

TREATMENT OF TEXTILE DYEING WASTE

A Thesis

By

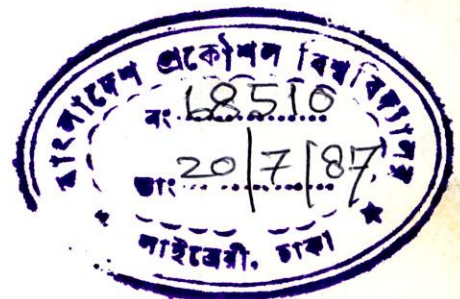
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of

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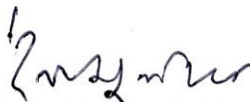
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ABSTRACT

Inoffensive disposal of industrial wastes into the surface water courses or on the land is one of the major steps of preventing environmental pollution. This work represents an attempt to evaluate the polluting effect of textile dyeing waste and to develop a suitable treatment method, using low cost materials, to prevent the pollution caused by this waste.

The physical, chemical and some of the biological characteristics of the textile dyeing effluent were determined through extensive laboratory tests. This waste is characterized by high concentration of colour imparted by the unused dye pigments and turbidity caused by the suspended fibers of yarn and the colour pigments. The chemical oxygen demand of the waste was higher than the biochemical oxygen demand signifying the presence of higher proportion of biologically nondegradable organic matters.

Physical treatment methods namely, sedimentation and sedimentation with coagulation were used to treat the effluent from textile dyeing industries. The effectiveness of aluminium alum and sodium hydroxide along with their effective pH range, in removing pollutants, were determined. Four low-cost locally available filter materials were tested to determine their

relative effectiveness in removing colour and turbidity from the effluent. Of the four materials used charcoal and burnt rice husk presented better result. Through careful examination of the results, conclusions regarding the efficiency and behaviour of different treatment methods were drawn and appropriate recommendations were made for further study.

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CHAPTER I

INTRODUCTION

1.1 GENERAL

The process of converting the grey clothes, made through weaving of the yarns, into coloured and printed clothes, almost ready for marketing, is known as dyeing. Dyeing is a very complex way of uniformly colouring the clothes, involving the use of highly complex organic dyes, which invariably contain polluting substances. Disposal of such wastes, containing mainly the unused ingredients, into surface water is often a major cause of water pollution.

The total number of textile mills in Bangladesh have increased from 53 in 1954 to 769 in 1986⁽²²⁾. The vast quantity of clothes produced in these mills are dyed and finished to make them marketable. The quantity of water required for textile dyeing varies between 1000 lit. and 1200 lit. per square yards of cloths dyed and most of the water comes out as waste. The textile dyeing wastes contain, in general, unused or partially used organic compounds, strong colour and high COD and BOD. So, the liquid wastes coming out from the textile dyeing industries have high pollution potential to cause severe environmental pollution. Disposal of these wastes into water courses or onto land, with or without prior treatment was not a problem

perhaps a decade ago. But in the recent years, the concentrated growth of these industries in certain localities have shown how the wastes from these industries can cause irreversible damage to the environment in and around the vicinity. Good water is essential for domestic as well as industrial uses. So, it is imperative that, all the sources of water are prevented from getting polluted. Therefore, the wastes coming into the ponds and rivers from these dyeing industries must be treated prior to disposal.

1.2 STATEMENT OF THE PROBLEM

(Treatment of liquid wastes prior to disposal has gained increasing importance in recent years with the increasing demand of good quality water in Bangladesh. This increase is due to the higher population growth and simultaneous increase in industries in the country. Development of a country depend on rapid industrialization. Although, zero pollution philosophy is advocated by some of the developed nations in the world, Bangladesh, being a developing nation can not afford it. Because, industrialization in Bangladesh is essential to improve the economic condition and living standard for 100 million inhabitants.)

Textile industries of Bangladesh are capable of satisfying only 30 percent of the total demand. The wastes produced during the production of grey clothes are solid wastes. But the bleaching,

dyeing and finishing of these grey clothes evolve considerable amount of liquid wastes. The average quantity of liquid wastes discharged from a textile dyeing mill in Bangladesh is about 100000 lit/hour. These liquid wastes, comprising of organic matters, toxic substances and some inorganic additives, when discharged onto land or in water courses will result in the deterioration of aesthetic condition and destruction of aquatic life, vegetation etc. Textile dyeing waste is increasingly becoming a major problem. [In Bangladesh, water flow rate in a river is considerably higher in monsoon than that in other seasons.] So, the liquid wastes discharged into the rivers during monsoon get diluted enough to be naturally degraded. [However, in dry season the problem is acute as the liquid waste may exceed the assimilation capacity of the receiving stream to cause serious water pollution. Again, the temperature of the waste is so high that it is almost impossible, even for the Thermophilic microorganisms to continue biological activities. So, biochemical treatment or bacteriological treatment of these wastes is not that effective. On the other hand, chemical treatment of these wastes is extremely costly.]

1.3 RATIONALE OF THE STUDY

Statistical survey of the textile dyeing industries shows that, in all the big cities of Bangladesh there are quite a few of the textile dyeing industry. However, the concentration

of these industries is maximum at Narayanganj and Demra in Dhaka, in Chittagong and in Khulna. These industries are mainly situated near the banks of different rivers, so that, the wastes coming out from them have direct link into the river. Disposal of industrial wastes into the Buriganga and the Sytalakkha rivers has polluted the water to such a degree that it has become unsuitable for public uses by the inhabitants living around these rivers. The wastes generated in the textile dyeing industries located at Tejgaon commercial area are disposed off in a nearby pond and marshy lands giving rise to colour and toxicity problems.

The pollution problems in Bangladesh are increasing with time due to indiscriminate disposal of sewage and industrial effluent in natural body of water. The magnitude of water pollution from textile dyeing waste has taken considerable dimension and it has become a necessity to study the pollution problems associated with textile dyeing process and to reduce the pollution potential of the waste using low cost materials.

1.4 OBJECTIVE OF THE RESEARCH

The following are the major objectives of this research work:

- 1) To assess the pollution potential of textile dyeing effluents discharged into natural water through extensive laboratory analysis.

- 2) To determine the effectiveness of commonly used chemicals like sodium hydroxide and alum in removing pollutants from textile dyeing effluent.
- 3) To compare the effectiveness of different low-cost locally available filter materials in reducing pollution potential of the effluent.
- 4) To develop the suitable treatment process in order to provide inoffensive disposal of textile dyeing wastes to prevent environmental pollution.

CHAPTER 2

LITERATURE REVIEW

2.1 ANATOMY OF DYE MOLECULES

With few exceptions all synthetic dyes are aromatic organic compounds. They may be divided into three main groups: non-ionic, anionic and cationic. The molecules of ionic (anionic or cationic) dyes are composed of two main parts, one of which is complex aryl radical. This is the colour-imparting ion. If the balance of the charge on the latter is negative then the dye is classed as anionic. On the other hand, if the balance of the charge on this ion is positive then the dye is classed as cationic.

The second part of an ionic dye molecule is an inorganic ion (or an aliphatic organic ion or, in a few cases, an aryl ion) of opposite charge to that colour-imparting aryl ion. The former is called gegen-ion and the latter the dye-ion. The function of the gegen-ion is to balance the charge on the dye-ion and to render the dye soluble in water. Almost all anionic dyes are manufactured as metallic salts. The vast majority of anionic dyes are sodium salts of sulphonic acids. Some, however, are sodium salts of carboxylic acids, uranine being a notable example. In case of cationic dyes the gegen-ion is usually the chloride ion. When dyes are used as reagents for the detection of certain ions, due consideration has to be given to the

gegen-ion of the dyes. However, unless gegen-ion itself is coloured, it has no influence upon the colour of the dye in aqueous solution. On the other hand, the dye-ion can not be replaced by another without profound changes in the nature and functioning of the dye molecule. The individual chemical, physical and tinctorial characteristics of a dye are due to its dye-ions.

The Colour Index gives the structures of about 2100 anionic dyes and classifies them variously as "acid", "basic", "direct" and "mordant" according to their manner of usage in the textile dyeing industry. About 1400 of these anionic dyes are amino acids. The remainder are wholly acid in that they have no basic side-chains.

The term "acid" dye has a special meaning in the textile dyeing industry. By definition an "acid" dye is one which dyes wool from a dyebath which contains acid. Such dyes now, however, find their main application not only for wool but for silk, polyamide, acrylic and regenerated protein fibers. They are applied from dyebaths containing sulphuric or formic or acetic acid or ammonium sulphate; sometimes from a neutral and occasionally from a slightly alkaline bath. The pH of the dyebaths may vary from 2.0 to 8.0. The "acid" dyes are also used in textile printing. They are not necessarily acid in reaction. Some basic (cationic) dyes are classified as "acid" by the

textile dyers on the account of the fact that they sometimes use them in acid solution for wool. However, all but a few dyes classed as "acid" by the textile-dyer could also be classed under that heading by the chemist since their dye-ions are negatively charged. From a standpoint of chemical constitution it is more rational to refer to these as "anionic" rather than as "acid" dyes. The textile-dyer is understandably more concerned with the manner of usage of the dye for the aesthetic colouring of fibers and fabrics than with its molecular structure and chemical constitution. The ideal dyes are apparently those which will stain proteins but not cellulose. It is not possible to find such dyes except by trial and error, which can be a time consuming process. Time can be saved, however, by restricting the experimental work in this connection to those dyes known to the textile dyer as "acid" dyes.

According to the Colour Index "direct" dyes were originally designed and marketed for the primary purpose of dyeing cellulosic fibers, such dyes having been defined as "Anionic dyes having affinity for cellulosic fibers when applied from an aqueous dyebath containing an electrolyte". Direct dyes provide the simplest means of colouring cellulosic materials as they are normally applied, in the textile dyeing industry, from a neutral or slightly alkaline dyebath, at or near boiling point, to which sodium chloride or sodium sulphate is added. All direct dyes are anionic. Whilst a few are wholly acidic the majority may be regarded as amphoteric since they possess side-chains which are basic in reaction.

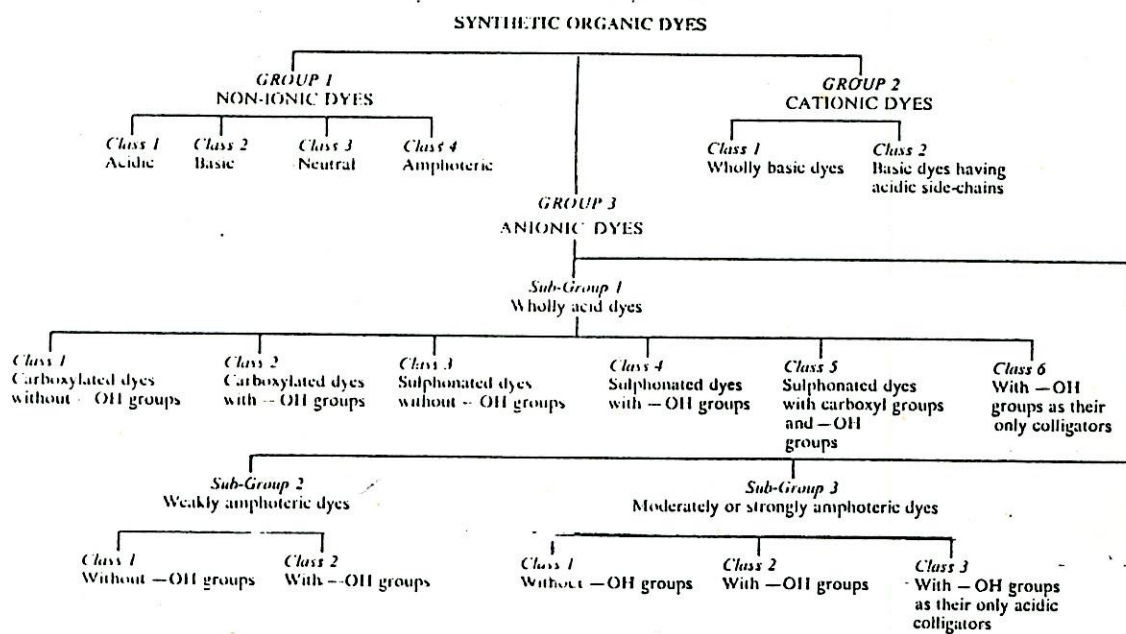
Venkatraman⁽²⁴⁾ describes "mordant" dyes as having the property of combining with metallic oxides and salts to form metallic complexes. Dyes of this class are, however, very difficult to define. The majority of these dyes are used with the aid of mordants, in the textile industry, mainly for dyeing wool, the secondary application being for the dyeing of silk and nylon and for printing cellulosic, silk and wool fabrics. Table 2.1 shows the classification of dyes⁽¹²⁾.

2.2 COLOUR AND CONSTITUTION OF DYES

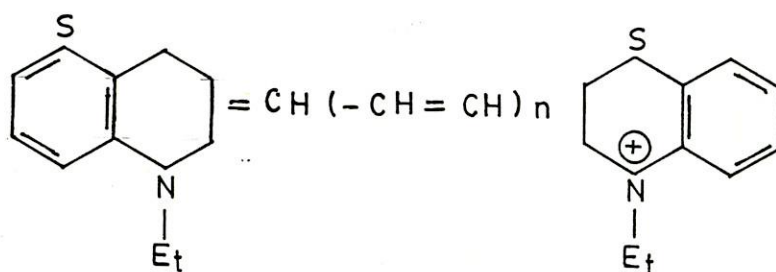
Parkin⁽¹⁴⁾ manufactured the first synthetic dye in 1857, when chemistry of dyes was not known and in fact, the constitution of Parkin's Mauveine⁽¹⁴⁾ was not established until many years later.

In 1868 Graebe and Libermann⁽¹⁴⁾ observed that all organic dyes then known were decolourised while unsaturated on reduction and they suggested that colour is associated with unsaturation (3). In 1876 Witt⁽¹⁴⁾ extended this view by pointing out that the colour of organic dyes is associated with the presence of certain groups of atoms, known as chromophores. Example of these include the nitro, nitroso, azo, ethylene and carbonyl groups, and they are generally unsaturated. In 1879 further studies in these fields pointed out that the colour of the dyes is depend by the addition of substituents, and that the effect is roughly proportional to

Table 2.1 Classification of Dye



the increase in molecular weight. In azo dyes the depth of colour increases with the length of a chain of alternating single and double bonds (called a conjugate chain). More recently Brooker and Lare⁽¹⁴⁾ found that in a series of methane dyes of general structure, as shown below, in which 'n' has the



value of 1, 2 and 3 the wavelength of absorption maxima in methanol solution are 423, 557.5 and 758 m μ (14). This indicates the increase in depth of colour of the azo dyes with the length of the chain.

2.3 DYEING PROCESS

The textile industries use fibers which can be classified broadly into four groups: cotton, wool, regenerated fibers and synthetics. The dyeing process and chemical dyes to be used depends on the type of the fibers. The grey clothes to be dyed go through different treatment processes some of which are described below.

2.3.1 Pretreatment of the Goods

Pretreatment of the goods involve removing of top loose

fibers and slivers. Then ageing is done in order to set the twist and pre-shrink the yarn. Stain removing involves the inspection and removal of stains from the grey clothes. Finally, washing is done to do away with the wastes. This is done by using 0.5- 1 g/l of highly concentrated Hostapal CV⁽²⁵⁾ at 80-90°C and continued for 20-30 minutes then rinsed warm and cold. Ageing is done by reducing the air pressure in the ager to 0.5 atm. Then steam is injected into the vaccumn and finally the yarn is aged for 10 minutes at 80°C. Stains from the grey clothes are removed by using Hostapal WN⁽²⁵⁾ after being diluted with water in the ratio 1:1 to 1:3. In no case the stain removing agent is allowed to work over 5 hours on the grey cloth. Otherwise spotty dyeing may occur. Then the grey clothes are washed throughly with tested non-ionic detergent. Washing is carried out prior to heat-setting, because this prevents stains from being fixed.

2.3.2 Dyeing

The grey clothes, after being pretreated, are sent to the different machines namely: Jigger or Jet Dyer, for final dyeing. Polyster fibers and their blends with cellulose fibers are generally dyed by any of the following three methods:

- a) Carrier process at boiling point
- b) High temperature process (HT process)
- c) Thermosol process

a) Carrier process at boiling point:

The grey cloth after pretreatment is passed into a dyebath and treated for 10-15 minutes at 60°C with 2-6 ml/l of Remol TRF (25). The dyebath is set at pH 5-6 with acetic acid and then the Samaron dyestuff⁽²⁵⁾ is added. Then the temperature of the water in the dyebath is brought to the boiling point within 30-40 minutes. The grey clothes are dyed at the boiling temperature for 1-2 hours depending on the depth of the shade. Then they are rinsed and dried.

b) High temperature process:

In this process the dyebath is set at 50-60°C with the specified percentage of Samaron dyestuff and 0.5-1 g/l of Solegal A⁽²⁵⁾. The pH value of the water is brought to 4-5 by using 0.05-0.1 ml/l of 96% H₂SO₄. Then the dyebath is heated to a temperature of 120-130°C within 30 minutes. Dyeing at this temperature is continued for 1-1.5 hours depending on the depth of the shade.

c) Thermosol process:

This process is suitable for mixed fabrics of polyester/cellulose and also those of polyester fiber/wool. This is a continuous process. First a padding liquor is prepared by dispersing the dispersed dyestuff in water at 50°C. To increase

the stability of the padding liquor it should be adjusted to a pH of 6-7 with acetic acid, after adding any other auxiliaries required. Migration of the dyes are counter acted by the addition of 50-100 g/l of neutral alginate thickening (2%). The fixing of the dispersed dyestuff is carried out within 60 seconds at 190-210°C depending on the dyestuff and the goods. Hot air fixing stenters are generally used for this purpose. After the heat treatment and washing out of the non-fixed dyestuff and the auxiliaries, the cellulose fiber component is cross dyed in the usual way, described earlier, with suitable dyestuff.

2.4 TREATMENT OF TEXTILE DYEING WASTES

2.4.1 General

The liquid waste generated from the dyeing and printing units generally contains colour, suspended solids, BOD and COD depending upon the quantity and type of raw materials used, and process of dyeing employed. The waste generated in most of the cases does not meet the effluent quality standard requirements and need treatment for the removal of colour, BOD, COD and suspended solids prior to its disposal. The line of treatment to be suggested especially for small scale industry must be such that the industry can afford economically to install and maintain it. Costly treatment units requiring considerable amount of money will discourage the industrialists from installing

any such treatment unit. This may ultimately lead to the pollution of the water courses. At present following five ways are being employed all over the world to treat the textile dye wastes before discharging them into the environment: (i) Equalization (ii) Neutralization (iii) Proportioning (iv) Colour removal and (v) Reduction of organic oxygen demanding matter. Equalization is the process to equalize the load of nutrients impressed upon biological treatment units, which is done through subdivision of the applied waste into two or more portions. This could also be done by recirculation of effluent into the influent. Neutralization is a process usually applied to neutralize the acid wastes present in the wastewater. This usually depends on the physical characteristics of the waste and the type of chemicals to be used to neutralize the waste. The biological processes involved in removing oxygen consuming matters from textile dyeing wastes are (a) Trickling filter (b) Activated sludge process and (c) Stabilization ponds. The construction, operation and maintenance in trickling filter and activated sludge method is very high. Both processes require greater skilled attendance because of the large equipments involved. Figures 2.1 and 2.2 show the annual per capita cost and area required for various methods of sewage treatment in India⁽⁹⁾. All the methods mentioned before require considerable amount of money. As always, use of water is very important, in view of increasing water demand, it is imperative that a suitable treatment process be developed which will enable the users to have better water for use in textile dyeing and which will also

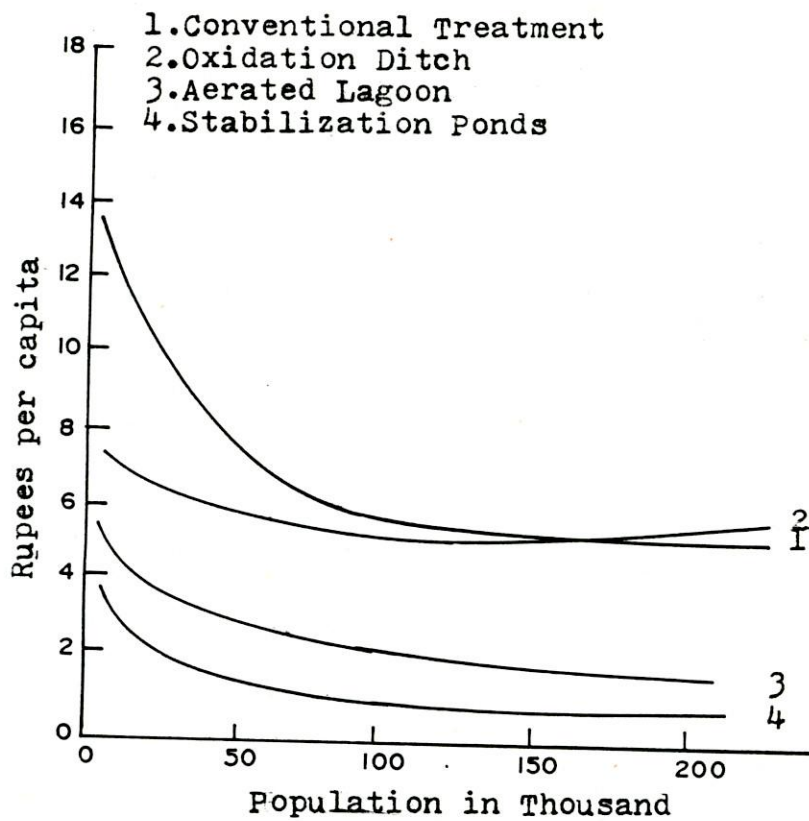


Figure 2.1 Annual expenditure per capita including maintenance, staff, power, repayment of loan, etc.

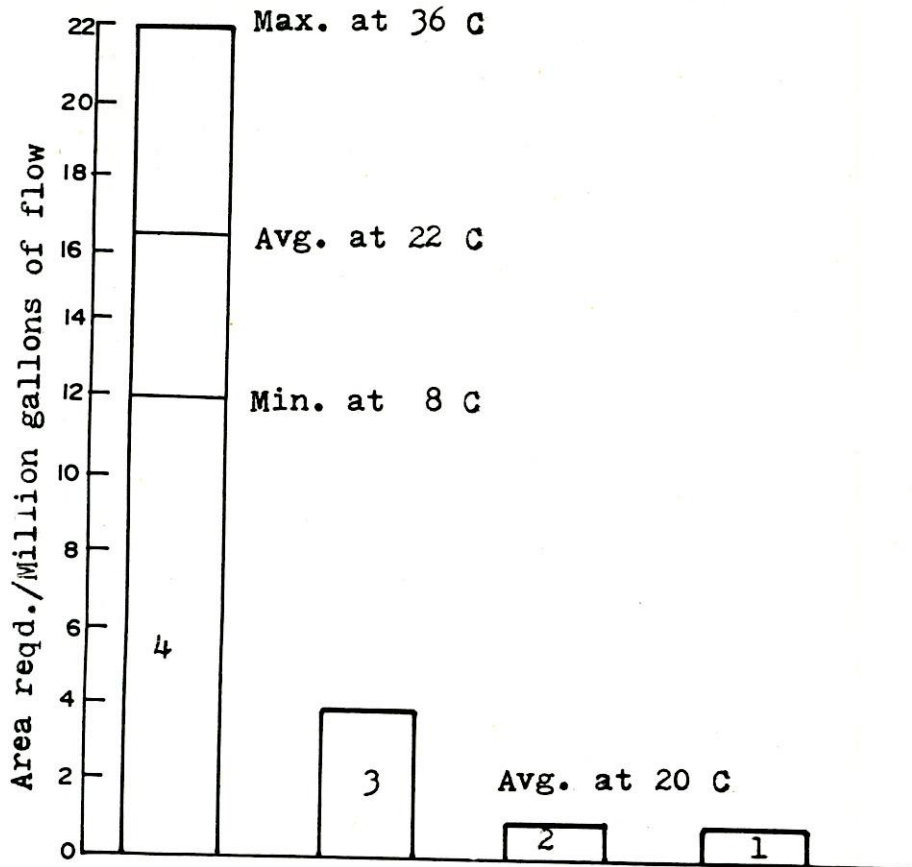


Figure 2.2 Land requirement for different types of treatment plants

require least possible money. Plain sedimentation, charge neutralization and agglomeration in flocculation sedimentation, adsorption and straining in filtration are some of the common methods for the treatments of textile dyeing wastes. Adsorption is a versatile process for the removal of colour, turbidity and suspended organic matters from the wastewater. In view of the aforementioned processes a treatment process is to be developed to make waste water from textile dyeing industries safe for disposal.

2.4.2 Sedimentation

In water and waste-water treatment, sedimentation or removal by gravitational settling of suspended particles heavier than water is perhaps the most widely used operation. When the impurities, held in suspension are separated from the fluid by the natural force alone i.e. by gravitation and natural aggregation of the settling particles, the operation is called plain sedimentation.

