Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil

by

SOPHIA BABY

(2016-11-041)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR 680656

KERALA, INDIA

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THESIS

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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VELLANIKKARA, THRISSUR 680656

KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **“Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil”** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara	Sophia Baby
27-04-2019	(2016-11-041)

CERTIFICATE

Certified that this thesis entitled **“Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil”** is a record of research work done independently by Ms. Sophia Baby (2016-11-041) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara

27-04-2019

Dr. Betty Bastin,

Professor (Soil Science and Agricultural Chemistry),

Department of Soil Science and Agricultural Chemistry,

College of Horticulture, Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Sophia Baby, a candidate for the degree of Master of Science in Agriculture with major field in Soil Science and Agricultural Chemistry, agree that the thesis entitled **"Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil"** may be submitted by Ms. Sophia Baby, in partial fulfilment of the requirement for the degree.

Dr. Betty Bastin
(Major Advisor, Advisory Committee)
Professor
Department of Soil Science and Agricultural Chemistry
College of Horticulture, Vellanikkara

Dr. Jayasree Sankar S.
(Member, Advisory Committee)
Professor and Head
Department of Soil Science and Agricultural Chemistry,
College of Horticulture, Vellanikkara

Dr.Usha K. E.
(Member, Advisory Committee)
Professor (Agronomy)
Plant Propagation and
Nursery Management Unit
Vellanikkara

Dr. P. Anitha
(Member, Advisory Committee)
Associate Professor
All India Coordinated Vegetable
Improvement Project
Department of Olericulture
College of Horticulture, Vellanikkara

Dr. Susan John. K
(External examiner)

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Sophia Baby

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LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
$\mu g\ g^{-1}$	Microgram per gram
^0C	Degree Celsius
AOAC	Association of Official Analytical Chemists
ATP	Adenosine tri-phosphate
$BaCl_2$	Barium chloride
BDL	Below detectable level
$CaCl_2$	Calcium chloride
$CaCO_3$	Calcium carbonate
CD	Critical difference
cm	Centimetre
CRD	Completely randomised design
DAT	Days after transplanting
Day^{-1}	Per day
DMRT	Duncan's multiple range test
$dS\ m^{-1}$	Deci Siemen per metre
EC	Electrical conductivity
et al	and co-workers
FAO	Food and Agriculture Organisation
Fig.	Figure
FYM	Farm yard manure

g	Gram
g^{-1}	Per gram
GPS	Geo positioning system
ha	Hectare
ICP-OES	Inductively coupled plasma optical emission spectrometry
KAU	Kerala Agricultural University
kg ha^{-1}	Kilogram per hectare
kg	Kilogram
m	Metre
M	Molar
m^2	Metre square
MBC	Microbial biomass carbon
me L^{-1}	Milli equivalents per litre
me	Milliequivalent
mg ha^{-1}	Milligram per hectare
mg kg^{-1}	Milligram per kilogram
mg L^{-1}	Milligram per litre
Mg m^{-3}	Megagram per meter cube
mgP kg^{-1}	Milligram phosphorus per kilogram
mL	Millilitre
mm	Millimetre
mM	Millimolar
N	Normal

Nm	Nanometre
No.	Number
NO_3-N	Nitrate nitrogen
NTU	Nephalometric turbidity unit
pH	Soil reaction
POP	Package of Practices
ppm	Parts per million
Sl. No.	Serial number
SOC	Soil organic carbon
sq. ft.	Square feet
t ha^{-1}	Tonnes per hectare
TDS	Total dissolved solids
TPF	Triphenyl formazon
Var.	Variety

Introduction

1. INTRODUCTION

Bricks are the common but cheapest material for construction. The utilization of clay for construction works has a history of many centuries. It goes back to the earliest times of human civilization. Heavy clay moulded into bricks was the chief building material even in ancient civilization. The hand-made, sun-dried, mud bricks were excavated from important sites of human civilizations. The evidences from many civilizations including Mesopotamian and Egyptian civilizations point to the fact that these simple mud bricks were used during the Pre-Pottery Neolithic Period. The ancient Babylonian and Roman Empire further spread the use of burnt bricks throughout the world. This tradition of using bricks had undergone several modifications during Gothic, Renaissance and Baroque periods and regained its popularity during eighteenth century. The era of industrialization saw the renaissance of brick industry. The mechanization of brick manufacture made it to flourish across the globe.

India was never an exception in brick making even in historic times. The history of making bricks with clay in India roots back to Indus Valley civilization which is almost 5000 years old. The extensively complex but well-planned cities of Harappa and Mohenjo-Daro points towards their skill and knowledge in framing clay into bricks and beautiful sculptures. This tradition of brick making is still continued in our country making it the second largest producer of brick after China. About 75 per cent of the global brick production is concentrated in four Asian countries, namely

China	54 per cent	700-800 billion / year
India	11 per cent	140 billion /year
Pakistan	8 per cent	100 billion / year
Bangladesh	4 per cent	50 billion / year

In the prehistoric era, brick production was concentrated in the banks of river due to the availability of water and good quality alluvium soil. But with the increasing demand for bricks, the agricultural soils are mined to produce clay fired bricks. Thus, the brick production has been shifted from river basins to fertile agricultural lands.

