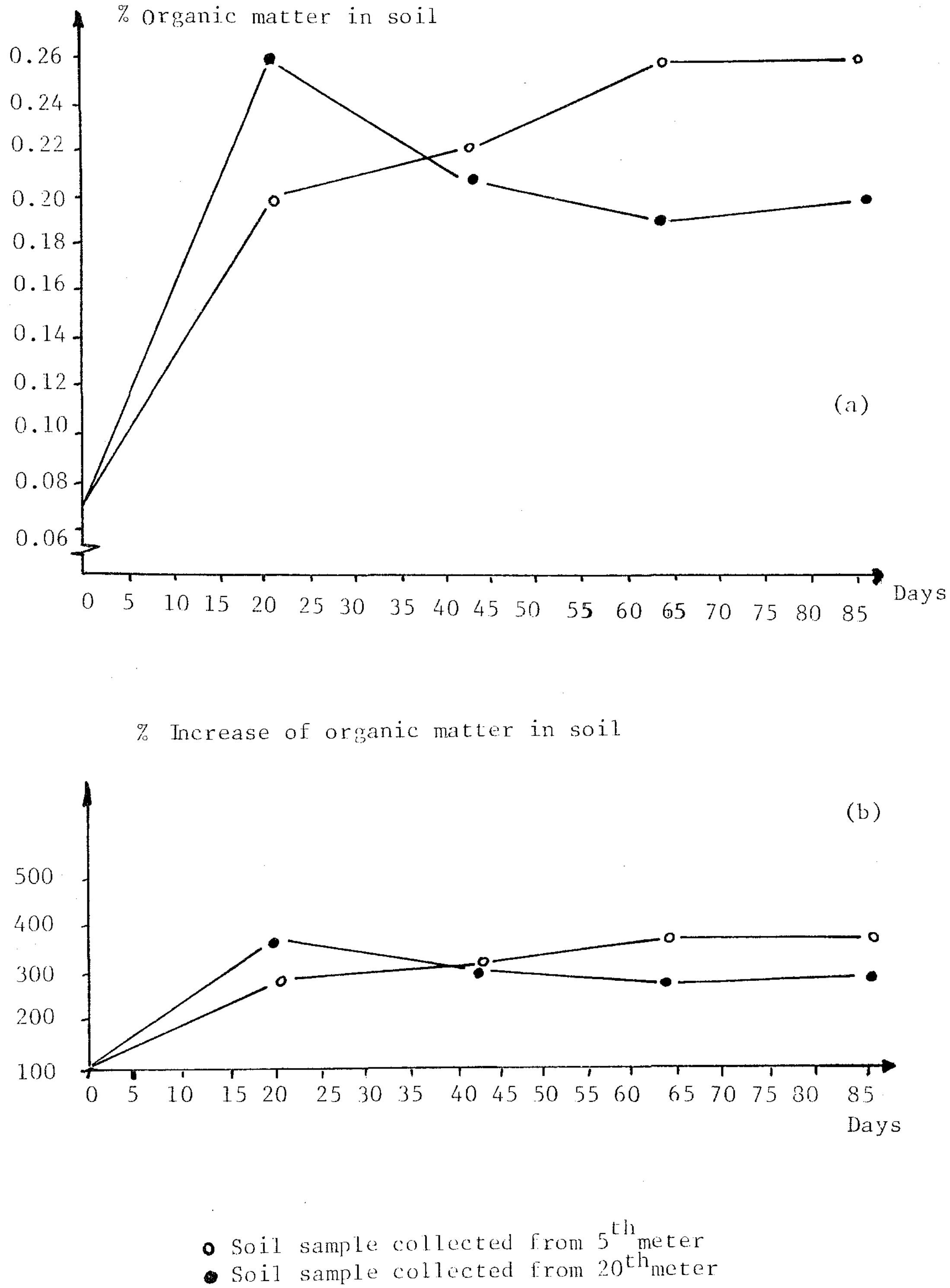

Figure 4.27 a) Graphical Presentation of the Variation of % Organic Matter in Soil With Time
b) Graphical Presentation of the % Increase of Organic Matter in Soil With Time

It is recognized that most of the organic matter is removed towards the end of the channel for a certain time at the beginning of infiltration and then as time progresses, most of the removal takes place within the first five meters. Figure 4.27 (b) shows the percent increase of the organic matter where the initial value is taken as 100 %.This figure reinforces the above stated results.

Mahida (1981) states that the actual percent of organic matter varies between 2-6% when the soil media is used for the purpose of wastewater infiltration.

