CHAPTER 4
TREATABILITY STUDIES OF SEWAGE OF BHAVNAGAR

4.1 INTRODUCTION.

Disposal of wastes to the land has been an accepted and recognized cultural practice through out the world. Stabilization and assimilation of body wastes in the soil is complete, and problems do not occur with low-density or migratory populations of man or animals. The value of the wastewaters – sewage as a fertilizer for vegetation and crop production was well recognized in Asian cultures. The higher population density conditions that can cause problems have been documented since Vedic periods and biblical times[1, 2]. These problems require a technique for the management of waste disposal, rather than random disposal. Controlled application of the wastes to the land emerged as a technology with the centralization of population in towns and cities.

The earliest documented system of land application was in Bunzlau, Germany, where sewage irrigation project was commissioned in 1531, and was in operation for over 300 years at Bunzlau[3].A similar system began operation in 1650 in the vicinity of Edinburgh, Scotland[3]. By the mid nineteenth century land application of wastewaters was considered to be the safest and most reliable method by the technical experts and by the regulatory authorities of the time.

In London, private companies were supplying drinking water from the Thames, in which raw sewage could be seen floating between reeking mud banks. People drank the untreated water without even filtering, complaining more about the insufficiency of their local supply than about its dirtiness. An English lawyer Edwin Chadwick showed in a report on the "Sanitary Conditions of the Laboring Population of Great Britain" in 1842 that the laborers suffered a far higher incidence of disease than the middle and upper middle class. Chadwick declared that most of their diseases were preventable.

A Cholera epidemic in London in 1848 – 1849, claimed over 25000, and a large body of public opinion began to form in favor of the good sanitarians facilities. A doctor, John Snow noted that the most of the Cholera victims were users of a busy public water pump in "Broad Street". Upon investigations it was found that the well supplying water through the "Broad Street" pump was contaminated by a cesspool. Snow published a report in 1855, which linked the cholera outbreak to contaminated water, but its implications were generally ignored. The connection between contaminated water and disease was recognized, although the causative agents were not identified. After that waste discharge to reservoirs of water was avoided wherever possible. George Rafter [4, 5, 6] of the U S Geological Survey, made the first comprehensive reviews of wastewater disposal in the United States. In his series of reports from 1894 to 1899, he reviewed the status of wastewater treatment facilities in the United States and Europe. Almost all the sewage treatment facilities, or sewage treatment plants in the United States and Canada as of 1899 were land treatment system. Many of them are still in operation. A short list of some of them is as given in Table 4.1.

Many of his conclusions were the subject of bitter debate and controversy. By the early 1920s the focus had shifted to "modern methods" of sewage treatments. Probably the germ theory for disease transmission, with the use of chlorine as a disinfectant, which made sewage "safe" to discharge to waterways was responsible for the decline in land treatment of sewage for agricultural use. By the late 1960s it was recognized that there was more pollution than BOD and TSS. It was felt by civil scientists that a strong role of government would be needed to clean up polluted waterways. Water Pollution Prevention Act and "Zero Discharge" goals came up with this.

TABLE 4.1

SOME EARLY LAND TREATMENT SYSTEMS FOR WASTEWATER IN THE UNITED STATES

Location	Year of Commissioning	Area Acres
Calumet City, Mich, *	1888	12
Woodland, Calif. *	1889	240
Boulder, Colo.	1890	Not known
Fresno, Calif. *	1891	4000
San Antonio, Tax.	1895	4000
Vineland N.J. *	1901	14
Bakersfield, Calif. *	1912	2400
Lubbock, Tax. *	1915	Not known

* Still in use

Rafter made following conclusions from his study.

- The most efficient purification method of sewage can be obtained by its application to land.
- On properly managed sewage farms, the utilization of sewage is not prejudicial to health.
- Sewage may be purified by broad irrigation in all seasons of the year at any place where the mean annual temperature of the coldest month is not lower than 20$^{\circ F}$ to 25$^{\circ F}$.

- From the experience gained abroad (India? Asian Countries?) it is clear that we may successfully cultivate almost any of the ordinary agricultural crops on sewage farms.

- When operated with reference to all the necessary conditions, a proper degree of purification may be obtained as well as satisfactory utilization.

- Sewage utilization should go hand in hand with purification.

- The proper method of utilizing sewage is, for purpose of irrigation, by means, which do not differ, except in matters of detail, from those of ordinary irrigation as practiced abroad for centuries.

Sewage treatment systems, in Rafter's time were typically found only at the larger, more sophisticated metropolitan centers that could not discharge to an open ocean. The design approach for land treatment system was empirical, based on observation of successful performance of some treatment plant, followed by derivation of criteria, and mathematical expressions predicting performance expectations. Much of the details about the properties of sewage were not known or not considered important. It was always suspending between cost effective and conservative design for waste treatments.

4.2 Sewage Treatability Studies

Treatability of sewage always must be studied in connection with characteristics of sewage itself and desired end-use. The need for direct and deliberate reuse of reclaimed sewage is increasing in many areas of the world. The reuse holds the key to the efficient and effective utilization of the limited fresh water resources by making it available as a major source of supply for the future. Unavoidable water reuse is an already well-established fact and accepted practice in many communities, although not often recognized as being so. The time is rapidly approaching when the degree of wastewater treatment required in many areas of pollution control will be so costly that it will not be affordable to the public the luxury of discharging once-used water. Advances in knowledge of science, particularly in the field of chemistry, applied microbiology and medical science related to public health have made it possible to evaluate properties properly. During this study, based on visual observations, physical properties, chemical properties and *microbiological* observations, sewage was subjected to purification experiments. The four main areas of reuse considered were,

- **Agricultural Use,**
- **Industrial Use,**
- **Domestic Use and**
- **Recreational Use.**

The type and degree of treatment is dependent of reuse targeted. Availability of water from alternate source and economics also play an important role. The treatments are generally classified as, Primary Treatment; Secondary Treatment and Polishing Treatment.

There are several requirements common for all the types of reuse. These requirements can be termed as primary requirements. The tests for these requirements are visual observation for appearance and odor. In most cases colour is the first visual, but basic observation that affects the selection or rejection of water for different uses. Any water for its use must be clean and free from any visible impurities. This mean, any water for its use or reuse after some treatment must be filtered through suitable filter, to make it acceptable. The second basic requirement is odor. The water for use must not smell disagreeable. For example Drinking Water may smell chlorine, as a part of treatment to make it free from harmful microorganisms and fit for drinking, but it should not smell too high.

4.2.1 Agricultural Use

Agricultural use of reclaimed wastewater can be for Irrigation uses or Groundwater Recharge.

Irrigation Uses

Use of sewage - wastewater for irrigation has been the major instance of wastewater - sewage reuse in the past. The chief concern has been to restrict the use for irrigation to prevent hazards from sewage contact with crops directly consumed by humans.

One of the attractive feature of irrigation with reclaimed wastewater, compared to several other non-potable reuses is, there is less stringent water quality requirement for irrigation. Hence simpler and less costly treatment is required[10].

The salt content and salinity of the irrigation water can affect the agricultural crop. Absolute limits of desirable salt content cannot be fixed, because plants vary widely in their tolerance to salinity. Wide variations in soil types, climatic conditions and irrigation practices are equally important. The relationship between ions is significant, usually illustrated as SAR, between calcium and sodium. Calcium and Magnesium in proper proportion maintain the soil in good condition. When sodium exceeds the desirable limit for a given soil, granular structure of soil begins to breakdown. The soil pores eventually seal, resulting in a decrease in soil permeability. The concentration of salt in most sewage will not usually be high enough to cause immediate damage to the crops. Where the soil has a higher cat ion exchange capacity, higher sodium content may be acceptable. The sodium hazard is increased if the water contains high concentrations of bicarbonates, because there is a tendency of calcium and magnesium to precipitate as carbonate[9]. Certain soluble salts can be harmful if present in excessive concentrations. For example high concentration of chlorides can cause leaf burns and possible death of the plant.

Nitrogen, Phosphorous and Potassium have proven nutrient value, and hence these elements are not harmful in the sewage, and need not to remove from it. Concentration of these elements in the wastewater is usually very low, agricultural crops are consuming it in varying proportions and therefore there is no possibilities of mineral built up of these elements in the agricultural soils. Aside from the possible risk of groundwater contamination, it is desired to recycle Nitrogen wherever possible, since it is an essential nutrient required for the production of fiber and food. Its reuse also represents energy conservation[15].

Regarding movement of pathogen into groundwater following irrigation with reclaimed wastewater, there is general agreement that soil is an effective filter of pathogens[11]. Sensible care is recommended in the handling of treated wastewater, because bacteria, viruses and helminthes eggs may remain viable in soil for the period of several days or longer.

