

**EFFECT OF EFFLUENTS DISCHARGED FROM DYEING
INDUSTRIES ON SOIL, WATER AND CROP QUALITY IN
NAGARI MANDAL, CHITTOOR DISTRICT,
ANDHRA PRADESH**

By
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B.Sc. (Ag.)

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THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE
IN THE FACULTY OF AGRICULTURAL SCIENCES
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)



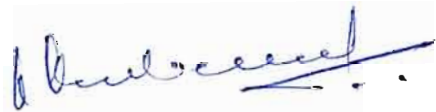
DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
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OCTOBER, 2002

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Mr. RAYUDU SWATANTRA PRASAD has satisfactorily prosecuted the course of research and that the thesis entitled “EFFECT OF EFFLUENTS DISCHARGED FROM DYEING INDUSTRIES ON SOIL, WATER AND CROP QUALITY IN NAGARI MANDAL, CHITTOOR DISTRICT, ANDHRA PRADESH” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for degree of any university.

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Place : TIRUPATI



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(Major Advisor)

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This is to certify that the thesis entitled “EFFECT OF EFFLUENTS DISCHARGED FROM DYEING INDUSTRIES ON SOIL, WATER AND CROP QUALITY IN NAGARI MANDAL, CHITTOOR DISTRICT, ANDHRA PRADESH” submitted in partial fulfilment of the requirements for the degree of Master of Science in Agriculture of the Acharya N G Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. RAYUDU SWATANTRA PRASAD under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

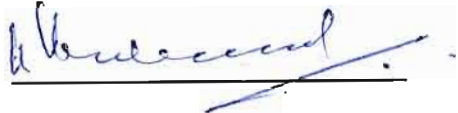
No part of the thesis has been submitted for any other degree or diploma or has been published. The published part has been fully acknowledged. The author of the thesis has duly acknowledged all assistance and help received during the course of investigation.

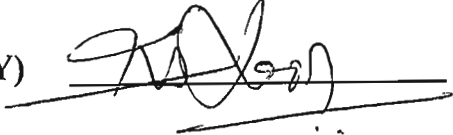


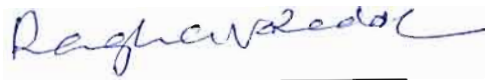
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LIST OF ACRONYMS AND ABBREVIATIONS

B	:	Boron
BOD	:	Biochemical oxygen demand
°C	:	Degree Celsius
Cd	:	Cadmium
Ca	:	Calcium
Cl	:	Chloride
cm	:	Centimeter
cmol L ⁻¹	:	Centimole per liter
cm hr ⁻¹	:	Centimeter per hour
CO ₃	:	Carbonate ion
COD	:	Chemical oxygen demand
Cr	:	Chromium
Cu	:	Copper
dSm ⁻¹	:	decisiemen per meter
DTPA	:	Diethylene triamine penta acetic acid
EC	:	Electrical conductivity
F	:	Fluoride
Fe	:	Iron
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
HCO ₃	:	Bicarbonate ion
ISI	:	Indian Standards Institute
K	:	Potassium
kg	:	Kilogram

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kg ha ⁻¹	:	Kilogram per hectare
L	:	Litre
m	:	meter
mm	:	millimeter
Mg	:	Magnesium
Mn	:	Manganese
μ mhos	:	Micro mhos
mg L ⁻¹	:	Milligram per litre
mg kg ⁻¹	:	Milligram per kilogram
N	:	Nitrogen
NO ₃ -N	:	Nitrate nitrogen
ND	:	Not detected
Ni	:	Nickel
Na	:	Sodium
OC	:	Organic carbon
P	:	Phosphorus
Pb	:	Lead
ppm	:	Parts per million
RSC	:	Residual sodium carbonate
SAR	:	Sodium absorption ratio
SO ₄ ²⁻	:	Sulphate ion
Viz.,	:	namely
Zn	:	Zinc
%	:	Per cent
mg L ⁻¹	:	Milligram per litre
>	:	More than

ACKNOWLEDGEMENTS

It is by the lavish love, benignant blessings and grace of the almighty that I have completed my studies and present this piece of work.

*I humbly place on record my esteem and affable thanks to my beloved chairman of advisory committee **Dr.Keerthi Venkaiah**, Associate Professor, Department of Soil Science and Agricultural Chemistry, S V Agricultural College, Tirupati for his learned counsel, inextinguishable encouragements, co-operation, affectionate advice, arduous and meticulous guidance, begin attitude, convivial exhortation and unstinted attention throughout the period of investigation. I take it as a great privilege and pride to have had an opportunity of working under his untiring, inspiring and indomitable spirit.*

*I am highly indebted to **Dr.K.Srinivasulu Reddy**, Associate Professor, Department of Soil Science and Agricultural Chemistry, **Dr.C.Raghava Reddy**, Associate Professor, Department of Agronomy members of my advisory committee for their constant help, valuable guidance and encouragement for successful conduct of the experiment.*

*I acknowledge with great pleasure for the services extended by **Dr N.Ramavatharam**, Professor and Head, **Dr.V.Bhanu Prasad**, Associate Professor, **Dr.M.V.S. Naidu**, **Dr.A.Madhavi**, **Dr.D.Vijaya**, Assistant Professors, Department of Soil Science and Agricultural Chemistry in enabling completion of thesis.*

*It is with love, I wish to express my gratitude to **Dr. K. Gopal**, Scientist (Path), AICRP, Tirupati, for the unbounded affection, cheerful assistance and encouragement and blessings during my course of study.*

I deeply acknowledge the kind co-operation of Dr. K.Bhupal Raju, Senior Scientist, AICRP on Micronutrients Scheme, Hyderabad and Dr. K.Kotaiah, Professor and Head, Department of Civil Engineering, S.V.U. College of Engineering, Tirupati rendered during my research work.

My warmest love and soulful attention to my loving grand father Sri Rayudu Prasada Rao and Brothers Sri Tirumal Prasad, Sri Gokul Prasad (Late), Leela Prasad and Raja Prasad who are the mighty personalities behind me for my successful studies.

I extend my warmest thanks to my family members Raghu, Chiranjeevi, Omprakash, Sundar, Vinolia, my sister Mrs. Swaroop (late) other family members.

A blend of real friendship is a necessity for any good relationship. I gratefully extend my deep feelings towards my nearest and dearest friends Govindacharyulu, Srinivasulu Reddy, Yella, Tarak, Yogi (late), Subbaiah and Subba Rao (KKD, Prasanna and Leela for their help and co-operation rendered to me during the course of my research work.

I feel immense pleasure and joy in expressing my heartfelt thanks and intrinsic affection to my friends and colleagues Vijayabhaskar Reddy, Pratap, Krishnaiah, Palamuriprasad, Uday (backstreet boy), Penchal, Palani, Vijay, Vamsi (pitta), Krishna Reddy, Saisankar Reddy, Praveena, Tulasigeeta, Yamini, and Leelavathi for their help and co-operation rendered to me during the course of my research.

I feel proud to mention my seniors Rajib, M.K. Boss, Subbu, Sobhan, Somu, Ramu and my juniors Hemanth, Venkatramudu, Srikanth, Bhaskar (bale), Rajandra, Laxmi, Sai (R.mate), Vijaya Sekhar, Thangaswamy, Vedamani for their constant encouragement during the course of my study.

I owe special thanks to Babanna, Prabhakar, Kesava, Sujatha (RA), Usha (Kutti).

It is the right occasion to express my heartfelt thanks to Mr. Babu, Mr.Reddimuni and Mrs. Chandramma (non-teaching staff) of our department.

I'm highly thankful to Acharya N G Ranga Agricultural University for providing financial assistance in form of stipend during the course of M.Sc. (Ag).

Finally I thank Sri Ashok and Yugandhar and Dr. Pathi, Sri Rudhvic Xerox & DTP, Tirupati for neat execution of thesis to finality.


Rayudu Swatantar Prasad

DECLARATION

I, Mr. RAYUDU SWATANTRA PRASAD here by declare that the thesis entitled "EFFECT OF EFFLUENTS DISCHARGED FROM DYEING INDUSTRIES ON SOIL, WATER AND CROP QUALITY IN NAGARI MANDAL, CHITTOOR DISTRICT, ANDHRA PRADESH" submitted to Acharya N.G.Ranga Agricultural University, Hyderabad for the degree of **Master of Science in Agriculture** is the result of original work done by me. I also declare that the material contained in this thesis has not been published earlier.

Date : 16/10/2002


(RAYUDU SWATANTRA PRASAD)

ABSTRACT

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Title of the thesis	:	EFFECT OF EFFLUENTS DISCHARGED FROM DYEING INDUSTRIES ON SOIL, WATER AND CROP QUALITY IN NAGARI MANDAL, CHITTOOR DISTRICT, ANDHRA PRADESH
Submitted for the award of degree	:	MASTER OF SCIENCE
Faculty	:	AGRICULTURE
Department	:	SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
Major advisor	:	Dr KEERTHI VENKAIAH
University	:	Acharya N.G. Ranga Agricultural University
Year of submission	:	2002

Studies on the "Effect of effluents discharged from dyeing industries on soil, water and crop quality in Nagari mandal, Chittoor district, Andhra Pradesh" were conducted with the object of assessing the effect of dyeing unit effluent on soil properties, ground water qualities, nutrient status of index leaf and crop yield losses at different distances from effluent stream. The ground water from wells/bore wells at different lateral distances from effluent stream and soil samples at 0, 10, 25, 50, 75, 100, 150 and 200 m distance from the effluent stream were collected and analysed for different properties in the year 2001. The crop yield losses in the farmers fields around effluent streams were also recorded.

The composition of dyeing unit effluent in terms of EC, pH, Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^- , HCO_3^- , Cl^- , SO_4^{--} and micronutrients viz., Zn, Fe, Mn and Cu was relatively more as compared to that of ground water adjoining

effluent streams. Heavy metals like Cd, Pd, Ni and Cr in dyeing unit effluents were more or less equal to heavy metals in ground water. Effluents discharged from dyeing industries increased the salt concentration, cationic and anionic concentrations, and micronutrients of ground water in the year of study. The maximum EC recorded was 4.48 dsm^{-1} in Ekambarakuppam, 2.92 dsm^{-1} in Satravada, 2.86 dsm^{-1} in Nagari. The adverse effects of dyeing unit effluents on quality of ground water in the immediate vicinity of the effluent stream, (interms of EC, cations, anions and micro nutrients) were more as compared to farther distances from effluent stream. The soluble salt content of ground water adjoining effluent stream was above the permissible levels upto 10 m distance from stream at Nagari, up to 28 m distance at Satravada and upto 32 m distance at Ekambarakuppam. The adverse soil salinity effects due to dyeing unit effluents was observed more in Ekambarakuppam followed by Nagari and Satravada. Mean EC of sols adjoining effluent streams ranged from 0.19 to 1.06 dsm^{-1} , 0.16 to 0.80 dsm^{-1} and 0.28 to 3.63 dsm^{-1} at Nagari, Satravada and Ekambarakuppam, respectively. The adverse salinity effects were up to 10 m, 10 m and 25 m at Nagari, Satravada, Ekambarakuppam, respectively.

The other soil properties like, Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^{--} , HCO_3^- , Cl^- , SO_4^{--} , micronutrients viz., Zn, Cu, Fe and Mn were significantly more in the immediate vicinity of the effluent stream. The accumulation of heavy metals were not observed in the soils adjoining to effluent streams. The water soluble ion viz., Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^{--} , HCO_3^- , Cl^- and SO_4^{--} were also more in the immediate neighborhood of the effluent stream. Due to dyeing unit effluent, the concentration of N, P, K, Ca, Mg, Zn, Cu, Fe, and Mn in the index leaf of rice, groundnut and sugarcane collected during study period were relatively lower in the immediate vicinity of the stream as compared to the farther distances. However the concentration of all these elements studied in index leafs of rice, groundnut, sugarcane were found to be sufficient. The adverse effects due to dyeing unit effluent were observed to be more on yield of groundnut at Satravada, sugarcane at Ekambarakuppam and paddy at Nagari respectively. No crop was grown at 0 m distance from stream at Nagari, Satravada and Ekambarakuppam. The adverse effects of effluents on rice, groundnut and sugarcane were continued up to 10 m, 10 m and 25 m at Nagari, Satravada and Ekambarakuppam, respectively.

There is need to take up legislation regarding to construction of dyeing industries, so as to maintain sufficient distance from agricultural fields and drinking / irrigation water source around human habitations.

Introduction

CHAPTER - I

INTRODUCTION

India is industrially growing rapidly since independence in all the spheres. Industrial development with least environmental degradation is highly desirable for the development of any country. In general any industry has both positive and negative environmental impact. It is the responsibility of the planners and environmentalists to document these impacts. So that these can be identified so as to enable to maximize positive impacts and minimize negative impacts.

Industrial activities do necessarily generate some form of the waste materials. The manufacturing process does not consist of 100 per cent conversion of materials and energy inputs into usable final products and some portion of the material and energy inputs inevitably end up as wastes. When waste generated exceeds the maximum assimilative capacity of the environment, it becomes "pollution". "Pollution prevention protects the environment" became a corporate slogan at present without putting much efforts on pollution prevention in the field of environment by the planners and environmentalists.

Industrialization has its inevitable effect on pollution of water and soil based on the type of industry, nature of raw materials used and the manufacturing processes involved (Audul Baki and Anderson, 1973).

Owing to rapid development of dyeing industry and textile processing industries during the last two decades, in India the disposal of effluents has become a serious problem. The large number of industries produces effluents at the rate of 1.5 mgd (7 million litre day⁻¹). The effluent without any treatment is being discharged into nearby rivers, irrigation canals and cultivated soils and streams adjoining to agricultural fields causing serious geo-environmental pollution and anthropogenic hazards, intensifying the adverse effects on soil, plant and water eco system. In India, adverse effects due to dyeing factory effluents on soil, plant and water eco-system were reported by several workers (Prabhakaran and Lakshmanan, 2000; Kotaiah, 1999; Jain and Gupta, 1992 and Gupta 1999).

There are 120 small-scale cotton yarn-dyeing industries in Nagari region of Chittoor district in Andhra Pradesh, which are scattered in five villages. The effluents of these dyeing industries are usually discharged from dyeing units located around Nagari region. There were many

complaints about ill effects of these units on soil, water and plant ecosystems made by the farmers (Eeenadu, 2000). Hence, there is an urgent need to quantify the adverse effects of effluents discharged from dyeing units on soil, plant and water ecosystem in a systematic manner. In view of the same, it has been proposed to investigate the negative effects associated with the effluent of dyeing units with the following specific objectives.

1. Physical and chemical characterization of effluents discharged from dyeing industries.
2. To investigate the influence of dyeing unit effluents on soil chemical properties and ground water quality.
3. To investigate the nutrient content of plant samples collected from the crops grown adjacent to the streams contaminated with the effluents.
4. To investigate the yield levels of crops grown adjoining streams.

Review of Literature

CHAPTER – II

REVIEW OF LITERATURE

The literature available relating to soil and ground water pollution due to effluents discharged from different industries especially from dyeing unit is very meagre. The published and unpublished has been reviewed and presented under following heads.

- 2.1 Characterization of dyeing unit effluents
- 2.2 Characterization of ground water effected due to dyeing unit effluents
- 2.3 Characterization of soils effected due to dyeing unit effluents
- 2.4 Nutrient status of index leaf of different crops effected due to dyeing unit effluents
- 2.5 Effect of dyeing unit effluents on growth and yield of the crops

2.1 CHARACTERISTICS OF DYEING EFFLUENTS

2.1.1 Physical Parameters

2.1.1.1 Colour and Odour

Verma *et al.* (1977) noted that colour of the mixed textile waste was mostly red or green and depends on dyes used. He also stated that effluents were odourless in Modi Textile Factory of Uttar Pradesh.

Matli Sreenivasachari *et al.* (1999) reported that colour and Odour of Sun Paper Mills Limited effluents was dark brown and phenolic odour in Charan Mahadevi of Mysore.

2.1.1.2 Temperature, suspended solids and turbidity

Verma *et al.* (1977) reported that temperature of the Modi Factory effluent in Uttar Pradesh was ranged between 28°C to 35°C. He also reported that suspended solids and turbidity of the same ranged between 80 to 142 mg L⁻¹ and 320-400 mg L⁻¹ respectively.

Matli Sreenivasachari *et al.* (1999) reported that suspended solids of Sun Paper Mills effluent was 105 mg L⁻¹ in Mysore of Karnataka.

2.1.2 pH

Somasekhar *et al.* (1984) reported that pH of the Textile effluent was alkaline in nature and average pH was 9.4 is Krishna Rajendra Textile Mills Limited of Mysore.

Gupta and Jain (1992) reported that pH of the textile effluent ranged between 10.0-11.5 in textile hand processing industries in Jodhpur of Rajasthan.

Gupta (1994) reported that pH of textile effluent ranged between 10.0-11.5 in Pali of West Rajasthan.

The pH of the textile effluent discharged from textile factory ranged between 7.8-9.6 in Allahabad (Singh 1996).

Kotaiah (1999) studied that pH of the dyeing effluent was 10.6 in Nagari Mandal of Chittoor District in Andhra Pradesh.

2.1.3 Electrical Conductivity (EC)

Somasekhar *et al.* (1984) revealed that electrical conductivity of textile effluent was 2380 $\mu\text{mhos cm}^{-1}$ in Krishna Rajendra Textile Mills situated in out side of Mysore city.

Gupta and Jain (1992) noted that electrical conductivity of textile effluent ranged between 8.5 to 13.9 dSm^{-1} in textile hand processing industries in Pali city of Rajasthan.

The studies conducted by research and design ground water department in Rajasthan (1992) revealed that effluent released from textile industry had EC of 5-10 dSm^{-1} .

Gupta (1994) reported that effluent of textile industry had EC 6.4-10.7 dSm^{-1} in Jodhpur city of Rajasthan.

Gupta (1999) studied that electrical conductivity of textile effluents of three industrial areas *i.e.*, Jodhpur, Pali and Balotra ranged between 5.6 and 6.9 dSm⁻¹, 5.3 and 9.4 dSm⁻¹, 30 and 34 dSm⁻¹ respectively.

Prabhakaran and Lakshmanan (2000) reported that textile effluents having higher concentration of sodic salts with elevated pH and EC polluted and deteriorated the ground water and soil bio, geo and chemical conditions in Tamil Nadu.

2.1.4 Calcium and Magnesium (Ca⁺⁺ and Mg⁺⁺)

Somasekhar *et al.* (1984) studied the calcium and magnesium content of textile effluents was found to be 87 mg L⁻¹ and 112 mg L⁻¹ respectively in Krishna Rajendra Textile Mills, Mysore.

Textile effluent samples collected from textile units in Pali city of Rajasthan had very low amount of calcium + magnesium ions (< 2 cmol L⁻¹), where as Ca content was in traces as compared to Mg content (Gupta and Jain, 1992).

Studies conducted at Central Arid Zone Research Institute have further revealed that textile effluents had very low amount of calcium + magnesium ions (<2 cmol L⁻¹) (Gupta, 1994).

Gupta (1999) reported that soluble salt content of textile effluents was abnormally high but concentration of Ca and Mg was low in Balotra district of Rajasthan.

2.1.5 Carbonates and Bicarbonates (CO_3^- and HCO_3^-)

Swaminathan and Vaidheswaran (1991) reported that carbonate and bicarbonates in dye factory effluent were 120 mg L^{-1} and 85.4 mg L^{-1} respectively in Coimbatore of Tamil Nadu.

Gupta and Jain (1992) revealed that carbonate and bicarbonate content of textile effluent ranged between 4.0 and 16.0 cmol L^{-1} and 14.0 and 40.0 cmol L^{-1} respectively in Textile units at Pali of West Rajasthan.

Studies conducted at Central Arid Zone Research Institute have revealed that textile effluents had high amount of carbonates ranged between 45 and 80 cmol L^{-1} (Gupta, 1994).

2.1.6 Sodium and Potassium (Na^+ and K^+)

Somasekhar *et al.* (1984) revealed that sodium and potassium concentrations in textile effluent was 0.9 mg L^{-1} and 100 mg L^{-1} respectively in Krishna Rajendra Textile Mills of Mysore.

Swaminathan and Vaidheswaran (1991) reported that sodium and potassium content of dyeing factory effluent were 99.5 mg L^{-1} and 0.48 mg L^{-1} respectively in Coimbatore of Tamil Nadu.

Studies conducted at Central Arid Zone Research Institute revealed that textile effluents had sodium ion concentration ranged between $60\text{-}100 \text{ cmol L}^{-1}$ whereas SAR and RSC values between $60\text{-}100 \text{ cmol L}^{-1}$ and $30\text{-}43 \text{ cmol L}^{-1}$ respectively (Gupta, 1994)

Gupta (1999) reported that sodium concentration in textile effluents in Pali of Jodhpur district ranged from 51.3 cmol L^{-1} and $104.3 \text{ cmol L}^{-1}$.

2.1.7 Sulphates and Chlorides (SO_4^{2-} and CO_3^{2-})

Somasekhar *et al.* (1984) reported that sulphate and chloride concentration of textile effluent was 642 mg L^{-1} and 750 mg L^{-1} in Krishna Rajendra Textile Mills of Mysore.

Gupta and Jain (1992) reported that sulphate and chloride concentration in textile effluent was ranged from $9.0 - 15.0 \text{ cmol L}^{-1}$ and $75\text{-}112 \text{ cmol L}^{-1}$ in textile industries at Jodhpur district of Rajasthan.

2.1.8 Boron (B)

Somasekhar *et al.* (1984) reported that boron content of textile effluent was not traced in Krishna Rajendra Textile Mills of Mysore.

Vivek Pandey *et al.* (1994) revealed that boron concentration in fly ash produced from the power house was 2.98 mg L^{-1} in Kanpur of Uttar Pradesh.

2.1.9 Nitrate Nitrogen ($\text{NO}_3\text{-N}$)

Soma Sekhar *et al.* (1984) reported that nitrate nitrogen content in textile effluents discharged from the Krishna Rajendra Textile Mills was 0.01 mg L^{-1} in Mysore.

Matli Sreenivasachari *et al.* (1999) studied that nitrate nitrogen content in paper mill effluent of Sun Paper Mills Limited was traces in Charan Mahadevi of Tamil Nadu.

2.1.10 Flouride (F)

Mamta Goswamy and Naik (1992) Studied that fluoride concentration in fertilizer effluent was $3069.18 \text{ mg L}^{-1}$ in Phosphatic Fertilizer Factory of Raipur city.

2.1.11 Micronutrients (Fe, Mn, Zn and Cu)

Somasekhar (1984) stated that Iron, copper and zinc content of textile factory effluents were 20 mg L^{-1} , 1.75 mg L^{-1} and 30 mg L^{-1} respectively in Mysore of Karnataka state where as the effluents were alkaline in reaction.

Swaminathan and Vaidheswaran (1991) stated that the Zn, Mn and Cu in dyeing factory effluent was nil where as the Fe was in traces in Selvapuram village of Coimbatore in Tamil Nadu.

2.1.12 Heavy Metals (Cd, Pb, Ni, and Cr)

Verma *et al.* (1977) noted that the chromium content in textile effluents ranged from $20\text{-}32 \text{ mg L}^{-1}$ with an average of 26 mg L^{-1} in Modi Textile Factory of Uttar Pradesh.

Somasekhar *et al.* (1984) reported that cadmium and chromium content in Textile effluents was 0.02 mg L^{-1} and 0.01 mg L^{-1} is Krishna Rajendra Textile Mills in Mysore of Karnataka.

2.2 CHARACTERIZATION OF GROUND WATER EFFECTED DUE TO DYEING UNIT EFFLUENTS

2.2.1 pH and EC

Gupta and Jain (1992) reported that electrical conductivity of polluted well waters adjoining effluent stream ranged between 5.5-12.5 dSm^{-1} .

Studies conducted by research and design Ground Water Department in Rajasthan (1992) revealed that average values of EC, SAR and RSC of textile effluents polluted well water having 13.5 dSm^{-1} , 29.7 and 2.2 cmol L^{-1} respectively compared to 5.5 dSm^{-1} , 14.3 and 1.9 cmol L^{-1} in use of non polluted water (Research and Design Ground Water Department, Government of Rajasthan, 1992).

Gupta (1994) revealed that electrical conductivity of ground water at Putima, Jevida and Godhwada villages adjacent to effluent carrying Bandi River was increased from 5 to 10 dSm^{-1} .

Ashok Kumar *et al.* (1998) reported that pH and EC of ground water effected due to mixed industrial effluents of various industries ranged from 8.1 to 9.4 dSm^{-1} and 1.2-9.3 dSm^{-1} in Sikindarabad area of Bulandsahar area in Uttar Pradesh.

Gupta (1999) reported that pH of the ground water polluted due to dyeing effluents was 6.7, 10.0 and 7.8 where as EC of the same was 8.4, 3.6 and 5.6 dSm^{-1} in Jodhpur, Pali and Balotra areas respectively in Rajasthan.

Sharma *et al.* (2000) revealed that the effluent polluted bandi, Luni and Jojri River water used for irrigation having pH range of 7.3 to 9.2 and EC range of 4.5 to 30.0 dsm^{-1} had turned the normal soils into saline and saline sodic soils in western Rajasthan.

2.1.2 Sodium (Na^+)

Gupta and Jain (1992) observed that polluted well water due to dyeing effluents having high sodium and carbonate had SAR and RSC ranging from 39.7 to 200.0 cmol L^{-1} and from 8.0 to 47.7 cmol L^{-1} respectively in Pali district of West Rajasthan.

Gupta (1994) reported that the sodium concentration of ground waters adjacent to textile effluent carrying Bandi River ranged from 38.0 to 112.0 cmol L^{-1} in Putima, Jevida, and Godhwada villages of Rajasthan.

Ashok Kumar *et al.* (1998) revealed that sodium ion concentration of contaminated pond water due to indiscriminate disposal of the various industrial effluents varied from 7.0 to 13.9 cmol L^{-1} in Secunderabad area of Bulandsahar district in Uttar Pradesh. He further reported that the effluents had aggravated the salinity and sodicity in the pond water.

The ground water adjoining polluted Jojri River due to release of dyeing effluents had sodium concentration ranging from 38.0 to 195.6 cmol L^{-1} in Jodhpur district of Rajasthan (Sharma *et al.*, 2000).

2.2.3 Calcium and Magnesium (Ca^{++} and Mg^{++})

Gupta and Jain (1992) reported that calcium and magnesium ion concentration in polluted well waters adjacent to effluent carrying River varied from 0.3 to 1.2 cmol L^{-1} in West Rajasthan.

Calcium and magnesium content of ground water adjoining textile mills ranged between 0.3 and 1.2 cmol L^{-1} as compared to normal ground water (4.8 to 17 cmol L^{-1}) in Jodhpur, Pali and Barmer areas of Rajasthan (Gupta, 1994).

Ashok Kumar *et al.* (1998) reported that the calcium content ranged from 0.0 to 11.12 cmol L^{-1} , 0.0 to 26.3 cmol L^{-1} and 0.0 to 22.7 cmol L^{-1} . Where as magnesium content ranged from 13.2 to 37.6 cmol L^{-1} , 12.2 to 75.2 cmol L^{-1} and 16.9 to 41.4 cmol L^{-1} in pond, hand pump and tube well water adjacent to industrial effluents streams respectively in Bulandsahar area of Uttar Pradesh.

Sharma *et al.* (2000) reported that the presence of calcium and magnesium of polluted well water adjoining effluent carrying Jojri River in smaller proportions ranging from 1.0 to 29.0 cmol L^{-1} and 1.5 to 21.0 cmol L^{-1} respectively suggested the dominance of sodium salts in West Rajasthan.

2.2.4 Potassium (K^+)

Ashok Kumar *et al.* (1998) studied that potassium content of pond, hand pump and tube well water in the effluent discharging industrial areas ranged from 0.3 to 1.1 cmol L^{-1} , 0.1 to 0.7 cmol L^{-1} and 0.2 to 0.8 cmol L^{-1} respectively in Bulandsahar area of Uttar Pradesh.

Gupta (1999) reported that potassium content of ground water effected by effluents of textile and steel rolling industry was 18.0 mg L^{-1} and 8.3 mg L^{-1} in Jodhpur and Pali areas of West Rajasthan.

Sharma *et al.* (2000) reported that potassium content of the well water effected due to effluent streams and effluent carrying rivers varied between 0.2 to 2.3 cmol L^{-1} and 0.2 to 6.1 cmol L^{-1} in West Rajasthan.

2.2.5 Carbonates and Bicarbonates (CO_3^{2-} and HCO_3^-)

Gupta (1994) studied that highest carbonate and bicarbonate ion concentration of polluted well waters adjacent to textile effluent carrying River ranged from 2.8.0 to 38.0 cmol L^{-1} as compared to that of non-polluted wells (2.0 to 6.0 cmol L^{-1}) in West Rajasthan.

Ashok Kumar *et al.* (1998) studied that carbonate and Bicarbonate ion concentration of ground water polluted due to mixed industrial effluents and non polluted ground water in Bulandsahar area of Uttar Pradesh ranged from 4.6 to 5.8 cmol L^{-1} and 1.2 to 2.7 cmol L^{-1} in the pond, 3.1 to 6.1 cmol L^{-1} and 0.0 to 2.7 cmol L^{-1} in the hand pump and 3.3 to 4.6 cmol L^{-1} and 0.0 to 1.2 cmol L^{-1} in the tube well respectively.

Sharma *et al.* (2000) reported that carbonate and bicarbonate content of polluted wells adjacent to effluent carrying Jojri River varied between 0.5 and 6.4 cmol L^{-1} and 1.2 and 10.3 cmol L^{-1} respectively where as the same of non polluted water ranged from 0.5 to 5.0 cmol L^{-1} and 1.4 to 6.0 cmol L^{-1} respectively.

2.2.6 Chlorides (Cl⁻)

Gupta (1994) reported that polluted wells nearer to the textile effluent contaminated River water had higher chlorides (40.0 to 90.0 cmol L⁻¹) as compared to that of non-polluted water (20-60 cmol L⁻¹) in West Rajasthan.

Ashok Kumar *et al.* (1998) studied that chloride ion concentration of polluted water of ponds, hand pumps and tube wells ranged from 11.1 to 42.5 cmol L⁻¹, 8.7 to 50.1 cmol L⁻¹ and 10.7 to 47.2 cmol L⁻¹ respectively in Bulandsahar area of Uttar Pradesh.

Gupta (1999) studied that the chloride content of combined waste water was 820 mg L⁻¹ and 220 mg L⁻¹ in the industrial areas of Pali and Jodhpur areas in West Rajasthan.

Chloride ion concentration of polluted well water adjacent to effluent contaminated rivers of Jojri and Luni varied between 28.0 and 141.5 cmol L⁻¹ and 26.0 and 224.0 cmol L⁻¹ respectively in West Rajasthan (Sharma *et al.*, 2000)

2.2.7 Sulphates (SO₄²⁻)

Gupta and Jain (1992) reported that sulphate ions of polluted well waters adjacent to the textile effluent carrying River ranged from 9.8 to 15.4 cmol L⁻¹ in West Rajasthan.

