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Changes of Available Nitrogen, Phosphorus and Sulfur in Sewage Sludge Amended Soils

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Dissertation submitted to Jawaharlal Nehru University
in partial fulfilment of the requirements
for the award of the Degree of
MASTER OF PHILOSOPHY

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D. SUDHAKARA RAO

SCHOOL OF ENVIRONMENTAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110067, INDIA
1990

जवाहरलाल नेहरु विश्वविद्यालय
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110067

CERTIFICATE

This dissertation entitled "Changes of Available Nitrogen, Phosphorus and Sulfur in Sewage sludge amended soils" has been carried out at the school of Environmental Sciences, Jawaharlal Nehru University, New Delhi. This work is orginal and has not been submitted in part or full for any other degree or diploma of any university.

D. SudhakaraRao.
D. SUDHAKARA RAO
(Student)

Dr. A.K. BHATTACHARYYA
(Supervisor)
28/11/90

PROF. C.K.VARSHNEY
(Dean)
28/11

August, 1990.

SCHOOL OF ENVIRONMENTAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110 067.

Gram : JAYENU   Tel. : 667676, 667557   Telex : 031-4967 JNU IN

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THE CHERISHED MEMORY OF

MY BELOVED FATHER

ACKNOWLEDGEMENTS

I express my deep sense of gratitude to Dr.A.K.Bhattacharyya, for having suggested to me this problem and also for his valuable guidance and supervision throughout the course of this work. His constrtuctive suggestions at the time of preparing this dissertation helped me in bringing it to the final shape.

I am thankful to Pro.C.K. Varshney, Dean and Prof.L.K. Pandey, the former Dean, School of Environmental Sciences, for providing me with necessary facilities and help.

I am thankful to the authorities of "Delhi water supply and sewage disposal undertaking" for their kind permission to collect the sewage sludge samples from Okhla sewage Treatment plant, New Delhi, for my research work. I am also thankful to Mr. S.K. Sharma, Water Analyst, for his active co-operation and necessary help.

I am thanful to Dr.R.Subramanian for his keen interest, inspiration and constant encouragement.

My sincere thanks are also due to my seniors, especially Mr. Mukesh Kumar and Raja Sekhar and friends, especially Ramesh Yadav and Krishna for their various kinds of help to complete this work.

I acknowledge the financial assistance in the form of JRF offered to me by the Department of Human Resource Development, Government of India to carry out this reaserch work.

I also express my gratitude to Anand Singh Rawat, and R.N.Shiney for their technical assistance in completing this work.

My thanks are also due to P.M. Anand for neatly typing this work without any delay.

Finally, I am greatly indebted to my parents and my brothers who constantly stood by me and gave me moral and emotional support at moments of depression.

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INTRODUCTION

INTRODUCTION

Pollution is an undesirable change in the physical, chemical and biological characteristics of air, land and water that will harmfully affect human life or that of desirable species, our industrial processes, living conditions, and cultural assets or that may or will waste or deteriorate our raw material resources. Pollutants are residues of the things we make, use and throw away. Pollution increases not only because people multiply and the space available for each person becomes smaller, but also because the demands per person are continuously increasing, so that each throws away more year by year. As the earth becomes more crowded, there is no longer an `away'. One person's trash basket is another's living space.

Domestic Wastes and Sewage :

Discharge of untreated or partially treated sewage into rivers is one of the most common primary sources of pollution, especially near big cities. Waste disposal in many countries is still archaic. Discharge of treated and untreated sewage into water bodies can produce the following symptoms. (a) depletion of oxygen content caused by biological oxidation of organic matter, (b) stimulation of algal growth and also a shift in the algal flora to the blue green algae, leading to production of obnoxious blooms, floating scums or blankets of algae etc. Sewage discharge into waterways can lead to the spread of waterborne diseases, but the most important effect is that sewage increases biological productivity and this can inturn affect the diverse use of the waterway.

The water and soil pollution due to industrialisation and urbanisation is a cosmopolitan problem, creating acute insanitation as well as affecting the soil and crops (Ajmal and Khan, 1983). But according to K.Day et al., (1972), irrigation with waste water over extended periods did not decrease field crop yields or result in any major deterious effects on agricultural soils in southern Arizona.

Proper management of municipal and industrial wastes is necessary not only for our welfare, but also for the well being of future generations. Land disposal remains one of the viable methods of waste management practices. In this case an adequate evaluation of the movement and accumulation of pollutants from the source of contaminants in the soil is required. Also precise information on the fate and attenuation of pollutants is needed to establish a base for evaluating waste disposal system (Amoozegar et al., 1984).

Sewage sludge is the byproduct during the sewage water treatment. Due to shortage and subsequent increased cost of fertilizers greater encouragement should be given in the use of sewage sludge for the fertility of culture land. The total consumption of fertilizers in our country is about 9.2 m.tonnes and is expected to increase to about 20 m.tonnes by the turn of the twentieth century. Chemical fertilizers are expensive and their manufacture depends on the dwindling resources of energy such as petroleum and coal. Their production also releases pollutants. Further, fertilizers aplied to crop lands are lost in surface run off and pollute soil and water resources. The sewage sludge are rich in plant nutrients. In addition to Nitrogen, the most important plant nutrients are the non-metals, viz. Phosphorus and Sulphur, and the metals, viz. Potassium, Calcium and Magnesium with smaler amounts of micronutrients particularly iron, manganese and boron (Sekar, T and Bhattacharyya, 1982; El Nennah and El.Kobbia, 1983).

Application of industrial wastes and sewage sludges on agricultural soils is receiving greater emphasis because of the increasing energy requirements and costs associated with alternative disposal methods and because of the benefits gained from recycling plant nutrients present in wastes. After application to soils, the various components in wastes are subjected to a diversity to chemical and biochemical process. The main processes of interest are decomposition of organic compounds, transforamtion of Nitrogen, Phosphorus and Potassium and alteration of metal solubility. These processes, either directly or indirectly influence the availability of metals and nutrients to plants, the morbidity of N, P, K, Ca and Mg, and the potential environmental impact (eg. ground water contamination) resulting from waste application on soil (Sommers et al., 1979).

In view of environmental polution and water shortage the waste water renovation and reuse technology has become a major area of interest. As the water resources are limited and are being rapidly despoiling and exhausting, it is very essential to pay attention to national conservation, renovation and reuse of water to protect our precious water resources and recycle them for the better use of man. The driving force to reuse waste water has mainly been the urgent need to conserve and reuse water in mid areas and to reduce river and take pollution (Shuval, 1977).

The advantages in the use of treated waste water for irrigation are (a) low cost source of water, (b) an economical way to dispose off waste water to prevent pollution and sanitary problems, (c) an effective use of plant nutrients contained in waste water, and (d) providing additional treatment before being recharged to the ground water reservoir. Waste water usually the cheapest water in the a areas. In some cases, it is the only water available for irrigation (Noy and Feinmesser, 1977). Direct reuse of municipal and industrial waste water for irrigation purposes is extensively practice in India. The first sewage farm in India was established in 1895. By 1976 there were over 132 farms covering more than 12,000 hectares and utilizing over 1 million m of sewage per day (Arceivalva, 1977).

<u>The Phases of Waste Treatment</u> :

The treatment of degradable wastes is in three stages. (i) Primary treatment, a mechanical screening and sedimentation of solids (which are burned or burried); (2) Secondary treatement, a biological reduction of organic matter; and (3) Tertiary or advanced treatment, the chemical removal of phosphates, nitrates, organics and other materials. The most common design is the activated sludge system which requires electric pumps or other energy to aerate and circulate the material. Another system is the `trickling filter' system in which the primary treatment affluent moves by gravity over stone or rocks of plastic surfaces that create an aerated surface resembling the rapids in a natural system.

Okhla Sewage Treatment Plant :

The Okhla sewage treatment plant is one of the three plants present in Delhi. It is situated in South Delhi about 6 km far from Lajpat Nagar. The other two plants are Keshorpur Sewage treatement Plant in West Delhi and Coronation Pillar in North Delhi.

The Okhla sewage treatment plant has undergone development in five successive stages started in 1936. The present capacity of the plant is 88 MGD. However it can withstand an overload of 25%. The treatement process is fully biochemical and no chemical is added from outside here. A part of the final treated effluents is bypassed to the Agra Canal. The treated effluents are continuously available for irrigation (Swamy et al., 1986).

The present investigation was undertaken to assess the characteristics of primary treated and secondary treated effluents from Okhla treatment plant and evaluate the available forms of Nitrogen, Phosphours and Sulphur in soil system.

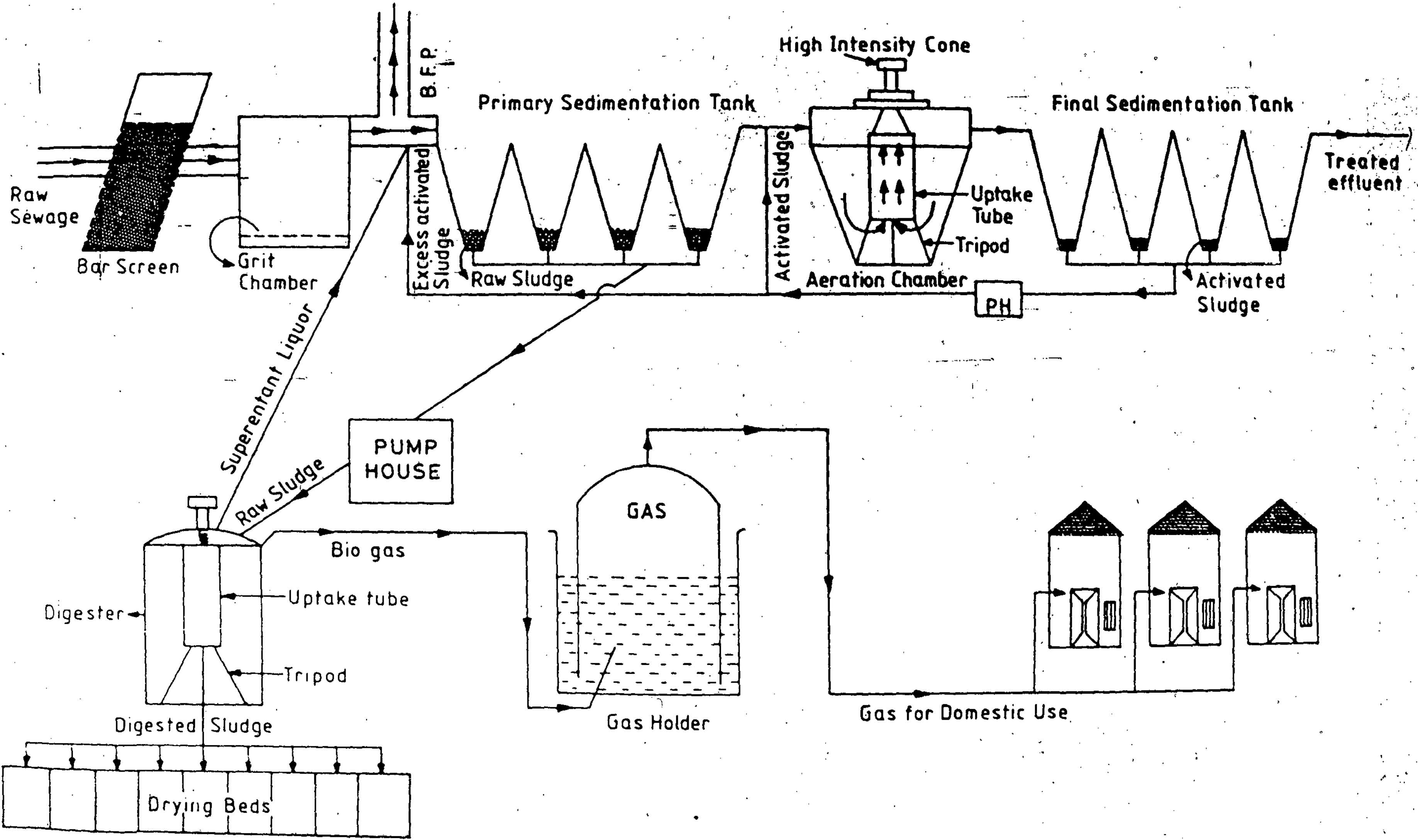


Fig. 1. Okhla Sewage Treatement Plant

Objectives :

The main objectives of this research work are summarised below :

(i) To study the physico-chemical properties of sewage effluents received from Okhla Sewage Treatment Plant, primary and secondary treated.

(ii) To analyse some physico-chemical characteristics of the soils of JNU and Mehrauli.

(iii) To study the changes of total and available forms of Nitrogen, Phosphorus and Sulphur in definite regular intervals of time, in the sewage sludge amended soils.

(iv) To evaluate the correlation, if any, between the available forms of N,P,S and other parameters, specially

(a) Oranic carbon, b) Cation exchange capacity c) pH and d) Electrical conductivity

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In this chapter, an attempt has been made to bring a review of the published work related to the present investigation. Importance has been given to certain aspects of Nitrogen, Phosphours and Sulphur requirements in soil system and their availability for plants considering various factors and effects of sewage sluge on these nutrients availability.

Nitrogen as a Nutrient :

Nitrogen is found in such important molecules as purines, pyramidines, porphrins and coenzymes. Purines and pyramidines are found in the nucleic acids RNA and DNA essential for protein synthesis. The porphrin structure is found in such metabolically important compounds and the chlorophyll pigments and the cytochromes essential in photosynthesis and respiration. Coenzymes are essential to the function of many enzymes.

Nitrogen deficiency symptoms : The most easily observed symptoms of nitrogen deficiency is the yellowing (Chlorosis) of leaves due to a loss in chlorophyll. The nitrogen deficiency symptoms appear last in the younger leaves because of the high mobility of nitrogen in the plant. Under severe conditions of nitrogen deficiency, the lowermost leaves on plants such as tobacco or bean will be dry and yellow and in many cases, will abscise. Under these conditions the topmost leaves are generally pale green in colour. If a plant supplied high concentration of Nitrogen, there is a tendency to increased leaf cell number and cell size with an overall increase in leaf production (Morton, and Watson, 1948). Lutman noted a decrease in leaf epidermal cell size due to nitrogen deficiency in millet and buck wheat.

Phosphorus as a nutrient :

Next to nitrogen the most critical element influencing plant growth and production is phosphorus. It is stored in seeds mainly as phytin, the calcium, magnesium salt of inositol hexaphosphoric acid. This component is hydrolysed enzymatically during germination and the inorganic phosphate released thereby is used by the developing seedlings. Like nitrogen, phosphorus is a constituent of every living cell (nucleotides).

In plant metaboism phosphorus plays a direct role as a carrier of energy. Phosphates in several organic linkages split off by hydrolysis releasing energy. The most important carrier of higher energy phosphate is adenosine tri phosphate (Black, 1973). Phosphorus is said to stimulate root growth. It has been observed that phosphours uptake is influenced by root morphology

(Schenk et al., 1979). As expected phosphorus starved plants tend to have a stunted root system (Barber, 1984). Phosphorus hastens the ripening of plants. It promotes seed formation and maturity of crops. Phosphorus favours pollination which affects quality of corn.

Deficiency Symptoms : If phospohorus is deficient, cell division in plants is retarted and growth is stunted. Plants develop a dark green or bluish green colour which may be coupled with tints of bronze or purple. Phosphorus deficiency produces certain effects that are similar to the effect of nitrogen deficiency (Black, 1973).

Sulfur as a nutrient :

Its most obvious function is its participation in protein structure in the form of the sulfur bearing amino acids, Cystine and Methionine. Sulfur is taken up by the plants as a sulfate ion (SO_4^{2-}) and is subsequently reduced via an activation step involving the compound 3' Phospho adenosine 5'-phosphosulfate (PAPS) and ATP. The activated sulfate is eventually reduced and incorporated into Cystine, Cysteine and Methionine and finally into the protein structure. Sulfur is involved in the metabolic activities of the vitamins like biotin, thiamine and coenzyme A. The sulfur is involved in the metabolic activities of these vitamins and may also be found in sulfhydral groups, which are present in many enzymes and are necesary for enzyme activity. Sulfur forms cross-links in the protein molecule and, in conjunction with the peptide and hydrogen bonding, acts to stabilize protein structure.

Sulfur Deficiency Symptoms

As in nitrogen deficient plants, there is a general chlorosis, followed by the production of anthocyanin pigments in some species (Eaton, 1951). Sulfur deficient plants show chlorosis of the younger leaves first (Gilbart, 1951). Hall and her colleagues found that sulfur deficiency resulted in a marked decrease of stoma lamellae and an increase in grana stacking. Eaton found that starch, sucrose and soluble nitrogen were accumulated under deficiency conditions but that reducing sugars were lower than normal. He suggested that the increase in soluble nitrogen resulted from an inhibition of protein synthesis and an increase in proteolytic activity.

Nutrient Cycles

Living organisms require various kinds of chemical elements for thier biosynthetic and metabolic processes. The absorption and utilization of such elements by organisms is compenstated by their recycling and regeneration back into the environment.

Nitrogen Cycle :

Nitrogen is a highly mobile nutrients and seems to have a highly complex nutrient cycle in terrestrial and aquatic ecosystems. The atmosphere contains some 80% nitrogen gas which cannot be directly utilized by most organisms except certain nitrogen fixers, symbiotic or free living bacteria and blue green algae and can also be fixed by lighting discharges. Nitrogenous compounds such as fertilizers are also manufactured industrially.

In the soil, nitrogenous compounds can undergo various kinds of transformation depending on soil conditions. Such transformation include incorporation into humus or organic matter of soil, conversion into ammonia (ammonification), absorption of NH_4^+ ion into clay and its oxidation to nitrite and nitrate (nitrification), absorption of plants, leaching of nitrate from the root zone by water and reduction of nitrate to N_2 and N_2O, followed by escape to the atmosphere by chemical or biological processes of denitrification.

Phosphours Cycle :

Phosphours is generally believed to be a critical limiting factor in the function of the biosphere because of its largely irretrievable loss into the oceans. It is an essential constituent of protoplasm but it is one of the highly immobile elements.

The only contribution of the atmosphere to the phosphorus budget of the soil plant system consists of fall out dust particles. Phosphorus obsorbed by soil organisms is replenished mainly by applied phosphatic fertilizers, plant residues and organic wastes. Some part of added phosphatic fertilizers become rather quickly recycled into the edaphic organic pool, from which it is slowly released through mineralization. The remaining part of phosphorus become distributed, absorbed or precipitated in the form of orthophosphates of calcium, iron or aluminium. Much of the applied phosphorus accumulated in the surface soil and remains there in insoluble form unless the sediment containing it happens to be carried away by runoff. Very low concentration of soluble phosphours are often sufficient to lead to eutrophication of surface wastes.

About 20 million tonnes of phosphorus are estimated to leach off from land into the oceans per year. The major pathway for returning phosphorus to land is the uplifting of marine sediments.

Sulfur Cycle :

The sulfur cycle is both sedimentary and gaseous. The sedimentary phase of sulfur cycle is long termed and in it sulfur is tied up in organic and inorganic deposits. From these deposits, it is released by weathering and decomposition and is carried to terrestrial and aquatic ecosystems in a salt solution.

Initially Sulfur enters the atmosphere as hydrogen sulfide, H_2S which quickly oxidizes into another volatile form, SO_2. Atmospheric SO_2 in water, is carried back to earth in rain waters as weak sulfuric acid, H_2SO_4 Whatever its source, sulfur in a soluble form, mostly as sulfur is absorbed through plant roots, where it is incorporated into certain organic molecules such as some amino acids (eg. Cystine) and proteins. From the producers the sulfur in the amino acids is transferred to the consumer animals, with excess being excreted in the faeces.

Excretion and death carry sulfur in living material back to the soil and to the bottoms of the ponds, lakes and seas where the organic material is acted upon by bacteria of detritous food chain, the sulfhydryl group (-SH) of amino acids (eg. L.Cysteine) is separated from the rest of the molecule as hydrogen sulfide (H_2S) by most decomposing bacteria as a normal part of the degradation of proteins. In an aerobic environment the hydrogen sulfide is oxidized to sulfate by bacteria specially adapted to perform this conversion.

$$H_2S + 2O_2 \dashrightarrow SO_4^{-} + 2H^{+}$$

The sulfate produced then can be reused by the autotrophs. In an aerobic environments, such as bottom of certain lakes, it is impossible to oxidize sulfide by this means, because the process of oxidation requires oxygen.

Distribution of these Nutrients in the Soil:

Forms of Nitrogen in the Soil:

Nitrogen in the soil falls into five categories. (1) Nitrogen in organic matter, (2) mineral nitrogen in the soil solution and on exchange sites, (3) nitrogen in the plant residue in the soil, (4) ammonium fixed in clay minerals; and (5) gaseous nitrogen in the soil's atmosphere. Interchange between various forms is primarily via microbiological activity.

Factors influencing Nitrogen influx :

Effect of pH: Van den Honert and Hooymans (1955) found that nitrate influx decreased by one third as pH was increased from pH 5.0 to 7.8. This decrease could not be compensated for by increasing nitrate concentartion. Lycklama (1963), using perennial ryegrass, found that nitrate uptake by this species reached a maximum at $\overset{H}{P}$ 6.2. In reviewing data from literature, Van den Honert and Hooymans (1955) found that the effect of $\overset{H}{P}$ on nitrate uptake was highly variable.

Effect of temperature : Van den Honert and Hooymans (1955) found that nitrate uptake by maize increased with increasing temperature over the range 5 to 30° C. Lycklama (1963), found that the maximum rate of nitrate uptake by ryegrass occured between 20 and 25° C. Barber found that the maximum value for Imax occured at 30° C for Corn and at 25° C or fescue and reed canary grass.

Distribution of Phosphorous in Soil:

Both organic and inorganic forms of phophorous occur in soil and their relative amounts vary considerably. More than half the portion of total phosphorus is in organic form, especially on the surface of the soil. Of the organic phophorus compounds identified so far, inositol phosphates forms the major part, to a lesser degree nuclei acids and phospholipids also ccur in soil (Barber, 1984).

Inorganic compounds occur almost exclosively as orthophosphates and may be grouped as a) Compounds containing calcium phoshphates and b) those containing aluminium and iron phosphates.

Effect of P^{H} on Phosphate Ions : The ionic forms of phosphorous is dependent on P^{H} and presence of other cations (Fe^{+++}, Al^{+++}, Ca^{+++}). In acid solution H_2PO_4 ion dominates but as the P^{H} is raised, first HPO_4 ion and finally PO_4 is released under highly alkaline conditions. It has been observed that these ions are further controlled by the presence of iron and aluminium componds in acid soils and calcium compounds in alkaline soils. At pH 7.0 both H_2PO_4 and HPO_4 ions are found (Russel, 1975; Brady, 1984).

Forms of Sulfur in the Soil:

Soil inorganic Sulfur : Inorganic sulfur in the soil can be divided into soil solution sulphate, absorbed sulphate and mineral sulfur.

Soil Organic Sulphur : Inorganic sulphur is usually only 5 to 10% of total sulfur in the soil (Neptune et al., 1975). Most soil sulfur is present in the organic fraction; soil organic matter contains approximately 0.5% sulfur. Organic sulfur has been fractioned (Anderson, 1975; Neptune et al., 1975) into reduceable sulfur, ester-sulphate sulfur, carbon bounded sulfur and identified organic sulfur. Unidentified sulfur is beleived to be additonal carbon-bounded sulfur not detected in the fractionation procedure.

Sulfur containing compounds in soil organic matter include the ammonia acids cystine and methionine and related compounds. The vitamins thiamine and biotin also contain sulfur in their ring structure.

Factors affecting Sulfate influx : Sulfate influx was most rapid at pH 4.0 and decreased with increased pH above 4.0 (Leggett and Epstein, 1956). Phosphate, nitrate and chloride concentration had no measurable effect on the sulphate uptake (Leggett and Epstein, 1956) while selenite competitively interfered sulphate uptake. Higher temperature increased sulphate uptake when temperature of 15, 25 and 35° C were compared (Rajan, 1966).

Cacco et al.,(1977) found a close similarity between sulphate uptake capacity and ATP-sulfurylase activity in plant roots. Rehmi and Caldnell (1968) found that sulphate uptake was influenced by ammonium and nitrate.

Total sulfur content of the humus layer was determined from scots pine forests in the sorrounding of Onlu, an industrialised city in the northern Finland. The sulfur content nearest to the city eccentre and emission sources was about twice as high as in three background areas 180 to 170 kms from the city, and about 40 to higher than at the sites which were calcium 20 km from the main emission sources. (Zone 1). The estimated accumulation of sulfur in humus layer was an average 0.4 to o.6 gm m^{-2} Yr^{-1} in the most polluted study sites and 0.1 to 0.2, 0.2 to 0.3 and 0.4 to 0.5 gm^{-2} Yr^{-1} in zones 1, 2, and 3 respectively. (Ghotonen, Markkola and Torvela, 1989).

<u>Sewage - Sludge</u> :

Legislative actions in the US have imposed strict limitations on the disposal of sewage sludge by incineration fresh water dilution and ocean dumping. There is a growing consensus that quality sludges (ie., those low in heavy metal content) should be used on land. One of the more attractive methods for sewage treatment is stabilising by composting. This process reduces odourus, destroys pathogens and produces a humus like organic material that can be conveniently stored, easily handled and uniformly spread on land as a soil container and low analysis fertilizer. These composts produced from sewage sluges and wood chips present a more biologically stable material than the sludge itself.(Wilson et al., 1980) and have different plant nutrient availability (Tester et al., 1977). There are no previous reports detailing compost nitrogen availability to plants that resulted from direct nitrogen analysis of the plant growing on compost amended soils in different environment.

Recommendations for using sewage sludge compost to satisfy the nitrogen requirement of crops, which resulted from green house and controlled environmental growth chamber studies, have not been validated with field trials. Studies were conducted to evaluate the effects of sewage sludge compost and complete fertilizer amendment on yields and nitrogen content of `Kentucky 31' tall fescue (Festuca arundiacea) grown on Evesporo loamy sand in different environment. Compost amendment increase the yields of fescue linearly in all three growth environments. For the second crop, yield were 50% of those of the first crop in the grotwth chamber and 60% of those for the first crop in the field. A conservative estimate for compost nitrogen utilisation by the Fescue crop was 8% for the initial cropping season and 5% on the second season Tester, (1989).

Chemical Composition of Sewage sludges :

The chemical composition of sewage sludge is of great importance when developing recommendations for the rates of sludge application on agricultural land. At the present time, recommendations for sludge application rates on land are based on the fertilizer value (N, P and K) and on the concentrations of trace metals present in sludge. The metals of primary concern are Zn, Cu, Pb and Cd which, when applied to soils in excessive amount, may reduce plant yields are impair the quality of food or fibre produced. Trace metal concentration in sewage slude have been revived recently by Page (1974). Data were summarised from numerous studies to indicate the extreme variability that can be found for metal levels in sewage sludges from different sources. The chemical composition of sludges has been evaluated in numerous localities including Wales and England (Berlow and Webber, 1972). Sweden (Berggren and Oden, 1972), Michigan (Blakesle, 1973) and Indiana (Soumers et al, 1976). Inaddition results from numerous studies have been published in the past few years containing data on the composition of sludges utilised in specific experiments. Agronomic and environmental considerations involved in the development of guidelines for sludge application on land and the properties of sewage sludges have been discussed in several recent reviews (Chaney, 1973; Dowdy et al., 1976; McCalla et al, 1977; Sommers and

Sutton, 1979).

The North central Cooperative Regional research project (NC 118) "Utlilisation and disposal of Municipal, industrial and agricultural processing wastes on land", initiated an effort to compile information on the composition of sewage sludges across the region, and to establish a broad data base concerning the variability of sewage sludges produced in different locations and by different types of sewage treatment process.

A regional Survey of Sewage Sludge Composition was conducted by obtaining data for 30 consitituents in less than 250 sewage sludge samples from approximately 150 treatment plants located on 6 states in the North-Central region and two in the eastern region. Computation of the mean and median values indicated that N, P and K levels were within a relatively narrow range, where as this statistics demonstrated that Pb, Zn, Cu, Ni and Cd concentrations were extremely variable. Median concentrations for Anaerobically digested sewage sludge were as follows : N, 4.2; P, 3.0; K, 0.3; Pb, 540; Zn, 1890; Cu 1000; Ni, 85; and Cd, 16 mg/kg and for aerobically treated sludges; N, 4.8; P, 2.7; K, 0.46; Pb, 300; Zn 1800, Cu, 960; Ni, 31; and Cd, 16 mg/kg. Based on population and sludge production estimate 1% of the agricultural land would be required for application of sewage sludge at the rate of 100 kg available nitrogen per hectare in most of the states considered. The hetrogenous nature of the sewage sludges produced by different cities and the presence of potentially harmful trace metals necessitates a knowledge of the chemical compositon of each individual sewage sludge prior to land application.

Structural features of Humic acid like substances from Sewage sludge :

Applying sewage sludge to agricultural land, both to dispose of organic matter and to improve soil fertility is receiving increasing attention in all developed countries.

Due to their complex nature, sewage sludges differ considerably from other oragnic amendments. These materials contain from 18 to 59% organic matter, and it is to expected that their application to the soil affects the status of its humic fraction (Boyd et al., 1980).