The concentration of trace elements in treated municipal wastewater is not high enough to result in short term harmful effects[11]. Metallic trace elements, for example Zinc, Cadmium, Nickel, Lead, and Copper tend to accumulate in the soil. Although the conventional wastewater treatment systems are not designed to the trace elements, they are removed effectively by absorption on suspended solids, or precipitated by suspended solids under the normal operating conditions[12]. To safeguard plants from possible detrimental effects of sludge-born trace elements in cropland sludge applications, the U S E P A has recommended that cumulative tota. loading of Cd, Cu, Ni, Zn, and Pb during the land application of sludge be limited according to the Cat-ion Exchange Capacity of the receiving soil[13, 14].

Groundwater Recharge.

Where soil and hydraulic conditions are favorable, ground water recharge through surface spreading of sewage or groundwater recharge through the recharging well is most economical method. Ultimately all waters used must be returned to nature in possible pure form, or in condition that nature can take care of it.

Nitrate in wastewater applied to land is subject to leaching if not intercepted by plant roots, immobilized by microorganisms, or denitrified. Leached nitrate may be transported to surface water by seepage. Otherwise it will move through the profile of soil into groundwater. In wastewater irrigation and groundwater recharge, the primary concern with respect to Nitrogen is the possibilities of nitrate contamination of domestic water and attendant risk of "Methemoglobinemia" that is "Blue Baby Disease" in human infants. Although the incidence of Methemoglobinemia is very low, and the risk is based on the possibilities of reduction of nitrate to nitrite - very unstable component, in the digestive tract of infants below the age of 6 months, sensible care is recommended. Nitrite absorbed into the blood stream can combine with hemoglobin, thereby reducing its capacity to carry oxygen. Older humans are much less susceptible to this disease than are very young infants. Methemoglobinemia is much more common in ruminant animals than in

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humans, but its occurrence is usually associated with high nitrate concentrations in forage rather than in drinking water[15].

Phosphorous added to the soil may be taken up by the crop or accumulated by the solid phase of the soil in sorption and precipitation reactions. Studies of the reactions of phosphate in soil have revealed the important roles of the hydrous oxides of aluminum, iron and calcium[16].

As stated earlier in this section, regarding movement of pathogen into groundwater following irrigation with reclaimed wastewater, there is general agreement that soil is an effective filter of pathogens[11].

Wastewaters always contain trace elements, and its transport to underground or subsurface water may render the water unfit for its intended use. The solubility of trace elements is pH sensitive. The solubility of cationic trace elements increases, as the pH decreases, and solubility of anionic trace element species tend to increase as the pH increases. Fortunately the concentration of trace elements in the wastewater is not high enough to cause any short-term acute harmful effects, the potential for harmful effects in the future should not be overlooked[17].

Trace organic substances are a group of newly discovered contaminants of water. Since their discovery, several hundred potentially hazardous chemicals have been found in natural water, wastewater and drinking water[18, 19]. Because of the inherent toxic effects associated with many trace organic substances, their presence in water has caused great concern.

Although conventional wastewater treatment processes are not designed for the removal of trace organics, such processes can greatly reduce the number and concentration of trace organics. When trace organics are introduced into the soil, the most effective mechanisms of attenuation are expected to be volatilization adsorption, and biodegradation. Because there are few data to quantitatively describe the fate of trace organics in the soil, adsorption coefficient and partition coefficient of selected organics in wastewater may provide useful index of behavior of trace organics[20]. Fortunately the concentration of trace organics and unknown organics in the wastewater is not very high, the potential for harmful effects in the future should not be overlooked.

4.2.2 Industrial Use.

Industrial use of water is estimated to be equal or higher than that of agricultural use. It is almost always several times that of municipal use. For Bhavnagar city, never satisfied water requirement of two clusters of small scale industries, known as Chitra Industrial Zone and Vithalvadi Industrial area is almost half of the equal to that of municipal water supply to Bhavnagar city – in hot summer months, that is about 20 MLD[21]. Soda-ash plant of Nirma Industries is producing about 11 MLD of soft water of less than 250 p.p.m. TDS from marine water at the rate of about 450M^3/Hour by Reverse Osmosis, and consuming it for its industrial requirements[22]. It is definite that Industrial water requirements will increase with the time. It is apparent that as the demand for water and cost of fresh water supplies increases, wastewater reclamation will be an attractive alternative for industries.

The required quality and quantity of water required varies widely depending upon the specific use. Cooling water quality differs greatly from that of boiler feed water[23, 24]. Water quality standards exceeds drinking water quality standards in some industrial applications such as Pharmaceutical Process Water, Beverage Preparation, High-pressure Boiler Feed Water and Electronics Manufacturing. Therefore it is not possible to tabulate the specific water quality requirements for all potential industrial uses. That is why, while considering specific use of reclaimed wastewater for industry, one should determine the needed quality and quantity, and evaluate the economics of obtaining this quality and quantity from wastewater stream as compared to other alternative sources such as Reverse Osmosis. Major factors to be considered are the consistency in quality and quantity of each source.

The major consideration for the use of reclaimed wastewater as industrial cooling water is that the water should not encourage

- corrosion,
- deposition of scale,
- delignification of wooden cooling towers,
- growth of microorganisms – algae and
- excessive foaming in the cooling towers.

Use of treated sewage as cooling water in industry has proven satisfactory in some cases. Chemical coagulation and sedimentation is often provided prior to use as a normal practice in industries, and pH is adjusted between 6.5 and 7.5 to avoid possible corrosion problem. Sewage constituents which may create trouble in cooling water are suspended solids, hardness, dissolved oxygen and other gases, nutrients – that is N P and K, and microorganisms that can produce slime.

Almost all industries use boiler. Adequate quality for boiler feed water is almost universal problem. As the operating pressure and steam quantity increases, the better quality of boiler feed water is required. For boilers operating at very high pressure, for example 60 Kg /cm2 and above, carefully deionized water is required, practically hardness must be zero and total dissolved solids below 0.5 m.g./L26. Silica is especially troublesome, because it forms a hard scale in boiler tubes. Usually high-pressure boilers require feed water treatments beyond normally used even for pharmaceutical industries.

Nitrogen and Phosphorous removal is required for the control of algal growth. Chemical additives to inhibit scale formation, algal growth and slime growth are almost a regular practice in industries.

As a common or basic requirements of quality of industrial water, it should be free from suspended solids, low in hardness, low in dissolved oxygen and other gases, low in nutrients – that is N P and K, free from microorganisms that can produce slime and free from oil / grease.

4.2.3 Domestic Use

"Reclaimed sewage water should not in any case be used as a source of domestic water supply when other sources are available." This is what I have known during my studies of sewage from the public of Bhavnagar after detailed survey of more than 400 houses of all the 17 administrative wards of Bhavnagar city. The people I have contacted to know their feelings about the reuse of sewage for domestic use were from different classes of society, based on economical status, socially conditions, education, religion, and facing different types of hardness in getting adequate quantity and quality of water for their everyday needs. The inner meaning of their reply was almost the same. They were ready to pay something extra for good quality water, or face the hardness. Economical use of water for domestic use was emphasized by almost everybody, but nobody was ready to use reclaimed SEWAGE WATER for domestic use when it was asked for it. The opposition was perhaps because of the word SEWAGE and it was not acceptable for them aesthetically. Large number of them did not know scientific reasons or any thing about bacterial and viral infections.

There are some significant differences of opinion in different parts of the world on the suitability of reuse of sewage or any other wastewater for domestic supply. The IS 10500 – 1991, specification for drinking water, and American Public Health Services Drinking Water Standards are based on assumption that raw water source for the supply as domestic water is relatively free from pollution. These standards appear to be reliable for supplies taken from fresh water sources since acute health effects have not been reported which can be ascribed to water that have meet these standards. All the water treatments of Municipal Water Supply are largely for the removal of majority of suspended solids by sand filtration, and disinfestations by chlorination.

The drinking water standards for the water supplies arranged from reclaimed sewage or reclaimed (industrial) wastewater may differ significantly from the prevailing standards. Presence of trace organic materials such as pesticides, antibiotics, industrial wastes, fecal matters and hormones will be the pollutants of these waters. Potential for bacterial and viral contaminations have not been determined accurately. Treatment designs for this new class of contaminants are still not foolproof. There are a number of good reasons to delay or not to accept the use of reclaimed sewage or any wastewater for domestic uses.

An instance of drought-forced recycle use of trickling filter (secondary treated) effluent through a 17-day retention pond directly to a softening plant intake in Chanute – Kansas U S A has received wide spread attention[25]. Although no health problems were traced to this direct recycled use, poor acceptance due to foaming and a pale yellow colour in the tap water was observed. Soluble materials were not removed from this secondary treated water obtained from their wastewater.