4.3 Crop Production

As mentioned in the previous sub-section, five pairs of soil samples were collected during the research period at different time intervals. Two different kinds of crop (wheat, bean) were grown. Attempts with corn did not give satisfactory results. Their growth was observed for a 21 day period. All the seeds were standard for experimental purposes in quality obtained from the Halkalı Agricultural School, in İstanbul. The samples were watered daily with 10 mL of tap water each.

Figures 4.28 - 4.32 show the variation of their height with time. Figure 4.28 represents the growth of the crops in the clean sand samples collected from the 5^{th} and 20^{th} meter distances respectively. It is recognized that wheat is grown more rapidly than bean. Bean degraded on the 14^{th} day for an unknown reason.

Figure 4.29 shows the growth of the crops in the second sample pair collected on the 21^{st} day after the start of the disposal of the wastewater through sand. As can be seen in this figure the growth or wheat is more or less similar to the previous sample pair. Although bean did not grown much it survived till the end of 21 days.

Figure 4.30 shows the behaviour of the third pair of samples. The maximum height of wheat was achieved in this pair. The growth of bean was similar to the previous pair.

Figure 4.31 shows the growth of crops for the forth sample pair. In this presentation bean growth achieved maximum height. It must be noted that the phosphorus concentration in soil samples indicate maximum values compared with other samples, and the pH of this pair is between 7.5-7.6.

Figure 4.32 represents the behaviour of crops grown within the last soil sample pair. It is recognized that this pair is not much useful for crop production, even though, the phosphorus concentrations are more or less the same with the previous pair, but the pH values varied between 7.6-7.9.

Considering all these growth analyses the following conclusions may be developed;

- the crop production basicly depends on pH value and on the phosphorus concentration in the soil.

The maximum height of wheat is observed in sample Pair 3, while the maximum height of bean is observed in Sample Pair 4.

From these results, it can be concluded that, the increase in pH has a negative effect on plantation. This is in full agreement with the literature (Table 4.5).