Gupta (1999) studied that sulphate ion concentration of effluent mixture discharged from different textile industries was 190 mgL^{-1} in Pali district of West Rajasthan.

Sharma *et al.* (2000) reported that chloride ion concentration in polluted well water adjoining textile effluent carrying Jojri River varied between 28.0 and $141.5 \text{ cmol L}^{-1}$ in West Rajasthan.

2.2.8 Micronutrients and Heavy Metals

Totawat (1993) reported the Cd, Zn and Fe concentration of ground waters adjoining smelters effluent stream was ranged from 0.01 to 0.09 mgL^{-1} , 0.1 to 0.7 mgL^{-1} and 0.1 to 0.4 mgL^{-1} respectively in Debari near Udaipur district of Rajasthan.

Joseph and Srivastava (1993) revealed the presence of Hg, Zn, Pb, Cu, Cr, Ni and Cd in the first two estuaries (Adyar and Ennore) while lake pulicat remained reasonably free from heavy metal pollution in Tamil Nadu.

Ashok Kumar *et al.* (1998) studied that Zn and Cu concentration were in traces in polluted pond and tube well water whereas the Zn and Cu concentrations in industrial polluted hand pump water were 0.1 and 1.0 mg L^{-1} respectively in Bulandsahar area of Uttar Pradesh.

2.3 CHARACTERIZATION OF SOILS EFFECTED DUE TO DYEING UNIT EFFLUENTS

2.3.1 pH and EC

Kotaiah (1999) studied that pH and EC of the soils polluted with dyeing effluents ranged from 9.0 to 10.6 and 2650 to 4120 μ mhos cm^{-1} respectively in Nagari region Chittoor district in Andhra Pradesh.

Sharma *et al.* (2000) reported that soils irrigated with textile effluent polluted water along Bandi, Jojri and Luni Rivers in west Rajasthan had been badly effected and turned saline and saline sodic which had pH and EC ranged from 8.3-9.9 and 2.0-274 dSm^{-1} respectively.

Moharana and Nepal Singh (2001) studied that the soils contaminated due to waste water disposal by textile industries had pH and EC ranged from 8.0 to 9.4 and 1.3 to 184.2 dSm^{-1} in West Rajasthan.

2.3.2 Organic Carbon (OC)

Totawat (1991) revealed that organic carbon content in soils irrigated with zinc smelter effluent polluted water varied from 0.2% to 0.4% in Udaipur district of Rajasthan.

Kotaiah (1999) reported that organic carbon content in soils adjacent to effluent stream ranged from 3.85 to 8.6 per cent in Nagari region of Chittoor District in Andhra Pradesh.

2.3.3 Calcium and Magnesium (Ca and Mg)

Sharma *et al.* (2000) reported that properties of soils adjoining the Bandi River were badly effected due to textile processing industrial effluents. The soils having calcium plus magnesium ranged from 1.0 to 174.0 cmol L^{-1} in Pali district of Rajasthan.

Moharana and Nepal Singh (2001) studied that land degradation occurred due to disposal of effluents from textile industries in the soils of West Rajasthan. He reported that Ca plus Mg of the same ranged from 2.8 to 175.0 cmol L^{-1} .

2.3.4 Potassium (K)

The potassium content of soils polluted with paper factory effluent ranged from 0.7 to 1.9 cmol L^{-1} in Tamil Nadu (Matli Srinivasachai, 1999).

Potassium content of soils adjacent to Bandi River and Uni River carrying textile effluent ranged from 0.02 to 25.6 cmol L^{-1} in Pali and Balotra areas of West Rajasthan (Sharma *et al.*, 2000).

Moharana and Nepal Singh (2001) reported that potassium content of soils effected due to release of waste water from textile industries in some areas of West Rajasthan ranged from 0.1 to 8.9 cmol L^{-1} .

2.3.5 Sodium (Na)

Matli Srinivasa Chari *et al.* (1999) reported that sodium content of soils irrigated with paper factory effluent polluted water ranged from 0.9 to 2.4 cmol L^{-1} in Sun Papers Mills Limited, Charan Mahadevi of Tamil Nadu.

Sharma *et al.* (2000) reported that the sodium content of soils irrigated with textile effluent polluted water containing high amount of sodium ranged from 22.0 to 2869.5 cmol L^{-1} in Pali area of West Rajasthan.

Moharana and Nepal Singh (2001) studied that sodium content of soils in Balotra area effected due to release of waste water from textile industries ranged from 7.5 to 343 cmol L^{-1} in west part of Rajasthan.

2.3.6 Carbonates & Bicarbonates (CO_3 and HCO_3)

Carbonate and bicarbonate content of soils adjoining textile effluent polluted Bandi River and Luni River ranged from 1.6 to 11.6 cmol L^{-1} and 1.6 to 16.8 cmol L^{-1} in Pali and Balotra area of West Rajasthan (Sharma *et al.*, 2000)

Moharana and Nepal Singh (2001) reported that carbonate and bicarbonate content of soils contaminated with release of waste water from textile industry varied from 1.5 to 10.2 cmol L^{-1} in West Rajasthan.

2.3.7 Chlorides (Cl)

Sharma *et al.* (2000) Studied that chloride content of saturation extract of soils polluted with textile effluents ranged from 7.5 to 293.0 cmol L^{-1} and 30.4 to 702.2 cmol L^{-1} in Pali and Balotra areas of West Rajasthan.

Soils effected due to release of waste water from textile industry had chlorides ranging from 35.2 to 282.0 cmol L^{-1} in Balotra area of West Rajasthan (Moharana and Nepal Singh, 2001).

2.3.8 Sulphates (SO_4)

Sharma *et al.* (2000) reported that the sulphate content of soils adjacent to Bandi River and Luni River polluted with textile processing industrial effluents ranged from 4.2 to 13.6 cmol L^{-1} and 11.0 to 95.0 cmol L^{-1} respectively in Pali and Balotra areas of West Rajasthan.

Sulphate content of soils contaminated with effluents of textile industry ranged from 0.2 to 102.9 cmol L^{-1} in western parts of Rajasthan (Moharana and Nepal Sing, 2001).

2.3.9 Nutrient Status of Soils

2.3.9.1 Micronutrients (*Zn, Cu, Fe and Mn*)

Narendar Siva Swamy (1991) studied that Mn and Zn content of soils contaminated with wastes discharged from Tanneries in Tamil Nadu were 238.5 mg kg^{-1} and 112.4 mg kg^{-1} when compared to control 24.7 mg kg^{-1} and 103.6 mg kg^{-1} respectively. However, Cu (0.1 mg kg^{-1}) and Fe (0.1 mg kg^{-1}) content in tanneries wastes contaminated soils were low as compared to control (Cu 5.8 and Fe 2.5 mg kg^{-1})

Jaya Bhaskaran and Sreeramulu (1996) reported that accumulations of DTPA extractable Fe, Cu, Mn and Zn of sewage contaminated soils were more in the surface soil and decreased with increasing soil depth and distance from sewage entry point in Madhurai and Coimbatore areas of Tamil Nadu.

Matli Srinivasachari (1999) reported that the accumulation of DTPA extractable micronutrients were more in soils around the Sun Paper Mills Limited of Charan Mahadevi in Tamil Nadu.

2.3.9.2 Heavy metals (*Cd, Pb, Ni and Cr*)

Burman and Lal (1994) reported that the level of heavy metals (*Viz.*, Pb and Cd) in the cultivated fields adjacent to Durgapur Industrial Belt in Uttar Pradesh were found to be much higher than the background level.

Singh and Singh (1994) reported that the accumulation of DTPA extractable Cd, Pb and Cr in soils effected due to sewage and industrial effluents were ranged between 0.18 – 3.90 mg kg⁻¹, 0.26 – 10.44 mg kg⁻¹ and 0.28 – 5.01 mg kg⁻¹ respectively in adjacent fields around Varanasi, Uttar Pradesh.

Jayabhaskaran and Sreeramulu (1996) reported that the accumulation of DTPA extractable heavy metals viz., Cd, Cr, Pb and Ni in soils effected due to sewage were more in the surface soil and decreased with increasing soil depth and distance from sewage entry point in Madhurai and Coimbatore area of Tamil Nadu. They also observed that vertical movement of extractable heavy metals was more in light textured soils than in heavy textured soils.

2.4 EFFECT OF DYEING UNIT EFFLUENTS ON GROWTH AND YIELD OF THE CROPS

Devarajan and Oblisami (1995) reported that the sugarcane yield reduction was 14.6 per cent and 8.3 per cent by using 50 times and 40 times diluted distillery effluents respectively as compared to that of irrigating with good quality of water. He further observed that 10 times diluted effluent decreased the cane yield by 6.6 per cent.

Matli Srinivasachari *et al.* (1999) reported that grains and straw yield of rice were unaffected by paper effluent irrigation. He suggested the probability of using paper mill effluent for irrigation in rice crop without much adverse effect on growth and yield.

2.5 EFFECT OF DYEING UNIT EFFLUENT ON NUTRIENT STATUS OF INDEX LEAVES

Singh *et al.* (1991) reported that micronutrients increased due to irrigation with sewage water as well as refinery effluents. The concentration of Cu, Fe and Mn was higher in berseem plants when irrigated with sewage water.

Burman and Lal (1994) reported that bio accumulation of Zn, Cu, Cd, and Pb of different plants of different plant species (vegetable) were found to be either within or beyond critical concentration and maximum localization found in edible parts followed by non edible leaves and shoots in Durgapur industrial belt of Uttar Pradesh.

Joshi *et al.* (1996) reported that sugarcane crops showed good response to application of concentrated distillery effluent without showing any reduction in yield whereas the crops like wheat and rice grown well after dilution of the effluent to BOD levels around 500-100 mg kg⁻¹.

Adhikari *et al.* (1998) reported that leaf Fe and Zn of cauliflower grown with sewage water ranged from 1000-1600 mg kg⁻¹ and 90-110 mg kg⁻¹ respectively whereas the Cu and Mn content of cauliflower leaf varied from 8 to 36 mg kg⁻¹ and 8 to 21 mg kg⁻¹ respectively.

Materials and Methods

CHAPTER – III

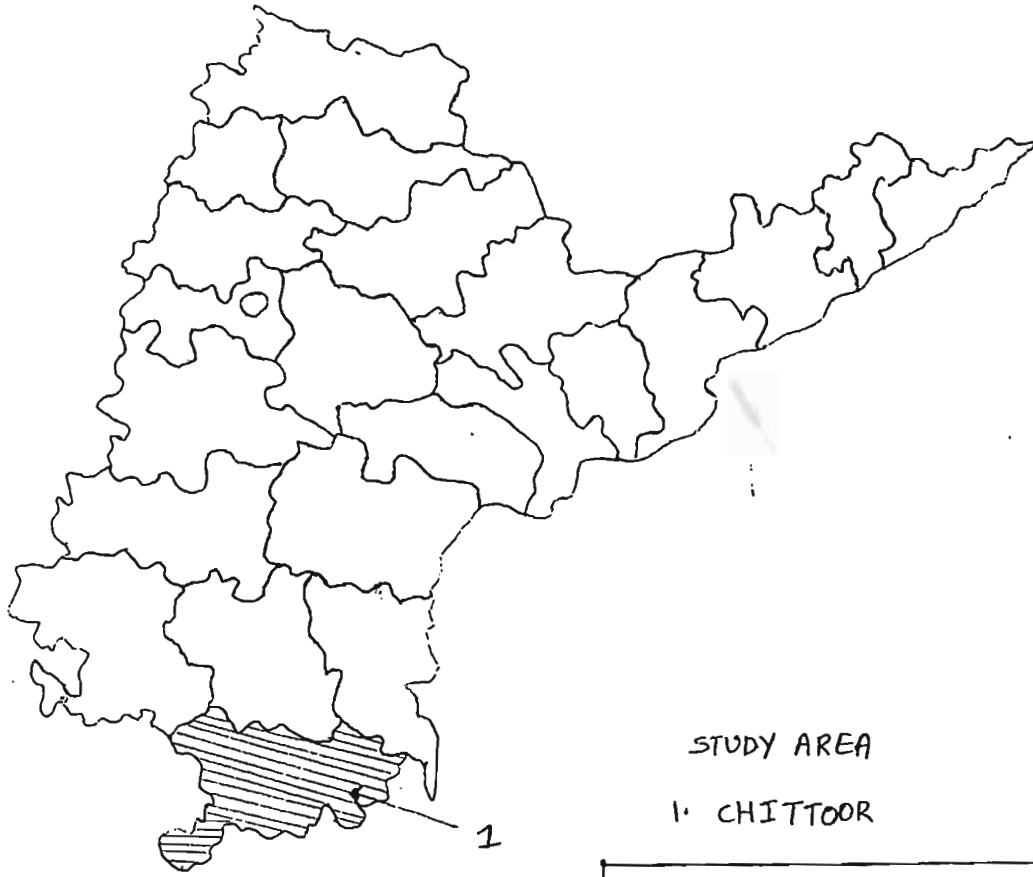
MATERIALS AND METHODS

The development of dyeing industries has both positive and negative impacts on the environment. A positive impact is that it creates employment generation to land less technical labours. On other hand these industries pollute the agricultural land. Release of dyeing unit effluents without proper treatment into the streams and fields causes environmental degradation and reduction of crop productivity.

The present investigation was carried out during 2000-2001 in order to characterize the physical and chemical properties of soils adjoining the effluent streams and to assess the quality of ground water upto 780 m lateral from effluent stream. The methods adopted and materials used in the study are presented in this chapter.

3.1 LOCATION

The study was carried out in three different locations of Nagari mandal in Chittoor district of Andhra Pradesh. The locations selected for the study were Nagari, Satravada and Ekambarakuppam. The three locations are shown in Fig 1 and 2.



STUDY AREA

1. CHITTOOR

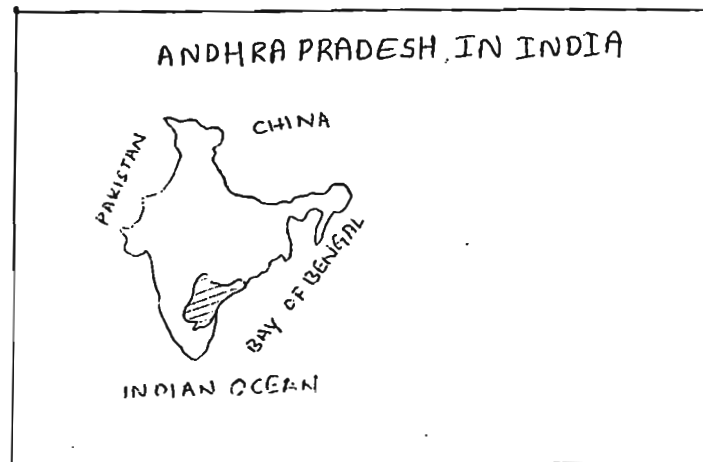


Fig 1: LOCATIONS OF STUDY AREA

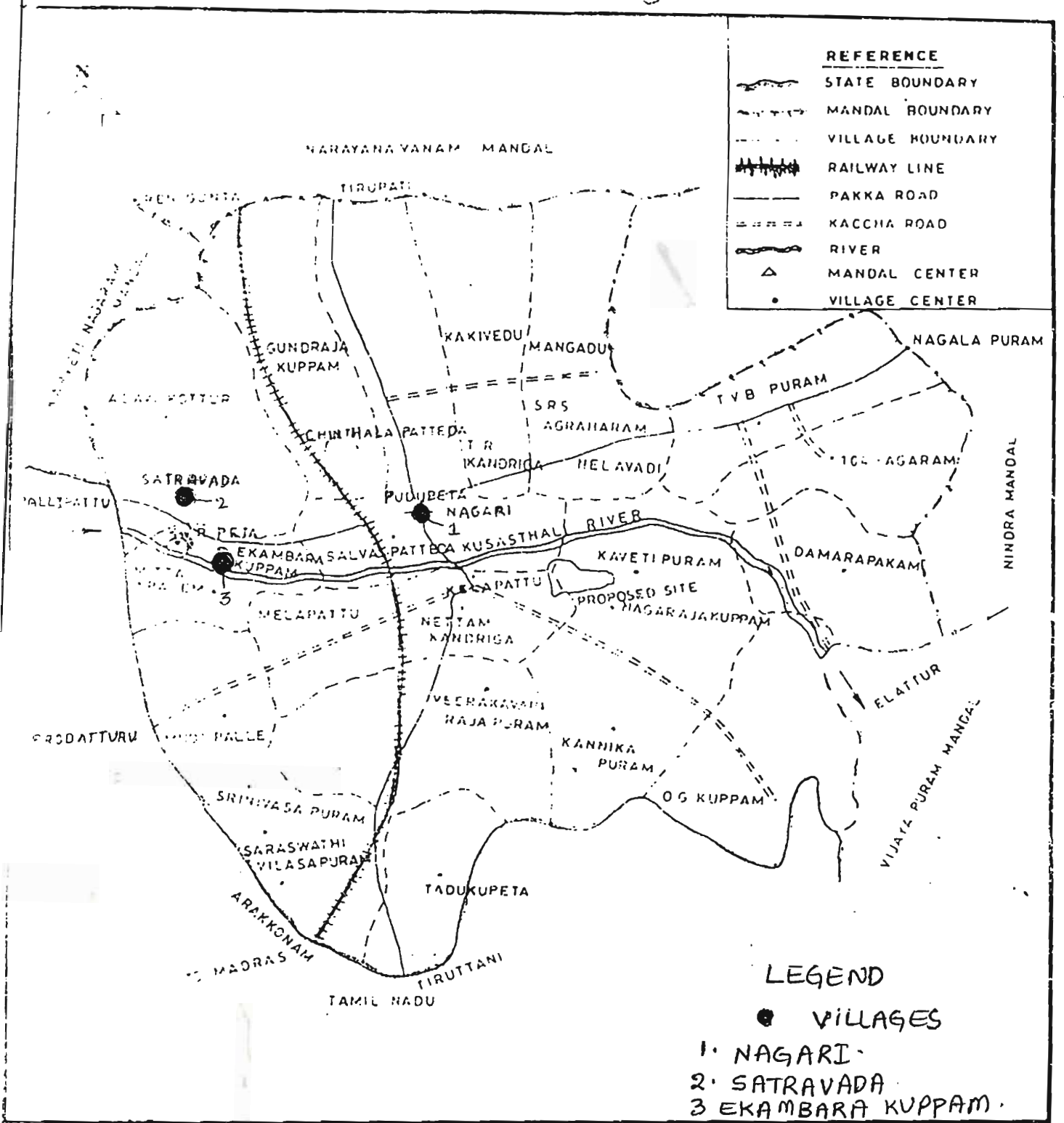


Fig 2: LOCATIONS OF STUDY AREA

3.2 WEATHER DATA DURING THE STUDY PERIOD

The meteorological data on maximum and minimum temperatures, number of rainy days, rainfall and evaporation pertaining to the study locations from January to December 2001 are furnished in Appendix II.

A survey work in the areas of Nagari, Satravada and Ekambara Kuppam was undertaken to study the impact of dyeing effluents discharged from dyeing units on the soils, ground water and crop growth. The effect of dyeing effluents on the physical characteristics, physico-chemical properties, micronutrients and heavy metals of soils around stream was studied. The physico-chemical properties and ionic components of ground water adjoining effluent streams were also studied. Further, the impact of dyeing effluents on plant nutrient composition and yield losses at different distances from the streams was studied during this survey work. The materials used and methods adopted during these investigations are presented in this chapter.

3.3 COLLECTION OF EFFLUENT SAMPLES FROM DYEING INDUSTRIES

Effluent samples were collected from outlets of dyeing industries at Nagari, Satravada and Ekambarakuppam. Effluent samples were collected in well cleaned polythene bottles. Before collection each bottle was washed with fresh water. Finally bottles were rinsed with distilled water. Immediately after collection the bottles were tightly stoppered. After filter the effluent samples, the pH and EC of the samples were immediately measured in the laboratory and after words the samples were stored at 4°C for further analysis. In these samples nutrients were estimated through standard procedures as summarized in Table 4.

3.4 COLLECTION OF SOIL SAMPLES

Soil samples were collected from the fields adjoining dyeing effluent streams at 0, 10, 25, 50, 75, 100, 150, 200 m away from the effluent stream at each location, the soil samples were collected at 0-15, 15-30 and 30-45 cm depth.

3.4.1 Sample Processing and Analysis

Soil samples: Immediately after collection the soil samples, were air dried under shade. Later, they were pounded with wooden pestle and mortar and passed through a 2 mm sieve and stored for analysis. These samples were analysed by following standard procedures summarized in Table 3.

Plant samples: Index leaf samples of rice, sugarcane and groundnut grown adjacent to stream at different distances 0, 10, 25, 50, 75, 100, 150 and 200 m were collected

All these plant samples were washed thoroughly first with 0.1 per cent dilute hydrochloric acid then with tap water and washed finally with distilled water. These samples were dried under shade and finally in a hot air oven at 60°C. The samples were ground to pass through 40 mesh sieve. Ground samples were stored in butter paper bags till analysis. In these samples micronutrients were estimated through standard procedures as summarized in Table 5.

3.5 SELECTION OF WELLS

Wells / bore wells at different distances from effluent streams, were selected *viz.*, Nagari, Satravada and Ekambarakuppam. The distances from the stream and particulars of wells are furnished in table 1, 2a and 2b.

3.5.1 Collection of Water Samples

Water samples were collected from field located at different distances from polluted streams. From each selected well / bore well water samples were collected in one litre capacity polythene bottles. Before collection each bottle was washed with dilute hydrochloric acid followed by fresh water. Finally bottles were rinsed with distilled water. A clean bucket was introduced into a well with the help of rope and water was taken out. This water was filled in the polythene bottles.

Prior to filling, bottles have rinsed with water in bucket. Immediately after collection, the bottles were tightly stoppered. All the wells were in use at the time of sampling. The pH and EC of the samples were immediately measured in the laboratory and after words the samples were stored at 4°C for further analysis. In these samples nutrients were estimated through standard procedures as summarized in Table 4.

Table 1: Details of ground water samples collected from Ekambarakuppam at different lateral distances from the effluent streams

S.No.	Name of the farmer	Well / bore well	Distance from stream(m)	Age of the well / bore well (year)
1.	P.Neelamegham	Well	0	13
2.	K.Thangabalu	Well	13	11
3.	A.Peddabba	Well	32	10
4.	K.Loganadham	Well	54	10
5.	G.Marugappa	Well	86	8
6.	N.Manivemkateswarulu	Well	110	8
7.	M.Ankam Naidu	Bore well	164	8
8.	G.Babu	Well	210	10
9.	K.Rama Subba Reddy	Well	512	7
10.	K.Rama Subba Reddy	Bore well	780	8

Table 2a: Details of ground water samples collected from Satravada at different lateral distances from the effluent streams

S.No.	Name of the farmer	Well / bore well	Distance from stream(m)	Age of the well / bore well (year)
1.	Sh.Allabakshu	Well	0	15
2.	M.Subramanyam	Well	14	13
3.	N.Saravanam	Well	28	13
4.	R.Mutyala Reddy	Well	45	10
5.	R.Mutyala Reddy	Well	78	10
6.	K.Venkata Reddy	Well	105	10
7.	G.Abraham	Well	158	12
8.	I.Elumali	Well	205	9
9.	M.Govinda Rajan	Well	490	8
10.	M.Govinda Rajan	Well	760	8

Table 2b: Details of ground water samples collected from Nagari at different lateral distances from the effluent streams

S.No.	Name of the farmer	Well / bore well	Distance from stream(m)	Age of the well / bore well (year)
1.	B.Tippeswamy	Well	0	14
2.	B.Tippeswamy	Well	10	12
3.	N.R.Chandra Naidu	Well	32	12
4.	A.Varamuni	Well	52	12
5.	A.Varamuni	Well	84	10
6.	G.Rangappa	Well	106	8
7.	M.Lokanadha Naidu	Well	158	8
8.	M.Lokanadha Naidu	Well	212	10
9.	P.Govinda Mudhali	Well	510	9
10.	P.Armugam	Well	760	9

Details of ground water samples collected from three locations at different lateral distances from the effluent streams are presented in Table 1, 2a and 2b.

3.6 YIELD ESTIMATION

The yield of rice, sugarcane and groundnut were recorded in fields adjoining effluent streams at a distance of 0, 10, 25, 50, 75, 100, 150 and 200 m. Yields were recorded by 12 sq.m area of the crop at randomly selected four places at each distance and calculated the grain yield per hectare.

3.7 STATISTICAL ANALYSIS

The data collected on various aspects were subjected to statistical analysis by adopting analysis of variance technique. Significant interactions were only presented. The data were scrutinized statistically as per the method given by Snedecor and Cochran (1975).

Table 3: Methods used for soil analysis

S.No.	Test	Principle method	Reference
1.	pH	Soil water suspension (1:2) using glass electrode pH meter	Jackson (1967)
2.	EC	Soil water suspension (1:2) using electrical conductivity bridge	Jackson (1967)
3.	Organic Carbon	Chromic acid wet digestion (Walkely and Black)	Jackson (1967)
4.	Ca ⁺⁺ Mg ⁺⁺	Soil water extract (1:2) using rapid EDTA Titration method	Vogel (1978)
5.	Na ⁺ and K ⁺	Soil water (1:2) using flame photometer	Jackson (1967)
6.	CO ₃ ⁻ and HCO ₃ ⁻	Soil water extract (1:2) titrating soil water extract with standard H ₂ SO ₄ using phenolphthalein and methyl orange	Piper (1966)
7.	Cl ⁻	Soil water extract (1:2) estimated volumetrically by titrating the water extract with standard Ag NO ₃ using potassium chromate in dicator	Reitemeier (1943)
8.	SO ₄ ⁻⁻	Soil extract (1:2) by turbidometric method at wave length 440 nm using spectronic 20 Bausch aid lomb spectrophotometer	Massoumi and Corn field (1963)
9.	Micro nutrients (Fe, Mn, Cu and Zn)	Using atomic absorption spectrometer	Lindsay and Norvell (1978)
10.	Heavy metals (Cd, Pb, Ni and Cr)	Using atomic absorption spectrometer	Lindsay and Norvell (1978)

Table 4: Methods used for water and effluent analysis

S.No.	Test	Principle method	Reference
1.	Colour	Visual observation	Kodarkar (1992)
2.	Temperature	Using centigrade thermometer (0-100°C)	APHA (1995)
3.	Turbidity	Using transparency value with the help of table given methodology for water analysis	Kodarkar (1992)
4.	pH	Using glass electrode pH meter	Jackson (1967)
5.	EC	Using conductivity bridge	Jackson (1967)
6.	Ca ⁺⁺ Mg ⁺⁺	Estimated volumetrically using EDTA Rapid titration method	Vogel (1978)
7.	CO ₃ ⁻ and HCO ₃ ⁻	Titration with standard sulphuric acid using phenolphthalein and methyl orange as indicator	Piper (1966)
8.	Cl ⁻	Estimated volumetrically by titrating the water with standard silver nitrate using potassium chromate as indicator by Mohr's method	Reitemeier (1943)
9.	SO ₄ ⁻⁻	Estimated by turbidometric method at wave length 440 nm using spectronic 20 Bausch and Lomb spectrophotometer	Massoumi and Cornfield (1963)
10.	Na ⁺ and K ⁺	Estimated with the aid of flame photometer (Systronics model 121)	Jackson (1967)
11.	B	Estimated by calorimetric method using carmine solution	Hatcher and Wilcox (1950)
12.	NO ₃	Estimated by using the sulphanilamide NED method.	Joseph (1994)
13.	Micro nutrients (Fe, Mn, Cu and Zn)	Using Atomic Absorption Spectrometer (Model 170-0036, Japan) at air pressure of 1.6 kg cm ² using Acetylene gas	Lindsay and Norvell (1978)
14.	Heavy metals (Cd, Pb, Ni and Cr)	Using Atomic Absorption Spectrometer (Model 170-0036, Japan) at air pressure of 1.6 kg cm ² using Acetylene gas	Lindsay and Norvell (1978)

Table 5: Methods used for plant analysis

S.No.	Test	Principle method	Reference
1.	N	By microkjeldhal method	AOAC (1980)
2.	P	Phosphorus by Vanadomolybdo phosphoric yellow colour method	Jackson (1967)
3.	K	Potassium by flame photometry	Jackson(1967)
5.	Ca and Mg	By atomic absorption spectrophotometer using lanthanum solution as interference eliminating reagent	Jackson (1967)
6.	Micronutrients (Zn, Cu, Mn and Fe)	Using Atomic Absorption Spectrometer	Lindsay and Norvell (1978)

Results

CHAPTER – IV

RESULTS

“Effect of effluents discharged from dyeing industries on soil, water and crop quality in Nagari Mandal, Chittoor District, Andhra Pradesh” involved survey study of soil, ground water, index leaf and yield of crops to find out the influence of effluent discharged from dyeing units on the properties of soils, quality of water and the quality and yield of the crops adjoining effluent streams. Results obtained in these studies were presented in this chapter.

4.1 CHARATERIZATION OF DYEING UNIT EFFLUENTS

Effluents discharged from dyeing units located at Nagari, Satravada and Ekambarakuppam locations were drawn in the month of April in the year 2001 and were analysed pH, EC, OC, Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^- , HCO_3^- , Cl^- , SO_4^{--} , F, NO_3^- , B and micronutrients like Zn, Cu, Mn and Fe, heavy metals like Cd, Pb, Ni and Cr. In addition to these characteristics, colour, odour, temperature pended solids and turbidity of the effluent were also studied. The results are presented in the Table 6.

4.1.1 Physical Characteristics of Dyeing Unit Effluent

From the data pertaining to physical characteristics of effluents are presented in Table 6.

4.1.1.1 Colour

Colours of the effluent discharged from dyeing industries during the study period at Nagari, Satravada and Ekambarakuppam were red, green, yellow and blue. Colour was mainly depends on the nature of dye used in dyeing units.

4.1.1.2 Odour

Dyeing unit effluent collected from three villages were odour less.

4.1.1.3 Temperature

Temperature of dyeing effluent was 30°C, 29°C and 30°C at Nagari, Satravada and Ekambarakuppam respectively.

4.1.1.3 Suspended Solids

Suspended solid of effluent was 125 mg L⁻¹, 120 mg L⁻¹ and 120 mg L⁻¹ at Nagari, Satravada and Ekambarakuppam respectively.

4.1.1.5 Turbidity

Maximum turbidity (360 mg L^{-1}) was recorded in Ekambarakuppam when compared to Nagari (355 mg L^{-1}) and Satravada (355 mg L^{-1}).

4.1.2 Chemical Characteristics of Dyeing Unit Effluents

The data pertaining to physical characteristics of effluents are presented in Table 6.

4.1.2.1 pH

The effluent of dyeing industries in Nagari region showed alkaline reaction. The maximum pH (9.6) was recorded in Ekambarakuppam as compared to that of Satravada (9.2) and Nagari (9.0).