This operation is used for grit removal, particulate matter removal, biological floc removal and chemical floc removal. In most cases, the primary purpose is to produce a clarified effluent. On the basis of the concentration and the tendency of the particle to interact, particle settlement manner can be classified in four general ways (9,15). First type of settling refers to the sedimentation of discrete particles that settle as individual entities and there is no significant interaction with

neighbouring particles. This is also called as discrete particle settling. Second type called flocculent settling refers to a rather dilute suspension of particle that coalesce, or flocculate, during the sedimentation operation. By coalescing, the particles increase in mass and settle at a faster rate. The third type of settling occur in suspension of intermediate concentration, in which interparticle forces are sufficient to hinder the settling of neighbouring particles. Hence it is called hindered settling or zone settling. When the rising layer of settled solids reaches the interface a compression zone occurs, this is the fourth type of settling, known as compression settling. It is common to have more than one type of settling taking place at a given time during a sedimentation operation, and it is possible to have all four occurring simultaneously.

2.4.3 Flocculation Sedimentation

The removal of very fine and highly colloidal impurities from water viz., clay particles, gels and emulsions is difficult to achieve in practice by aforesaid process of sedimentation. This removal can be greatly increased by the addition of certain chemical compounds in water. When chemical compounds are added to water, an insoluble, gelatinous flocculent snow flake like precipitates are formed, which in its formation and descent through water absorb and entrain suspended and colloidal matters more rapidly than plain sedimentation^(1,8,11).

This phenomenon is known as flocculation sedimentation. Colloidal particles as a result of their smaller size have a large ratio of surface area and volume. This immense surface area indicates the predominancy of chemical phenomenon. A schematic representation of the resulting colloidal state is presented in Figure 2.3 (23). Most colloidal particles in water and wastewater are negatively charged as shown in Figure (2.3).

The stationary charged layer on the surface is surrounded by a boundlayer of water in which ions of opposite charge drawn from the bulk solution produce a rapid drop in potential. This drop within the bound water layer is called the stern potential. A more gradual drop is called zeta potential, occurs between the shear surface of the bound water layer and the point of electroneutrality in the solution.

The surface charge on colloidal particles is the major contributor to their longterm stability, particles which otherwise settle or coalesce are mutually repelled by their like charge. Coagulation is a chemical technique directed towards destabilization of colloidal particles and flocculation, in engineering usage, is a slow mixing technique which promotes the agglomeration of the destabilized particles. The resultant interaction between the colloidal particles is the sum of the Vander-Waals forces of attraction and the electrostatic forces of repulsion. At small and large distances the attractive force

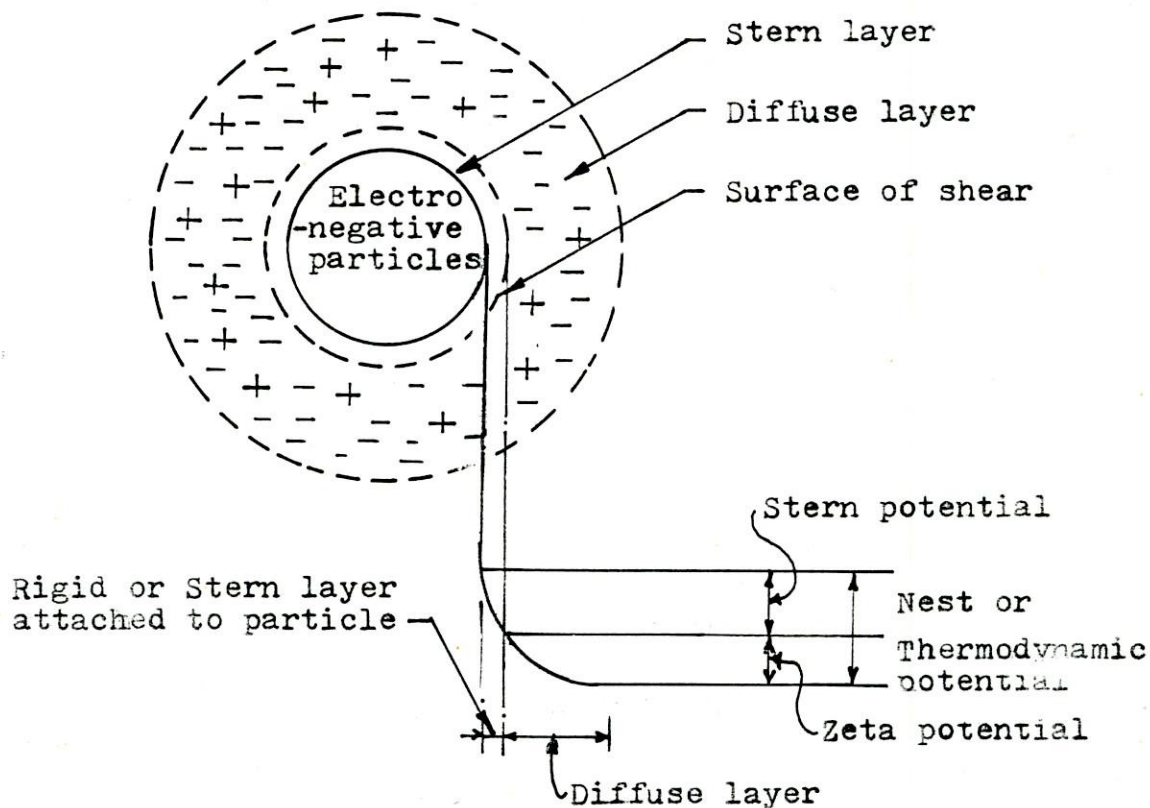


Figure 2.3 Guoy-Stern colloidal model.

between the particles predominates, which is shown in the schematic representation of interaction of colloidal particles, Figure 2.4 (1).

This is because the electrostatic forces of double layer at long distances diminishes more rapidly with increasing distances than the Vander-Waals forces and because at the small distance comparable with atomic dimensions, atomic attractive forces always predominate. Mutual interaction does not occur, however, until the distance between the particles is not so small that the penetration of the diffuse part of the double layer or the solvated layer begins to take place.

The interaction when repulsive, is responsible for the stability of the colloidal system. At intermediate distance, corresponds approximately to the thickness of the diffuse double layer, repulsive electrostatic forces may predominate. This occurs when ψ -potential (potential at the plane between diffuse and non-diffuse parts of double layer), of the interacting particles is high and of the same sign and when the diffuse layer is sufficiently thick under such condition 'energy barrier' is formed which can prevent the approach of the particles within a distance at which the attractive force predominates. Under this condition the colloid is stable and does not coagulate.

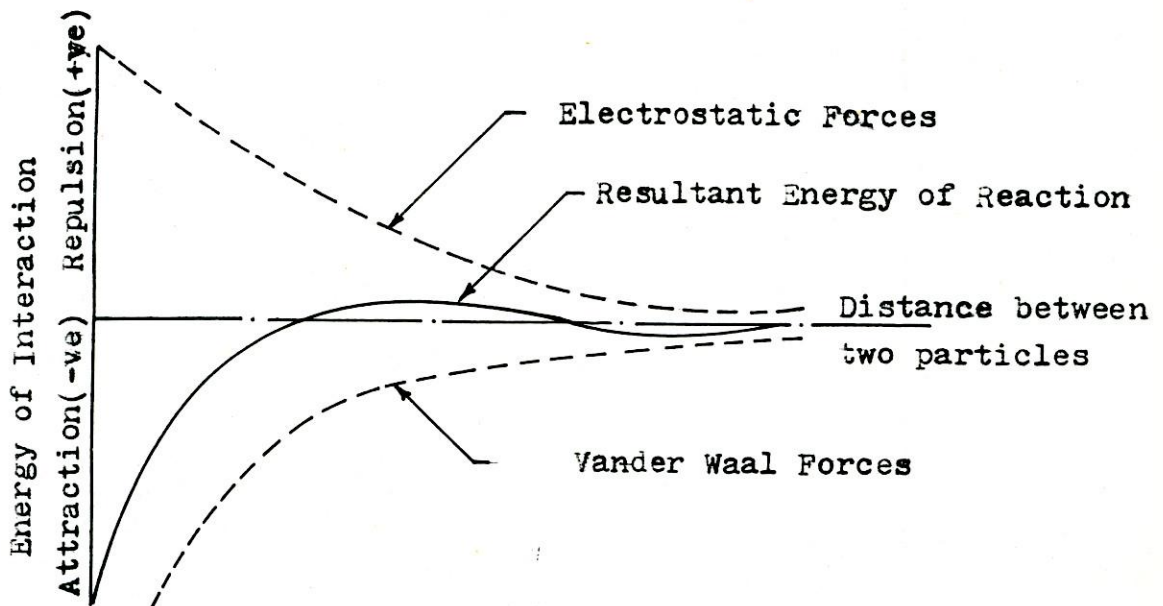


Figure 2.4 Schematic diagram of potential curves

The instability, on the other hand, is due to the Brownian motion and Vander Waals forces of attraction. The effect of the Brownian motion is that the particles are driven closer to each other to a distance at which the influence of interaction between them occurs. The instability of the colloidal system results in coagulation which occurs when the energy barrier is sufficiently reduced and the energy level of the resulting agglomerates is lower than the original agglomerates. The condition may be obtained by:

- 1) The contraction of the diffuse part of the double layer:
The contraction of the diffuse part of the double layer can be produced by increasing the ion concentration of the solution.
- 2) The reduction of the psi-potential of the colloidal particles: The psi-potential can be reduced by (a) changing the concentration of the potential determining ions and (b) adding ions that possess a charge opposite to that of the potential determining ions and that are able to replace those ions in the Helmholtz (inner nonsolved) part of the double layer⁽⁴⁾.

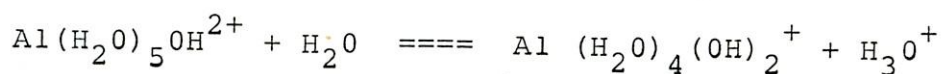
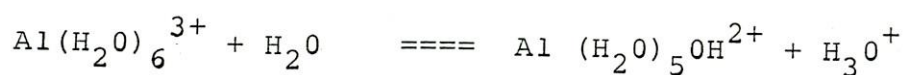
The destabilization and aggregation of colloidal system have been explained by four models:

- i) The double layer compression

- ii) Adsorption and charge neutralization
- iii) Adsorption and inter particle bridging
- iv) Enmeshment in a precipitate (sweeping flocculation).

In Practice, the colloidal destabilization is likely to be caused by more than one method. A summary of these four idealized modes as produced by Jordan has been represented in Table 2.2⁽¹⁴⁾.

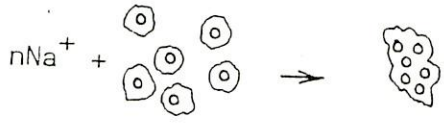
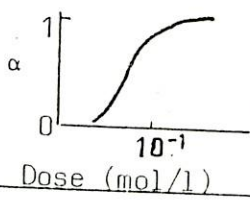
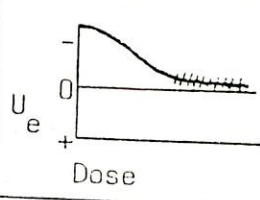
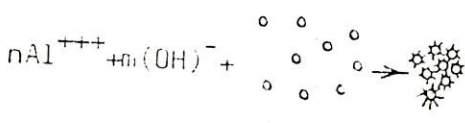
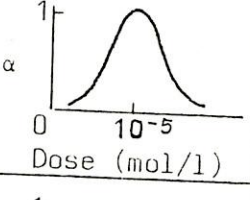
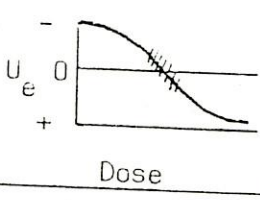
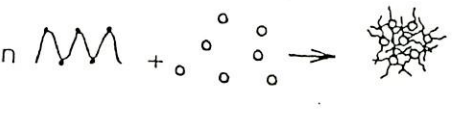
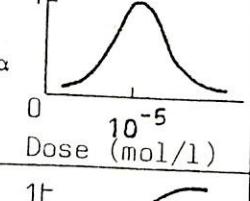
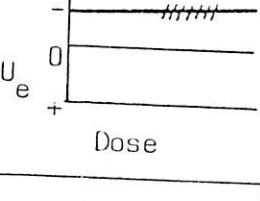
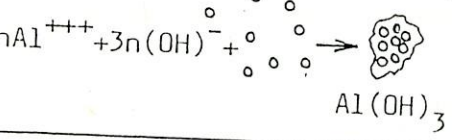
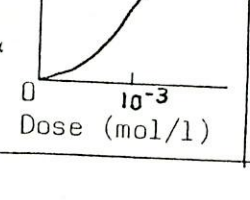
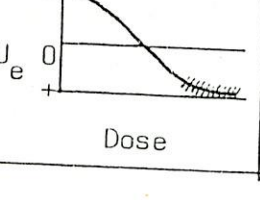
When an aluminium salt is added in a colloidal suspension a series of reaction occurs with the water (or with other ions in the suspension) a process broadly described as hydrolysis, aluminium ions, almost instantly after addition to water, enter into a series of hydrolytic reactions with water to form a series of multivalent charged hydroxide species depending on pH, these compounds may range from positive at lower pH values to negative at more basic pH values. These reactions can be represented as follows: (7,23).



This reaction can proceed until the neutral species $\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3$ or a negatively charged species $\text{Al}(\text{H}_2\text{O})_2(\text{OH})_4^-$ are formed.

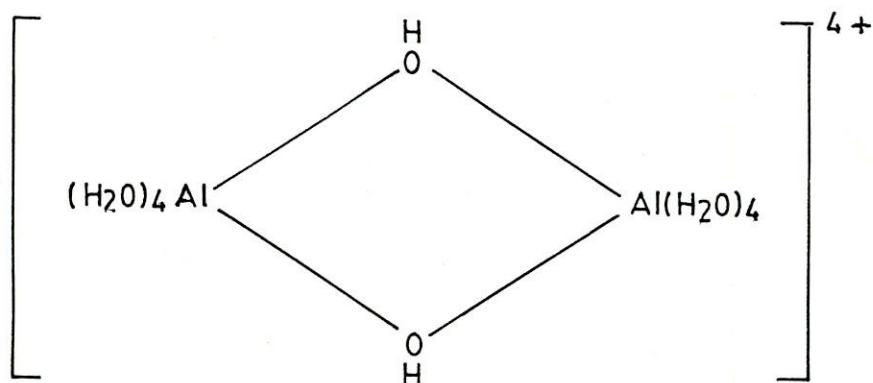
AWWA summarized that the monomeric species i.e., these compounds containing only one aluminium ion, are at best

Table 2.2 : Schematic Summary of Mechanism of Particle Destabilization

Type of Destabilization	Conceptual picture of the action	Degree of destabilization α and dose	Electrophoretic mobility (U_e) and dose	Reqd. dose for α optimum and colloidal surface conc.
Double-layer compression	nNa^+ + 			Independent
Adsorption and charge neutralization	$nAl^{+++} + m(OH)^-$ + 			Direct Proportionality
Adsorption and inter-particle bridging	n 			Direct Proportionality
Enmeshment in precipitate (sweep flocculation)	$nAl^{+++} + 3n(OH)^-$ +  $Al(OH)_3$			Inverse Relationship

* ##### Region where α approaches optimum

transient and that a second type of reaction called 'Olation' a series of polymerization occur resulting complex containing several aluminium ions bridged by two hydrozyl groups. A model of simple complex containing two aluminium ion can be illustrated as follows:



One of the significant points that emerges from the studies of these reactions is that both hydroxide and hydrogen ions are involved. From this it can be easily surmised that pH has an important role in coagulation.

Coagulation is influenced by the kind of coagulant, quantity of coagulant, concentration of colour and turbidity, time of mixing and flocculation, temperature, violence of agitation and presence of nuclei.

2.4.4 Rate of Floc Formation

Physical contact between the moving floc masses causes flocculation. This physical contact results from the velocity difference of gradients in water during gentle stirring. Shearing stresses developed along the planes in water due to this gentle stirring and considerable energy is required to overcome these stresses. According to Camp⁽⁵⁾, the rate of floc formation is proportional to the root-mean-square (RMS) velocity gradient value, which is defined as:

$$G = \sqrt{\frac{W}{\mu}} \quad (2.1)$$

where, G = root-mean-square velocity gradient in the basin
in ft. per sec. per ft. (Sec.^{-1}).

W = the mean value of the dissipation function
= the total power dissipated divided by the
volume of the chamber or conduit

μ = the absolute viscosity of water in pound-second
per square foot.

The larger the value of G the shorter will be the time required to form floc. Also a very high value of G will result in excessive shearing forces. As the floc grows larger the bonds between the floc particles become weaker. So, the excessive shearing stress will tend to shear apart the floc particles.

Therefore, there must be a definite RMS velocity beyond which the performance will gradually diminished.

The optimum value of G is considered between 25 to 65 Sec^{-1} . In case of rotating blades the peripheral speed should be between 0.6 to 2.5 ft. per sec. Usually, the velocity of water will be about one-fourth the blade velocity. Total paddle area should not exceed 15 to 20 percent of the cross-sectional area.

2.4.5 Adsorption and Filtration

Adsorption may be defined as the tendency exhibited by all solids to condense upon their surfaces a layer of any gas or liquid with which they are in contact. There are two general types of adsorption, physical adsorption and chemical adsorption. Physical adsorption is relatively non-specific and is due to the operation of weak forces of attraction between molecules. The adsorbed material may condense and form several superimposed layers on the surface of the adsorbing material. Physical adsorption is quite reversible. Chemical adsorption, on the other hand, is the result of much stronger forces, comparable with those leading to the formation of chemical compounds. Normally the adsorbed material forms a layer over the surface which is only one molecule thick. When the surface is covered by this monomolecule layer, the capacity of the adsorbent is essentially exhausted. Also, chemical adsorption is seldom reversible.

The adsorbing material generally, must be heated to higher temperatures to remove the adsorbed materials. Although there are significant differences between physical and chemical adsorption, there are instances in which it is hard to assign the adsorption definitely to one of these types.

Activated carbon is used extensively for adsorptive purposes because of its tremendous surface area in relation to mass. At a given temperature and pressure a sample of activated carbon will adsorb a definite quantity of solutes from solution. If the pressure is increased, it will adsorb more and if the pressure is decreased, it will adsorb less. This is illustrated in Figure 2.5. From the graph, it may be concluded that the quantity of substance adsorbed by a given sample of adsorbent depends upon the nature of the material and its concentration. Temperature is also a factor which is not demonstrated by the graph presented. Ferundlich⁽²⁰⁾ studied the adsorption phenomenon extensively and showed that adsorption from solutions could be expressed as empirically by the equation

$$\frac{x}{m} = k C^{1/n} \quad \text{or,} \quad \left(\frac{x}{m} \right)^n = k' C \quad (2.2)$$

Where, C is the concentration of solute after adsorption

x/m is the amount of material adsorbed per unit of the adsorbent

k and n are constants which must be evaluated for each of the solute and temperature

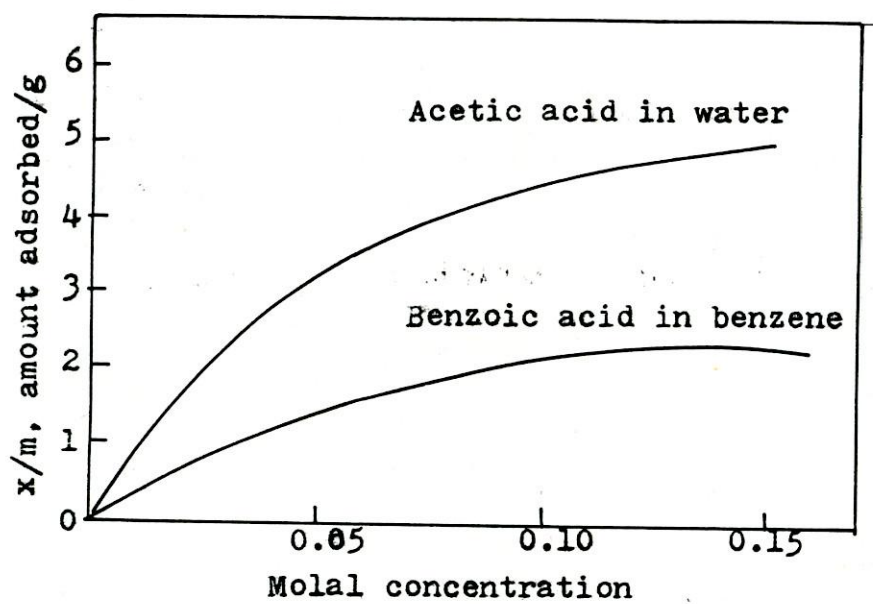


Figure 2.5 Adsorption of solutes on charcoal
(temp. & press. constant)

Filtration is one of the principal unit operations in the treatment of potable water. However, the filtration of the effluents from wastewater treatment processes is a relatively recent practice. Filtration is already a well established operation for achieving supplemental removals of suspended solids (including particulate BOD and colour) from wastewater. Filtration is accomplished by passing the wastewater to be filtered through a filter bed composed of granular materials with or without the addition of chemicals. Within the granular filter bed, the removal of the suspended solids contained in the wastewater is accomplished by a complex process involving one or more removal mechanisms, such as straining, interception, impaction, sedimentation and adsorption. The end of the filter run is reached when the suspended solids in the effluent start to increase (break through) beyond an acceptable level, or when a limiting headloss occurs across the filter bed. Ideally, both these events should occur at the same time. Once either of these condition is reached, the filter phase is terminated, and the filter must be backwashed to remove the material that has accumulated within the granular bed. The principal mechanisms that are believed to contribute to the removal of material within a granular-medium filter bed are:

- 1) Straining:
 - a) Mechanical
 - b) Chance contact

- 2) Sedimentation
- 3) Impaction
- 4) Interception
- 5) Adhesion
- 6) Chemical Adsorption: a) Bonding
 b) Chemical Interaction
- 7) Physical Adsorption: a) Electrostatic Forces
 b) Electrokinetic Forces
- 8) Flocculation
- 9) Biological Growth.

Straining can occur in two ways: Mechanical straining is the phenomenon of removal of particles larger than the pore space of the filtering medium and these particles are strained out mechanically. Particles smaller than the pore space are trapped within the filter bed through chance contact. Sedimentation occurs when particles settle on the filtering medium within the filter. Heavy particles present in the wastewater will not follow the flow streamlines and will settle on the filtering medium, this is known as Impaction. Many particles that move along in the streamline are removed when they come in contact with the surface of the filtering medium. This phenomenon is known as Interception. Flocculant particles become attached to the surface of the filtering medium as

they pass by. Because of the force of the flowing water, some material is sheared away before it becomes firmly attached and pushed deeper into the filter bed. As the bed becomes clogged, the surface shear force increase to a point at which no additional material can be removed. This way the flocculant particles are removed from wastewater through Adhesion. Once a particle has been brought in contact with other particles, either chemical or physical adsorption, or both, may be responsible for holding it there through bonding, chemical interaction, electrostatic forces, electrokinetic forces or Vander Waal forces. Large particles overtake smaller particles, join them and form still larger particles during filtration. This is known as flocculation. These particles are then removed by any of the above processes. Bacterial growth within the filter will reduce the pore volume and may enhance the removal of particles.

The most important process variables of filtration are the nature of particulate matter in the influent to be filtered, the size of the filter materials and the filtration flow-rate.

2.5 SUMMARY OF THE PREVIOUS WORKS

Nemerow (16) has reported complete removal of colour from a mixed sewage and dye-waste liquor by treatment with 200 ppm of alum at 8.3 pH, or with 140 ppm at 7.0 pH, a 63 percent

reduction in BOD was also achieved. However, he also suggested individual studies of wastes at each plant before employing chemical coagulation.

The wastes from textile dyeing units, according to Roetman⁽¹⁹⁾, can be treated on biological trickling filters after neutralization. The results obtained by Roetman with waste washings after desulferizing on 6 feet deep recirculating filters show that, for effluent operation an application of 300 lbs of BOD per-acre-foot was possible when the pH of the liquor was 10.5, and a 66% reduction in BOD could be obtained. The loading could be increased to 1050 lbs of BOD per acre foot, producing an effluent with 30 ppm of BOD.

Although textile dye wastes have high COD:BOD ratio, which makes biological treatment very difficult. It is possible, according to Rao and Datta⁽¹⁸⁾, to treat them biologically, if they are diluted with municipal wastes in a ratio of at least 1:3. However, a direct aeration, preceded by dilutions neutralization, and addition of phosphoric acid, is reported to be capable of about 85% COD reduction.

Coburn⁽¹⁰⁾ observed from the pilot plant consisting of equalization, coagulation and sedimentation that turbidity was reduced to 42.8 percent, alkalinity was reduced to 43.5 percent,

suspended solids reduced to 37.2 percent and BOD reduced to 45.2 percent with an alum dose of 213.3 g/l (1780 lb per 1000 gal.).