Tile and brick kilns are closely associated with Kerala's culture and traditional architecture, which is continued in modern buildings as well. In Kerala, tile/brick clay occurs in the wetlands/paddy fields in the lowlands and midlands. Studies in clay mining regions of Kerala have demonstrated that exceptional increment in the infrastructural needs of the State and the consequent increment in the clay extraction situations have prompted fast deterioration of the wetlands (paddy fields), which is altogether reflected in the declining agricultural profitability of the State. Brick making has become a whooping lucrative business in many districts such as Wayanad, Kollam, Ernakulam, Thrissur and Palakkad. This has led to the mushrooming of a number of legal and illegal, small scale brick producing units in these districts. The foot hills of Western Ghats in Palakkad were once dominantly agricultural area. As farming became a non-profitable business, the farmers started shifting from agriculture to brick industry. The entry of brick industry has created drastic changes in the traditional agricultural scenario. The traditional practices of farming have been wiped out as a number of brick kilns were established in the farmland. This adversely affected the entire landscape causing irreversible damages to soil, hydrology and ecological balance.

In the study report published by National Centre for Earth Science Studies on the impact of clay mining, following recommendations were given with respect to tile/brick clay mining: "It is of imminent importance to regulate random mining from the paddy fields/wetlands of Kerala by allowing only location-specific resource extraction under well-conceived guidelines. It is also crucial to limit the extraction of tile and brick clays to meet indigenous and local demand only. This is to save the prime agricultural land and also to increase the rice production in the area. The depth of mining should be demarcated so as to regulate mining with respect to the water table condition in the summer season. Also, adequate measures are to be taken to regenerate the natural ground water table using the stored water in the clay mine pits for irrigating the agricultural crops of the hinterland areas."

The Kerala Conservation of Paddy Land and Wetland Act, 2008 which was enacted to protect the wetlands and paddy lands of Kerala imposed strict restrictions in mining soil from such areas. The Kerala Minor Mineral Concession Rules, 2015 further made it mandatory to get 'No Objection Certificate' from the District Collector concerned, based on the recommendation of the District Expert Committee constituted by the Government.

Many of the mined areas remain barren and reduce the extent of agriculture along with the emergence of serious problem of water scarcity. Hence, the present research work was carried out with an objective to study the impact of mining soil for brick production on the soil health and water quality and to identify suitable amelioration methods for soils degraded by mining activity.

Review of Literature

2. REVIEW OF LITERATURE

Each brick production unit occupies a considerable land area which was once used for agricultural purposes. Top soil harvesting has not only depleted the fertility of the soil but also affected the physical properties of soil. The high temperature generated further affects the soil flora and fauna also. This makes the land unfit for agricultural use.

Brick making process demands huge amounts of water which is obtained from the nearby water bodies and ground water sources. This creates the problem of water scarcity in such areas of brick production. Thus, brick making units accelerate the process of depletion of arable land which creates a concern over the food security of our country.

2.1 IMPACT OF SOIL QUARRYING FOR PRODUCTION OF BRICKS

2.1.1 General impact

In an experiment conducted by Larney *et al.* (1995) to study the effect of inorganic fertilizers on artificially eroded dark brown Chernozoic sandy clay loam soils of Canada, it was reported that the simulated erosion (desurfacing) had significantly reduced the grain and straw yield of wheat. The removal of 10 cm and 20 cm of topsoil had resulted in the yield reduction of 43-66 per cent and 60-85 per cent respectively when compared within unfertilized undisturbed soils.

Haack and Khatiwada (2007) reported that the rapid increase in the brick manufacturing had led to an unusual crop rotation of ‘rice and then bricks’ in Kathmandu valley of Nepal where same land is used for rice production in monsoon and brick production in summer. This has led to reduction soil fertility as well as productivity.

The huge consumption of clay and continuous soil quarrying has resulted in the degradation of top soil (Vyas *et al.*, 2009). In their study to assess the extent of land degradation due to brick production in Ujjain city, it was reported that about 4 sq.ft. of soil is required for the production of 470 bricks and the annual production in Ujjain city is about 1.6 crores which account to the loss of about 138255 sq. ft. of top soil annually.