4.1.2.2 EC

The dyeing unit effluent of all the three villages had shown high values of electrical conductivity in Ekambarakuppam (5.6 dSm^{-1}), Satravada (5.5 dSm^{-1}) and Nagari (5.5 dSm^{-1}).

4.1.2.3 Organic Carbon (OC)

The organic carbon of dyeing unit effluent at Nagari, Satravada and Ekambarakuppam was 2.0, 2.2 and 2.2 per cent respectively.

Table 6: Characteristics of effluent discharged from dyeing units at different locations

S.No.	Characteristics	Locations		
		Nagari	Satravada	Ekambara kuppam
1	Colour	Red, Green, Yellow, Blue dependent on dye used		
2	Odour	Odour less	Odour less	Odour less
3	Temperature (°C)	30	29	30
4	Suspended solids (mg L ⁻¹)	125	120	120
5	Turbidity (mg L ⁻¹)	355	355	360
6	pH	9.0	9.2	9.6
7	EC (dSm ⁻¹)	5.5	5.5	5.6
8	OC (%)	2.0	2.2	2.2
9	Ca ⁺⁺ (cmol L ⁻¹)	5.5	5.5	5.6
10	Mg ⁺⁺ (cmol L ⁻¹)	3.5	3.5	3.7
11	Na ⁺ (cmol L ⁻¹)	31.4	31.8	34.2
12	K ⁺ (cmol L ⁻¹)	4.0	4.1	4.2
13	Cl ⁻ (cmol L ⁻¹)	30.8	31.2	32.2
14	SO ₄ ⁻ (cmol L ⁻¹)	6.8	6.8	7.0
15	CO ₃ ⁻ (cmol L ⁻¹)	0.6	0.9	0.7
16	HCO ₃ ⁻ (cmol L ⁻¹)	7.0	7.8	7.2
17	NO ₃ ⁻ (cmol L ⁻¹)	0.01	0.01	0.02
18	B (cmol L ⁻¹)	Nil	Nil	Nil
19	F (cmol L ⁻¹)	0.02	0.02	0.02
20	Zn (mg L ⁻¹)	0.100	0.092	0.099
21	Fe (mg L ⁻¹)	0.36	0.35	0.36
22	Mn (mg L ⁻¹)	0.54	0.56	0.58
23	Cu (mg L ⁻¹)	0.17	0.18	0.17
24	Cd (mg L ⁻¹)	0.024	0.023	0.033
25	Pb (mg L ⁻¹)	0.13	0.13	0.15
26	Ni (mg L ⁻¹)	0.172	0.172	0.179
27	Cr (mg L ⁻¹)	0.332	0.330	0.335

4.1.2.4 Calcium (Ca^{++})

The calcium ion concentration in dyeing unit effluent at Nagari, Satravada and Ekambarakuppam was 5.5 cmol L^{-1} , 5.5 cmol L^{-1} and 5.6 cmol L^{-1} respectively.

4.1.2.5 Magnesium (Mg^{++})

The highest concentration of magnesium was recorded in Ekambarakuppam (3.7 cmol L^{-1}) followed by Satravada (3.5 cmol L^{-1}) and Nagari (3.5 cmol L^{-1}).

4.1.2.6 Sodium (Na^+)

Highest concentration of sodium (34.2 cmol L^{-1}) was obtained at Ekambarakuppam whereas the same was 31.8 cmol L^{-1} , 31.4 cmol L^{-1} at Satravada and Nagari respectively.

4.1.2.7 Potassium (K^+)

Highest potassium content was recorded in Ekambarakuppam 4.2 cmol L^{-1} whereas lowest potassium content was recorded at Nagari (4.0 cmol L^{-1}) and Satravada (4.1 cmol L^{-1}).

4.1.2.8 Carbonates (CO_3^-)

Highest carbonate ion concentration (0.9 cmol L^{-1}) was recorded in Satravada effluent whereas lowest values were observed as 0.7 cmol L^{-1} and 0.6 cmol L^{-1} at Ekambarakuppam and Nagari respectively.

4.1.2.9 Bicarbonates (HCO_3^-)

The bicarbonate content of effluent was 7.8 cmol L^{-1} , 7.2 cmol L^{-1} and 7.0 cmol L^{-1} in Satravada, Ekambarakuppam and Nagari respectively.

4.1.2.10 Chlorides (Cl^-)

Highest chloride content was recorded in Ekambarakuppam (32.2 cmol L^{-1}) followed by Satravada (31.2 cmol L^{-1}) and Nagari (30.8 cmol L^{-1}).

4.1.2.11 Sulphates (SO_4^-)

Sulphate concentration of effluent was 7.0 cmol L^{-1} , 6.8 cmol L^{-1} and 6.8 cmol L^{-1} at Ekambarakuppam, Nagari and Satravada respectively.

4.1.2.12 Nitrate nitrogen (NO_3^-)

Nitrate concentration of effluent was 0.01 cmol L^{-1} , 0.01 cmol L^{-1} and 0.02 cmol L^{-1} at Nagari, Satravada and Ekambarakuppam, respectively

4.1.2.13 Boron(B)

Boron concentration of effluent at Nagari, Satravada and Ekambarakuppam were found to be nil.

4.1.2.14 Flouride (F)

Flouride concentration of effluent was 0.02 cmol L^{-1} at Nagari, Satravada and Ekambarakuppam.

Micronutrients (Zn, Cu, Fe and Mn)

4.1.2.15 Zinc (Zn)

The zinc content of effluent was 0.100 mg L^{-1} , 0.099 mg L^{-1} and 0.092 mg L^{-1} at Nagari, Ekambarakuppam and Satravada.

4.1.2.16 Copper (Cu)

Copper concentration was maximum in Satravada effluent (0.18 mg L^{-1}) as compared to Nagari (0.17 mg L^{-1}) and Ekambarakuppam (0.17 mg L^{-1}).

4.1.2.17 Iron (Fe)

Highest Iron concentration was recorded in Ekambarakuppam (0.38 mg L^{-1}) where as the iron content was (0.36 mg L^{-1}) and (0.35 mg L^{-1}) at Nagari and Satravada respectively.

4.1.2.18 Manganese (Mn)

Manganese concentration recorded in Ekambarakuppam was 0.58 mg L^{-1} where as the same was 0.54 mg L^{-1} and 0.56 mg L^{-1} at Nagari and Satravada respectively.

Heavy Metals

4.1.2.19 Cadmium (Cd)

Highest cadmium concentration recorded at Ekambarakuppam was 0.033 mg L^{-1} while is Nagari and Satravada cadmium content was 0.024 mg L^{-1} and 0.023 mg L^{-1} respectively.

4.1.2.20 Lead(Pb)

The highest lead concentration (0.15 mg L^{-1}) was recorded at Ekambarakuppam as compared to that of Nagari (0.13 mg L^{-1}) and Satravada (0.13 mg L^{-1}).

4.1.2.21 Nickle (Ni)

Highest Nickle concentration (0.179 mg L^{-1}) was recorded at Ekambarakuppam as compared to that of Satravada (0.172 mg L^{-1}) and Nagari (0.168 mg L^{-1}).

4.1.2.22 Cromium (Cr)

The cromium content of effluent was 0.335 mg L^{-1} , 0.332 mg L^{-1} and 0.330 mg L^{-1} at Ekambarakuppam, Nagari and Satravada respectively.

4.2 CHARACTERISTICS OF THE GROUND WATER ADJOINING EFFLUENT STREAMS IN NAGARI REGION

The data presented in Tables 7 to 12 and depicted in Fig 3 to 19. Effect of effluent streams on quality of ground water was assessed by drawing samples from wells/bore wells located at varying lateral distances from the effluent stream upto a distance 760 m. Samples collected in the month of April, 2001 were analysed for pH, EC, OC, Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^- , HCO_3^- , Cl^- , SO_4^{--} and micronutrients *viz.*, Zn, Cu, Mn, Fe and heavy metals *viz.*, Cd, Pb, Cr, Ni.

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4.2.1 pH

From the data presented in Table 7, 9 & 11 and depicted in Fig. 3. It was noticed that pH of the ground water was generally higher in the immediate vicinity of effluent stream at all the three locations studied. The pH ranged from 7.94 to 8.02 between 0 and 10 m distance, 7.74 to 8.06 between 0 and 28 m distance and 7.84 to 8.21 between 0 and 32 m distance at Nagari, Satravada and Ekambarakuppam respectively. The higher pH range of the ground water was obtained up to 10 m lateral distance from the effluent stream in case of Nagari, up to 28 m distance in case of Satravada and 32 m distance in case of Ekambarakuppam as compared to that of farther distances. The pH was not influenced beyond 10 m distance, 28 m distance and 32 m distance in case of Nagari, Satravada and Ekambarakuppam respectively due to effluent discharged from dyeing units.

4.2.2 EC

The data on EC of ground water presented in Table 7, 9 & 11 and illustrated in Fig 4 indicated that the EC of the ground water was generally higher in the immediate vicinity of effluent stream at all three locations. Higher EC varied between 0.86 to 4.48 dSm⁻¹ between 0 to

Table 7: Characteristics of ground water adjoining effluent stream at Nagari

Distance (m)	pH	EC (dSm ⁻¹)	Cations (cmol L ⁻¹)				Anions (cmol L ⁻¹)			
			Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cl ⁻	SO ₄ ⁻⁻	CO ₃ ⁻	HCO ₃ ⁻
0	8.02	2.86	21.6	2.0	1.9	0.9	19.8	0.9	0.8	4.9
10	7.94	1.74	13.2	1.4	1.2	0.6	11.9	0.5	0.7	3.3
32	7.63	0.96	7.0	0.7	0.8	0.4	5.8	0.4	0.9	1.8
52	7.62	0.88	6.4	0.6	0.7	0.4	5.3	0.4	0.7	1.7
84	7.14	0.42	2.7	0.5	0.6	0.3	1.6	0.3	0.6	1.5
106	7.18	0.38	2.1	0.6	0.7	0.4	1.7	0.4	0.6	1.1
158	7.12	0.38	2.3	0.4	0.6	0.3	1.6	0.3	0.6	1.1
212	7.23	0.34	2.1	0.3	0.5	0.3	1.5	0.2	0.6	0.9
510	7.20	0.38	2.1	0.4	0.7	0.3	1.6	0.2	0.6	1.1
760	7.26	0.36	2.3	0.2	0.5	0.2	1.5	0.2	0.5	1.0

Table 9: Characteristics of ground water adjoining effluent stream at Satravada

Distance (m)	pH	EC (dSm ⁻¹)	Cations (cmol L ⁻¹)				Anions (cmol L ⁻¹)			
			Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cl ⁻	SO ₄ ⁻	CO ₃ ⁻	HCO ₃ ⁻
0	8.06	2.92	22.8	2.1	1.8	0.9	21.4	1.4	0.9	3.9
14	7.92	1.58	11.2	1.2	1.0	0.6	9.0	0.8	1.0	3.2
28	7.74	0.92	6.4	0.9	0.8	0.5	4.7	0.5	1.0	2.4
45	7.32	0.58	4.3	0.7	0.6	0.4	2.9	0.4	0.8	1.9
78	7.28	0.54	4.1	0.6	0.6	0.4	2.7	0.4	0.8	1.8
105	7.28	0.58	4.0	0.5	0.6	0.3	2.6	0.3	0.7	1.8
158	7.24	0.52	4.7	0.5	0.4	0.3	2.9	0.4	0.6	1.9
205	7.22	0.54	4.1	0.4	0.5	0.2	2.4	0.4	0.6	1.8
490	7.20	0.53	4.2	0.4	0.5	0.2	2.5	0.4	0.6	1.8
760	7.24	0.55	4.3	0.5	0.5	0.2	2.5	0.5	0.6	1.9

Table 11: Characteristics of ground water adjoining effluent stream at Ekambarakuppam

Distance (m)	pH	EC (dSm ⁻¹)	Cations (cmol L ⁻¹)					Anions (cmol L ⁻¹)			
			Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cl ⁻	SO ₄ ⁻⁻	CO ₃ ⁻⁻	HCO ₃	
0	8.21	4.48	29.0	3.8	4.6	2.7	25.3	4.8	1.1	6.4	
12	8.02	2.12	13.7	1.6	2.8	1.3	11.3	2.2	1.1	3.8	
32	7.84	1.28	7.8	1.2	1.8	0.9	6.1	1.4	1.0	2.7	
54	7.58	0.84	4.5	0.8	1.7	0.9	3.7	0.9	0.8	2.3	
86	7.56	0.86	4.6	0.7	1.8	0.9	3.8	0.8	0.8	2.3	
110	7.44	0.44	2.5	0.5	1.0	0.5	1.8	0.3	0.8	1.6	
164	7.42	0.48	2.7	0.6	0.9	0.6	2.0	0.4	0.5	1.7	
210	7.48	0.42	2.8	0.5	0.8	0.4	1.4	0.3	0.7	1.6	
512	7.42	0.40	2.5	0.6	0.9	0.4	1.8	0.3	0.4	1.4	
780	7.56	0.48	2.4	0.5	0.9	0.5	1.8	0.2	0.7	1.7	

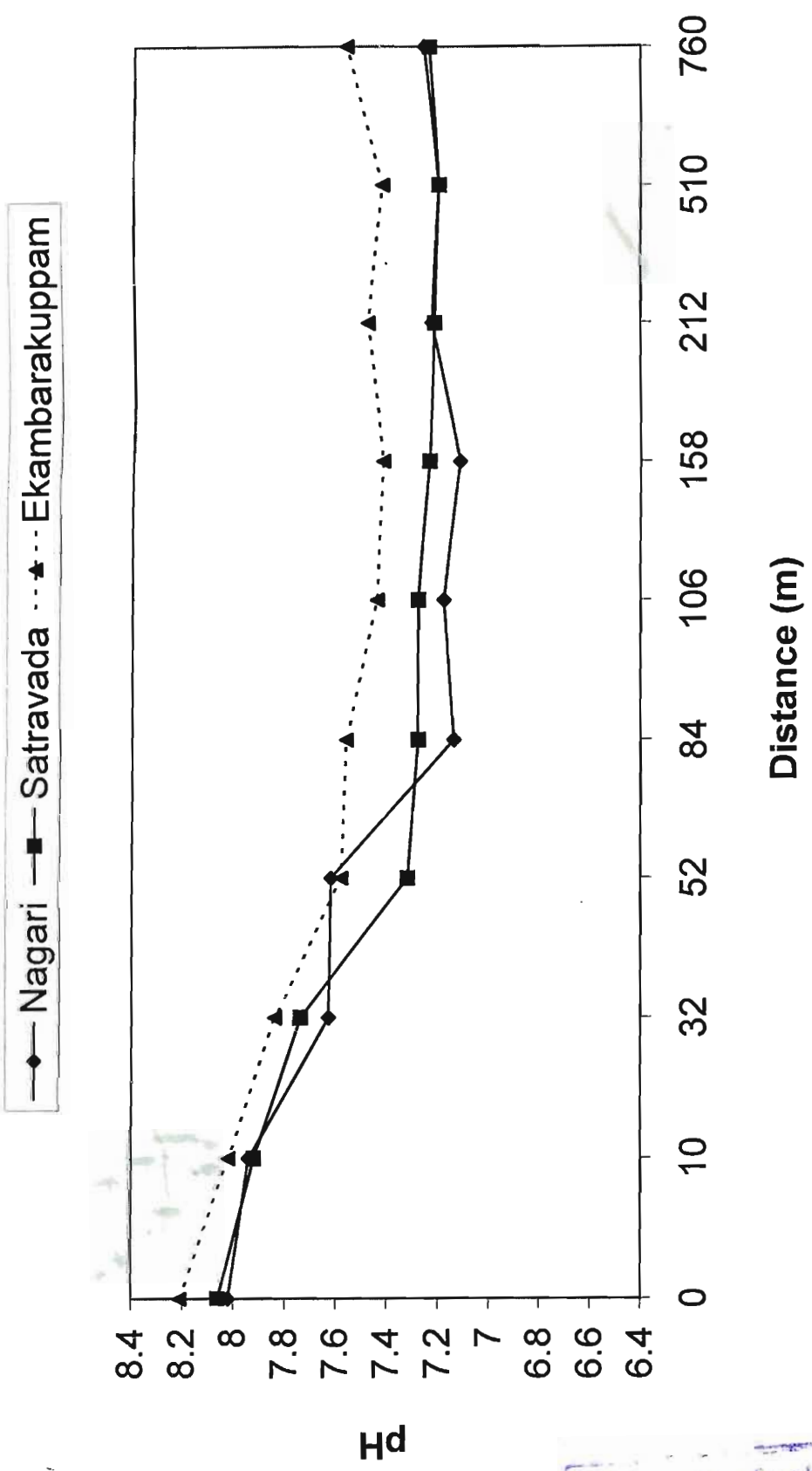


Fig 3: Influence of dyeing unit effluent on pH of ground water at different distances from the effluent stream

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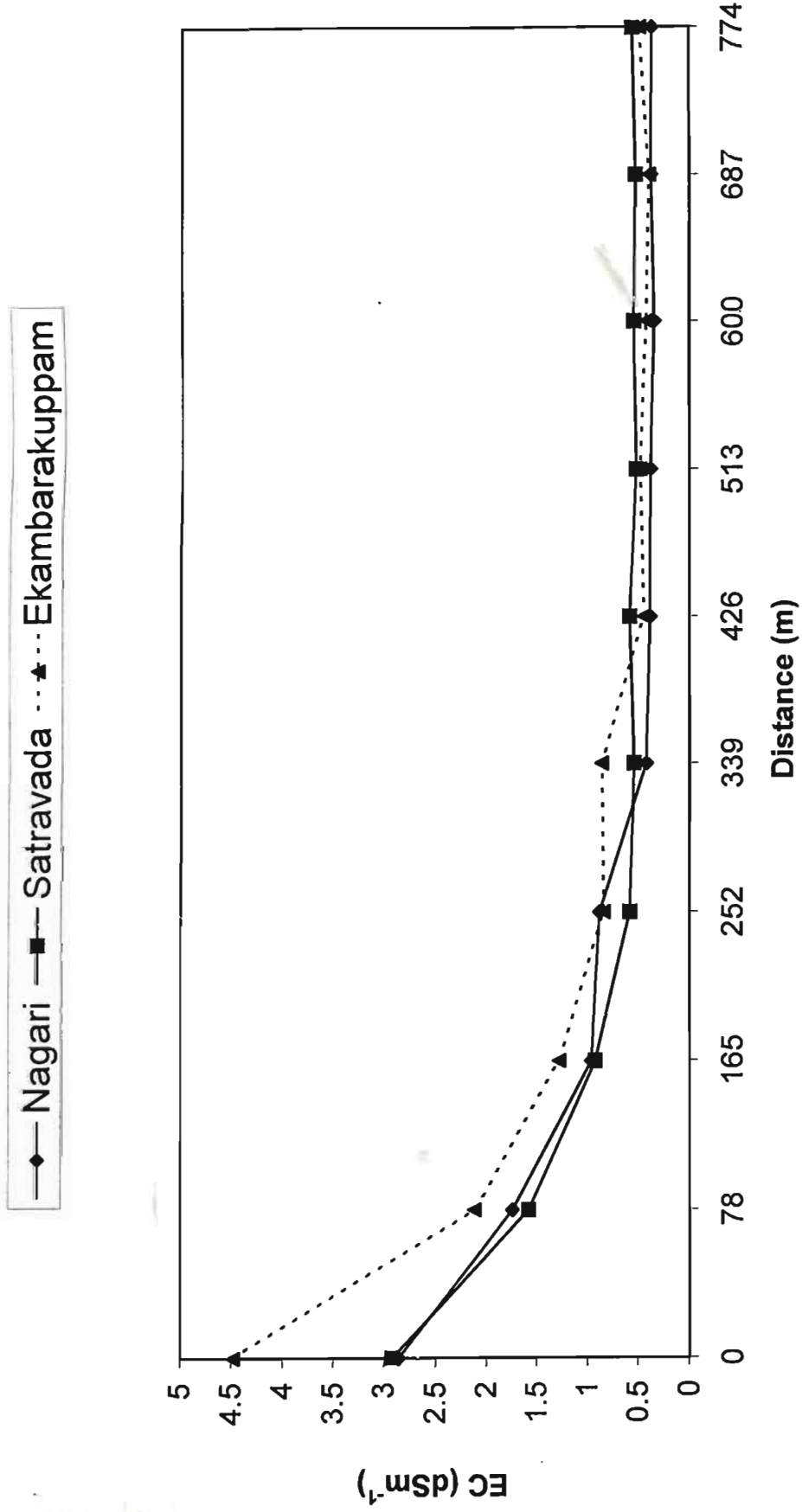


Fig 4: Influence of dyeing unit effluent on EC (dSm^{-1}) of ground water at different distances from the effluent stream

86 m distance, 0.92 to 2.92 dSm⁻¹ between 0 and 28 m distance and 0.42 to 2.86 dSm⁻¹ between 0 and 84 m distance at Ekambarakuppam, Satravada and Nagari respectively. The EC in general was higher in Ekambarakuppam in the immediate vicinity of the effluent stream followed by Satravada and Nagari. EC ranged from 0.34 to 2.86 dSm⁻¹, 0.52 to 2.92 dSm⁻¹ and 0.40 to 4.48 dSm⁻¹ at all the three locations studied. The adverse effects of EC of ground water continued up to 86 m in Ekambarakuppam, 28 m in Satravada and 52 m in Nagari. The EC of the ground water was not appreciably influenced beyond 86 m, 28 m and 52 m distance at Ekambarakuppam, Satravada and Nagari respectively.

4.2.3 Cationic Composition

The amount of cations in the ground water varied in the following order Na⁺>K> Ca⁺⁺> Mg⁺⁺ (Table 7, 9 & 11 and Fig. 5,6,7& 8).

4.2.3.1 Sodium (Na⁺)

The sodium content (Tab 7, 9 & 11 and Fig. 5) of ground water was varying in the order of Ekambarakuppam (2.42 to 29.0 cmol L⁻¹)> Satravada (4.1 to 22.8 cmol L⁻¹)> Nagari (2.1 to 21.6 cmol L⁻¹). The Na⁺ accumulation was continued up to 86 m (4.6 to 29.0 cmol L⁻¹), up to (6.4 to 22.8 cmol L⁻¹) and 52 m (6.4 to 2.6 cmol L⁻¹) at

—◆— Nagari —■— Satravada ···▲··· Ekambarakuppam

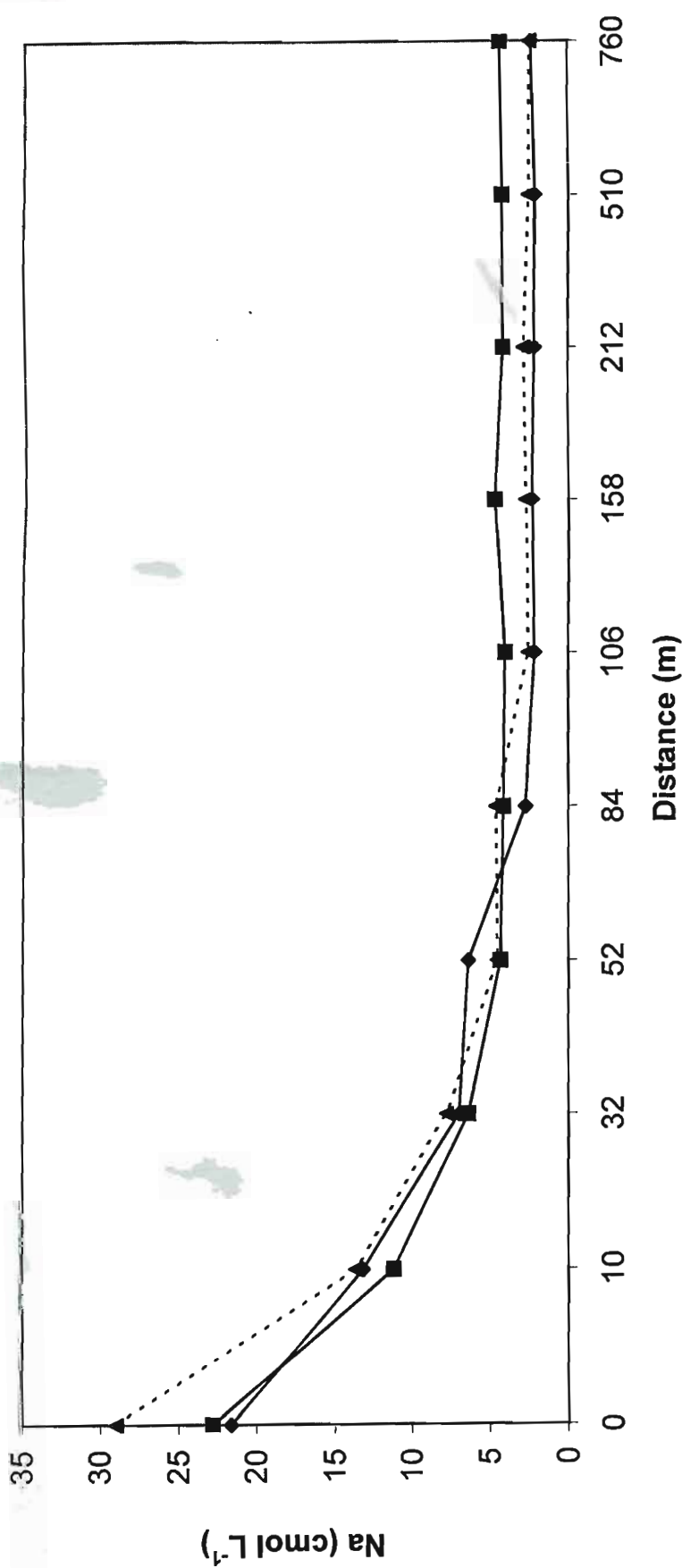


Fig 5: Influence of dyeing unit effluent on Na⁺ content of ground water at different distances from the effluent stream

Ekambarakuppam, Satravada and Nagari respectively. Beyond 86.0 m, 28.0 m, and 52.0 m distance, Na^+ content was not influenced due to effluent streams at Ekambarakuppam, Satravada and Nagari respectively.

4.2.3.2 Potassium (K^+)

The K^+ content in the ground water (Table 7, 9 & 11 and Fig.6) was varying in the order of Ekambarakuppam (0.5 to 3.8 cmol L^{-1}) > Satravada (0.4 to 2.1 cmol L^{-1}) > Nagari (0.2 to 2.0 cmol L^{-1}). The higher K content continued up to 86 m at Ekambarakuppam (0.7 to 3.8 cmol L^{-1}), up to 28 m distance at Satravada (0.5 to 0.9 cmol L^{-1}) and up to 58 m distance at Nagari (0.4 to 0.9 cmol L^{-1}). But the K^+ was almost identical beyond the earlier said distances.