Shelat and Gohil⁽²¹⁾ proposed a series of treatment involving equalization, neutralization, proportioning, colour removal and reduction of organic oxygen demanding matters. From a case study on a textile mill having an effluent rate of 160 thousand liters per hour, he suggested treatment units consisting of an equalization tank, a clariflocculator and sludge drying beds. The size of the equalization tank for the case considered is 3m x 2m x 1m (depth) with a retention time slightly more than 45 minutes and appropriate horizontal baffles were provided for better mixing. The average depth of the clariflocculator is 3.5 m and dia. 1.5 m. The retention time for the above effluent rate was 47 minutes. The sludge drying bed for removal of solids of the order of 720 kg/day area required was 470.6 m² (25m x 20m). The effluent after treatment had suspended solid concentration less than 100 mg/l, COD less than 130 mg/l and BOD less than 60 mg/l. Although very effective, this treatment could not reduce these concentrations below the standard set by IS for safe disposal.

Ramproshad and Mowli⁽¹⁷⁾ suggested adsorption on low-cost materials to remove dye colours from aqueous solutions. Five low cost materials; (i) rice husk, (ii) teakwood bark, (ii) cotton

waste, (iv) hair and (v) bituminous coal were taken by Ramproshad as adsorbent and column studies were performed to determine their effectiveness on removal of dye colours. Column studies have shown that rice husk and bark have high adsorption capacities for basic dyes. Among all the low-cost materials, used as adsorbent, the service time of bark has shown higher values. By increasing the depth, longer service times of the fixed bed columns can be achieved for the other materials, but they will be limited in their usefulness because of the small volume of effluent they can treat.

The study reports described above indicate that although physical and biological processes removed bulk pollution load from textile dye wastes, the resulting effluent is not of desired quality for safe disposal. In some cases, an acceptable reduction of some pollutants was described with high dosages of chemicals. This process is not acceptable from economic point of view. Present status of problem demands intensive study for reduction of the strength of the pollutants from the effluent reasonable cost.

In Bangladesh no study regarding applicability of different physical, chemical and biological methods for the treatment of the textile dyeing wastes has been carried out. A study of this

nature under local condition in Bangladesh is considered to be of prime importance for inoffensive disposal of textile dyeing wastes in the surface water sources.

CHAPTER 3

ASSESSMENT OF THE QUALITY OF TEXTILE DYEING WASTE

3.1 GENERAL

The whole operation of this work may be broadly classified into two categories: (1) collection of representative sample, (2) detail analysis in the laboratory to evaluate the quality of the effluent coming out of textile dyeing industry.

3.2 COLLECTION OF REPRESENTATIVE SAMPLES

Water or wastewater samples must be collected in a proper manner, as it has great importance from the contamination point of view. However, sampling for ordinary chemical analysis requires no specific precautions other than collecting it in a clear glass container of good quality having glass stopper. Samples for bacterial analysis must be collected in a sterilized bottle with stopper.

Samples of waste collected from different sources should fairly represent the body of the waste from which they were collected. As the effluents from the textile dyeing industries are disposed off at the adjoining waste disposal ponds, the samples were collected at the point of juncture of the surface

drain and the pond. During collection of waste in the sampling bottle, the open bottle was plunged beneath the surface of the waste, having the neck downward. The samples thus collected were promptly carried to the laboratory and almost all the physical and chemical properties were determined. Possible efforts were made to minimize the time-lag between collection and analysis, so that the no significant change in the quality of the textile dyeing waste could occur.

3.3 ANALYSIS OF THE DYEING EFFLUENT

3.3.1 General

Physical, chemical and biological qualities of the waste were determined through extensive laboratory analysis. The different tests performed were colour, turbidity, total solids, dissolve solids and suspended solids for ascertaining physical qualities, pH, alkalinity, total hardness, chloride and COD for chemical qualities and BOD for biochemical quality. The test results are presented in Table 3.1 in Appendix-A.

3.3.2 pH and Acidity

The term pH is used to express the acidic or alkaline condition of a solution. It is a measure of hydrogen ion concentration and is important in almost every phase of sanitary engineering practice. In sewage and industrial wastewater

treatment involving biological or chemical process, pH must be controlled within a range favourable for best results. pH controls, the nature and magnitude, of surface charge of colloidal particles and degree of ionisation of organic matters. Hence it plays an important role in aggregation and sedimentation of suspended and colloidal particles.

Acidity is the quantitative measurement of acid present in the waste. It is usual to consider acidity as due to the presence of organic and inorganic acids resulting from the organic matters used during chemical processing of the water.

pH values are determined by pH meter shown in Plate 3.1. The acidity was determined by acid titration method, using diluted samples with the help of digital titrator, shown in Plate 3.2. The pH value of the sample was 6.85. Although the pH value of the sewage was within the limit, it had to be altered gradually to form flocs in order to form precipitates. The acidity present was well above the acceptable limit and is capable of causing pollution at the point of disposal.

3.3.3 Colour, Turbidity and Solids Content

High colour turbidity and solids content cause physical pollution to the receiving body of water. A secondary

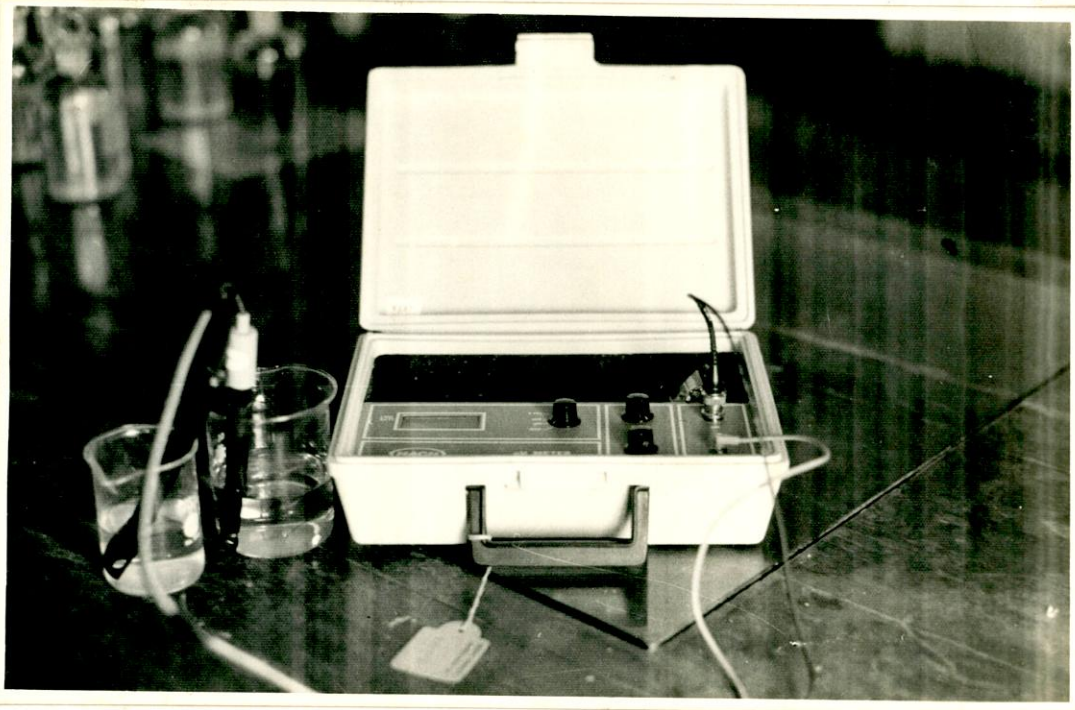


Plate 3.1 - pH Meter

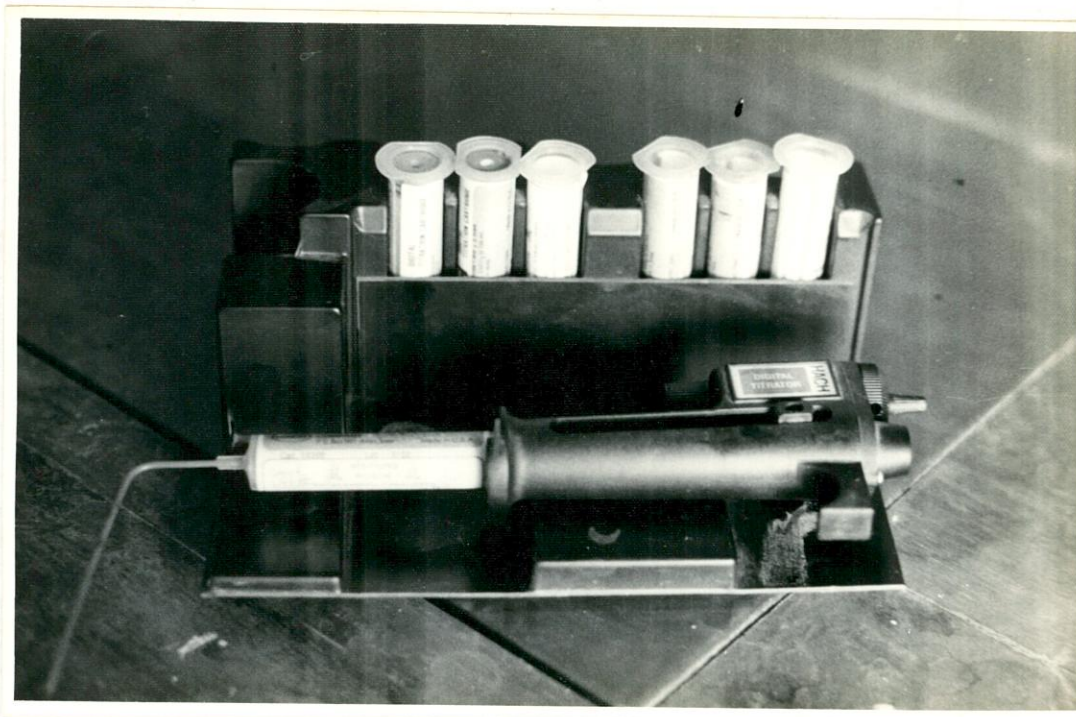


Plate 3.2 - Digital Titrator

pollution of the stream occurs due to the deposition of solids near the discharge point.

Textile dyeing waste is highly coloured due to the presence of various impurities in the colloidal and suspended forms and these colloidal form of impurities are the dye pigments used for dyeing and printing of grey clothes. Colour caused by colloidal form of impurities is called true colour and that caused by suspended matter is called apparent colour. Colour of textile dyeing effluent is mainly caused by the dye pigments added during dyeing and other causes are the suspended impurities and foreign matters coming out of the grey clothes. Colour was determined by DR-EL/5 apparatus shown in Plate 3.3, using highly diluted sample. Determination of colour through this apparatus was done by comparing the % transmittance of light through the sample and that through standard potassium-cobalt solution at optimum wavelength of 455 nm. Two clean sample cell were filled upto the 25ml mark, one with clear water other with the diluted waste. The first one is placed inside the cell holder and then the 455nm wavelength colour meter scale was inserted into the scale holder and was adjusted for zero reading. Then the clear water cell was replaced by the cell filled with the diluted waste and the colour concentration was determined from the meter reading.



Plate 3.3 - DR-EL/5 Apparatus

Turbidity is caused by wide varieties of suspended materials. In case of textile dyeing effluent turbidity is caused mainly by the cotton fibers coming from grey clothes and the colour pigments which remain suspended in the waste. Turbidity is measured by the deflection of light caused by variety of suspended materials, which range in size from colloid coarse dispersions, depending upon the degree of turbulence. Turbidity was determined by turbidimeter shown in Plate 3.4, using highly diluted dyeing effluent.

Solids may be classified as total solids, dissolved solids and suspended solids. Total solids refer to the matter that remains as residue upon evaporation and drying at 103-105°C. The particles having size less than or equal to 0.001 μm when present in the waste, they are known as dissolved solids. Experimentally, dissolved solids, are generally referred to the matter that passes through Whatman No. 1 filter paper and remain as residue after evaporation and drying at 103-105°C. The difference between total solids and dissolved solids give the amount of suspended solids present in the wastewater. Total solids, dissolved solids and suspended solids are determined by standard test procedure (16,17). The concentrations of colour, turbidity and solids (suspended and dissolved) present in the dyeing effluent is given in the Table 3.1 in Appendix-A. The wastewater was extremely turbid and coloured.

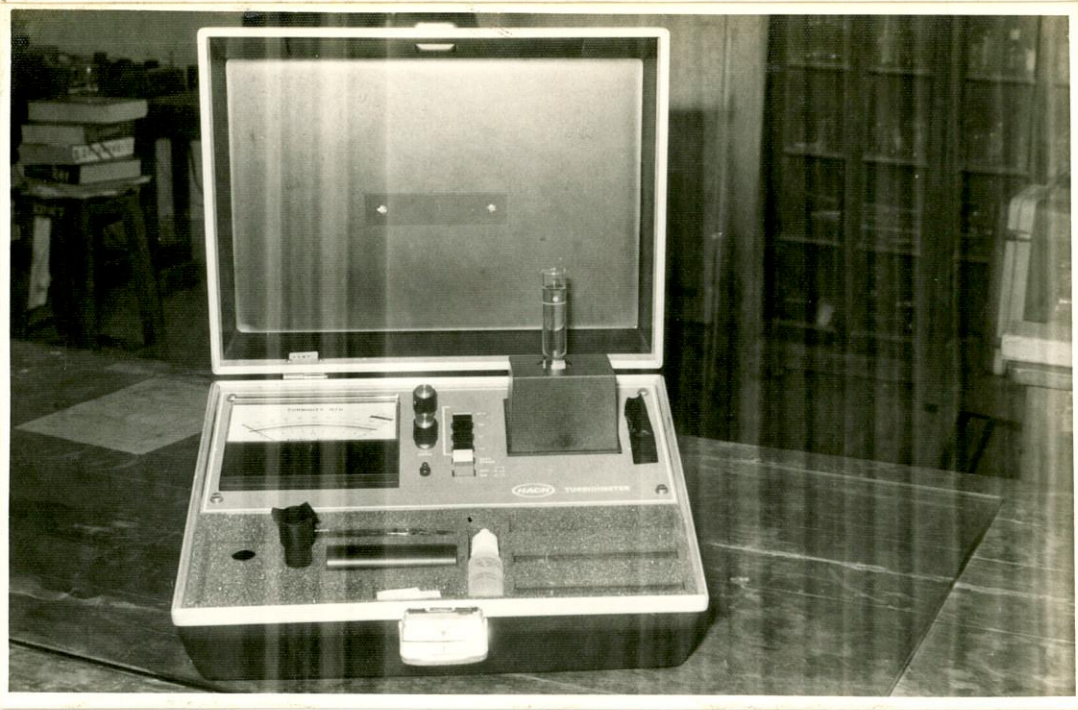


Plate 3.4 - Turbidimeter Model 168000

The concentration of colour and turbidity of the wastewater were 6600 ppm and 1110 ppm respectively. The concentrations of total solids, dissolved solids and suspended solids were 6360 ppm, 1730 ppm and 4630 ppm respectively. The higher values of solids content are due to the presence of large amounts of organic, inorganic substances and colloidal pigments held in suspension in the textile dyeing and printing waste.

3.3.4 Total Hardness

Hardness is caused by divalent metallic cations. Such ions are capable of reacting with soap to form precipitates and with certain anions present in the water form scale. The principal hardness-causing cations are calcium magnesium, strontium, ferrous ions and manganous ions. The anions with which these cations usually associate to cause hardness are sulphate, chloride, nitrate, silicate, bicarbonate etc. The hardness of wastewaters from the textile dye units is caused by the lime, chlorides used for bleaching and cleaning.

Hardness is classified in two ways: (a) with respect to the metallic ion and (b) with respect to the anions associated with the metallic ions. Calcium and magnesium causes by far the greatest portion of the hardness in case of natural water. However, in wastewater, hardness may be caused by the hardness

causing elements coming as wasted chemicals. Usually hardness is expressed as total hardness or calcium or magnesium hardness, where, total hardness is the algebraic sum of calcium and magnesium hardness. Again hardness may be classified as carbonate and non-carbonate hardness. The hardness data is usually used to interpret the extent of treatment required for the waste to make it palatable. The total hardness of the waste was determined through titration and was found to be 500 ppm.

3.3.5 BOD and COD

BOD is the amount of oxygen required by the living microscopic organism in waste water to oxidize the organic matter present which serve as food for them. BOD test is widely used to determine the pollution strength of sewage and industrial waste in terms of oxygen that the microorganism will require if discharged into natural water courses in which aerobic condition exists. The test also indicates the rate at which the oxygen depletion of the receiving water could take place. COD is the chemical oxygen demand that indicates the total quantity of readily oxidizable materials present in wastewater.

BOD tests were performed according to the recommended procedure described in standard methods of laboratory analysis⁽⁶⁾ using diluted samples. In the determination of COD, equal volumes (10 ml) of diluted sulphuric acid and standard potassium

permanganate were added to 100 ml of sample and heated in a water bath for 30 minutes. 10 ml of standard ammonium oxalate was added to the boiled sample. The standard potassium permanganate was then added to the mixture until first permanent pink colour was obtained. The COD value was obtained from the additional volume of standard potassium permanganate added to the sample. The BOD and COD values of the waste are given in the Table 3.1 of Appendix-A. It shows that COD is higher than the BOD. It indicates that the waste contains lower proportion of biodegradable organic matter in comparison to the higher proportion of readily oxidizable organic matters. The textile dyeing wastes with high values of COD (395 ppm) and BOD (180 ppm) if discharged in natural waters will rapidly deplete the dissolved oxygen of the stream, due to higher rate of chemical and biological oxidation of organic matters.

3.3.6 Polluting Loads

A textile dyeing unit in Bangladesh discharges at an average of 100000 lit./hour of wastes into the natural water courses. The wastes disposed per day contain at an average of 636 kg of total solids of which 463 kg suspended solids and 173 kg dissolved solids. The quantity of BOD and COD imparted by the waste per day are 18 kg and 39.5 kg respectively. The average

turbidity and colour of the waste per day are 111 kg and 660 kg respectively. This huge quantity of pollutants coming into the receiving body per day from the textile dyeing wastes invariably cause excessive contamination of this receiving body.

CHAPTER 4

EXPERIMENTAL RESULTS AND DISCUSSION

4.1 PLAIN SEDIMENTATION

4.1.1 General

Plain sedimentation removes pollutants caused by particles heavier than water. The process also removes lighter particles that come in contact with heavier one by their intermolecular forces of attraction. In textile dyeing waste treatment sedimentation has special importance as the solids removed during plain sedimentation eventually removes considerable amount of inorganic as well as organic loads on the subsequent treatment processes employed for their treatment. So, plain sedimentation process has been chosen as a primary treatment unit for initial removal of the particulate matters of the dyeing waste.

4.1.2 Experimental Results

Sedimentation is used to remove the settleable suspended solids from wastewater⁽¹¹⁾. Hence, suspended solids present in the effluent from the sedimentation tank, must be tested. Colour being the major pollutant of a textile dyeing waste,

must be determined to assess the percentage removal after sedimentation. In this study, removal of suspended solids and colour has been taken as the basic criteria to fix up the detention period of the sedimentation tank. In the laboratory, samples were collected from a depth of 3 inches below the free surface of liquid in the sedimentation tank at detention periods of 2,3,3.5,4,4.5,5 and 24 hours and tested for suspended solids, BOD, COD and colour according to the standard procedure (6,16,20) as discussed in Chapter 3. The test results are presented in Table 4.1 in Appendix-A and the graphical representation of these values are shown in Figures 4.1(a), 4.1(c), 4.1(e) and 4.1(g) respectively. The percentage removal of suspended solids, BOD, COD and colour with detention period, during sedimentation, are shown graphically in Figures 4.1(b), 4.1(d), 4.1(f) and 4.1(h) respectively. These curves are drawn in semi-logarithmic graph papers because, after regression analysis of each of these curves it has been found that, the regression co-efficients of all the curves come closest to unity if and only if their equations are represented by the equation $y = a + b \ln x$. Which when drawn on a semi-logarithmic graph paper, with y-axis as linear variation and x-axis as logarithmic variation, represents a straight line. The regression co-efficient of each of the curves are given in the figures for the four cases; linear regression, logarithmic

regression, exponential regression and power regression, for which they have been tested. From Figures 4.1(a) and 4.1(b) it can be easily surmized that initally the rate of removal of suspended solids with detention period is high which decreases with the passage of time. Figures 4.1(c) and 4.1(d) graphically represent the concentration and percentage removal of BOD respectively. The behaviour of the curves are similar to those described earlier. Figures 4.1(e) and 4.1(f) represents the concentration of COD and its percentage removal with time. The concentration and percentage removal of colour are shown in Figures 4.1(g) and 4.1(h). It can be concluded after examining all the curves that the maximum percentage removal of suspended solids, BOD, COD and colour when the detention period is 24 hours were 81.97%, 53.33%, 41.01% and 22.73% respectively. However, with a more reasonable detention period of 5 hours, the percentage removal of the above from a textile dyeing waste, after being treated in a sedimentation tank were 75.59%, 47.22%, 37.97% and 10.30% respectively.

4.2 SEDIMENTATION WITH COAGULATION

4.2.1 General

Plain sedimentation of the textile dyeing waste did not improve the physical, chemical and biological qualities

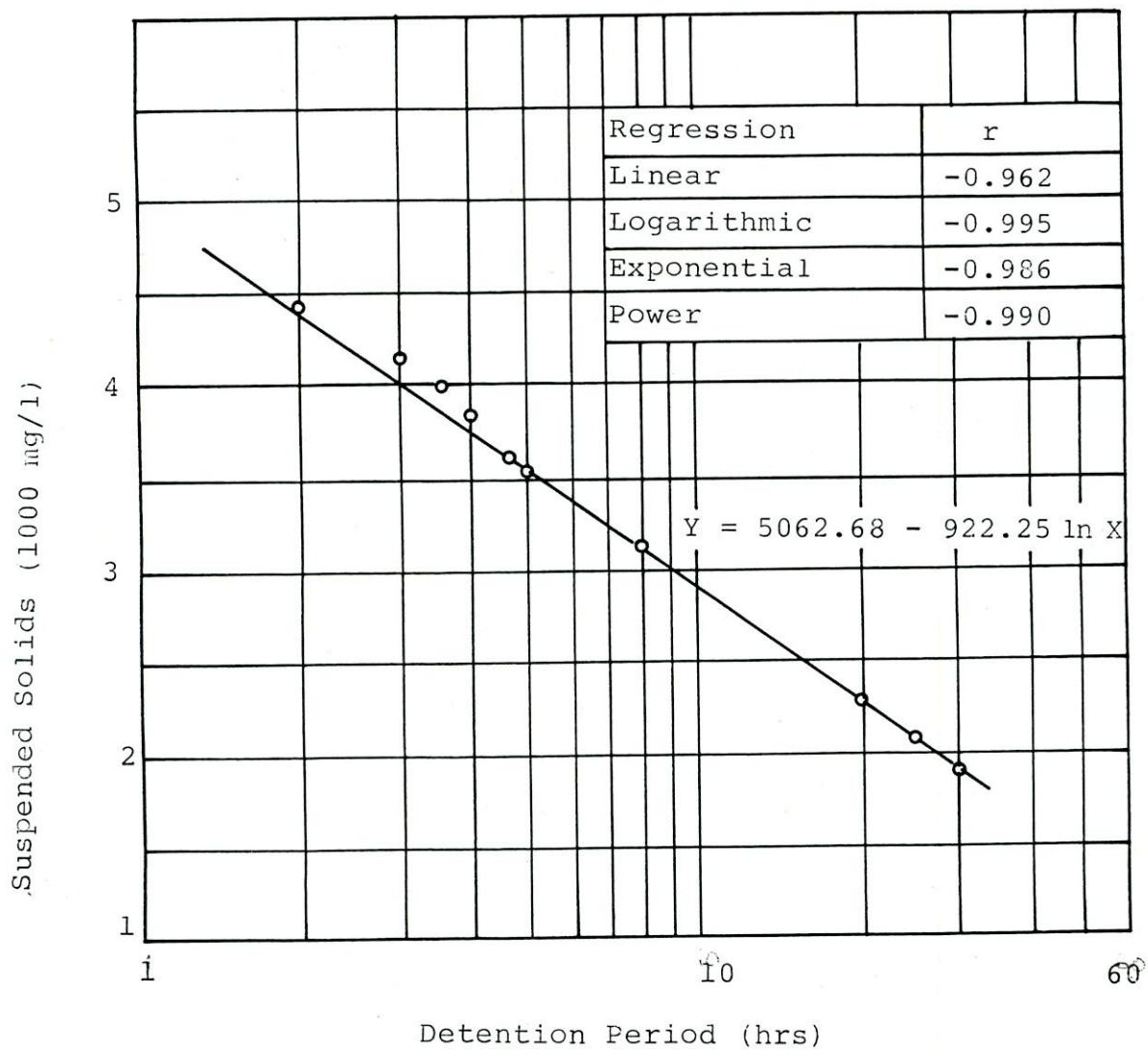


Figure 4.1(a) Variation of Suspended Solids with Detention Period During Sedimentation.