The nature of sewage sludge humic like fraction is quite different from that soils because the former has undergone a quite short period of transformation by a technological process. Thus one can suppose that it must show particular characteristics. A full knowledge of this charcteristic is necessary for understanding some important agronomical effects of the sludge application, such as micro nutrients solubility and heavy metal transfered in the soil.

One of the chracteristics of the soil in south eastern and southern Spain is their low content of organic matter. Because of the current limited amounts of organic resources and because suppliers of farmyard manure have diminished however, all the sewage sludge produced in this region used for improving their fertility and crop production. Therefore, the study of the humic acid like fraction from these sludges has a great importance due to the economical and environmental implications of the widespread application of these materials to agricultural lands.

In previous works, humic acids extracted from sewage sludges were mainly charcterised by physico-chemical methods (Boyd et al., 1980; Riffaldi et al., 1982; Almendros et al, 1983; Gelasimowicz 1985, 1986).

Toxity of effluents from two sewage treatment plants in Tophini, Missouri was tested using Ceriodaphnia dubia and Piniephales promeleas. No test organisms survived in effluents from either plant, in effluents diluted with water from Turkey Creek (the receiving stream) or in water from Turkey Creek. Mortality was complete in all but the most dilute treatment of effluents in which he constituted water was used as diluent. High concentration of Pentachlorophenol in effluents and the receiving stream widely caused mortality during the 7 day tests (Glemor D.Wisely, Finger and W.Crawford, 1989).

Large losses of metals applied to soil in metal - contaminated sewage sludge have been reported. The potential pathways of cost, including lateral movement from treated plot areas have not been examined. A field experiment which started in 1942, was investigated to determine the amount of lateral movement of Zinc, Cadmium, copper, nickel, chromium and lead due to conventional alluviation process. Detailed analysis of soil profile sample showed that approximately 1% of the metals applied had moved 3.5 cm below the plough layer or less, but there was no evidence of accumulation of metals in deeper horizons down to 46 cms (S.P.McGrath and P.W. Lane, 1989).

Improving the slude containing potential of Moringa seed: The oil free seed has been found to have higher conditioning potential than the ordinary moringa seed. However, the traditional ferric flouride is still a better sludge conditioner than Moringa seed mark. (Ademilursi, Ezeffansud).

Major Components of N,P,S Cycle

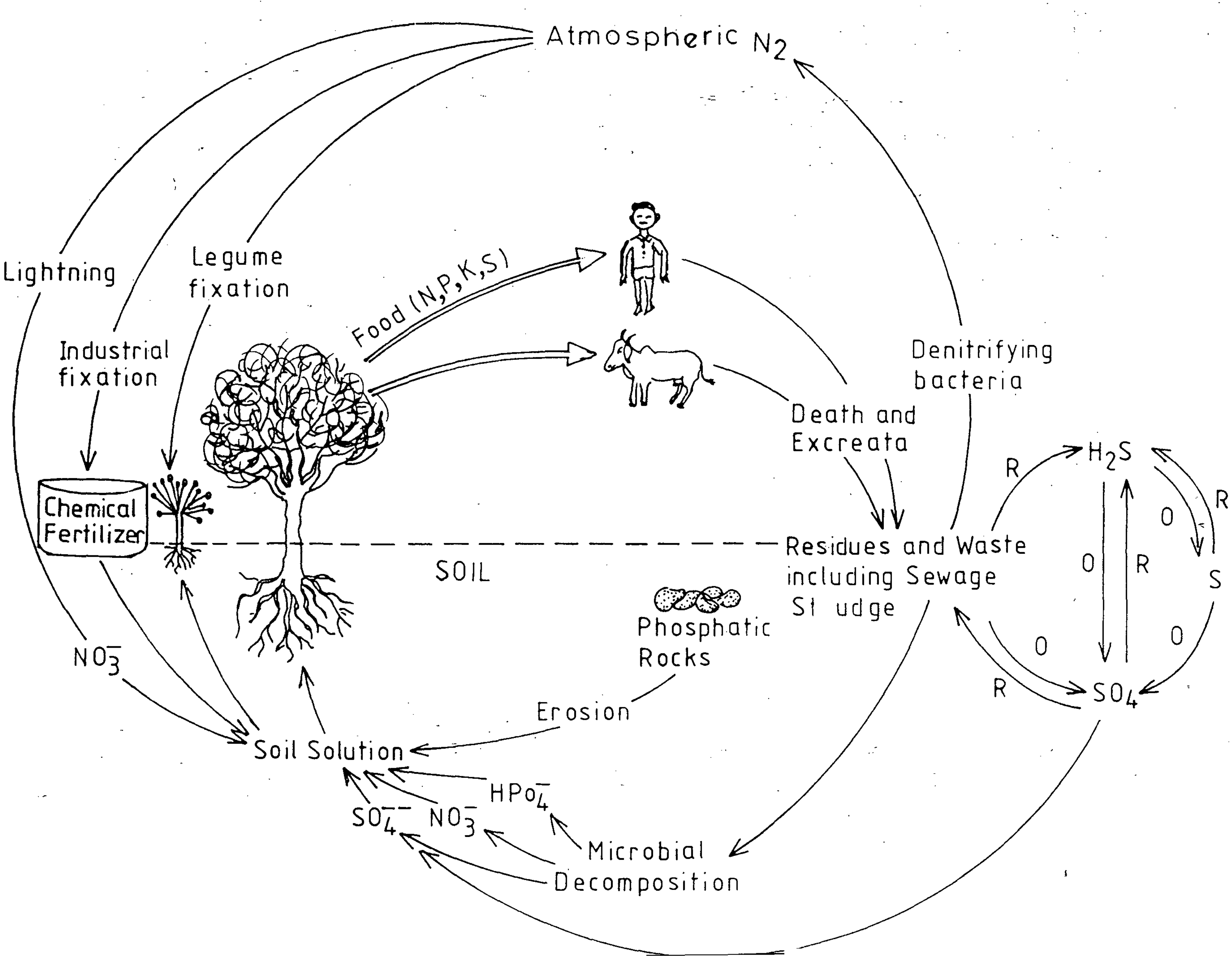


Fig. 2. Major components of N,P,S cycles

MATERIALS AND METHODS

MATERIALS AND METHODS

1. Collection and Preparation of Soil Samples

Soil samples used in this study were collected from the fallow land adjacent to the J.N.U. nursery and at Mehrauli. They were undisturbed soils and presumed to be free of contamination. shrubs and grasses were the main vegetation. Samples were randomly collected from different points in the same field at 0 to 15 cm depth. All the samples were mixed and brought to laboratory.

Then the soil was air dried, powdered and sieved through a 2 mm perforated sieve (Indian Standard, 1983). A portion of soil samples were stored in plastic bags for physico-chemical analysis and remaining sieved soils were filled in the 1000 ml plastic beakers.

II. Sewage Sluge Sampling :

Two types of sewage sludges, primary treated and secondary treated sewage sludges were collected from Okhla Sewage Treatment Plant, New Delhi and brought to laboratory.

Then the sludges were dried, powdered and sieved through a 2 mm perforated sieve (Indian Standard, 1983). A portion of the samples were taken and stored in polythene bags for the physico-chemical analysis and remaining samples were mixed with the soil samples in definite proportion in the plastic beakers.

III. Experimental Setup :

The sewage sludges were thoroughly mixed with two types of soils, JNU and Mehrauli in such a way that there were two beakers for 10% primary treated sludge, two for 20% primary treated sludge, 2 for 10% Secondary treated and two for 20% Secondary treated sludges. All these eight beakers were with three replicas. Then they were irrigated with tap water and incubated at room temperature (27 C)in the incubator. The samples were taken at the interval of 10 days for about 7 times i.e. 0th day, 10th, 20th, 30th, 40th, 50th, and 60th day for the physico-chemical cnalysis.

IV. Analysis of Soil Samples :

1. pH of Soil :

pH of the soil samples was measured with the help of pH meter (Elico, model LI-12) using 1:5 soil-water suspension as suggested by Jackson (1973).

2. Electrical Conductivity (E.C) :

E.C. was determined by using the same soil : water suspension (i.e. 1 : 5) with the help of systeonics direct reading Electrical conductivity meter.

3. Soil Mechcanical Analysis :

Mechanical analysis was done by hydrometer method as described by Piper (1966).

4. Water Holding Capacity :

Principle :

The water holding capacity of the soil depends upon the particle size of the soil.

Procedure :

The funnels with the filter paper Whatman No-1 were filled with soil samples and sprayed water in it till all the soil became wet. The petridishes were weighed and noted the weights (W1). Then the moistened sample in the funnel was collected in the petridish and weighed again (W2). The petridishes were kept in the oven and after complete drying the petridishes were again weighed (W3).

Calculations :

$$\text{Water Holding Capacity (\%)} = \frac{(W2 - W3)}{(W3 - W1)} \times 100$$

5. Cation Exchange Capacity (CEC) :

The samples were dried at 105-110 C to 24 hours to measure CEC (Indian Standard, 1983) and the CEC of the samples was determined by neutral 1N ammonium acetate extraction method (Jackson, 1973).

Reagents :

(a) IN Aluminium Acetate :

57.5 ml galcial acetic acid and 60 ml concentreated ammonium solution were added in 30 ml of water and mixed well. The solution was diluted to 1 litre and mixed thoroughly. The pH of the solution was adjusted to 7.00 + 0.05 with drops of acetic acid or ammonia as necessary (Allen, 1974).

b) Ethyl alcohol (95%)

(c) Potassium Chloride (10%)

100 gm KCl was dissolved in 1000 ml of distilled water and pH was adjusted to 2.5.

(d) Sodium hydroxide solution (40%) :

40 gm NaoH was dissolved in distlled water and volume was made upto 100 ml.

(e) Boric Acid Solution (2%) :

20 gm of boric acid was dissolved in distilled water and diluted to 1000 ml.

(f) Mixed Indicator :

0.1 gm of methylene blue was dissolved in 50 ml of ethanol and 0.2 gm of methyl red was dissolved in 100 ml of enthanol and the two solutions were mixed.

g) Indicator boric acid solution :

10 ml of mixed indicator was added to 1000 ml of 2 % boric acid solution.

(h) Standard Sulphuric acid (0.01N)

Procedure :

5 gm of soil and 33 ml ammonium acetate (IN) were taken in a 50 ml plastic Centrifuge tube. It was shaken for 5 minutes and centrifuged for about 10 minutes. The supernatant liquid was rejected. The process was repeated three times. The soil was treated exactly in the same manner with ethanol.

Finally 33 ml 10% Kcl was added to the soil residue and subjected to the same treatement three times. In this case the decanted extract was collected in a 100 ml volumentric flask. The volume was made upto 100 ml with KCl soluttion.

The extract collected was transferred to a kjeldahl flask and diluted to about 200 ml distilled water. 25 ml of 40% NaOH solution was added and ammonia distilled was collected in 50 ml boric acid-indicator solution. Finally the solution was back titrated against standard H_2SO_4. An equal portion of KCl solution as a blank was run simultaneously.

Calculation :

$$\text{CEC (meq/100 gm soil)} = \frac{100/v \times a \times N \times 100}{W}$$

Where, V = Volume of extract taken out from total of 100 ml for distillation.

a = ml of H_2SO_4 required for titration

N = normality of H_2SO_4 used

W = Weight of the soil in grams.

6. Organic Carbon :

Organic carbon was determined by the method of Walkley and Black as modified by Smith and Weldon 1940), in which the reducing material in the soil samples is oxidized by chromic acid formed by addition of concentrated H_2SO_4 to potassium dichromate solution as described by Allison (1965), Piper (1966) and, Chopra and Kanwar (1976).

Principle :

Organic matter is oxidized by a known volume of acidified standard potassium dichromate and the excess of dichromate is back titrated with N/2 ferrous ammonium sulphate using diphenyl amine as indicator.

Reagents :

(a) Standard Potassium dichormate (IN)

49.0 gm of $K_2Cr_2O_7$ was dissolved in distilled water and the volume made upto 1000 ml.

(b) Ferrous ammonium sulphate (N/2)

196.0 gm of $FeSO_4 (NH_4)_2SO_4 6H_2O$ was dissolved in distilled water, 15 ml of concentrated H_2SO_4 was added and made upto 1000 ml with distilled water. This was standardised with standard 1N $K_2Cr_2O_7$ solution.

c) Diphenylamine indicator :

0.5 gm of reagent grade diphenylamine was dissolved in 20 ml of water and 100 ml of Conc H_2SO_4 was added and mixed slowly.

d) 85% Orthophosphoric acid :

Analytical grade 85% H_3PO_4.

e) Solid Sodium Flouride (NaF)

Procedure :

2 gm of soil sample was taken in 500 ml conical flask and exactly 10 ml IN $K_2Cr_2O_7$ solution and about 20 ml of conc. H_2SO_4 were added to it. The mixture was allowed to stand for 30 minutes and then diluted to 200 ml with distilled water.

10 ml of H_3PO_4, 0.2 gm of NaF and about 1.0 ml of diphenylamine indicator were added and the solution was back titrated with N/2 ferrous ammonium sulphate solution. The colour was dull green at the beginning then shifted to a turbid blue and at the end point, this colour changed sharply to brilliant green. A standardisation blank without soil was run in the same way.

Calculation :

$$\text{\% of Organic carbon in Soil} = \frac{(a-b) \times 0.003 \times N \times 100}{W}$$

Where,

a = Blank titration value

b = Sample titration value

N = Strength of ferrous ammonium sulphate

W = Weight of the soil sample.

7. Available Nitrogen :

The modified alkaline permanganate digestion method was suggested by Subbiah and Asija (1956) was employed to assess the available Nitrogen content of sewage sludge as well as soil samples. The method was evaluated by Hussain and Malik (1985) as an index of soil nitrogen availability.

Principle :

Soil, when digested with alkaline permanganate solution releases :

a) Ammonia from ammonium compound (inorganic) present in the soil, and

b) Ammonia from soil organic nitrogen pool by the process of oxidation and hydrolysis.

Reagents :

a) Pottassium permanganate (0.32%)

3.2 gm of KM_nO_4 was dissolved in distilled water and volume was made upto 1000 ml.

b) Sodium hydroxide solution (2.5%) :

25 gm of Na OH was dissolved in distilled water and volume was made upto 1000 ml.

c) Standard Sulphuric acid (0.02N)

It was prepared by titration against standard sodium hydroxide.

d) Standard Sodium Hydroxide (0.02N)

The solution was standardised by titrating against standard oxalic acid.

e) Methyl red indicator :

0.1 gm reagent was dissolved in a mixture of 60 ml methyl alcohol and 40 ml water and mixed well.

Procedure :

20 gm of soil was taken in a Kjeldahl falsk. It was mositened with 20 ml of distilled water, and then 100 ml of 0.32 % $KMnO_4$ solution and 100 ml of 2.5% NaOH solution were added. The contents of the flask were distilled and about 75 ml of the distillate was collected in 20 ml standard sulphuric acid (0.02 N).

Ammonia released during the reaction, reacted with standard H_2SO_4 which was back titrated against standard 0.02 N NaOH using methyl red indicator which turned from red to pale yellow colour at the end point. A blank was also run simultaneously.

Calculation :

1 ml of 0.02 N H2SO4 = 0.28 of `N'

$$\text{ppm of Nitrogen} = \frac{(a-b) \times 0.28 \times 1000}{W}$$

Where

a = Blank titration value with N/50 NaOH

b = Sample titration value with N/50 NaOH

w = Weight of soil in gm.

8. Total Nitrogen :

Kjeldahl digestion method :

Principle : The digestion of the sample with H_2SO_4 and pottassium sulphate, converts all the organic nitrogen and ammonia into ammonium sulphate. However, most of the other forms remain unaffected. NaCl is added to prevent the partial reduction of nitrate to ammonia which converts the NO_3 into NaCl. The nitrogen in the form of ammonium sulphate can be determined by distillation.

Reagents :

a) Conc. Sulphuric acid

b) Digestion Mixture :

20 gm copper sulphate

3 gm mercuric oxide

1 gm Selenium powder

Mixed one part of this mixture with 20 parts of potassium sulphate.

c) NaOH (40%)

40 gm of sodium hydroxide pellets were dissolved in distilled water and made upto 100 ml.

d) Boric acid solution (2%)

20 gm boric acid was dissolved in 100 ml distilled water.

e) Mixed indicator :

Solution 1 : 0.1 gm of Methylene blue was dissolved in 50 ml ethanol.

Solution 2 : 02 gm methyl led was dissolved in 100 ml ethanol. Mixed both the solutions 1 and 2.

f) Indicator - Boric acid Solution :

10 ml mixed indicator was mixed with 1000 ml of 2% Boric acid solution.

g) Standard Sulphuric acid (0.1 N)

Procedure : -

Digestion : 1 gm of soil sample was taken into digestion tubes. 2 gms of catalyst mixture and 3.5 ml conc. H_2SO_4 were added. Swirrled it to mix gently and kept the tubes in the digester. The temperature was kept at 100° C and increased to 200, 250, 300 gradually, at each time with one hour gap. Heated till the samples turn to clear or light green colour. Allowed to cool the digest for 30 min. and added 50 ml double distilled water (DDW) slowly. Washed the tubes and made up the volume to 100 ml in volumetric flask. Out of it 25 ml digest was used for microdistillation.

Distillation : 25 ml of digest was put into the distillataion flask, and 25 ml of 40% NaOH was added to it. The distillate was collected in 50 ml boric acid mixed indicator solution till 40 ml of distillate was collected. The mixed indicator was turned to blue colour as it collected the distillate due to the dissolution of ammonia.

Titration : This boric acid collected the distillate was titrated against the 0.1 N sulphuric acid till the colour changed to light brown pink.

Calculations :

$$\% \text{ Nitrogen} \quad \frac{(a-b) \times N \times 1.4 \times V}{v \times S}$$

Where, a = ml of H_2SO_4 used with sample

b = ml of H_2SO_4 used with blank

N = Normality of H_2SO_4

V = ml of total digest

v = ml digest used for distillation

S = Weight of the soil sample.

9. Available Phosphorus

Principle :

Phosphorus in soil is generally determined as available phosphours, which can be extracted from soil with Bray and Kurtz No. 1 solution. The phosphate react with ammonium floride and form complexes heteropoly acid (molybdophosphoric acid), which gets reduced to a complex of blue colour in the presence of $SnCl_2$. The absorption of light by this blue colour can be measured at 690nm. to calculate the concentration of phosphates.

Reagents :

1) Bray and Kurtz No. 1 solution :

0.03 N NH_4F was mixed with 0.025 N Hcl. 0.025 N HCl was prepared by adding 2.088 ml conc. Hcl in 1 litre double distilled water. Then dissolved 1.11 gm of NH_4F in 1 litre 0.025 N HCl.

2) Standard Phosphours solution (50 ppm of P)

0.2195 gm of potassium dihydrogen phosphate dried at 40 C was dissolved in distilled water and the volume was made upto one litre to give a stock solution containing 50 ppm of phosphours. From this, dilute standard solution of concentration, varying from 0.1 to 1 ppm of phosphorus were prepared when required.

c) Ammonium molybdate solution :

a) 25 gm of ammonium lolybdate was dissolved in 175 ml of distilled water. b) 280 ml of conc. H_2SO_4 was dissolved in 400 ml of distilled water and cooled. Mixed the two solutions a and b and diluted to 1 litre.

d) Stannous Chloride Solution :

2.5 gm of Stannous chloride solution was dissolved in 100 ml glycerol by heating on a water bath for rapid dissolution.

Procedure :

1 gm of soil sample was dissolved in 20 ml of Bray and Cuts No. 1 solution shaked for 1 minute and filtered immediately through Whatman No.41.

5 ml of the filtrete was taken in 25 ml volumet flask and added 2 ml of ammonium molybdata followed by 5 drops of $SnCl_2$ solution and made up to the mark (25 ml) with distilled water. A blue colour was appeared. Then the readings were taken at 690 mm wavelength on spectronic 20 using a distilled water blank with the same amount of the chemicals. The readings were taken after 5 minutes but before 12 minutes of the addition of the last reagent. The concentrations were found with the help of the standard curve.

Preparation of Standard Curve :

Various dilutions from 0.1 to 1 ppm of 20 ml were transferred to 25 ml volumetric flasks. 2ml of ammonium molybdate and 5 drops of $Sn\,cl_2$ solution were added and made upto the mark with distilled water. The readings were taken at 690 nm on spectronic 20 and plotted a graph between absobance a trasmittance and concentration.

Total Phosphours

Principle :

All the forms of phosphorus, whether dissolved or particulate, are converted to inorganic forms (phosphate) after digestion of the sample. The phosphate thus released can be determined colorimetrically.

Reagents :

a) Perchloric acid (60%)

b) Nitric acid

c) Sulphuric acid

d) Ammonium molybdate :

i) 25 gm of Ammonium molybdate was dissolved in 175 ml of distilled water. ii) 280 ml of conc H_2SO_4 was mixed to 400 ml distilled water and cooled. Mixed the two solutions and diluted to 1 litre.

e) Stannous Chloride Solution :

Dissolved 2.5 gm of stannous chloride in 100 ml glycerol by heating on a water bath for rapid dissolution.

Procedure :

Mixed acid digestion : 0.5 gm dried soil sample was weighed into the Kjeldah test tube and then 1 ml 60% perchloric acid ($HClO_4$), 5 ml of HNO_3 and 0.5 ml sulphuric acid were added into the tube. Swirlled gently and digested slowly, at moderate heat increasing it in stages 100°C, 150, 200, 250, 300°C. Digested for a while longer after it gave out white fumes and colour changed to light green. Allowed it cool and removed the digest with the help of D.D.W. into volumetric flask and made up the volume to 100 ml after filtering the digest first. 25 ml of this diluted digest was taken into 50 ml volumentric flask and added 2 ml ammonium molybdate and 0.5 ml of Stannous chloride and made up the volume to 50 ml just before taking the readings. A blue colour was appeared. The readings were taken at 690 nm. on Spectronic 20 using the double distilled water as blank with the same amount of chemicals. The reading were taken after 5 minutes and before 12 minutes of addition of last reagent. The concentration were found with the help of the standard curve.

Calculations :

$$p\% = \frac{C\ (\text{mg}) \times \text{Soln. Volume(ml)} \times 100\ (\text{for \% cal})}{1000\ (C) \times \text{aliquot}\ (\text{ml}) \times \text{Sample}\ (\text{gm})}$$

$$= \frac{C \times \text{Soln. Vol.}}{10 \times \text{aliquot} \times \text{Sample}}$$

Where,

C = mg phosphorus

Available Sulfur :

Principle :

Like chloride, most of the sulfates are solube in water and can directly be determined in the soil solution. Any method by which sulphate is determined in water can also be employed to determine sulphate in soil solution. Although gravimetric method is conventionally used, but turbidimetric method can also be followed.

Sulphate ion is precipitated in the form of barrium sulphate by adding barium chloride.

Reagents :

a) Extracting Solution :

39 gm of Ammonium acetate was dissolved in 1 litre of 0.25 N acetic acid.

b) Norit `A' activated Charcoal

c) Barium chloride crystals

d) Anhydrous Sodium Sulphate

Procedure :

10 gm of soil sample was taken in 50 ml volumetric flask and added 25 ml of extracting solution and shaked well. Then 0.25 gm of charcoal was added and then filtered the soil suspension with Whatman No.42. To this 25 ml filtrate 0.5 gm of Barium Chloride crystals were added. After 1 min. swirlled solution frequently. With in 2 to 8 minutes absorbance was read at 420 nm wave length in Spectromic - 20. The sulfate concentration was found from the standard curve.

<u>Preparation of Standard Curve</u> :

0.1479 gm of anhydrous Na_2SO_4 dissolved in distilled water and made to 1 litre of solution. This solution contains 100 mg/l of sulphate. Various dilutions from 10 mg/l to 100 mg/l were prepared from the standard sulphate solution. 25 ml each dilution was taken and added 0.5 g of Barium chloride crystals. After 1 min. swirlled the solution frequently. With in 2 to 8 minutes the light transmission or absorbance was read at 420nm wavelength in Spectronic-20 and plotted a graph between the absorbance or transmittance and concentration.

Total Sulfur:

Principle:

When the soil is fused with sodium carbonate the sulfur present in the soil reacts with it and becomes sodium sulphate. This total sulfur is precipitated by Barium chloride which gives turbidity.

Reagents:

a) Sodium carbonate

b) Sodium nitrate

c) Norit 'A' activated charcoal

d) Barium chloride crystals

Procedure:

Sodium carbonate fusion: 0.5 g of soil samples were taken in the Nickel crucibles and added 2.5 g of sodium carbonate and kept in the Muffle furnace. The temperature was adjusted to 450° C and heated for 30 minutes. 0.2 g of sodium nitrate also added to improve the flux. These samples were transferred into the 50ml volumetric flasks and made upto the mark with double distilled water, shaked well

and filtered. 0.25 g of charcoal was added and then filtered again the soil suspension with Whatman No. 42. From this 5ml filtrate was taken into 25ml volumetric flask and 0.5 g of Barium chloride crystals were added. After 1 minute swirlled the solution frequently. Within 2 to 8 minutes absorbance was read at 420 nm wave length in Spectronic-20. The total sulfur concentration was found from the standard curve.

Calculations:

$$S\ (\%) = \frac{C\ (mg) \times \text{Solution Vol. (ml)}}{10 \times \text{aliquot (ml)} \times \text{Sample wt. (g)}}$$

TABLES

Table 1

PHYSICO-CHEMICAL CHARACTERSTICS OF SOILS AND SEWAGE SLUDGES

Parameters	Soils		Sludges	
	JNU	Mehrauli	Primary treated	Secondary treated
Particle size				
% Sand	57.40	62.50	-	-
% Silt	30.43	25.50	-	-
% Clay	12.17	12.00	-	-
pH	8.80	8.52	7.58	7.24
EC (mmhos/cm)	0.102	0.106	1.05	1.20
Organic carbon(%)	0.308	0.395	0.0063	0.003
Availasble Nitrogen (ppm)	54.02	48.70	22.40	17.36
Total Nitrogen(%)	0.054	0.049	-	-
Available phosphorus (ppm)	9.20	12.48	-	-
Total phosphorus(%)	0.033	0.034	-	-
Available sulfur (ppm)	8.32	7.63	-	-
Total sulfur(%)	0.045	0.052	-	-

Data present average of three replicas

Table 2

PERIODIC CHANGES OF pH IN THE SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	8.80	8.50	8.30	8.2	8.3
10	8.63	8.41	8.00	8.2	8.0
20	8.54	8.25	7.80	7.61	7.4
30	8.50	8.10	8.00	7.54	7.3
40	8.40	8.00	7.73	7.50	7.28
50	8.40	8.00	7.70	7.28	7.21
60	8.37	7.98	7.66	7.23	7.04

pH of control Soil = 8.80
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	8.52	8.46	7.94	8.24	7.26
10	8.36	8.27	7.53	8.13	7.06
20	8.30	8.16	7.29	7.9	7.02
30	8.05	8.00	7.16	7.34	6.95
40	8.04	7.98	7.15	7.24	6.96
50	8.02	7.96	7.15	7.12	6.98
60	8.02	7.96	7.14	7.16	6.85

pH of Control Soil = 8.52
Data present average of three replicas

TABLE 3

PERIODIC CHANGES OF EC (mmhos/cm) IN THE SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.102	0.155	0.162	1.235	1.865
10	0.128	0.193	0.204	1.570	2.760
20	0.164	0.215	0.229	1.958	3.135
30	0.195	0.234	0.246	2.480	3.465
40	0.186	0.228	0.236	2.356	3.450
50	0.178	0.225	0.229	2.340	3.494
60	0.160	0.215	0.224	2.335	3.430

EC of Control Soil = 0.102
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.106	0.164	0.186	1.695	2.100
10	0.130	0.196	0.217	2.120	2.760
20	0.164	0.226	0.238	2.345	3.125
30	0.202	0.265	0.276	2.700	3.235
40	0.192	0.250	0.265	2.665	3.220
50	0.184	0.245	0.260	2.650	3.215
60	0.179	0.220	0.257	2.500	3.210

EC of Control Soil = 0.106
Data present average of three replicas

TABLE 4

CATION EXCHANGE CAPACITY (meq/100 gm soil) AND WATER HOLDING CAPACITY (%) OF SEWAGBE SLUDGE AMENDED SOILS

JNU SOIL

Charac-teristic	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
CEC (meq/100gm)	10.0	13.2	13.6	13.3	16.4
WHC (%)	32.97	33.11	36.17	43.506	48.51

CEC of Control Soil = 10.0 meq/100 gm.

WHC of Control Soil = 32.97 %

Data present average of three replicas

MEHRAULI SOIL

Charac-teristic	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
CEC (meq/100gm)	12.0	12.5	12.8	15.4	16.7
WHC (%)	33.506	34.77	38.25	45.84	49.39

CEC of Control Soil = 12.0 meq/100 gm.