4.2.3.3 Calcium (Ca^{++})

From the data presented in Table 7, 9 & 11 and depicted in Fig.7, it was noticed that the higher Ca^{++} content of groundwater continued up to 86 m at Ekambarakuppam, up to 28 m at Satravada and up to 32 m at Nagari. The Ca^{++} content of ground water varying in the order of Ekambarakuppam (0.8 to 4.6 cmol L^{-1}) > Nagari (0.5 to 1.9 cmol L^{-1}) > Satravada (0.4 to 1.8 cmol L^{-1}). The higher Ca^{++} content ranged

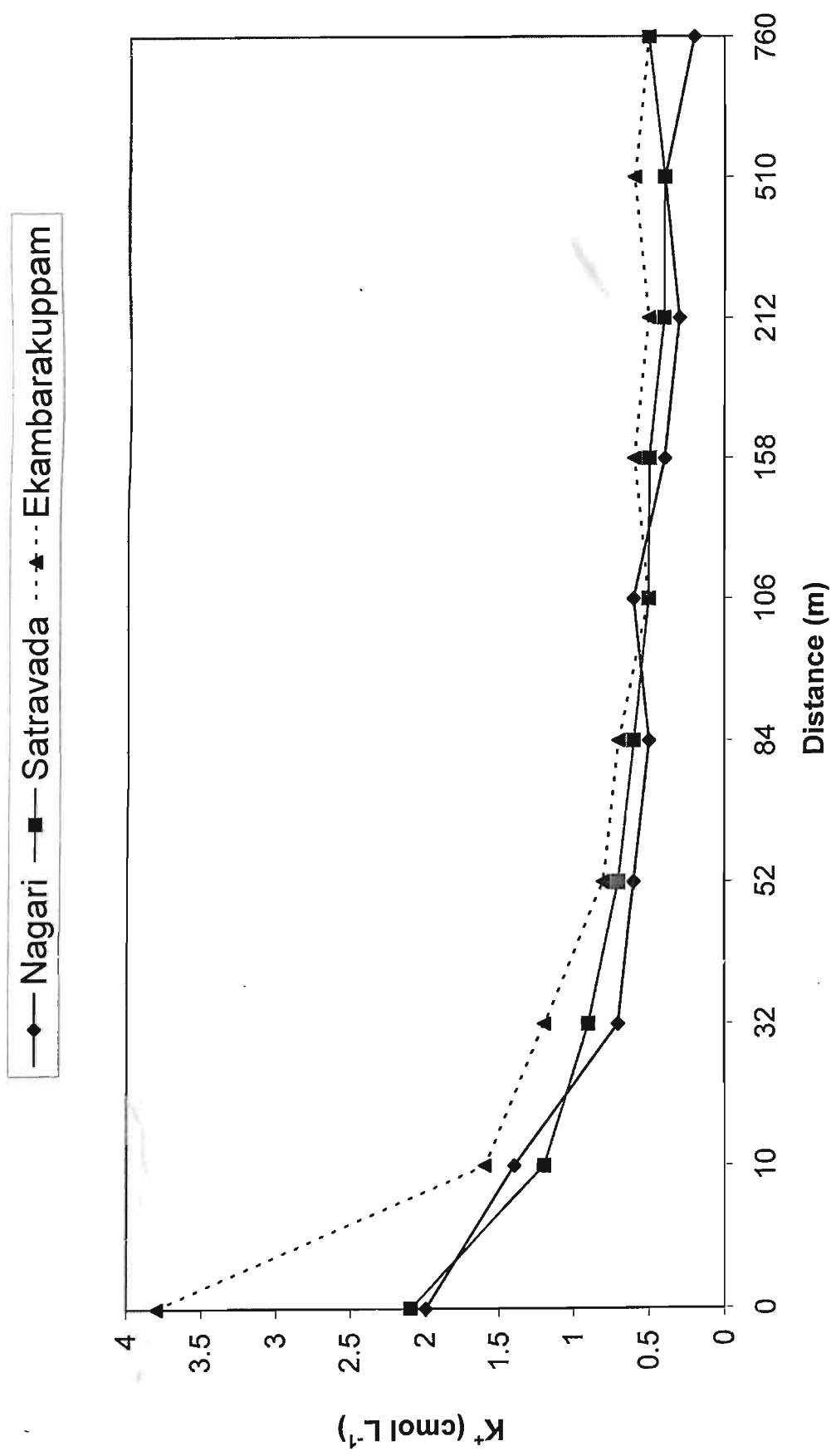


Fig 6: Influence of dyeing unit effluent on K⁺ content of ground water at different distances from the effluent stream

—◆— Nagari —■— Satravada ···▲··· Ekambarakuppam

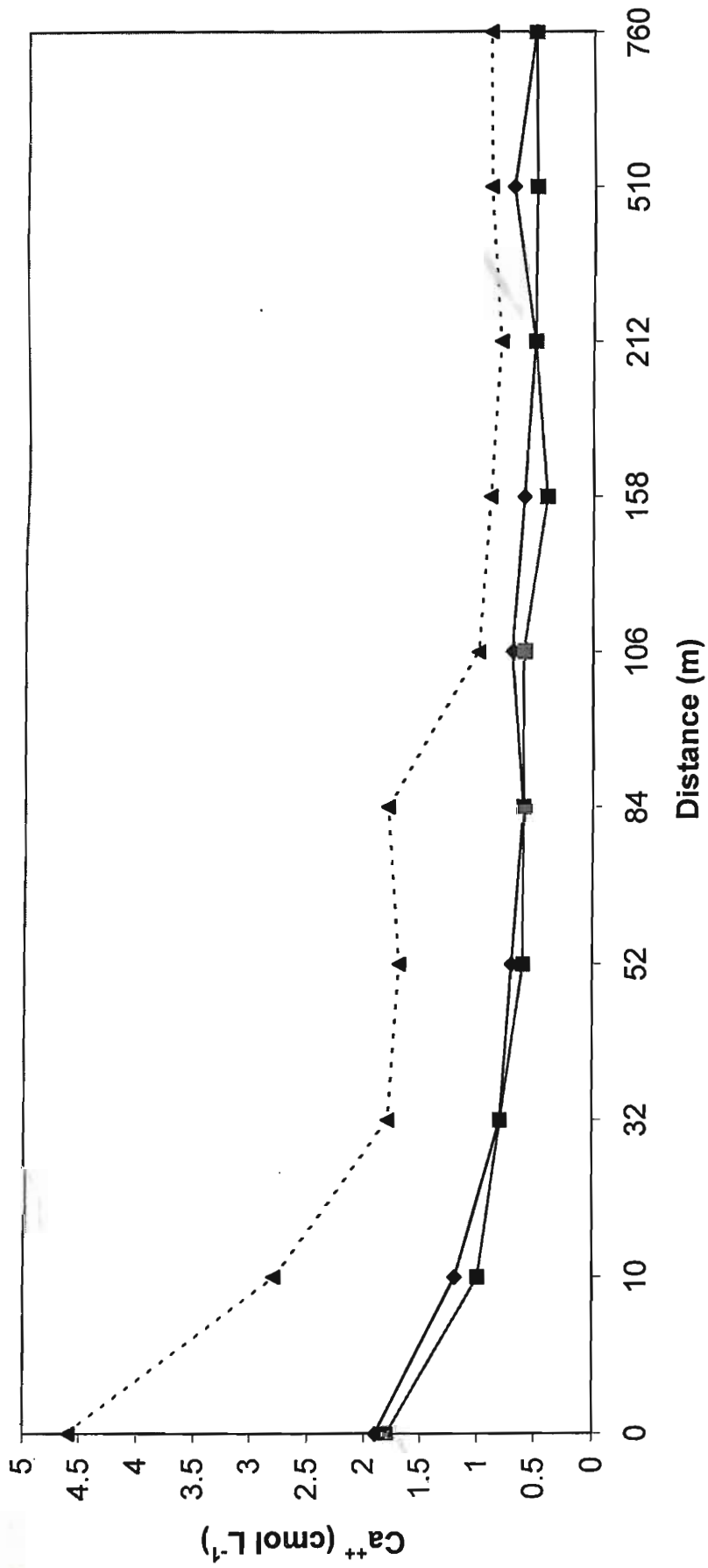


Fig 7: Influence of dyeing unit effluent on Ca⁺⁺ content of ground water at different distances from the effluent stream

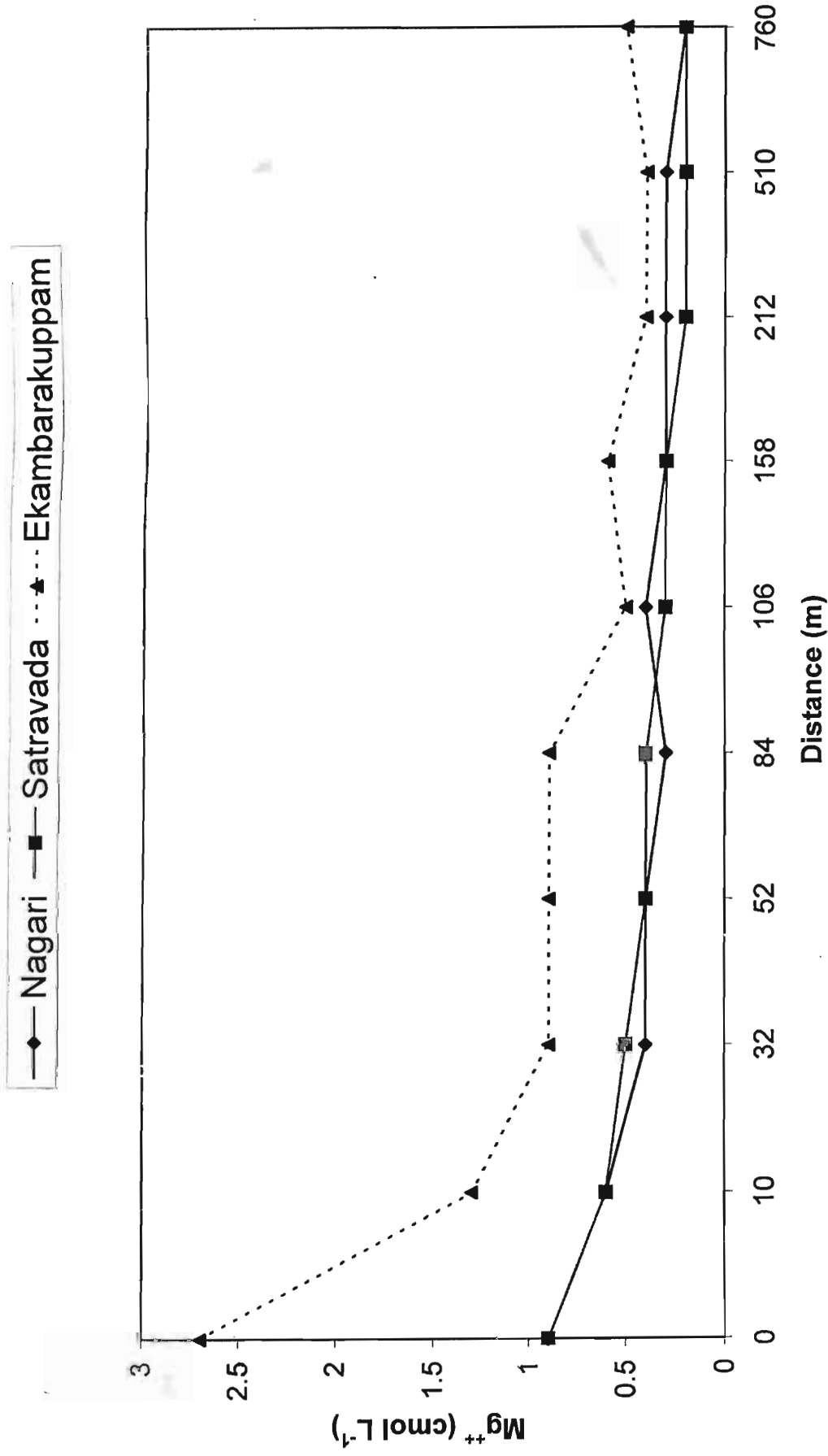


Fig 8: Influence of dyeing unit effluent on Mg⁺⁺ content of ground water at different distances from the effluent stream

between 1.8 and 4.6 cmol L^{-1} up to 86 m distance, 0.8 to 1.8 cmol L^{-1} up to 28 m distance and 0.8 to 1.9 cmol L^{-1} up to 32 m distance at Ekambarakuppam, Satravada and Nagari respectively as compared to other distances. Presence of higher range of Ca^{++} of ground water in the immediate vicinity of the effluent stream as compared to farther distance was closed to the Ca^{++} present in the effluent at all the three locations studied.

4.2.3.4 Magnesium (Mg^{++})

From the data presented in Table 7, 9 11 and depicted in Fig. 8. it was noticed that the Mg^{++} content was higher in the immediate neighborhood of the effluent stream and was less faraway from the effluent stream. The Mg^{++} content in ground water was varying in the order of Ekambarakuppam (0.42 to 2.7 cmol L^{-1}) > Satravada (0.22 to 0.90 cmol L^{-1}) > Nagari (0.22 to 0.90 cmol L^{-1}). The higher Mg^{++} content continued up to 86 m at Ekambarakuppam (0.90 to 2.7 cmol L^{-1}), up to 28 m distance (0.5 to 0.9 cmol L^{-1}) at Satravada and up to 52 m distance (0.4 to 0.9 cmol L^{-1}) at Nagari.

The Mg^{++} was not influenced beyond 86 m distance, 28 m distance and 52 m distance at Ekambarakuppam, Satravada and Nagari respectively due to effluent streams.

4.2.4 Anionic Composition

The amount of anions in ground water varied in following order of $\text{Cl}^- > \text{HCO}_3^- > \text{CO}_3^{2-} > \text{SO}_4^{2-}$.

4.2.4.1 Chlorides (Cl^-)

From the data presented in Table (7,9 & 11) and illustrated in Fig. 9. It was noticed that the chloride content of ground water at all the three locations studied was varying in the order of Ekambarakuppam (1.4 to 25.3 cmol L^{-1}) > Satravada (2.4 to 21.4 cmol L^{-1}) > and in Nagari (1.5 to 19.8 cmol L^{-1}). In general, the chloride content in the neighborhood of the stream was many times more compared to far away places. The higher chloride content in the ground water continued up to 86 m at Ekambarakuppam (3.8 to 25.3 cmol L^{-1}), up to 28 m at Satravada (4.7 to 21.4 cmol L^{-1}) and up to 52 m at Nagari (5.3 to 19.8 cmol L^{-1}). Beyond these distances, the chloride content did not vary much during study period.

4.2.4.2 Sulphates (SO_4^{2-})

From data presented in Table 7,9 & 11 and depicted in Fig. 10, the SO_4^{2-} content of ground water was varying in the order of Ekambarakuppam (0.2 to 4.8 cmol L^{-1}) > Satravada (0.4 to 1.4 cmol L^{-1}) > Nagari (0.2 to 0.9 cmol L^{-1}). In general, the higher SO_4^{2-}

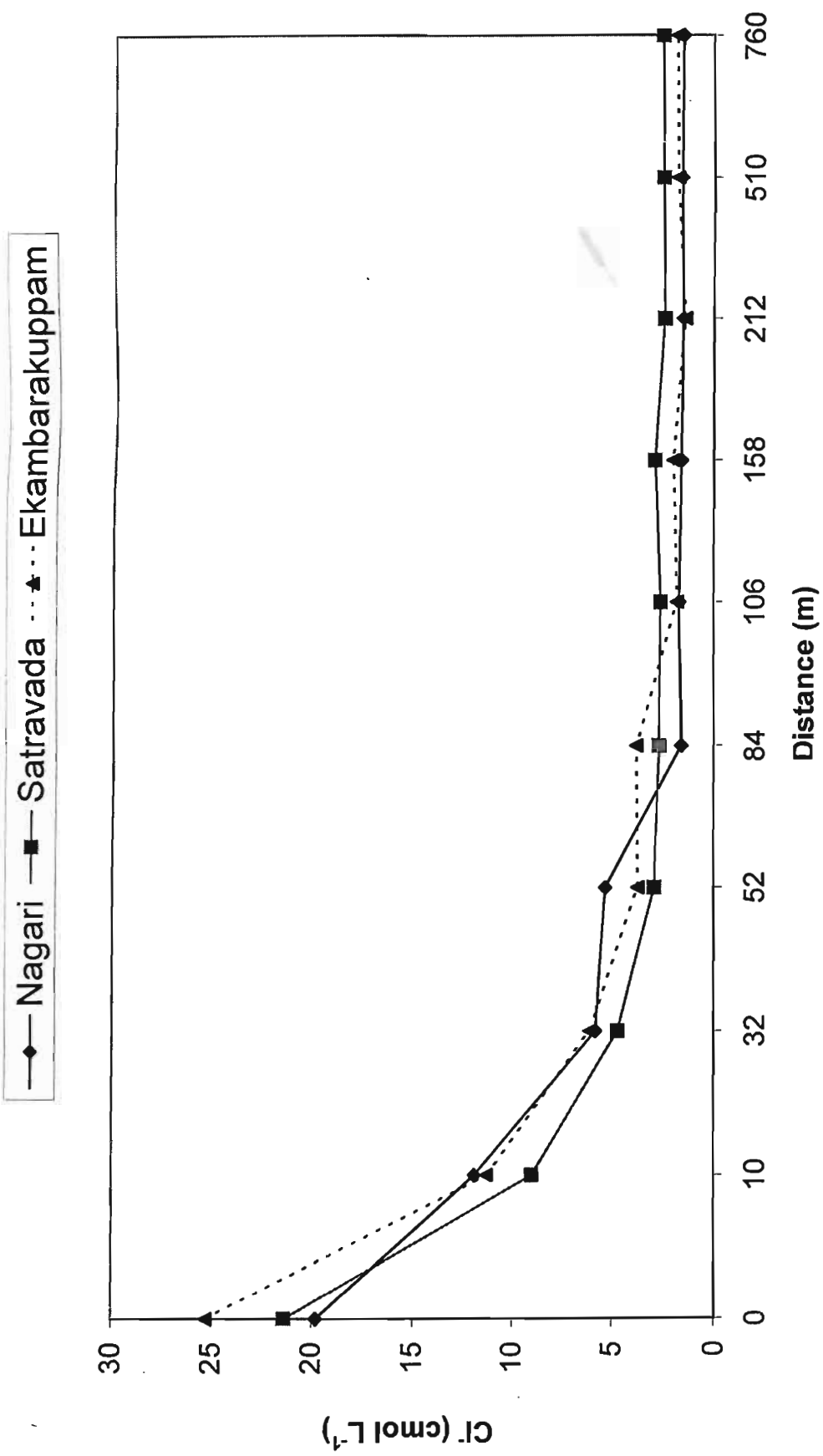


Fig 9: Influence of dyeing unit effluent on Cl⁻ content of ground water at different distances from the effluent stream

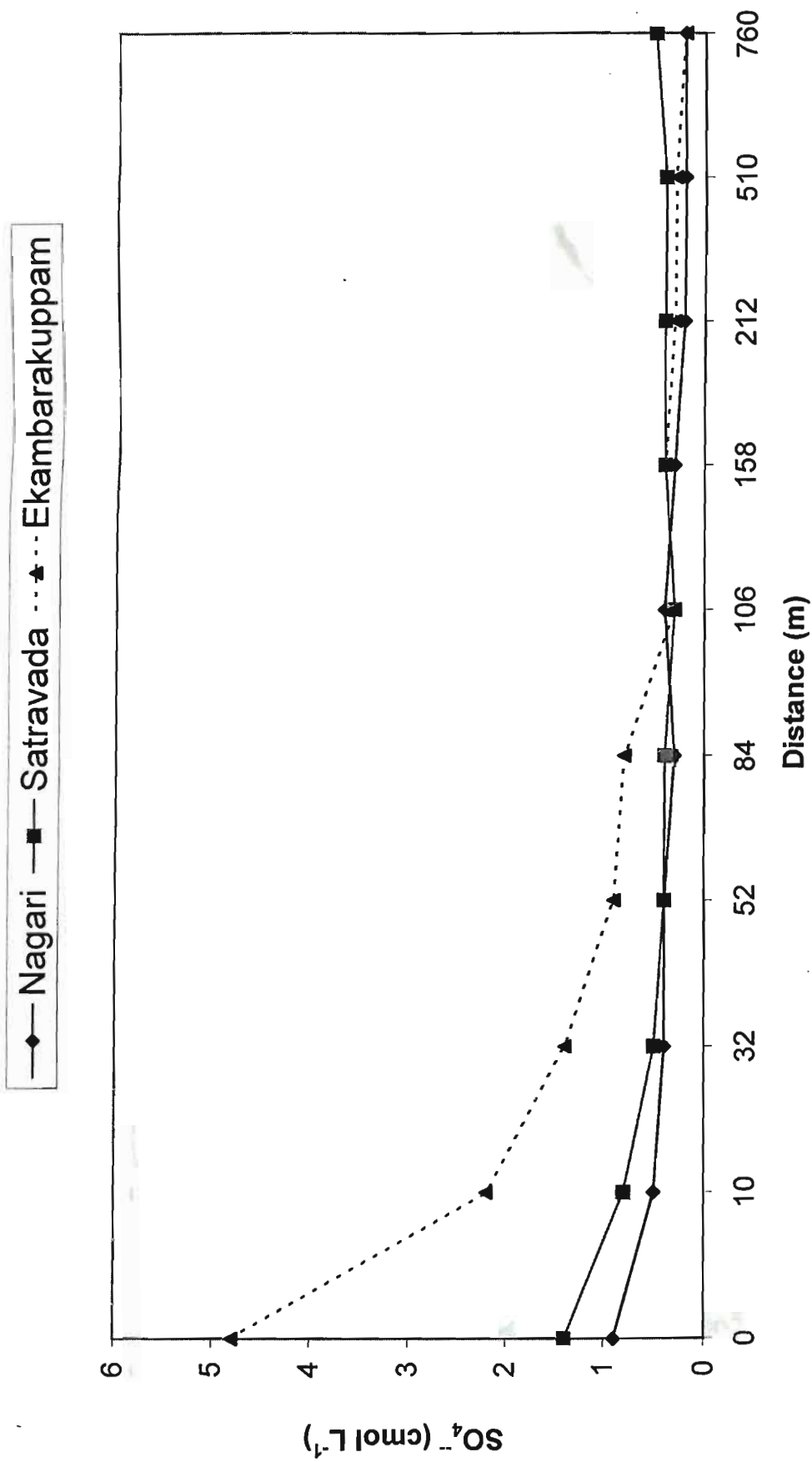


Fig 10: Influence of dyeing unit effluents on SO₄²⁻ content of ground water at different distances from the stream

content of ground water was noticed in the immediate vicinity of the stream as compared to other distances at all the three locations studied. The higher SO_4^- content in ground water continued up to 86 m at Ekambarakuppam (0.8 to 4.8 cmol L^{-1}), up to 28 m distance at Satravada (0.5 to 1.4 cmol L^{-1}) and up to 10 m distance at Nagari (0.5 to 0.9 cmol L^{-1}). Beyond these distances, identical values were obtained at all the three locations.

4.2.4.3 Carbonates (CO_3^-)

From data presented in Table 7,9 & 11 and depicted in Fig. 11, The accumulation of carbonates were slightly higher in the immediate vicinity of effluent streams as compared to farther distances. The carbonates content of ground water was varying in the order of Ekambarakuppam (0.4 to 1.1 cmol L^{-1})> Satravada (0.6 to 1.0 cmol L^{-1})> and Nagari (6.9 to 1.9 cmol L^{-1}).

4.2.4.4 Bicarbonates (HCO_3^-)

From data presented in Table 7,9 & 11 and depicted in Fig. 12, The bicarbonates content of ground water was varying in the order of Ekambarakuppam (1.4 to 6.4 cmol L^{-1})> Satravada (1.8 to 3.9 cmol L^{-1})> Nagari (0.9 to 4.9 cmol L^{-1}). Higher bicarbonate content

—◆— Nagari —■— Satravada ···▲··· Ekambarakuppam

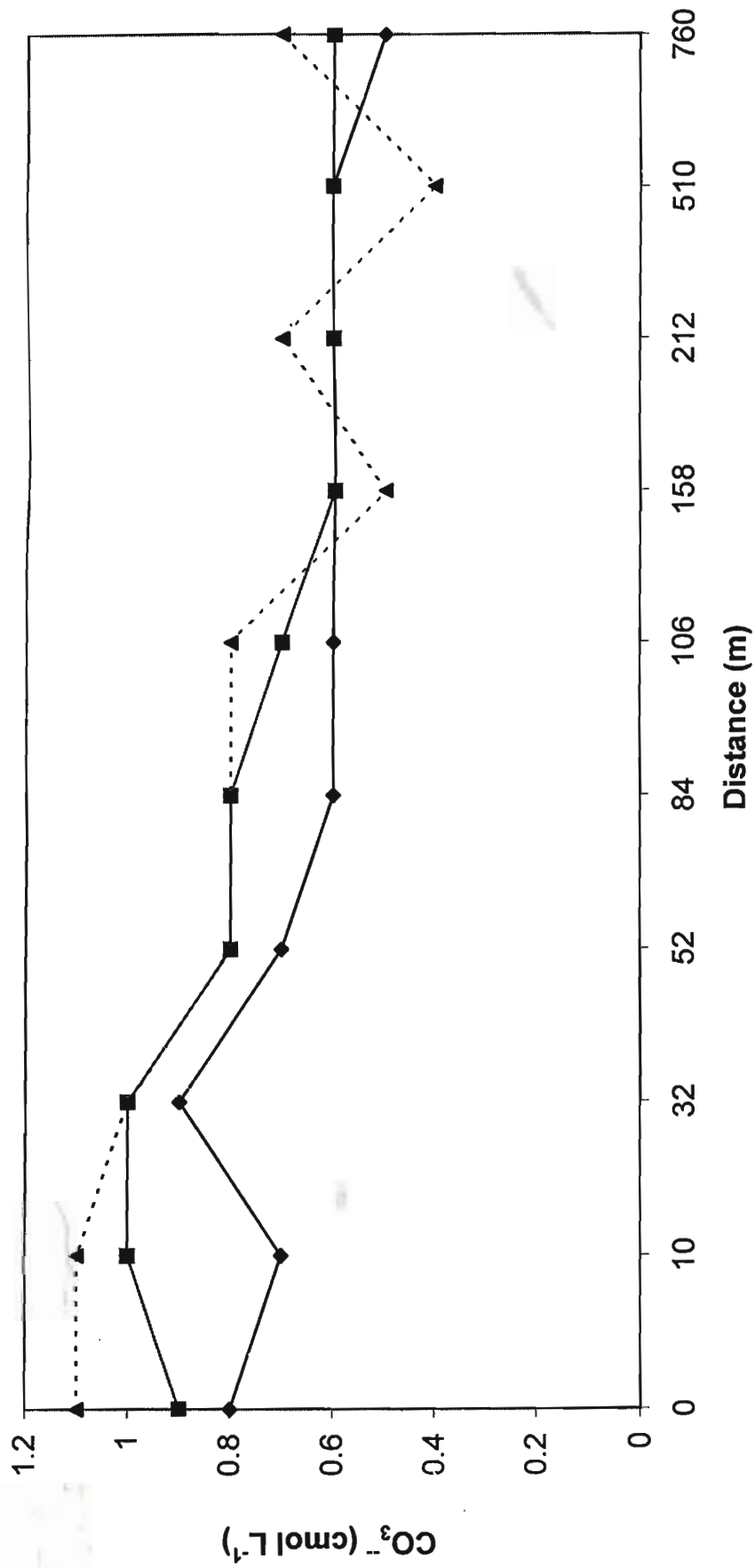


Fig 11: Influence of dyeing unit effluent on CO₃²⁻ content of ground water at different distances from the effluent stream

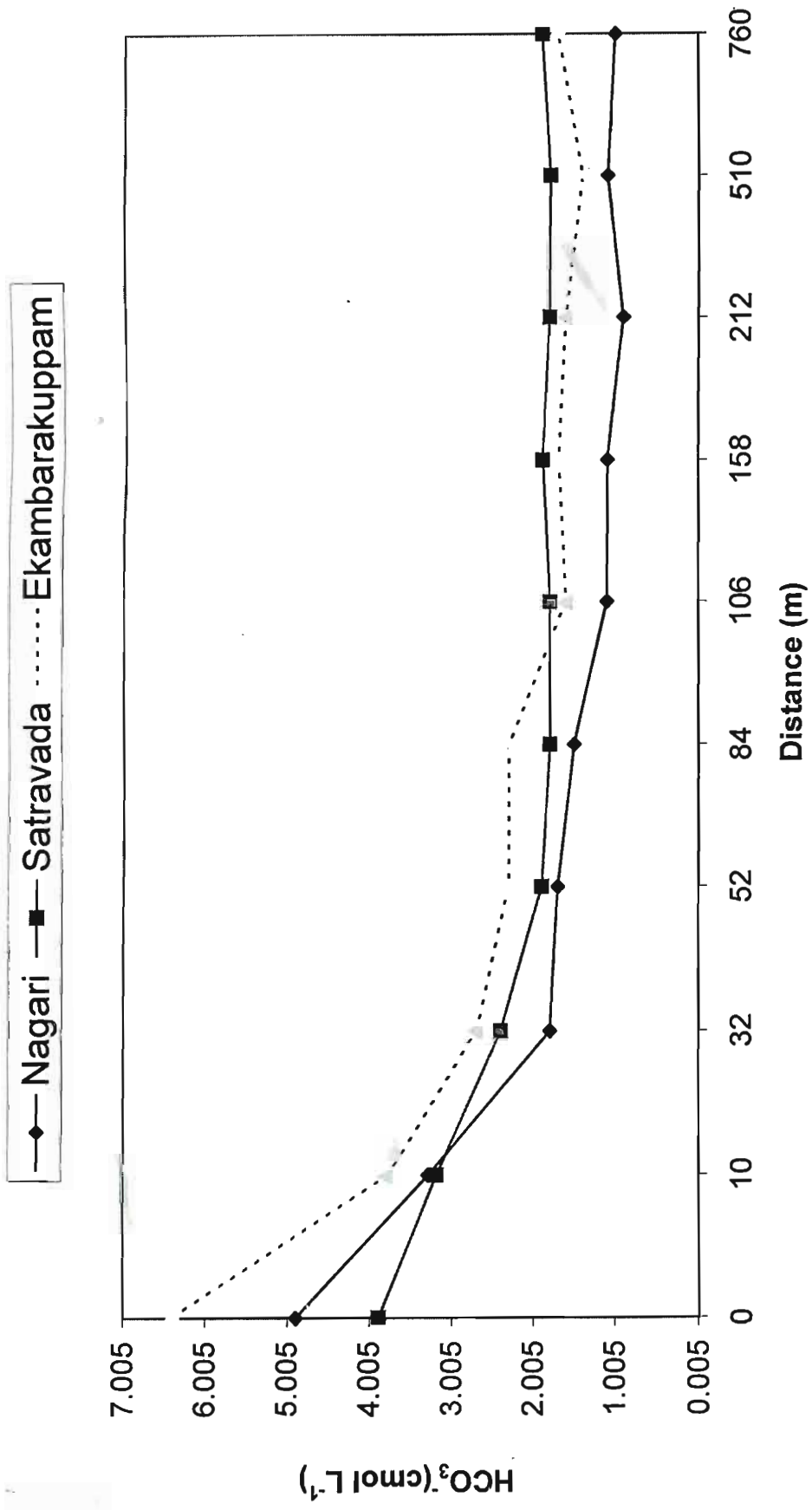


Fig 12: Influence of dyeing unit effluent on HCO_3^- (cmol L^{-1}) content of ground water at different distances from the effluent stream

continued up to 86 m at Ekambarakuppam (2.3 to 6.4 cmol L^{-1}), up to 28 m at Satravada (2.4 to 3.9 cmol L^{-1}) and upto 84 m distance at Nagari (1.5 to 4.9 cmol L^{-1}). Beyond these distances, the potassium was not influenced due to effluent streams at all the three locations studied.

4.2.5 Heavy Metals

From the data presented in Table 8, 10 & 12 and depicted in Fig. 13, 14, 15 & 16, it was noticed that the heavy metals like Cd, Pd, Ni and Cr were not influenced due to effluent streams at all the three locations studied.

4.2.5.1 Cadmium (Cd)

From the data presented in Table 8, 10 & 12 and depicted in Fig. 13, it was noticed that the range of Cd content of ground water was generally higher at Nagari (0.180 to 0.023 mg L^{-1}) followed by Ekambarakuppam (0.018 to 0.022 mg L^{-1}) and Satravada (0.018 to 0.021 mg L^{-1}). Its content did not vary due to the effluent streams at all the three locations studied.