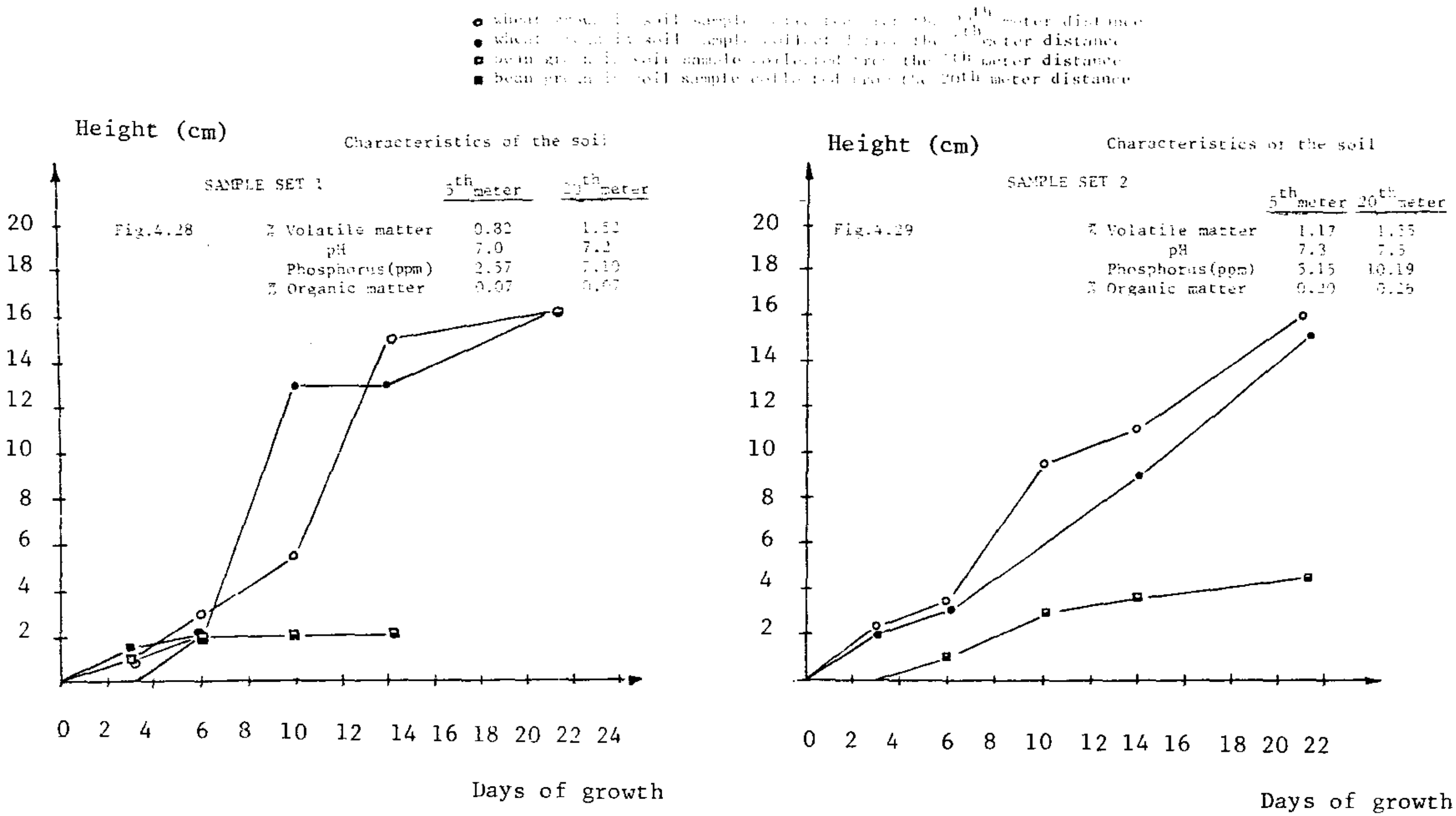

Figure 4.28 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 1

Figure 4.29 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 2

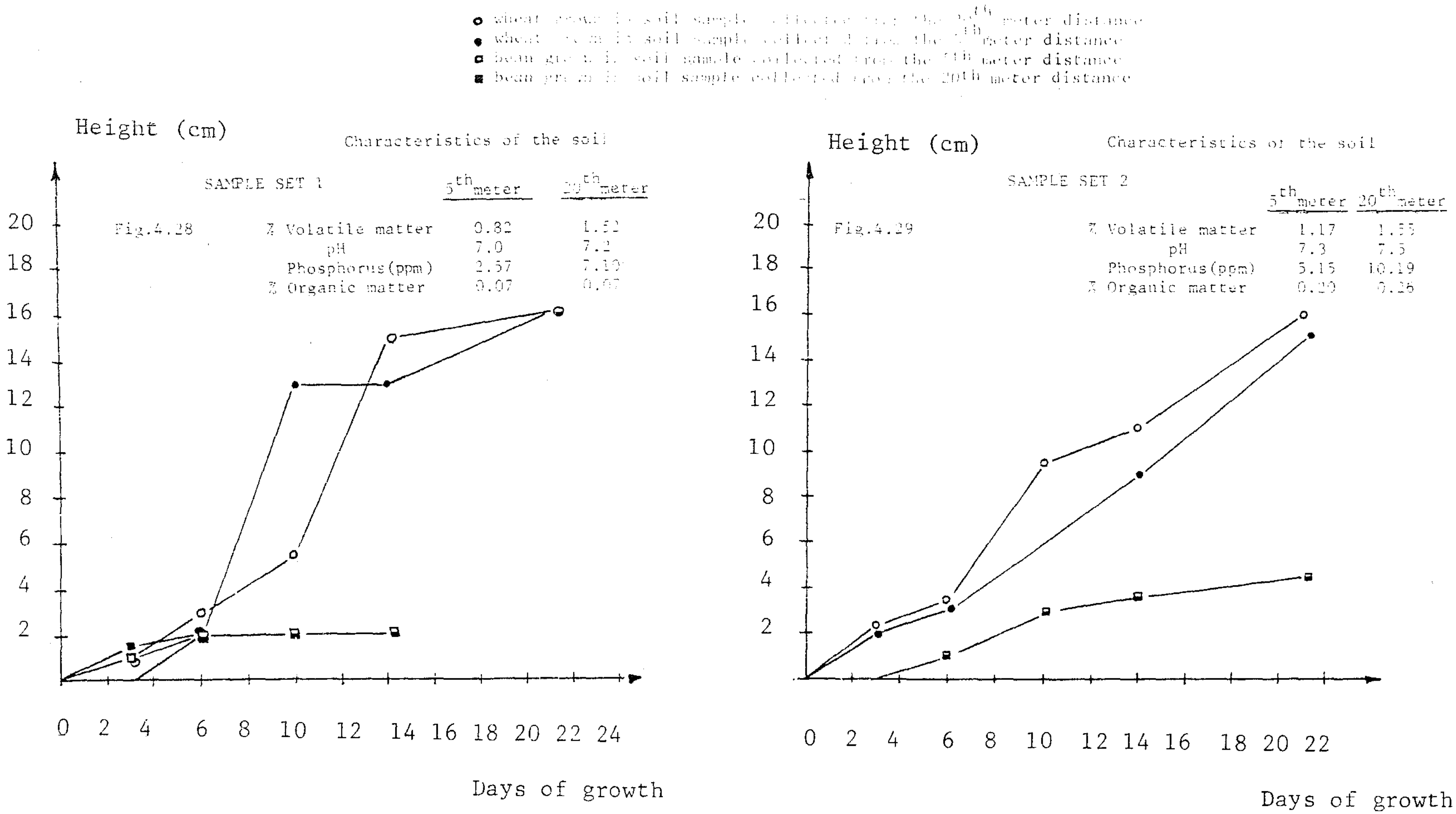

Figure 4.28 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 1

Figure 4.29 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 2

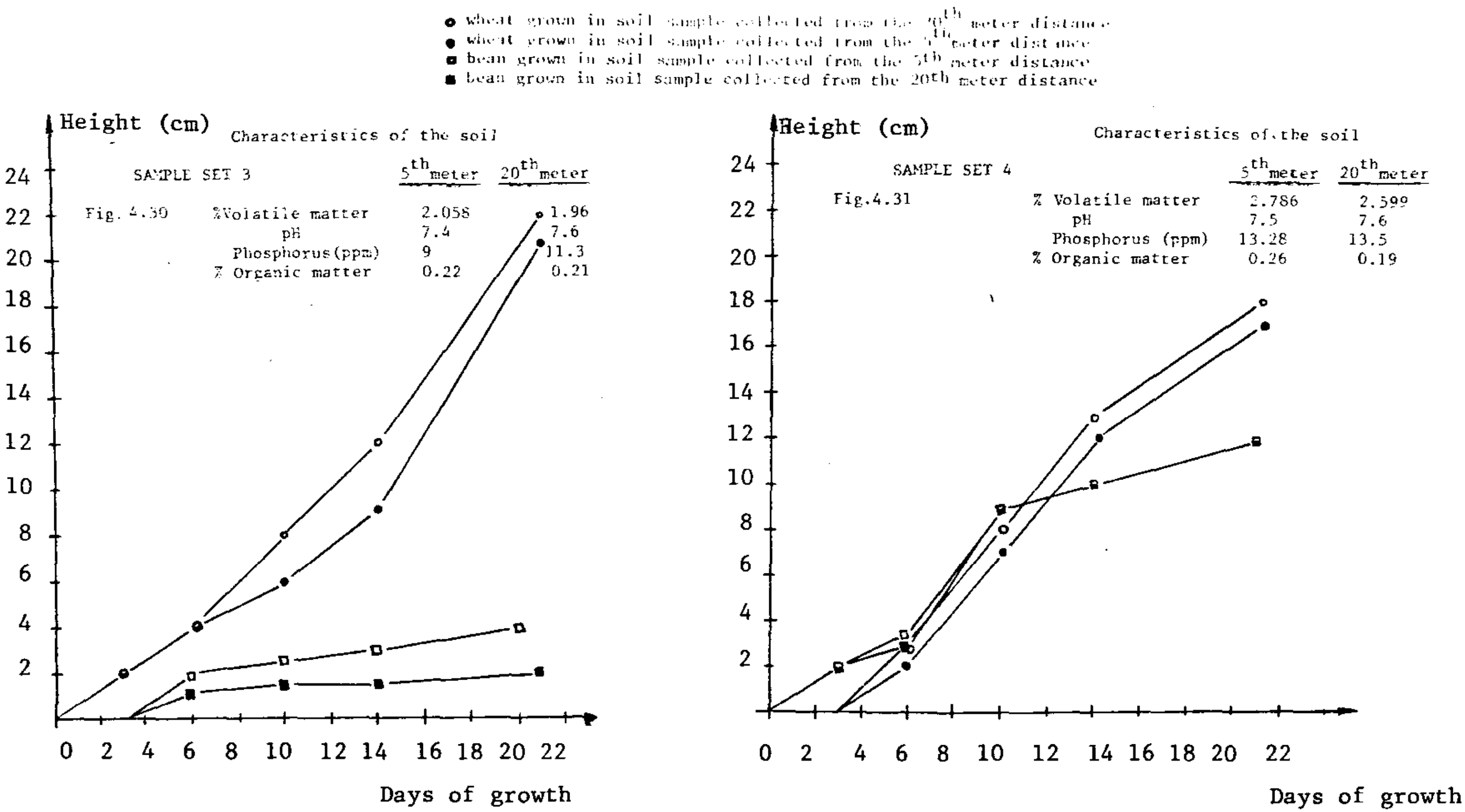

Figure 4.30 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 3

Figure 4.31 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 4

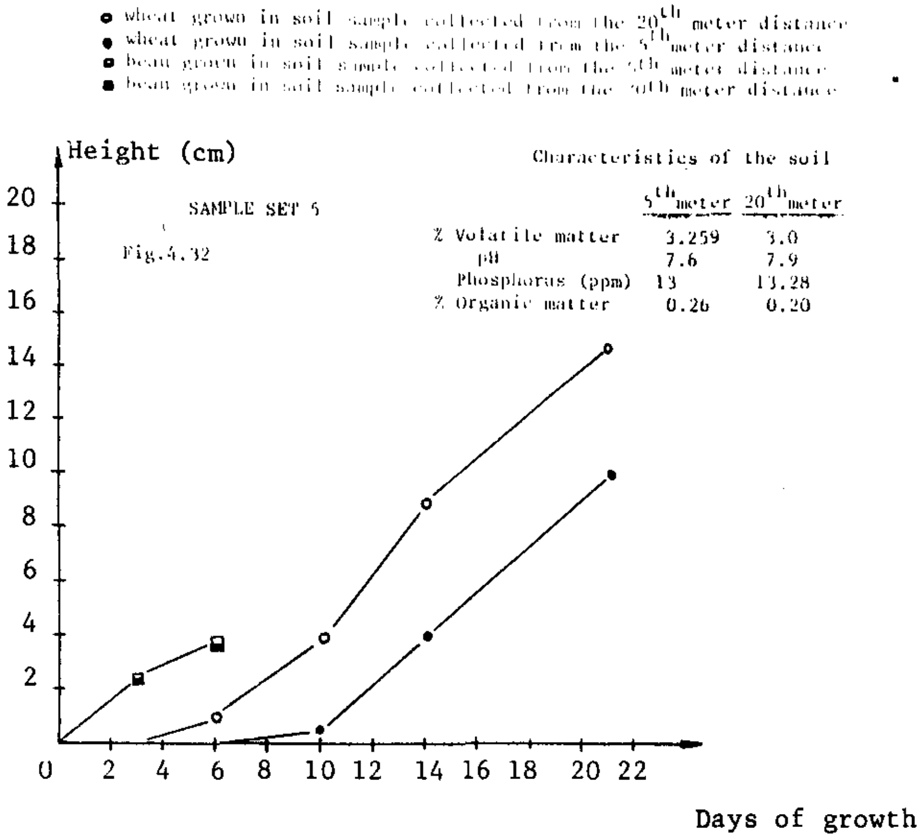

Figure 4.32 Graphical Presentation of Crop Growth with Time in Soil Sample Pair 5

CHAPTER V

CONCLUSIONS

Disposal of wastewater on land is a process which has been used for many years in different countries. In Turkey, however, so far this disposal method has not been used. The present study investigated the applicability of land disposal under the prevailing