Despite the any health problems not reported from Chanute in the past, with rather crude and incomplete treatment technique, it appears that the most acceptable approach at the present is to use reclaimed sewage for many or any non-potable uses, where it is unquestionable for adequate quality. This will increase the availability of fresh water for drinking and other domestic supply, and increase the acceptability of reclaimed water for general non-potable uses among the public. Indirect use of reclaimed wastewater through ground water recharging is an acceptable idea to the public. Recycled use of wastewater by either intentional or unintentional effluent discharge to surface water used illegally by industries and other communities is not objected till it creates dispute. All this practices will continue till adequate treatment designs are accepted by the public and reuse itself becomes safe and accepted, and economically attractive.

4.2.4 Recreational use.

Any use of water not defined as Agricultural use, Industrial use or Domestic use can be classified as Recreational use, - if it is not used for fire fighting or medical uses. There are many uses of water that may differ in opinion as the class of use. Why seeing large quantity of water surrounded by trees is pleasant? Why showering in the rain, touching the water coming out from a pump in the farm, swimming in the rivers or swimming bath, and boating is pleasant? How much water is consumed in viewing a fall? All these uses are recreational uses, and it is difficult to define as to why it is done or how much water is consumed for it. What category can be assigned to water used for watering the kitchen garden of a house? Is it an agricultural use? or Domestic use? or recreational use? Vegetables or flowers or fruits produced in a garden of a house are not accounted as agricultural produces. The products are used in the house or gifted to anybody without any excepted return or account. Use of such products is very much enjoyable by the producer and the user but not paid for it. Why such activities are done with water and around water? All such activities can be classified as recreational use of water.

When others were limited to the BOD, Suspended Solids, and sometimes the Turbidity of effluents discharged into water-bodies, Imhoff and Fair classified waters as follows[26].

TABLE 4.2

Class	Use	Standard
A	Drinking Water, after chlorination	Without filtration, bacterial count less than 50 B.coli. per 100 c.c.
B	**Bathing, shell-fish Culture and Recreational use**	**No visible sewage matter, Bacterial count less than 100B.coli. per 100 c.c.**
C	Fishing	Dissolved oxygen not less than3 ppm, and preferably 5 ppm. Carbon dioxide not more than 40 ppm, and preferably not more than 20 ppm.
D	Industrial use and Irrigation use	Absence of nuisance, odors and unsightly suspended Floating matters. Dissolve oxygen present.

The recreational facilities for bathing, boating and fishing furnished by our natural streams should be preserved, even though no monetary value can be placed on them. Public sympathy and support for sewage treatment can be secured in the hope of preserving recreational resources and securing the expectations of protecting health. Among the bacterial criteria for the quality of water at bathing and boating places proposed, which provides, in effect, that coli-aerogenes index of water in a safe area should not exceed an average of 100 per 100 c.c..

Recreational use of water must be aesthetically acceptable, must not contain substances that are toxic upon ingestion, or irritating the skin and must be free from pathogenic organisms, particularly for the uses in which water used comes in body contact. This includes water sports including swimming, fishing and other water sports. Limits of pH, turbidity, color, odor and specific ions, if required, can be defined for all but health related conditions.

The Santee County, California has proved the suitability of reclaimed wastewater for recreational use[27]. Treated wastewater is the principal supply for a series of recreational lakes. State health officer granted the permission to allow establishment of swimming program during the summer of 1965. The subsequent success of swimming program demonstrated the ability to treat wastewater to the degree that meet public health standards and accepted by the public. In 1969 Indian Creek Reservoir in Alpine County, California was approved for all water contact sports by all local and state authorities[27]. Recreation activities include sail boating, swimming and trout fishing. The lake is filled with reclaimed wastewater from the South Tahoe Public Utility District Plant at South Lake Tahoe, California. Bacteriological tests of water delivered to this reservoir are consistently negative for coliform bacteria.

Fishing is the recreational activity where quality of water is very important. It is not possible to establish uniform quality criteria for fish because the effects of substances present in water vary species, size and age of fish, and chemical composition of the water. certain salts act synergistically while others act antagonistically. Dissolved oxygen, free carbon dioxide, ammonia and nitrogen, suspended solids, temperature etc. are the major parameters to be evaluated for the particular species of fish. Warm-water species have been successfully supported in the Santee County reservoir while rainbow trout have been supported in the South Lake Tahoe effluent reservoir. No health hazards have been related to eating fish from these reservoirs made of reclaimed effluents[27].

4.3 Targets of Reclamation Studies

The government body, and part of Public Works Department, looking after water supply and sewage is titled in Gujarat as "Gujarat State Water Supply and Sewage Board". Water supply and sewage are two ends of a system to support consumption of water by the public. Usually the sewage treatments are designed, to treat the sewage as,

(1) Protection to public health

(2) To avoid nuisance (caused by odors) and

(3) To prevent pollution of natural water sources

Sewage contains disease-producing microorganisms (and macro organisms – animal life) and chemical substances that may contaminate source of water supply, food and can produce health hazards. Ultimately all waters are returned to the nature after use, one way or the other, sewage can pollute the source of water supply. Therefore to protect the public against threat of health hazards, and to minimize the possible load on water treatment, it is essential to treat the sewage.

As a nuisance sewage may be offensive to the eye and to the nose. It is probably the greatest potential creator of sensory nuisance. Its power in this respect is out of proportion to its menace to health. The importance of the problems created by sewage is so generally recognized that the need for its proper disposal is universally conceded.

Sewage is a liability to the community producing it. There are all possibilities of considerable quantities of recoverable constituents in sewage, but like the extraction of GOLD from sea water[28], the process of recovery may be much costly than the value of recovered substances. However the cost of treatment of sewage may be partially recovered for its fertilizer value by irrigation or any other use for any other components of sewage.

It is generally impossible to reuse a wastewater completely or indefinitely. The reuse potential of treated wastewater by direct or indirect means is a method of disposal that compliments the other disposal methods. The amount of wastewater that can be reused is affected by the availability and cost of fresh water, reclamation potential of the wastewater and treatment cost of treated wastewater. It is studied from various possible sectors of reuse discussed earlier that,

- Agricultural use of reclaimed sewage (and any other wastewater) has largest use potential.
- Agricultural use of reclaimed water is an accepted , and well-practiced phenomena throughout the world.
- There is minimum chance of adverse public opinion in agricultural use of reclaimed wastewater.
- Agricultural use of reclaimed wastewater is safe considering microbiological aspects of sewage recycle.
- The second larges possible use of reclaimed sewage could be industrial application.
- Quantity of available reclaimed wastewater will be sufficient for industrial use, particularly for Bhavnagar.
- Large enough quantity of fresh water can be made available for drinking water requirements and domestic use by supplying reclaimed wastewater to the industries.

- Use of reclaimed wastewater for domestic use (for non potable uses) is not acceptable to the public of Bhavnagar aesthetically.
- Distribution of reclaimed wastewater for non-potable domestic use may require large infrastructure facilities and distribution network, costing large amounts.
- Recreational use of reclaimed wastewater is not common in our country, and particularly in our region.

Considering all this facts, it was decided to target reclamation studies principally for the agricultural uses and industrial use.

4.4 Classification of Sewage Treatments

The contaminants in wastewater can be removed by physical, chemical and biological means. The individual methods are classified as Physical Unit Operations, Chemical Unit Processes and Biological Unit Processes. Although these operations and processes occur in a variety of combinations in treatment plants, each one is studied separately in many cases.

Physical Unit Operations.

Treatment methods in which the application of physical forces predominates are known as Physical Unit Operations. Most of these methods evolved directly from man's observations of nature, they were the first to be used for wastewater and sewage treatment. Screening, Mixing, Sedimentation, Flotation, and filtration are typical unit operations.

Chemical Unit Processes.

The treatment methods in which the removal or conversion of contaminants is brought about by chemical reactions or by the addition of chemicals are known as Chemical Unit Processes. Precipitation, adsorption and disinfections by chlorination are the most common examples of chemical unit processes used in wastewater treatment. For example, in chemical precipitation, treatment is accomplished by producing precipitates that will settle down and can be removed. In most cases, the settled precipitates will contain both, the constituent that may have reacted with the added chemical, and the constituents that were swept out of the wastewater as the settled precipitates.

Biological Unit Processes.

Treatment methods in which the removal of contaminants is brought about by biological activity are known as Biological Unit Processes. In most of the cases actual work is done by the activity of microorganisms or enzymes secreted by such living organisms. Biological Treatment is used primarily to remove biodegradable dissolved or colloidal organic substances. Principally these organic substances are either converted into gases that can escape to the atmosphere – for example as carbon dioxide, or enter the biological cell (as food) that can be removed by settling with the microorganisms or biological cells. Biological treatment can remove Nitrogen and Phosphorous from the wastewater.

In practice Sewage Treatments are classified as[29],

Primary Treatments,

Secondary Treatments and

Tertiary or Advanced or Polishing Treatments.