Table 8: Influence of dyeing effluent on DTPA extractable micronutrients and heavy metals in ground water (mg L⁻¹) at Nagari

Distance (m)	Heavy metals (mg L ⁻¹)					Micronutrients (mg L ⁻¹)				
	Cd	Pb	Cr	Ni	Zn	Cu	Mn	Fe		
0	0.023	0.108	0.190	0.116	0.052	0.030	Tr	0.202		
10	0.023	0.107	0.198	0.119	0.018	0.030	Tr	0.138		
32	0.020	0.103	0.204	0.118	0.012	0.020	Tr	0.102		
52	0.022	0.112	0.198	0.112	0.007	0.020	Tr	0.096		
84	0.022	0.108	0.194	0.110	0.009	0.020	Tr	0.082		
106	0.020	0.109	0.196	0.112	0.009	0.020	Tr	0.066		
158	0.020	0.110	0.198	0.113	0.009	0.020	Tr	0.082		
212	0.018	0.108	0.198	0.112	0.008	0.010	Tr	0.074		
510	0.019	0.108	0.196	0.112	0.008	0.010	Tr	0.076		
760	0.022	0.109	0.198	0.112	0.009	0.010	Tr	0.074		

Table 10: Influence of dyeing effluent on DTPA extractable micronutrients and heavy metals in ground water (mg L⁻¹) at Satravada

Distance (m)	Heavy metals (mg L ⁻¹)					Micronutrients (mg L ⁻¹)				
	Cd	Pb	Cr	Ni		Zn	Cu	Mn	Fe	
0	0.021	0.090	0.278	0.120		0.072	0.114	Tr	0.311	
14	0.022	0.089	0.274	0.116		0.064	0.098	Tr	0.262	
28	0.019	0.089	0.276	0.124		0.054	0.036	Tr	0.079	
45	0.020	0.088	0.274	0.118		0.034	0.042	Tr	0.072	
78	0.021	0.088	0.278	0.119		0.022	0.022	Tr	0.078	
105	0.020	0.084	0.274	0.112		0.022	0.034	Tr	0.094	
158	0.022	0.086	0.274	0.120		0.020	0.054	Tr	0.090	
205	0.020	0.087	0.276	0.128		0.021	0.026	Tr	0.082	
490	0.018	0.086	0.276	0.120		0.021	0.024	Tr	0.082	
760	0.019	0.086	0.278	0.118		0.025	0.022	Tr	0.088	

Table 12: Influence of dyeing effluent on DTPA extractable micronutrients and heavy metals in ground water (mg L^{-1}) at Ekambarakuppam

Distance (m)	Heavy metals (mg L^{-1})				Micronutrients (mg L^{-1})				
	Cd	Pb	Cr	Ni	Zn	Cu	Mn	Fe	
0	0.020	0.145	0.307	0.133	0.082	0.121	Tr	0.342	
12	0.022	0.144	0.309	0.134	0.080	0.106	Tr	0.291	
32	0.020	0.138	0.308	0.138	0.024	0.044	Tr	0.242	
54	0.022	0.140	0.308	0.138	0.016	0.042	Tr	0.068	
86	0.019	0.142	0.304	0.132	0.014	0.028	Tr	0.062	
110	0.018	0.148	0.306	0.134	0.015	0.032	Tr	0.074	
164	0.018	0.140	0.306	0.130	0.012	0.036	Tr	0.064	
210	0.020	0.142	0.308	0.134	0.012	0.024	Tr	0.062	
512	0.022	0.142	0.305	0.139	0.012	0.030	Tr	0.062	
780	0.022	0.140	0.306	0.130	0.014	0.022	Tr	0.058	

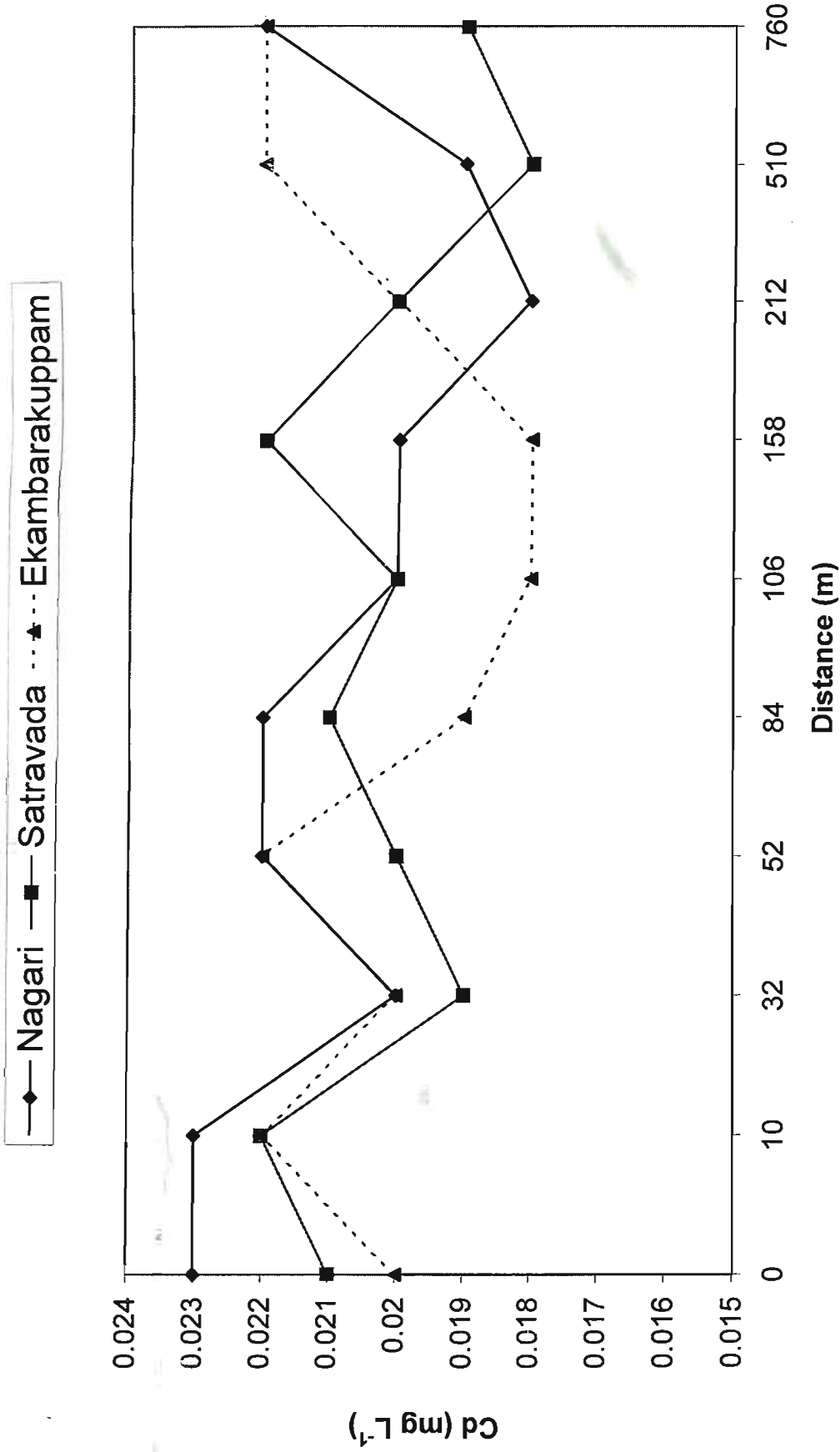


Fig 13: Influence of dyeing unit effluent on Cd (mg L⁻¹) content of ground water at different distances from the effluent stream

4.2.5.2 Lead (Pb)

From the data presented in Table 8, 10 & 12 and depicted in Fig. 14, it was noticed that the Pb content of ground water was in the order of Ekambarakuppam (0.140 to 0.148 mg L⁻¹) > Nagari (0.103 to 0.112 mg L⁻¹) > Satravada (0.084 to 0.090 mg L⁻¹). The effluent streams did not influenced the Pb in the ground water at all the three locations studied.

4.2.5.3 Cromium (Cr)

From the data presented in Table 8, 10 & 12 and depicted in Fig. 15, it was noticed that the cromium content of ground water was generally higher in Ekambarakuppam (0.304 to 0.309 mg L⁻¹) as compared to the ground water at Satravada (0.274 to 0.278 mg L⁻¹) and Nagari (0.194 to 0.204 mg L⁻¹). The Cr content was identical between distances at all the three locations studied.

4.2.5.4 Nickle (Ni)

From the data presented in Table 8, 10 & 12 and depicted in Fig. 16, it was noticed that the Ni content of ground water was generally higher at Ekambarakuppam (0.130 to 0.138 mg L⁻¹) followed by Satravada (0.112 to 0.128 mg L⁻¹) and Nagari (0.110 to 0.119 mg L⁻¹). From the identical values obtained between distances Ekambarakuppam, Satravada and Nagari, it was known that Ni was not influenced due to effluent streams.

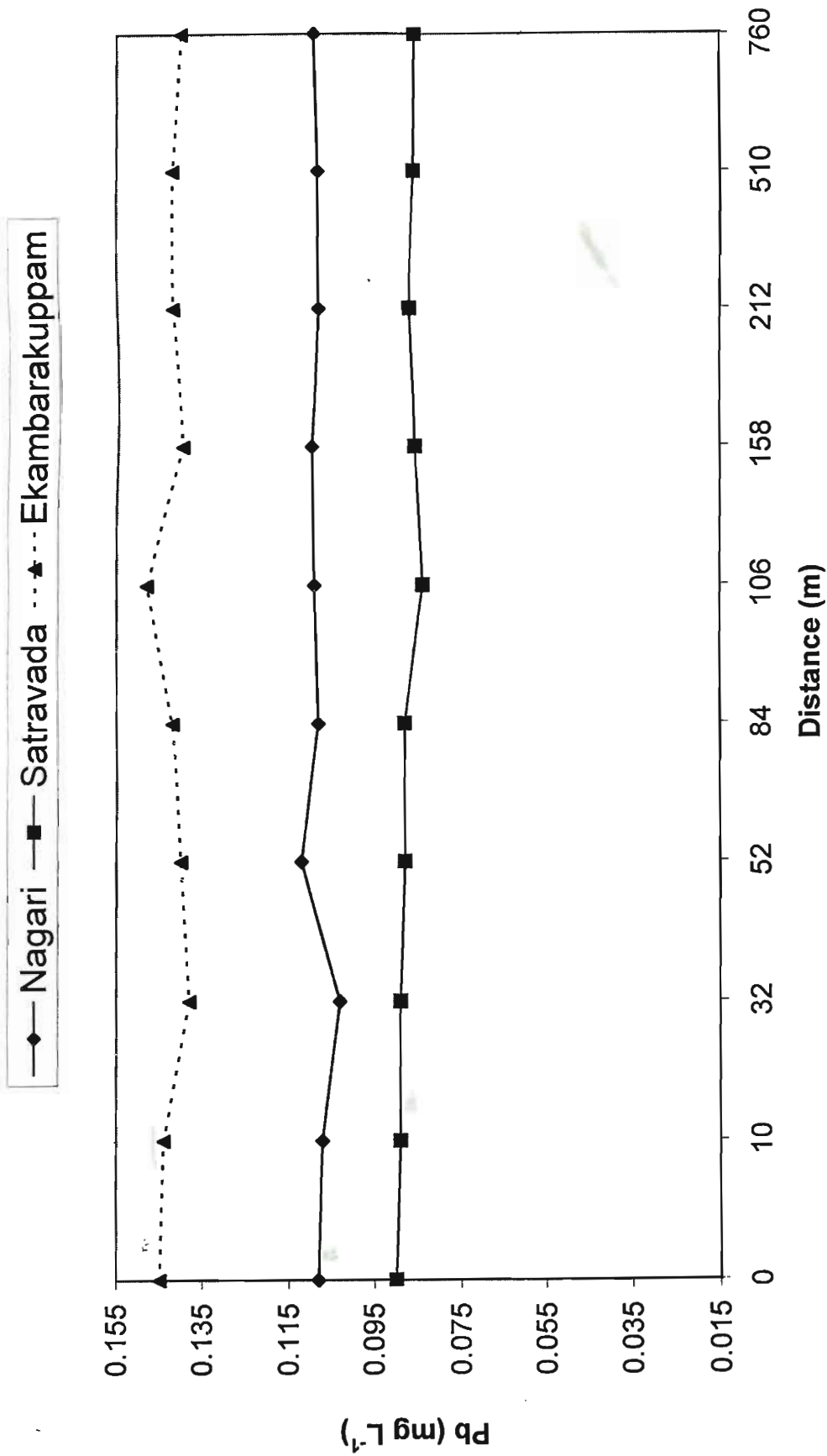


Fig 14: Influence of dyeing unit effluent on Pb (mg L⁻¹) content of ground water at different distances from the effluent stream

—◆— Nagari —■— Satravada ···▲··· Ekambarakuppam

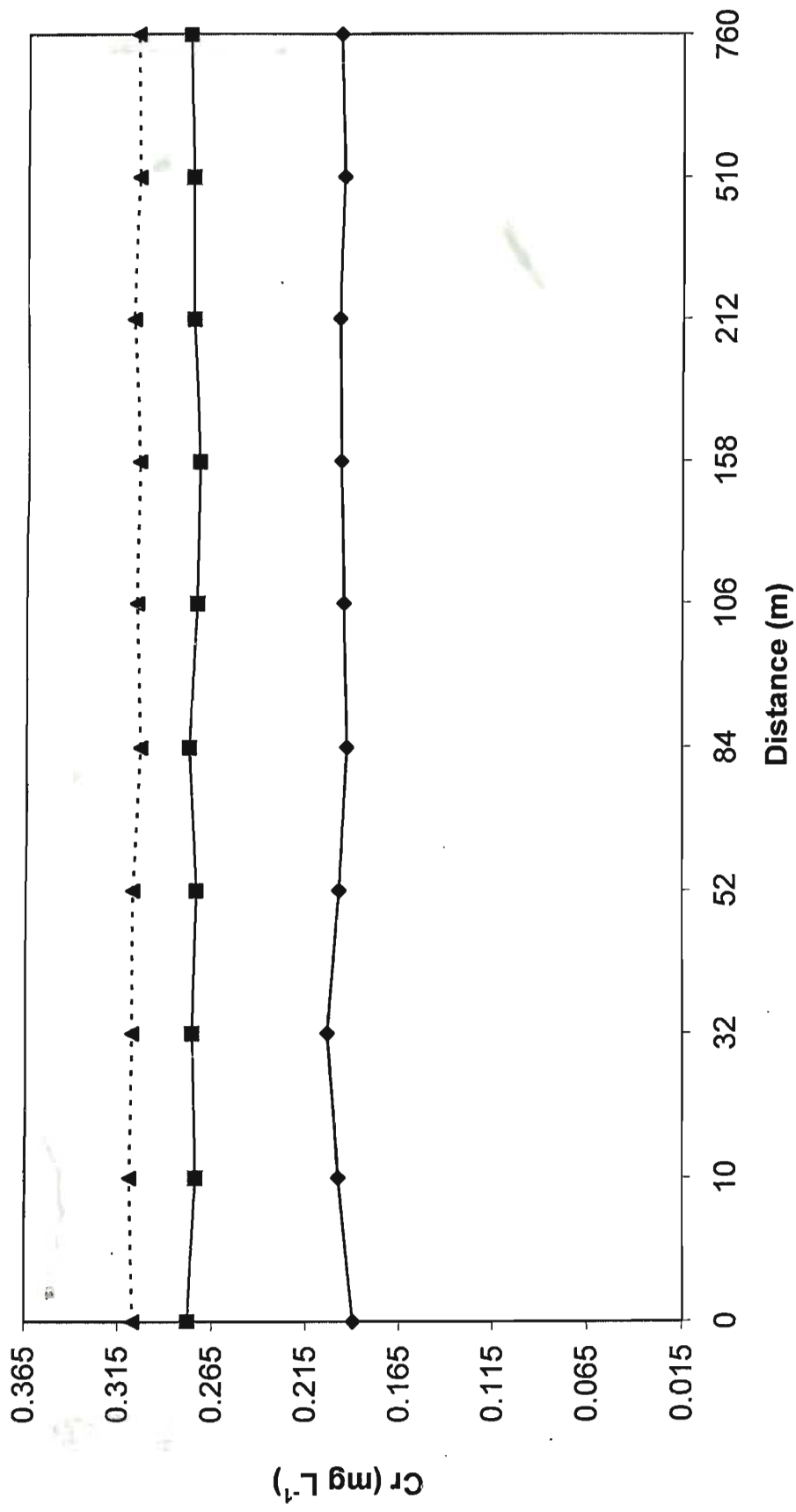


Fig 15: Influence of dyeing unit effluent on Cr(mg L⁻¹) content of ground water at different distances from the effluent stream

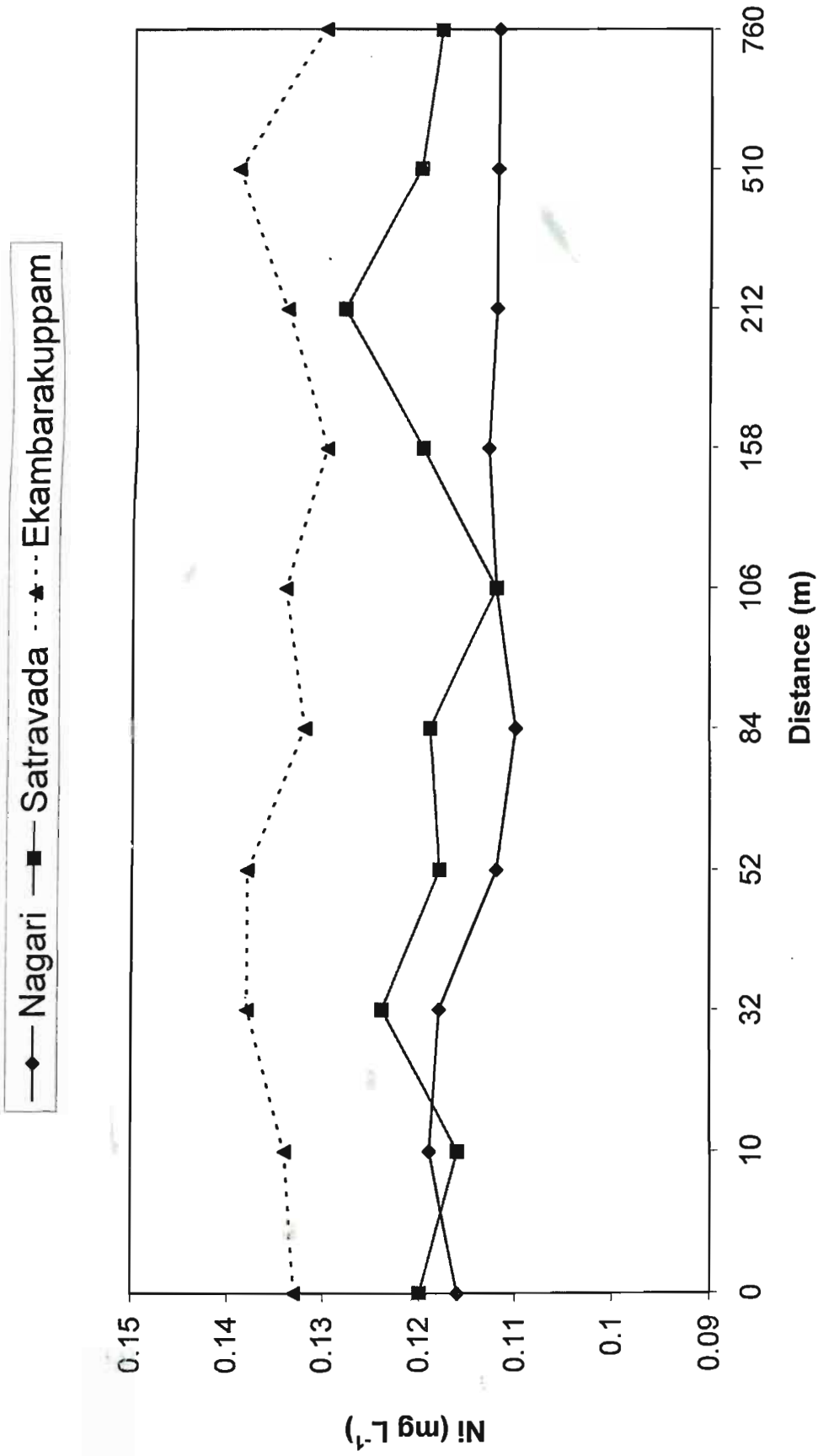


Fig 16: Influence of dyeing unit effluent on Ni(mg L⁻¹) content of ground water at different distances from the effluent stream

4.2.6 Micronutrients

From the data presented in Table 8,10 & 12 and depicted in Fig. 16, 17 & 18, it was noticed that all the micronutrients except Mn were accumulated more as compared to farther distances at the three locations studied. Thereby indicating that dyeing unit effluent was the potential source of micronutrients for contaminating the ground water.

4.2.6.1 Zinc (Zn)

From the data presented in Table 8,10 & 12 and illustrated in Fig. 17, it was noticed that Zn was higher at Ekambarakuppam (0.012 to 0.082 mg L⁻¹), followed by Satravada (0.020 to 0.072 mg L⁻¹) and Nagari (0.007 to 0.052 mg L⁻¹).

In general accumulation of Zn was generally higher in the immediate vicinity of stream as compared to that of farther distances at all three locations studied. The higher Zn content continued up to 54m, 45m and 35m distances from the effluent stream at Ekambarakuppam (0.082 to 0.016 mg L⁻¹), Satravada (0.072 to 0.034 mg L⁻¹), Nagari (0.012 to 0.052 mg L⁻¹). Beyond 54m distance at Ekambarakuppam, 45m at Satravada and 32m at Nagari, the identical Zn values were obtained.

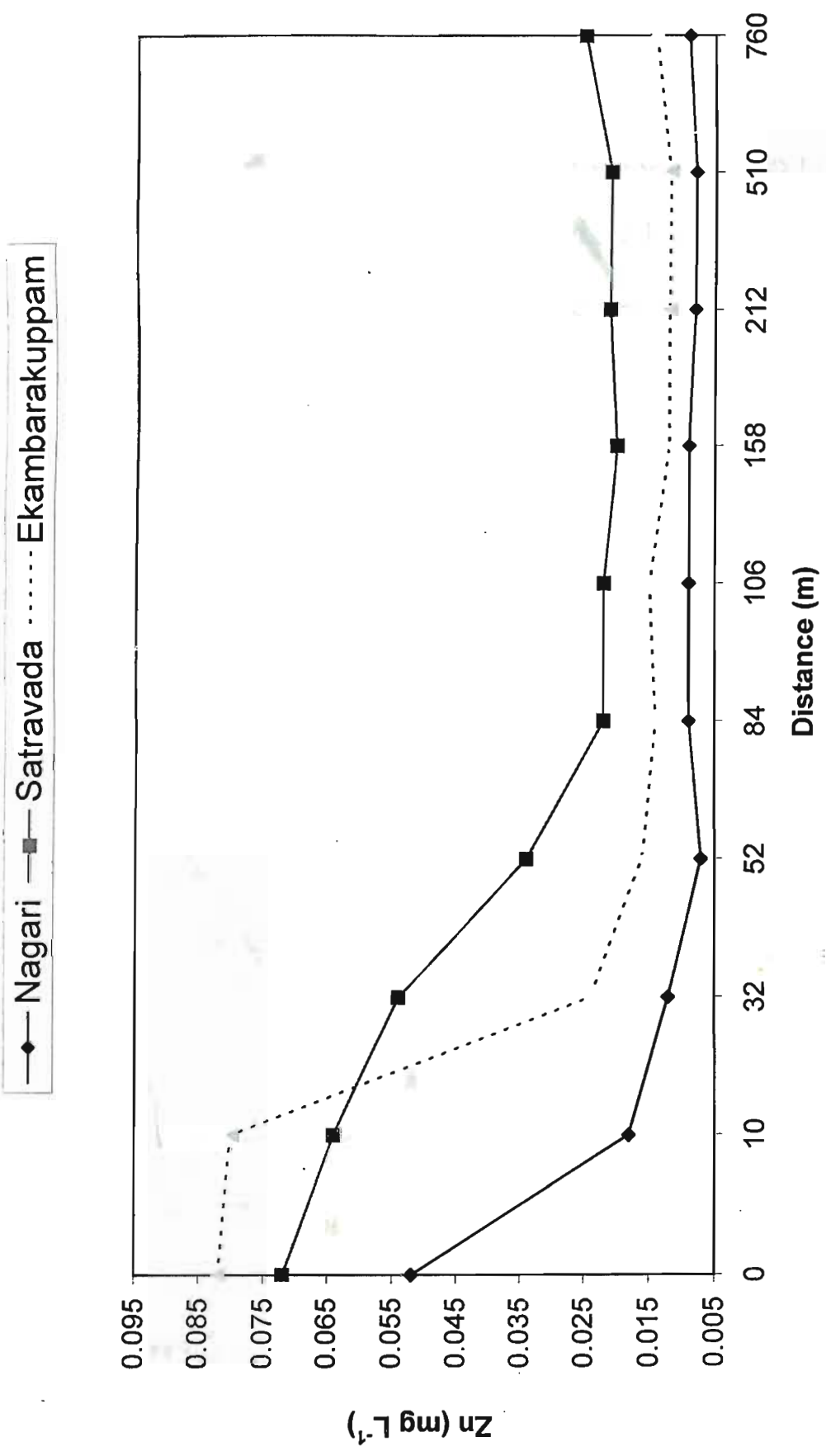


Fig 17: Influence of dyeing unit effluent on Zn(mg L⁻¹) content of ground water at different distances from the effluent stream

4.2.6.2 Copper (Cu)

From the data presented in Table 8, 10 & 12 and illustrated in Fig. 18, it was noticed that copper content of ground water was higher in the neighborhood of the effluent stream at all three locations studied and generally decreased with increasing distance up to 32m distance at Ekambarakuppam (0.121 to 0.044 mg L⁻¹) upto 45 m distance at Satravada (0.114 to 0.042 mg L⁻¹) and upto 10 m distance at Nagari (0.03 mg L⁻¹). The copper content was almost identical beyond 32 m, 45 m and 10 m distance from the effluent streams at Ekambarakuppam, Satravada and Nagari respectively.

4.2.6.3 Manganese (Mn)

From data presented in Table 8, 10 & 12, the Mn content of ground water was in traces at Ekambarakuppam, Satravada and Nagari.

4.2.6.4 Iron (Fe)

From the data presented in Table 8, 10, 12 and illustrated in Fig. 19. It was noticed that Fe was generally higher at Ekambarakuppam (0.058 to 0.34 mg L⁻¹), followed by Satravada (0.072 to 0.311 mg L⁻¹) and at Nagari (0.066 to 0.202 mg L⁻¹).

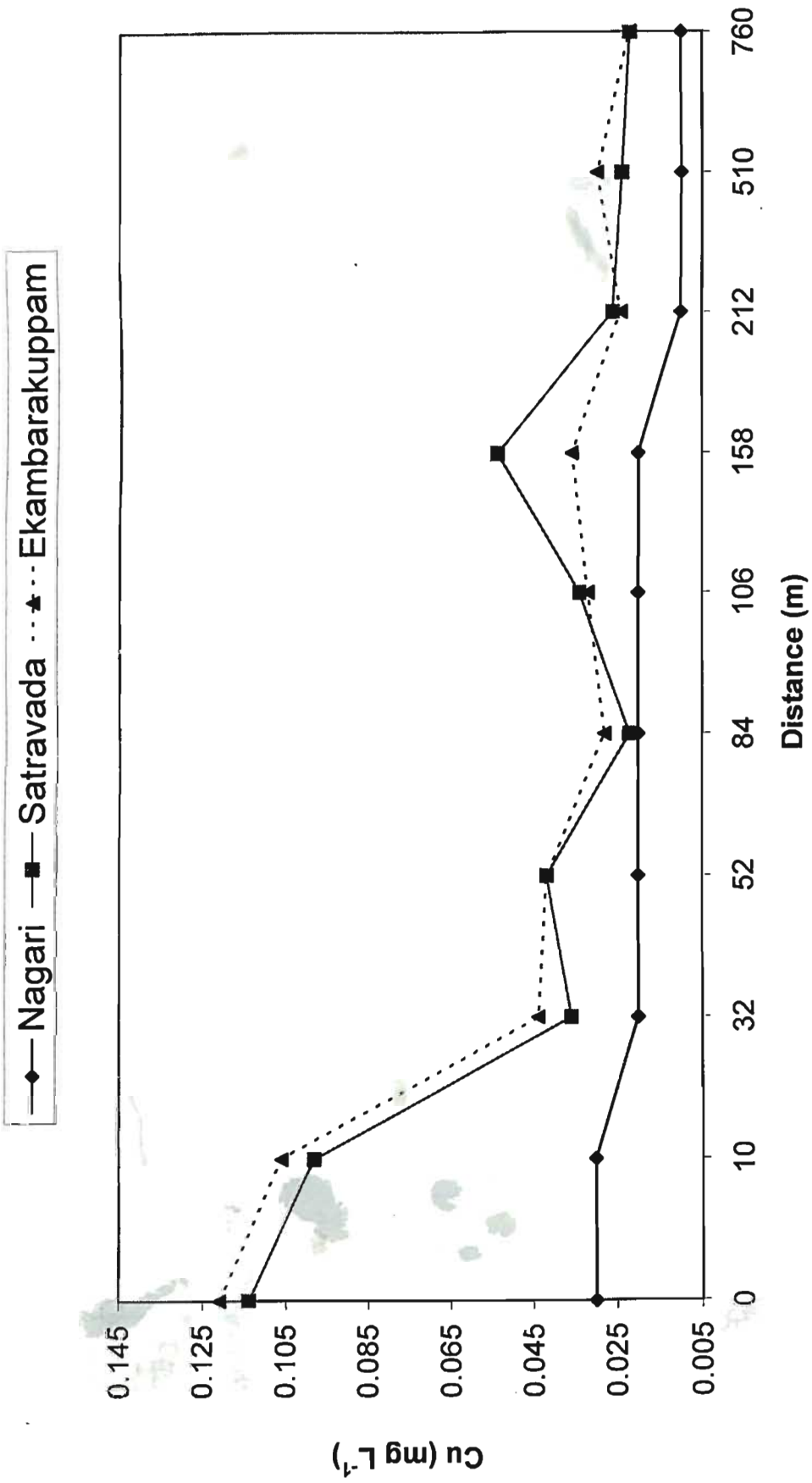


Fig 18: Influence of dyeing unit effluent on Cu(mg L⁻¹) content of ground water at different distances from the effluent stream

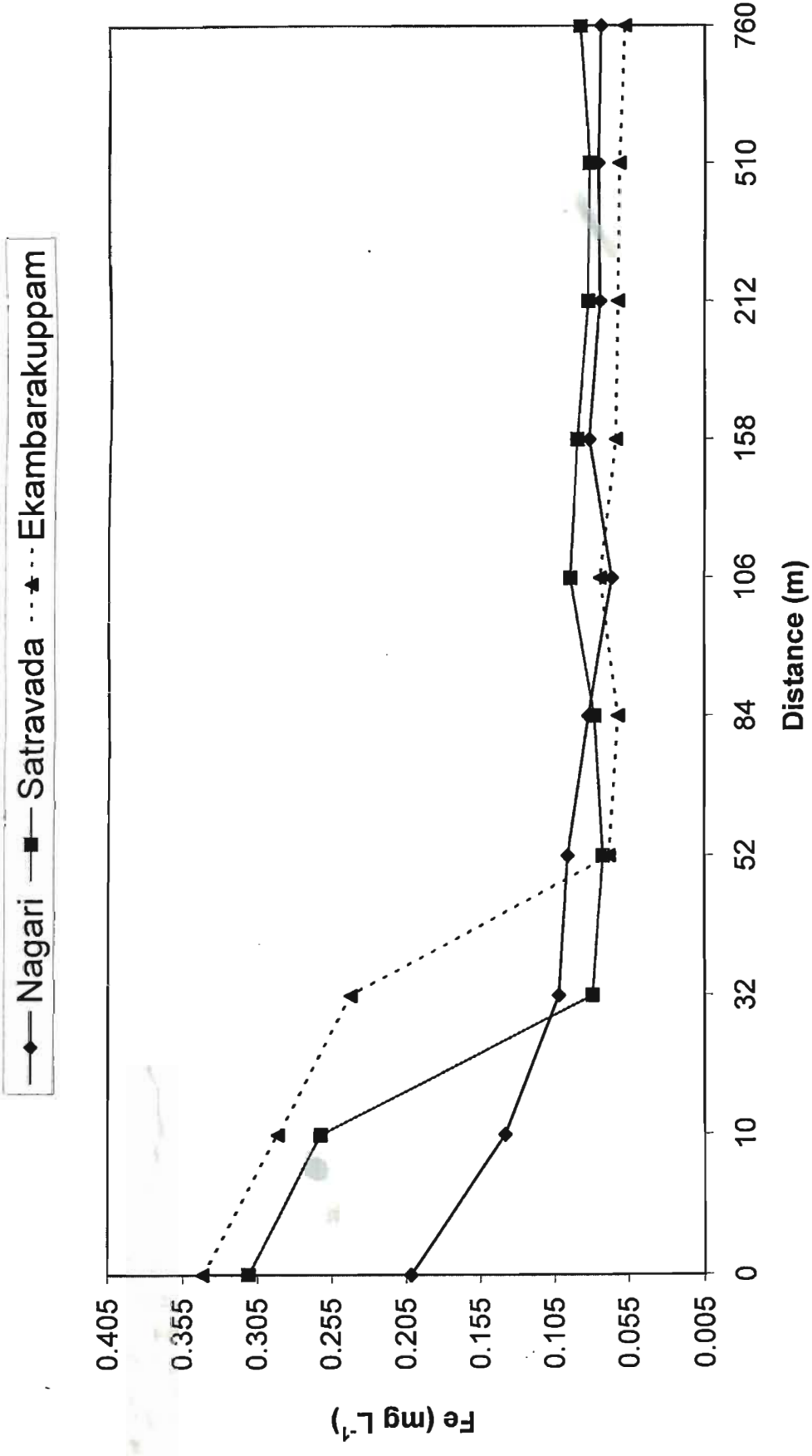


Fig 19: Influence of dyeing unit effluent on Fe(mg L⁻¹) content of ground water at different distances from the effluent stream

Accumulation of Fe was more in the neighborhood of the effluent stream as compared to farther distances. It gradually decreased with increase in distance up to 32m distance at Ekambarakuppam (0.342 to 0.242 mg L⁻¹), up to 14m in Satravada (0.311 to 0.262 mg L⁻¹) and up to 52 m distance at Nagari (0.202 to 0.096 mg L⁻¹). The accumulation of Fe in ground water in the immediate vicinity of the stream at all the three locations studied indicated the ground water getting contaminated with effluent in course of time.