WHC of Control Soil = 33.506 %

Data present average of three replicas

Table 5

PERIODIC CHNGES OF ORGANIC CARBON(%) IN SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.308	0.320	0.340	0.755	0.910
10	0.286	0.295	0.325	0.730	0.885
20	0.265	0.280	0.315	0.710	0.875
30	0.255	0.265	0.310	0.695	0.850
40	0.253	0.260	0.300	0.685	0.840
50	0.245	0.255	0.290	0.680	0.835
60	0.240	0.255	0.290	0.670	0.835

Organic Carbon of Control Soil = 0.308%
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.395	0.420	0.450	0.930	1.65
10	0.380	0.400	0.435	0.895	1.370
20	0.365	0.392	0.420	0.860	1.075
30	0.355	0.375	0.410	0.845	0.905
40	0.345	0.365	0.400	0.835	0.890
50	0.340	0.363	0.400	0.830	0.885
60	0.335	0.362	0.390	0.830	0.880

Organic Carbon of Control Soil = 0.395%
Data present average of three replicas

Table 6

PERIODIC CHANGES IN AVAILABLE NITROGEN (ppm) IN SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	54.02	54.25	55.60	64.20	65.50
10	56.75	57.50	58.20	67.85	67.35
20	58.00	61.60	61.00	69.50	73.10
30	60.25	63.40	63.25	72.60	74.30
40	57.20	60.80	60.50	68.50	71.00
50	54.30	55.50	56.80	65.20	67.80
60	50.25	52.75	53.85	62.10	65.10

Available Nitrogen in Control Soil = 54.02ppm
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	48.70	49.60	50.50	63.85	66.75
10	51.60	51.30	51.80	66.60	68.80
20	52.00	53.65	54.75	71.20	72.65
30	54.60	55.20	56.25	73.40	74.00
40	52.80	52.15	53.60	70.60	70.10
50	48.25	50.60	51.25	64.60	66.60
60	46.20	47.60	48.55	61.30	64.00

Available Nitrogen in Control Soil = 48.70 ppm
Data present average of three replicas

TABLE 7

PERIODIC CHANGES IN TOTAL NITROGEN (%) IN SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.054	0.057	0.061	0.064	0.068
10	0.053	0.055	0.060	0.062	0.067
20	0.049	0.053	0.058	0.061	0.067
30	0.047	0.052	0.057	0.059	0.065
40	0.045	0.048	0.055	0.057	0.064
50	0.044	0.047	0.055	0.058	0.064
60	0.042	0.047	0.054	0.058	0.063

Total Nitrogen in control soil = 0.054
Data present averge of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.049	0.050	0.053	0.055	0.058
10	0.048	0.050	0.052	0.055	0.057
20	0.048	0.048	0.052	0.053	0.055
30	0.046	0.048	0.050	0.052	0.055
40	0.045	0.046	0.048	0.050	0.052
50	0.040	0.043	0.048	0.048	0.050
60	0.038	0.042	0.046	0.048	0.050

Total Nitrogen in control = 0.049
Data present average of three replicas

Table 8

PERIODIC CHANGES OF AVAILABLE PHOSPHORUS (ppm) IN SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	9.20	9.82	18.40	31.78	32.62
10	9.34	15.6	22.52	32.82	35.56
20	10.94	20.4	38.90	39.41	40.72
30	22.58	42.58	48.20	76.38	84.60
40	7.46	19.67	21.82	72.80	84.60
50	5.76	11.45	12.34	67.60	72.82
60	2.92	8.36	9.58	58.74	60.06

Availble Phosphorus in Control Soil = 9.20ppm
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	12.48	13.96	26.4	32.80	38.8
10	17.08	18.72	30.0	36.0	42.58
20	19.44	23.78	36.62	47.76	49.76
30	23.22	30.30	41.82	65.72	80.82
40	19.82	12.84	27.48	64.78	70.74
50	10.48	11.90	23.22	59.10	59.57
60	8.12	11.42	13.32	34.80	59.58

Available Phosphorus in Control Soil = 12.48 ppm
Data present average of three replicas

Table 9

PERIODIC CHANGES OF TOTAL PHOSPHORUS IN SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.033	0.036	0.039	0.042	0.045
10	0.032	0.033	0.036	0.040	0.043
20	0.032	0.032	0.035	0.040	0.042
30	0.030	0.031	0.033	0.039	0.042
40	0.028	0.030	0.032	0.038	0.040
50	0.028	0.028	0.030	0.036	0.039
60	0.027	0.028	0.029	0.036	0.039

Total phosphorus in control soil = 0.033%
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.034	0.038	0.042	0.045	0.048
10	0.032	0.035	0.040	0.043	0.046
20	0.032	0.033	0.036	0.042	0.044
30	0.030	0.032	0.036	0.042	0.044
40	0.030	0.031	0.035	0.040	0.042
50	0.029	0.030	0.034	0.040	0.042
60	0.028	0.030	0.032	0.038	0.040

Total phosphorus in control soil = 0.034 %
Data present average of three replicas

Table 10

PERIODIC CHANGES OF AVAILABLE SULFUR (ppm) IN SEWAGE SLUDGE AMENDED SOIL

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	8.32	8.52	8.72	10.12	10.35
10	8.73	8.95	9.15	10.63	10.50
20	8.935	9.435	9.40	10.90	11.20
30	9.630	9.752	9.82	11.43	12.05
40	9.125	9.353	9.30	10.88	11.76
50	8.735	8.675	8.7	10.40	11.15
60	7.982	8.282	8.37	10.05	10.8

Available Sulfur in Control Soil = 8.32 ppm
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	7.63	7.75	7.92	9.80	10.25
10	8.05	7.98	8.05	10.15	10.50
20	8.15	8.32	8.55	10.65	10.75
30	8.20	8.55	8.88	10.90	10.95
40	8.05	7.98	8.35	10.54	10.45
50	7.75	7.90	8.02	9.95	10.20
60	7.40	7.56	7.85	9.40	9.75

Available Sulfur in control Soil = 7.63 ppm
Data present average of three replicas

Table 10a

PERIODIC CHANGES OF TOTAL SULFUR (%) IN SEWAGE SLUDGE AMENDED SOILS

JNU SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.045	0.048	0.052	0.054	0.058
10	0.042	0.046	0.048	0.052	0.054
20	0.040	0.046	0.046	0.050	0.052
30	0.038	0.042	0.044	0.049	0.051
40	0.036	0.040	0.042	0.046	0.048
50	0.035	0.039	0.042	0.044	0.046
60	0.034	0.038	0.040	0.042	0.045

Total sulfur in control soil = 0.045
Data present average of three replicas

MEHRAULI SOIL

Incubation period (days)	Control	Primary treated sludge		Secondary treated sludge	
		10%	20%	10%	20%
0	0.052	0.056	0.060	0.068	0.072
10	0.050	0.056	0.059	0.065	0.068
20	0.048	0.055	0.058	0.062	0.065
30	0.048	0.052	0.054	0.062	0.064
40	0.046	0.048	0.052	0.060	0.064
50	0.044	0.046	0.052	0.060	0.062
60	0.042	0.045	0.050	0.058	0.061

Total sulfur in control soil = 0.052
Data present average of three replicas

Table 11

CORRELATION COEFFICIENTS AMONG VARIOUS PARAMETERS

Sl.No.	Parameters		Soils	
			JNU	Mehrauli
1.	Available Nitrogen X	Organic Carbon	0.836	0.308
2.	Available Nitrogen X	pH	- 0.63	- 0.57
3.	Available X Phosphorus	Organic Carbon	0.750	0.166
4.	Available X Phosphorus	pH	- 0.78	- 0.707
5.	Available X Sulfur	Organic Carbon	0.87	0.334
6.	Available X Sulfur	pH	- 0.68	- 0.62
7.	Available X Sulfur	Available Nitrogen	0.98	0.991
8.	Available X Sulfur	Available Phosphorus	0.90	0.907

EXPERIMENTAL RESULTS AND DISCUSSION

EXPERIMENTAL RESULTS AND DISCUSSION

Effects of Sewage Sludge on Characteristics of Soil :-

A laboratory experiments under controlled conditions were set up to study the changes of available Nitrogen, Phosphourus and Sulfur in Sewage Sludge amended soils (JNU and Mehrauli) at a regular interval of 10 days for a period of two months. The detailed results of these experiments have been incorporated in this dissertation.

pH :

The periodic changes in the pH of the sewage sludge amended soils - JNU and Mehrauli at an interval of 10 days have been shown in table 2 and figs. 3 and 4.

The initial pH of the Control JNU soil was 8.80 i.e slightly alkaline. As the incubation period increases, the values of soil pH were found to be decreased. The decrease in pH values was observed to be gradual within the first 30 days of incubation period i.e from 8.8 to 8.5. Different trends were observed in the other soil samples amended with primary treated and secondary treated sludges. The decrease in pH values within 30 days of incubation period in the soil amended with 10% and 20% primary treated sludge and 10% and 20% secondary treated sludges were 8.5 to

8.1, 8.3 to 8.0, 8.2 to 7.54 and 8.3 to 7.3 respectively. However, the decrease of pH of the soil amended with secondary treated sludge after 30 days of incubation period was white sharp in comparison to the corresponding values of the control soil and soil amended with primary treated sludges.

In Mehrauli soil also similar trends were observed. The pH of the control soil was 8.52. As the incubation period increases the values of soil pH were found to be decreased. The decrease in pH values was observed to be gradual within the first 30 days of incubation period i.e from 8.5 to 8.05. Whereas in the soils amended with secondary treated sludge the pH decreased quite sharply i.e from 8.24 to 7.34 in 10% secondary treated sludge amended soils and from 7.26 to 6.95 in 20% secondary treated sludge amended soils.

Since the pH was slightly alkaline in all the cases, the transformation of applied NH_4^+ to NO_3^- (Nitrification) is thought to be the main reason for the change in the soil pH (Iskander, 1978). Thus the decrease in soil pH could be attributed to the nitrification (Lance and Whisler, 1972; Broad bent et al, 1977) and resulted from hydrogen ions having been generated according to the following equation.

$$NH_4^+ + 2\,O_2 \dashrightarrow NO_3^- + H_2O + 2H^+$$

Since the samples were in direct contact with the atmosphere throughout the incubation period, they were subjected to aerial oxidation and microbial decomposition of organic matter (Spyridakis and Welch, 1976). As a consequence some organic acids might have been formed during the incubation period resulting in decrease in pH of the soil (Robertson et al, 1982). The more decrease in the pH values of secondary treated sludge amended soils was attributed to high acidic levels of the secondary treated sludge.

Electrical Conductivity (EC) :

The periodic variations in EC at different intervals under the application of different sludges on the soils have been presented in the table no-3 and fig. - 3 and 4. The values of EC increased during the incubation period and increase was made significant upto 30 days in all the soil samples. However in the samples amended with secondary treated sludges, the values were showing comparatively higher changes than the primary treated sludge amended soil samples as well as control soil samples. The EC values of 10% and 20% secondary treated sludge amended JNU soils increased by 1 unit and 2 units respectively at the end of incubation period (from 1.235 to 2.335 and from 1.865 to 3.430 m mohs/cm respectively). However, eventhough the EC values of the Control soil samples and primary treated sludge amended samples showing increasing trend, the increase in the values were less significant as compared to the secondary treated sludge amended soil samples (Fig - 5 & 6). Similar changes were observed for the Mehrauli soil samples both with the primary treated and secondary treated sludge amended soil.

The EC of soil solution depends upon the ions present in the medium. Thus when soils were amended with sewage sludges, the accumulation of ions in the soils could take place resulting in the increase of EC upto 30 days of incubation period. The ions complexation and chelation of soluble ions with the organic matter might account for slightly lower values of EC after 30 days of incubation period.

Organic Carbon :

The periodic changes in organic carbon content of the soil under the application of various sewage sludges were shown in the table.5 and (fig. 7 & 8). The initial organic carbon content of the control JNU soil was 0.308%, the 10% and 20% primary treated sludge amended JNU soil and 10% and 20% secondary treated sludge amended JNU soils were 0.320%, 0.340% and 0.7555% and 0.910% respectively. This organic carbon content of all the soil samples decreased during the period of incubation. However, the decrease was more pronounced upto 30 days of incubation period. The percentage of organic carbon of all the above five soil samples at the end of 30 days of incubation period were

0.255, 0.265, 0.310, 0.695 and 0.850 and at the end of 60 days were 0.240, 0.255, 0.290, 0.670 and 0.835 respectively. Mehrauli soil samples also showed similar kind of changes at all the given intervals of incubation.

The decrease in organic matter content throughout the incubation period could be due to the loss of carbon that might have occured in the form of CO_2 through normal microbial decomposition process.(Spyridakis and Welch, 1976). Nyle C.Brady, 1984 also stated that soil organic matter is subjected to vigorous attack by several soil micro-organims which use them as source of energy and tissue building material.

Cation Exchange Capacity (CEC) :

The Cation Exchange Capacity of the experimental samples were shown in the table 4. and fig. 10. It has been observed that there was a gradual increase from control soil sample to 20% secondary treated sludge amended soil samples. The CEC value of the control JNU soil samples was 10.0 meq/100 gm, and of 10% and 20% primary treated sludge amended soils were 13.2 and 13.6 and 10% and 20% secondary treated sludge amended soils were 13.3 and 16.4 respectively. Similar results have been observed in the case of Mehrauli soil samples. The figure clearly indicates that the increase in CEC values are indicative of the extent of the sludge amendment in the soils.

The increase in the CEC may also be ascribed to the pH level. The pH was found to be above 6 in all the experimental samples at all the given intervals of incubation period. Hence the charge on the initial colloids increases slightly because of ionisation of hydrogen from exposed OH groups at crystal edges which led to the increase in the values of CEC (Coleman, 1957; and Helling et al, 1964).

Water Holding Capacity (WHC) :

The water holding capacity of the experimenal soil samples was given in the table no.4 and shown in the fig no.9. It has been observed that the water holding capacity showed higher values with the increase in the amendment of the sewage sludges to the soil. It has also been observed a higher WHC value in the secondary treated sludge amended soil samples among all the experimental soil samples. The WHC of the original JNU and Mehrauli soils were 32.97% and 33.506% respectively. The WHC of 10% and 20% primary treated sludge amended JNU and Mehrauli soil samples were 33.11%, 36.17% and 34.77%, 38.25% respectively. Whereas 10% and 20% secondary treated sludge amended JNU soil and Mehrauli soil samples were 43.50%, 48.5%

and 45.84%, 49.39% respectively.

The increase of the WHC in primary treated sludge and secondary treated sludge amended soil samples was due to the increase in porsoity and it also depends upon the particle size. The porosity is more in secondary treated sludge than the primary treated sludge. It was also due to the more organic carbon content in the secondary treated sludge than the primary treated sludge.

Available Nitrogen :

The periodic changes in available Nitrogen of sewage sludge amended soils were shown in the table no. 6 and fig. no. 11 and 12. The available nitrogen in the control JNU soil at the initial period was 9.20 ppm and 12.48 ppm in Mehrauli soil. As the incubation period increases upto 30 days the available nitrogen increased steadily and from 30 days to 60 days it decreased gradually and the final values were lesser than the initial value. A similar trend was observed in all the four experimental samples. The higher values of available nitrogen were obtained at 30 days of incubation period which were 63.48 and 63.25 ppm at 10% and 20% primary treated sludge amended JNU soil and 72.60 and 74.30 in 10% and 20% secondary treated sludge amended JNU soils respectively. Similarly in Mehrauli soil 55.20 ppm and 56.25 ppm in 10% and 20% primary treated sludge amended soil and 73.40 ppm and 74.0 in

10% and 20% secondary treated sludge amended soil respectively.

The increase in available nitrogen in various sludge amended soils was due to the presence of fairly high amount of available nitrogen in the treated sludges. Besides this, mineralisation of organic nitrogen from organic matter which accumulated in the soil samples could also account for high value of available nitrogen in the soil samples. The steady increase of available nitrogen was mainly attributed to the nitrification process by the aerobic microorganisms, Nitrosomonas and Nitrobacter. In this process ammonium gets converted to Nitrates, so the level of nitrate in the soil increased in hyperbolic fashion over time.

The decrease in available nitrogen after 30 days of incubation period might be due to one or more reasons. It could be due to denitrification, Volatalisation of NH_4^+, incorporation into microbial tissues and adsorption of ammonium ions by organic matter indicated here that the rate of loss of nitrogen exceeded the amount entering the soil profile through the sludges.

Sekar and Bhattacharyya (1982), also found similar variations in available nitrogen while working on the effects of sewage effluents on carbon and nitrogen mineralisation in Delhi soil.

Total Nitrogen :

The periodic changes in total nitrogen in sludge amended soils were given in the table no.7 and shown in the fig. 13 and 14. The total nitrogen of the control JNU soil was 0.054 at the initial period and Mehrauli soil was 0.049%. It has been observed that in all the experimental soil samples there was a decreasing trend as the incubation period proceeded. It has also been noticed that relatively the decrease in total nitrogen was negligible in blank samples, less significant in primary treated sludge amended soil samples and was significant in secondary treated sludge amended samples upto the 30 days of incubation period. There after in all the samples the decrease was significant.

The decrease in the total nitrogen content upto 30 days of incubation period is attributed to the utlisation of nitrogen by micro-organisms as the source of tissue building material as well as the source of energy. It was clear from the studies of available nitrogen changes (fig. no.11 & 12) that the decrease in total N content was mainly due to the denitrification after 30 days of incubation period which led to the release of nitrogen into the atmosphere, thus causing significant decrease in the levels of total nitrogen after 30 days of incubation.

Available Phosphorus :

The periodic changes of available phosphorus in sewage sludge amended soils were given in the table no. 8 and were shown in the fig. no. 15 and 16. It has been observed that there was gradual increase in available phosphorus level in all the soil samples upto 30 days of incubation period. It has also been observed a drastic increase from 20 days to 30 days period where the peak values were obtained and gradual decrease thereafter (table no.8). In the control soil samples and 10% and 20% primary treated sludge amended soil samples a overall decrease was observed in available phosphorus levels i.e. from 9.20 ppm to 2.92; from 9.82 to 8.36 and from 18.40 ppm to 9.58 ppm respectively at the end of the incubation period. Whereas in secondary treated sludge amended soil samples it showed overall increase at the end of the incubation period i.e, from 31.78 ppm to 58.74 ppm in 10% and from 32.62 to 60.06 ppm of phosphorus in 20% seondary treated sludge amended JNU soil samples. However all the experimental soil samples including the secondary treated sludge amended soil samples were showing a decreasing trend in their available phosphorus levels after 30 days of incubation period. Similar trends were also observed in case of Mehrauli soils.

The increase in the available phosphorus levels were primarily due to the presence of soluble phosphates. A linear relationship exists between the soluble phosphours extracted and the amount added through the sludge amending (Sharpley et al, 1984). This accounts for the comparitively higher values in the available phosphorus levels. The increase in available phosphorus levels is also due to the less mobility of phosphate ions in the soils (Hill et al, 1981, Sleight et al., 1984). It may also be due to addition of relatively high soluble phosphates present in the sludges and mineralisation of organic phosphorus (Hooker et al., 1980).

The decrease in phosphorus levels after 30 days of incubation period may be due to the fact that the amount of phosphate fixation in the soil was more than the amount entering soil profile. Milne and Graveland (1972) found that the available phosphorus in sludge amended soils increased after two weeks of incubation under laboratory experimental conditions, but the decrease only after four weeks in two of their soil samples. This decrease was attributed phosphate fixation in the soils. They also found the increase in available phosphorus after 15 days could be due to the release of phosphate from some labile source as a result of moist conditions imposed after the treatment. A subsequent decrease at the end of the treatement might be due to the reversion of phosphate. The mirobial population regulates available phosphorus. Increase in microbial population would mobilise a portion of phosphorus. The decrease in the phosphorus levels of 10% and 20% secondary treated sludge amended soil samples indicated that as the time proceeded the decrease in phosphorus levels at all conditions is quite obvious irrespective of the concentration of the sludges. Further it was noticed the 20% secondary treated sludge amended sample needed more time to get its levels obsolutely come down than that of the initial values.

Total phosphorus :

The periodic changes of total phosphorus were given in the table no 9. and shows in the fig.no.17 & 18. It has been observed that there was no significant change in total phosphorus content in the 60 days of incubation period. But on minute observation, an overall decrease in the total phosphorus content by the end of incubation period has been observed. The decrease was very minute i.e., from 0.033% to 0.027% in JNU control soil and 0.034% to 0.028% in Mehrauli original soil. Similarly in the experimental samples also there was a little decrease in the total phosphrous content as the incubation time proceeded. It has also been observed that in secondary treated sludge amended soil samples the total phosphorus content was more than in primary treated sludge amended samples and the original soil samples.

The insignificant decrease without any specific trend is due to various obvious reasons. Had it been in the field the total phosphorus content can have decrease as the time period increases due to leaching process. Where as this experiment there was no scope for leaching. So the total phosphorus content present in the initial period remaind same even at the end of the incubation period. The little decrease at the end of the incubation period attributes to some evaporation process.

Total Sulfur

The periodic changes in total sulfur content in sewage sludge amended soil samples were given in the table 11 and figs. 21 and 22. It was observed that there was a very little significant change in total sulfur content in the whole incubation period. There was a little decrease in the sulfur content as the incubation period increased. In the control soils-JNU and Mehrauli the decrease was from 0.045% to 0.034and 0.052 to 0.045% respectively. In case of experimental soil samples there was a little decrease which is not very significant. In 10%, 20% primary treated sludge amended JNU soil samples and 10%, 20% secondary treated sludge amended JNU soil samples the decrease was from 0.048 to 0.038, 0.052 to 0.040 and 0.054 to 0.042and 0.058to 0.045 respectively. Similarly in Mehrauli soil amended with 10%, 20% primary treated sludge and 10%, 20% secondary treated sludge the decrease in sulfur content was from 0.056 to 0.045, 0.06 to 0.050 and 0.068 to 0.058 and 0.072 to 0.061 respectively by the end of the incubation period.

The decrease in the total sulfur content of the soil samples after the incubation period of 60 days could be attributed to the oxidation process which results the release of SO_2 into the atmosphere.

Available Sulfur :

The periodic changes of available sulfur in sewage sludge amended soil samples were given in the Table No. 10. and Fig. No. 19 & 20. The available sulfur content in the control soils at the initial period of incubation was 8.32 ppm in JNU soil and 7.63 ppm in Mehrauli soil. It has been observed that the avilable sulfur content decreased during the 60 days of incubation period (from 8.32 ppm to 7.892 ppm in JNU soil and 7.63 ppm to 7.40 ppm in Mehrauli soil. It has also been observed that as the incubation period increased the available sulfur content increased upto 30 days of incubation period. The values were given in the table. i.e, 9.630 ppm in original JNU soil and 9.752, 9.82, 11.43 and 12.05 in 10%, 20% primary treated sludge amended JNU soil and 10%, 20% secondary treated sludge amended JNU soil respectively. Similarly in Mehrauli soil samples also the peak values were at the interval of 30 days of incubation period.

The increase in the available sulfur content upto 30 days of incubation period may be attributed to the decomposition of organic sulfur into available form by certain microbial action such as <u>Thiobacellus</u> and <u>thiooxidans</u>.

The decrease in available sulfur content after 30 days of incubation period may be ascribed to the reduction process. They are reduced to sulfides by a number of bacteria of two genera, Desulfovibrio and Desulfotomaculum (Brady, 1982).

The changes studied in the above experiment were confirming the prescribed organic matter, nitrogen, sulfur balance in the soil. The changes occured in the available sulfur were correlated with changes in available nitrogen (r = 0.98 for JNU soil and 0.99 for Mehrauli Soil).

Correlation among the Various Parameters

The correlation coefficients among the various parameters of JNU and Mehrauli soil were given in the table no. 11 and scatter grams in fig. 23 to 39.

The parameters are

1) Available Nitrogen Vs Organic Carbon.
2) Available Nitrogen Vs pH.
3) Available Phosphorus Vs Organic Carbon.
4) Available Phosphorus Vs pH
5) Available Sulfur Vs Organic Carbon
6) Available Sulfur Vs pH
7) Available sulfur Vs Nitrogen
8) Available sulfur Vs Phosphorus

It was observed that correlation between available nitrogen and organic carbon was + 0.83, while with pH it was -0.63. Thus it infers when the organic carbon content increases, the available nitrogen also increases in JNU soil. The negative correlation between nitrogen and pH shows that more nitrogen is available at lower pH while it decreases at alkaline pH.

The correlation coefficient between the available phosphorus and organic carbon was found to be highly positive and its value is + 0.750 whereas the correlation coefficient between the phosphorus and pH was found to be negative i.e. -0.78. It infers that as the organic carbon content increases the available phosphorus also increases with the decrease of pH value.

It has been observed that the correlation coefficient between available sulfur and organic carbon was + 0.87 i.e highly correlated and between sulfur and pH it was negative i.e - 0.68. Thus it inferes more organic carbon content in JNU soil, more the available sulfur and as the pH value decreases the available sulfur increases.

The correlation coefficient between nitrogen and sulfur was found to be highly significant and its value is + 0.98. It shows that the available nitrogen increases the available sulfur also increases in JNU soil.

The correlation coefficient value between phosphorus and sulfur was + 0.90. It is highly significant indicating that higher the available phosphorus content in the soil higher the content of sulfur.

Mehrauli Soil :

It has been observed that the correlation between available nitrogen and organic carbon was + 0.308 while the pH values it was - 0.57. It shows that the available nitrogen content increased with the increase of organic carbon content and decrease of pH values.

The correlation coefficient between the available phosphorus and organic carbon was found to be positive and its value was + 0.166 wherever the correlation coeffcient between phosphorus and pH was negative i.e., -0.707. It infers that as the organic carbon content increases, the available phosphorus also increases in Mehrauli soil. The negative correlation between phosphorus and pH shows that the available phosphorus increases with the decrease of pH values.

It was observed that the correlation coefficient between available sulfur and organic carbon was 0.334 and between available sulfur and pH was -0.619 i.e., negative. It indicates that as the organic carbon content increase, the available sulfur also increases in Mehrauli soil. The negative correlation between sulfur and pH shows that the available sulfur increases with the decrease of pH.

The correlation coefficient between nitrogen and sulfur and phosphorus and sulfur were + 0.991 and +0.9077 respectively. This highly positive correlation between them shows that higher available sulfur content. With the higher contents of Nitrogen and Phosphorus.