In a study conducted by Gupta and Narayan (2010) in Uttar Pradesh, it was reported that the long term brick kiln industrial activity not only affected the soil characteristics but also altered the biomass and diversity structure of plant communities. The areas with longer exposure to disturbance were dominated by perennial plants. Those areas exposed to shorter duration of disturbances were noted by the presence of seasonal weeds. The accumulation of brick dust and huge of amount of heat also resulted in making the area susceptible to invasion by non-native weed species like *Parthenium hysterophorus* and *Chenopodium murale*.

In a study conducted by Pragathesh and Jain (2013) on behalf of Environment impact agency (EIA) Resource and Response Centre (RRC), it was reported that the growth of brick industries in agricultural area had a negative impact in the agricultural sector. Brick kilns had wiped off the traditional farming practices, changed the dynamics of the landscape and caused unalterable damage to ecology and drainage. The area having large concentration of brick kilns now suffer severe land degradation as industries extract soil beyond the permissible levels.

Das (2015) reported that the mushrooming of brick kilns in West Bengal is due to three reasons, *viz.,* the availability of good quality soil, low value of land and availability of cheaper transport. As the top soil sale is remunerative and agriculture is less attractive, farmers are forced to sell their land to brick kiln industries. Apart from affecting soil fertility, top soil quarrying is causing erosion and water logging in quarried lands. It leads to choking of water movement causing fragile irrigation system. Consequently, cultivation of the quarried lands can be much more risky enterprise.

Kumar *et al.* (2015) conducted a study on the role of soil brick industry in land degradation in Telangana State. They reported that the harvesting of top soil from agricultural land had resulted in severe soil erosion along with increasing land and environmental pollution. Almost 6240 cubic meters of black soil was quarried from Nizamabad district of Telangana State for brick production. Further, the open burning of bricks using coal increased the impact on environment.

Singh *et al.* (2015) reported that the desurfacing had caused a decrease of 4.73 per cent in the agricultural land area in national capital region (Haryana state) in 5 years. While there was an increase in built up area by 92.25 per cent, the forest area, grassland and wetland were decreased. The desurfaced land area was increased by 41.7 per cent during 5 years (2007-2012).

2.1.2 Physical properties

Khan *et al.* (2007) reported that the burning of soils near to the brick kiln affects the physical properties of the soil. The average sand content in burnt soil were increased by 330 per cent whereas silt and clay contents decreased by 49 and 40 per cent respectively.

Singh *et al.* (2015) investigated the impact of soil desurfacing on the physico-chemical properties of the soil. They reported that desurfacing has impaired the physical properties like texture, bulk density and hydraulic conductivity of soil. The bulk density was increased by 14.3 per cent (1.43 – 1.67 µg m^{-3}) and hydraulic conductivity was decreased by 51.43 per cent in the desurfaced soil. This has led to soil compaction and thus adversely affected the water movement within the soil.

2.1.3 pH and electrical conductivity

Khan *et al.* (2007) reported that the pH values of the burnt soils around brick kilns were reduced by 0.4 pH units whereas EC values were increased from 0.26 to 1.77 mS cm^{-1} than that of unburnt soils.

Islam *et al.* (2015) reported that the pH and EC of burnt and unburnt soil near brick kiln are significantly different. The pH of the burnt soil (6.52 to 7.23) was slightly higher than that of unburnt soil (5.62 to 6.15). Similarly, EC of burnt soil (32.4 – 70.9 µS cm^{-1}) was found to be twice than that of unburnt soils (17.2 to 24.8 µS cm^{-1}). It may be due to the burning of salts in the soils.

The pH of the desurfaced soil was found to be higher than that of normal soils. This has led to the less availability of micronutrients in desurfaced soils. The EC values of desurfaced soils was found to be lesser than that of normal soils (Singh *et al.*, 2015)

2.1.4 Organic matter

Morgan and Lal (2003) evaluated the soil organic carbon concentration in natural forest, traditional cultivation and top soil removed areas. The loss of SOC pool in the topsoil removal treatment was 94.8 MgC ha^{-1} compared with natural forest. Severe erosion, leading to a complete loss of topsoil as in the case of the topsoil removal treatment, has drastic adverse impacts on productivity and quality of the exposed sub-soil.

Khan *et al.* (2007) reported that the burning of the agricultural top soils for brick production had resulted in the loss of 6.3 per cent of total organic matter in the soil. The total of 75 per cent of the organic matter and soil nutrients were lost during burning of top soil or brick production.

In a study conducted by Islam *et al.* (2015) in Bangladesh, it was reported that the burning of top soil near brick kilns had caused significant reduction in the organic matter content. The organic matter content of burnt soils was in the range of 1.07-2.05 per cent compared to unburnt soils (0.6-0.8 per cent).

Singh *et al.* (2015) studied the impact of top soil harvesting on the carbon content in the soil. The loss of top soil leads to the exposure of lower horizon which is poor in organic content. They reported that the organic carbon stock (mg ha^{-1}) was decreased by 47.43 per cent in desurfaced soil. The organic carbon content of the study area was reported to be decreased by 55 per cent than the normal soils.