4.3 EFFECT OF DYEING UNIT EFFLUENT ON SOIL PROPERTIES AND AVAILABLE NUTRIENTS

4.3.1 Soil texture

The soils were sandy loam to sandy clay loams at Nagari, Satravada and Ekambarakuppam upto a lateral distance of 200 m and upto depth of 30-45 cm (Appendix-I). The soils were sandy clay loam at 30-45 cm depths upto 200 m distance studied at Nagari, Satravada and Ekambarakuppam. Clay was varying in the soils collected upto 200 m distance, was as follows.

Locations	Depth of soil (cm)		
	0-15	15-30	30-45
Nagari	14.0 to 17.0	18.0 to 21.0	26.0 to 29.0
Satravada	21.0 to 24.0	25.0 to 28.0	27.0 to 30.0
Ekambarakuppam	13.0 to 15.0	16.0 to 20.0	26.0 to 30.0

Thus, the soils particularly at lower depths have considerable amount of clay and clay percentage in general was tending to increase with depth in the soils. There was wide variations of sand in the soils around with effluent streams. The sand percentage was varying between 36.0 to 48.0 at Nagari 36.0 to 47.0 at Satravada and 37.0 to 50.0 at Ekambarakuppam.

4.3.2 pH

From the data presented in Table 13, it was noticed that the pH of the soil in the immediate vicinity of the stream in Nagari, at 100 m distance in Satravada at 25 m distance in Ekambarakuppam was significantly higher as compared to other distances. The differences in pH between 0 to 200 m distance at Nagari, Satravada and Ekambarakuppam was significantly varied. Significantly lowest values obtained at 25 m distance, 100 m distance and 75 m distance were 8.11, 7.56 and 7.82 at Nagari, Satravada and Ekambarakuppam respectively as compared to farther distances.

Table 13: Influence of dyeing unit effluent on pH of soil at various distances and depths of soil

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	8.39	8.36	7.87
10	8.18	8.45	8.09
25	8.11	8.32	8.19
50	8.23	7.95	8.20
75	8.59	8.19	7.82
100	8.26	7.56	8.24
150	8.48	7.93	8.54
200	8.56	7.97	8.58
CD at 5%	0.317	0.0142	0.0236
Depths of soil (cm)			
0-15	8.32	7.93	7.96
15-30	8.35	8.10	8.28
30-45	8.38	8.21	8.33
CD at 5%	0.0194	0.0087	0.0144

Table 14: Interaction between distances and depths on pH of soil

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
0	8.92	7.92	8.33	8.12	8.45	8.53	7.89	7.80	7.93	7.89	7.80	7.93
10	7.58	8.84	8.14	8.26	8.47	8.63	7.94	8.23	8.12	7.94	8.23	8.12
25	7.88	8.20	8.27	8.12	8.25	8.59	8.01	8.27	8.29	8.01	8.27	8.29
50	8.12	7.98	8.59	7.91	7.86	8.10	7.99	8.20	8.42	7.99	8.20	8.42
75	8.72	8.64	8.41	8.06	8.23	8.28	7.45	7.94	8.09	7.45	7.94	8.09
100	8.61	8.05	8.14	7.37	7.65	7.68	7.90	8.50	8.34	7.90	8.50	8.34
150	8.35	8.52	8.57	7.84	7.93	8.040	8.26	8.65	8.73	8.26	8.65	8.73
200	8.43	8.65	8.61	7.87	8.01	8.14	8.25	8.71	8.79	8.25	8.71	8.79
CD at 5%	0.0549				0.0246				0.0408			

The pH of the soil was influenced significantly at Nagari, Satravada and Ekambarakuppam by the depth of the soil. Significantly lower pH of 8.32 at Nagari, 7.93 at Satravada and 7.96 at Ekambarakuppam were noticed in surface layer of 0-15 cm depth as compared to 15-30 cm depth and 30-45 cm depth. Higher pH values of 8.38, 8.24 and 8.33 were recorded at 30-45 cm depth at Nagari, Satravada and Ekambarakuppam respectively as compared to that of 15-30 cm and 0-15 cm depth.

Interaction between distances and depths of the soil was significant on pH of the soil at all the three locations at three depths of soil studied (Table 14). The pH of the soil was significantly differed between the distances 0 to 200 m at all the three locations at three depth of the soil studied. However, no specific trend of variation in pH of the soil nearer to the effluent stream adjoining effluent stream and distances away from effluent stream were observed at all the three locations at three depths of soil studied.

4.3.3 Electrical Conductivity (EC)

From the data presented in Table 15, it was noticed that the EC was significantly influenced in the immediate vicinity of stream at all the three locations studied. It was higher in the immediate neighborhood of the stream except at Nagari. It decreased with

Table 15: Influence of dyeing unit effluent on EC (dSm^{-1}) of soil at various distances and depths of soil

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	1.06	0.80	3.63
10	1.27	0.51	1.42
25	0.59	0.29	0.28
50	0.24	0.34	0.33
75	0.38	0.30	0.50
100	0.23	0.19	0.27
150	0.19	0.30	0.29
200	0.515	0.16	0.29
CD at 5%	0.0515	0.0165	0.0507
Depths of soil (cm)			
0-15	0.81	0.41	1.35
15-30	0.57	0.34	0.65
30-45	0.30	0.32	0.63
CD at 5%	0.0315	0.0101	0.0311

Table 16: Interaction between distances and depths on EC (dSm^{-1}) of soil

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	0-15	15-30	30-45	0-15	15-30	30-45	
0	1.58	1.06	0.54	1.10	0.91	0.40	4.30	3.40	3.20	3.20	3.20	
10	1.80	1.53	0.50	0.46	0.52	0.56	3.70	0.22	0.30	0.30	0.30	
25	0.88	0.60	0.30	0.32	0.31	0.24	0.36	0.25	0.25	0.25	0.25	
50	0.86	0.36	0.29	0.35	0.41	0.28	0.44	0.26	0.31	0.31	0.31	
75	0.37	0.22	0.14	0.43	0.23	0.26	0.90	0.34	0.28	0.28	0.28	
100	0.48	0.39	0.29	0.19	0.21	0.18	0.38	0.21	0.24	0.24	0.24	
150	0.25	0.26	0.18	0.32	0.38	0.21	0.39	0.26	0.22	0.22	0.22	
200	0.26	0.17	0.15	0.17	0.16	0.15	0.37	0.31	0.21	0.21	0.21	
CD at 5%	0.0892				0.0286				0.0878			

successive increase in distance from 10 to 50 m (1.27 dSm⁻¹ to 0.24 dSm⁻¹) at Nagari, 0 to 25 m (0.803 to 0.29 dSm⁻¹) at Satravada and 0 to 25 m (3.63 to 0.28 dSm⁻¹) at Ekambarakuppam. Significantly lowest values as compared to other distances were obtained at 200 m distance (0.19 dSm⁻¹), at 200 m distance (0.16 dSm⁻¹) and at 150 m distance (0.27 dSm⁻¹) at Nagari, Satravada and Ekambarakuppam respectively.

EC of the soil was significantly influenced by depth of the soil at all the three locations studied. It was higher in surface layer and decreased with depth. Higher EC of 0.81 dSm⁻¹ at Nagari, 0.41 dSm⁻¹ at Satravada and 1.35 dSm⁻¹ at Ekambarakuppam was obtained in surface layer (0-15 cm depth) as compared to sub surface length. The EC of the soil significantly decreased with increasing depth of the soil. The EC was significantly lower at 30-45 cm depth in Nagari (0.30 dSm⁻¹), Satravada (0.32 dSm⁻¹) and Ekambarakuppam (0.63 dSm⁻¹) as compared to surface layers.

Interaction between distances and depths of the soil was significant on the EC of the soil (Table 16). It decreases with distance from the effluent stream upto 0-15 cm, 30-45 cm, at Nagari and upto 10 m distance at Satravada at all the depths of the soil studied while it decreased with increasing distance upto 10 m at Ekambarakuppam. Higher EC was obtained at 15-30 cm, 15-30 cm and 30-45 cm depth at Nagari, Satravada and Ekambarakuppam, respectively.

In general, the EC of the soil those significant between the distances away from the effluent stream was less significantly lower as compared to the distances adjacent to effluent stream at all the three locations at the three depths of soil studied.

4.3.4 Organic Carbon (OC)

The accumulation of organic carbon (Table 17) was significantly higher at 0 m distance from the effluent stream as compared to other distance at all the three locations studied. In general the organic carbon was significantly varied between 10 m to 200 m distances from the effluent stream. The highest organic carbon obtained at 0 m was 1.04, 1.11 and 1.30 per cent at Nagari, Satravada and Ekambarakuppam respectively as compared to farther distances. The lowest values and significantly lower than the other distance at 100 m, 200 m and 200 m was recorded in Nagari (0.45%), Satravada (0.37%) and Ekambarakuppam (0.37%) respectively. Significantly decreasing trend of organic carbon from 1.04 to 0.45 per cent at Nagari, 1.11 to 0.71 per cent at Satravada and 1.30 to 0.37 per cent at Ekambarakuppam was recorded as the distance decreased from 0 to 100 m, 0 to 50 m, and 0 to 200 m respectively.

Table 17: Influence of dyeing unit effluent on organic carbon content (%) of soil at various distances and depths of soil

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	1.04	1.11	1.30
10	0.76	0.93	1.11
25	0.68	0.83	1.05
50	0.56	0.71	0.77
75	0.48	0.72	0.67
100	0.45	0.56	0.62
150	0.49	0.63	0.58
200	0.48	0.37	0.37
CD at 5%	0.0018	0.0017	0.0013
Depths of soil (cm)			
0-15	0.70	0.90	0.84
15-30	0.63	0.72	0.83
30-45	0.52	0.58	0.76
CD at 5%	0.0011	0.0010	0.0008

Table 18: Interaction between distances and depths on organic carbon content (%) of soil

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
0	1.17	1.14	0.81	1.29	0.93	1.11	1.12	1.27	1.51	1.12	1.27	1.51
10	0.86	0.78	0.65	1.00	0.90	0.90	1.07	1.06	1.20	1.07	1.06	1.20
25	0.83	0.60	0.62	0.96	0.71	0.81	1.05	0.94	1.17	1.05	0.94	1.17
50	0.53	0.59	0.56	0.90	0.53	0.69	0.96	0.74	0.62	0.96	0.74	0.62
75	0.65	0.51	0.28	1.01	0.58	0.57	0.75	0.67	0.58	0.75	0.67	0.58
100	0.59	0.44	0.31	0.67	0.83	0.17	0.70	0.83	0.34	0.70	0.83	0.34
150	0.56	0.47	0.42	0.84	0.92	0.12	0.87	0.47	0.40	0.87	0.47	0.40
200	0.40	0.49	0.53	0.52	0.34	0.24	0.22	0.64	0.25	0.22	0.64	0.25
CD at 5%		0.0018			0.0029			0.0023			0.0023	

Organic carbon was significantly higher in surface layers as compared to deeper layers at all the sampling sites. Highest organic carbon content of 0.70 per cent at Nagari, 0.90 per cent at Satravada and 0.84 per cent in Ekambarakuppam was observed at a depth of 0-15 cm. Lowest organic carbon of 0.52 per cent at Nagari, 0.58 per cent at Satravada and 0.76 per cent at Ekambarakuppam was observed at a depth of 30-45 cm.

Interaction between distances and depths of the soil was significant at Nagari, Satravada and Ekambarakuppam (Table 18). In general, the organic carbon content of the soil was significantly higher at distances neared to the effluent stream at all the three depths of the soil as compared to that of farther distances from the effluent stream.

4.3.5 Micronutrients

4.3.5.1 Zinc (Zn)

From the data presented in Table 19, it was noticed that the DTPA extractable Zn varied significantly with distance at all the three locations. It was higher in the immediate vicinity of the effluent streams. In general, Zn decreased gradually with an increase distance from effluent stream at all three locations studied. Higher DTPA extractable zinc of 4.941 mg kg⁻¹ at Nagari, 4.079 mg kg⁻¹ at Satravada

and 4.926 mg kg^{-1} at Ekambarakuppam was obtained at 0 m distance from the effluent streams. The D1PA extractable Zn was lower at 200 m distance at Nagari (1.242 mg kg^{-1}) at Satravada (1.080 mg kg^{-1}) and at Ekambarakuppam (2.354 mg kg^{-1}) as compared to remaining distances of sampling.

The accumulation of Zn due to effluent was continued upto 25 m distance at Nagari (4.941 to 2.447 mg kg^{-1}) and Satravada (4.079 to 1.338 mg kg^{-1}) while at Ekambarakuppam, the accumulation of Zn was continued upto 50 m distance (4.926 to 3.120 mg kg^{-1}) at Ekambarakuppam. Beyond, 25 m distance at Nagari and Satravada and 50 m distance at Ekambarakuppam, the significantly lowest values were obtained ranging from 1.242 to 1.744 mg kg^{-1} , 1.080 to 1.293 mg kg^{-1} and 2.354 to 2.966 mg kg^{-1} respectively as compared to that of distances located in the vicinity of the stream. However, these values were significantly varied between the distances.

The DTPA extractable Zn was varied due to the depth of the soil. It was higher in surface layers and significantly decreased with increasing in depth of the soil at all the three locations. It decreased from 2.527 mg kg^{-1} to 2.257 mg kg^{-1} , 1.733 mg kg^{-1} to 1.631 mg kg^{-1} , and 3.686 mg kg^{-1} to 3.164 mg kg^{-1} at Nagari, Satravada and Ekambarakuppam respectively.

Table 19: Influence of dyeing unit effluent on DTPA extractable soil Zinc (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	4.941	4.079	4.926
10	4.124	2.173	4.473
25	2.447	1.338	4.466
50	1.744	1.225	3.120
75	1.628	1.293	2.966
100	1.527	1.174	2.921
150	1.442	1.121	2.653
200	1.242	1.080	2.354
CD at 5%	0.0008	0.0011	0.0013
Depths of soil (cm)			
0-15	2.527	1.733	3.686
15-30	2.348	1.692	3.605
30-45	2.257	1.631	3.164
CD at 5%	0.0005	0.0007	0.007

Table 20: Interaction between distances and depths on soil zinc (mg kg^{-1})

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
0	5.086	4.926	4.812	4.106	4.102	4.028	5.186	5.066	4.526	4.526	4.526	4.526
10	4.158	4.122	4.092	2.182	2.180	2.158	4.682	4.526	4.212	4.212	4.212	4.212
25	2.623	2.432	2.286	1.386	1.376	1.252	4.646	4.642	4.110	4.110	4.110	4.110
50	1.872	1.636	1.724	1.246	1.224	1.204	3.286	3.180	2.894	2.894	2.894	2.894
75	1.924	1.523	1.436	1.382	1.284	1.212	3.152	3.112	2.634	2.634	2.634	2.634
100	1.734	1.510	1.338	1.212	1.208	1.102	3.140	3.106	2.518	2.518	2.518	2.518
150	1.624	1.418	1.285	1.192	1.101	1.070	2.862	2.784	2.314	2.314	2.314	2.314
200	1.432	1.214	1.080	1.154	1.063	1.024	2.532	2.424	2.106	2.106	2.106	2.106
CD at 5%	0.0013				0.0019				0.0019			

Interaction between distances and depth of the soil on available Zn was presented in Table 24. In general, Zn content decreased with distance from effluent stream at all depth of the soil at all the locations. The available zinc was significantly higher in the immediate vicinity of steam at all the depth of soil as compared to the distances away from the steam.

4.3.5.2 Copper (Cu)

From the data presented in the Table 20, it was noticed that the DTPA extractable copper varied due to distance of sampling at all the three locations studied while it was higher in immediate vicinity of the effluent streams. In general it decreased with an increased distance of sampling from the effluent streams especially in the soils nearer to the effluent streams. Highest value of copper at 0 m distance was obtained at Nagari (3.281 mg kg⁻¹), Satravada (3.479 mg kg⁻¹) and Ekambarakuppam (3.093 mg kg⁻¹) as compared to other distances.

The Cu was lower at 200 m distance at Nagari (1.479 mg kg⁻¹), Satravada (2.233 mg kg⁻¹) and Ekambarakuppam (1.924 mg kg⁻¹) compared to the remaining distances from the effluent stream.

Table 21: Influence of dyeing unit effluent on DTPA extractable soil copper (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	3.281	3.479	3.093
10	3.129	3.115	3.028
25	2.454	2.720	2.951
50	2.199	2.491	2.103
75	2.114	2.470	2.062
100	2.031	2.380	1.988
7150	1.653	2.240	2.008
200	1.479	2.233	1.924
CD at 5%	0.0017	0.0095	0.0008
Depths of soil (cm)			
0-15	2.400	2.708	2.537
15-30	2.323	2.671	2.498
30-45	2.155	2.545	2.149
CD at 5%	0.0011	0.0058	0.0005

Table 22: Interaction between distances and depths on soil copper (mg kg⁻¹)

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
0	3.432	3.318	3.092	3.622	3.584	3.232	3.284	3.176	3.176	3.176	2.818	
10	3.234	3.142	3.012	3.143	3.108	3.094	3.202	3.155	3.155	3.155	2.726	
25	2.482	2.494	2.386	2.843	2.732	2.584	3.113	3.104	3.104	3.104	2.636	
50	2.322	2.184	2.090	2.522	2.520	2.432	2.186	2.140	2.140	2.140	1.984	
75	2.188	2.143	2.012	2.518	2.502	2.389	2.132	2.112	2.112	2.112	1.942	
100	2.088	2.024	1.982	2.436	2.386	2.318	2.096	2.052	2.052	2.052	1.816	
150	1.732	1.684	1.543	2.284	2.254	2.182	2.158	2.143	2.143	2.143	1.722	
200	1.724	1.592	1.120	2.293	2.280	2.126	2.124	2.102	2.102	2.102	1.546	
CD at 5%	0.0030				0.0165				0.0013			

The accumulation of Cu between 0 to 25 m distance at Nagari (3.281 to 2.454 mg kg⁻¹), and Satravada (3.479 to 2.720 mg kg⁻¹) whereas the same was accumulated between 0 and 50 m distance at Ekambarakuppam (3.093 to 2.103 mg kg⁻¹). Beyond 25 m distance at Nagari and Satravada and 50 m distance at Ekambarakuppam, through the values were varied significantly, lower values were obtained as compared to the distances located in the immediate vicinity of the effluent stream.

The DTPA extractable copper varied significantly due to depth of the soil at all the three locations. The copper content of soils decreased significantly with increasing depth of soil. Highest DTPA extractable Cu content of 2.400 mg kg⁻¹ at Nagari, 2.708 mg kg⁻¹ at Satravada and 2.537 mg kg⁻¹ at Ekambarakuppam was obtained in surface layer of 0-15cm which progressively decreased with soil depth at all the three locations.

Interaction between distances and depth of the soil on available copper was significant at Nagari, Satravada and Ekambarakuppam (Table 22). In general available iron decreased with distance from effluent stream at each depth of the soil at all the three locations studied. The available copper was significantly higher in the soils adjoining effluent stream at all the three depths of the soil at all the locations as compared to distances faraway from the stream.

4.2.5.3 Iron (Fe)

From the data presented in Table 24, it was noticed that the DTPA extractable Fe was varied significantly due to distances at all the three locations studied. The accumulation to Fe was significantly more in the immediate vicinity of the effluent stream as compared to other distances at all the three locations studied. A significant decrease in Fe content with increase in distance from the effluent stream was observed upto 25 m distance (5.415 to 3.597 mg kg⁻¹) at Nagari and 50 m distance (7.203 to 4.168 mg kg⁻¹) at Ekambarakuppam. Whereas at Satravada highest value of Fe was noticed at 10 m distance (7.048 mg kg⁻¹) followed by 0 m (6.303 mg kg⁻¹), 25 m distance (4.334 mg kg⁻¹) and 50 m distance (3.172 mg kg⁻¹). Highest value of Fe (5.415 mg kg⁻¹) at 0 m, (7.048 mg kg⁻¹) at 10 m distance and (7.203 mg kg⁻¹) at 0 m distance was obtained at Nagari, Satravada, and Ekambarakuppam, respectively where as the lowest values were obtained at 200 m distance (2.879 mg kg⁻¹), at 150 m distance (2.237mg kg⁻¹) and at 200 m distance (3,232 mg kg⁻¹) at Nagari, Satravada and Ekambarakuppam respectively.

Fe content was significantly higher in the surface layers (0-15cm depth) and decreased significantly with increasing depth of the soil at all the locations studied except at Satravada. The Fe content was

Table 23: Influence of dyeing unit effluent on DTPA extractable soil iron (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	5.415	6.303	7.203
10	3.990	7.048	7.016
25	3.597	4.334	4.247
50	3.170	3.172	4.168
75	3.381	2.776	4.097
100	3.224	2.413	3.831
150	3.145	2.237	3.318
200	2.879	2.776	3.232
CD at 5%	0.0015	0.0671	0.0051
Depths of soil (cm)			
0-15	3.747	4.198	4.786
15-30	3.616	3.356	4.661
30-45	3.445	3.868	4.470
CD at 5%	0.0009	0.0411	0.0031

Table 24: Interaction between distances and depths on soil iron (mg kg^{-1})

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
0	5.626	5.434	5.184	8.622	8.446	7.842	7.432	7.136	7.042	7.432	7.136	7.042
10	4.096	4.012	3.863	7.186	7.094	6.864	7.130	7.095	6.824	7.130	7.095	6.824
25	3.743	3.623	3.424	4.534	4.346	4.122	4.318	4.310	4.112	4.318	4.310	4.112
50	3.243	3.140	3.128	3.282	3.143	3.092	4.228	4.212	4.063	4.228	4.212	4.063
75	3.436	3.420	3.286	2.922	2.863	2.543	4.152	4.128	4.012	4.152	4.128	4.012
100	3.324	3.284	3.124	2.463	2.453	2.322	4.022	3.828	3.643	4.022	3.828	3.643
150	3.412	3.106	2.918	2.284	2.242	2.184	3.543	3.324	3.086	3.543	3.324	3.086
200	3.092	2.912	2.634	2.293	2.259	1.976	3.464	3.252	2.980	3.464	3.252	2.980
CD at 5%	0.0027				0.1162				0.0089			

significantly decreased from 0 to 15cm depth to 15 to 30cm depth but the higher content of Fe was noticed at 30 to 45cm depth (3.868 mg kg⁻¹) at Satravada.

Interaction between distances and depths of the soil on available Fe was significant at all the three locations studied (Table 28). In general, the available Fe decreased with increasing distance and decrease was significantly lower beyond the distance faraway from the stream as compared to the distances in immediate vicinity of the streams.

4.2.5.4 Manganese (Mn)

From the data presented in Table 25, it was noticed that the DTPA extractable Mn was varied significantly due to distance at all the three locations studied. The accumulation of Mn was significantly more in the immediate vicinity of the effluent stream as compared to other distances at all the three locations studied. Significantly higher content of Mn was obtained at 0-25 m distance (3.051 to 3.755 mg kg⁻¹), 0-10 m distance (3.771 to 3.187 mg kg⁻¹) and 0-25 m distance (2.257 to 3.112 mg kg⁻¹) at Nagari, Satravada and Ekambarakuppam, respectively as compared to the distances faraway from the effluent stream. Highest value of Mn (3.755 mg kg⁻¹) at 0 m, 3.187 mg kg⁻¹ at 0 m distance and

Table 25: Influence of dyeing unit effluent on DTPA extractable soil manganese (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	3.755	3.187	3.112
10	3.545	2.776	2.933
25	3.051	2.213	2.257
50	2.829	2.212	2.194
75	3.147	2.053	2.151
100	3.108	1.989	2.023
150	2.627	1.884	1.948
200	2.374	1.761	1.847
CD at 5%	0.0015	0.0011	0.0013
Depths of soil (cm)			
0-15	3.248	2.476	2.439
15-30	3.054	2.302	2.332
30-45	2.861	2.001	2.157
CD at 5%	0.0009	0.0007	0.0008

Table 26: Interaction between distances and depths on soil manganese (mg kg^{-1})

Distance (m)	Depth of Soil (cm)											
	Nagari				Satravada				Ekambarakuppam			
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
0	3.830	3.812	3.622	3.522	3.126	2.914	3.162	3.143	3.062	3.162	3.143	3.062
10	3.762	3.548	3.324	3.128	2.784	2.416	3.094	2.962	2.744	3.094	2.962	2.744
25	3.186	3.094	2.872	2.232	2.218	2.190	2.386	2.280	2.106	2.386	2.280	2.106
50	3.092	2.832	2.564	2.248	2.224	2.163	2.343	2.144	2.094	2.343	2.144	2.094
75	3.184	3.180	3.076	2.186	2.138	1.836	2.226	2.216	2.012	2.226	2.216	2.012
100	3.158	3.152	3.014	2.242	2.092	1.634	2.112	2.094	1.863	2.112	2.094	1.863
150	2.863	2.587	2.432	2.142	1.984	1.526	2.106	1.943	1.794	2.106	1.943	1.794
200	2.910	2.226	1.987	2.108	1.846	1.328	2.086	1.873	1.583	2.086	1.873	1.583
CD at 5%		0.0027			0.0019			0.0023			0.0023	

3.112 mg kg⁻¹ at 0 m distance was obtained at Nagari, Satravada and Ekambarakuppam respectively whereas the lowest values at 200 m distance (2.374 mg kg⁻¹), at 200 m distance (1.761 mg kg⁻¹) and at 200 m distance (1.847 mg kg⁻¹) were recorded at Nagari, Satravada and Ekambarakuppam respectively.

Mn content was significantly higher in the surface layers (0-15cm depth) and increased significantly with increasing depth of the soil at all the three locations studied. The Mn content significantly decreased from 3.248 to 2.861 mg kg⁻¹, 2.476 to 2.001 mg kg⁻¹ and 2.439 to 2.157 mg kg⁻¹ with increasing the depth of soil at Nagari, Satravada and Ekambarakuppam, respectively.

Interaction between distances and depths of the soil on available Mn were significant at all the three locations (Table 30). In general the available Mn decreased with increasing distance from the effluent stream at three depths of the soil at all the three locations studied. Significantly higher content of available Mn was obtained in the immediate vicinity of the stream at three depths of the soil at Nagari, Satravada and Ekambarakuppam as compared to that of farther distances.

4.3.6 Heavy Metals

4.3.6.1 Cadmium (Cd)

From the data presented in Table 27, it was noticed that DTPA extractable heavy metal Cd varied significantly due to distance at all the three locations studied while it was higher in the immediate neighborhood of the stream. Highest value of 0.054 mg kg⁻¹, 0.048 mg kg⁻¹ and 0.103 mg kg⁻¹ at 0 m distance was recorded at Nagari, Satravada and Ekambarakuppam respectively. DTPA extractable Cd at 100 and 150 m distance 0.033 mg kg⁻¹, 150 and 200 m distance, 150 and 200 m distance 0.029 mg kg⁻¹ and 200 m distance 0.054 mg kg⁻¹ was significantly lower than other distances in Nagari, Satravada, and Ekambarakuppam respectively. Significantly decreasing trend of DTPA extractable cadmium from 0 to 200 m distance was noticed (0.103 mg kg⁻¹ to 0.054 mg kg⁻¹) at Ekambarakuppam village where as such type of decreasing trend was not noticed in Nagari and Satravada villages.

DTPA extractable cadmium varied significantly with depth of soil at all the three locations. Higher values obtained in surface layers decreased with depth of the soil. It significantly decreased from 0.055 mg kg⁻¹ to 0.031 mg kg⁻¹, 0.045 mg kg⁻¹ to 0.030 mg kg⁻¹ and 0.087 mg kg⁻¹ to 0.058 mg kg⁻¹ at Nagari, Satravada and Ekambarakuppam respectively as soil depth increased up to 30-45 cm.

Table 27: Influence of dyeing unit effluent on DTPA extractable soil cadmium (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	0.054	0.048	0.103
10	0.051	0.043	0.085
25	0.042	0.041	0.077
50	0.036	0.036	0.070
75	0.037	0.033	0.064
100	0.033	0.039	0.060
150	0.033	0.029	0.056
200	0.041	0.029	0.054
CD at 5%	0.0013	0.0017	0.0003
Depths of soil (cm)			
0-15	0.055	0.045	0.087
15-30	0.037	0.036	0.069
30-45	0.031	0.030	0.058
CD at 5%	0.0008	0.0011	0.0002

4.3.6.2 Lead (Pb)

From data presented in Table 28, it was noticed that DTPA-extractable Pb of soil varies significantly between 0 and 200 m distance at all the three locations studied. It ranged from 0.415 mg kg⁻¹ to 0.415 mg kg⁻¹, 0.425 mg kg⁻¹ to 0.473 mg kg⁻¹, and 0.343 mg kg⁻¹ to 0.50 mg kg⁻¹ at Nagari, Satravada and Ekambarakuppam respectively. The accumulation of lead of soils adjoining effluent stream was not observed at all the three locations studied.

The DTPA extractable lead varied due to depth of soil at all the three locations. It was higher in surface layer and decreased with successive increasing depth of the soil. It ranged from 0.443 mg kg⁻¹ to 0.409 mg kg⁻¹, 0.442 mg kg⁻¹ to 0.411 mg kg⁻¹ and 0.446 mg kg⁻¹ to 0.404 mg kg⁻¹ at Nagari, Satravada and Ekambarakuppam respectively.