FIGURES

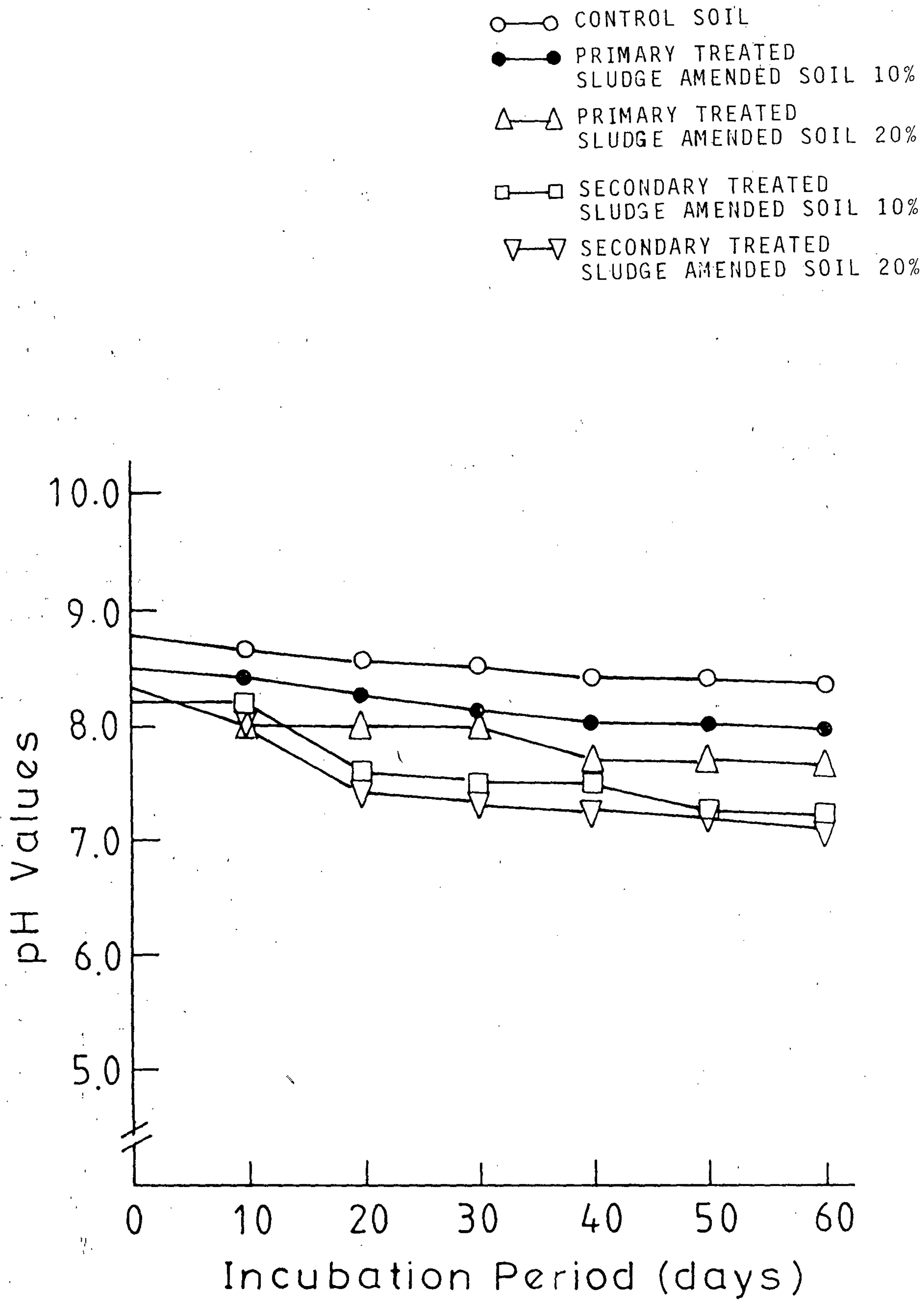


Fig. 3 : PERIODIC CHANGES OF pH VALUES IN SEWAGE SLUDGE AMENDED SOIL - JNU

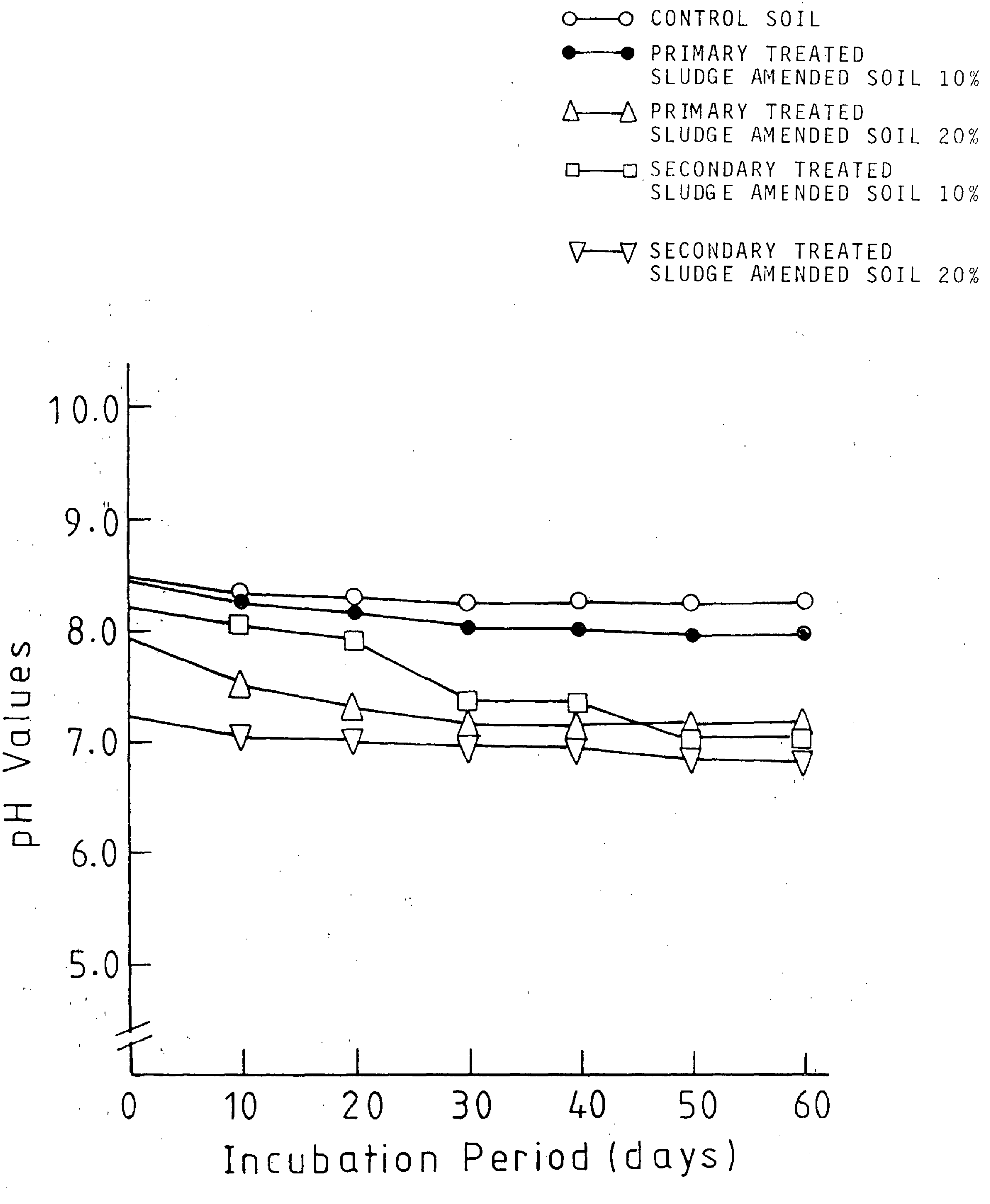


Fig. 4: PERIODIC CHANGES OF pH VALUES IN SEWAGE SLUDGE AMENDED SOIL - MEHRAULI

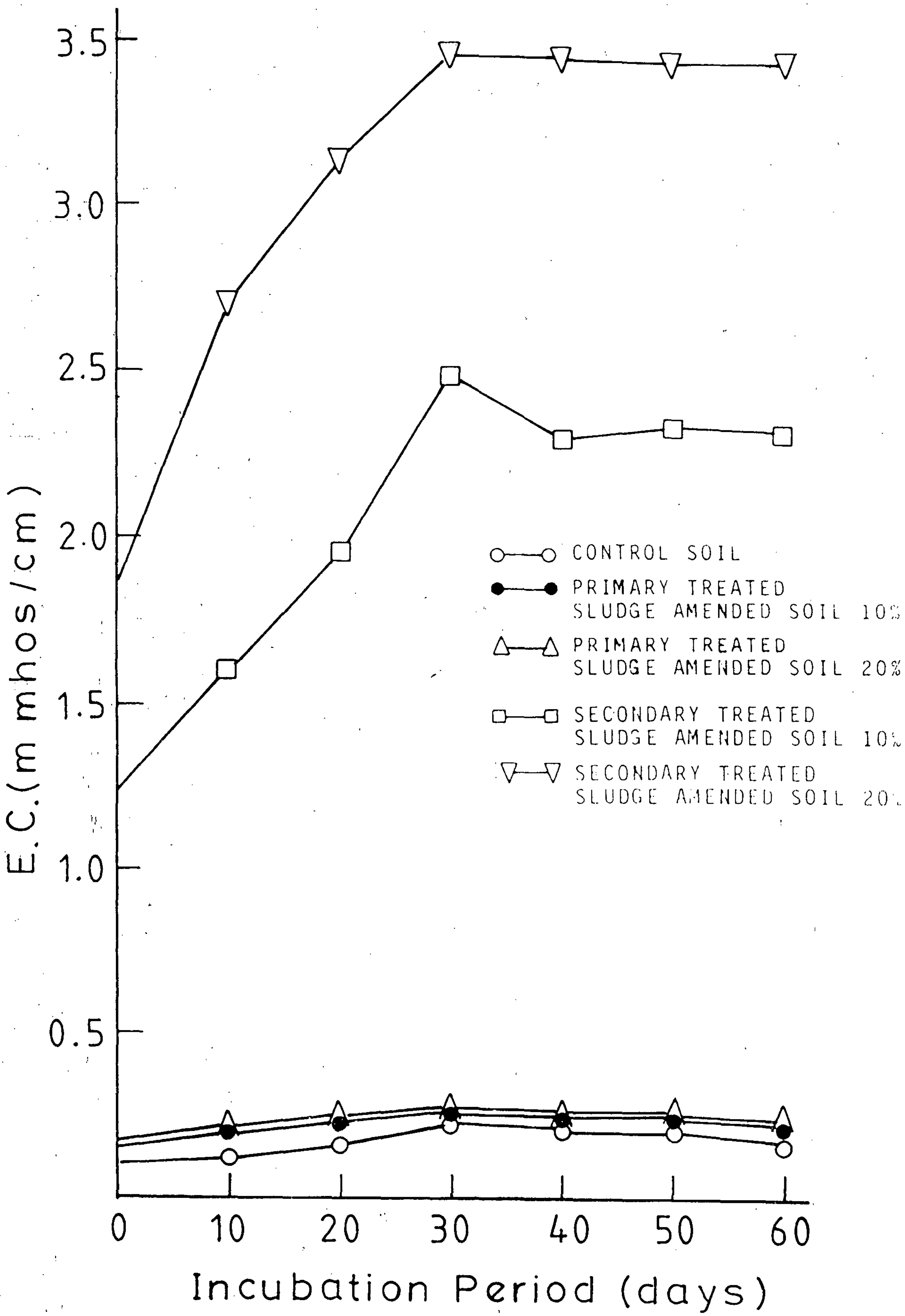


Fig. 5: PERIODIC CHANGES OF ELECTRICAL CONDUCTIVITY(m mhos/Cm) IN SEWAGE SLUDGE AMENDED SOIL - JNU

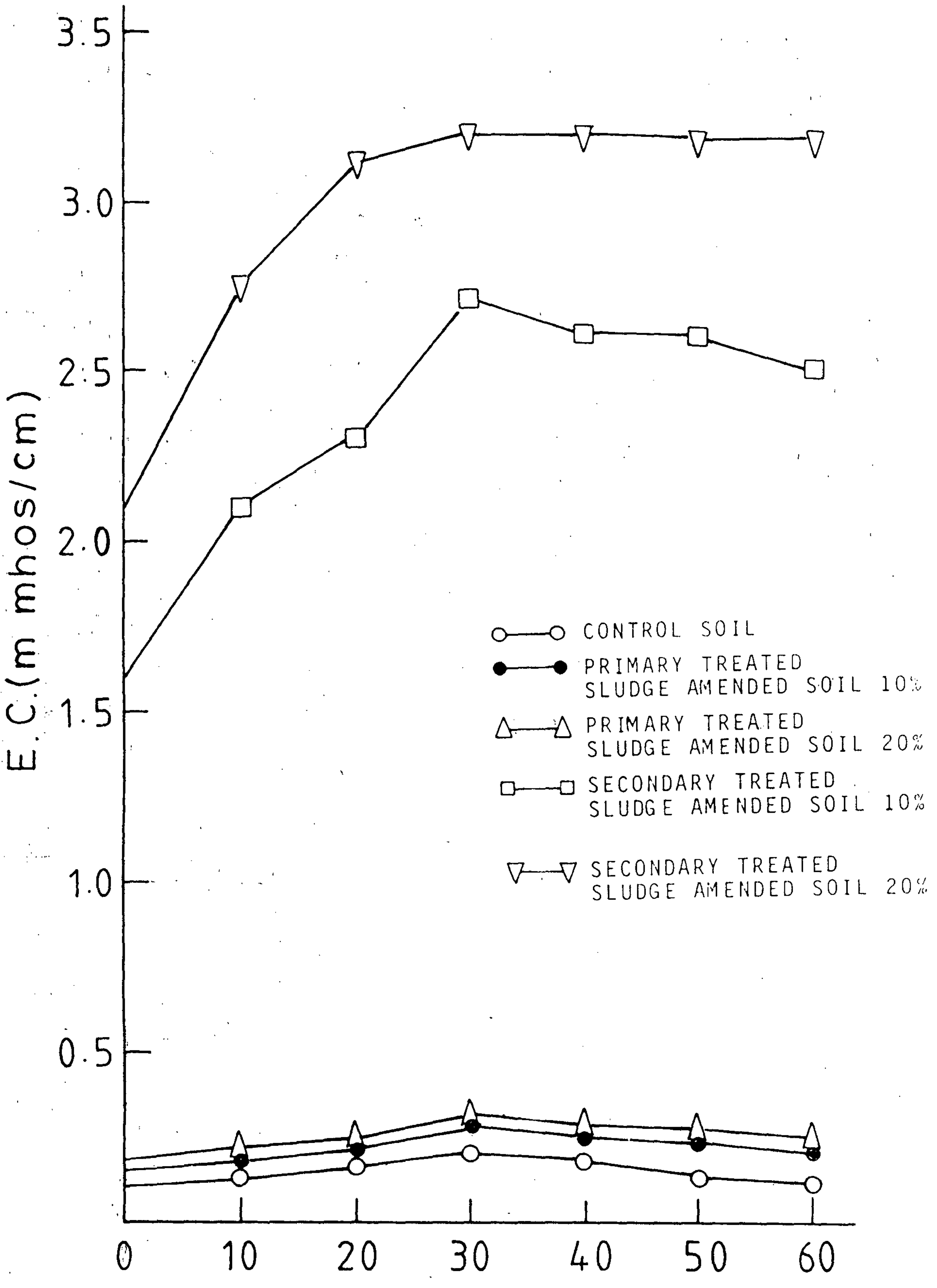


Fig. 6. Periodic changes of Electrical Conductivity in sewage sludge amended soil - Mehrauli

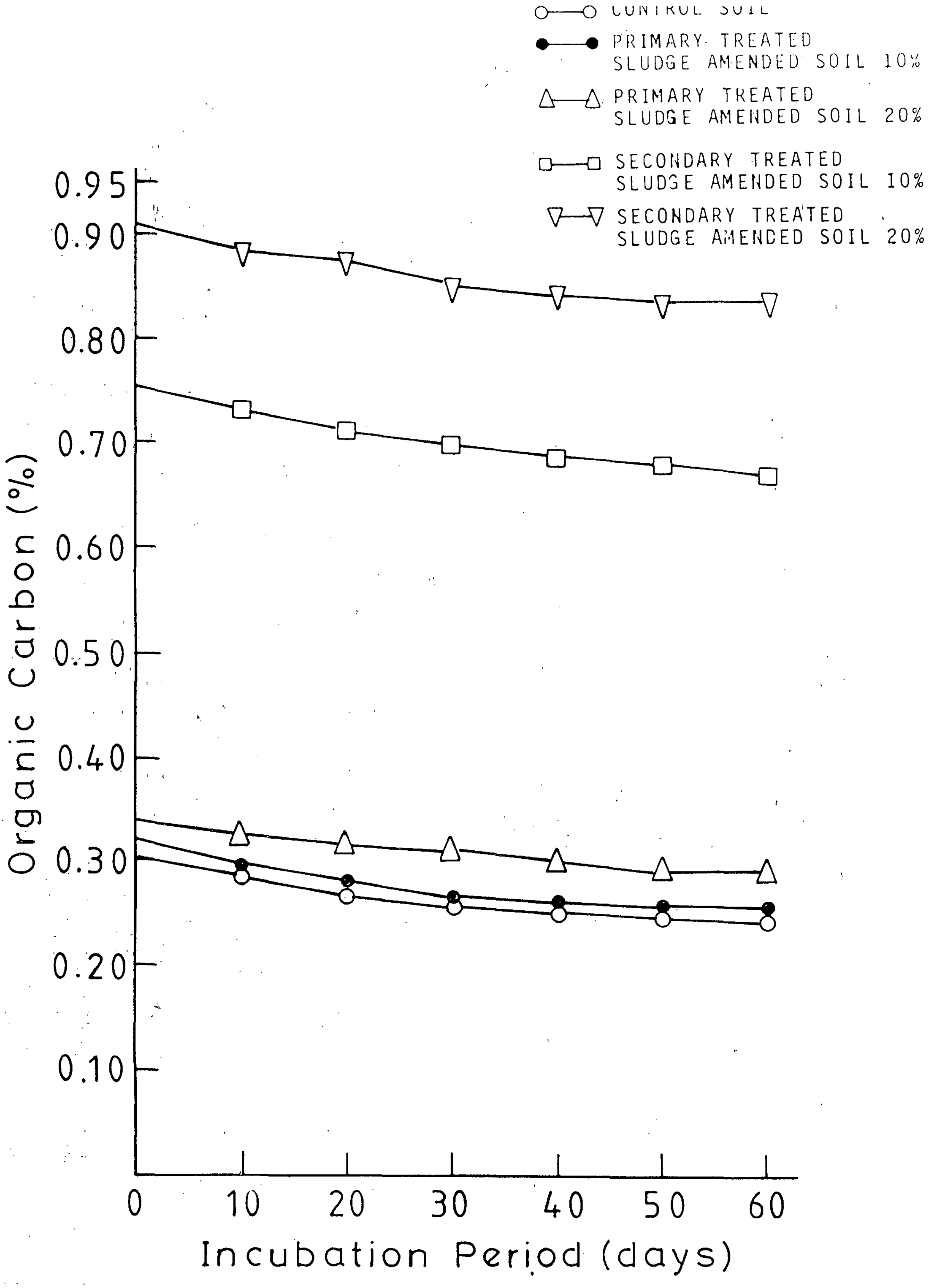


Fig. 7. Periodic changes of Organic Carbon in sewage sludge amended soil - JNU

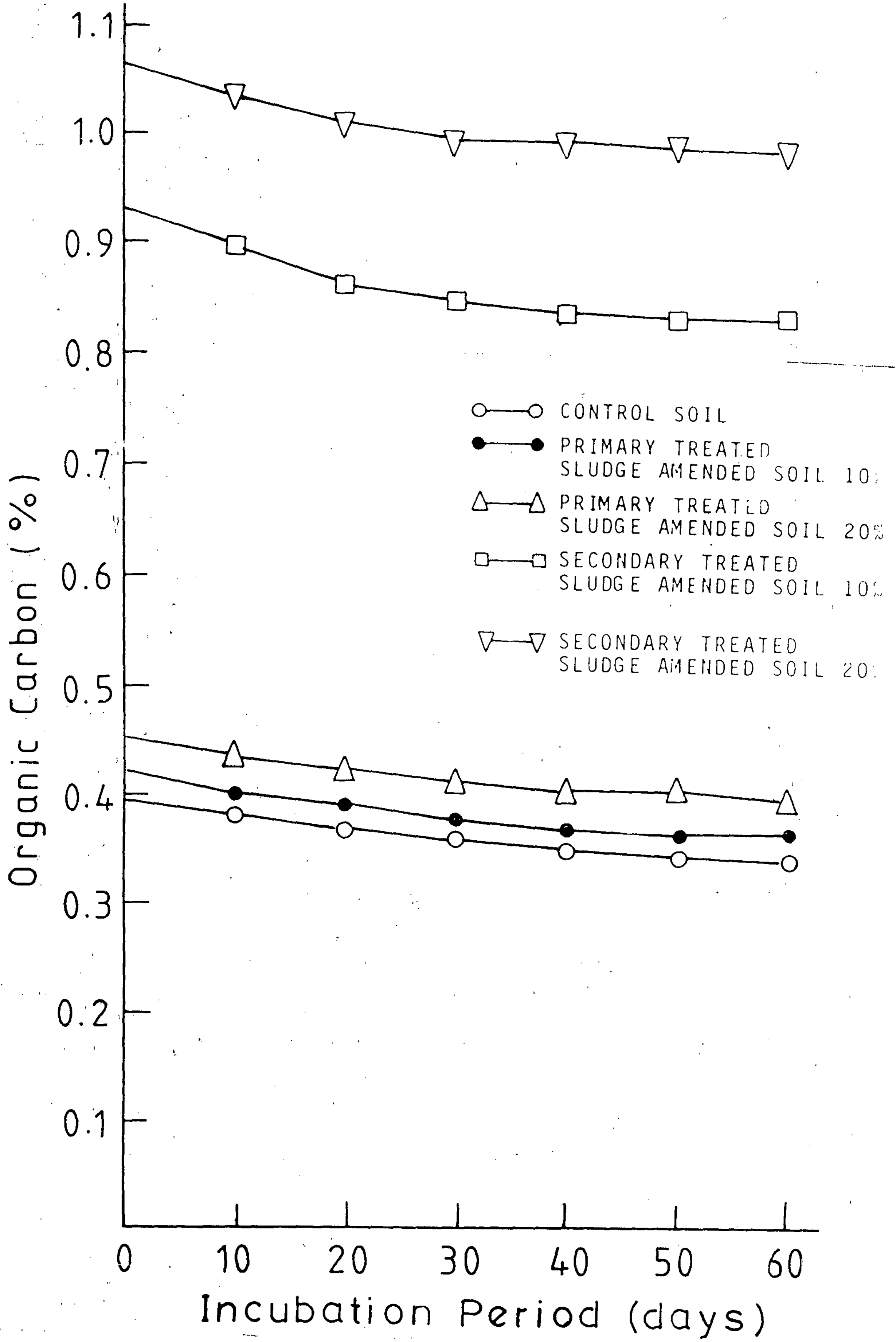
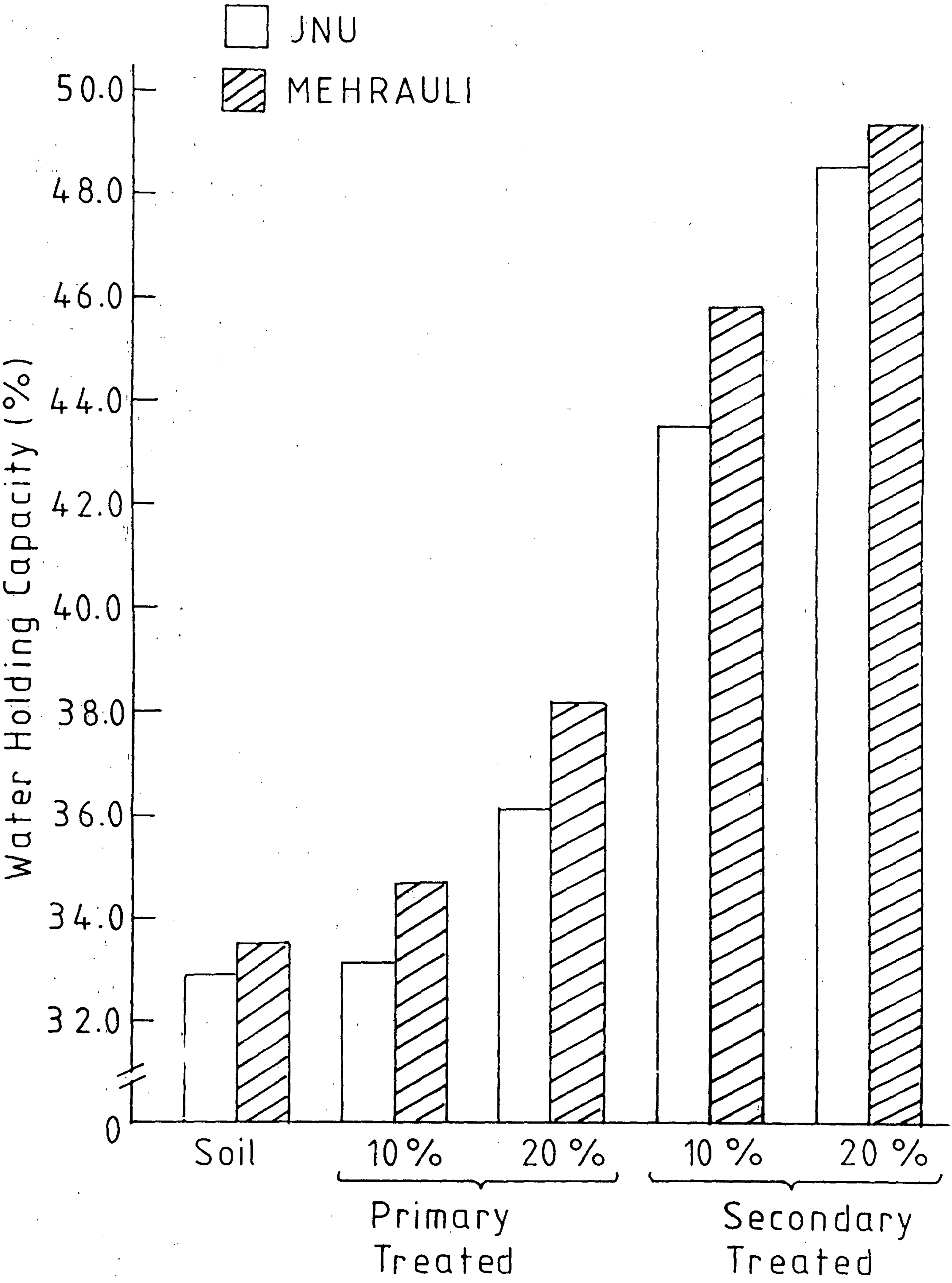


Fig. 8. Periodic changes of Organic Carbon in sewage sludge amended soil - Mehrauli

Fig. 9. Water Holding Capacity of Sewage Sludge amended soils - JNU and Mehrauli



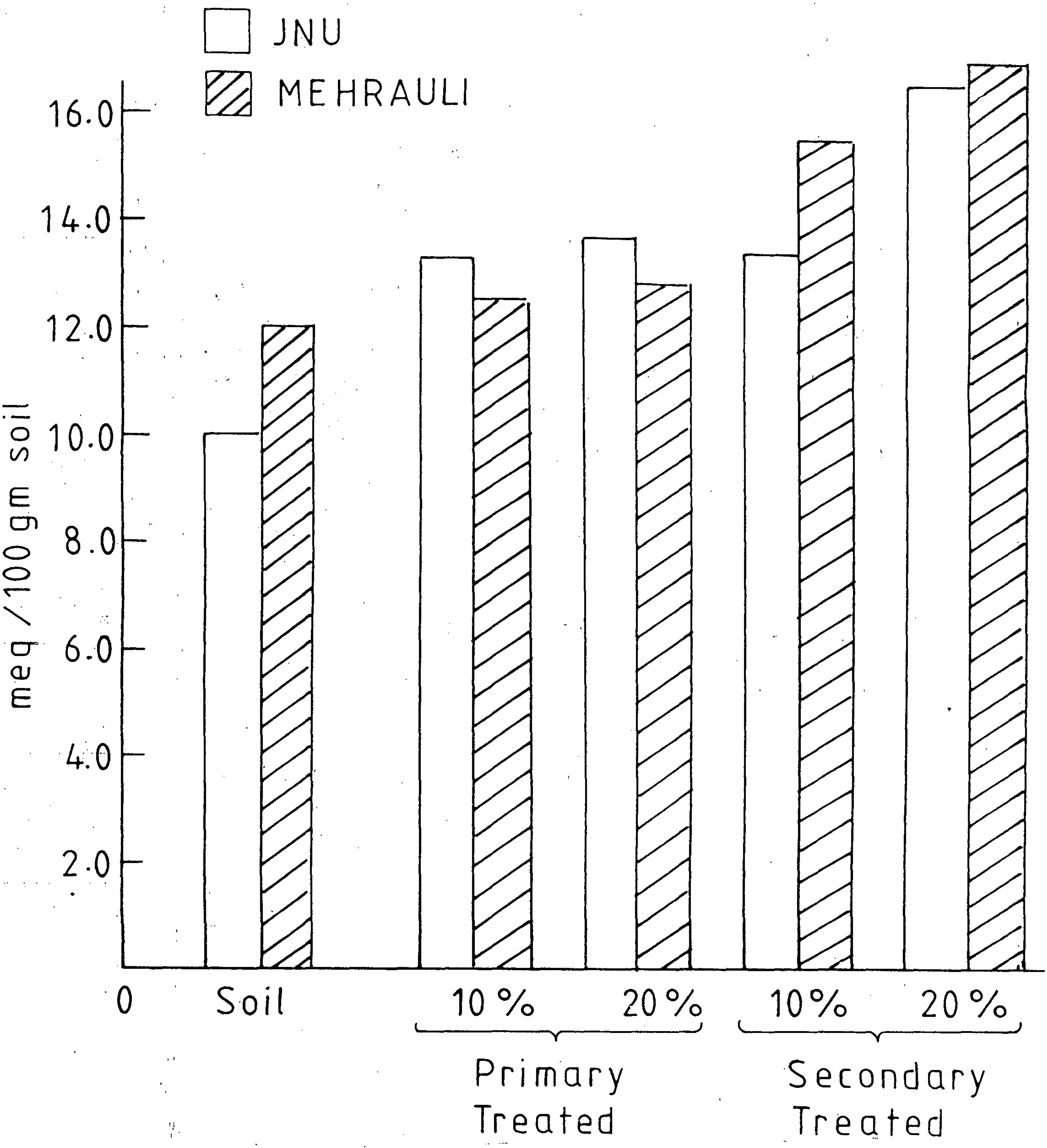


Fig. 10. Cation of exchange of Sewage sludge amended soils - JNU and Mehrauli

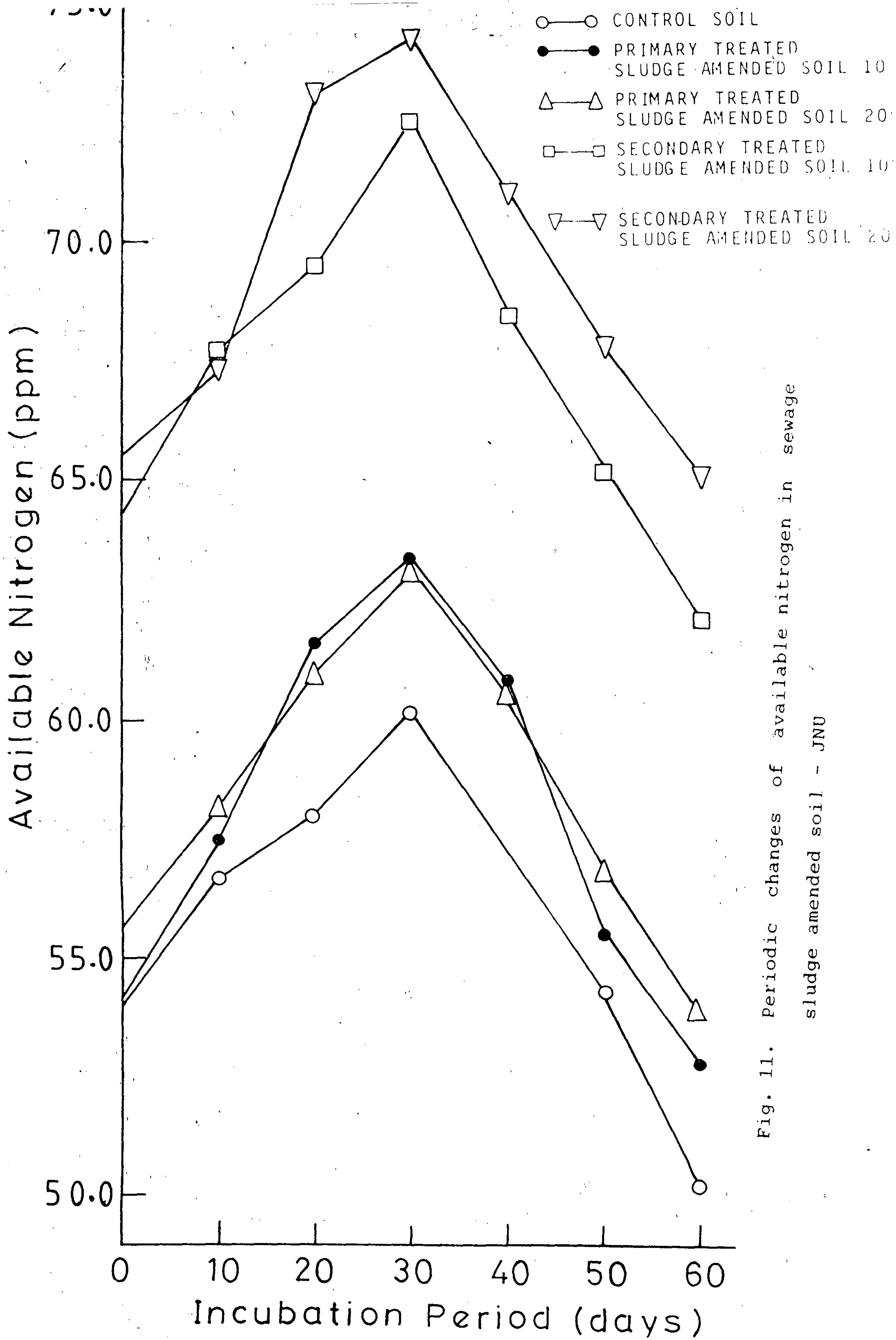


Fig. 11. Periodic changes of available nitrogen in sewage sludge amended soil - JNU