conditions in Turkey. The system developed did not require any pre-treatment of wastewater before disposal. This condition was considered necessary due to economical reasons as well as the unavailability of skilled personnel which can operate and maintain properly the pre-treatment units. As disposal site, it was preferred to assimilate the conditions of a sandy ground, because some parts of Turkey, started to resemble desert due to erosion.

The most important general conclusions which were derived from this study are;

- purification of wastewater to an acceptable level is possible to be achieved even without any pre-treatment, provided that the wastewater travels approximately 20-25 meters through a sandy layer,

- the operation cost as well as the initial capital investment is minimum with respect to other conventional wastewater treatment systems; thus, land disposal is an economical method which can be used efficiently in less developed and in developing countries,

- land treatment enables the reuse of nutrients present in wastewater. As wastewater penetrates through the sandy layer, the nutrients and the organic matter present initially in the wastewater accumulates on the sand particles and thus enriches the soil with materials necessary for crop production.

The more specific observations made in this study are;

- the productivity of the soil varies with distance and time of operation. The most appropriate crop, however, for each specific condition is different depending on the characteristics of the crop.

The results of this study are in agreement with the results obtained by other investigators. One important characteristic of the present study was that by using a 25 meter long channel, the actual conditions were initiated in a more realistic way. In our literature review, we did not encounter any filter bed longer than 2 meters.