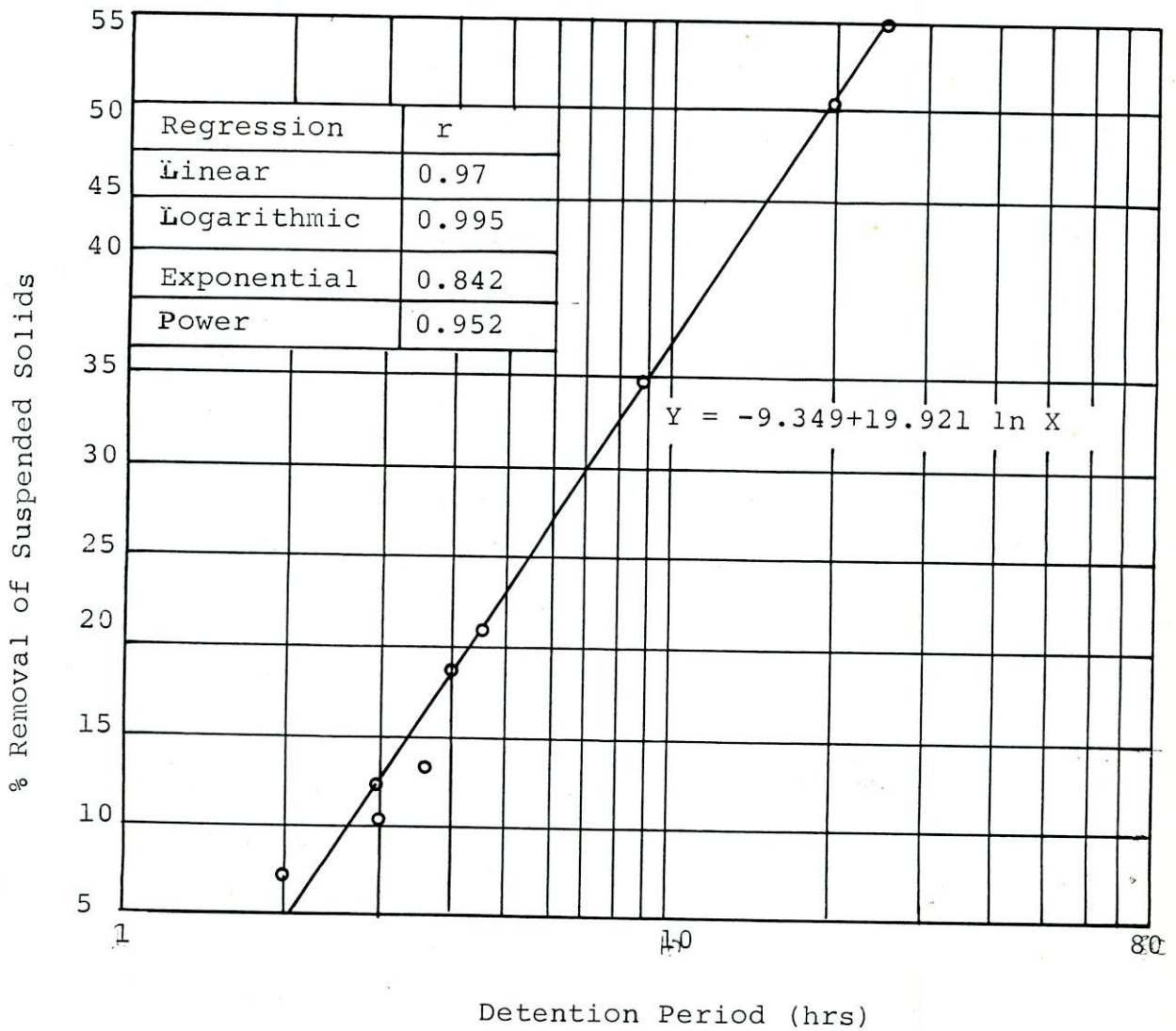


Figure 4.1(b) % Removal of Suspended Solids vs Detention Period During Sedimentation

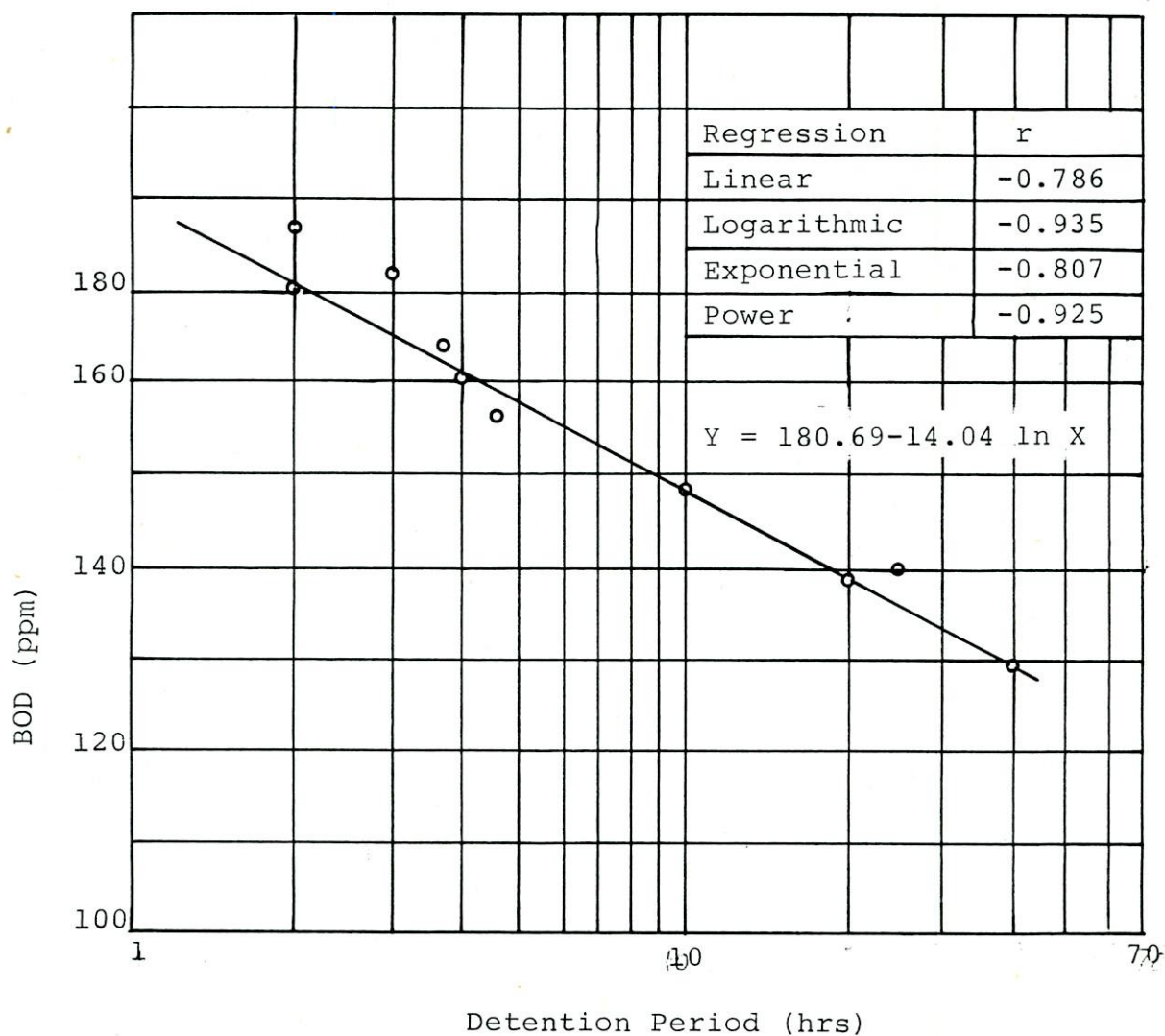


Figure 4.1(c) Variation of BOD with Detention Period During Sedimentation

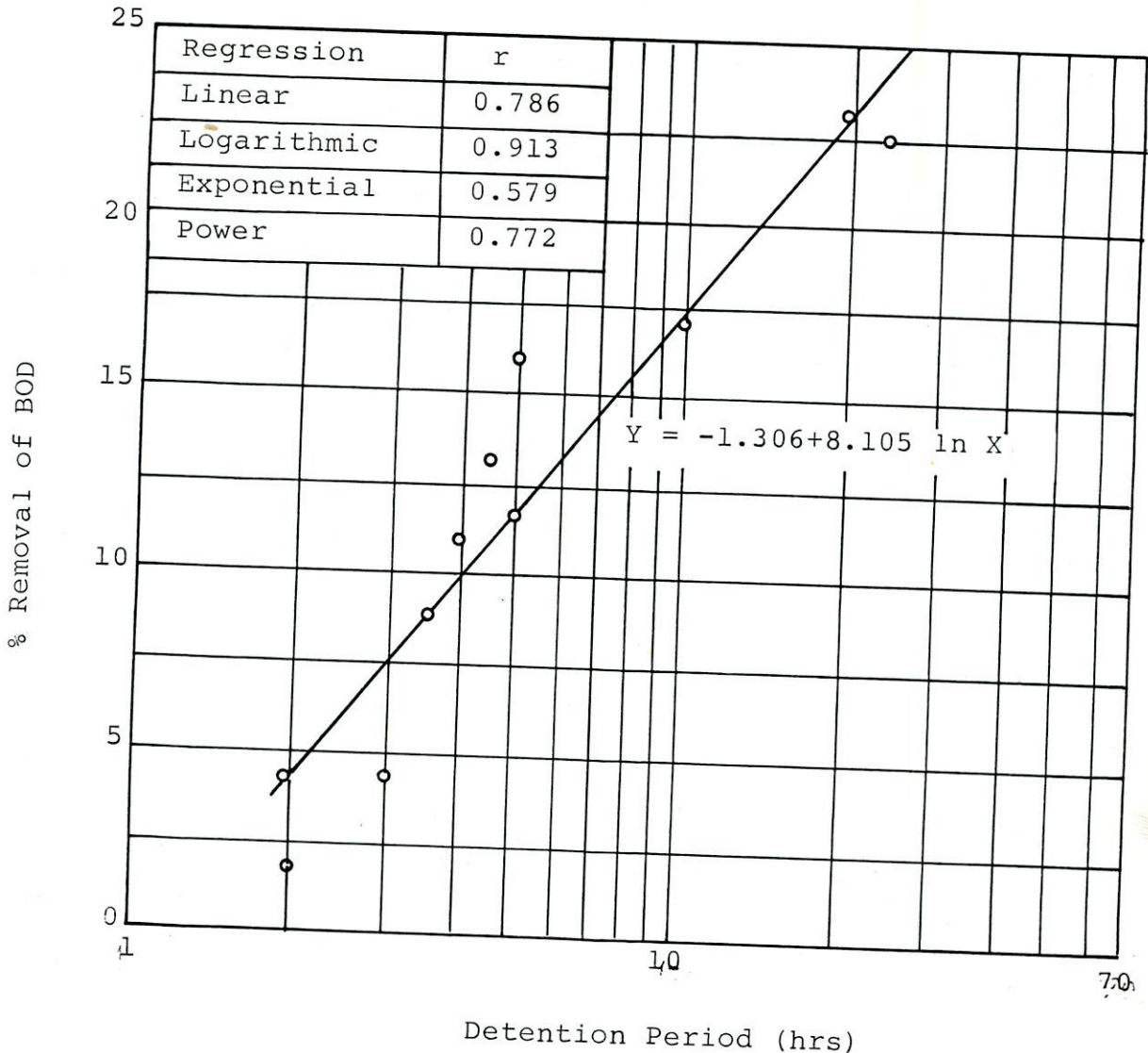


Figure 4.1(d) % Removal of BOD vs Detention Period During Sedimentation.

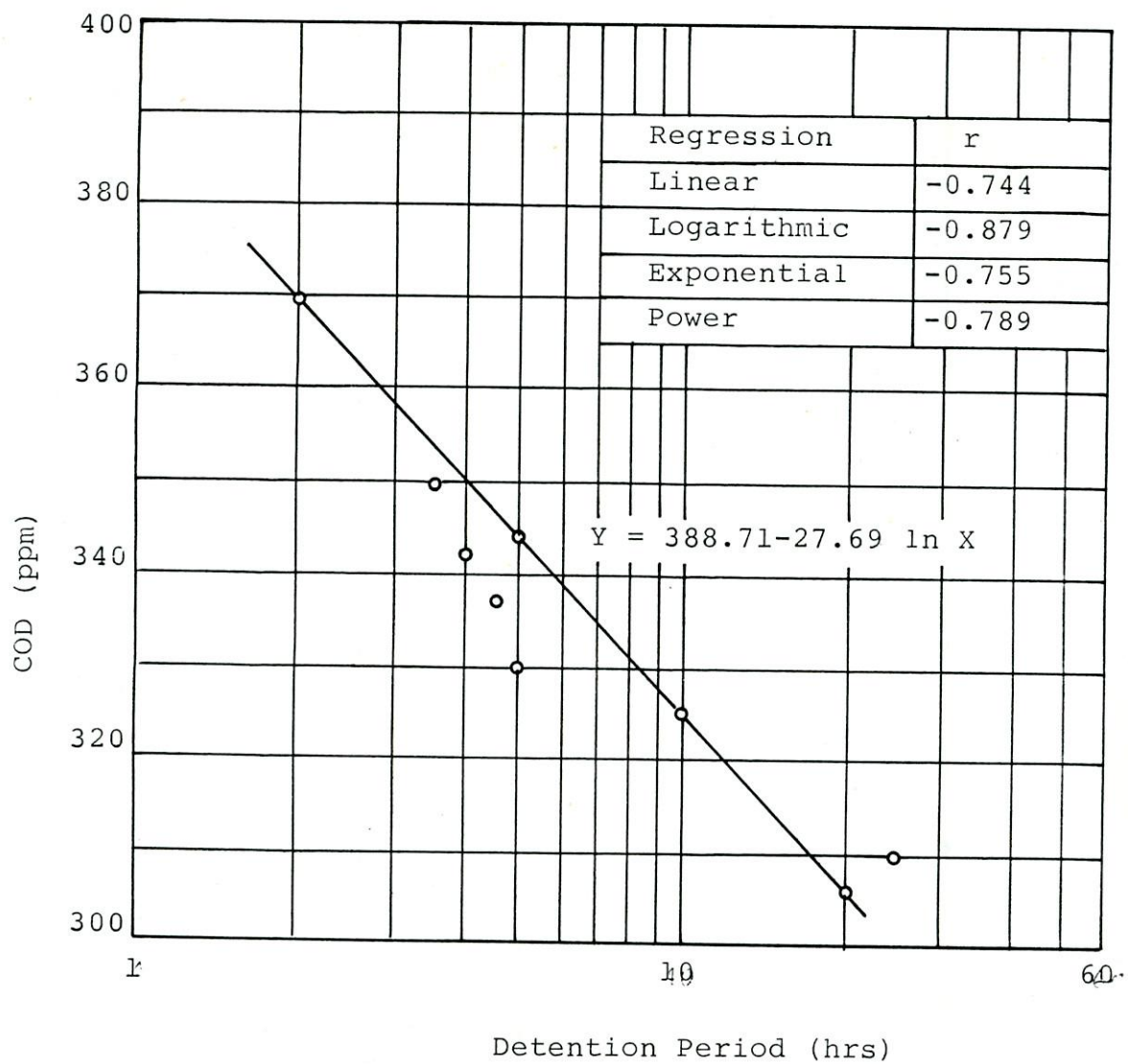


Figure 4.1(e) - Variation of COD with Detention Period During Sedimentation.

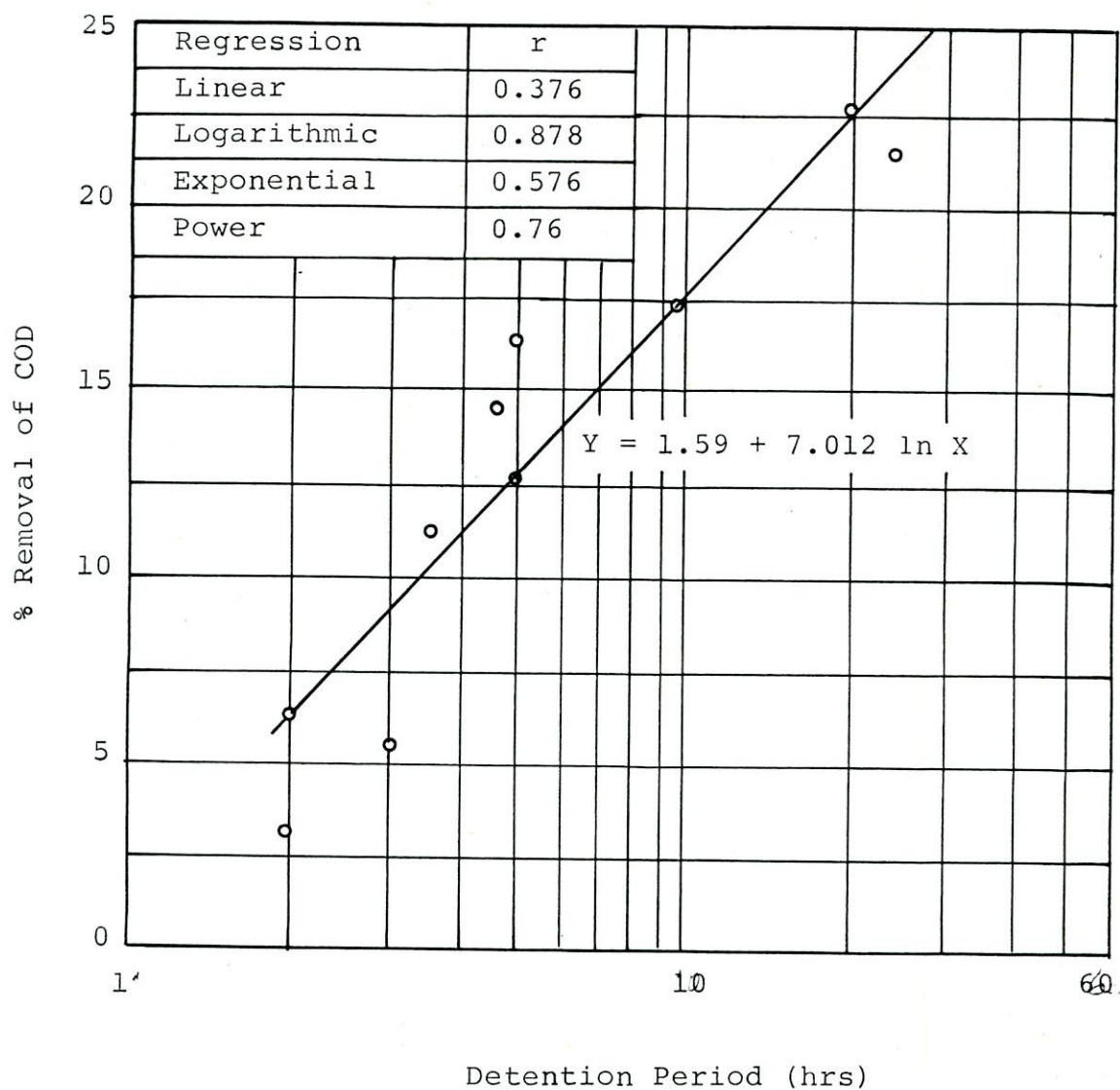


Figure 4.1(f) % Removal of COD vs Detention Period During Sedimentation.

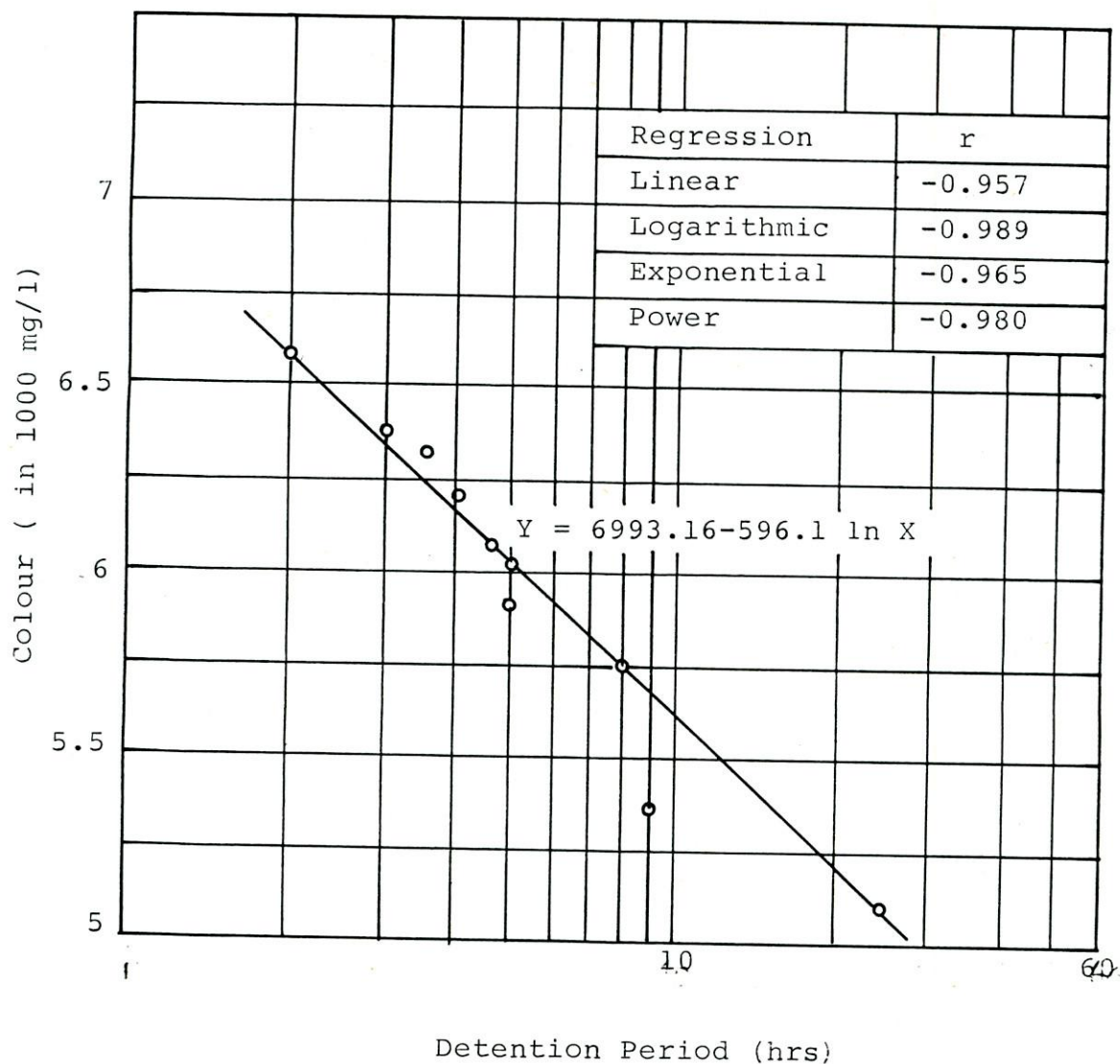


Figure 4.1(g) Variation of Colour with Detention Period During Sedimentation.