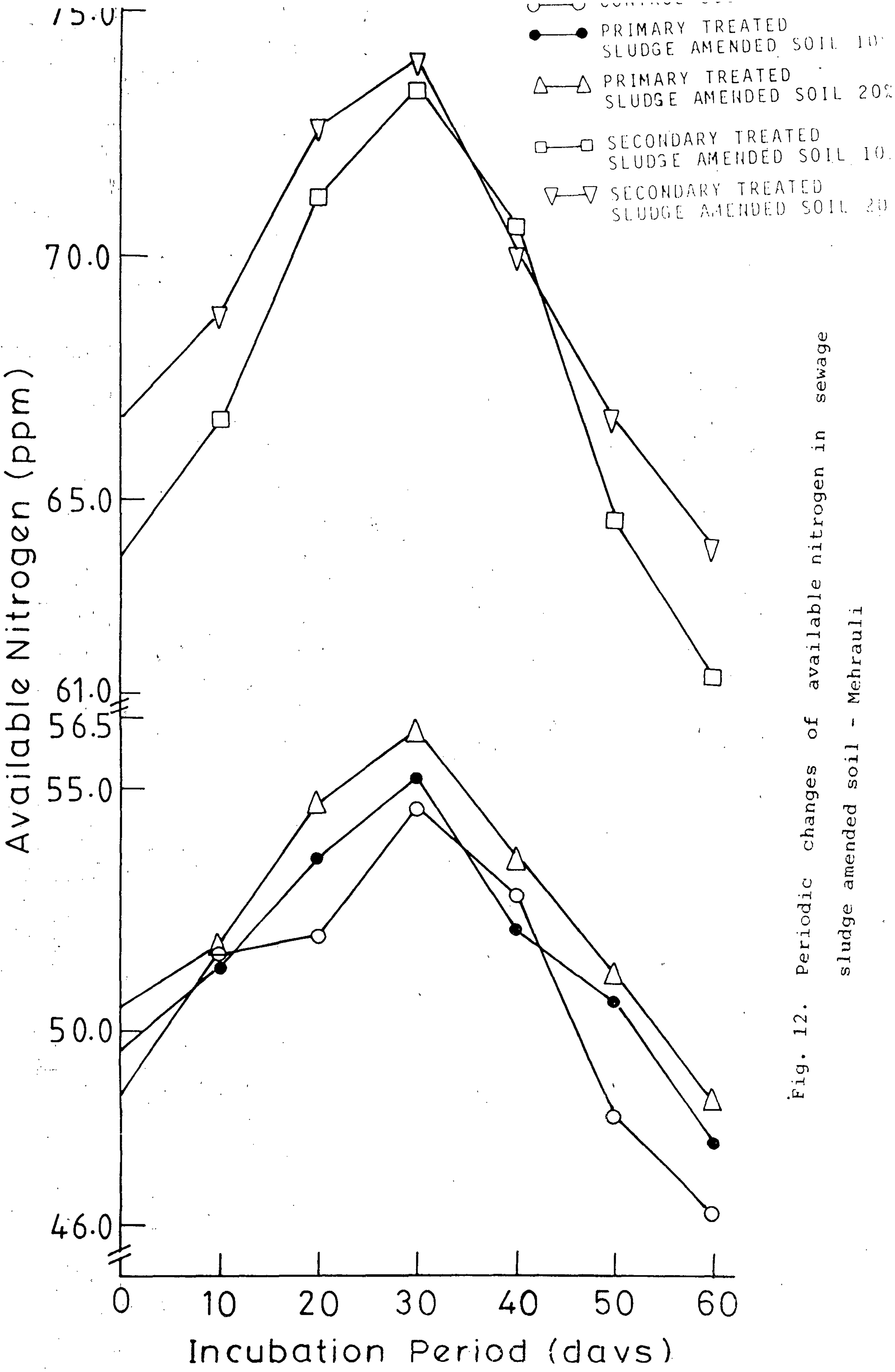


Fig. 12. Periodic changes of available nitrogen in sewage sludge amended soil - Mehrauli

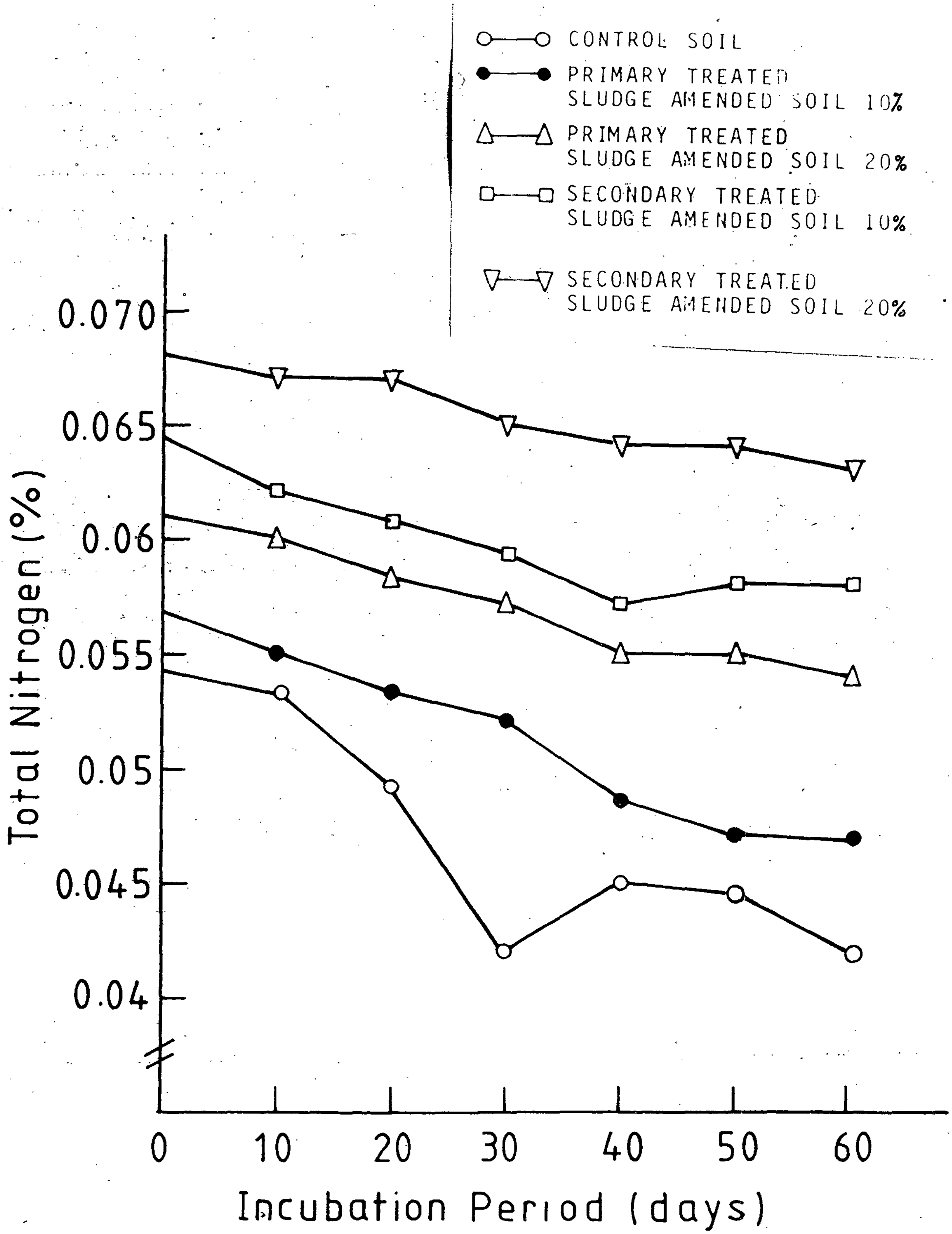


Fig. 13. Periodic changes of total nitrogen in sewage sludge amended soil - JNU

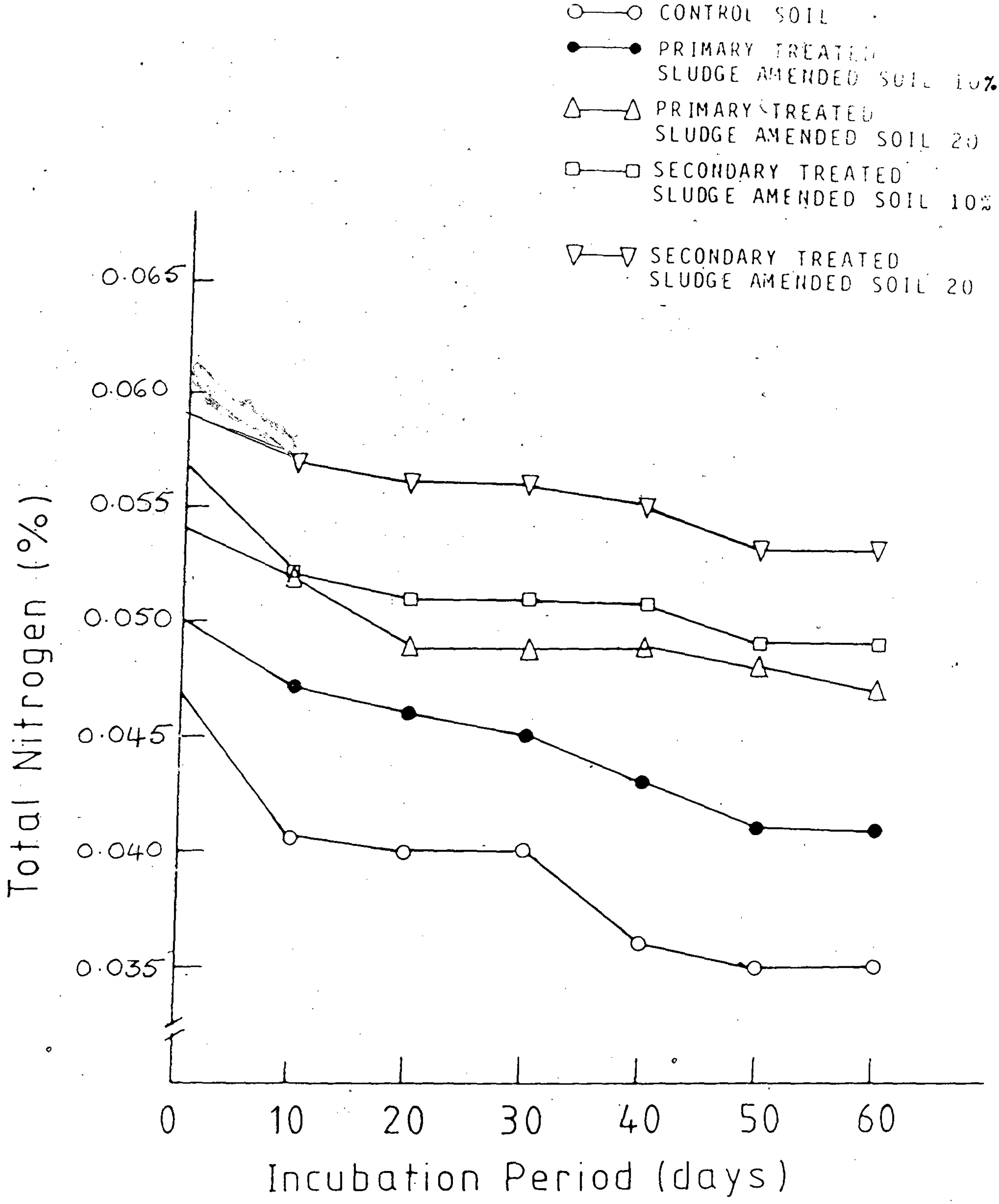


Fig. 14. Periodic changes of total nitrogen in sewage sludge amended soil - Mehrauli

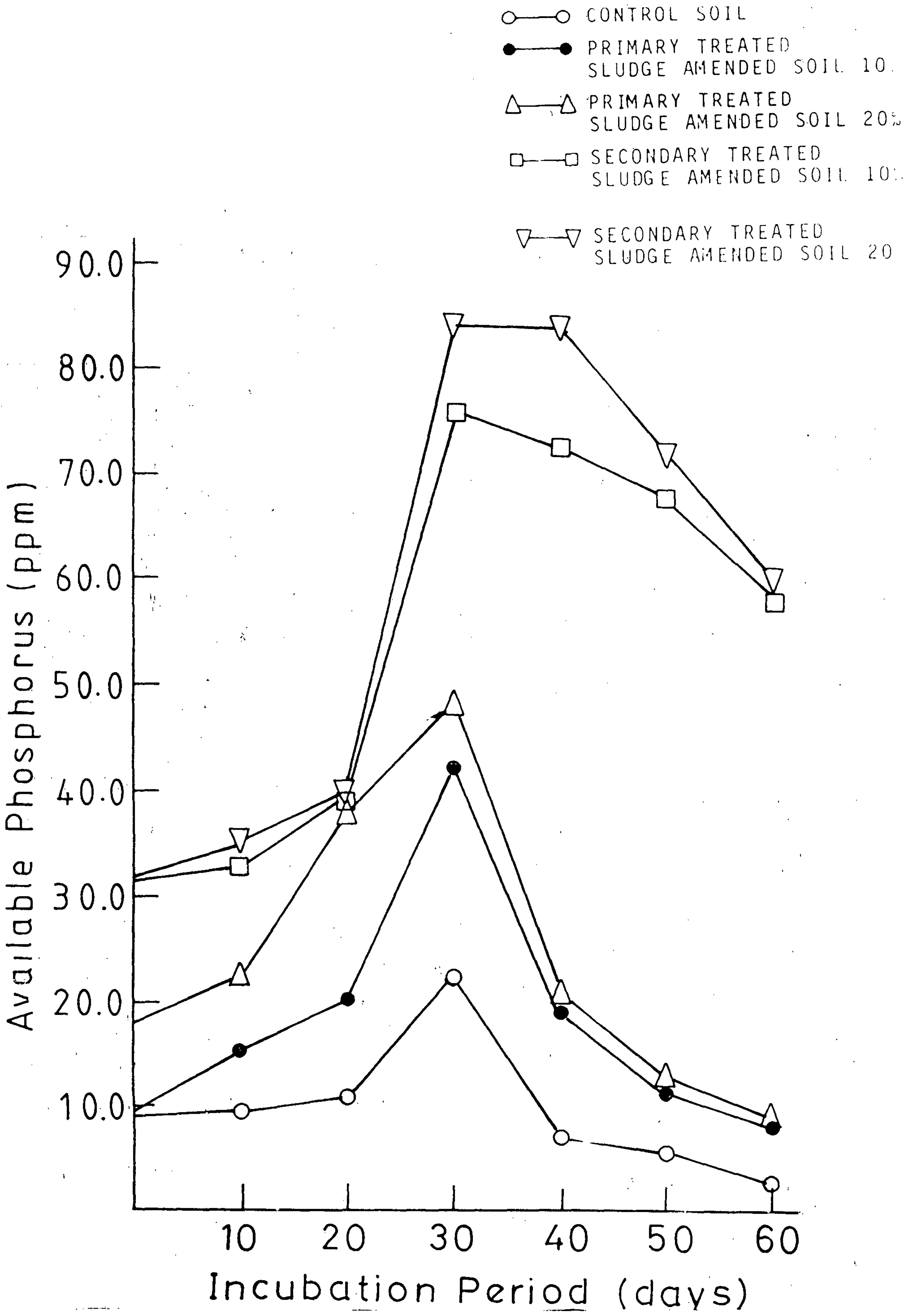


Fig. 15. Periodic changes of available phosphorus in sewage sludge amended soil - JNU

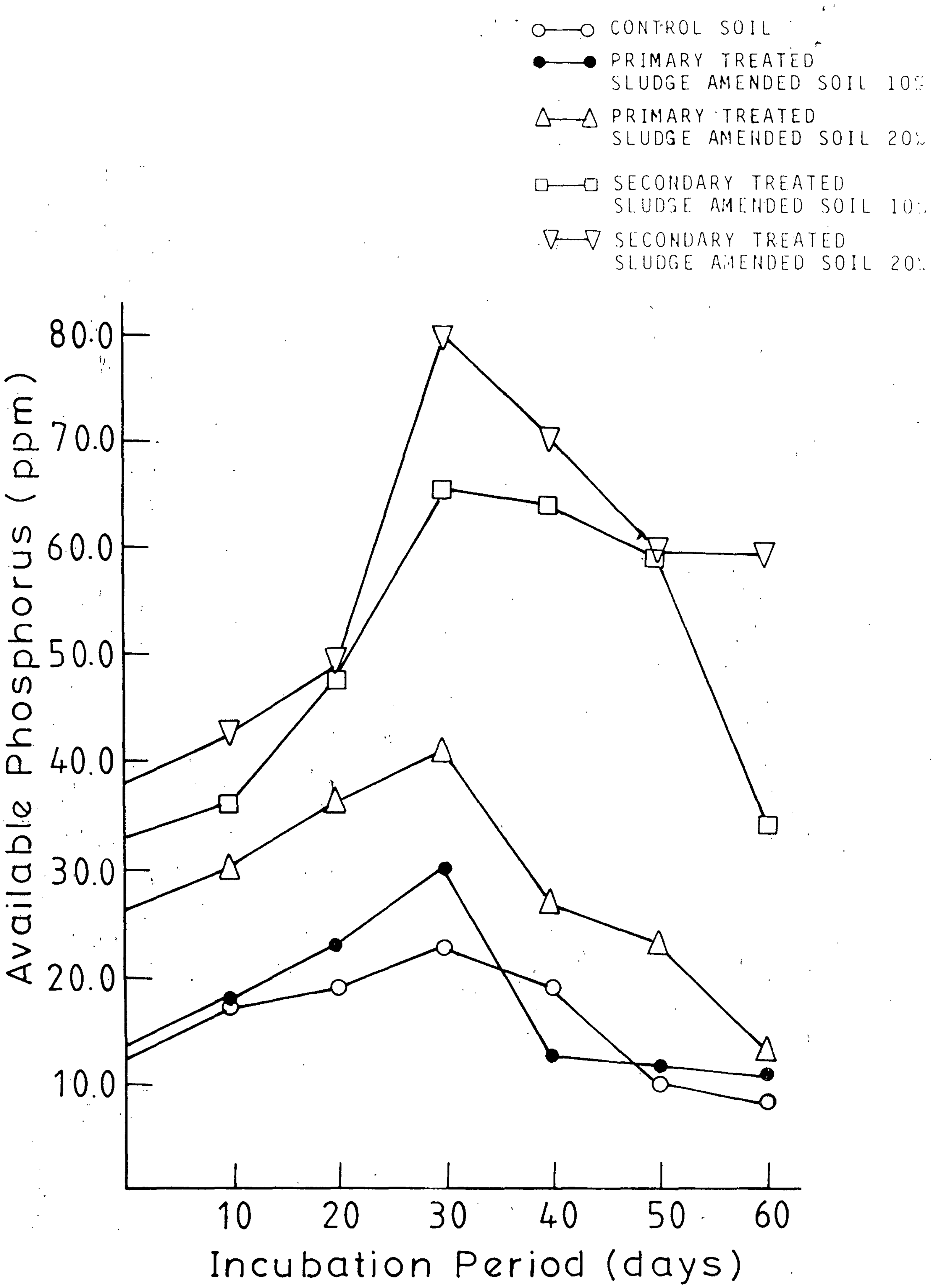


Fig. 16. Periodic changes of available phosphorus in sewage sludge amended soil - Mehrauli

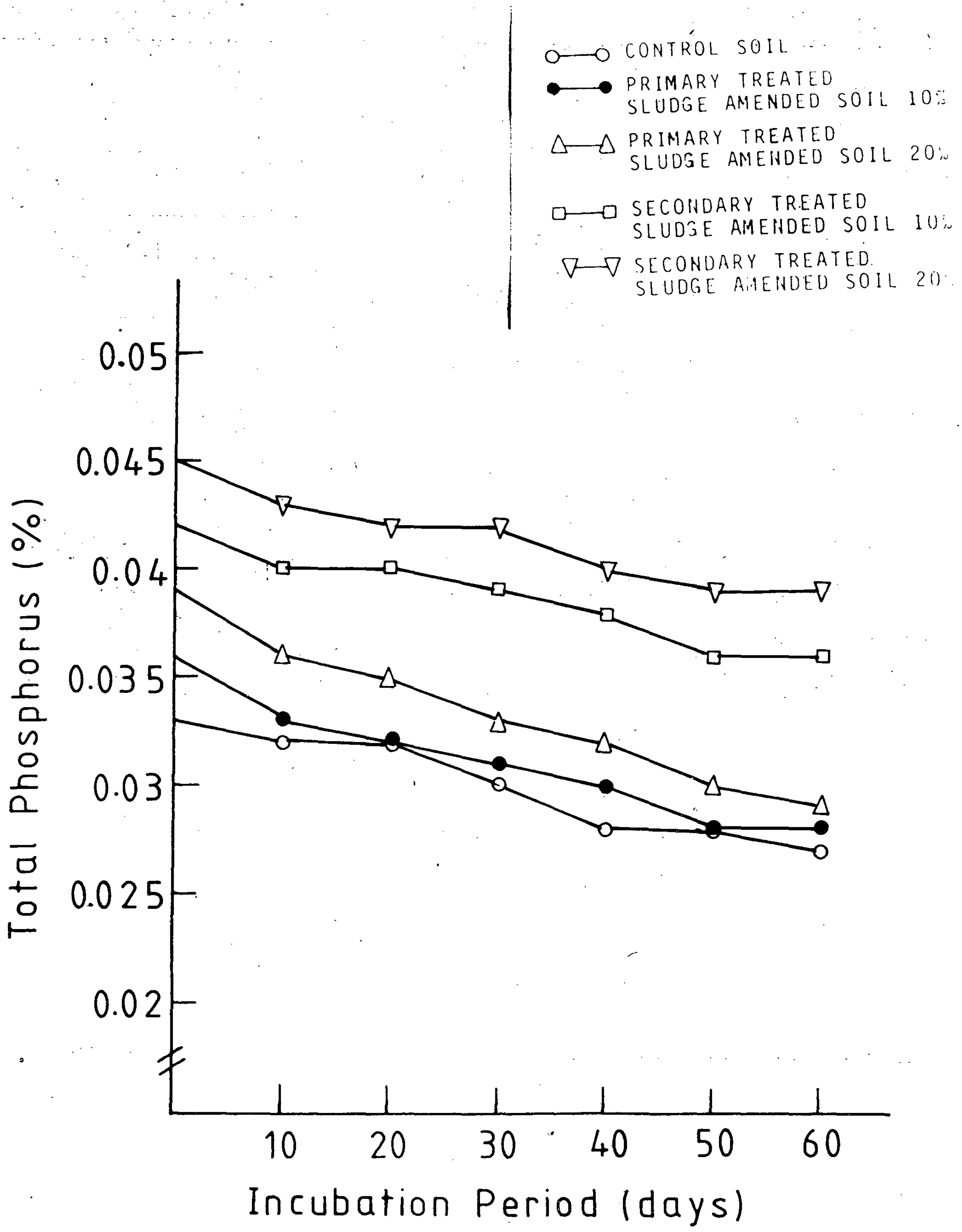


Fig. 17. Periodic changes of total phosphorus in sewage sludge amended soil - JNU

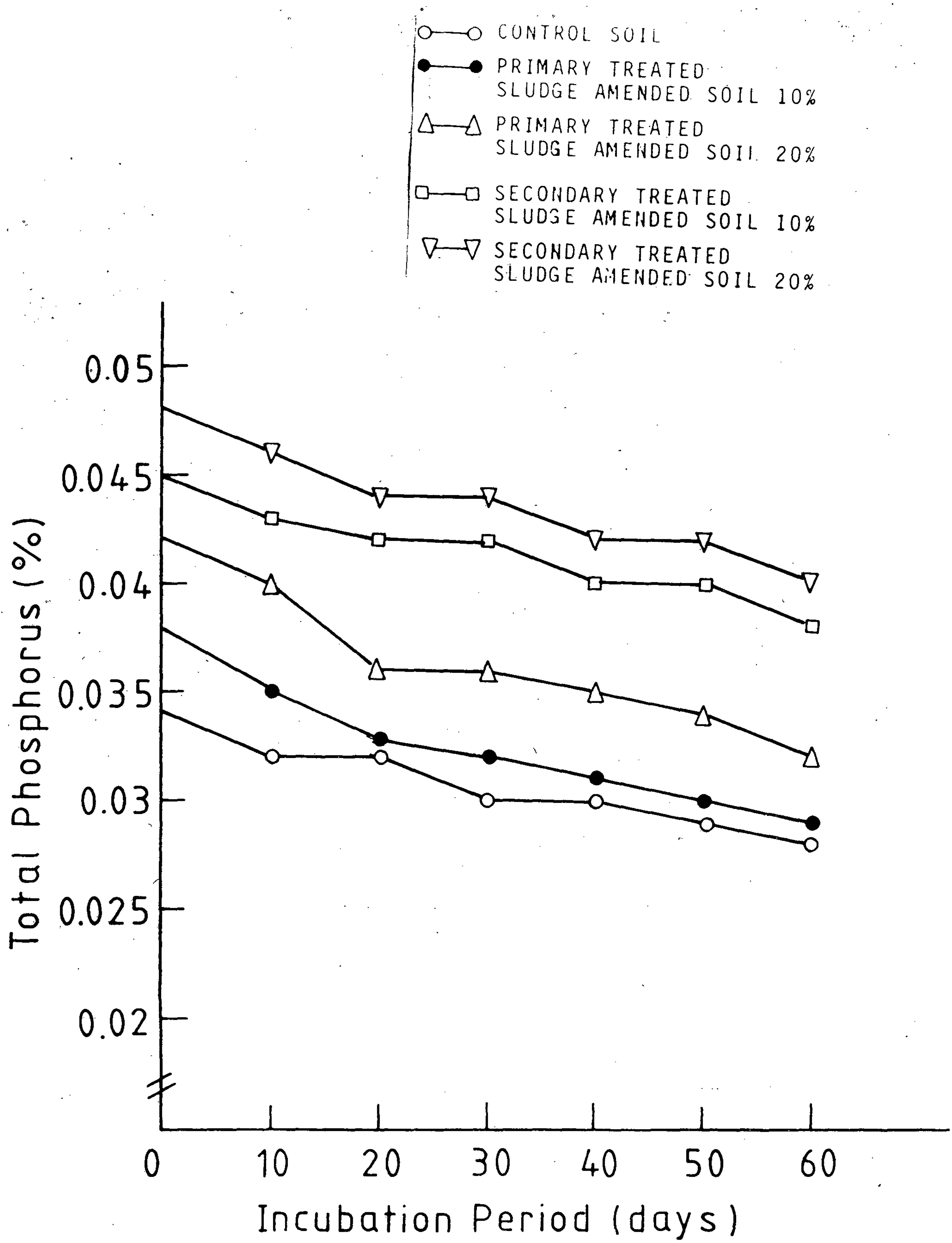


Fig. 18. Periodic changes of total phosphorus in sewage sludge amended soil - Mehrauli