From the time, water being used, physical, chemical and biological processes is at work breaking down organic matters and transforming other constituents in other substances. A primary treatment process is one in which fresh, raw or untreated sewage is influent. Primary treatments are comparatively simple, physical in most cases and less expensive in operation, and do not require much skill. Depending upon quality of sewage, and disposal methods suitable and applicable, the primary treatment are used to remove the floating materials, settleable solids and most but not all solids. It consists of any one or more of,

Grit removal,

Screening

Sedimentation (or separation of suspended solids and turbidity)

Sludge digestion or disposal.

In most of the cases primary treatment consist of screening, grit removal and oil and grease removal.

In secondary treatment, biological and chemical processes are used to remove most of the organic matter. Activated sludge process, with extended aeration is considered as secondary treatment now a day. It can be achieved without primary settling in many cases. The system is aerobic and BOD removal to very high degree can be obtained through simple system. Some times chlorination of sewage is done at the end of treatment as a part of secondary treatment to render the sewage free from microorganisms, to use it for some specific uses.

In tertiary treatment additional combinations of unit operations and unit processes are employed to remove other – soluble or refractory constituents such as Nitrogen, and Phosphorous, which are not removed by secondary treatment. The tertiary treatments usually consists of,

Chemical coagulation,

Flocculation,

Sedimentation,

Filtration,

Activated Carbon Treatment

Chlorination and

Softening treatments according to the targeted end-use of the treated sewage.

A more rational approach is first to establish the degree of contaminants removal required before the wastewater can be reused, or discharged to the environment. The required unit operations and unit processes then can be grouped together on fundamental considerations. Unit operations, Unit processes or methods applicable for the removal of the contaminants from wastewaters of major interest are tabulated below.

TABLE 4.3

Unit Operations, Unit Processes and Treatment Systems Applicable to remove the Major Contaminants of Wastewater[30].

Contaminant	Unit Operation, or Unit Process or System Applicable
o **Suspended Solids**	
	▪ Screening
	▪ Sedimentation
	▪ Filtration
	▪ Flotation
	▪ Chemical – polymer addition
	▪ Coagulation followed by Sedimentation
	▪ Land treatment Systems
o **Biodegradable Organics**	
	▪ Activated Sludge process
	▪ Trickling Filters
	▪ Fixed Film: Rotating Biological Contactors
	▪ Intermittent Sand Filtration
	▪ Land treatment Systems

- **Pathogens**
  - Chlorination
  - Ozonation
  - Hypochlorination
  - Land treatment Systems

- **Nutrients Removal Nitrogen**
  - Suspended Growth Nitrification and
  - Denitrification
  - Fixed Film Nitrification and Denitrification
  - Ammonia Stripping
  - Breakpoint Chlorination
  - Land treatment Systems

- **Nutrients Removal Phosphorous**
  - Metal Salt Precipitation
  - Lime Coagulation followed by
  - Sedimentation
  - Biological Phosphorous removal
  - Land treatment Systems

- **Refractory Organics**
  - Activated Carbon Adsorption
  - Tertiary Ozonation
  - Land treatment Systems

- **Heavy Metals**
  - Chemical precipitation
  - Ion Exchange
  - Land treatment Systems

- **Dissolved Inorganic Solids**
  - Ion Exchange
  - Electrodialysis
  - Reverse Osmosis

It is studied from the above information that when any other method of treatment is not application or economical for the removal of any of the contaminants, except for the Inorganic Solids, Land Treatment is the final alternative solution. Ultimately everything must be returned to The Land – The Nature – The Environment in the form that it can tolerate.

The classification according to Primary Treatment, Secondary Treatment and Tertiary Treatment, was used to define the treatment class for this studies of treatments of the sewage of Bhavnagar.

4.5 Experimental Work

Eighteen Sewage samples were treated in OUR laboratory BY US for Primary treatment, Secondary Treatment and Tertiary Treatment, one sample every month, from June 1999 to November 2000. Detailed characterization of the sample was done as a characterization study, and these results were used to evaluate the effect of treatment efficiency. Important or targeted effects were studied after tertiary treatment.

4.5.1 Methodology of Experiments

(A) Primary Treatment.

Sample of fresh sewage Disposal Plant - Anandnagar, and as a primary treatment it was allowed to settle for 1 hour for grit removal and removal of settle able solids, without addition of any chemical to help sedimentation. The sample was filtered through course nylon net and subjected to Secondary Treatment.

(B) Secondary Treatment

15 liters of primary treated sample was placed in a Activated Sludge Process Reactor, converted from an aquarium, fitted with an aerator (used for aeration in aquarium). The sample was seeded with 3 % activated sludge, composed of cow dung. Samples were collected initially for six months (six samples) for tertiary treatment after aeration of 6 hours, 12 hours and 24 hours respectively. It was observed that the aeration of six hours was almost sufficient and no remarkable difference compared to samples with extended aeration of 12 hours and 24 hours was observed. Therefore aeration for 6 hours was used for all the experiments. The samples were allowed to settle for 30 minutes, and supernatant liquor was used for the tertiary treatment.

(C) Tertiary Treatment

Samples from secondary treatment were subjected for chemical coagulation using (1) Alum, (2) Lime and (3) Lime followed by Carbon dioxide purging as tertiary treatment. The idea behind Carbon dioxide purging was to precipitate any residual lime remained in the solution after treatment as Carbonate of lime. The treated samples were filtered through nylon filter cloth and analyzed for the evaluation of treatment effects.

The results are tabulated under Table No. **Treatment 01** to Table No. **Treatment 18,** at the end of the chapter. Graphical presentation of results is made after the tables of results.

4.6 Observations and Remarks.

It is observed from the results of Treatability studies that pH of the sewage is not affected by primary treatment or secondary treatment. An increase in pH is observed by lime treatment. As CO2 treatment to the lime treated sewage removes most of the lime and magnesium, pH comes down to acceptable level.

Primary and Secondary treatment has some effect on T D S. some of the dissolved solids are converted into insoluble form or get precipitated during this treatments. Addition of alum or lime has no remarkable effect on T D S. Only part of the soluble salts is removed by this treatment. As CO2 treatment after lime treatment removes most of the Ca and Mg salt as carbonate, remarkable decrease in T D S is observed. This is reflected in the results as decrease in the hardness of the sewage samples.

Effect on Chloride ions of any of the treatment is not remarkable. It remains almost unchanged. Sulfate ions are not affected by primary treatment or secondary treatment. Increase is observed by alum treatment in the concentration of sulfate ions. Lime treatment and subsequent CO2 treatment removes sulfate ions remarkably.

Most important of all treatments, reduction in C O D of sewage is observed by secondary treatment that is activated sludge process. This process is process of aerobic digestion or oxidation in presence on microbial organisms for the removal of organic substances. It is observed from the results that up to about 98 % reduction in C O D can be achieved by combining activated sludge process with some polishing treatment.

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$$S A R = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

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TABLE 01

SEWAGE TREATABILITY STUDIES

Date of Sample	18-Jul-99	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.31	7.76	7.25	8.15	7.22
T D S	1750	1610	1350	1380	880
Hardness	398	371	358	499	154
Ca	80	76	74	124	42
Mg	48.1	44	42	46	12
Cl	420	410	413	408	398
SO4	95	94	183	65	65
D O	0.3	3.2	2.8	2.6	0.3
C O D	737	45	32	18	16
B O D	438	<10	<10	<10	<10

TABLE 02

SEWAGE TREATABILITY STUDIES

Date of Sample	15-Aug-99	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.74	7.86	7.36	8.24	7.34
T D S	1910	1840	1580	1470	1020
Hardness	396	391	390	458	143
Ca	61.8	62	63	104	35
Mg	56.9	57	57	48	14
Cl	499	485	510	502	513
SO4	112	111	214	73	62
D O	0.3	3.5	3.3	2.4	0.3
C O D	842	52	34	17	15
B O D	368	<10	<10	<10	<10

TABLE 03

SEWAGE TREATABILITY STUDIES

Date of Sample	12-Sep-99	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.32	7.86	7.36	8.24	7.34
T D S	1660	1600	1370	1350	890
Hardness	350	330	332	453	142
Ca	60.8	62	60	102	34
Mg	48.1	43	45	48	14
Cl	422	418	432	428	428
SO4	95	96	204	68	62
D O	0.3	3.6	3.4	2.6	0.3
C O D	648	40	27	13	12
B O D	480	<10	<10	<10	<10

TABLE 04

SEWAGE TREATABILITY STUDIES

Date of Sample	10-Oct-99	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.86	7.86	7.24	8.34	7.26
T D S	1490	1430	1180	1160	760
Hardness	318	314	314	416	131
Ca	58.4	56	57	98	33
Mg	41.8	42	42	41	12
Cl	368	372	366	368	371
SO4	83	82	176	59	54
D O	0.3	4.2	3.8	2.4	0.2
C O D	847	52	34	17	15
B O D	417	<10	<10	<10	<10