4.3.6.3 Nickle (Ni)

From the data presented in Table 29, it was noticed that the DTPA extractable nickle of soil varied significantly with distances at all the three locations. Significantly higher nickle content at 200 m distance (0.422 mg kg⁻¹) 10 m distance (0.413 mg kg⁻¹) and 0 m distance (0.506 mg kg⁻¹) was obtained at Nagari, Satravada and

Table 28: Influence of dyeing unit effluent on DTPA extractable soil lead (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	0.415	0.425	0.500
10	0.415	0.398	0.515
25	0.418	0.445	0.501
50	0.419	0.425	0.470
75	0.451	0.416	0.422
100	0.438	0.431	0.444
150	0.437	0.418	0.393
200	0.415	0.473	0.343
CD at 5%	0.0008	0.0003	0.347
Depths of soil (cm)			
0-15	0.443	0.442	0.446
15-30	0.426	0.432	0.431
30-45	0.409	0.411	0.404
CD at 5%	0.0005	0.0003	0.0002

Table 29: Influence of dyeing unit effluent on DTPA extractable soil nickel (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	0.401	0.401	0.506
10	0.411	0.413	0.502
25	0.419	0.401	0.445
50	0.407	0.416	0.435
75	0.413	0.405	0.400
100	0.405	0.409	0.395
150	0.393	0.387	0.342
200	0.422	0.375	0.341
CD at 5%	0.0013	0.0006	0.0003
Depths of soil (cm)			
0-15	0.433	0.429	0.495
15-30	0.410	0.411	0.405
30-45	0.382	0.361	0.362
CD at 5%	0.0008	0.0004	0.0002

Ekambarakuppam villages respectively. The values at 100 m distance (0.393 mg kg^{-1}) at 200 m distance (0.375 mg kg^{-1}) and at 200 m distance (0.31 mg kg^{-1}) was significantly lower at Nagari, Satravada and Ekambarakuppam respectively as compared to other distances.

The Ni content of soils varied significantly with depth of the soils in all three locations studied. In general, it was noticed that the Ni content of soil significantly decreased with successive increasing depth of the soil at all three locations studied. Nickel was higher in surface layer as compared to deeper layers at all sampling sites. Higher Ni content of 0.438 mg kg^{-1} at Nagari, 0.435 mg kg^{-1} at Satravada and 0.495 mg kg^{-1} at Ekambarakuppam was observed at 0-15 cm depth. Lower nickel of 0.382 mg kg^{-1} at Nagari, 0.361 mg kg^{-1} at Satravada and 0.362 mg kg^{-1} at Ekambarakuppam was observed at a depth of 30-45 cm depth.

4.3.6.4 Chromium (Cr)

From the data presented in Table 30, it was noticed that DTPA extractable chromium of soil varied significantly between 0 and 200 m distance of sampling at all three locations. Highest chromium content at 10 m distance was obtained at Nagari (0.417 mg kg^{-1}), 0 m distance at Satravada (0.437 mg kg^{-1}) and 10 m distance at Ekambarakuppam

Table 30: Influence of dyeing unit effluent on DTPA extractable soil chromium (mg kg^{-1})

Treatment	Village		
	Nagari	Satravada	Ekambarakuppam
Distance (m)			
0	0.407	0.437	0.421
10	0.417	0.421	0.449
25	0.394	0.398	0.437
50	0.374	0.383	0.429
75	0.357	0.387	0.422
100	0.351	0.373	0.409
150	0.345	0.377	0.404
200	0.374	0.368	0.401
CD at 5%	0.0004	0.0008	0.0003
Depths of soil (cm)			
0-15	0.430	0.426	0.452
15-30	0.362	0.401	0.426
30-45	0.338	0.352	0.401
CD at 5%	0.0003	0.0005	0.0002

(0.449 mg kg⁻¹). Significantly lowest values of chromium obtained at Nagari, Satravada and Ekambarakuppam were 0.345 mg kg⁻¹ at 150 m distance, 0.368 mg kg⁻¹ at 200 m distance and 0.401 mg kg⁻¹ at 200 m distance respectively. The chromium content recorded during this study ranged from 0.345 mg kg⁻¹ to 0.407 mg kg⁻¹ at Nagari, 0.368 mg kg⁻¹ to 0.437 mg kg⁻¹ at Satravada and 0.401 mg kg⁻¹ to 0.449 mg kg⁻¹ at Ekambarakuppam between 0 to 200 m distance.

The chromium content of the soils varied significantly due to depths of the soil at all three locations. It was significantly decreased with successive increase in depth of the soil from 0-15 cm depth to 30-45 cm depth at Satravada (0.426 mg kg⁻¹ to 0.352 mg kg⁻¹), at Ekambarakuppam (0.452 to 0.401 mg kg⁻¹) and at Nagari (0.430 to 0.338 mg ka⁻¹).

4.4 INFLUENCE OF DYEING UNIT EFFLUENT ON IONIC COMPOSITION OF SATURATED SOIL WATER EXTRACT (1:2)

The effect of effluent discharged from dyeing units on EC of saturation extract of soil samples in the year 2001 at 10,25,50,100,150 and 200 m distance from the effluent stream was studied. It was observed that the effect of effluent on the soil adjoining effluent stream was observed to be significant up to 10 m, 50 m distance at Nagari, up

to 10 m distance at Ekambarakuppam and Satravada. Cationic and anionic concentrations of saturation extract of soil were studied in detail.

The results are presented in Tables 31 to 33.

Effect of salt build up in the soil (EC):

From the data presented in Tables 31 to 33, it was noticed that there was considerable build up of salts at all the locations studied and it was higher at Ekambarakuppam as compared to that of Nagari and Satravada. Against EC of 5.6 dSm^{-1} in the effluent (Table 6) and 0.22 to 0.38 dSm^{-1} in the soil at 200 m distance at Ekambarakuppam, the EC in the soil at 0 m and 10 m distance ranged from 3.24 to 4.32 dSm^{-1} and 0.38 to 3.72 dSm^{-1} respectively. The salt build up in the soil was 11 and 5 times more at 0 m and 10 m distance respectively than that of the farther point (200 m distance).

At Nagari, against EC of 5.5 dSm^{-1} in the effluent and 0.17 to 0.28 dSm^{-1} in the soil at 200 m, EC in the soil at 0 m, 10 m, 25 m and 50 m ranged between 0.82 dSm^{-1} and 1.64 dSm^{-1} , 0.50 dSm^{-1} and 1.88 dSm^{-1} , 0.33 dSm^{-1} and 0.92 dSm^{-1} respectively, which was indication of salt accumulation in the soil during the last 8 years. The salt build up in the soil was 5,7,3 and 2.3 times more than that of the farther point (200 m distance) at 0,10,25 and 50 m distance respectively.

At Satravada against EC of (5.5) dSm^{-1} in the effluent and 0.15 dSm^{-1} to 0.19 dSm^{-1} in the soil at 200 m, EC in the soil at 0 m and 10 m distance from effluent stream ranged from 0.54 to 1.20 dSm^{-1} and 0.52 to 0.55 dSm^{-1} respectively. The salt build up in the soils at 0 m and 10 m distance from the effluent stream was 6 and 3 times more as compared to that of the farther point (200 m distance) respectively. This data revealed the considerable amount of salt accumulation in soil within eight years.

The concentration of salts in the soils at 25,50,75,100,150 and 200 m distance at Ekambarakuppam, 50,75,100,150 and 200 m distance at Nagari and 25,50,75,100,150 and 200 m distance at Satravada was very much lower than the concentration of salts in the effluent thereby indicating that the salt content in the above said soils was not contaminated with the salts of effluents.

Effect of dyeing unit effluent on the nature of the salts in the soil

A critical examination of the data (Tables 31, 32 & 33) on the cationic composition at Ekambarakuppam, Nagari and Satravada indicated the considerable build up of Na^+ in the soil followed by Ca^{++} , Mg^{++} , and K^+ . The accumulation of Na^+ , Ca^{++} , Mg^{++} and K^+ content due to effluent ranged from 1.1 cmol L^{-1} to 27.8 cmol L^{-1} , 0.4 cmol L^{-1}

Table 31: Influence of dyeing unit effluent on ionic composition soil-water extract (1:2) at Nagari

Depth (cm)	EC (dSm ⁻¹)	Cations (cmol L ⁻¹)				Anions (cmol L ⁻¹)			
		Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cl ⁻	SO ₄ ⁻	CO ₃ ⁻	HCO ₃ ⁻
Distance: 0 m									
0-15	1.64	9.8	0.8	2.4	1.6	7.8	0.6	2.3	3.9
15-30	1.08	6.6	0.5	2.1	1.2	5.5	0.4	1.5	2.9
30-45	0.82	4.9	0.4	1.8	1.0	4.2	0.3	1.1	2.5
Distance: 10 m									
0-15	1.88	10.4	1.2	3.4	2.6	9.4	0.8	2.8	4.4
15-30	1.56	9.6	0.7	2.3	1.5	7.6	0.5	2.2	3.8
30-45	0.80	4.8	0.4	1.7	0.8	4.1	0.3	1.0	2.3
Distance: 25 m									
0-15	0.92	5.1	0.5	2.0	1.1	4.3	0.4	1.3	2.7
15-30	0.64	3.5	0.3	1.6	0.8	3.1	0.2	1.0	1.9
30-45	0.33	1.4	0.2	1.0	0.6	1.2	0.2	0.7	1.1
Distance: 50m									
0-15	0.88	5.0	0.4	1.9	1.0	4.2	0.3	1.2	2.6
15-30	0.37	1.5	0.2	1.2	0.7	1.1	0.2	0.8	1.5
30-45	0.30	1.2	0.2	0.9	0.6	1.0	0.2	0.6	1.1
Distance: 75 m									
0-15	0.39	1.7	0.3	1.1	0.7	1.2	0.3	0.8	1.5
15-30	0.25	1.0	0.2	0.9	0.4	0.7	0.2	0.6	1.0
30-45	0.20	0.6	0.2	0.8	0.4	0.5	0.2	0.5	0.8
Distance: 100 m									
0-15	0.48	2.1	0.4	1.4	0.8	1.6	0.4	0.8	1.7
15-30	0.41	1.8	0.3	1.2	0.7	1.4	0.3	0.7	1.6
30-45	0.31	1.2	0.2	1.0	0.6	1.1	0.2	0.7	1.0
Distance: 150m									
0-15	0.27	1.0	0.2	0.9	0.6	0.9	0.3	0.6	0.9
15-30	0.26	0.9	0.2	0.8	0.5	0.8	0.2	0.5	0.9
30-45	0.19	0.7	0.1	0.7	0.4	0.6	0.2	0.4	0.7
Distance: 200 m									
0-15	0.28	1.1	0.2	0.9	0.6	1.0	0.3	0.5	1.0
15-30	0.19	0.8	0.1	0.7	0.3	0.6	0.2	0.4	0.7
30-45	0.17	0.6	0.1	0.6	0.4	0.5	0.2	0.3	0.7

Table 32: Influence of dyeing unit effluent on ionic composition soil-water extract (1:2) at Satravada

Depth (cm)	EC (dSm ⁻¹)	Cations (cmol L ⁻¹)				Anions (cmol L ⁻¹)			
		Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cl ⁻	SO ₄ ⁻⁻	CO ₃ ⁻	HCO ₃ ⁻
Distance: 0 m									
0-15	1.20	7.2	0.7	2.3	1.3	6.6	0.5	1.8	2.6
15-30	0.96	5.6	0.6	2.2	1.0	4.8	0.4	1.5	2.7
30-45	0.54	2.3	0.5	1.6	0.9	2.1	0.3	1.0	1.9
Distance: 10 m									
0-15	0.52	2.2	0.5	1.5	0.9	1.8	0.4	0.8	1.9
15-30	0.54	2.3	0.5	1.6	0.9	2.0	0.3	0.9	2.1
30-45	0.55	2.3	0.5	1.7	1.0	2.0	0.3	1.0	2.2
Distance: 25 m									
0-15	0.36	1.8	0.4	0.9	0.5	1.9	0.4	0.4	0.9
15-30	0.34	1.6	0.3	0.9	0.6	1.8	0.4	0.4	0.8
30-45	0.28	1.4	0.3	0.7	0.4	1.3	0.3	0.4	0.8
Distance: 50m									
0-15	0.37	1.5	0.3	1.1	0.7	1.9	0.3	0.5	0.9
15-30	0.42	1.8	0.3	1.2	0.8	2.3	0.3	0.4	0.9
30-45	0.28	1.1	0.2	0.9	0.6	1.4	0.2	0.4	0.8
Distance: 75 m									
0-15	0.45	1.9	0.5	1.3	0.7	2.1	0.4	0.7	1.2
15-30	0.23	1.0	0.4	0.6	0.3	0.8	0.3	0.4	0.8
30-45	0.26	1.2	0.4	0.7	0.3	1.0	0.3	0.4	0.9
Distance: 100 m									
0-15	0.22	1.0	0.4	0.5	0.3	0.8	0.3	0.4	0.7
15-30	0.21	0.9	0.4	0.5	0.3	0.7	0.3	0.4	0.7
30-45	0.18	0.8	0.3	0.4	0.3	0.6	0.2	0.3	0.7
Distance: 150m									
0-15	0.34	1.5	0.4	0.9	0.6	1.7	0.4	0.4	0.9
15-30	0.38	1.6	0.5	1.1	0.6	1.8	0.5	0.5	1.0
30-45	0.21	0.9	0.4	0.5	0.3	0.7	0.3	0.4	0.7
Distance: 200 m									
0-15	0.19	0.8	0.2	0.6	0.3	0.6	0.2	0.4	0.7
15-30	0.16	0.7	0.1	0.5	0.3	0.4	0.2	0.4	0.6
30-45	0.15	0.7	0.1	0.4	0.2	0.4	0.1	0.3	0.6

Table 33: Influence of dyeing unit effluent on ionic composition soil-water extract (1:2) at Ekambarakuppam

Depth (cm)	EC (dSm ⁻¹)	Cations (cmol L ⁻¹)				Anions (cmol L ⁻¹)			
		Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cl ⁻	SO ₄ ⁻⁻	CO ₃ ⁻⁻	HCO ₃ ⁻
Distance: 0 m									
0-15	4.32	27.8	3.6	5.2	3.1	24.6	5.8	3.6	5.7
15-30	3.44	21.6	2.8	4.4	2.9	19.0	4.7	2.7	5.3
30-45	3.24	20.2	2.6	4.2	2.8	17.9	4.3	2.5	5.1
Distance: 10 m									
0-15	3.72	24.8	3.2	4.6	3.5	24.7	5.3	2.9	5.6
15-30	0.24	1.1	0.4	0.6	0.3	1.0	0.3	0.4	0.7
30-45	0.38	1.7	0.6	0.9	0.5	1.8	0.5	0.5	0.9
Distance: 25 m									
0-15	0.36	1.6	0.6	0.9	0.5	1.8	0.5	0.4	0.9
15-30	0.25	1.1	0.4	0.6	0.4	1.2	0.3	0.3	0.7
30-45	0.26	1.1	0.5	0.6	0.4	1.2	0.3	0.4	0.7
Distance: 50 m									
0-15	0.48	1.8	0.9	1.3	0.7	1.9	0.6	0.8	1.4
15-30	0.26	1.1	0.5	0.6	0.4	1.2	0.3	0.4	0.7
30-45	0.30	1.2	0.6	0.8	0.4	1.3	0.4	0.5	0.8
Distance: 75 m									
0-15	0.92	2.8	1.4	2.4	1.6	2.9	1.1	1.5	2.7
15-30	0.36	1.6	0.6	0.9	0.5	1.8	0.5	0.4	0.9
30-45	0.28	1.2	0.5	0.7	0.4	1.3	0.3	0.4	0.8
Distance: 100 m									
0-15	0.40	1.8	0.6	0.9	0.6	1.9	0.5	0.6	0.9
15-30	0.22	1.0	0.4	0.5	0.3	0.8	0.3	0.4	0.7
30-45	0.23	1.1	0.4	0.5	0.3	0.9	0.3	0.4	0.7
Distance: 150 m									
0-15	0.39	1.8	0.6	0.9	0.5	1.9	0.5	0.5	0.9
15-30	0.27	1.2	0.5	0.6	0.4	1.3	0.3	0.4	0.7
30-45	0.22	1.0	0.4	0.5	0.3	0.8	0.3	0.4	0.7
Distance: 200 m									
0-15	0.38	1.7	0.5	0.9	0.5	1.8	0.4	0.5	0.9
15-30	0.31	1.3	0.5	0.9	0.4	1.4	0.4	0.4	0.9
30-45	0.22	1.0	0.4	0.5	0.3	0.8	0.3	0.4	0.7

to 3.6 cmol L^{-1} , 0.6 to 5.2 cmol L^{-1} , and 0.3 to 3.1 cmol L^{-1} up to 10 m distance at Ekambarakuppam. At Nagari accumulation of Na^+ , Ca^{++} , Mg^{++} and K content up to 50 m distance ranged from 1.2 to 9.8 cmol L^{-1} , 0.9 to 2.4 cmol L^{-1} , 0.6 to 1.6 cmol L^{-1} , and 0.2 to 0.8 cmol L^{-1} respectively. The accumulations of Na^+ , Ca^{++} , Mg^{++} and K content ranged from 2.3 to 7.2 cmol L^{-1} , 1.5 to 2.3 cmol L^{-1} , 0.9 to 1.3 cmol L^{-1} and 0.5 to 0.7 cmol L^{-1} up to 10 m distance at Satravada respectively.

The Na^+ , Ca^{++} , Mg^{++} and K^+ content at farther distances from the effluent streams (beyond 10 m distance) ranged from 1.0 to 1.8 cmol L^{-1} , 0.5 to 2.4 cmol L^{-1} , 0.3 to 1.6 cmol L^{-1} , 0.4 to 1.4 cmol L^{-1} respectively at Ekambarakuppam whereas at Nagari, Na^+ , Ca^{++} , Mg^{++} , and K content beyond 50 m distance ranged from 0.17 to 0.39 cmol L^{-1} , 0.6 to 1.1 cmol L^{-1} , 0.3 to 0.7 cmol L^{-1} and 0.1 to 0.3 cmol L^{-1} respectively while the same was ranged from 0.7 to 1.9 cmol L^{-1} , 0.4 to 0.9 cmol L^{-1} , 0.2 to 0.5 cmol L^{-1} and 0.1 to 0.4 cmol L^{-1} respectively beyond 10 m distance at Satravada.

Among the anions, the accumulation of Cl^- were the highest followed by HCO_3^- , CO_3^- and SO_4^- in that order at all the three locations of study with the effluents. The accumulation of chlorides was more higher at Ekambarakuppam (1.8 to 24.8 cmol L^{-1}) followed by that of

Nagari (1.4 to 7.8 cmol L^{-1}) and Satravada (2.0 to 6.6 cmol L^{-1}). The accumulation of HCO_3^- , SO_4^- and CO_3^- content ranged from 0.9 to 5.7 cmol L^{-1} , 0.3 to 5.8 cmol L^{-1} and 0.4 to 3.6 cmol L^{-1} up to 10 m distance respectively. At Nagari the HCO_3^- , CO_3^- and SO_4^- content up to 50 m distance ranged from 1.1 to 3.9 cmol L^{-1} , 0.6 to 2.3 cmol L^{-1} and 0.2 to 0.6 cmol L^{-1} respectively. The Cl^- , HCO_3^- , CO_3^- and SO_4^- content at farther distances to all the three locations studied ranged from 0.4 to 2.1 cmol L^{-1} , 0.6 to 2.7 cmol L^{-1} , 0.3 to 1.5 cmol L^{-1} , 0.1 to 1.1 cmol L^{-1} at Ekambarakuppam, Nagari and Satravada respectively.

4.5 EFFECT OF DYEING UNIT EFFLUENT ON NUTRIENT CONTENT OF INDEX LEAF

The data on N, P, K, Ca, Mg, Zn, Cu, Mn and Fe contents of index leaf of rice, groundnut and sugarcane are presented in Table 34, 35 & 36.

4.5.1 Rice

From the data presented in Table 34, it was noticed that the nutrient content of index leaves were low in the immediate vicinity of the stream as compared to farther distances at Nagari. The N, P and K content were found to vary from 2.64 to 2.68 per cent, 0.18 to 0.19 per

cent, and 1.90 to 1.92 per cent respectively at 10 and 25 m distance while calcium and magnesium ranged between 1.21 and 1.32 per cent, 0.26 and 0.38 per cent respectively at same. The micronutrients like Zn, Cu, Fe and Mn ranged from 18.5 to 18.9 mg kg⁻¹, 8.4 to 8.5 mg kg⁻¹, 149.8-150.2 mg kg⁻¹, and 170.2 to 170.8 mg kg⁻¹ respectively at 10 and 25 m distance. Contrary to 10 and 25 m distance all the nutrient were higher beyond 25 m distance. The nutrient contents viz., N, P, K ranged from 3.42 to 3.58 per cent, 0.20 to 0.23 per cent and 2.78 to 2.87 per cent respectively beyond 25 m distance. Where as calcium and magnesium content varied from 1.30 to 1.37 per cent, 0.28 to 0.30 per cent respectively at the same distance. The micro nutrient contents viz., Zn, Cu, Fe and Mn ranged from 24.2 to 25.2 mg kg⁻¹, 9 to 9.7 mg kg⁻¹, and 153.9 to 154.8 mg kg⁻¹ and 175.4 to 175.9 mg kg⁻¹ respectively beyond 25 m distance.

All the nutrients contents in the index leaf of rice grown at all the distances were above the critical limits as proposed by Tandon *et al.* (1993) (N-2.60%, P-0.18%, K- 1.0%, Ca-1.20%, Mg-0.20%, Zn-18ppm, Cu-8 mg ka⁻¹, Fe – 70 mg ka⁻¹ and Mn – 150 mg ka⁻¹).

Table 34: Effect of dyeing unit effluent on nutrient content of index leaf of rice at Nagari

Distance (m)	N%	P%	K%	Ca%	Mg%	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)
0	No crop								
10	2.64	0.18	1.92	1.21	0.26	18.9	8.5	150.2	170.2
25	2.68	0.19	1.90	1.32	0.28	18.5	8.4	149.8	170.8
50	3.42	0.22	2.82	1.36	0.30	24.6	9.0	154.6	175.6
75	3.58	0.23	2.87	1.34	0.28	25.2	9.9	154.8	175.4
100	3.46	0.22	2.78	1.32	0.29	24.8	9.5	154.8	176.1
150	3.44	0.20	2.84	1.30	0.28	24.2	9.7	153.9	175.9
200	3.48	0.22	2.86	1.37	0.28	24.6	9.6	154.7	175.4

Table 34: Effect of dyeing unit effluent on nutrient content of index leaf of rice at Nagari

Distance (m)	N%	P%	K%	Ca%	Mg%	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)
0	No crop								
10	2.64	0.18	1.92	1.21	0.26	18.9	8.5	150.2	170.2
25	2.68	0.19	1.90	1.32	0.28	18.5	8.4	149.8	170.8
50	3.42	0.22	2.82	1.36	0.30	24.6	9.0	154.6	175.6
75	3.58	0.23	2.87	1.34	0.28	25.2	9.9	154.8	175.4
100	3.46	0.22	2.78	1.32	0.29	24.8	9.5	154.8	176.1
150	3.44	0.20	2.84	1.30	0.28	24.2	9.7	153.9	175.9
200	3.48	0.22	2.86	1.37	0.28	24.6	9.6	154.7	175.4

4.5.2 Groundnut

The data on nutrient content of index leaf of groundnut are presented in Table 35. In general all the nutrients studied in the index leaf groundnut were generally lower at 10 m distance from the effluent stream as compared to that of farther distances. The N, P, K, Ca and Mg in the leaf index of groundnut obtained at 10 m distance from effluent stream were 2.58, 0.22, 1.72, 0.81 and 0.34 per cent respectively while the micronutrients like Zn, Cu, Fe, Mn contents were 23.0 mg kg⁻¹, 7.7 mg kg⁻¹, 76.4 and 35.4 mg kg⁻¹ respectively at 10 m distance.

Beyond 10 m distance from the effluent streams, identical values were obtained in case all the nutrients studied. N, P, K content ranged from 2.72 to 2.74 per cent, 0.27 to 0.30 per cent and 1.90 to 1.98 per cent respectively beyond 10 m distance. From 25 m distance to 200 m distance, where as calcium and magnesium content varied from 0.82 to 0.84 per cent, 0.41 to 0.43 per cent respectively. Beyond 10 m distance Zn, Cu, Fe and Mn content ranged from 30.8 to 32.0 mg kg⁻¹, 7.8 to 7.9 mg kg⁻¹, 78.2 to 78.6 mg kg⁻¹ and 40.1 to 40.9 mg kg⁻¹ respectively.

Table 35: Effect of dyeing unit effluent on nutrient content of index leaf of groundnut at Satravada

Distance (m)	N%	P%	K%	Ca%	Mg%	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)
0	No crop								
10	2.58	0.22	1.72	0.81	0.34	23.0	7.0	75.4	35.4
25	2.74	0.27	1.70	0.82	0.41	32.0	7.8	78.2	40.1
50	2.72	0.28	1.96	0.82	0.41	31.6	7.9	78.6	40.6
75	2.72	0.27	1.95	0.82	0.43	30.8	7.8	78.4	40.8
100	2.73	0.30	1.96	0.84	0.42	31.2	7.8	78.2	40.6
150	2.74	0.29	1.98	0.84	0.42	31.4	7.9	78.5	40.1
200	2.76	0.29	1.97	0.82	0.43	31.2	7.8	78.3	40.9

All the nutrients viz., N, P, K, Ca, Mg, Zn, Cu, Fe & Mn in the index leaf of groundnut grown at 10, 25, 75, 100, 150 and 200 m distance were above the critical limits as per the critical limits (P-20, K-1.7, Ca-75, Mg-3.0, Zn - 20 mg kg⁻¹, Cu-6 mg kg⁻¹, Mn 25 mg kg⁻¹ and Fe-68 mg kg⁻¹) proposed by Kanwar (1976) and Indian Council of Agricultural research.

4.5.3 Sugarcane

The data on nutrient contents of N, P, K, Ca, Mg, Zn, Cu, Fe and Mn in index leaf of sugarcane was presented in Table 36.

From the data presented in Table 36, it was noticed that all the nutrients in the index leaf of sugarcane studied at 10 m and 25 m distance were slightly lower as compared to that of farther distances whereas all the nutrient values obtained beyond 25 m distance were almost identical. The N, P, K, Ca and Mg content between 10 and 25 m distance ranged from 2.16 to 2.18 per cent, 0.21 to 0.22 per cent, 1.22 to 1.24 per cent, 0.32 to 0.33 per cent and 0.24 to 0.26 per cent respectively, while the Zn, Ca, Fe and Mn content varied from 38.6 to 38.9 mg kg⁻¹, 7.0 to 7.4 mg kg⁻¹, 232.8 to 236.4 mg kg⁻¹, 60.2 to 60.8 mg kg⁻¹ respectively at yield effected area of 10 m and 25 m distance from effluent stream. Beyond 25 m distance and up to 200 m distance the N,

Table 36: Effect of dyeing unit effluent on nutrient content of index leaf of sugarcane at Ekambarakuppam

Distance (m)	N%	P%	K%	Ca%	Mg%	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)
0									
	No crop								
10	2.18	0.21	1.22	0.33	0.24	38.6	7.4	236.4	60.2
25	2.16	0.22	1.24	0.32	0.26	38.9	7.0	232.8	60.8
50	2.59	0.28	1.82	0.46	0.30	46.2	10.2	246.4	74.3
75	2.56	0.27	1.80	0.49	0.31	48.2	10.6	245.8	74.8
100	2.58	0.29	1.84	0.45	0.33	48.5	10.1	246.1	74.5
150	2.56	0.28	1.86	0.48	0.30	48.4	9.9	246.6	75.1
200	2.54	0.29	1.84	0.47	0.32	48.6	10.4	245.9	74.9

P, K, Ca, Mg ranged from 2.54 to 2.59 per cent, 0.27 to 0.29 per cent, 1.80 to 1.86 per cent, 0.45 to 0.49 and 0.30 to 0.33 per cent respectively. While the Zn, Ca, Fe, Mn content ranged from 46.2 to 48.6 mg kg⁻¹, 9.9 to 10.6 mg kg⁻¹, 245.8 to 246.6 mg kg⁻¹ and 74.3 to 75.1 mg kg⁻¹ respectively. Considering the critical limits N-2.0 per cent, P-0.18 per cent, K-1.10 per cent, Ca-0.20 per cent, Mg-0.10 per cent, Zn-40 mg kg⁻¹, Cu- 7 mg kg⁻¹, Mn-25 mg kg⁻¹, Fe-40 mg kg⁻¹, in sugarcane index leaf proposed by Tandon *et al.* (1993) and plant samples analysed during this study at the all distances were found sufficient.

4.6 INFLUENCE OF DYEING UNIT EFFLUENTS ON MEAN YIELD OF RICE, GROUNDNUT AND SUGARCANE AT VARIOUS DISTANCES IN THE YEAR 2001

The fields adjoining effluent streams were continuously effected due to dyeing unit effluents discharged from the dyeing units for the last eight years. The effects of effluents on the crop productivity were studied by recording yield data in the adjoining land from 10 m to 200 m distance from the effluent stream. Rice was the mainly principle crop cultivated around Nagari mandal followed by sugarcane and ground nut. The rice, groundnut, sugarcane were generally cultivated in the fields adjoining effluent streams at Nagari, Satravada and Ekambarakuppam villages respectively.

The data (Table 37) on the yield of these crops at varying lateral distances were collected as per the procedure given under materials and methods. The effect of effluents was reflected on reduction of yield of rice, groundnut, sugarcane grown in the immediate vicinity of effluent stream at all the three locations studied. No crop was grown at 0 m distance at Nagari, Satravada and Ekambarakuppam. Yield reduction was noticed at 10 m and 25 m distance at Nagari, 10 m distance at Satravada, 10 m and 25 m at Ekambarakuppam. The adverse effects was not reflected on the yield of rice beyond 25 m distance at Nagari, beyond 10 m distance at Satravada where as the yield reduction in case of sugarcane was not observed beyond 25 m distance from effluent stream. The lowest yield of rice and groundnut was recorded at 10 m distance (4941 kg ha^{-1}) and 25 m distance (5262 kg ha^{-1}) at Nagari and at 10 m distance (2000 kg ha^{-1}) at Satravada respectively, where as the lowest yield observed at 10 m, 25 m distance from effluent stream was 74.4 t ha^{-1} and 80.5 t ha^{-1} respectively as compared to other distances. The yield reduction of rice at Nagari was 10 and 45 per cent at 10 and 25 m distance respectively during summer season where as the 28.6 per cent of ground nut yield reduction was noticed as compared to 200 m distance. The variation in sugarcane yield reduction from 6.9 to 14 per cent was recorded between 10 and 25 m distance at Ekambarakuppam

at 25 m, 10 m and 50 m distances from effluent stream and
 distance, the average yield of rice, groundnut, sugarcane
 of farmers varied from 5444 to 5566 kg ha⁻¹, 2690 to 2800

Table 37: Influence of dyeing unit effluent on mean yield of rice, groundnut and sugarcane at various distances at Nagari, Satravada and Ekambarakuppam in the year 2001

Distance (m)	Nagari	Satravada	Ekambarakuppam
	Rice yield (kg ha ⁻¹)	Groundnut yield (kg ha ⁻¹)	Sugarcane (t ha ⁻¹)
0	No crop	No crop	No crop
10	4941 (10%)	2000 (28.6%)	74.4 (14%)
25	5262 (4.5%)	2750	80.5 (6.9%)
50	5444	2710	83.2
75	5575	2780	82.8
100	5455	2690	86.1
150	5566	2750	87.8
200	5508	2800	86.5

Value in bracket indicates per cent yield reduction.

at 25 m, 10 m and 50 m distance from effluent stream and

hence, the overall yield of rice, groundnut, sugarcane

Yields varied from 5444 to 5566 kg ha⁻¹, 2690 to 2800

Table 37: Influence of dyeing unit effluent on mean yield of rice, groundnut and sugarcane at various distances at Nagari, Satravada and Ekambarakuppam in the year 2001

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75	5575	2780	82.8
100	5455	2690	86.1
150	5566	2750	87.8
200	5508	2800	86.5

Value in bracket indicates per cent yield reduction.

village. Beyond 25 m, 10 m and 50 m distance from effluent stream and up to 200 m distance, the normal yield of rice, groundnut, sugarcane obtained by the farmers varied from 5444 to 5566 kg ha⁻¹, 2690 to 2800 kg ha⁻¹, and 82.8 to 87.8 t ha⁻¹ up to 200 m distance respectively.