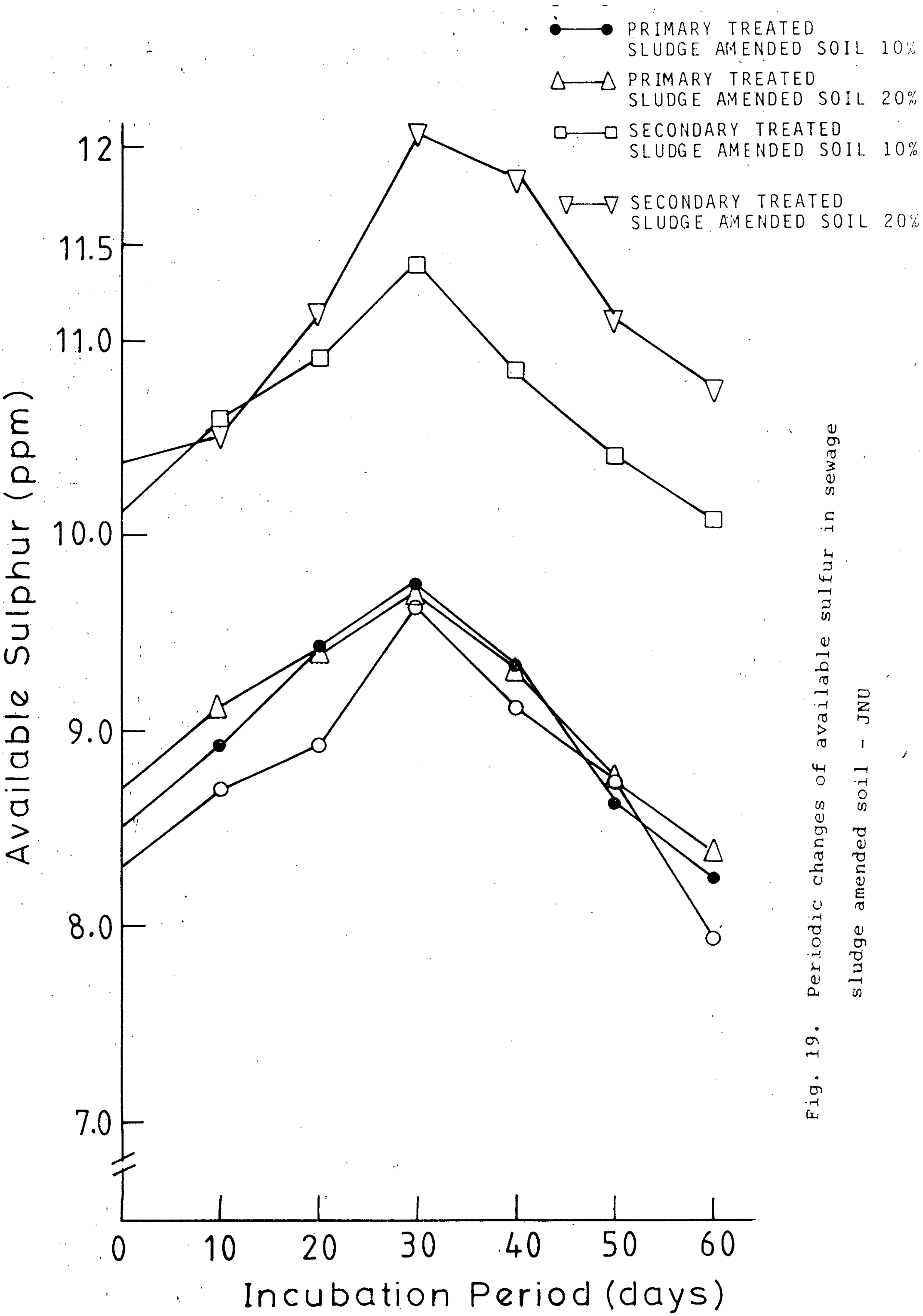


Fig. 19. Periodic changes of available sulfur in sewage sludge amended soil - JNU

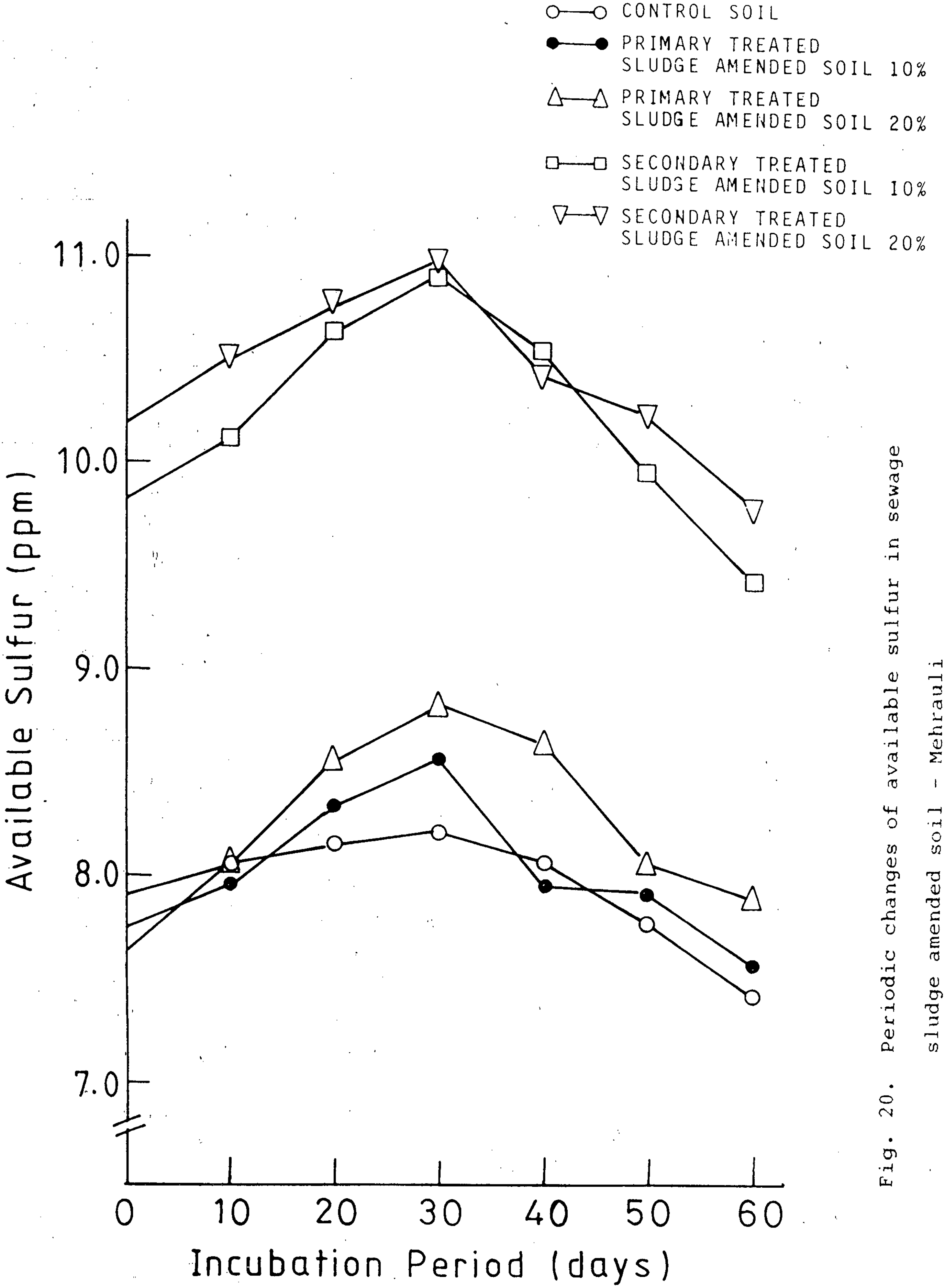


Fig. 20. Periodic changes of available sulfur in sewage sludge amended soil - Mehrauli

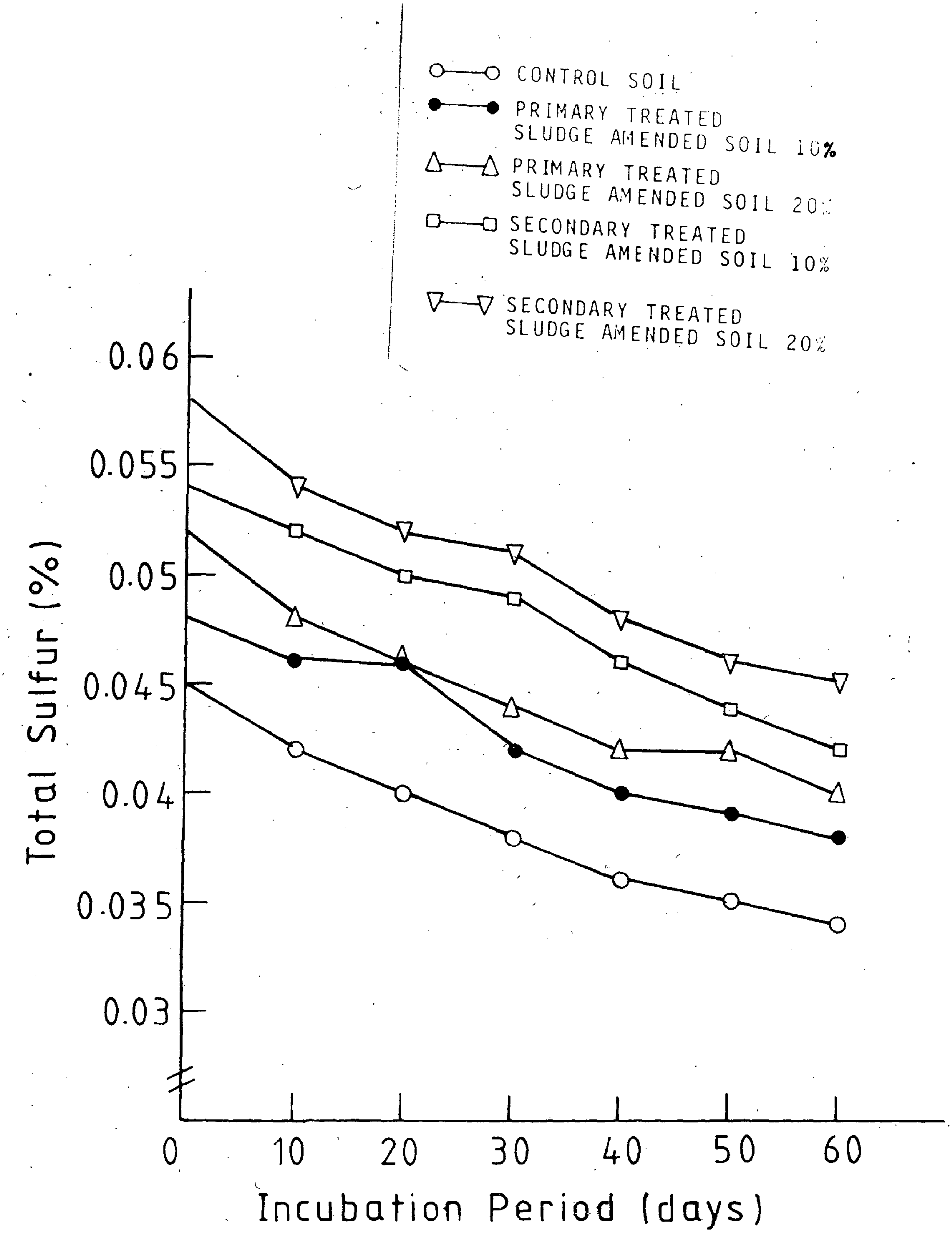


Fig. 19. (a) Periodic changes of total sulfur in sewage sludge amended soil - JNU.

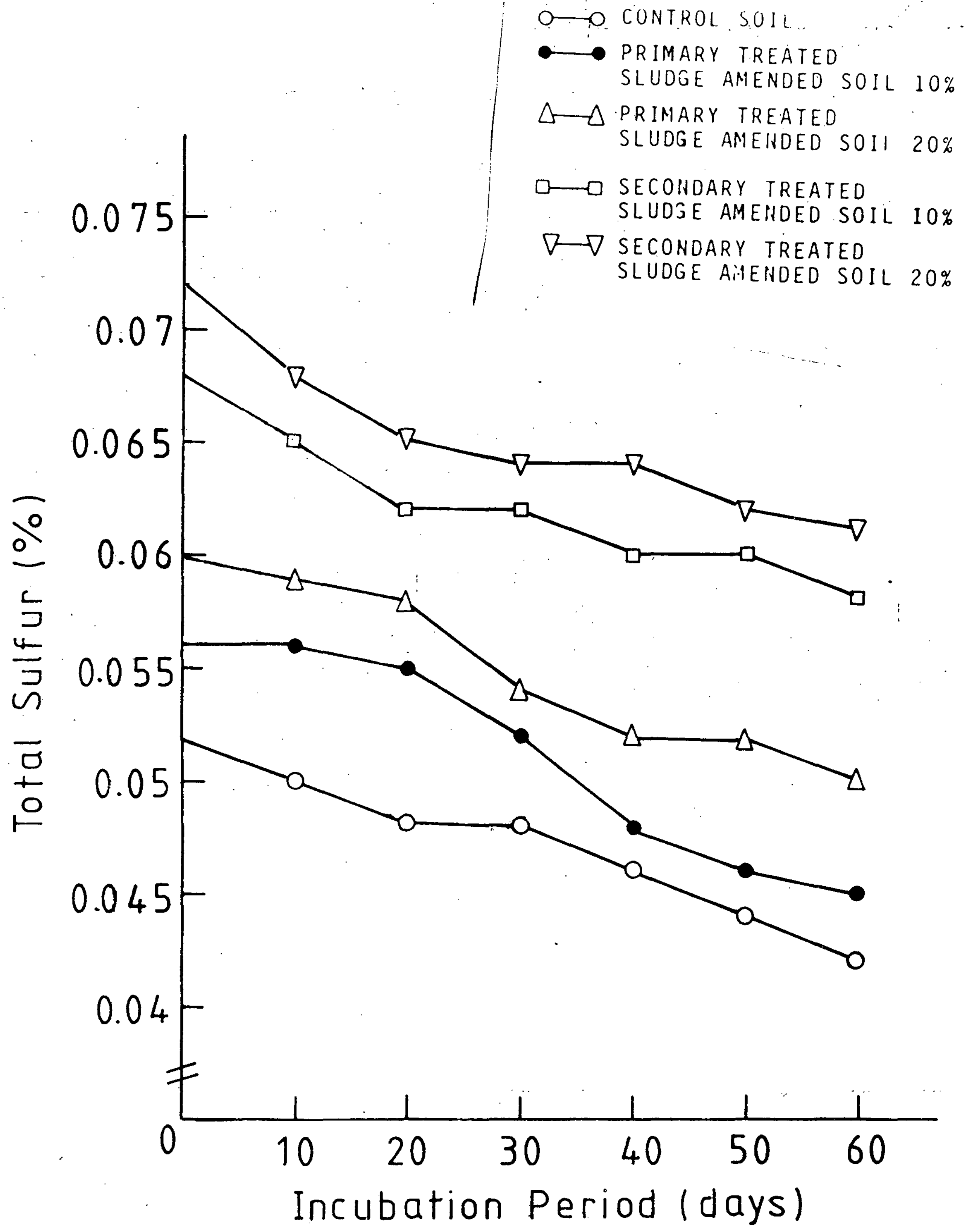


Fig. 20. (a) Periodic changes of total sulfur in sewage sludge amended soil - Mehrauli.