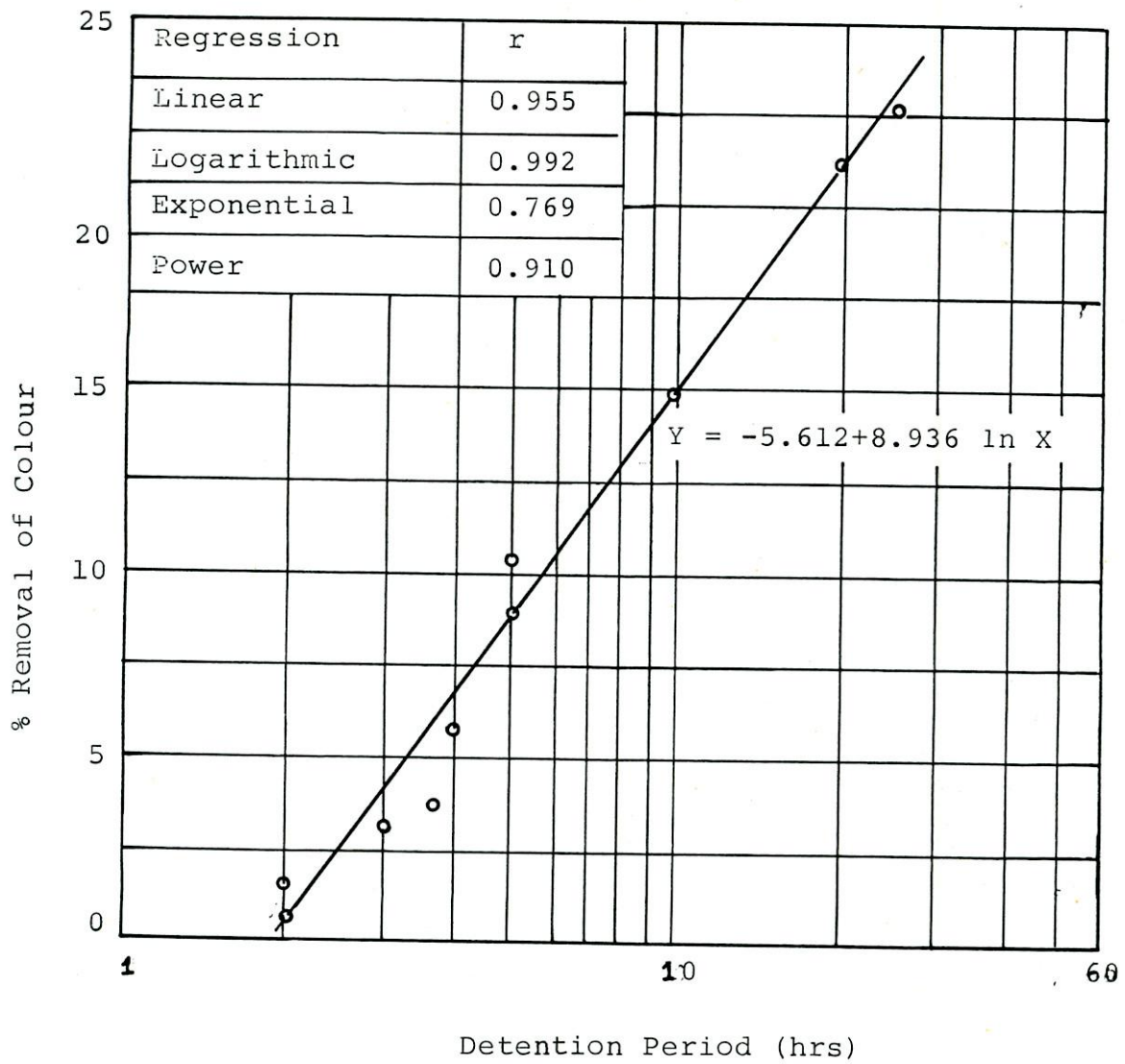


Figure 4.1(h) % Removal of Colour vs Detention Period During Sedimentation.

appreciably. In fact, the effluent coming out from this treatment process still had higher residual organic and inorganic load for inoffensive discharge into natural water courses. So, in order to remove the organic matters further, sedimentation with coagulation was employed. This coagulation sedimentation process removed the waste matters present in suspended or colloidal form which did not settle out on plain sedimentation and could not be removed by conventional physical treatment processes. In the laboratory, jar test apparatus was used for coagulation, which consisted of six metallic paddles each 4 inch long and $3/4$ inch wide attached to a vertical rod. The rotating velocity exerted by the motor was transferred to the vertical rods by a horizontal shaft through the gear system. The horizontal shaft is rotated by an electric motor, and consequently the speed of the paddle could be controlled by an adjustable switch. There was a speed indicator attached on the body of the apparatus. By careful adjustment constant speed could be maintained throughout the time of mixing and flocculation. Plate 4.1 represents the jar test apparatus employed for coagulation and sedimentation.

4.2.2 Experimental Results

Agglomeration and settling of the colloids is prevented by the repelling force created by their electrical properties. Colloids are generally negatively charged particles. The

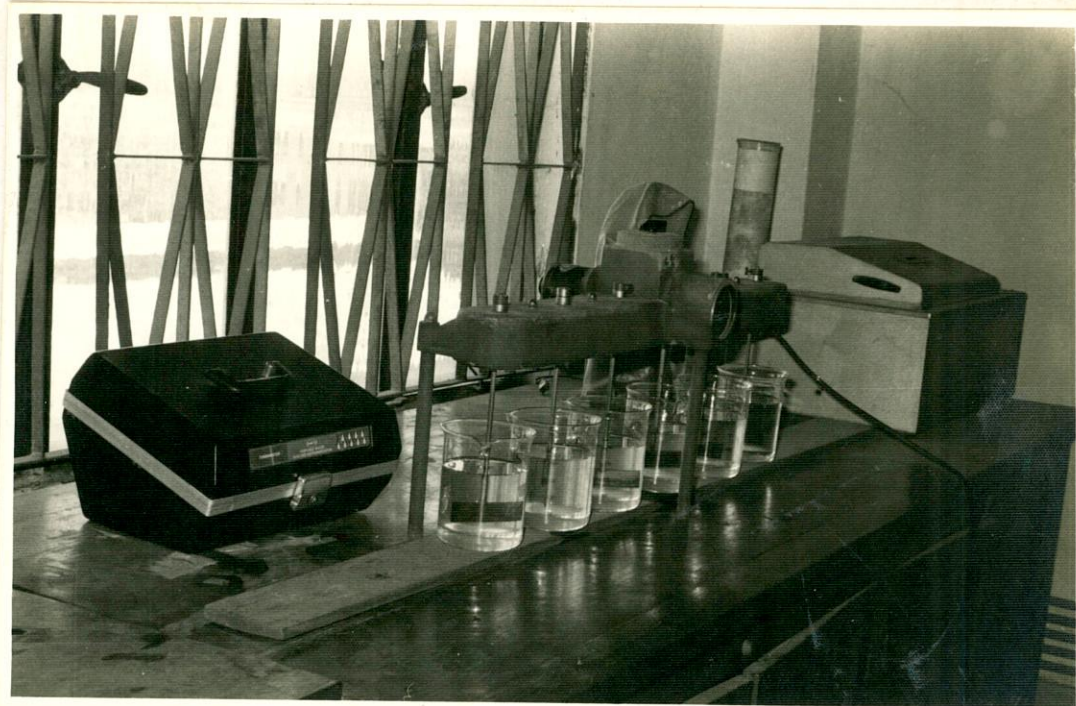


Plate 4.1 - Jar Test Apparatus

addition of high valency cations, such as alum, will depress the particle charges and the effective distance of double layer, thereby reducing zeta potential. As aluminium sulphate dissolves, the cations serve to neutralize the negative charge on the colloids resulting flocculation and sedimentation.

Initially, aluminium alum was used as coagulant. The pH of the textile dyeing waste was 6.85 and it was found that pH of the sample gradually decreased with the addition of alum. This variation is given in Table 4.2 in Appendix-A. Also, the graphical variation is shown in Figure 4.2(a). This type of variation was ascertained by regression analysis of all these data and comparing the regression co-efficients 'r' for the types of regression considered. The values of the regression co-efficients are shown figure. The equation of the linear variation was found to be:

$$Y = 7.962 - 0.0028 X \quad 4.2.1$$

where, Y = pH of the sample and

X = alum dose in mg/l

The Jar test was performed to determine the effectiveness of alum as a coagulant. It was found that for any dose of alum added to the sample, the turbidity of the sample increased and exceeded the initial turbidity of the textile dyeing waste.

However, when allowed to stand for a long period, the suspended particles settled gradually. The variations of turbidity with alum dose and time of detention are given in Table 4.2 in Appendix-A. Figure 4.2(b) represents the variation of turbidity of the sample with detention period for different dosage of alum. From Figure 4.2(b) it could be said that, turbidity of the sample increased with the addition of alum.

The colour of the textile dyeing waste was 6600 ppm before being treated with alum and after being treated it decreased slightly with the addition of alum. The variation of colour with alum dosage is given in Table 4.2 in Appendix-A and the graphical representation is shown in Figure 4.2(c). This variation of colour was found to be linear, as the linear regression co-efficient was close to unity. This linear variation could be expressed by the equation:

$$Y = 7394.80 - 3.353 X \quad 4.2.2$$

where, Y = colour of the sample and

X = alum dose in mg/l

After comparing the Figures 4.2(a), 4.2(b) and 4.2(c) it could be concluded that, alum reduces the pH and the colour

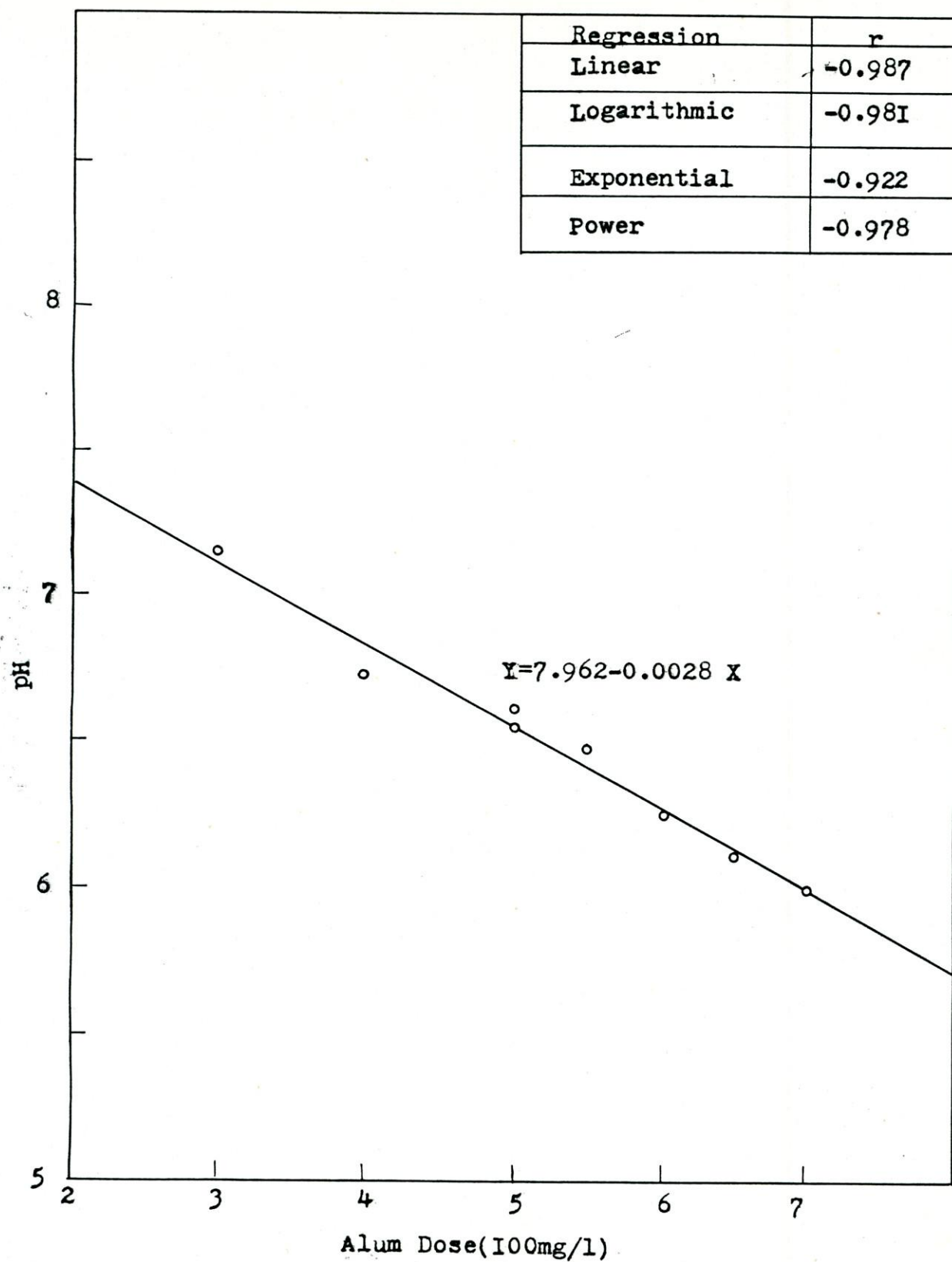


Figure 4.2(a) Variation of pH with Alum Dose

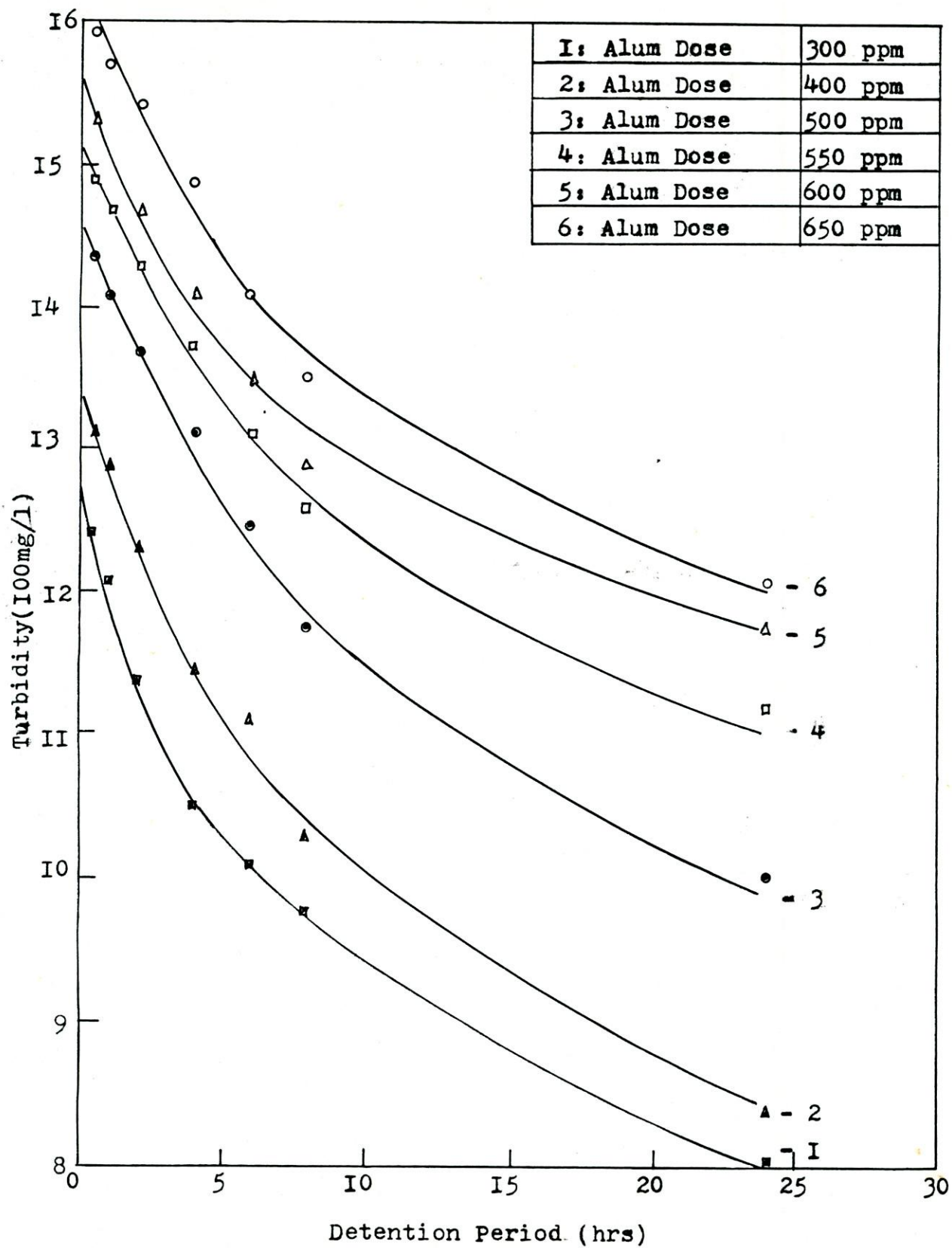


Figure 4.2(b) Variation of Turbidity with Detention Period at different Alum dosage

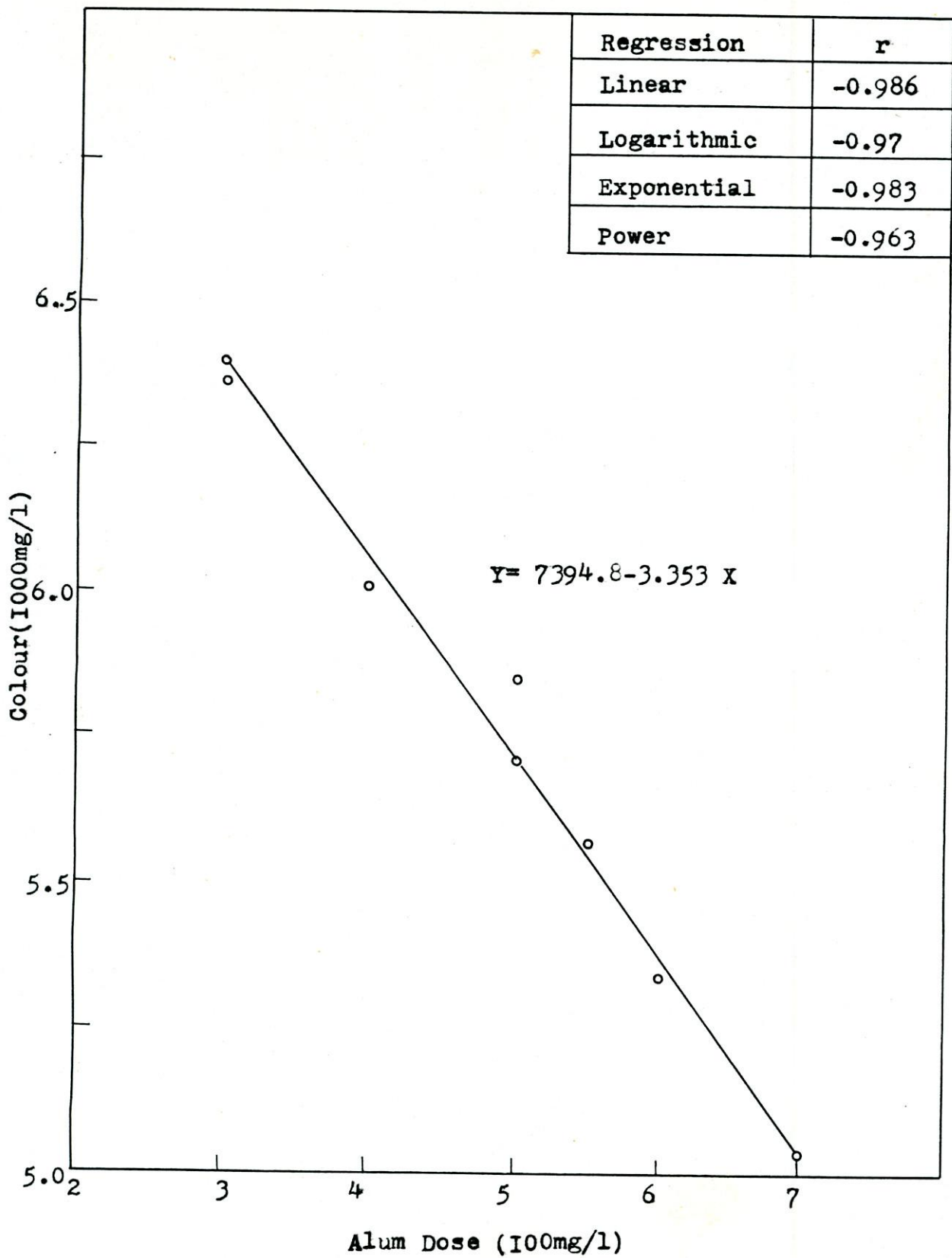


Figure 4.2(c) Variation of Colour with Alum dose

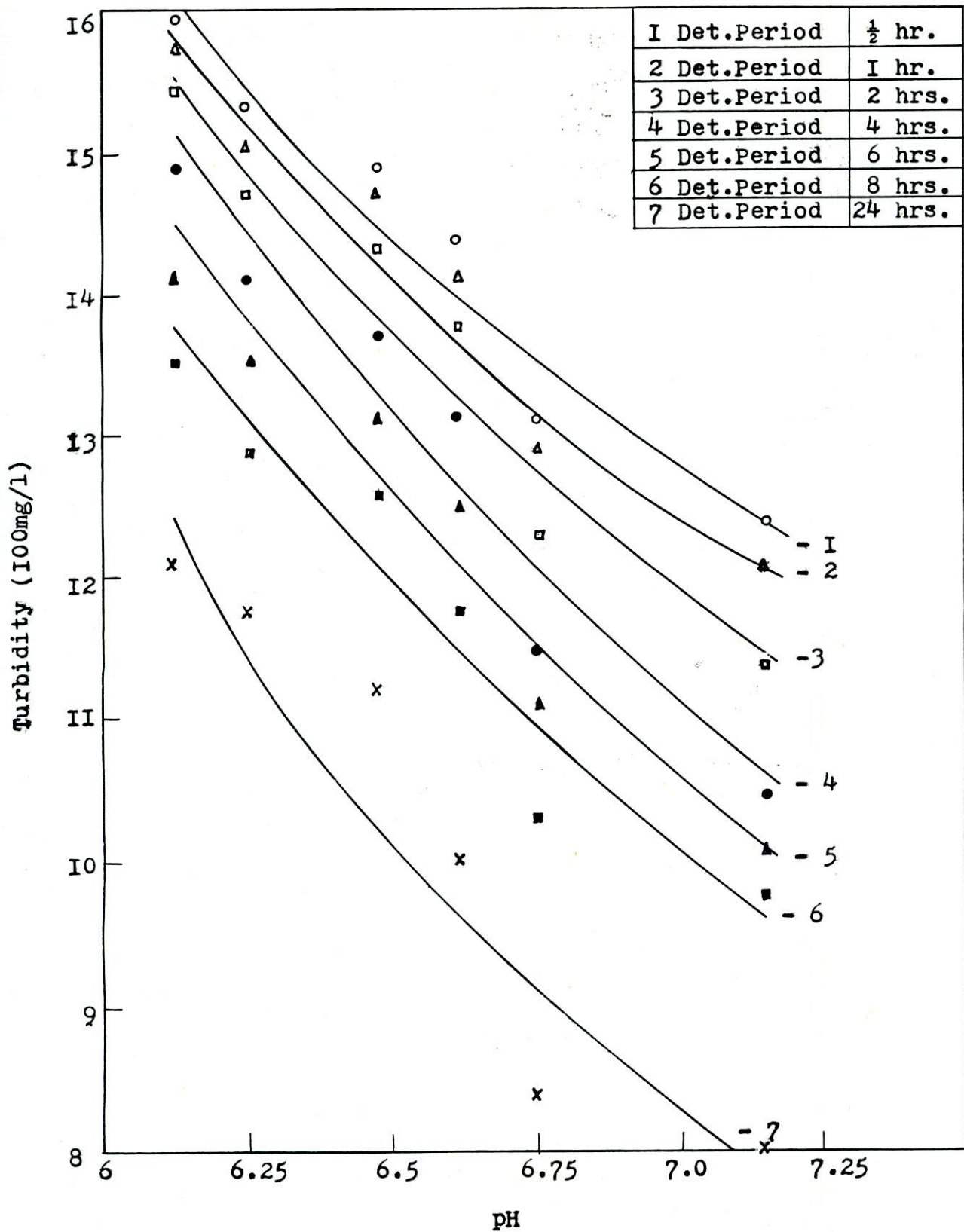


Figure 4.2(d) Turbidity vs pH at different Detention Period
(Coagulant: Alum)

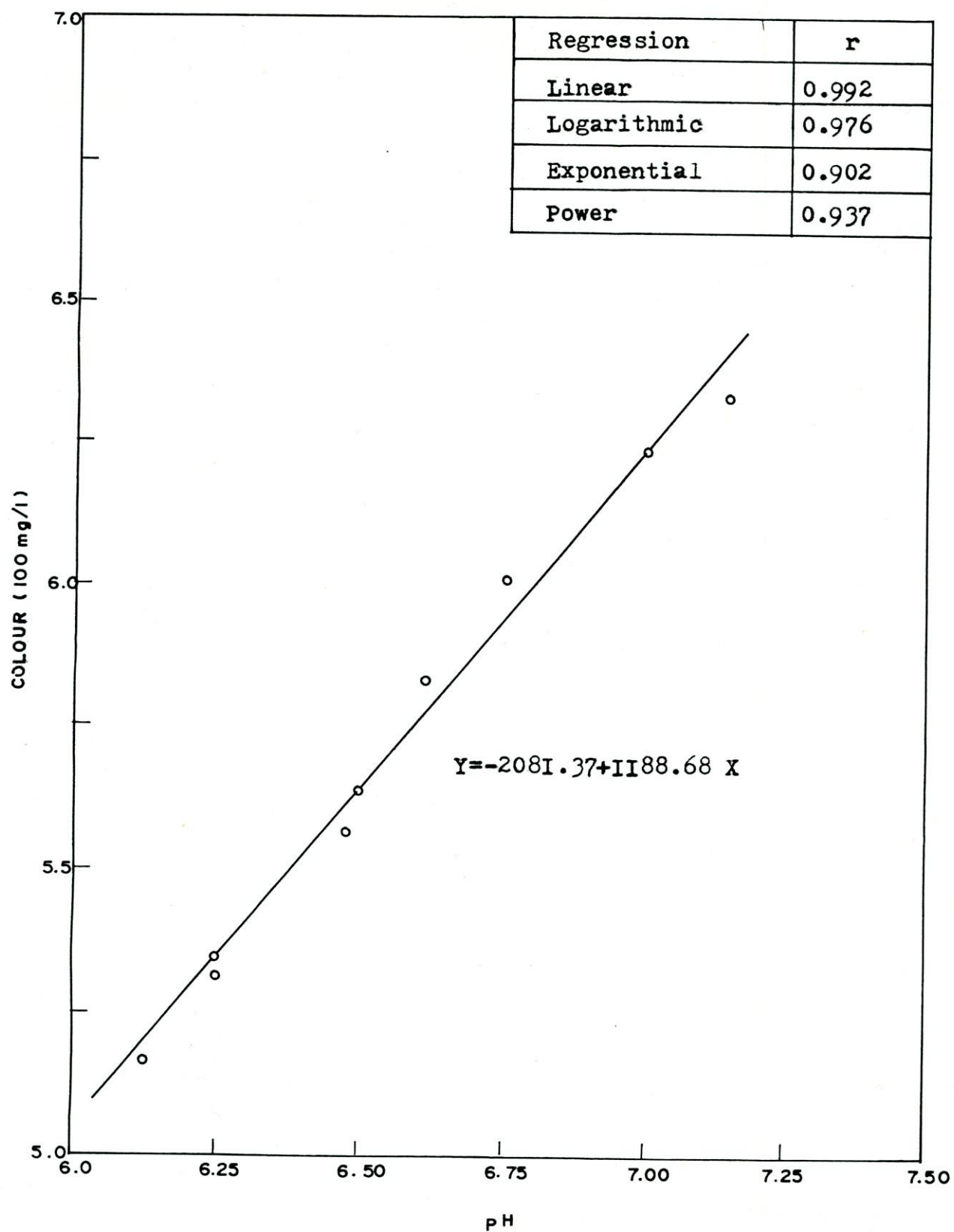


Figure 4.2(e) Colour vs pH (Coagulant: Alum)

of the textile dyeing waste. However, turbidity of the sample increase initially, with the addition of alum and decreases when allowed to settle.