Discussion

CHAPTER 4V
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CHAPTER – V

DISCUSSION

“Effect of effluents discharged from dyeing industries on soil, water and crop quality in Nagari mandal, Chittoor district, Andhra Pradesh” was judged by studying the quality of ground water, properties of adjoining soils and yield of crops at different distances from the effluent stream after critically analyzed are discussed in this chapter.

5.1 QUALITY OF EFFLUENT

The results obtained (Table 6) have clearly shown that there was wide variation in the quality of effluent as compared to that of ground water at all the three locations studied. The physicochemical analysis of the effluent revealed that the effluent discharged from dyeing units at all the three locations were having different colours but not having offensive odour. Red, green, yellow and blue colours of effluent discharged from dyeing units located at Nagari, Satravada and Ekambarakuppam might be due to the nature of dyes used from time to time during the dyeing process involved in the dyeing unit technology. The temperature was normal and almost identical at all the three locations studied (30°, 29° and 30°C).

The effluents of three sampling sites were alkaline having pH range 9.0-9.6 which was slightly higher than the limits (pH 5.5-9.0) prescribed by Indian Standard Institution (1981). The effluent contained significant amount of soluble salts (5.5 to 5.6 dSm^{-1}), calcium (5.5 to 5.6 cmol L^{-1}), magnesium (3.5 - 3.7 cmol L^{-1}), sodium (31.4 - 34.2 cmol L^{-1}), potassium (4 - 4.2 cmol L^{-1}) chlorides (30.8 - 32.2 cmol L^{-1}), sulphates (6.8 - 7.0 cmol L^{-1}), carbonates (0.6 - 0.9 cmol L^{-1}) and bicarbonates (7.0 - 7.8 cmol L^{-1}). The soluble salt content sodium and chlorides of effluent were very high when compared to Indian standard institution limits (Appendix III). The considerable amount of micronutrients as compared to that of ground water present in the effluent collected from dyeing units at Nagari, Satravada and Ekambarakuppam unlike micronutrients the effluent lack heavy metals like Cd, Pb, Ni and Cr. The chemicals used in dyeing factories like Hydrochloric acid, Sodium nitrate, Aluminium sulphate, Caustic soda and Soda ash might be responsible for high pH, turbidity, EC, calcium, magnesium, sodium, potassium, chlorides, sulphates, carbonates and bicarbonates. From the results it was evident that the high amount of suspended solids, higher soluble salt content and high concentration of sodium and chlorides present in the dyeing factory effluent might impart toxicities of the effluent. Similar results were also reported by Soma Sekhar *et al.* (1984), Swaminathan and Vaidheswaran (1991).

5.2 THE EFFECT OF EFFLUENTS ON GROUND WATER QUALITY

From the data presented in Table 7, 9 and 11, salt accumulation in ground water in the immediate vicinity of stream was much higher at Ekambarakuppam followed by Satravada and Nagari as compared to that of farther distances. The salt accumulation as indicated by EC varied from 1.28 to 4.48 dSm⁻¹ at Ekambarakuppam, 0.92 to 2.92 dSm⁻¹ at Satravada, 0.88 to 2.86 dSm⁻¹ at Nagari over the 18 years effect of effluents. The higher salt accumulation in ground waters as compared to that of further distances apparently was result of very high salt content in the effluent (5.5 to 5.6 dSm⁻¹).

The higher salt accumulation up to a distance of 86 m at Ekambarakuppam ranging from 0.86 to 4.48 dSm⁻¹ as compared to that of other distances was mainly due to the more number of dyeing units located at sampling sites so as to increase the more amount of effluent discharged from dyeing units continuously into the stream and also due to coarse textured nature of the soil (Table 7, 9 and 11). The soluble salt content of polluted ground water due to effluent at 0 m distance (4.48 dSm⁻¹) at Ekambarakuppam, 0 m distance (2.86 dSm⁻¹) at Nagari and at 0 m distance Satravada (2.92 dSm⁻¹) above the safe limit of 2.25 dSm⁻¹

prescribed by Indian Standard Institution (1983) (Appendix III). The data obtained (Table 7,9 and 11) indicated deleterious effects of dyeing unit effluents on quality of ground water in the immediate vicinity of the stream. The cationic and anionic composition showed that nature of the salts accumulated had a close linkage with quality of the effluent discharged from dyeing units. The adverse effects of dyeing unit effluent on the quality of ground water had been reported by several workers (Gupta and Jain, 1992; Gupta, 1999 and Sharma *et al.*, 2000).

People living around the study area have faced problems of deteriorated ground water quality for drinking and special arrangement has to be made to ensure drinking water to the effected people which was noticed during the field study.

The micronutrients viz., Zn, Cu, Fe and Mn in the ground water adjoining effluent stream were much higher as compared to farther distances. The higher micronutrients in ground water in the immediate vicinity of the stream as compared to farther distances (Table 8, 10 and 12) apparently was a result of very higher micronutrients in the effluent at all the three locations studied (Table 6). However all the micronutrients in ground water adjoining effluent stream were below the safe limits (Zn-5 mg L⁻¹, Fe-.3 mg L⁻¹, Cu-.05 mg L⁻¹ and Mn-.1 mg L⁻¹)

as prescribed by Indian Standard Institution (1983). Ashok kumar *et al.* (1998) also reported the higher content of micronutrients in the ground water effected due to mixed industrial effluents in Uttar Pradesh. Totalawat (1993) also reported higher micronutrients concentration in ground water adjoining smelters effluent stream at Udaipur districts of Rajasthan.

The data clearly indicated that the kind of properties / constituents and soil properties were significantly influence the ground water quality. Apparently the percolating effluents in the process of vertically down ward and lateral movement was getting reduced in the different kinds of salts and ions through a process of ion exchange between percolating effluent and soil colloids on one hand and through various kinds of chemical reactions with other soil constituents, which were changing from location to location.

5.3 IMPACT OF EFFLUENTS ON PHYSICOCHEMICAL PROPERTIES AND NUTRIENT STATUS OF THE SOILS

To find out the effect of effluent on the properties of soils adjacent to effluent stream, soils samples were collected at different distances from the effluent stream to an extent of 200 m. The soil analysis data on both physicochemical properties and nutrient status presented in results chapter are discussed here under.

Physico-chemical properties of soils

Soil reaction (pH): The pH of the soils was significantly influenced either by lateral distance (or) vertical depth at all the three locations studied. The trend of significant variation from 0 m to 200 m distance from the effluent stream was might be due to the varied mechanical behavior of the soil and different cultivation and management practices adopted by the farmers. The effect of effluent on soil pH was not observed in the immediate vicinity of the stream. This appears to become have possible due to fact that the pH itself is related to buffering capacities of the soil. Similar results were also reported by Kotaiah (1999), Sharma *et al.* (2000) and Moharana and Nepal Singh (2001).

Salinity (EC)

Dyeing unit effluent significantly increased the soil salinity around the effluent streams at varying distances at all the three locations (Table 15). There was variation in the extent of influence of the effluent on soil salinity at three places. The influence of effluents was maximum at Ekambarakuppam to a lateral distance of 25 m. In case of Nagari, the effect was seen up to 75 m distance and at Satravada the effect was up to 25 m distance from the effluent stream. The variation in the spread of salts at the three locations might be attributed to EC of effluent. It was highest (3.63 dSm^{-1} , 1.06 dSm^{-1} and 0.80 dSm^{-1}) at all the three

locations. The variations might also due to the factor like slope of the soil, nature of sub soil and management practices adopted by the farmer around effluent stream. The soil adjacent to effluent stream at Ekambarakuppam was more saline compared to other locations. This might be due to the more number of dyeing units located around Ekambarakuppam, which was responsible for the discharge of more quantity of effluent from dyeing units. The salt accumulation was higher in surface layers as compared to that of sub surface layers. Coincidence of the sampling time with summer season might be the cause of higher accumulation of soluble salts in the surface layers of the soil as compared to sub surface layers. Kotaiah (1999) also studied the same trend of accumulation of salts (2.650 to 4.120 dSm^{-1}) in the soils adjacent to effluent stream at Nagari region of Chittoor districts in Andhra Pradesh. Similar results were also reported by Sharma *et al.* (2000) and Moharana and Nepal Singh (2001).

Organic Carbon (OC)

Organic carbon content in the soils adjacent to effluent streams was significantly influenced at lateral and vertical distances of soils (Table 17). Organic carbon was more around the streams up to distance of 200 m at Ekambarakuppam, 50 m at Nagari and 100 m at Satravada. Continuous higher moisture content of soils adjacent to the effluent

stream coupled with higher salt content might have significant influence on the microflora in the soils adjacent to the effluent stream which might have resulted in less decomposition of organic matter that lead to its accumulation. Kotaiah (1999) also reported that the accumulation of organic carbon content in soils adjacent to dyeing unit effluent stream ranging from 3.85 to 8.6 per cent at Nagari region of Chittoor District, in Andhra Pradesh. The accumulation of organic carbon was more in surface soil followed by sub-soil. This might be mainly due to the translocation of soluble organic compounds towards lateral distances and it subsequently spread towards the surface layer due to evaporation of water at the surface. Coincidence of sampling time during the summer might in the cause for the translocation of soluble organic compounds towards the surface layer.

Nutrient status of soils

Available micronutrients viz., Zn, Fe, Mn and Cu were significantly influenced by the distance of sampling from the effluent stream and depth of soil at all the three locations studied (Table 19-26). The accumulation of micronutrients were more in the soils adjacent to effluent stream. The accumulation of Zn was up to 50 m distance (4.941 to 1.744 mg kg⁻¹), 25 m distance (4.079 to 1.338 mg kg⁻¹) and 50 m distance (4.926 to 3.120 mg kg⁻¹), as compared to farther distances at

Nagari, Satravada and Ekambarakuppam respectively. In case of Cu, significantly higher was noticed up to 25 m distance at Satravada (3.479 to 2.720 mg kg⁻¹), 25 m distance at Nagari (2.199 to 3.281 mg kg⁻¹) and 25 m distance at Ekambarakuppam (2.951 to 3.093 mg kg⁻¹) as compared to farther distances. Similar to copper, the accumulation of Fe was more as compared to farther distances up to 25 m distance at Nagari (3.597 to 5.415 mg kg⁻¹) and up to 50 m distance at Satravada (3.172 to 6.303 mg kg⁻¹) and up to 50 m distance at Ekambarakuppam (4.168 to 7.203 mg kg⁻¹). The same trend of accumulation of Mn due to effluents was continued up to 10 m at Nagari (3.545 to 3.755 mg kg⁻¹) at Satravada (2.776 to 3.187 mg kg⁻¹), and Ekambarakuppam (2.933 to 3.122 mg kg⁻¹) respectively. In general the available micronutrients viz., zinc, copper, Iron and manganese were significantly higher in soils in immediate neighborhood of soils as compared to soils away from stream. The higher micronutrients in the neighborhood of the stream was mainly due to the presence of considerable amount of micronutrients in the effluents at all the three locations studied (Table 19-26). Another reason for higher concentration of micronutrients was the presence of higher amount of organic carbon in the immediate neighborhood of the effluent stream (Table 17 and 18).

The accumulation of micronutrients like Manganese and Zinc adjoining in soil Tanneries was reported by Narendra Sivaswamy (1991). Matli Srinivasachari (1999) has been reported the accumulation of DTPA extractable micronutrients in soils around Sun Paper Mills Limited of Charanmahadevi of Tamilnadu.

Effect of effluents on soluble salt content in the adjoining soils:

Were observed to have close relation with composition of effluents (Table 31, 32 and 33) the salt accumulation was much higher at Ekambarakuppam followed by Nagari and Satravada. The reason for higher salt accumulation at Satravada was due to the continues flowing of effluents discharged from more number of dyeing units over a period of time. The dominant cation in soil was sodium at all the three locations studied (Table 31, 32 and 33). There by indicating alkali hazards with dyeing unit effluents. The next dominating cation in soil was calcium while magnesium content was slightly higher than the potassium. These variations in the soluble salt content in the soils again was manifestation of the variation in the composition of effluents discharged from dyeing units rather than the soils at macro level. The data showed that the most dominating influence of soluble salts of Na^+ and calcium compared to that of Mg^{++} and K^+ .

Among the anions, chlorides were dominating in the adjoining soils of effluent streams. The next dominating anion in the soil was bicarbonates followed by the carbonates and sulphates. Similar results were also reported by Sharma *et al.* (2000) and Moharana and Nepal Singh (2001) in soils adjacent to textile effluents.

Nutrient status of index leaves:

The nutrients content of rice, ground nut and sugarcane index leaves namely N, P, K, Ca, Mg, Zn, Cu, Mn, Fe were row in the immediate vicinity of the streams ac compared to farther distances at Nagari, Satravada and Ekambarakuppam respectively (Table 34, 35 and 36). However the nutrients values obtained from the index leaves of rice, groundnut and sugarcane were well above critical limits for rice and sugarcane proposed by *Tandon et al.* (1993) and for groundnut proposed by *Kanwar* (1976). The lower nutrient content of index leaves in respect of all the crops might be due to unfavorable physical and chemical environment in the soils which would have resulted in less absorption of the nutrients by the plants. It was evident from the accumulation of considerable of amount of soluble salts in the immediate vicinity of the effluent stream as compared to the distances far away from the effluent stream. Farmers in Nagari region have also reported to the district revenue authorities about the degradation of the soils due to effluent strem.

Effect of dyeing unit effluents on crop productivity

Data on crop yield showed that drastic reduction on crop yield of groundnut at Satravada was noticed as compound to that of yield of sugarcane and groundnut (Table 37). No Crop could be taken up by the farmers adjacent to effluent streams during the study period at all the three locations studied. The paddy yield reduction at Nagari was 10 per cent at 10 m distance and 45 per cent at 25 m distance while sugarcane yield reduction at Ekambarakuppam was 14 and 6.9 per cent at 10 and 25 m distance from effluent stream respectively. The groundnut yield was more or less similar beyond 10 m distance at Satravada, except at 10 m distance where maximum reduction was (28.6%) was observed as compared to other two locations. The drastic reduction of groundnut yield (28.6%) at 10 m distance at Satravada was due to the salt sensitive nature of the crop grown adjoining effluent streams. This was evident from the research findings in which the crop was placed under the salt semi tolerant crop. The crop effected due to effluent as reflected by the reduction in the yield was sugarcane at Ekambarakuppam followed by rice at Nagari. These adverse effects reflected the variation in the EC of sugarcane and rice grown soils. Electrical conductivity of effluents was in the order Ekambarakuppam (5.6 dSm-1) > Nagari (5.5 dSm-1) > Satravada (5.5 dSm-1) similar results were also reported by Devarajan and Oblisami (1995), Matlisrinivasachari *et al.* (1999) and Swaminathan and Vaideeswaran (1991).

The results indicate that the adverse effects of dyeing unit effluents were severe up to 25 m distance, 10 m distance and 25 m distance from effluent stream at Nagari, Satravada and Ekambarakuppam.

The farmers in the area have reported to the district revenue authorities demanding the abonding of dyeing units constructed in the villages of Nagari Mandal in Andhra Pradesh as the these dyeing units in their opinion spoiled the ground water, yield of crops grown adjoining effluent streams (Eenadu, 2000). Quantified information in the adverse effects of the dyeing unit effluents was not available. Results of the present investigation clearly indicated that there was deterioration in the physico-chemical and chemical properties of soils, quality of ground water and crops grown adjoining effluent streams.

Summary

CHAPTER - VI

SUMMARY

Studies on the Effect of effluents discharged from dyeing industries on soil, water, crop quality in Nagari mandal of Chittoor district, Andhra Pradesh were conducted with the specific objectives

- Physical and chemical characterization of effluents discharged from dyeing industries.
- To investigate the influence of dyeing unit effluents on soil chemical properties and ground water quality.
- To investigate the nutrient content of plant samples collected from the crops grown adjacent to the streams contaminated with the effluents.
- To investigate the yield levels of crops grown adjoining streams.

The study was carried out in three different locations of Nagari mandal in Chittoor district of Andhra Pradesh. The location selected for the study were Nagari, Satravada and Ekambarakuppam. The quality of effluent discharged from dyeing units at all the three locations were studied.

Ground water samples from wells/bore wells adjoining effluent stream were collected at 0, 10, 32, 52, 84, 106, 158, 212, 510 m and 760

m distance from the effluent stream at Nagari, 0, 14, 28, 45, 105, 158, 205, 490 m and 760 m from effluent stream at Satravada and 0, 13, 32, 54, 86, 110, 164, 210, 512 m and 780 m from effluent stream at Ekambarakuppam in month of April, 2001. The effluent discharged from dyeing units located at the villages of Nagari, Satravada and Ekambarakuppam was also collected in the April, 2001. Ground water and effluent samples were analysed for pH, EC, Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^- , HCO_3^- , Cl^- , SO_4^- heavy metals viz., Cd, Pb, Ni, Cr and Micronutrients viz., Zn, Cu, Fe and Mn for assessing the effect of effluent on soil and ground water adjoining effluent streams.

Soil samples were collected at different lateral distances of 0, 25, 50, 75, 100, 150 m and 200 m away from effluent stream at three locations at 0-15, 15-30 and 30-45 cm depth. These samples were analysed for physico-chemical properties and chemical properties of soils like pH, EC, OC, Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^- , HCO_3^- , Cl^- , SO_4^- , and heavy metals like Cd, Pb, Ni, Cr, micronutrients like Zn, Cu, Fe and Mn, water soluble ions (saturation extract of soils) viz., Ca^{++} , Mg^{++} , Na^+ , K^+ , CO_3^- , HCO_3^- , Cl^- , SO_4^- and EC of saturation extract of soil, the yield of rice, ground nut and sugarcane grown adjoining effluent stream located at villages of Nagari, Satravada and Ekambarakuppam respectively were collected at different distances 10, 25, 50, 75, 100, 150 m and 200 m from the stream in the summer season of 2001.

The index leave sample were analysed for N, P, K, Ca, Mg, Zn, Cu, Mn and Fe. The yield of rice, groundnut and sugarcane at 10, 25, 50, 75, 100, 150 m and 200 m distance away from the effluent stream at Nagari, Satravada, Ekambarakuppam were recorded respectively.

The results obtained and conclusions drawn were summarized below.

Characteristics of the effluent

1. The temperature range of (29-30°C), suspended solids (120-125 mg L⁻¹) and turbidity (355-360 mg L⁻¹) values were almost identical at Nagari, Satravada, Ekambarakuppam.
2. The effluent of all the three villages had shown high values of pH (alkaline reaction), EC and OC content at Nagari, Satravada and Ekambarakuppam pH (9.0-9.6), EC (5.5-5.6 dSm⁻¹) and OC (2.0-2.2%) values did not vary at all the three locations studied.
3. Na⁺ (31.4 to 34.2 cmol L⁻¹) was the dominating cation in the effluent at all the three locations. The next dominating cation in the effluent was Ca⁺⁺ (5.5 to 5.6 cmol L⁻¹) followed by K⁺ (4-4.2 cmol L⁻¹) and Mg⁺⁺ (3.5-3.7 cmol L⁻¹).

4. Among the anions, chloride was the dominating anion in the effluent (30.8 to 32.2 cmol L⁻¹). The next dominating anion was HCO₃⁻ (7.0 to 7.8 cmol L⁻¹) followed by SO₄⁻ (6.8-7.0 cmol L⁻¹) and CO₃⁻ (0.6 to 0.9 cmol L⁻¹).
5. The effluent discharged from dyeing units had relatively more micro nutrients like Zn, Cu, Fe and Mn as compared to the groundwater faraway from the effluent stream. Mn was the dominant micronutrient (0.54 to 0.58 mg L⁻¹) followed by Fe (0.35-0.36 mg L⁻¹) and Cu (0.17 to 0.18 mg L⁻¹), while Zn was least in the effluent (0.079 to 0.100 mg L⁻¹).
6. The heavy metals like Cd (0.024-0.33mg L⁻¹), Pb (0.13- 0.15mg L⁻¹), Ni (0.172-0.179mg L⁻¹), Cr (0.330-0.335mg L⁻¹) did not vary widely at all the distances at Nagari, Satravada and Ekambarakuppam.
7. The heavy metals like Cd, Pb, Ni and Cr obtained from effluent and ground water were almost identical.
8. The effects of effluent on the salt concentration both cationic and anionic composition and micronutrients was relatively more in the ground water in the immediate vicinity of effluent stream as compared to distances far away from effluent steam in the study period of April, 2001.

Quality of ground water adjoining effluent streams

9. The effluents discharged from dyeing units at Nagari, Satravada and Ekambarakuppam adversely effected the quality of the ground water in terms of soluble salt content (EC), Na^+ , Cl^- , Ca^{++} , K^+ and Mg^{++} and relatively increased the micronutrients contents of ground water.
10. The adverse effects of effluent gradually decreased with varying lateral distances depending upon the property/constituent and location of the effluent streams, which apparently varied from location to location.
11. The adverse effects of effluent on the ground water quality was higher at Ekambarakuppam as compared to Nagari and Satravada.
12. The soluble salt content of groundwater adjoining effluent streams were above the permissible levels at 0 m distance (4.48 dsm^{-1}) at Ekambarakuppam, 0 m distance (2.86 dsm^{-1}) at Nagari and at 0 m distance (2.92 dsm^{-1}) at Satravada from the effluent stream was above safe limit of 2.25 dsm^{-1} prescribed by Indian Standard Institution (1983).

13. Under the influence of effluent streams, ionic constituents (micro nutrients and other cationic and anions) in the ground water nearer to effluent streams were more as compared to distances away from the effluent streams.
14. Groundwater adjoining effluent streams at Satravada and Ekambarakuppam contained relatively higher amounts of micronutrients Zn, Cu, Fe and Mn but these were below the permissible levels for drinking.
15. The streams carrying effluent discharged from dyeing units located at Nagari, Satravada, Ekambarakuppam generally increased the salt concentration, cationic and anionic composition and micronutrients in the ground water especially in the immediate vicinity of effluent stream during the study period.

Soil properties

16. The soils collected at different depths 0-15, 15-30 and 30-45 cm adjoining effluent streams showed deterioration in soil properties. Soils at three depths nearer to effluent streams had higher pH, EC, OC and micronutrients.

17. The soils collected in the immediate vicinity of effluent streams contained relatively higher proportions of micronutrients but these were below the permissible polluting levels whereas the tendency of accumulation of heavy metals were less in the soils nearer to the effluent streams.

18. The adverse effects of soil salinity due to effluent streams were more at Ekambarakuppam as compared to Nagari and Satravada. The higher soil salinity was up to 25 m ($0.59 - 1.06 \text{ dSm}^{-1}$), 25m ($0.29 - 0.80 \text{ dSm}^{-1}$) and 75 m ($0.50 - 3.63 \text{ dSm}^{-1}$) distance from effluent stream at Nagari, Satravada, Ekambarakuppam, respectively. EC of the soils adjoining effluent streams ranged from 0.19 to 1.27 dsm^{-1} , 0.16 to 0.80 dsm^{-1} , 0.29 to 3.63 dsm^{-1} at Nagari, Satravada and Ekambarakuppam, respectively.

19. The adverse effects of effluent on the EC of soil were severe at all the three depths of the soil in the immediate vicinity of the stream.

20. Among the water soluble ions, considerable build up of Na at three depths of the soil was noticed followed by that of calcium and magnesium at Nagari, Satravada and Ekambarakuppam. Among the anions the accumulation of chlorides was higher

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followed by HCO_3^- , SO_4^{--} and CO_3^{--} . Effluent stream generally increased the concentration of water soluble ions in the immediate neighborhood of the stream.

Nutrient status of index leaf

21. The concentration of N, P, K, Ca, Mg, Zn, Cu, Fe, Mn in the index leaf of rice, groundnut and sugarcane collected during the study period were relatively lower in the immediate vicinity of the stream as compared and to the farther distances. However the concentration of all these elements studied in index leaf of rice, groundnut and sugarcane were found to be sufficient.

Crop yield

22. The adverse effects of effluents on crop yield of groundnut at Satravada were more severe as compared to that rice and sugarcane grown at Nagari and Ekambarakuppam respectively. No crop could be taken up by the farmers adjacent to effluent streams during the study period at all the three locations. Reduction in yield of paddy at Nagari was 10 per cent at 10 m distance and 4.5 per cent at 25 m distance while sugarcane yield reduction at Ekambarakuppam was 14 per cent and 6.9 per cent at

10 and 25 m distance from effluent stream respectively. The groundnut yield reduction at Satravada was 28 per cent at 10 m distance from the effluent stream. The adverse effects of effluents reflected on the rice yields up to 25 m distance at Nagari, upto 25 m distance at Ekambarakuppam and up to 10 m distance at Satravada.

23. Results in the present investigations clearly brings out the need for adequate pollution control measures and proper treating of the effluent before discharging from dyeing units into effluent streams so as to reduce the toxic constituent in the effluent and effluent disposal system to reduce the adverse effects of effluents in the soils and ground water. There is a need to take up legislation regarding the location of dyeing industries so as to maintain sufficient distance from agriculture fields and drinking irrigation water sources around human habitations.

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Date	Time	Temp	Wind	Humidity	Pressure	Rain	Clouds	Remarks	Remarks
1/1	0800	15.0	10.0	75.0	1010.0	0.0	10.0		
1/1	1200	18.0	15.0	70.0	1010.0	0.0	10.0		
1/1	1600	15.0	10.0	75.0	1010.0	0.0	10.0		
1/1	2000	12.0	5.0	80.0	1010.0	0.0	10.0		
1/1	2400	10.0	5.0	80.0	1010.0	0.0	10.0		
1/2	0000	10.0	5.0	80.0	1010.0	0.0	10.0		
1/2	0400	10.0	5.0	80.0	1010.0	0.0	10.0		
1/2	0800	12.0	10.0	75.0	1010.0	0.0	10.0		
1/2	1200	15.0	15.0	70.0	1010.0	0.0	10.0		
1/2	1600	18.0	20.0	65.0	1010.0	0.0	10.0		
1/2	2000	15.0	15.0	70.0	1010.0	0.0	10.0		
1/2	2400	12.0	10.0	75.0	1010.0	0.0	10.0		
1/3	0000	10.0	5.0	80.0	1010.0	0.0	10.0		
1/3	0400	10.0	5.0	80.0	1010.0	0.0	10.0		
1/3	0800	12.0	10.0	75.0	1010.0	0.0	10.0		
1/3	1200	15.0	15.0	70.0	1010.0	0.0	10.0		
1/3	1600	18.0	20.0	65.0	1010.0	0.0	10.0		
1/3	2000	15.0	15.0	70.0	1010.0	0.0	10.0		
1/3	2400	12.0	10.0	75.0	1010.0	0.0	10.0		

Appendices

Date	Time	Temp	Wind	Humidity	Pressure	Rain	Clouds	Remarks	Remarks
1/4	0000	10.0	5.0	80.0	1010.0	0.0	10.0		
1/4	0400	10.0	5.0	80.0	1010.0	0.0	10.0		
1/4	0800	12.0	10.0	75.0	1010.0	0.0	10.0		
1/4	1200	15.0	15.0	70.0	1010.0	0.0	10.0		
1/4	1600	18.0	20.0	65.0	1010.0	0.0	10.0		
1/4	2000	15.0	15.0	70.0	1010.0	0.0	10.0		
1/4	2400	12.0	10.0	75.0	1010.0	0.0	10.0		
1/5	0000	10.0	5.0	80.0	1010.0	0.0	10.0		
1/5	0400	10.0	5.0	80.0	1010.0	0.0	10.0		
1/5	0800	12.0	10.0	75.0	1010.0	0.0	10.0		
1/5	1200	15.0	15.0	70.0	1010.0	0.0	10.0		
1/5	1600	18.0	20.0	65.0	1010.0	0.0	10.0		
1/5	2000	15.0	15.0	70.0	1010.0	0.0	10.0		
1/5	2400	12.0	10.0	75.0	1010.0	0.0	10.0		

APPENDIX – II

Monthly weather data during the study period 2001 at Nagari region, Chittoor district

Month	Rainfall (mm)	Temperature (°C)		Mean RH (%)	Sunshine hours	No. of rainy days	Mean evaporation (mm)
		Maximum	Minimum				
January	-	27.5	15.8	67.5	7.4	-	4.4
February	-	33.2	20.4	64.0	9.1	-	5.7
March	-	34.6	20.7	52.5	9.5	-	6.5
April	-	38.7	24.5	42.3	10.0	-	7.8
May	79.6	39.0	27.4	40.4	10.4	3	8.4
June	87.8	39.5	27.8	50.3	10.8	5	8.0
July	30.9	38.7	26.0	61.5	8.7	2	7.8
August	62.6	35.9	27.4	70.2	7.4	6	7.9
September	70.4	34.5	23.4	63.5	7.5	4	6.8
October	119.6	32.1	24.5	68.3	5.4	10	5.3
November	109.8	30.5	19.4	68.4	6.8	7	3.8
December	24.8	28.5	16.1	58.5	8.3	2	4.6

APPENDIX – III

ISI* (1983) Standards for irrigation and potable water IS: 10500

S. No	Test	Unit	Standards for potable and irrigation waters ISI*
1	PH	-	6.5-8.5
2	EC	dSm ⁻¹	2.25 dSm ⁻¹
3	Total Dissolved Salts	mg L ⁻¹	500
4	Chlorides	mg L ⁻¹	250
5	Sulphates	mg L ⁻¹	150
6	Flouride	mg L ⁻¹	0.6-1.2
7	Nitrare	mg L ⁻¹	45
8	Cu	mg L ⁻¹	0.05
9	Fe	mg L ⁻¹	0.3
10	Mn	mg L ⁻¹	0.1
11	Zn	mg L ⁻¹	5.0
12	Cd	mg L ⁻¹	0.01
13	Pb	mg L ⁻¹	0.10
14	Cr	mg L ⁻¹	0.05
15	Ni	mg L ⁻¹	-



Plates



Plate No.1: The drain of dyeing unit effluents flowing in Nagari



Plate No.2: The process of dyeing by the workers in Satrvada



PlateNo. 3: The process of dyeing by the workers in Satravada

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