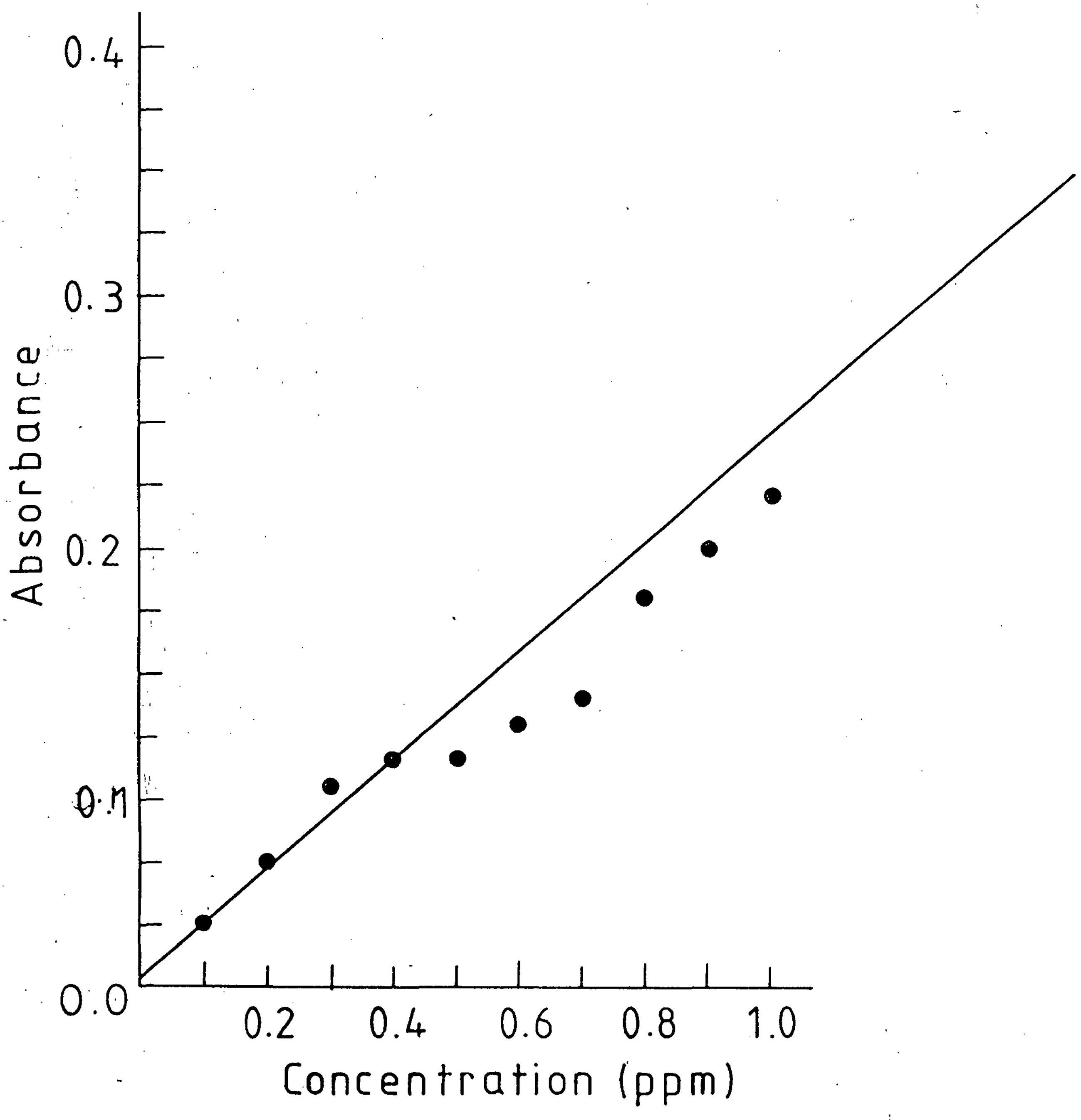


Fig. 21. Phosphorus Statndard Curve

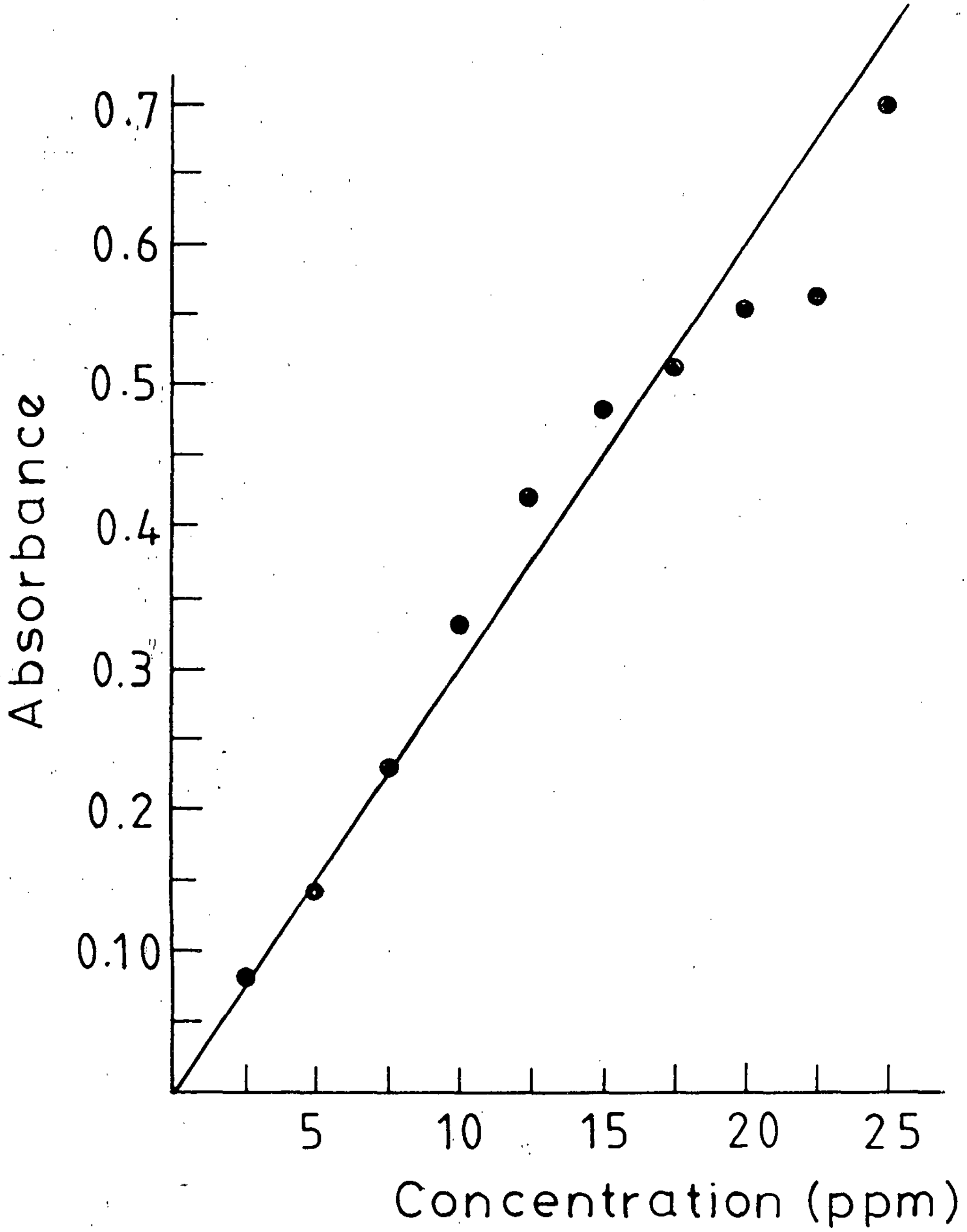


Fig. 22. Sulfur Standard Curve

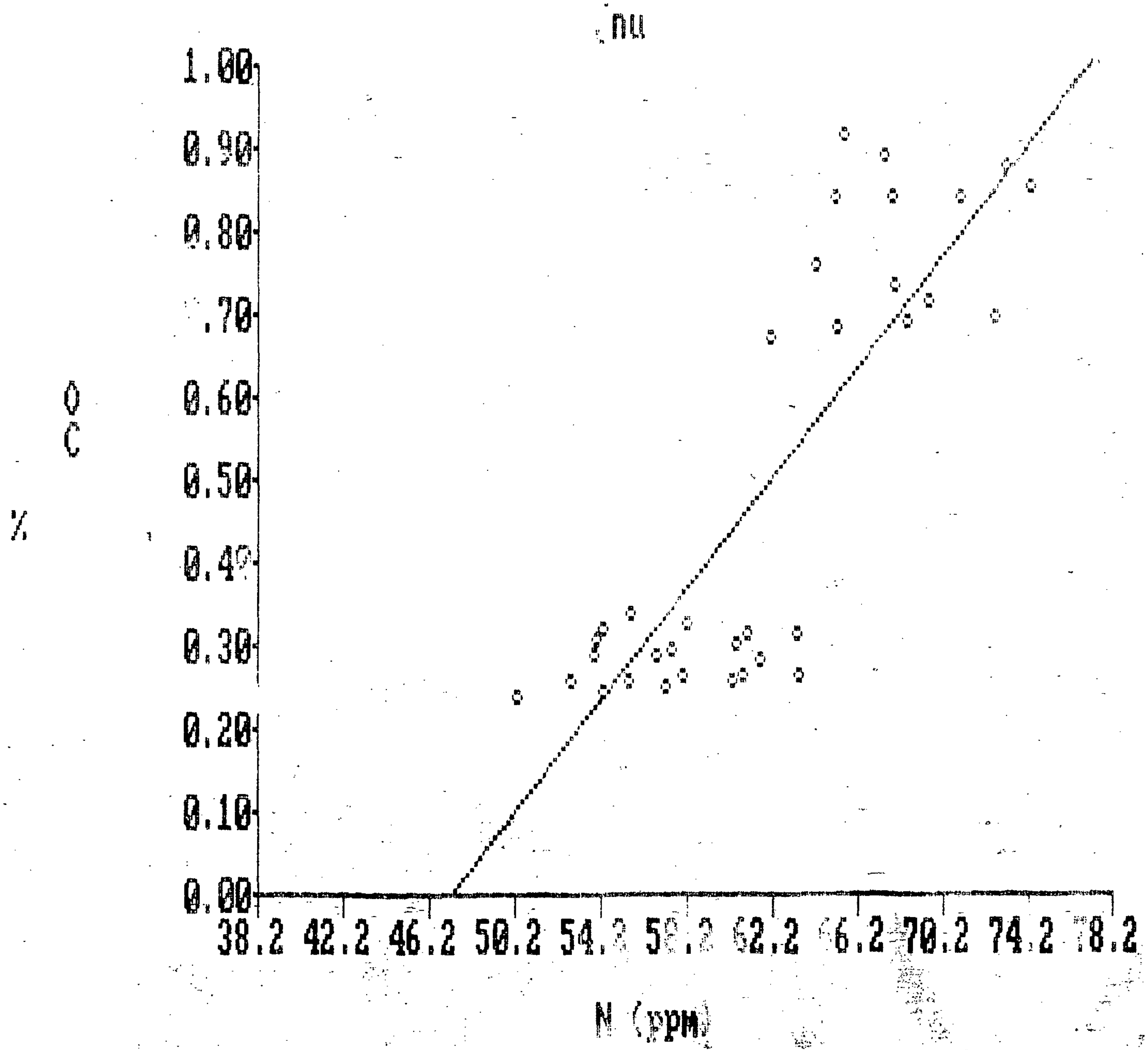


Fig. 23. Available Nitrogen Vs. Organic Carbon - JNU

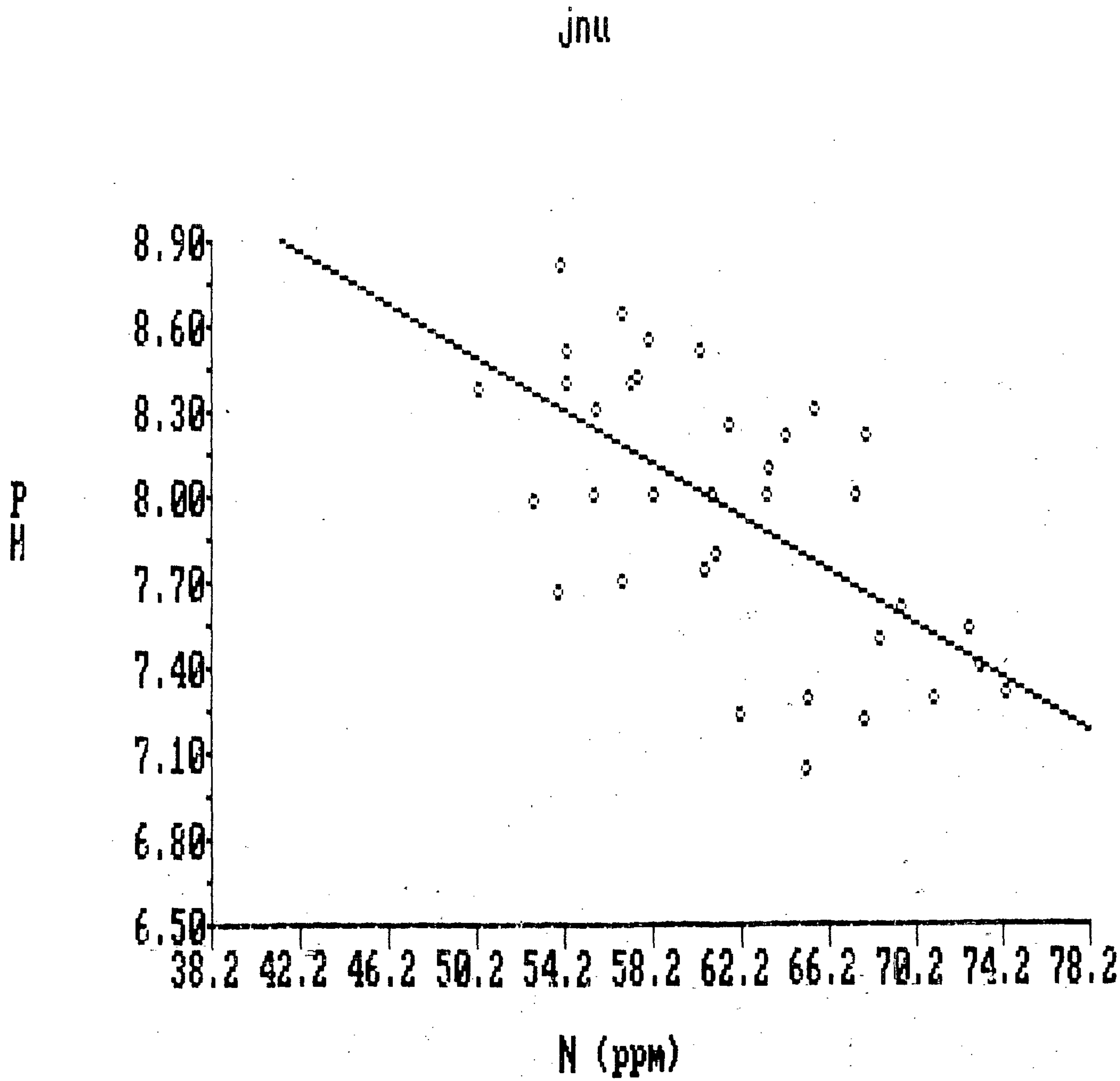


Fig. 24. Avialable Nitrogen Vs. pH - JNU

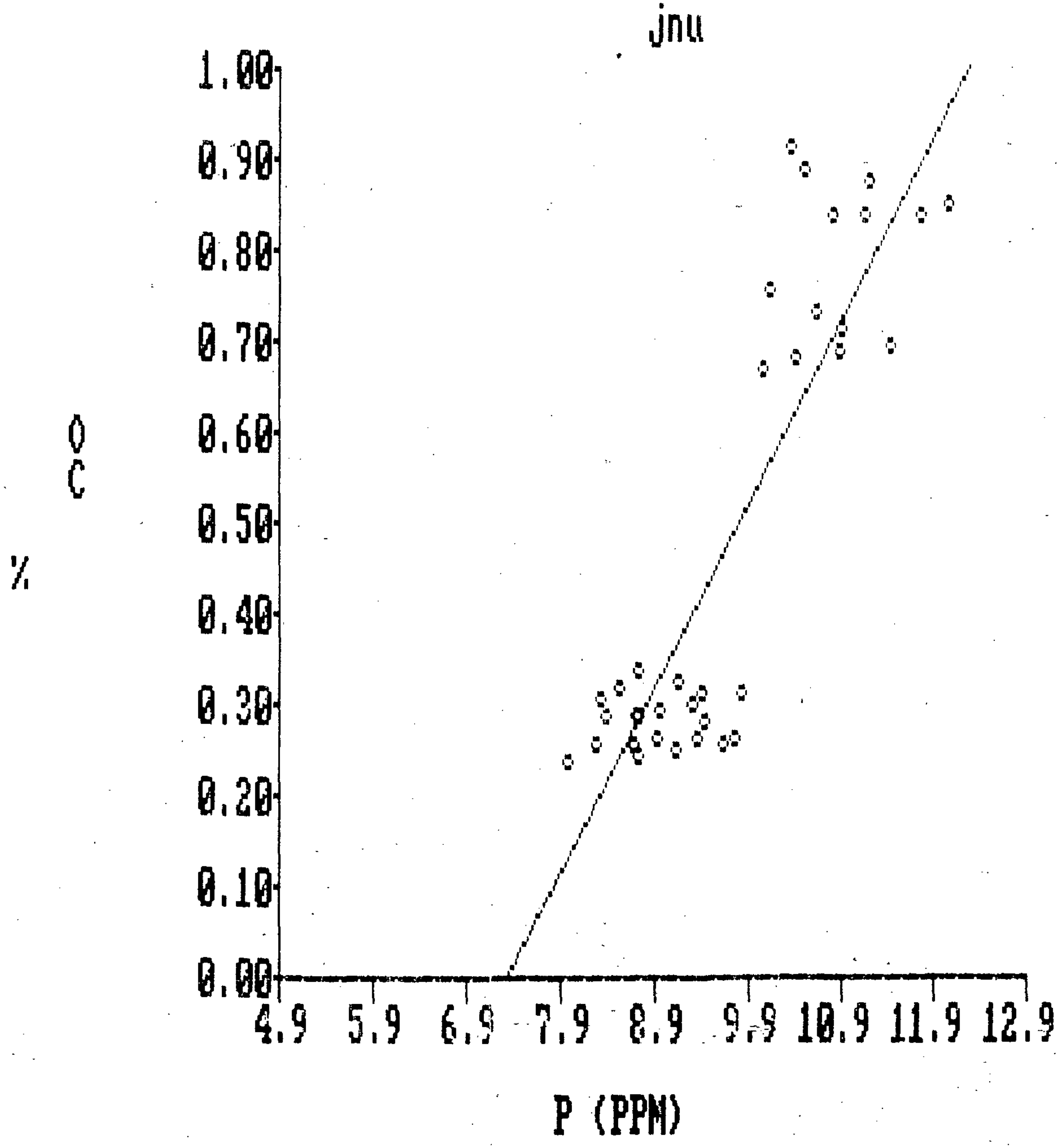


Fig. 25. Available Phosphorus Vs. Organic Carbon - JNU

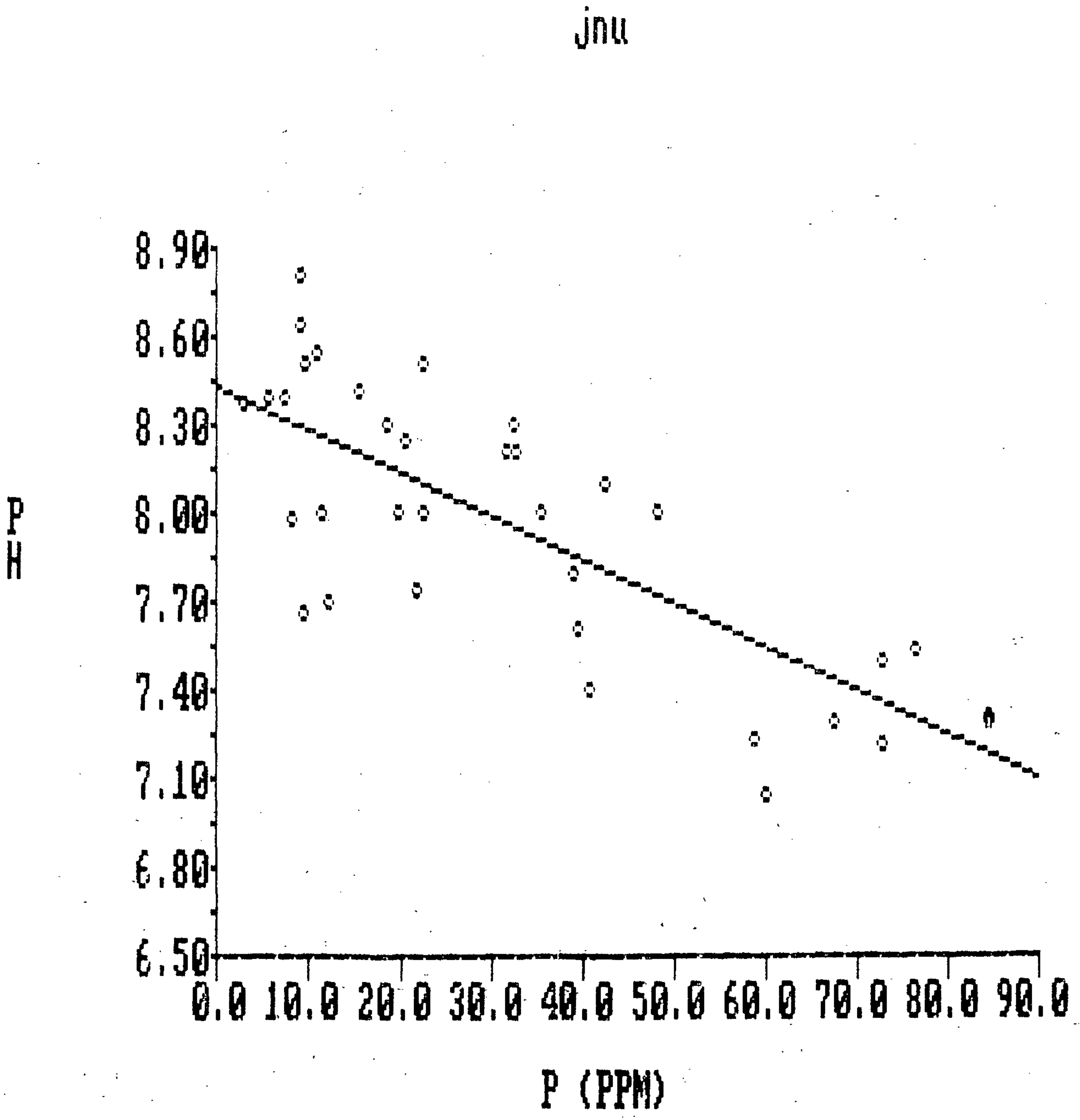


Fig. 26. Available Phosphorus Vs. pH - JNU

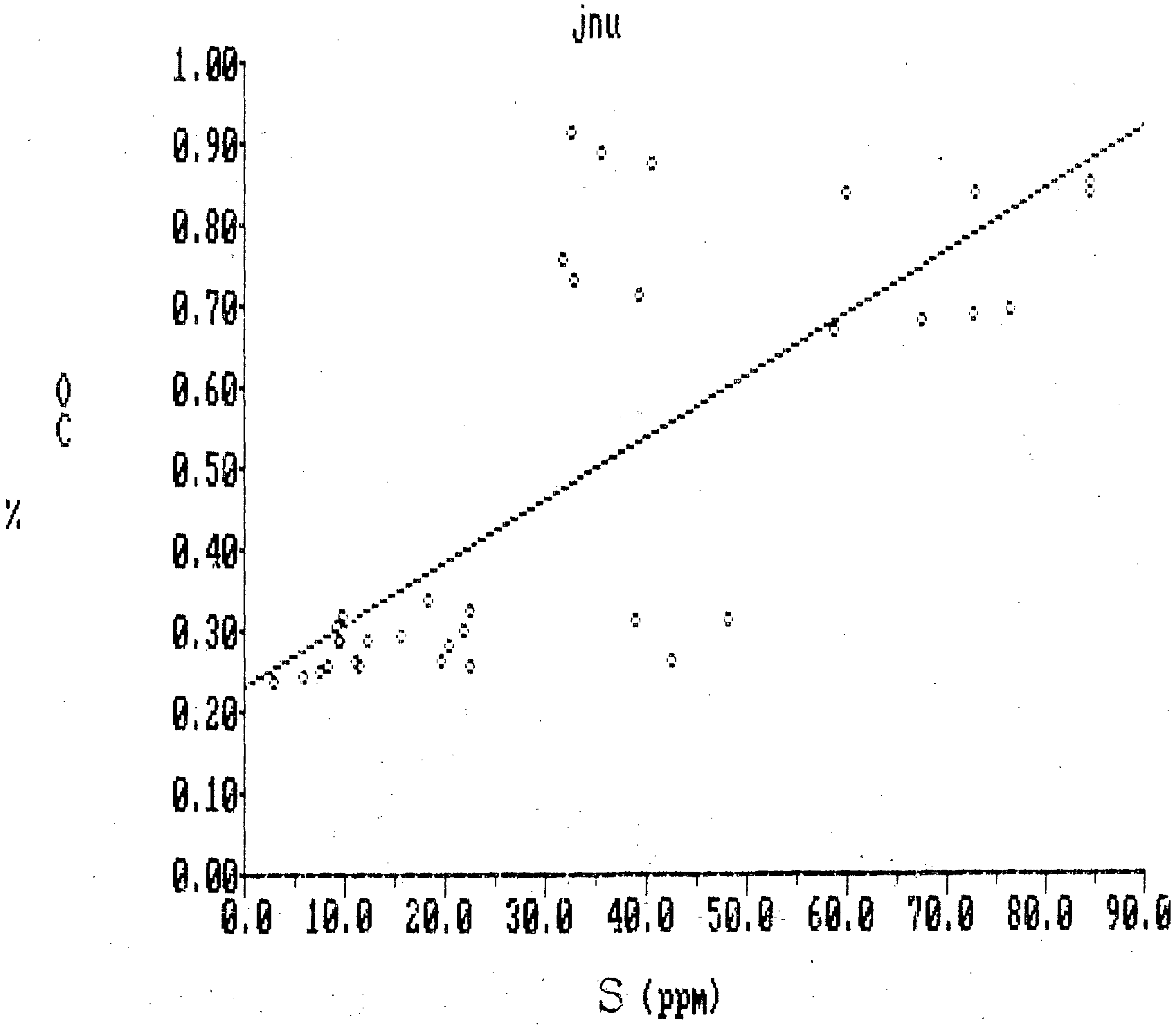


Fig. 27. Available Sulfur Vs. Organic Carbon - JNU

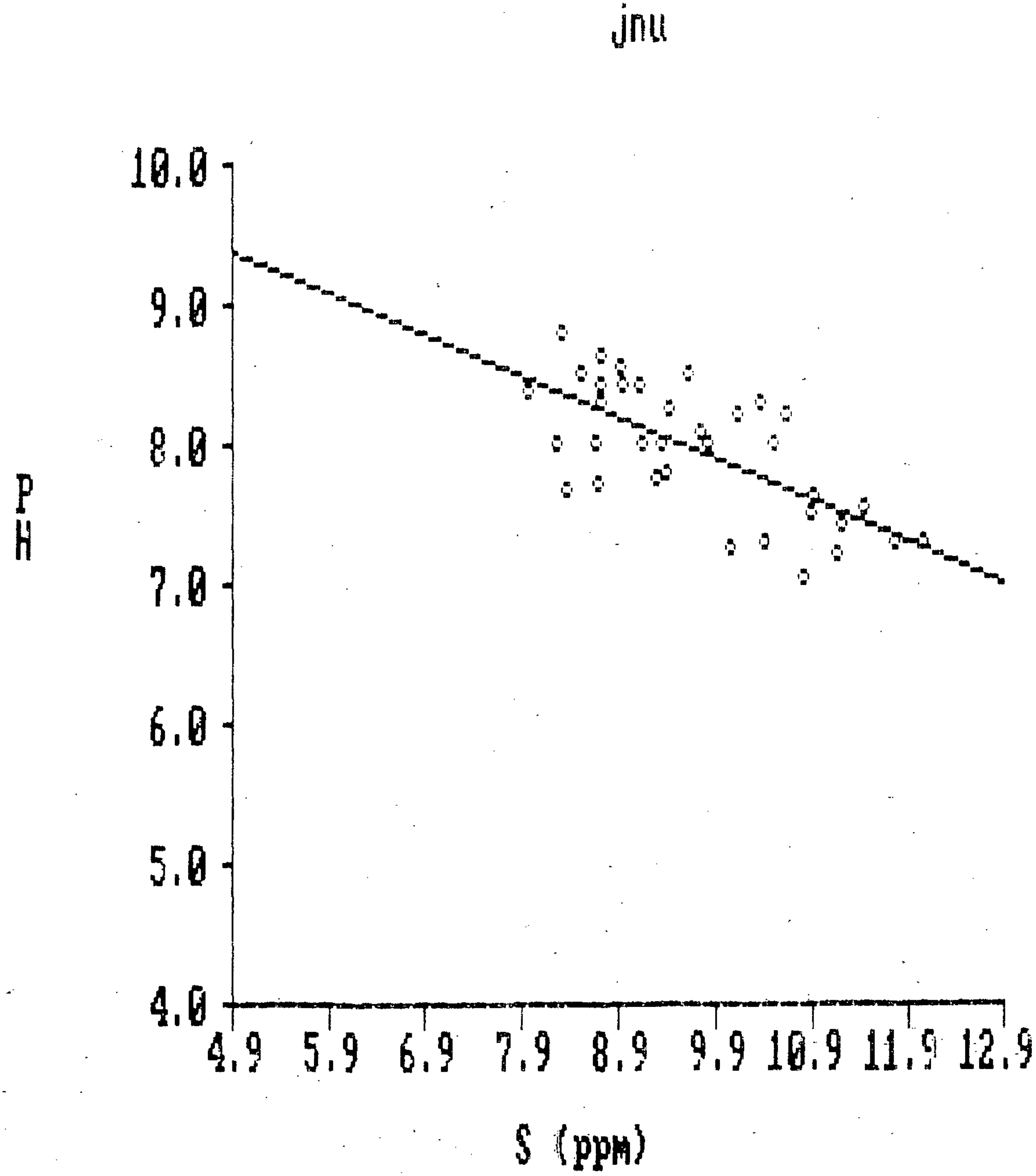


Fig. 28. Available Sulfur Vs. pH - JNU

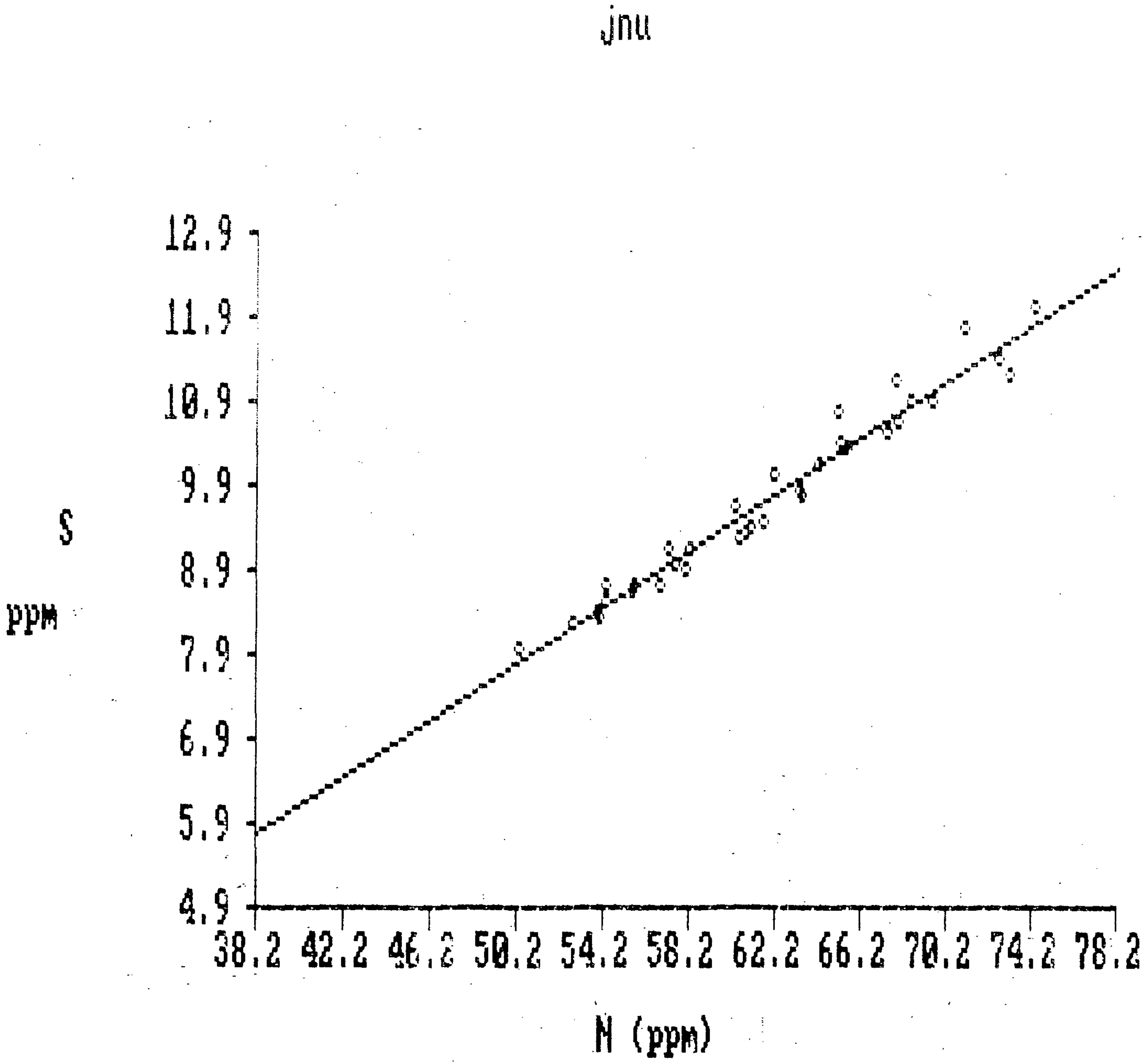


Fig. 29. Available Sulfur Vs. available Nitrogen - JNU

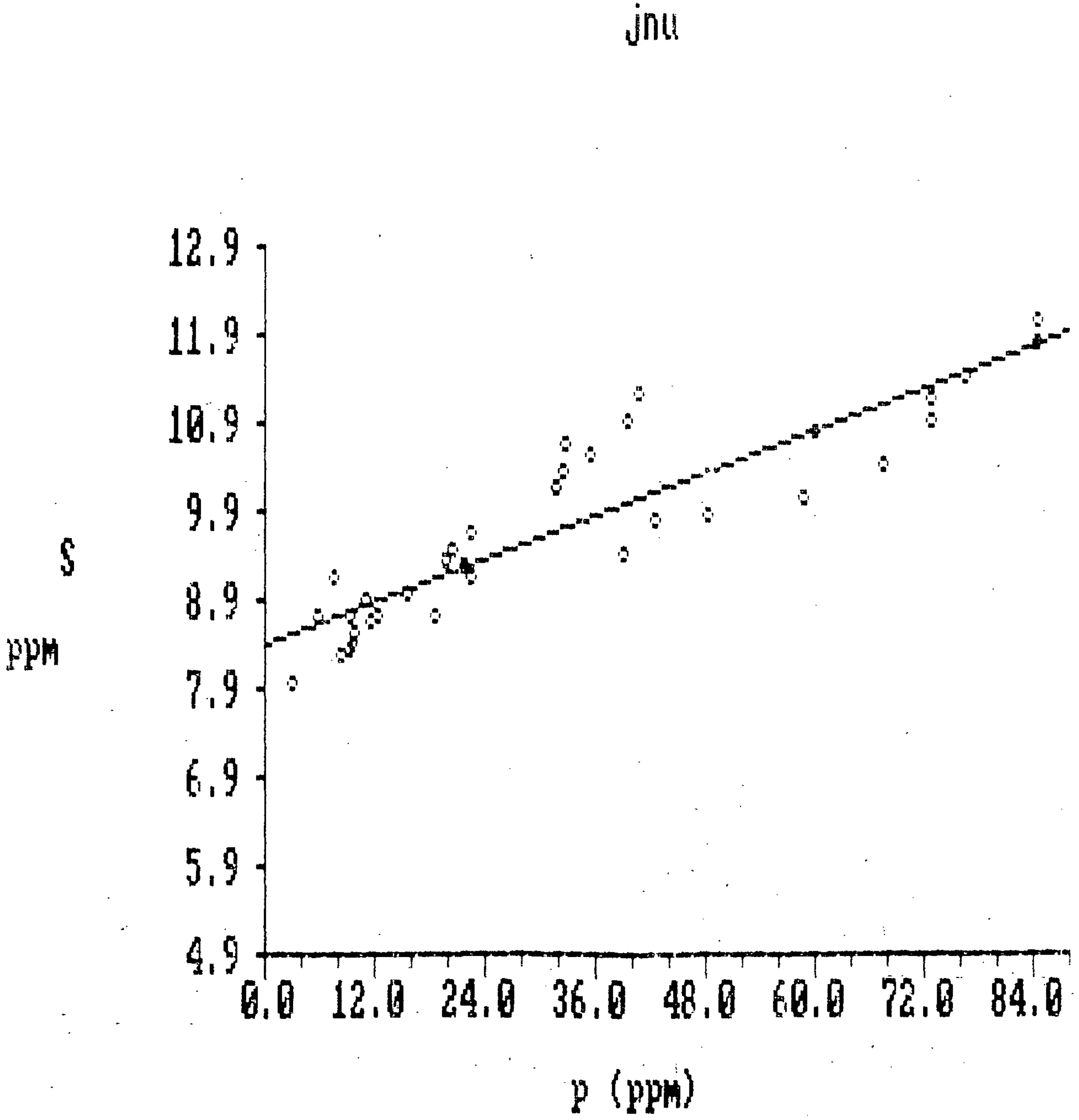


Fig. 30. Available Sulfur Vs. available Phosphorus - JNU

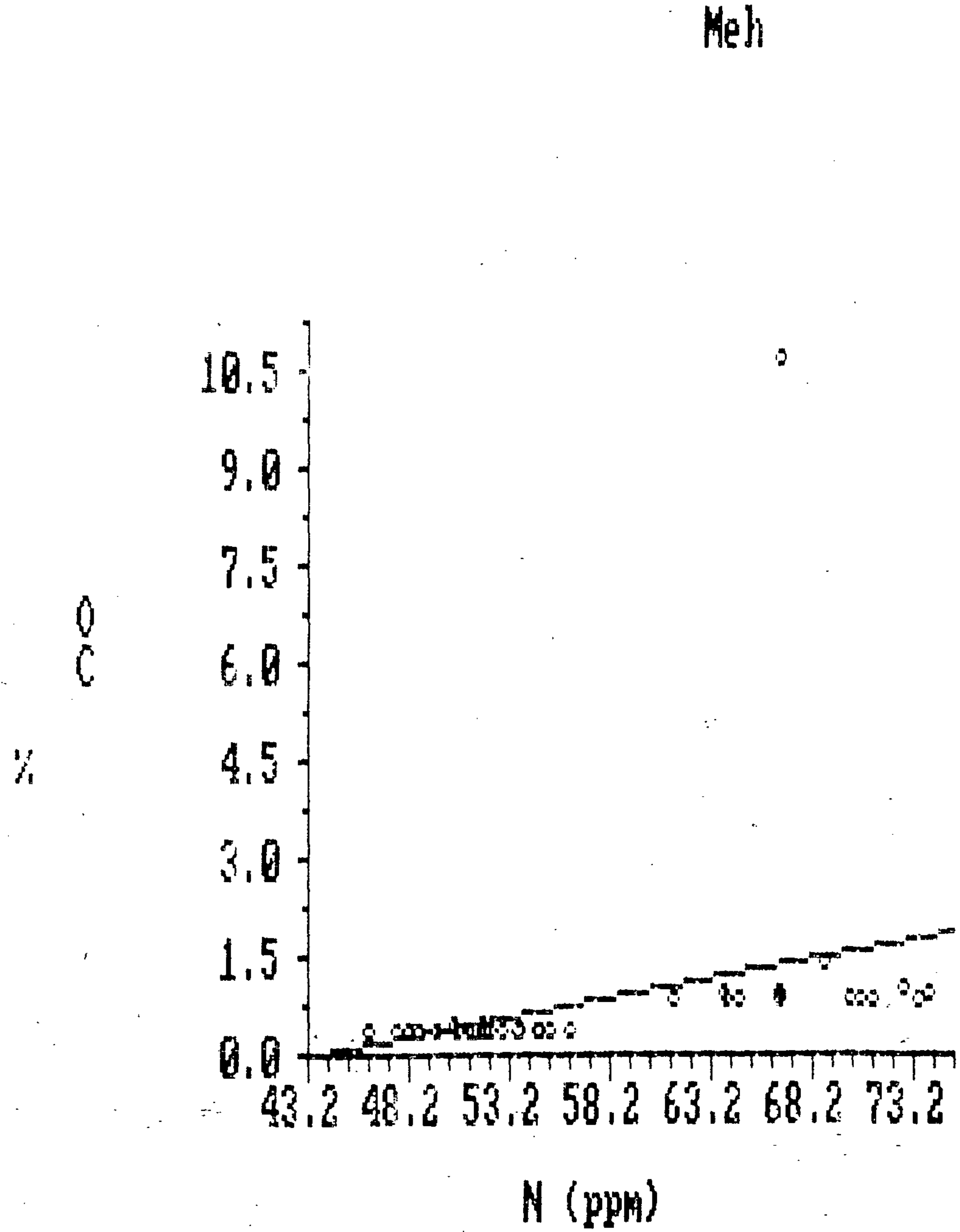


Fig. 31. Available Nitrogen Vs. Organic Carbon - Mehrauli

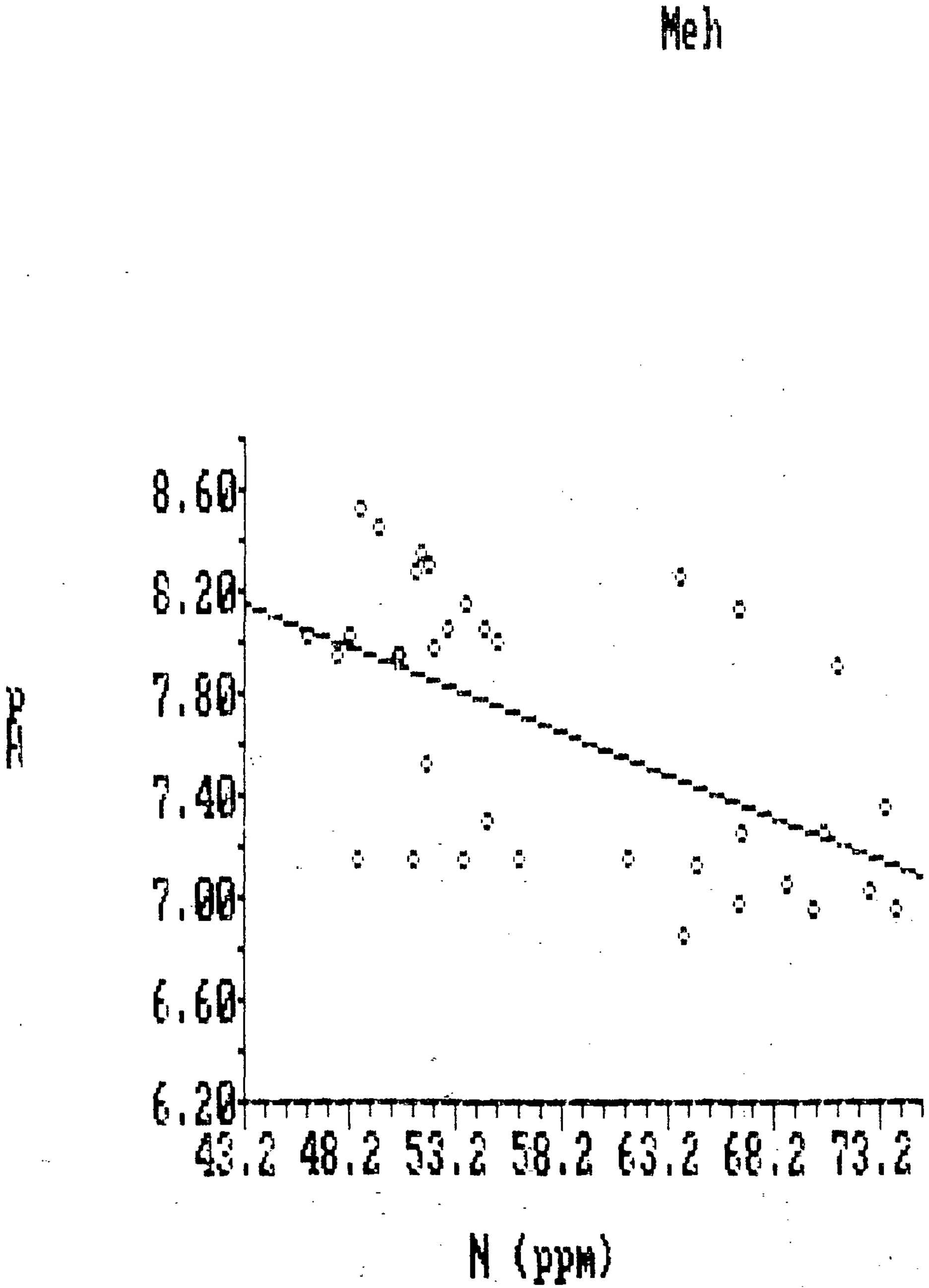


Fig. 32. Avialable Nitrogen Vs. pH - Mehrauli

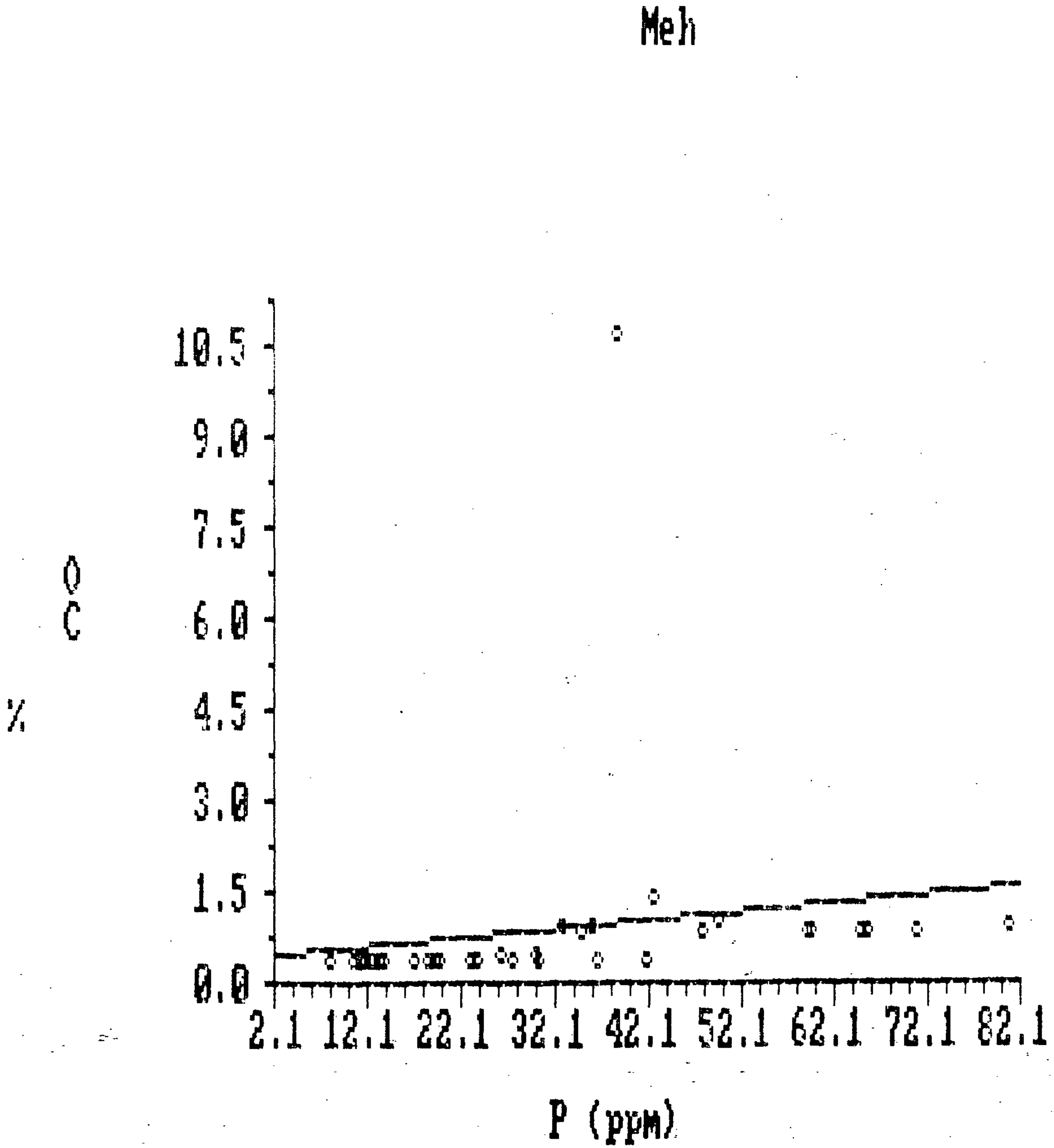


Fig. 33. Available Phosphorus Vs. Organic Carbon - Mehrauli

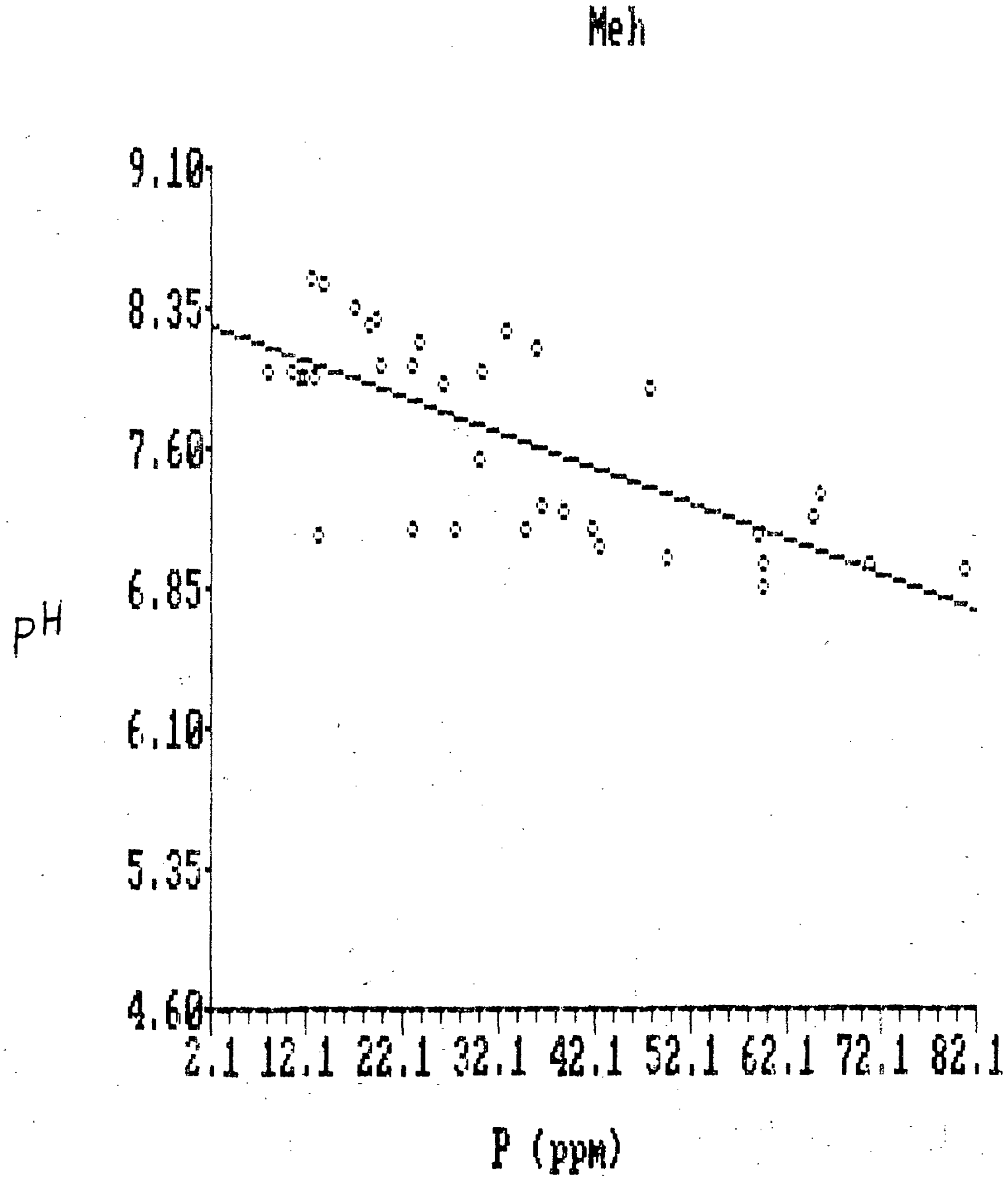


Fig. 34. Available Phosphorus Vs. pH,- Mehrauli

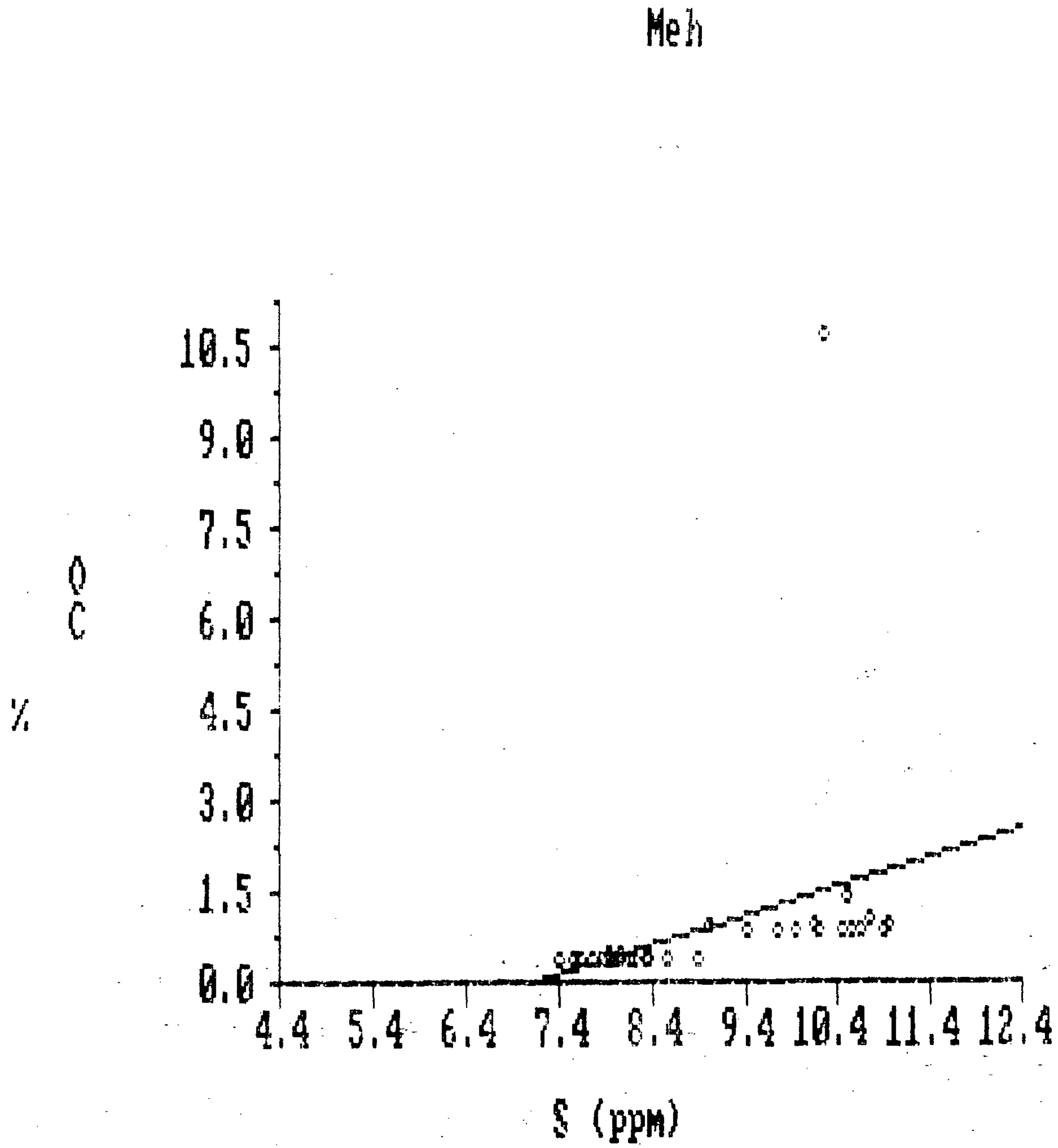


Fig. 35. Available Sulfur Vs. Organic Carbon - Mehrauli

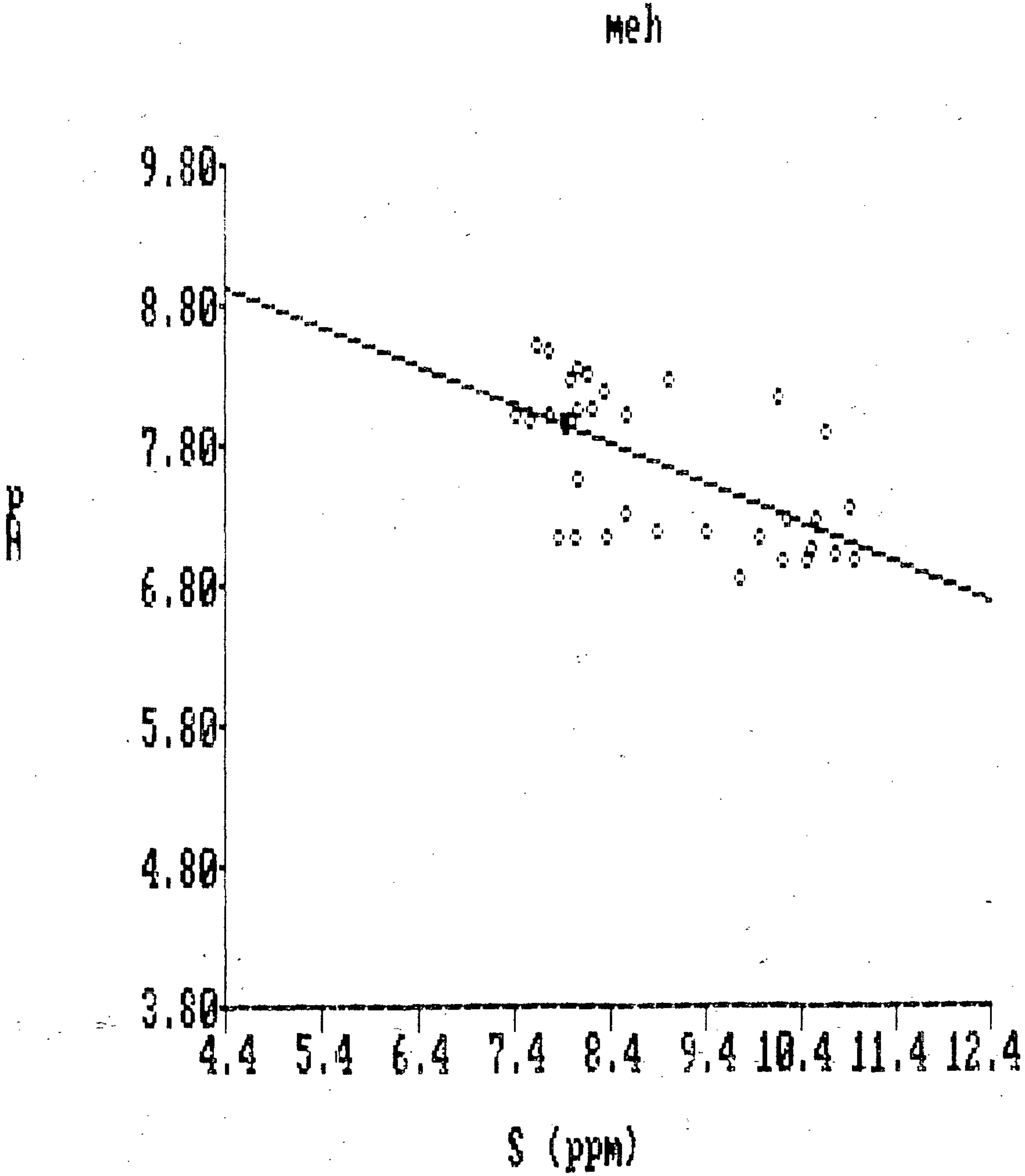


Fig. 36. Available Sulfur Vs. pH - Mehrauli

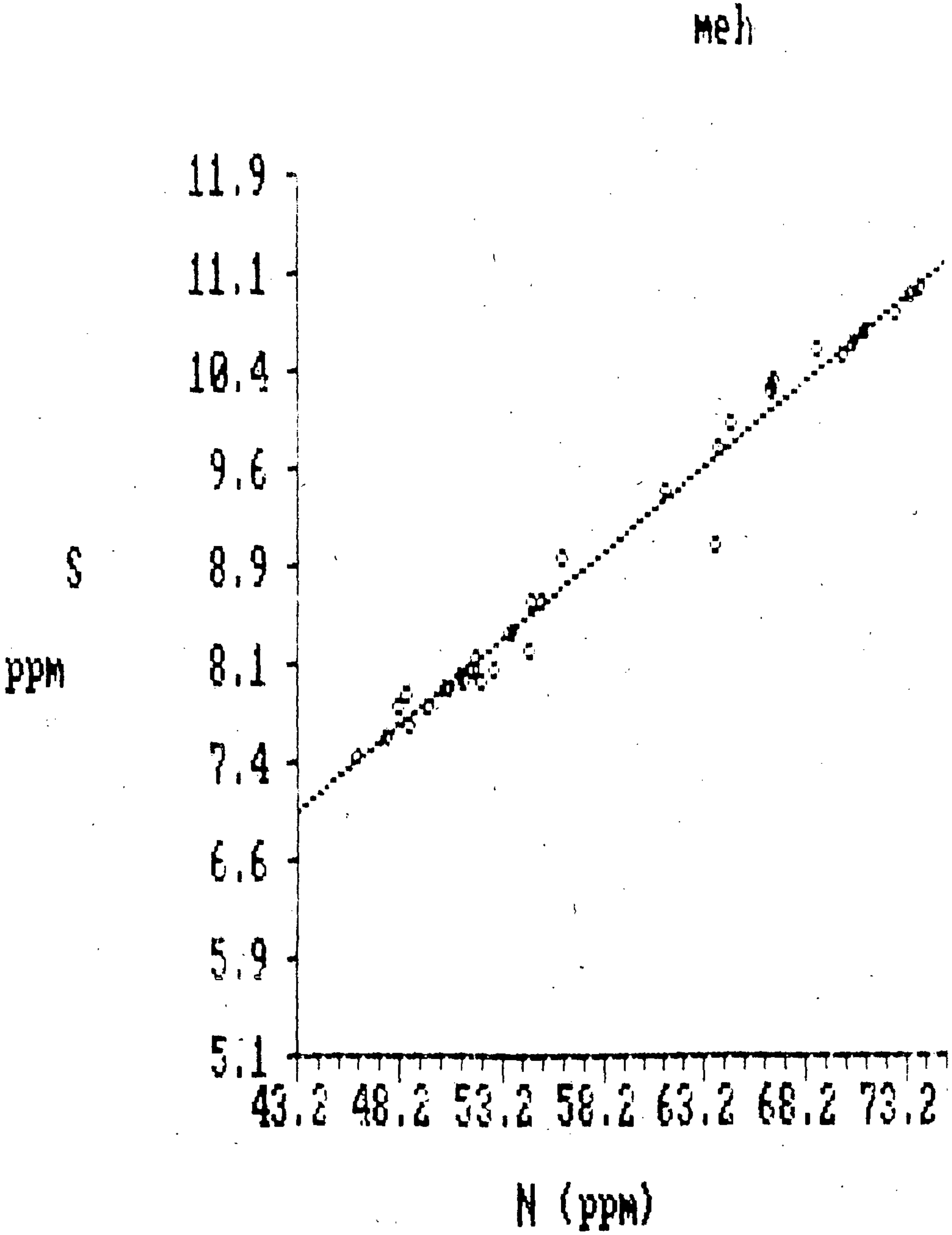


Fig. 37. Available Sulfur Vs. available Nitrogen - Mehrauli

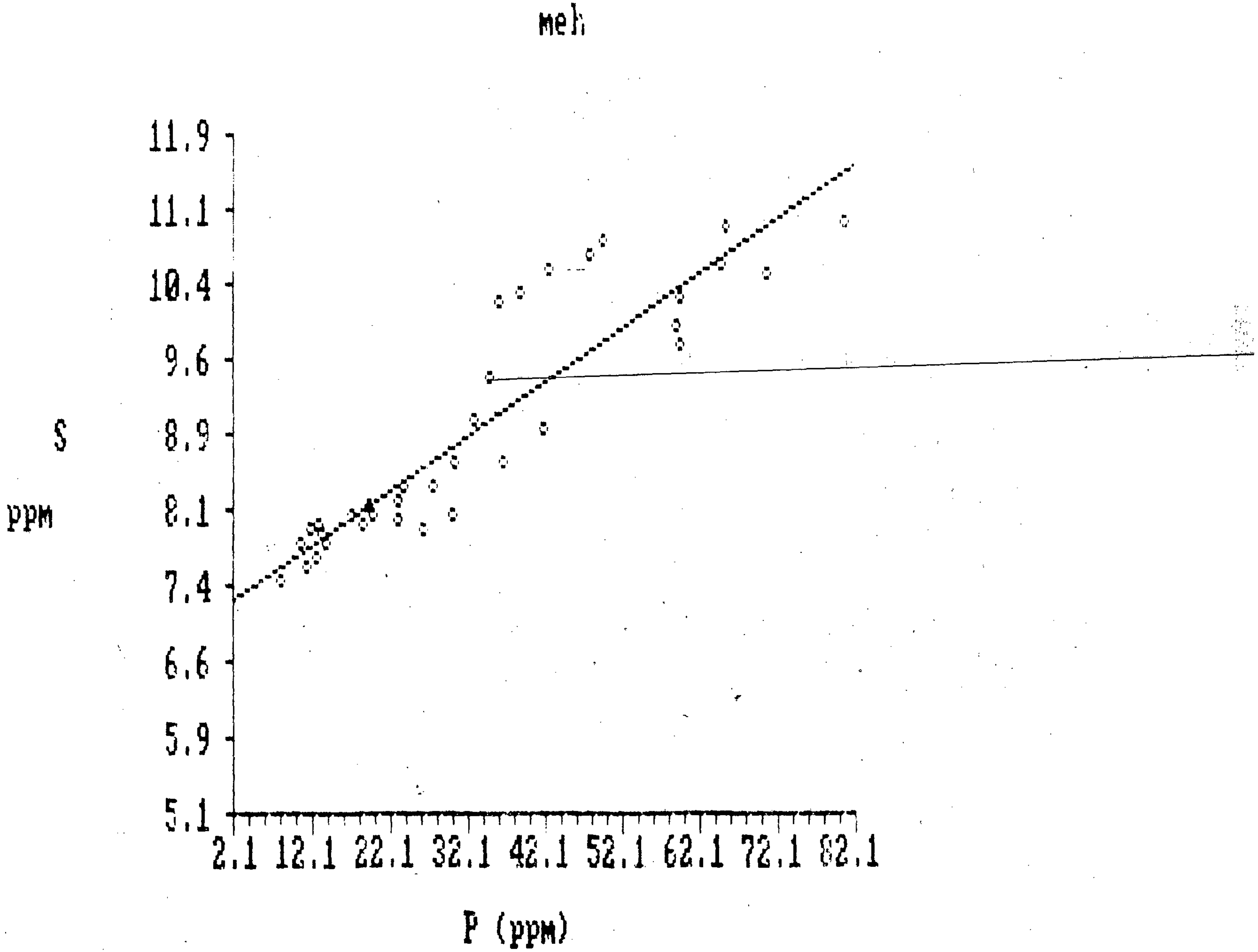


Fig. 38. Available Sulfur Vs. available Phosphorus-Mehrauli

CONCLUSION AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from the incubation experiments conducted on the soils amended with different types of sewage sludges in different proportions to analyse some physico-chemical properties such as pH, EC, organic carbon, CEC and Water holding capacity and available forms of Nitrogen, phosphorus and sulfur content.

1 The pH of the soil samples decreased with the increase of incubation period. The pH was less in the secondary treated sluge amended soil samples.

2. The electrical conductivity increases slightly during the incubation period. It showed higher value in secondary treated sludge amended soil samples and increased the amount of the sludge.

3. The organic carbon content decreased with the increase of incubation period. In secondary treated sludge amended soil samples the carbon content was more than primary treated sludge amended soil samples and in control soil samples.

4. The cation exchange capacity and water holding capcity are more in the secondary treated sludge amended soil samples than primary treated sludge amended samples and control soil samples.

5. The available nitrogen gradually increased upto the 30th day of incubation and there after decreased

and there is an overall decrease in available nitrogen at the end of the incubation period i.e. 60 days. The peak values are obtained at the 30th day of incubation period. Whereas the total nitrogen decreased slightly from the beginning of the incubation.

In case of the available Phosphorus and Sulfur content also the same trends were obtained as for nitrogen. The maximum available phosphorus and sulfur content was at the 30th day of incubation period andc there after decreased by the end of the incubation.

RECOMMENDATIONS :