TABLE 05

SEWAGE TREATABILITY STUDIES

Date of Sample	7-Nov-99	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offoncive	Tolerable	Tolerable	not specific	not specific
pH	7.64	7.84	7.24	8.54	7.18
T D S	1810	1430	1550	1470	990
Hardness	374	375	374	477	149
Ca	62.4	63	63	104	35
Mg	53	53	53	53	15
Cl	463	462	468	458	461
SO4	105	98	206	62	56
D O	0.3	3.8	3.6	2.8	0.3
C O D	1035	63	41	21	19
B O D	436	<10	<10	<10	<10

TABLE 06

SEWAGE TREATABILITY STUDIES

Date of Sample	5-Dec-99	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.58	7.42	7.38	8.42	7.21
T D S	1890	1490	1600	1530	1030
Hardness	400	400	374	477	149
Ca	68	68	63	104	35
Mg	55.9	56	53	53	15
Cl	491	491	503	495	496
SO4	110	99	204	62	57
D O	0.3	3.6	2.8	1.6	0.3
C O D	967	59	39	19	18
B O D	337	<10	<10	<10	<10

TABLE 07

SEWAGE TREATABILITY STUDIES

Date of Sample	30-Jan-00	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.42	7.62	7.26	8.42	7.19
T D S	1550	1230	1320	1290	820
Hardness	352	352	343	452	143
Ca	72	72	69	113	38
Mg	41.8	42	42	42	12
Cl	366	365	366	364	364
SO4	83	86	183	54	50
D O	0.3	3.2	2.4	1.2	0.3
C O D	1146	70	45	23	21
B O D	482	<10	not analyzed	not analyzed	not analyzed

TABLE 08

SEWAGE TREATABILITY STUDIES

Date of Sample	27-Feb-00	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.74	7.68	7.46	8.24	7.21
T D S	1830	1440	1440	1430	940
Hardness	390	391	392	529	166
Ca	67.2	68	68	122	41
Mg	54	54	54	54	15
Cl	473	468	476	462	468
SO4	107	106	201	67	61
D O	0.3	2.8	2.6	2.4	0.3
C O D	980	60	39	20	18
B O D	352	<10	<10	<10	<10

TABLE 09

SEWAGE TREATABILITY STUDIES

Date of Sample	26-Mar-00	Secondary Treated sewage	Tertiary treatment		
Parameter	Raw Sewage		Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.61	7.66	7.36	8.49	7.32
T D S	1620	1420	1240	1200	780
Hardness	358	356	357	456	144
Ca	72.8	72	73	113	38
Mg	42.8	43	42	42	12
Cl	377	382	364	384	384
SO4	85	86	198	54	49
D O	0.3	3.6	3.3	2.1	0.3
C O D	1070	67	43	22	22
B O D	392	<10	<10	<10	<10

TABLE 10

SEWAGE TREATABILITY STUDIES

Date of Sample	23-Apr-00	Secondary Treated sewage	Tertiary treatment		
Parameter	Raw Sewage		Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.31	7.56	7.36	8.36	7.21
T D S	1470	1310	1140	1100	700
Hardness	340	349	337	431	136
Ca	72	72	69	109	36
Mg	38.9	41	40	39	11
Cl	340	340	338	338	338
SO4	77	77	172	49	44
D O	0.3	3.9	3.6	2.2	0.2
C O D	1247	78	50	26	22
B O D	373	<10	<10	<10	<10

TABLE 11

SEWAGE TREATABILITY STUDIES

Date of Sample	21-May-00	Secondary Treated sewage	Tertiary treatment		
Parameter	Raw Sewage		Alum Treated	Lime Treated	Lime + CO_2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.83	7.66	7.24	8.53	7.34
T D S	1700	1480	1170	1180	760
Hardness	382	352	322	442	140
Ca	80.8	75	71	114	38
Mg	43.8	40	35	38	11
Cl	387	377	368	384	384
SO_4	86	77	174	47	43
D O	0.3	4.2	3.5	2.9	0.3
C O D	1150	73	47	24	26
B O D	462	<10	<10	<10	<10

TABLE 12

SEWAGE TREATABILITY STUDIES

Date of Sample	18-Jun-00	Secondary Treated sewage	Tertiary treatment		
Parameter	Raw Sewage		Alum Treated	Lime Treated	Lime + CO_2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.46	7.54	7.33	8.41	7.21
T D S	1750	1520	1240	1230	810
Hardness	394	362	331	441	139
Ca	78.4	73	69	108	36
Mg	48.1	44	39	42	12
Cl	420	410	400	417	417
SO_4	95	87	184	53	49
D O	0.3	3.9	3.6	3.2	0.3
C O D	1458	91	58	26	22
B O D	427	<10	<10	<10	<10

TABLE 13

SEWAGE TREATABILITY STUDIES

Date of Sample	16-Jul-00	Secondary Treated sewage	Tertiary treatment		
Parameter	Raw Sewage		Alum Treated	Lime Treated	Lime + CO_2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.73	7.86	7.35	8.42	7.18
T D S	1850	1580	1360	1320	860
Hardness	422	410	375	485	153
Ca	83.2	84	79	118	39
Mg	52	48	43	46	13
Cl	446	439	437	433	433
SO_4	103	100	197	61	56
D O	0.3	3.4	3.2	2.1	0.3
C O D	1264	79	57	19	19
B O D	364	<10	<10	<10	<10

TABLE 14

SEWAGE TREATABILITY STUDIES

Date of Sample	13-Aug-00	Secondary Treated sewage	Tertiary treatment		
Parameter	Raw Sewage		Alum Treated	Lime Treated	Lime + CO_2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.61	7.68	7.28	8.67	7.32
T D S	1630	1410	1270	1240	810
Hardness	358	375	344	454	143
Ca	67.2	79	75	114	38
Mg	46.2	43	38	41	12
Cl	401	412	410	406	406
SO_4	91	97	184	59	53
D O	0.3	3.6	3.3	1.8	0.3
C O D	679	42	34	<10	<10
B O D	479	<10	<10	Not Analyzed	Not Analyzed

TABLE 15

SEWAGE TREATABILITY STUDIES

Date of Sample	10-Sep-00	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.48	7.68	7.28	8.67	7.32
T D S	1710	1470	1270	1250	820
Hardness	366	383	351	461	145
Ca	68.8	81	76	115	38
Mg	47.2	44	39	42	12
Cl	412	414	411	407	407
SO4	93	93	180	57	50
D O	0.2	3.6	3.3	1.8	0.3
C O D	737	46	37	16	16
B O D	439	<10	<10	<10	<10

TABLE 16

SEWAGE TREATABILITY STUDIES

Date of Sample	8-Oct-00	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.83	7.68	7.38	8.54	7.21
T D S	1880	1600	1410	1380	920
Hardness	402	416	381	491	154
Ca	72	84	79	118	39
Mg	54	50	45	48	14
Cl	474	479	475	471	471
SO4	107	105	192	64	57
D O	0.3	3.6	3.3	1.8	0.3
C O D	1079	67	57	Not Analyzed	Not Analyzed
B O D	472	Not analyzed	Not Analyzed	Not Analyzed	Not Analyzed

TABLE 17

SEWAGE TREATABILITY STUDIES

Date of Sample	5-Nov-00	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.56	7.72	7.34	8.59	7.22
T D S	1720	1480	1330	1290	850
Hardness	378	400	366	476	150
Ca	70.4	82	78	117	39
Mg	49.1	47	42	45	13
Cl	429	431	429	425	425
SO4	97	96	193	59	58
D O	0.3	3.8	3.2	2.1	0.3
C O D	972	61	46	17	17
B O D	356	<10	<10	<10	<10