A final conclusion, which can be reached from this study is that land disposal is a method which can be used very effectively in Anatolian Villages of Turkey. This method will not have only economical benefits, but, at the same time will improve the conditions of the soil.

The authorities responsible for the disposal of wastewaters and the protection of the environment, should no delay taking any action and allow wastewaters to be disposed in a primitive way. They should encourage, and even in same cases force the use of the land disposal technique. This we believe will be an important contribution to "The International Drinking Water Supply and Sanitation Decade".

CHAPTER VI

RECOMMENDATIONS FOR FUTURE STUDIES

This chapter may be separated in two parts; the first part stating improvements which should be made on the present experimental set-up while, the second part suggest subjects worthy to be investigated in the future.

6.1 Improvements of the Present Set-up

a) The inlet structure as it is now, does not permit simultaneous use of both channels while controlling the flow. Alterations to this system should be made so that the flow can be kept constant or varied according to the desire of the investigator while both of the channels are used,

b) A structure like parshall-flume or a weir should be constructed which will enable more accurate flow determinations,

c) The covers of the channels sholud be changed by more firm ones, preventing the intrusion of rain water into the system.

d) The porous media should be washed thoroughly before being located in the channel, because otherwise, (as it happens in the present study) if the media is washed after, the impurities washed out from the beginning will be accumulated at the end portion of the channel and thus, uniform conditions will not be achieved at the beginning of the study.

6.2 Recommendations for further Research

The following subjects may be of interest for further investigations;

- variation of the treatability efficiency as well as of the soil conditions by changing the media size, type, depth and flow rate,

- determination of the maximum duration of use of a given land disposal area without deteriorating the quality of the effluent,

- determination of the most appropriate crop suitable to the conditions resulting for different types of use,

- application of the sand disposal process in a sandy area where along with horizontal movement of the wastewater, vertical movements can take place and determination of the efficiency of this application.

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APPENDIX A

Details of the Porous Media and the Wastewater

The total surface of the channel ⇛
0.385 meter x 24.66 meter ⇛ 9.4941 m^2 ⇛ 9.5 m^2

The surface area of the channel filled with sand is ⇛
22.22 meter x 0.385 m ⇛ 8.5547 m^2 ≃ 8.60 m^2

The sieve analysis of the sand samples are shown in Tables A.1 and A.2

The height of the sand ⇛ 0.35 meter.

The height of the sand from which wastewater passes ⇛ 0.25 m at the beginning of the channel and decreases to 0.18m at the end of the channel. The average value ⇛ 0.18 + 0.25/2 = 0.215 m is used in the calculations.

The volume of the sand at depth 0.215 m ⇛ 0.215 m x 22.22 m x 0.385 m ⇛
1.8392 m^3 ≃ 2 m^3

The total volume of the sand ⇛
0.35m x 22.22 m x 0.385 m ⇛ 2.9941 m^3 ≅ 3 m^3
Out of 3m^3 of sand only 2 m^3 are actively used.

The porosity (n) of the sand is found to be 42.8 % with a specific yield of 27.1 %.

The void of the submerged part of the sand at 0.35 m. depth ⇛ 0.428 x 0.35 m x 22.22 m x 0.385 m ⇛ 1.28149 m^3

The void of the submerged part of the sand at 0.215 m depth ⇛ 0.428 x 0.215 m x 22.22 m x 0.385m ⇛ 0.7872 m^3
Out of 1.28149 m^3 of void space; 0.7872 m^3 ise used for water transfer along the channel.

The flow rate of the wastewater ⇛ 640 mL/min.
(recorded experimentally; by using a bucket and chronometer.)

The time of flow along the channel ⇛ 14.1 hours.

TABLE A.1 SIEVE ANALYSIS OF SAND SAMPLE TAKEN FROM THE 5 METER DISTANCE

Sample Weight - 379 gr. (dry)

Sieve number	Hole diameter mm.	Weight of sample retained on the sieve (gr)	% of sample on the sieve	% finer
3"	76.2			
2.1/2"	63.5			
2"	50.8			
1./2"	38.1			
1"	25.4			
1.4"	19.05			
3/8"	9.52			
4.3/16"	4.76	45.6	12.04	87.96
10	2.00	72	19.017	68.943
16	1.19	-	-	-
20	0.84	167.5	44.24	24.703
30	0.59	-	-	-
40	0.42	62.5	16.5	8.203
50	0.297	-	-	-
60	0.210	26	6.867	1.336
100	0.149	3	0.792	0.544
200	0.074	2	0.528	0.016
325	0.044	-	-	-
Finer Sample				
TOTAL		378.6		