Sodium hydroxide having a normality of 6N was used as the second coagulant. As the textile dyeing waste was highly polluted with different impurities, it was diluted before treatment. The variation of turbidity with various detention period and sodium hydroxide dosage is given in Table 4.3.1. The graphical representation of the results is shown in Figure 4.3(a). It could be determined by examining the figure that, unlike alum, turbidity of the waste decreased with the increase in the dosage of NaOH. Again, this turbidity further decreased with the increase in detention period. Visual examination showed a rapid formation of flocs by these dye pigments with the increase in the concentration of NaOH. Eventually these flocs settled down when allowed to stand still. Textile dyeing waste contained acetic acid which was used to dilute the dispersed dyes before dyeing. This acetic acid reacted with the sodium hydroxide to form flocs and led to eventual settling.

pH of the waste increased with the increase in NaOH dosage. As the pH value increased, the dissolved and colloidal impurities became insoluble and formed flocs with sodium ions. The flocs grew larger and heavier and finally settled at the

bottom of the glass jar. The variation of pH with the NaOH dosage is shown in the Figure 4.3(b). Through regression analysis of the data given in the Table 4.3.1 in Appendix-A, it was found that the linear regression co-efficient was the one closest to unity. So, the pH of the waste varies linearly with the NaOH dosage applied to it.

The colour pigments present in a textile dyeing waste are the major impurities causing turbidity and colour simultaneously. When NaOH was added to the diluted waste and mixed by stirring and then allowed to settle, it was found that colour of the waste decreased rapidly. The rate of reduction of colour increased with the increase in sodium hydroxide dosage. When the colour values were considered from Table 4.3.2 in Appendix-A it could be seen that, initially the rate of reduction of colour with time was high and the rate reduction decreased with the increase in time. The effect of sodium hydroxide on the removal of colour has been shown in Figure 4.3(d).

Finally, NaOH and 600 mg/l of alum were simultaneously used as coagulant. Their effect on the textile dyeing waste are given in Tables 4.3.3 and 4.3.4 in Appendix-A. The graphical representation of variation of turbidity and colour with time at different sodium hydroxide dosage and a fixed amount of alum are shown in Figures 4.3(f) and 4.3(i) respectively.

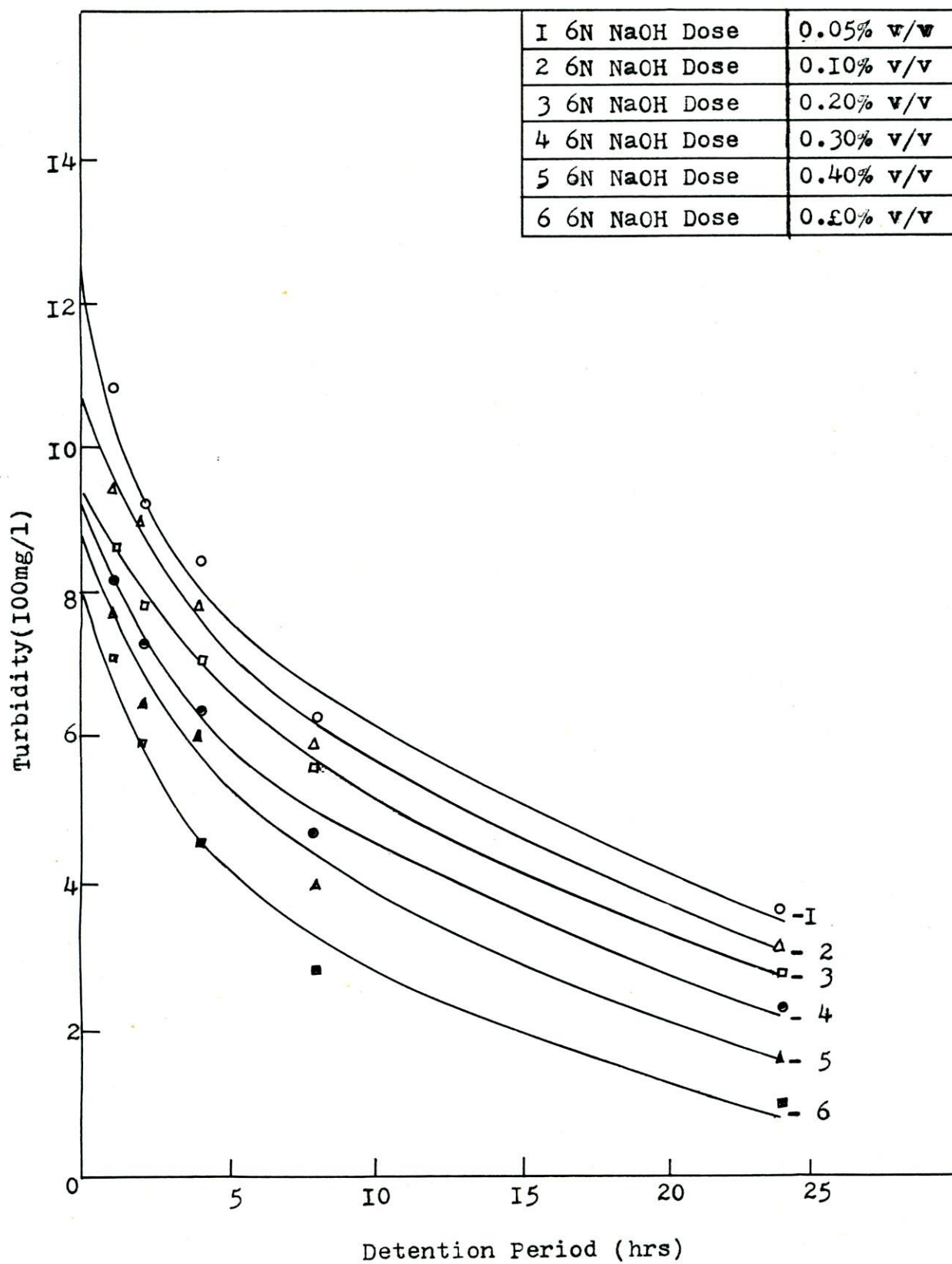


Figure 4.3(a) Variation of Turbidity with Detention Period at different dosage of NaOH

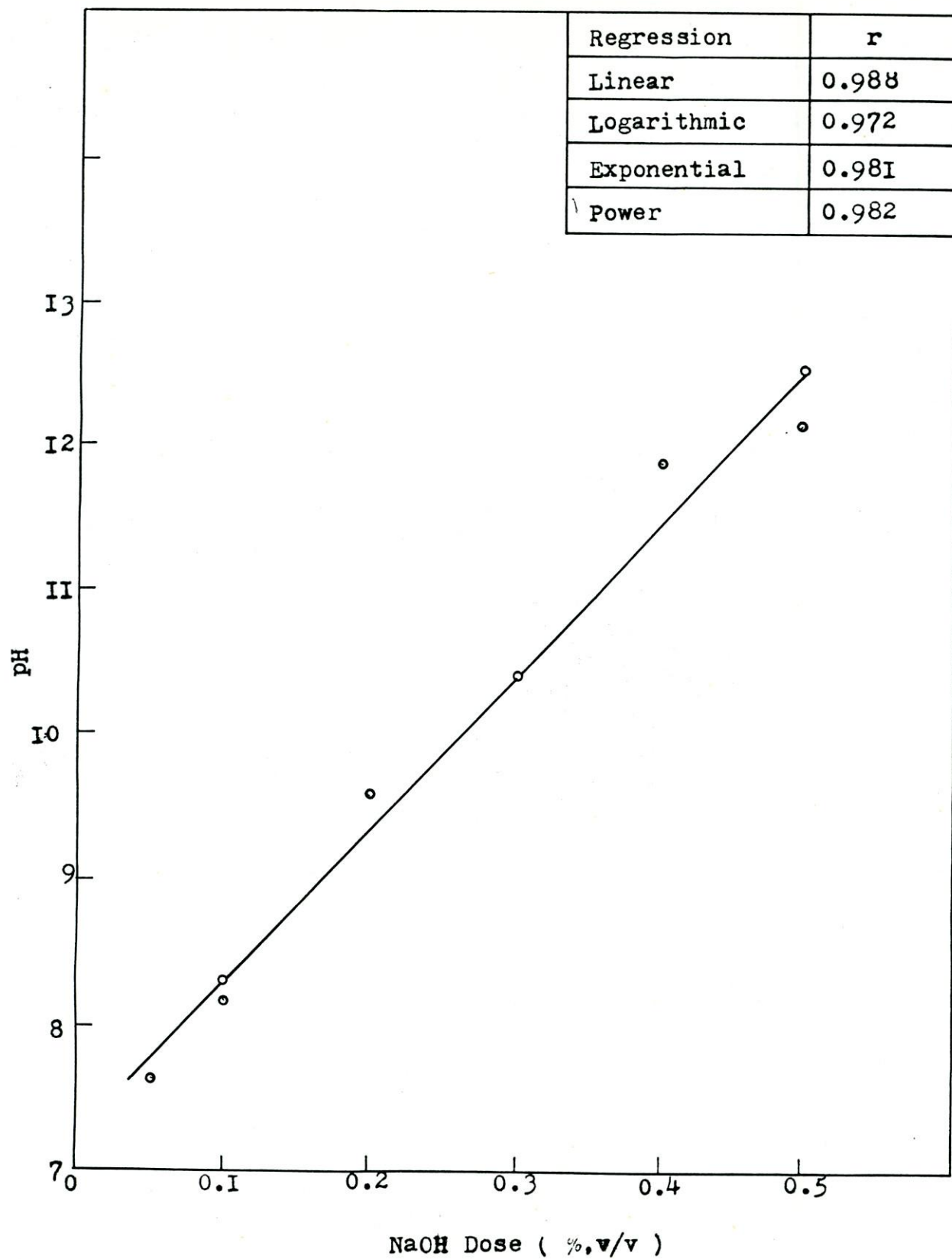


Figure 4.3(b) Variation of pH with NaOH

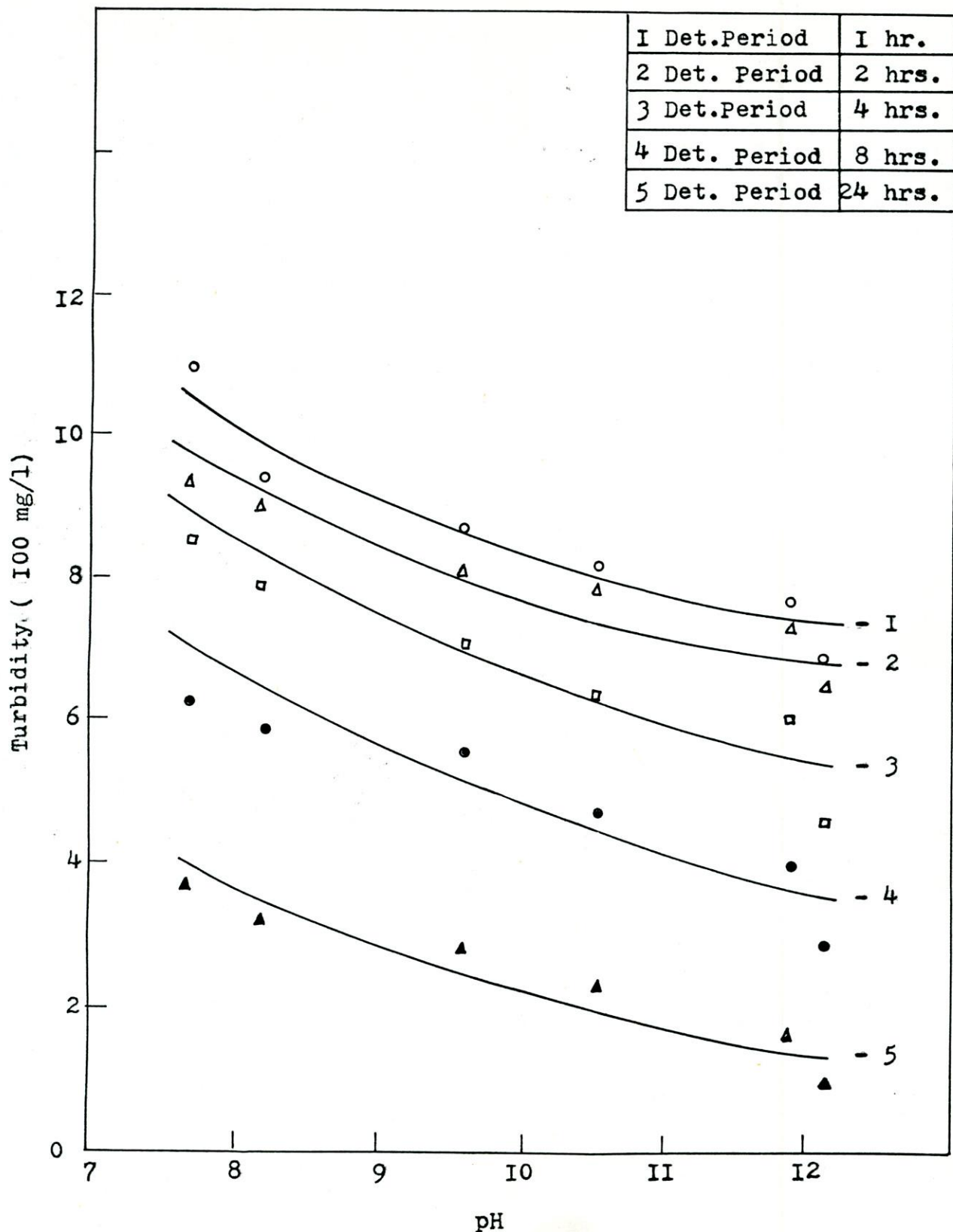


Figure 4.3(c) Turbidity vs pH at different Detention Period
(Coagulant : NaOH)

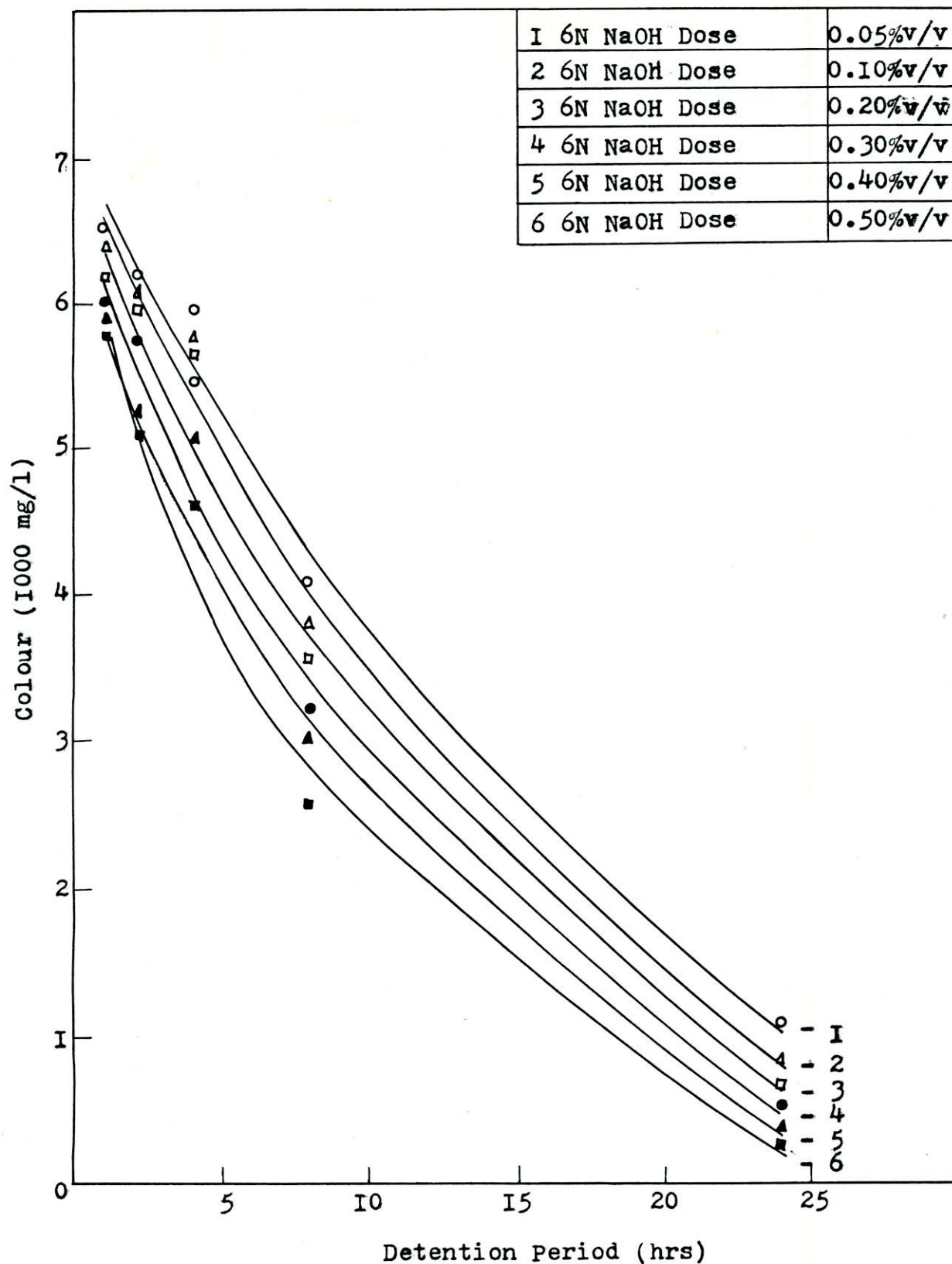


Figure 4.3(d) Variation of Colour with Detention Period at different dosage of NaOH

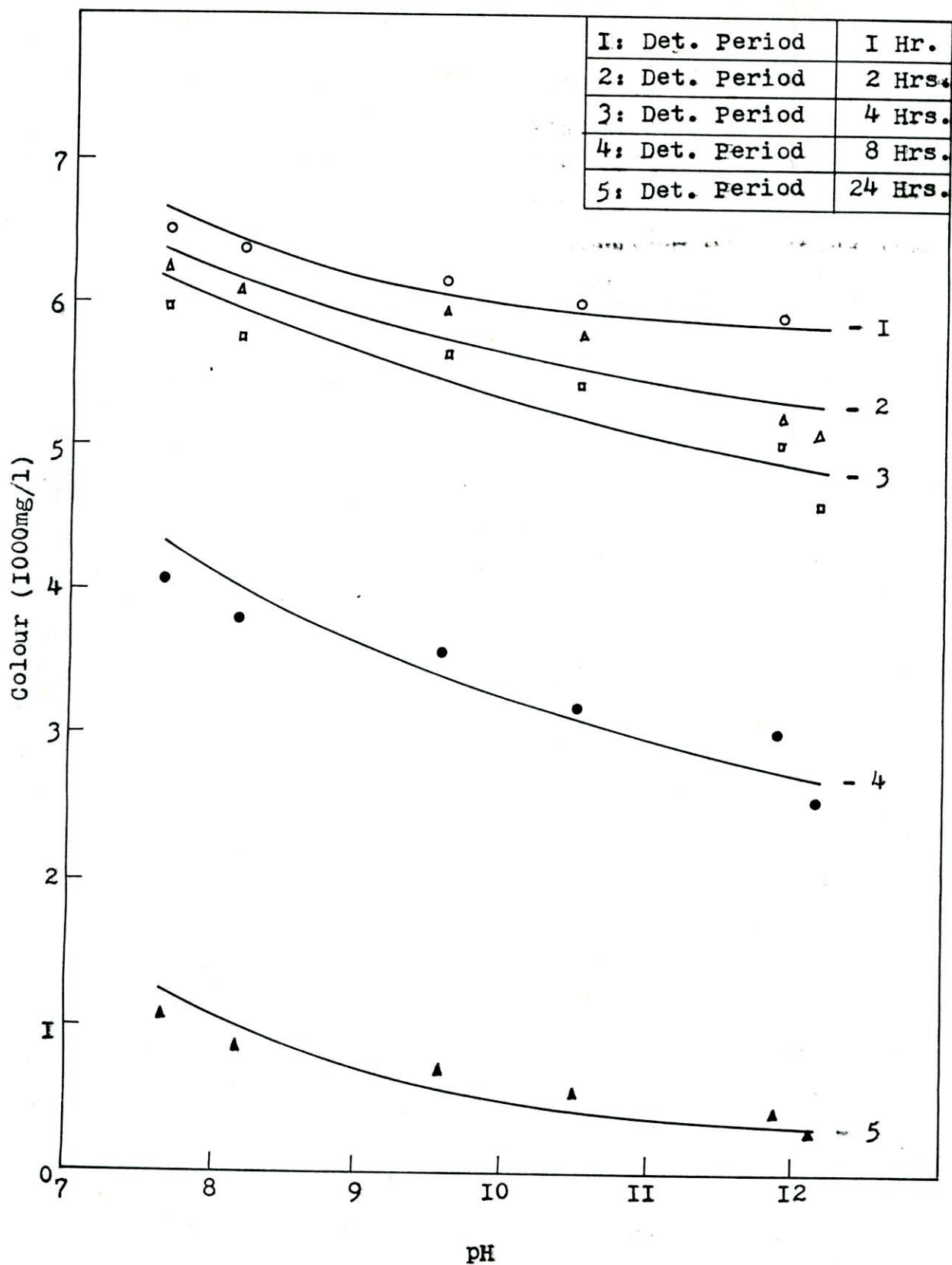


Figure 4.3(e) Colour vs pH at different Detention Period
(Coagulant : NaOH)

Figure 4.3(g) shows the variation of pH with NaOH dosage at a fixed dose of alum. This variation was linear and was determined by regression analysis of the data given in Table 4.3.3 in Appendix-A.

After comparing these results with those found earlier for alum and NaOH it could be seen that the pH value increased, in this case, with the increase in NaOH dosage. But, this increase was less than that occurred during coagulation with NaOH used alone. Similarly, the rate of reduction of turbidity and colour in this case, was not as high as that with NaOH alone but higher than that with alum alone. So, it could be concluded that NaOH plus a fixed dose of alum used as coagulant is more effective than alum alone and less effective than NaOH in reducing the concentration of colour and turbidity of the textile dyeing waste.