TABLE 18

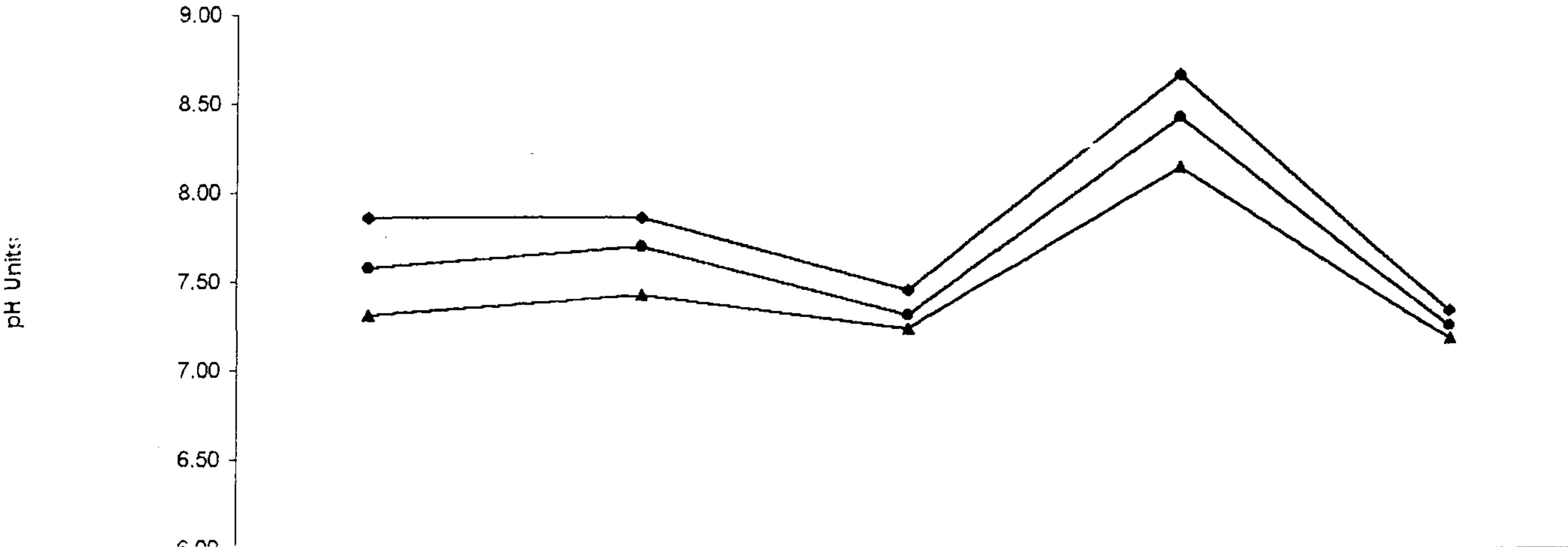
SEWAGE TREATABILITY STUDIES

Date of Sample	3-Dec-00	Secondary	Tertiary treatment		
Parameter	Raw Sewage	Treated sewage	Alum Treated	Lime Treated	Lime + CO2 Treated
Color	smokey	No change	No change	Clear	Clear
Odor	Offencive	Tolerable	Tolerable	not specific	not specific
pH	7.39	7.66	7.26	8.42	7.24
T D S	1710	1470	1300	1260	800
Hardness	382	403	370	480	152
Ca	76.8	88	83	122	41
Mg	46.2	44	39	42	12
Cl	405	404	402	398	398
SO4	91	91	188	55	42
D O	0.3	3.7	3.6	2.5	0.3
C O D	1130	102	71	21	21
B O D	483	<10	<10	<10	<10

Effect of Treatment on pH

Sr.No.	DATE OF SAMPLE	RAW SEWAGE	SECONDARY TREATED SEWAGE	Tertiary Treatment		
				ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
1	18-Jul-99	7.31	7.76	7.26	8.15	7.22
2	15-Aug-99	7.74	7.86	7.36	8.24	7.34
3	12-Sep-99	7.32	7.86	7.36	8.24	7.34
4	10-Oct-99	7.86	7.86	7.24	8.34	7.26
5	07-Nov-99	7.64	7.84	7.24	8.54	7.18
6	05-Dec-99	7.58	7.42	7.38	8.42	7.21
7	30-Jan-00	7.42	7.62	7.26	8.42	7.19
8	27-Feb-00	7.74	7.68	7.46	8.24	7.21
9	26-Mar-00	7.61	7.66	7.36	8.49	7.32
10	23-Apr-00	7.31	7.56	7.36	8.36	7.21
11	21-May-00	7.83	7.66	7.24	8.53	7.34
12	18-Jun-00	7.46	7.54	7.33	8.41	7.21
13	16-Jul-00	7.73	7.86	7.35	8.42	7.18
14	13-Aug-00	7.61	7.68	7.28	8.67	7.32
15	10-Sep-00	7.48	7.68	7.28	8.67	7.32
16	08-Oct-00	7.83	7.68	7.38	8.54	7.21
17	05-Nov-00	7.56	7.72	7.34	8.59	7.22
18	03-Dec-00	7.39	7.66	7.26	8.42	7.24
	Maximum Value	7.86	7.86	7.46	8.67	7.34
	Average Value	7.58	7.70	7.32	8.43	7.25
	Minimum Value	7.31	7.42	7.24	8.15	7.18

Effect of Treatment on pH



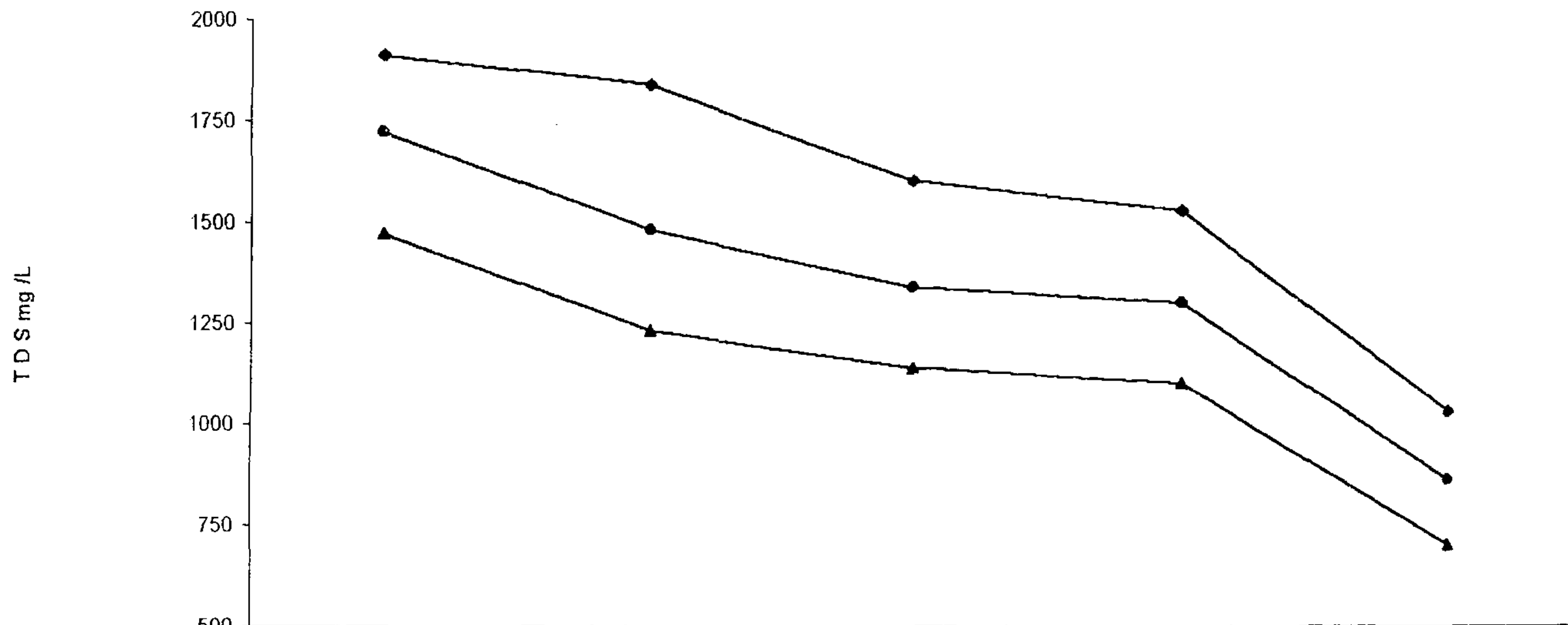
	RAW SEWAGE	SECONDARY TREATED SEWAGE	ALUM TREATMENT (Tertiary Treatment)	LIME TREATMENT (Tertiary Treatment)	LIME + CO2 TREATMENT (Tertiary Treatment)
Maximum Value	7.86	7.86	7.46	8.67	7.34
Average Value	7.58	7.70	7.32	8.43	7.25
Minimum Value	7.31	7.42	7.24	8.15	7.18

Sample Source

Effect of Treatment on T D S

Sr.No.	DATE OF SAMPLE	RAW SEWAGE	SECONDARY TREATED SEWAGE	Tertiary Treatment		
				ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
1	18-Jul-99	1750	1610	1350	1380	880
2	15-Aug-99	1910	1840	1580	1470	1020
3	12-Sep-99	1660	1600	1370	1350	890
4	10-Oct-99	1490	1430	1180	1160	760
5	07-Nov-99	1810	1430	1550	1470	990
6	05-Dec-99	1890	1490	1600	1530	1030
7	30-Jan-00	1550	1230	1320	1290	820
8	27-Feb-00	1830	1440	1440	1430	940
9	26-Mar-00	1620	1420	1240	1200	780
10	23-Apr-00	1470	1310	1140	1100	700
11	21-May-00	1700	1480	1170	1180	760
12	18-Jun-00	1750	1520	1240	1230	810
13	16-Jul-00	1850	1580	1360	1320	860
14	13-Aug-00	1630	1410	1270	1240	810
15	10-Sep-00	1710	1470	1270	1250	820
16	08-Oct-00	1880	1600	1410	1380	920
17	05-Nov-00	1720	1480	1330	1290	850
18	03-Dec-00	1710	1470	1300	1260	800
	Maximum Value	1910	1840	1600	1530	1030
	Average Value	1720	1480	1340	1300	860
	Minimum Value	1470	1230	1140	1100	700