From the above incubation experiments it can be recommended the ustage of sewage sludge in the field but the availability of the other nutrients and toxic heavy metals also should be monitered continuously and other permutations and combinations of treatement should be further explored so as to suit the local conditions keeping in view of preservation and protection of environment. So more investigation should be necessary on the sewage sludge to use as a manure for the crops.

SUMMARY

SUMMARY

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A short term incubation experiment was conducted to monitor the changes in available forms of Nitrogen, Phosphorus and Sulfur along with other physico-chemical properties in the sewage sludge amended soils of JNU and Mehrauli under laboratory conditions. The results obtained are summarised below:

1. The pH of the soil samples decreased as the incubation period increased. In the secondary treated sludge amended soil samples it was lesser than in the primary treated sludge amended samples and the original soil. This was attributed to the formation of hydrogen ions during nitrification and possible generartion of organic acids.

2. The electrical conductivity of the soil increased during the incubation period. The EC in the secondary treated sludge amended soil samples was considerably higher than the other samples.

3. The Cation Exchange Capacity was more in secondary treated sludge amended soil samples than the primary treated sludge amended samples and original soil samples. The Cation Exchange Capacity increased with the increasing concentration of the sludge.

4. The water holding capacity of the primary treated sludge amended soil samples was more than the original soil and the water holding capacity of the

secondary treated sludge amended soil samples was more than the primary treated sludge amended soils. It was also increased with the concentration of the sludge.

5. The organic carbon content decreased as the incubation period proceeded. In secondary treated sludge amended soil samples it was more than the other samples. The decrease in organic carbon content throughout the incubation period was attributed to the loss of carbon in the form of CO_2 through normal microbial decomposition process.

6. The available nitrogen increased steadily upto 30 days of incubation and decreased gradually thereafter and the final values were lesser than the initial values.

7. The total nitrogen content of the experimental soil samples was decreased throughout the incubation period.

8. The available phosphorus content increased soil in all the soil samples upto 30 days of incubation period and thereafter decreased by the end of incubation period. In secondary treated sludge amended soil samples the available phosphorus content was more than the primary treated sludge amended soil and control soil samples. This increase was due to the presence of soluble phosphates.

9. The toal phoisphorous content in all the soil samples throughout the incubation period remained same

without any significant change.

10. The available sulphur content in the samples gradually increased upto 30 days of incubation period and decreased slightly thereafter. The available sulfur content was more in secondary treated sludge amended soil samples than in the primary treated sludge amended as the concentration of the sludge increased.

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