TABLE A.2. SIEVE ANALYSIS OF SAND SAMPLE TAKEN FROM 20 METER DISTANCE

Sample Weight- 360 gr. (dry)

Sieve number	Hole Diameter mm.	Weight of Sample retained on the sieve (gr.)	% of sample on the sieve	% finer
3"	76.2			
2.1/2"	63.5			
2"	50.8			
1.1/2"	38.1			
1"	25.4			
1/4"	19.05			
3/8"	9.52			
4 3/16"	4.76	49.5	13.78	86.22
10	2.00	76.1	21.197	65.023
16	1.19	-	-	-
20	0.84	160.3	44.65	20.373
30	0.59	-	-	-
40	0.42	53.3	14.846	5.527
50	0.297	-	-	-
60	0.210	16.8	4.679	0.848
100	0.149	2	0.557	0.291
200	0.074	1	0.278	0.013
325	0.044			
Finer Sample				
TOTAL		359		

APPENDIX B

RESULTS OF THE EXPERIMENTS

B.1 Wastewater Analysis

- Chemical Oxygen Demand (COD) Data

distance / time (days)	0 meters mg/L	5 meters mg/L	10 meters mg/L	15 meters mg/L	20 meters mg/L	25 meters mg/L
0	463.36					173.76
6	448.8					132
12	574.93					156.8
13	365.86					78.4
17	365.86					104.53
19	380	320	287.46	235.2	104.53	95
21	320	267	187	160	133	106.68
27	480	427	380	320	267	107
33	533.33					106.7
34	586.67	400	213.33	186.67	133.33	
39	453.33	400	346.66	293.33	186	80
46	747	690	586.67	426	267	200
59	480	400	294	213	107	80
68	586.67	450	346.67	266.67	133.33	90

- Nitrogen (N) Data

distance / time (days)	0 meters mg/L	5 meters mg/L	10 meters mg/L	15 meters mg/L	20 meters mg/L	25 meters mg/L
0	12.85					6.40
4	18.5					4.50
6				12.88	10948	
8			15.46			8.37
11	22.54					9.66
14	23.83			12.88		7.728
20	12.88		11.592	9.66	8.372	8.2
26	12.88		10.304	7.728	6.44	4.508
33	15.68		15	10.9	7.73	4.50
47	18.2		13.5	9.8	7.68	4.65
55	22		18.52	12.88	9.67	6.87

- Phosphorus (P) Data

distance / time (days)	0 meters mg/L	5 meters mg/L	10 meters mg/L	15 meters mg/L	20 meters mg/L	25 meters mg/L
0	4.4					0.7
3	6.5					0.7
5	4.4					1
6	4.4					1
12	4.8					1
13	5					1
17	6.5					1.7
19	4.5	4.5	4.5	2.9	2.5	1.7
21	6.5	6.5	6.5	3.5	2.5	1.7
27	4.4	4.4	3.5	2.5	1.7	1
33	4.6					1
34	6.5	4.4	2.5	1	0.5	0.5
39	6.5	4.4	3.5	3.0	2.5	1.7
46	6.5	5.5	4.5	3	2	1.5
60	6.5	6.5	4.4	2.5	1.7	0.5
68	7	6	3.5	2.5	1.5	0.5

- Total Solids Data

distance / time (days)	0 meters mg/L	25 meters mg/L
0	361	246
9	432	420
12	403	350
27	633	450
34	507	473
48	624	564
56	477	472

- Suspended Solids Data

distance / time (days)	0 meters mg/L	25 meters mg/L
5	232	60
9	60	46
12	42	10
27	180	98
34	160	75
48	110	44
56	190	96

- Turbidity Data

distance / time (days)	0 meters Turb.Units	5 meters Turb.Units	10 meters Turb.Units	15 meters Turb.Units	20 meters Turb.Units	25 meters Turb.Units
0	286					116
3	280					110
6	270					140
8	270					136
9	380					120
15	380					160
16	240					180
20	400					160
22	420	360	236	200	200	160
24	240	160	160	160	120	100
30	252	170	120	120	100	90
36	280					80
37	200	120	98	90	80	
42	420	260	140	140	135	87
49	340	220	190	100	90	80
64	350	240	160	140	100	90
71	360	220	160	120	90	80