Effect of Treatment on T D S

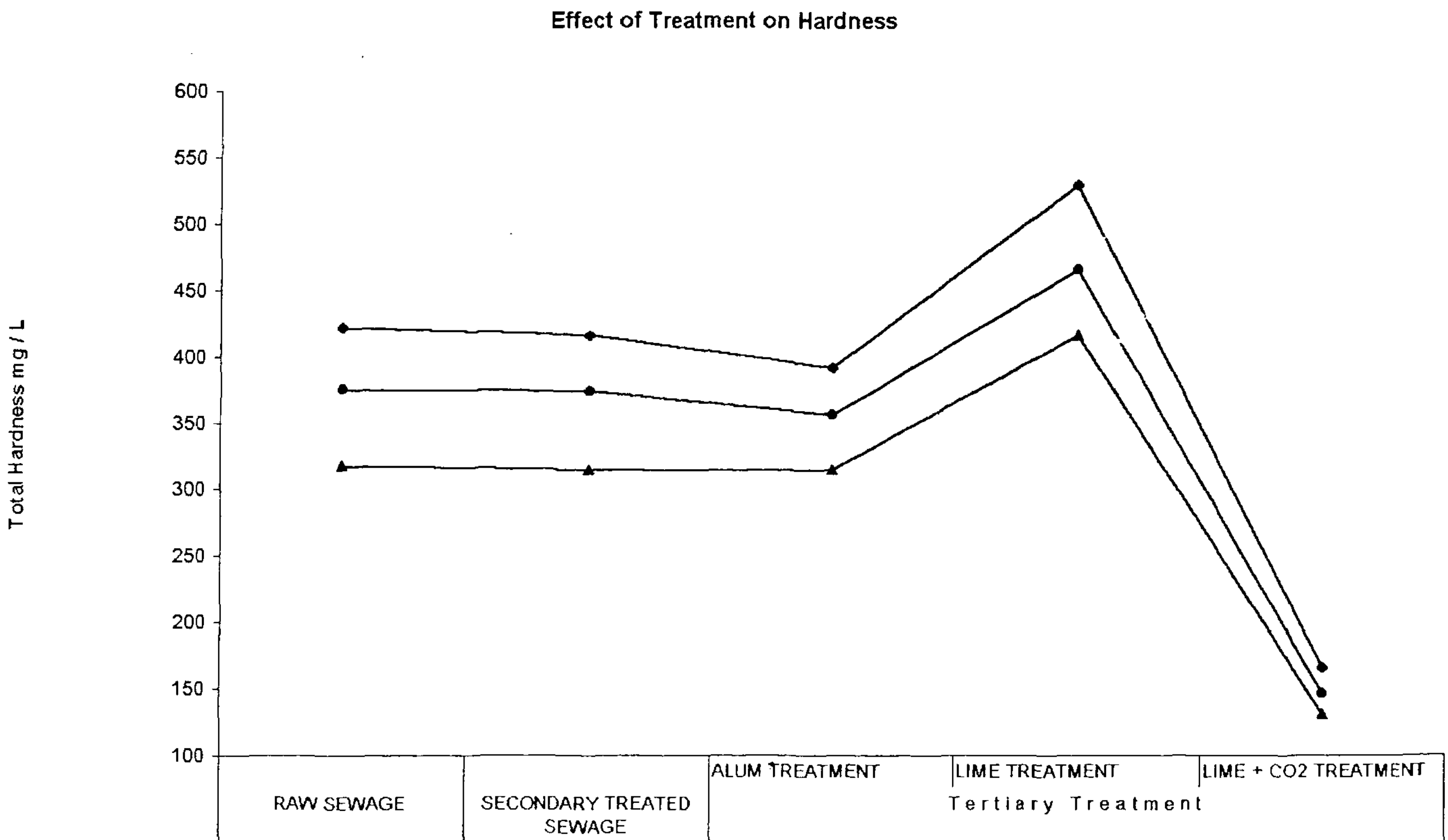


	RAW SEWAGE	SECONDARY TREATED SEWAGE	ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
			Tertiary Treatment		
Maximum Value	1910	1840	1600	1530	1030
Average Value	1720	1480	1340	1300	860
Minimum Value	1470	1230	1140	1100	700

Sample Source

Effect of Treatment on Hardness

Sr.No.	DATE OF SAMPLE	RAW SEWAGE	SECONDARY TREATED SEWAGE	Tertiary Treatment		
				ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
1	18-Jul-99	398	371	358	499	154
2	15-Aug-99	396	391	390	458	143
3	12-Sep-99	350	330	332	453	142
4	10-Oct-99	318	314	314	416	131
5	07-Nov-99	374	375	374	477	149
6	05-Dec-99	400	400	374	477	149
7	30-Jan-00	352	352	343	452	143
8	27-Feb-00	390	391	392	529	166
9	26-Mar-00	358	356	357	456	144
10	23-Apr-00	340	349	337	431	136
11	21-May-00	382	352	322	442	140
12	18-Jun-00	394	362	331	441	139
13	16-Jul-00	422	410	375	485	153
14	13-Aug-00	358	375	344	454	143
15	10-Sep-00	366	383	351	461	145
16	08-Oct-00	402	416	381	491	154
17	05-Nov-00	378	400	366	476	150
18	03-Dec-00	382	403	370	480	152
	Maximum Value	422	416	392	529	166
	Average Value	376	374	356	465	146
	Minimum Value	318	314	314	416	131



	RAW SEWAGE	SECONDARY TREATED SEWAGE	ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
Maximum Value	422	416	392	529	166
Average Value	376	374	356	465	146
Minimum Value	318	314	314	416	131