It has been described in Chapter-2 that, during dyeing the stability of padding liquor is achieved by adding acetic acid at pH value 6-7⁽²⁵⁾. Migration of dyes during dyeing are prevented by the addition of neutral alginate thickening (2%). When alum was added as a coagulant the net effect of the addition had been the formation of large, insoluble, positively charged particles and production of free hydrogen ion from

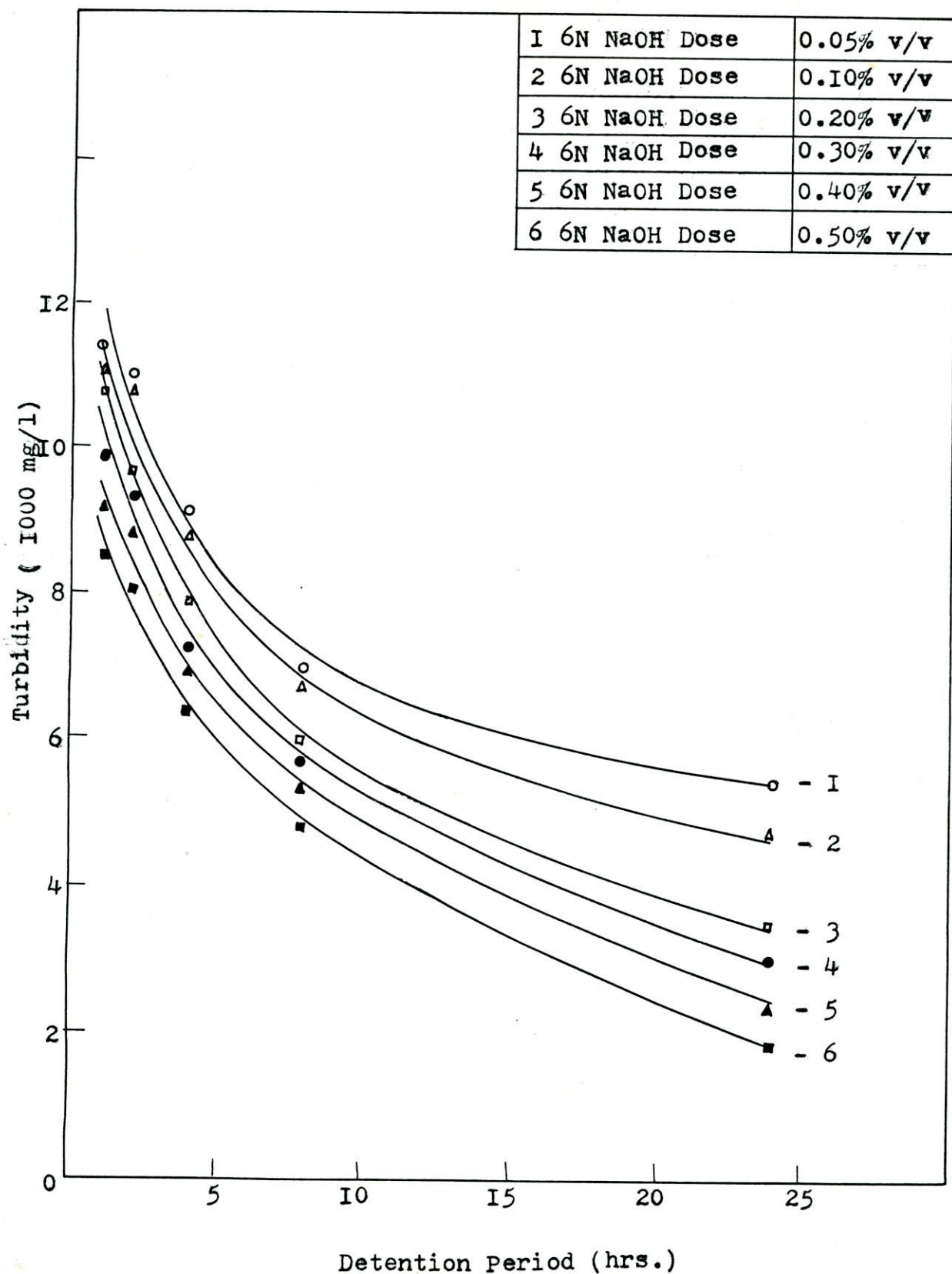


Figure 4.3(f) Variation of Turbidity with Detention Period at different dosage of NaOH & 600mg/l of Alum

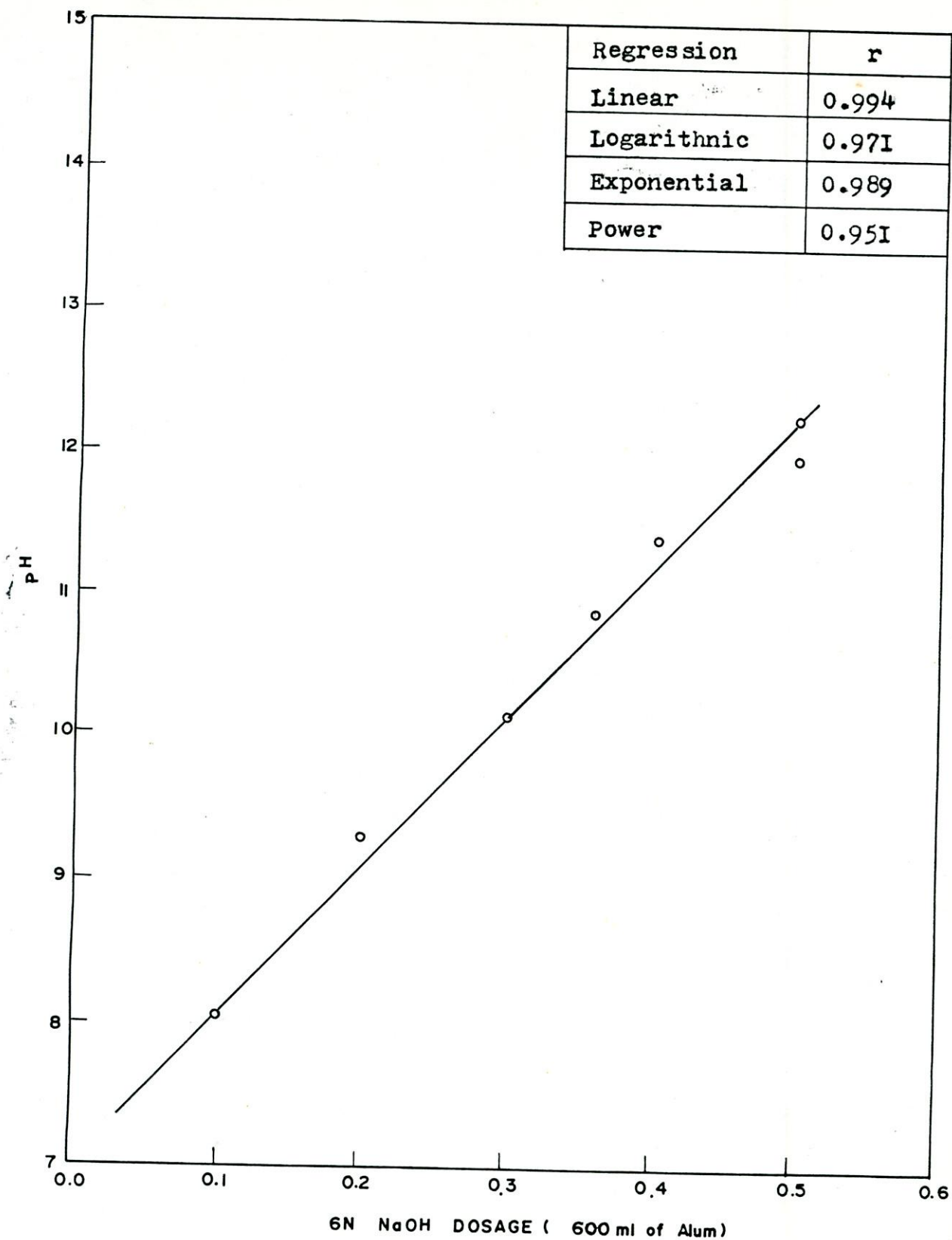


Figure 4.3(g) Variation of pH with NaOH and 600 mg/l Alum

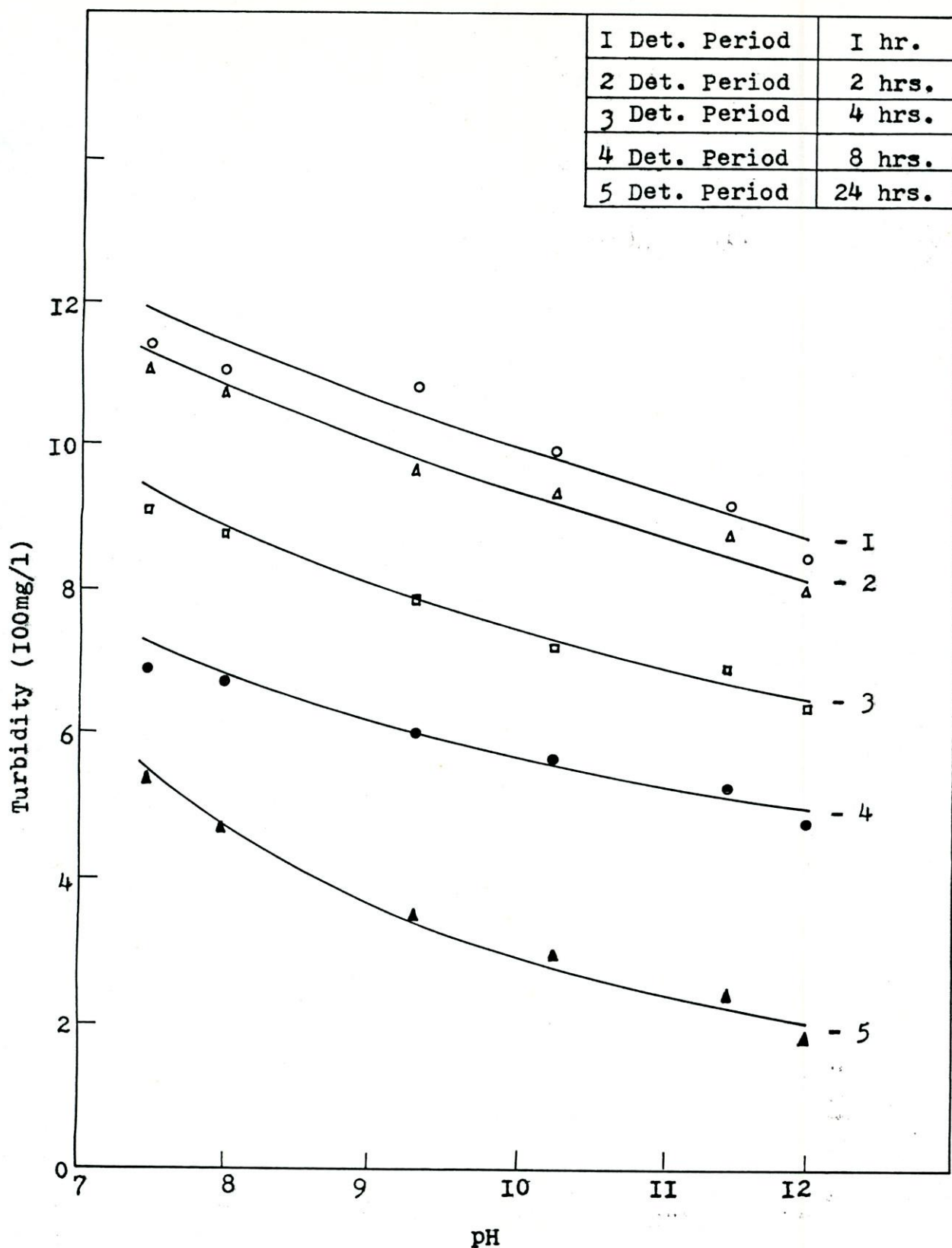


Figure 4.3(h) Turbidity vs pH at different Detention Period
(Coagulant: NaOH and 600mg/l Alum)

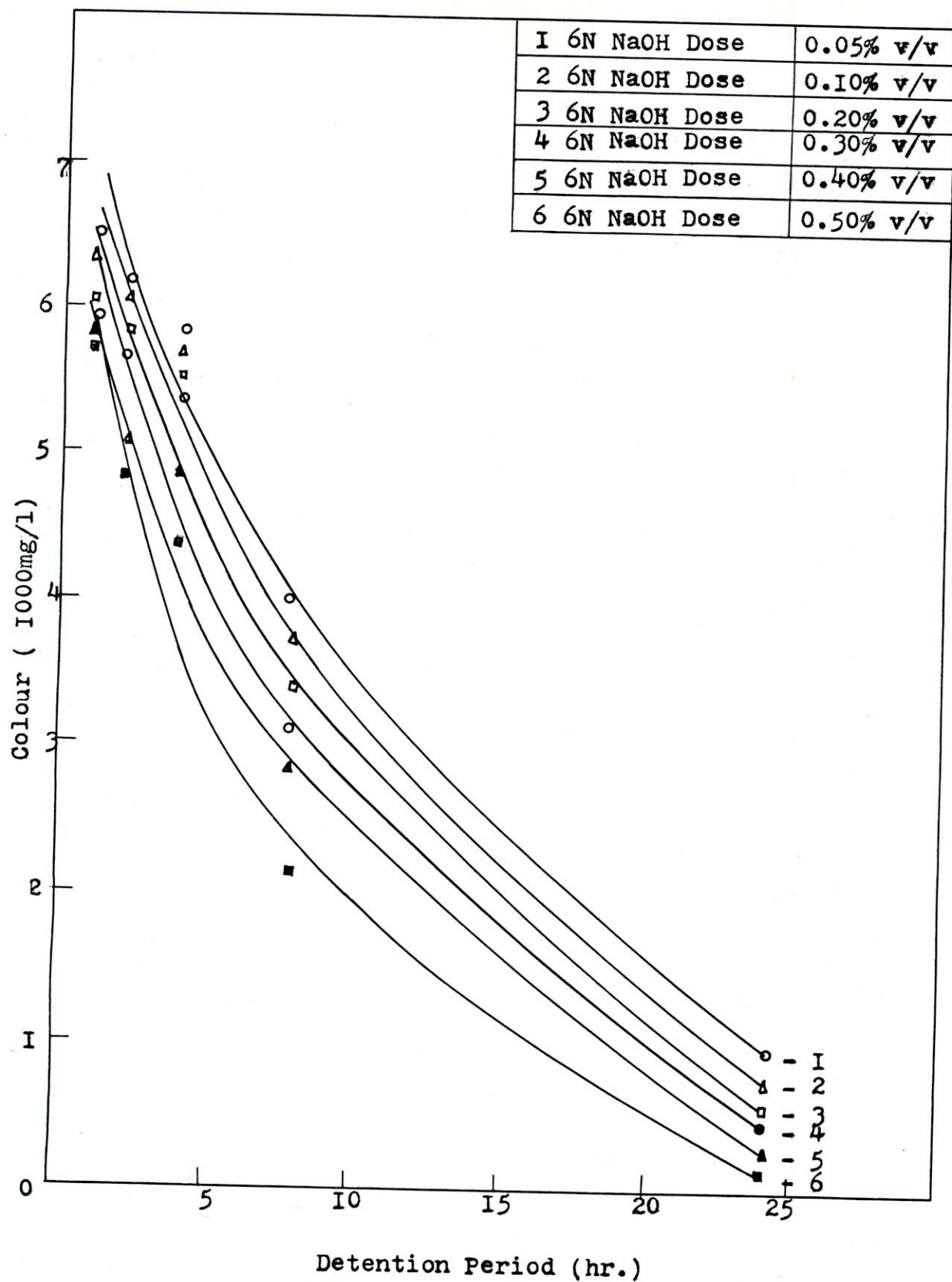


Figure 4.3(i) Variation of Colour with Detention Period
(Coagulant: NaOH and 600 mg/l Alum)

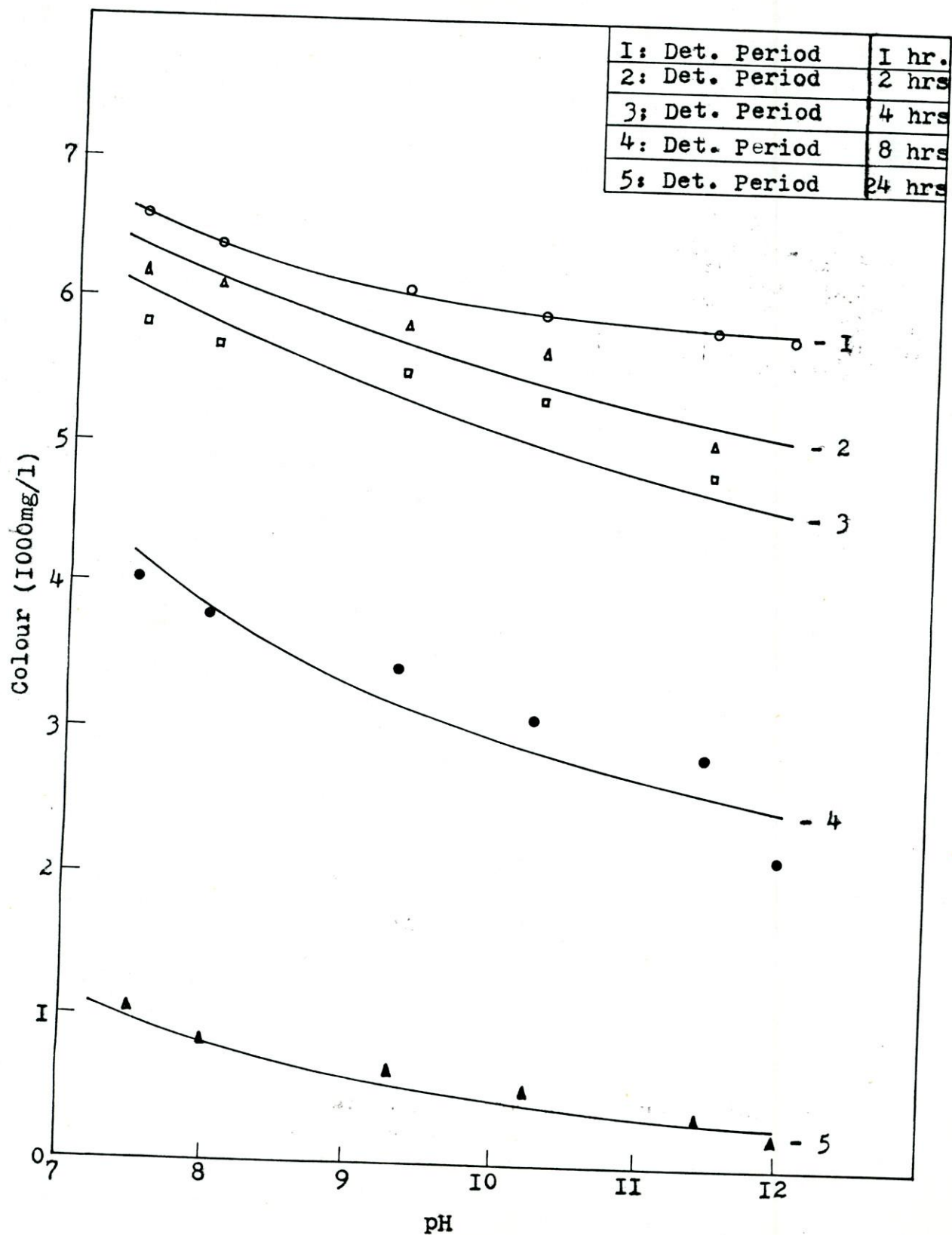
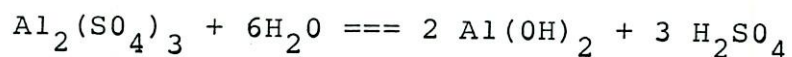
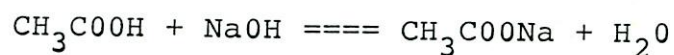


Figure 4.3(j) Colour vs pH at different Detention Period
(Coagulant: NaOH and 600 mg/l Alum)

the water involved in the hydrolysis. The complex process involved could be represented by a more simplified form by the equation



The sulphuric acid generated from the above reaction reduced the pH of the waste, which is represented by the Figure 4.2(d). The NaOH used as coagulant reacted with the acetic acid of the diluted waste to form flocs which were eventually removed by settling. The reaction involved here was



However, this NaOH when added to the raw waste did not produce any floc. This was due to the neutral alignate thickening (2%) which was added during dyeing to prevent migration of dyes and which eventually prevented any feasible reaction with acetic acid. When diluted the concentration of alignate thickening decreased allowing NaOH to react with acetic acid. Again, alum and NaOH individually reduced colour and turbidity. But when they were simultaneously used as coagulants the reduction of colour and turbidity were less than that achieved by NaOH. During simultaneous use of alum and NaOH, the net amount of free available NaOH, which eventually reacts with the acetic acid, is reduced. This is because, the sulphuric acid produced

during the reaction between alum and water is neutralized by a portion of the NaOH added.

4.3 FILTRATION WITH LOW-COST MATERIALS

4.3.1 General

Filtration is a physical process to treat industrial wastewater and surface water. It can be accomplished by passing the water through a prearranged granular medium with or without the addition of chemicals. The mechanisms associated with filtration are straining, interception, impaction, sedimentation and adsorption described in section 2.4.5. Chemical treatment, such as sedimentation with coagulation, requires considerable amount of chemicals and the cost of operation and treatment of the wastes increase considerably. So, filtration, the physical treatment process, using low-cost materials, was used to remove the colour and turbidity along with other impurities present in the textile dyeing waste. Plate 4.2 represents one of the filter columns used.

4.3.2 Experimental Results

As discussed earlier, the major mechanisms involved in removing the impurities from the waste during filtration are straining, adsorption, interception and impaction. The four

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Plate 4.2 - Filtration Apparatus

low-cost materials chosen as the filter material are (i) rice husk, (ii) saw dust, (iii) charcoal and (iv) burnt rice husk or ashes of rice husk.

Fixed bed, down flow column studies were conducted to evaluate the practical usefulness of the low-cost materials. Glass burettes of 1/2 inch inner diameter and 30 inch in length were used as filter columns. They were first filled with glass-wool and then ordinary cotton to prevent washing down of the sorbent materials as well as a solid bed for the granular filter materials. Then an one inch layer of Ottawa sand was provided in each filter column. The columns were then stopped at the bottom with stop-cocks and then were slowly and uniformly filled with sorbent or filter materials to a depth of 6 inches. All the columns were filled upto 18 inches above the sorbent materials with the wastewater. The flow rate of all the filter columns were fixed manually at 1ml/ per minute and a close check was maintained to keep the head, under which the flow occurred, constant by manually adding wastewater to the 18 inch mark. The column effluent, after filtration were analyzed after 5 hours of filtration period, which is the average filter run of all the filter columns considered and the test results are given in Tables 4.4.1, 4.4.2, 4.4.3 and 4.4.4.

Figure 4.4(a) is the bar-chart showing the raw and treated wastewater qualities, where, the filter column was filled with

rice husk filtering material. During treatment it was observed that the break through of the waste occurred rapidly in case of rice husk aggravating the effluent quality at an alarming rate. The removal of colour and turbidity through this filter column was 29.7% and 31.53% respectively. Removal of suspended and dissolved solids were 38.23% and 20.23% respectively. This indicates that the use of rice husk in the removal of pollutants from textile dyeing waste is not an effective way.

The physical properties of the textile dyeing waste before and after filtration through the filter column filled with saw dust are shown in Figure 4.4(b). It was observed that the surface of the saw dust which adsorb the colour pigments and other impurities rapidly became ineffective and clogging of the filtering media caused disruption of further filtration. The colour of the waste was quite high and only 10% colour was removed through treatment. In case of turbidity, suspended solids and dissolved solids the percentage removals were 17.12%, 20.52% and 9.25% respectively.