- pH Data

distance / time(days)	0 meters	5 meters	10 meters	15 meters	20 meters	25 meters
0	7.4					7.0
3	6.8					7.2
6	6.7					7.0
7	6.8					7.2
8	6.8					6.9
9	6.9					7.6
15	6.7					7.0
16	6.8					7.4
20	6.9					7.6
22	7.0	7.1	7.6	7.8	8.0	
24	7.1	7.4	7.7	7.7	8.1	7.9
30	7.2	7.7	7.5	7.8	7.9	7.6
36	7.0	7.1	7.5	7.4	7.8	7.4
42	8.4	7.3	7.6	7.8	8	7.4
49	6.8	7.4	7.5	7.5	7.8	7.3
64	7.4	6.9	7.3	7.6	7.6	7.5
72	6.5	6.4	6.7	6.7	7.0	6.9

- Coliform Data

number of coliforms/100 ml

distance / time(days)	0 meters	5 meters	10 meters	15 meters	20 meters	25 meters
0	$9.2x10^4$					$3.6x10^4$
3	$1x10^5$	$8.6x10^4$	$5x10^4$	$4.6x10^4$	$4x10^4$	
7	$1x10^5$	$1x10^5$	$9.5x10^4$	$9.0x10^4$	$4x10^4$	$4x10^4$
17	$1.8x10^5$	$1.3x10^5$	$1x10^5$	$8x10^4$	$5x10^4$	$4x10^4$
22	$2.0x10^5$	$1.4x10^5$	$1x10^5$	$9x10^4$	$5x10^4$	$3.5x10^4$
29	2.2010^5	$2x10^5$	$1.4x10^5$	$1x10^5$	$8x10^4$	$5x10^4$
43	$2.1x10^5$	$1.6x10^5$	$1.15x10^5$	$8x10^4$	$4.6x10^4$	$4x10^4$
51	$2.2x10^5$	$1.8x10^5$	$1.2x10^5$	$9x10^4$	$6.5x10^4$	$4.5x10^4$

B.2 Soil Analysis

- Percent Volatile Matter in Sand Data

distance / time (days)	5 meters %	20 meters %
0	0.82	1.52
21	1.17	1.55
43	2.058	1.96
64	2.786	2.599
85	3.259	3.0

- pH in Sand Data

distance / time (days)	5 meters	20 meters
0	7.0	7.2
21	7.3	7.5
43	7.4	7.6
64	7.5	7.6
85	7.6	7.9

- Phosphorus Concentration in Soil Data

distance / time (days)	5 meters	20 meters
0	2.57	7.10
21	5.15	10.19
43	9	11.3
64	13.28	13.5
85	13	13.28

- Percent Organic Matter in Soil Data

distance / time (days)	5 meters	20 meters
0	0.07	0.07
21	0.20	0.26
43	0.22	0.21
64	0.26	0.19
85	0.26	0.20

B.3 Growth of Crops

- Data of SAMPLE TEST 1

distance / time (days)	Wheat 5 meters (cm)	Wheat 20 meters (cm)	Bean 5 meters (cm)	Bean 20 meters (cm)
0	0	0	0	0
3	0	1	1	1.6
6	2	3	2	2
10	13	5.4	2	2
14	13	15	2	2
21	16	16	-	-

- Data of SAMPLE TEST 2

distance / time (days)	Wheat 5 meters (cm)	Wheat 20 meters (cm)	Bean 5 meters (cm)	Bean 20 meters (cm)
0	0	0	0	0
3	2	2.4	0	0
6	3	3.4	1	1
10	6	9.4	3	3
14	9	11	3	3.6
21	15	16	4.4	4.4

- Data of SAMPLE TEST 3

distance / time(days)	Wheat 5 meters (cm)	Wheat 20 meters (cm)	Bean 5 meters (cm)	Bean 20 meters (cm)
0	0	0	0	0
3	2	2	0	0
6	4	4	2	1.2
10	6	8	2.5	1.5
14	9	12	3	1.5
21	21	22	4	2

- Data of SAMPLE TEST 4

distance / time(days	Wheat 5 meters (cm)	Wheat 20 meters (cm)	Bean 5 meters (cm)	Bean 20 meters (cm)
0	0	0	0	0
3	0	0	2	2
6	2	3	2.4	2
10	7	8	9	9
14	12	13	10	10
21	17	18	12	12

- Data of SAMPLE SET 5

	Wheat	Wheat	Bean	Bean
distance / time(days)	5 meters (cm)	20 meters (cm)	5 meters (cm)	20 meters (cm)
0	0	0	0	0
3	0	0	2.4	2.4
6	0	1	3.8	3.8
10	0.5	4.0	-	-
14	4	9	-	-
21	10	15	-	-