Sample Source

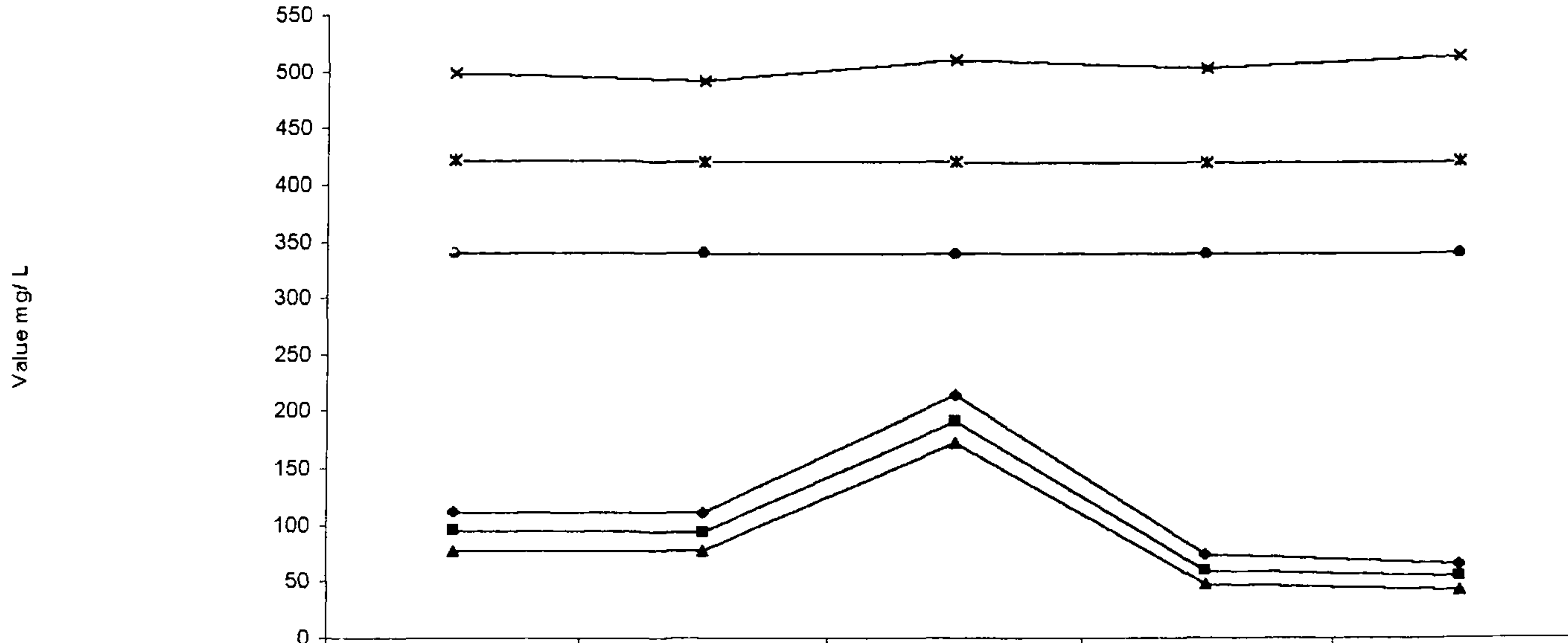
Effect of Treatment on Chloride

Sr.No.	DATE OF SAMPLE	RAW SEWAGE	SECONDARY TREATED SEWAGE	Tertiary Treatment		
				ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
1	18-Jul-99	420	410	413	408	398
2	15-Aug-99	499	485	510	502	513
3	12-Sep-99	422	418	432	428	428
4	10-Oct-99	368	372	366	368	371
5	07-Nov-99	463	462	468	458	461
6	05-Dec-99	491	491	503	495	496
7	30-Jan-00	366	365	366	364	364
8	27-Feb-00	473	468	476	462	468
9	26-Mar-00	377	382	364	384	384
10	23-Apr-00	340	340	338	338	338
11	21-May-00	387	377	368	384	384
12	18-Jun-00	420	410	400	417	417
13	16-Jul-00	446	439	437	433	433
14	13-Aug-00	401	412	410	406	406
15	10-Sep-00	412	414	411	407	407
16	08-Oct-00	474	479	475	471	471
17	05-Nov-00	429	431	429	425	425
18	03-Dec-00	405	404	402	398	398
Maximum Value Chloride		499	491	510	502	513
Average Value Chloride		422	420	420	419	420
Minimum Value Chloride		340	340	338	338	338

Effect of Treatment on Sulphate

Sr.No.	DATE OF SAMPLE	RAW SEWAGE	SECONDARY TREATED SEWAGE	Tertiary Treatment		
				ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
1	18-Jul-99	95	94	183	65	65
2	15-Aug-99	112	111	214	73	62
3	12-Sep-99	95	96	204	68	62
4	10-Oct-99	83	82	176	59	54
5	07-Nov-99	105	98	206	62	56
6	05-Dec-99	110	99	204	62	57
7	30-Jan-00	83	86	183	54	50
8	27-Feb-00	107	106	201	67	61
9	26-Mar-00	84	86	198	54	49
10	23-Apr-00	77	77	172	49	44
11	21-May-00	86	77	174	47	43
12	18-Jun-00	95	87	184	53	49
13	16-Jul-00	103	101	198	61	56
14	13-Aug-00	91	97	184	59	53
15	10-Sep-00	93	93	180	57	50
16	08-Oct-00	107	105	192	64	57
17	05-Nov-00	97	96	193	59	58
18	03-Dec-00	91	91	188	55	42
Maximum Value Sulphate		112	111	214	73	65
Average Value Sulphate		95	93	191	59	54
Minimum Value Sulphate		77	77	172	47	42
Maximum Value Chloride		499	491	510	502	513
Average Value Chloride		422	420	420	419	420
Minimum Value Chloride		340	340	338	338	338

Effect of Treatment on Chlorides and Sulphates



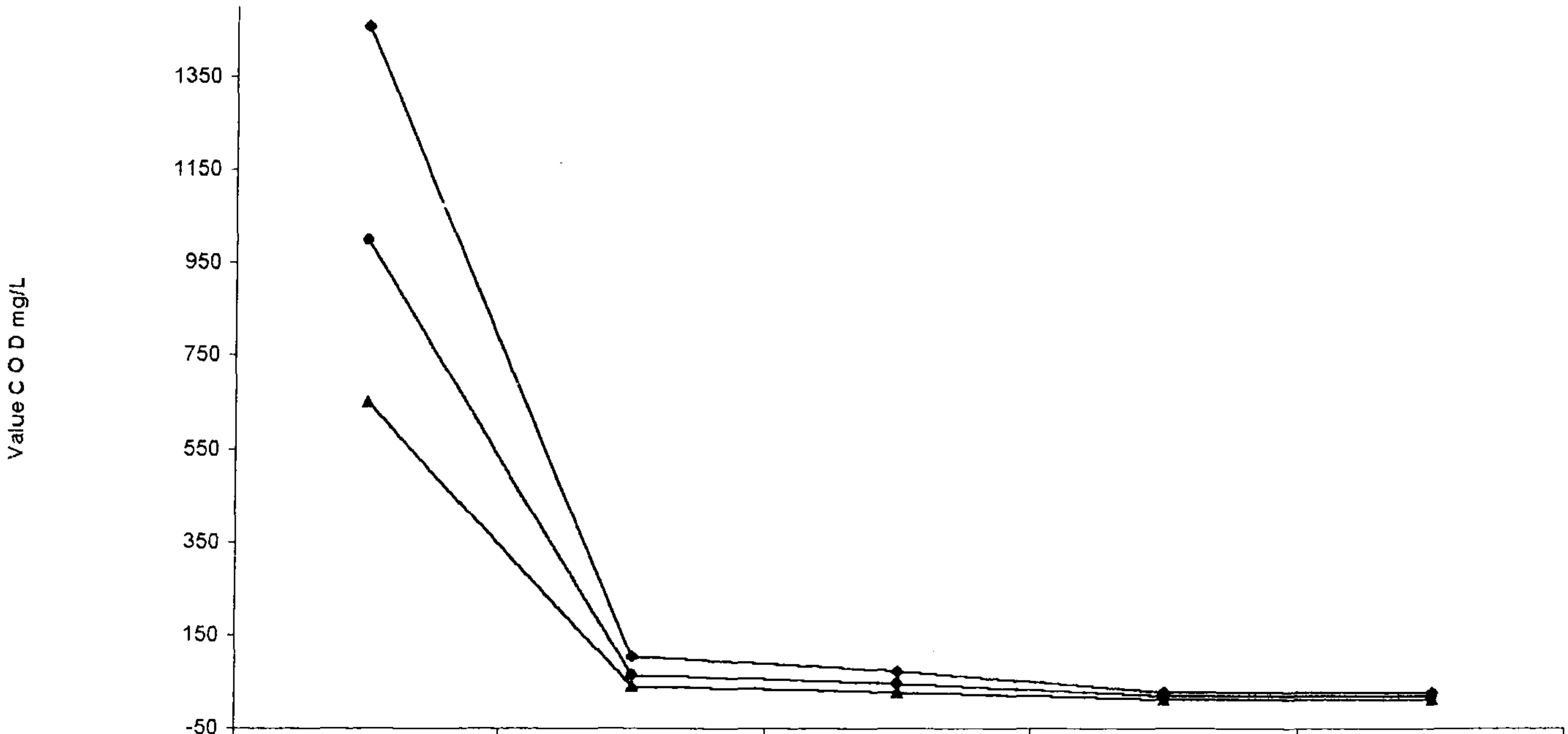
	RAW SEWAGE	SECONDARY TREATED SEWAGE	ALUM TREATMENT (Tertiary Treatment)	LIME TREATMENT (Tertiary Treatment)	LIME + CO2 TREATMENT (Tertiary Treatment)
Maximum Value Sulphate	112	111	214	73	65
Average Value Sulphate	95	93	191	59	54
Minimum Value Sulphate	77	77	172	47	42
Maximum Value Chloride	499	491	510	502	513
Minimum Value Chloride	422	420	420	419	420
Minimum Value Chloride	340	340	338	338	338

Source of Sample

Effect of Treatment on C O D

Sr.No.	DATE OF SAMPLE	RAW SEWAGE	SECONDARY TREATED SEWAGE	Tertiary Treatment		
				ALUM TREATMENT	LIME TREATMENT	LIME + CO2 TREATMENT
1	18-Jul-99	737	45	32	18	16
2	15-Aug-99	842	52	34	17	15
3	12-Sep-99	648	40	27	13	12
4	10-Oct-99	847	52	34	17	15
5	07-Nov-99	1035	63	41	21	19
6	05-Dec-99	967	59	39	19	18
7	30-Jan-00	1146	70	45	23	21
8	27-Feb-00	980	60	39	20	18
9	26-Mar-00	1070	67	43	22	22
10	23-Apr-00	1247	78	50	26	22
11	21-May-00	1150	73	47	24	26
12	18-Jun-00	1458	91	58	26	22
13	16-Jul-00	1264	79	57	19	19
14	13-Aug-00	679	42	34	10	10
15	10-Sep-00	737	46	37	16	16
16	08-Oct-00	1079	67	57	N A	N A
17	05-Nov-00	972	61	46	17	17
18	03-Dec-00	1130	102	71	21	21
	Maximum Value	1458	102	71	26	26
	Average Value	999	64	44	19	18
	Minimum Value	648	40	27	10	10

Effect of Treatment on C O D



	RAW SEWAGE	SECONDARY TREATED SEWAGE	ALUM TREATMENT (Tertiary Treatment)	LIME TREATMENT (Tertiary Treatment)	LIME + CO2 TREATMENT (Tertiary Treatment)
Maximum Value	1458	102	71	26	26
Average Value	999	64	44	19	18
Minimum Value	648	40	27	10	10

Source of Sample