Table 4.4.3 in Appendix-A, represents the quality of the textile dyeing waste before and after filtration through charcoal filter column and also gives the percentage removal of all the impurities. Figure 4.4(c) is the bar-chart showing the effects given in Table 4.4.3 in Appendix-A. The percentage removal of colour and turbidity were 85.61% and 76.58%

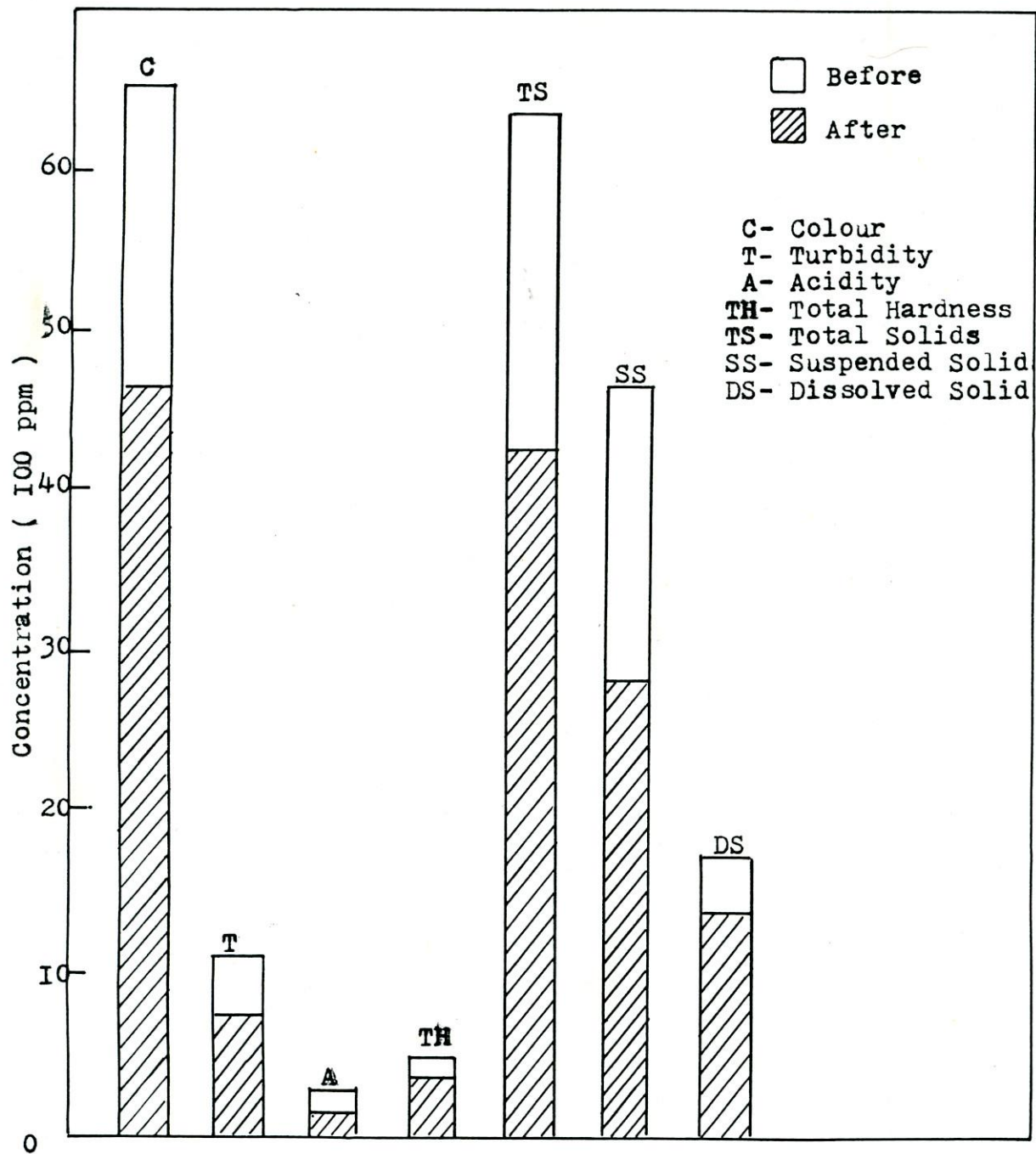


Figure 4.4(a) Effect of Filtration through RICE HUSK filter column

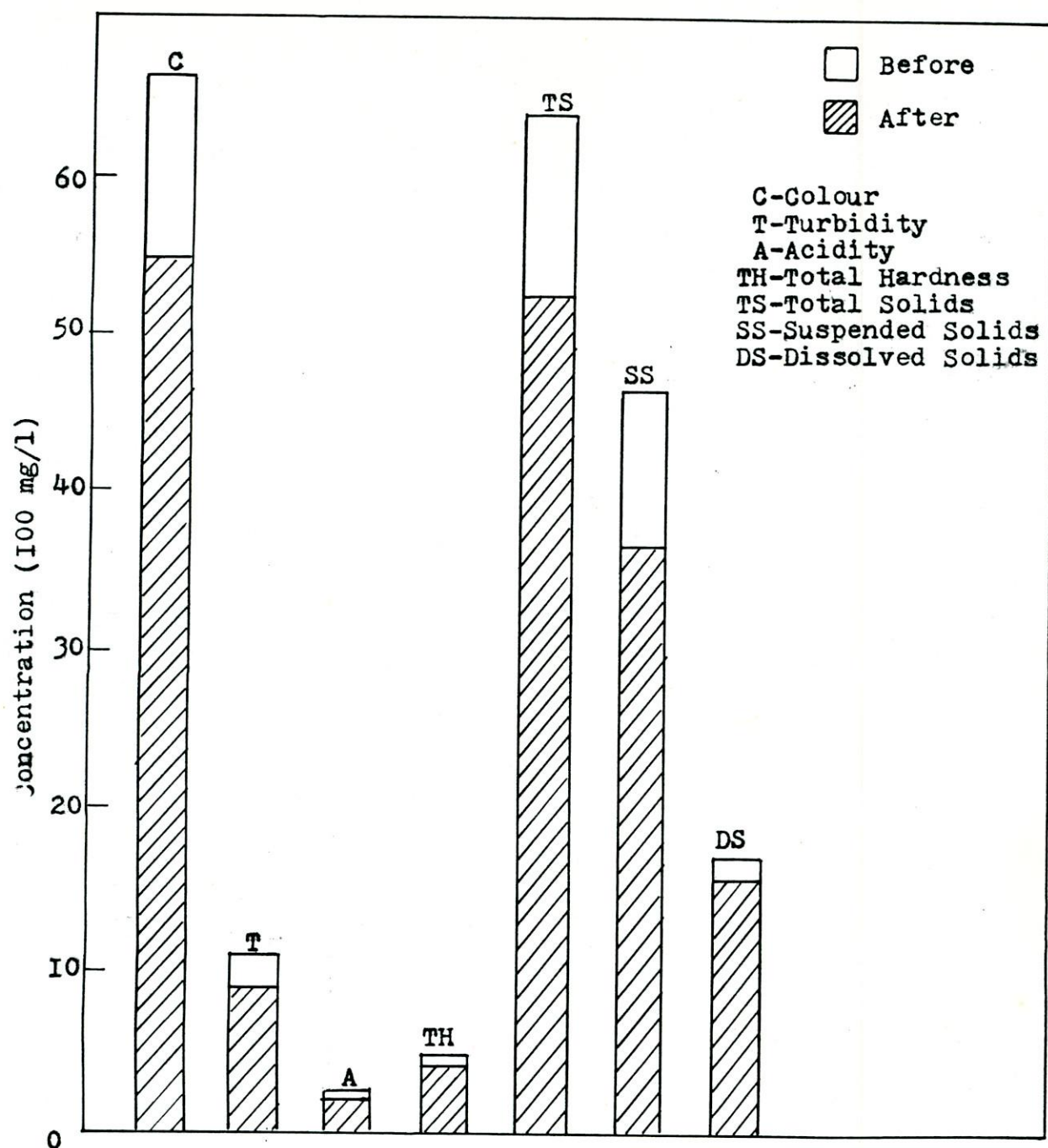


Figure 4.4(b) Effect of Filtration through SAW-DUST filter column

respectively. The suspended and dissolved solids removed due to filtration through charcoal were 92.96% and 85.72%. However, the effectiveness of the charcoal filter column decreased rapidly with time as the dry surface of the filtering materials got wet due to the formation of thin layer on charcoal by the colour pigments and turbidity causing elements.

The effectiveness of the filter column formed with burnt rice husk is shown in Table 4.4.4 and graphically through bar-chart in Figure 4.4(d). Studying the results obtained, it could be easily seen that, the colour and turbidity removed by this filter column were 92.27% and 84.23% respectively. The total, suspended and dissolved solids removed by this filter column were 92.28%, 93.84% and 88.09% respectively. However, this filter column showed the same difficulties as those shown by the charcoal filter column.

Filter column studies of these four low-cost material have shown that burnt rice husk and charcoal have the highest adsorption capacities. However, these filter materials get clogged within a short period and the adsorption capacities of both of these materials gradually decrease with time. This is because, the adsorbing surface of the filter materials swiftly become covered with the dye pigments and the suspended particles and reduce the effectiveness of the filter column.

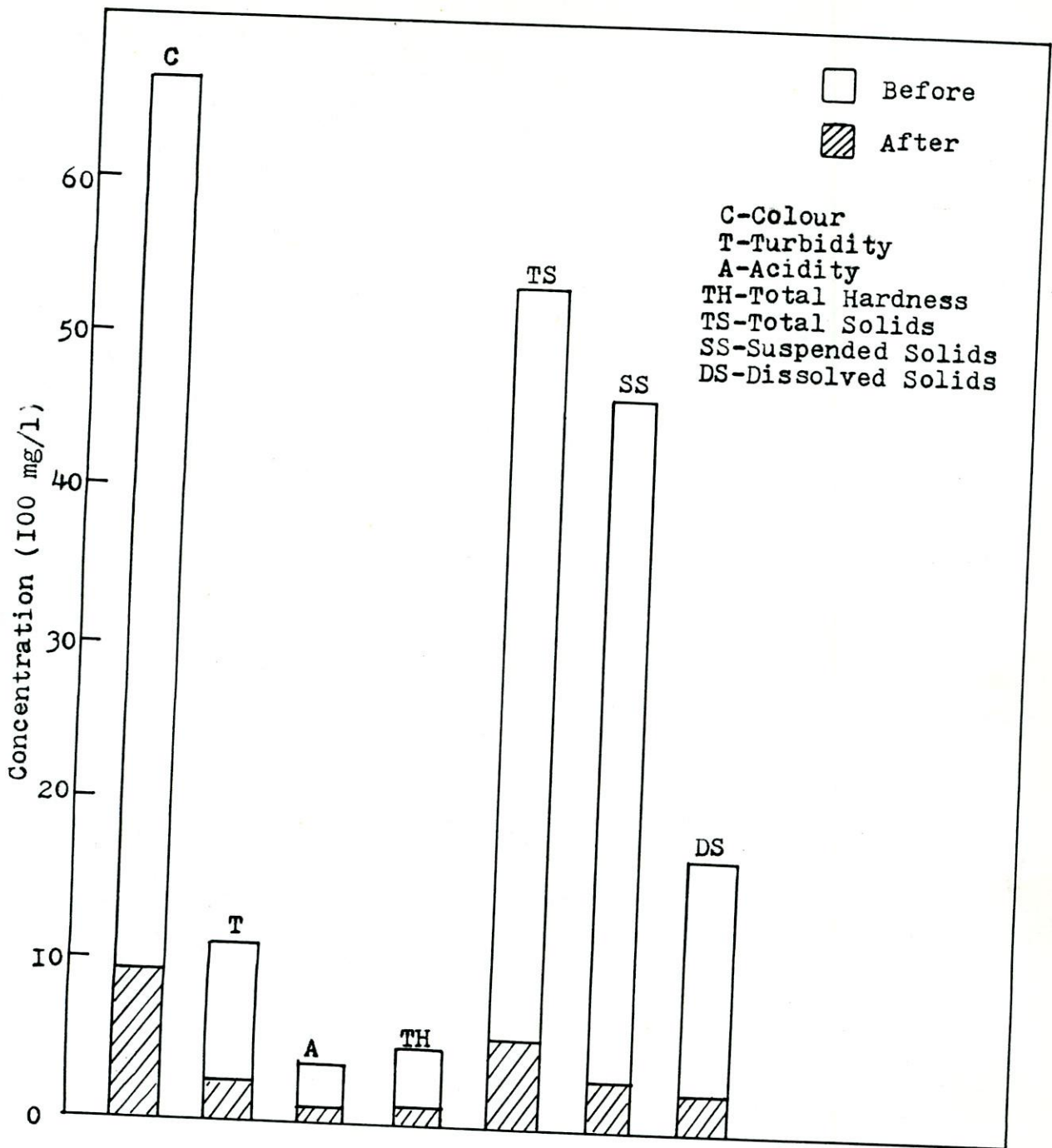


Figure 4.4(c) Effect of Filtration Through CHARCOAL filter column

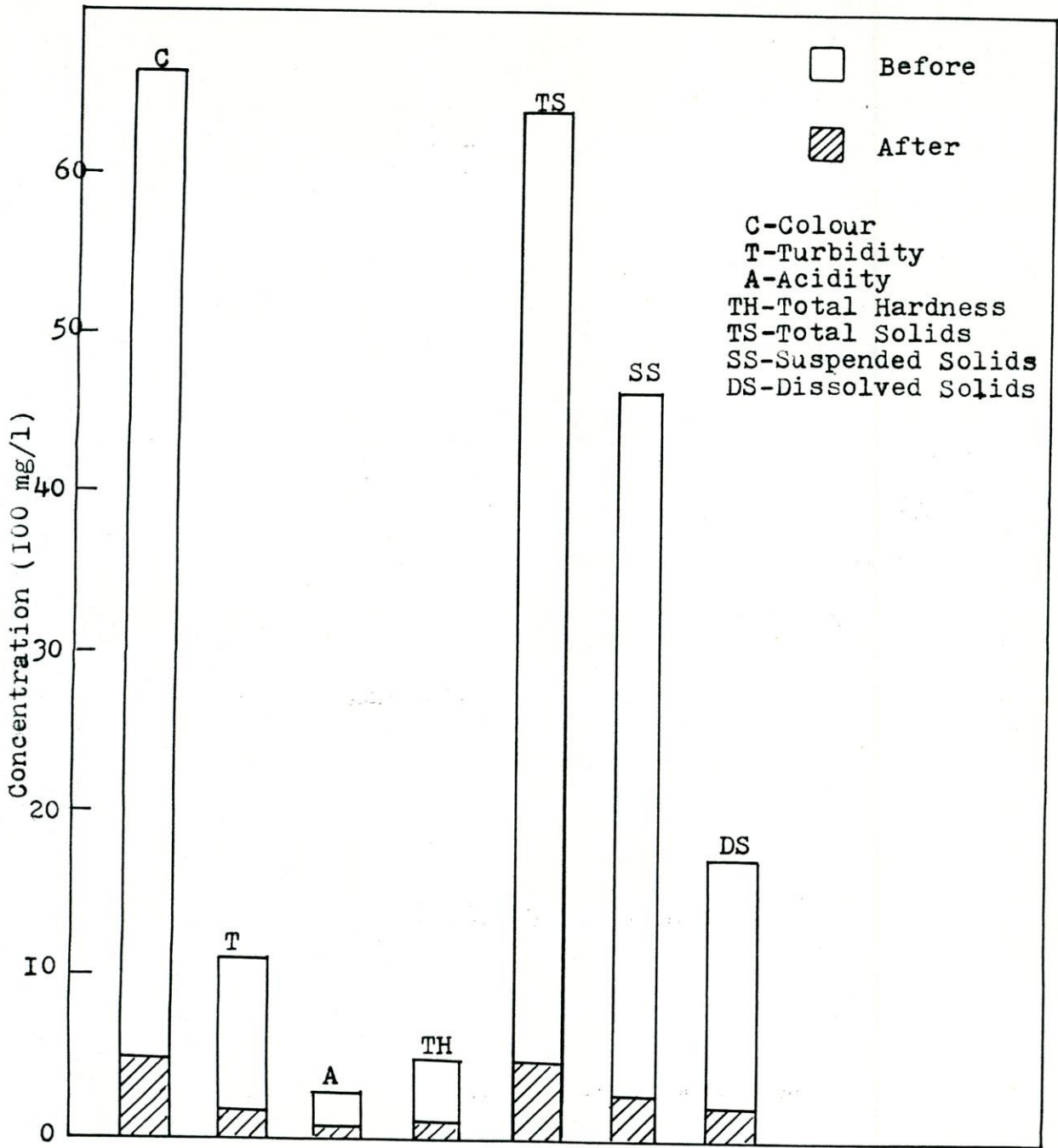


Figure 4.4(d) Effect of Filtration through BURNT RICE-HUSK filter column

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The quality of the textile dyeing effluent was evaluated through detail laboratory analysis. The improvement of the quality of the effluent by treatment processes like plain sedimentation, sedimentation with coagulation and filtration through different low-cost materials was observed. The results were critically examined and the following conclusions were drawn:

- 1) High organic and inorganic substances are inherent of the textile dyeing wastes which require extensive treatment before final disposal in the natural water courses to prevent water pollution.

- 2) The biodegradability of the waste, determined through COD:BOD ratio, has been found to be within 2.0 to 3.0, which indicates that maximum 50% of the organic matters could be stabilized through biological treatment process.

- 3) 24 hours of detention during plain sedimentation reduced about 50% of the suspended solids and about 25% of COD, BOD and colour from the textile dyeing waste. The concentration of

impurities in the effluents from plain sedimentation remained extremely high which rendered it unfit for inoffensive disposal of the effluents into the city sewer line.

4) The efficiency of flocculation sedimentation process in removing the colour and turbidity varied with the type of coagulant used. Alum, used as coagulant, initially increased the turbidity of the waste but, eventually reduced it to an acceptable limit when allowed to settle for a long period. Sodium hydroxide, when used as coagulant, caused floc formation and eventual reduction of colour and turbidity to an acceptable level within a reasonable detention period. Combination of NaOH and a fixed concentration of alum as coagulants in the treatment of textile dyeing waste was more effective than alum acting alone and less effective than NaOH alone. This may be due to the presence of alignate thickening used during textile dyeing.

5) pH of the textile dyeing waste has been found to be 6.85. It varied with the addition of coagulant. Alum reduced the pH of the waste and increased its acidity resulting an increase in turbidity and lesser floc formation. Sodium hydroxide increased the pH of the waste and made it alkaline, resulting higher floc formation and finally, reduction of turbidity and colour. This was due to the reaction between acetic acid and sodium hydroxide.

6) Physical treatment of filtration with low-cost materials removed considerable amount of colour, turbidity, suspended solids and dissolved solids. The effectiveness of filtration depends on the type of material used. Both rice husk and sawdust removed the impurities. But, the percentage removal of the impurities by filtration through these materials was not high enough for inoffensive disposal of waste into natural water sources. Removal of colour and turbidity by filtration through charcoal was higher than that obtained by filtration through rice husk and saw dust. The percentage of colour and turbidity removed by burnt rice husk were very high. So, filtration through charcoal and/or burnt rice husk made the textile dyeing waste significantly free from pollutants and made it suitable for inoffensive disposal into natural water courses or domestic sewer system.

5.2 RECOMMENDATIONS FOR FURTHER STUDY

The general picture of the polluting effects of the textile dyeing wastes collected from Tejgaon industrial area in Dhaka, is represented by the study conducted here. The quality of the waste varies considerably with time. In order to assess the actual situation, samples must be collected and analyzed more frequently over the whole year.

The chemical treatment, conducted on the waste with sodium hydroxide, proves to be less effective on the raw

waste. However, when diluted the effectiveness of this coagulant increases appreciably. Further tests may be carried out to determine the composition of the chemical causing this problem. The effectiveness of sodium hydroxide on the waste having acid or basic dyes may be examined.

Physical treatment of filtration although proves to be effective in the laboratory. The operational problems may make it unsuitable in the field condition. This may be ascertained by constructing model treatment plant in the adjacent region. Areas may be explored to overcome the major problem of rapid clogging of the low-cost filter materials. Furthermore, the rate of reduction of colour with time can be determined. The variation of the percentage removal of colour with the depth of the filter materials can also be explored.

Biological treatment studies may be carried out on the textile dyeing waste by mixing it with domestic sewage. Plain sedimentation preceded by aeration may prove to be effective.

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APPENDIX

Table 3.1 Quality of Textile Dyeing Waste

Location	Parameters	Concentration Present	USPHS (Maximum) Limit* 1971
Tejgaon Industrial Area	pH	6.85	7.0-8.0
	Colour	6600.0	20.0
	Turbidity	1110.0	10.0
	Acidity	280.0	120.0
	Total Hardness	500.0	150.0
	Total solids	6360.0	1000.0
	Suspended solid	4630.0	-
	Dissolved solid	1730.0	-
	BOD at 20°C	180.0	-
	COD	395.	-

Note: Except pH all are in ppm or mg/l.

Table 4.1 Reduction of Suspended Solids, BOD and COD with Detention Period in Plain Sedimentation.

Detention, period, hour	Suspended solids, ppm	% removal of suspended solids	BOD ppm	% removal of BOD	COD ppm	% removal of COD	Colour	% removal of colour
Original sample	4630	-	180	-	395	-	6600	-
2.0	4310	6.91	177	1.67	382	3.29	6510	1.36
3.0	4140	1.58	172	4.44	373	5.57	6390	3.18
3.5	3990	13.83	164	8.88	350	11.39	6330	4.09
4.0	3770	18.57	160	11.11	342	13.42	6210	5.91
4.5	3650	21.17	156	13.33	337	14.68	6100	7.58
5.0	3580	22.68	151	16.11	330	16.46	5920	10.30
24.0	2110	54.43	140	22.22	310	21.52	5100	22.73

Table 4.2 Flocculation Sedimentation of Textile Dyeing Waste
by stirring in the Jar Test

Jar No.	1	2	3	4	5	6	
Coagulant	Alum	Alum	Alum	Alum	Alum	Alum	
Dosage (mg/l)	300	400	500	550	600	650	
Turbidity (mg/l) after detention time of (hour)	1/2	1240	1310	1440	1490	1530	1590
	1	1210	1290	1410	1470	1500	1570
	2	1140	1230	1370	1430	1470	1540
	4	1050	1150	1310	1370	1410	1490
	6	1010	1110	1250	1310	1350	1410
	8	980	1030	1180	1260	1290	1350
	24	800	840	1000	1120	1180	1210
pH	7.15	6.75	6.62	6.48	6.25	6.12	
Colour (mg/l)	6360	6010	5860	5570	5340	5170	

Table 4.3.1 Effect of NaOH Dosage and Detention Period
Upon Residual Turbidity of the Sample.

6N NaOH Dosage (% , v/v)	0.05	0.1	0.2	0.3	0.4	0.5
Turbidity (mg/l) after detention period of (hour)						
1	1090	940	870	820	780	700
2	930	900	810	790	740	650
4	850	790	720	640	600	460
8	630	590	560	470	400	290
24	370	320	280	230	170	110
pH	7.67	8.19	9.6	10.52	11.90	12.13

4.3.2 Effect of NaOH and Detention Period on Colour of the Sample

6N NaOH Dosage (% , v/v)	0.05	0.1	0.2	0.3	0.4	0.5
1	6550	6400	6180	6010	5910	5830
2	6230	6100	5970	5760	5200	5090
4	5960	5730	5650	5420	5030	4630
8	4100	3820	3630	3210	3010	2570
24	1070	860	710	580	410	290
pH	7.67	8.19	9.6	10.52	11.90	12.13

Colour (mg/l) After
Detention Period of
(hours)

Table 4.3.3 Effect of Alum, NaOH Dosage and Detention Period Upon Residual Turbidity of the Sample.

Coagulant (Alum) Dosage (mg/l)	600	600	600	600	600	600	
6N NaOH Dosage (% ,v/v)	0.05	0.1	0.2	0.3	0.4	0.5	
Turbidity (mg/l) After Detention Period of (hours)	1	1140	1100	1080	990	920	850
	2	1100	1070	970	930	880	800
	4	910	880	790	730	700	640
	8	700	680	600	570	530	480
	24	540	470	350	300	240	190
pH	7.45	7.97	9.30	10.21	11.43	11.96	

Table 4.3.4 Effect of Alum, NaOH and Detention Period Upon Colour of the Sample.

Coagulant Dose (mg/l)	600	600	600	600	600	600	
6N NaOH Dosage (% v/v)	0.05	0.1	0.2	0.3	0.4	0.5	
Colour (mg/l) After Detention Period of (hours)	1	6530	6370	6050	5920	5840	5770
	2	6160	6070	5830	5660	5070	4880
	4	5830	5690	5510	5320	4860	4380
	8	4010	3770	3440	3110	2870	2190
	24	1000	820	640	510	360	210
pH	7.45	7.97	9.3	10.21	11.43	11.96	

Table 4.4.1 Quality of Textile Dyeing Waste After
Filtration Through Rice-husk Filter Column

Location	Parameters	<u>Concentration Present</u>		% Removal
		Before Treatment	After Treatment	
Tejgaon Industrial Area	pH	6.85	7.27	-
	Colour	6600.0	4640.0	29.70
	Turbidity	1110.0	760.0	31.53
	Acidity	280.0	156.0	44.29
	Total hardness	500.0	370.0	26.0
	Total solids	6360.0	4240.0	33.33
	Suspended solids	4630.0	2860.0	38.23
	Dissolved solids	1730.0	1380.0	20.23

Note: Except pH all units are in ppm or mg/l.

Table 4.4.2 Quality of Textile Dyeing Waste After Filtration Through Saw-dust Filter Column

Location	Parameters	<u>Concentration Present</u>		% Removal
		Before Treatment	After Treatment	
Tejgaon Industrial Area	pH	6.85	7.34	-
	Colour	6600.0	5490.0	10.0
	Turbidity	1110.0	920.0	17.12
	Acidity	280.0	210.0	25.0
	Total hardness	500.0	430.0	14.0
	Total solids	6360.0	5250.0	17.45
	Suspended solids	4630.0	3680.0	20.52
	Dissolved solids	1730.0	1570.0	9.23

Note: Except pH all units are in ppm or mg/l.

Table 4.4.3 Quality of Textile Dyeing Waste After Filtration Through Charcoal Filter Column

Location	Parameters	<u>Concentration Present</u>		% Removal
		Before Treatment	After Treatment	
Tejgaon Industrial Area	pH	6.85	7.15	-
	Colour	6600.0	950.0	85.61
	Turbidity	1110.0	260.0	76.58
	Acidity	280.0	96.0	65.71
	Total hardness	500.0	110.0	78.0
	Total solids	6360.0	573.0	91.0
	Suspended solids	4630.0	326.0	92.96
	Dissolved solids	1730.0	247.0	85.72

Note: Except pH all are in mg/l or ppm.

Table 4.4.4 Quality of Textile Dyeing Waste After Filtration Through Burnt Rice-husk Filter Column

Location	Parameters	Concentration Present		% Removal
		Before Treatment	After Treatment	
Tejgaon Industrial Area	pH	6.85	7.06	-
	Colour	6600.0	510.0	92.27
	Turbidity	1110.0	175.0	84.23
	Acidity	280.0	53.0	81.07
	Total hardness	500.0	97.0	80.60
	Total solids	6360.0	491.0	92.28
	Suspended solid	4630.0	285.0	93.84
	Dissolved solid	1730.0	206.0	88.09

Note: Except pH all are in mg/l or ppm.