The organic matter content near brick production units decreases considerably due to the reduction of organic carbon and it increases as the distance from the brick production unit increases. Decrease in pH had resulted in the decrease of microbial activity. The change in the texture of soil affects the infiltration rate of water which further lowers the water level of that area. There is a reduction in sulphate and nitrate content of the soil. The concentration of heavy metals is found to be high in such areas (Bisht and Neupane, 2015).

2.1.5 Nitrogen (N)

Islam *et al*. (2015) reported that the total N in burnt and unburnt soils near brick kilns vary to a great extent. The total N content ranged from 0.046 – 0.051 per cent and 0.057 to 0.072 per cent in the burnt and unburnt soils respectively. The low status of total N in burnt soil is attributed to the loss of organic carbon containing nitrogen and nitrogen fixing organisms.

2.1.6 Phosphorus (P)

Islam *et al*. (2015) observed that the available P content varies due to the brick kiln operations in the agricultural soils. The available P content of the burnt and unburnt soil samples near to brick kilns were in the range of 10.54 – 14.57 ppm and 17.54 – 32.72 ppm respectively.

Singh *et al.* (2015) reported that land desurfacing has a significant effect on the available P content in soil. The plant available P content in desurfaced soil was declined to about 33.08 per cent.

2.1.7 Potassium (K)

In a study conducted by Singh *et al.* (2015) to investigate the impact of soil desurfacing on physico-chemical properties of soil, it was reported that desurfacing significantly affects the exchangeable K in the soil. About 44.70 per cent of decline in exchangeable K content was observed during the study. This may be due to the exposure of biologically less active subsoil which contain very less amount of organic matter. The loss of potassium rich clays, illite present in the top soil also might have contributed to the decline in exchangeable K in desurfaced soil.

2.1.8 Sulphur (S)

Islam *et al.* (2015) carried out a study on degradation of agricultural soil arising from brick burning in Bangladesh. They found that there was a significant variation in the amount of available S in the burnt and unburnt soils. The available S ranged from 4.3 to 10.6 ppm in the burnt and 9.47 to 13 ppm in the unburnt soils near brick kilns.

2.1.9 Heavy metals and micronutrients

Islam *et al.* (2015) conducted a study to understand the impact of brick kiln operation on the top soil quality of agricultural land. The mean value of total copper (Cu) in burnt and unburnt soils were 0.087 and 0.094 ppm respectively whereas total zinc (Zn) content of burnt and unburnt soils were 2.06 and 2.47 ppm respectively.

In a study conducted by Singh *et al.* (2015), it was found that micronutrient status of the desurfaced soils was much lower than that of normal soils of that area. The available zinc, iron (Fe), copper and manganese (Mn) were decreased by 78.40 per cent, 39.4 per cent, 31.74 per cent and 55.21 per cent respectively.

The concentration of heavy metals such as lead (Pb), cadmium (Cd) and chromium (Cr) is found to be higher in the soils near to brick kilns (Ishaq *et al.*, 2009).

Ismail *et al.* (2012) conducted an experiment to study the effect of brick kiln emissions on heavy metal concentration in soil and plant. The concentration of Cd in soil samples near to brick kilns were in the range 0.036 to 2.40 ppm. Similarly, Cr concentration was found to be ranging from 0.03 to 0.26 ppm. They reported that the average Cd and Cr in plants near to brick kilns were found to be 2.03 and 5.76 ppm respectively.

In a case study carried out by Achakzai *et al*. (2015) in Pakistan, the heavy metal concentration was found to be high in soils near to the brick kilns. The concentration of investigated heavy metals *viz.,* Zn, Ni, Cd, Cu and Pb as per World Health Organization (WHO) standards were found above the permissible limits in the soil. They reported that the accumulation of heavy metals in plants was higher that the permissible limits prescribed by World Health Organization (WHO).

Proshad *et al.* (2018) investigated the presence of hazardous heavy metals around brick kilns. They reported that the contamination factor values and pollution load index of As and Cd indicates progressive deterioration of soil due to metal contamination.

2.1.10 Biological properties

Agera *et al.,* (2018) reported that the brick production activities alter the microclimate for microorganisms which in turn affect the microbial population of the soil. The increase in depth of soil excavation for brick production also affects the diversity and population of soil microorganisms.

2.1.11 Hydrology

Haack and Khatiwada (2007) pointed out that soil mining for brick production is seriously affecting the surface hydrology of desurfaced lands in Kathmandu valley of Nepal. The ground water level had decreased to 20 m from 1-2 m. Similarly, the extraction of soil had resulted in the increased possibility of rainfall induced landslides and disruption of irrigation schemes. The over exploitation of land for bricks had resulted in unusual surface elevations, thus making irrigation difficult.

Pragadesh and Jain (2013) conducted a detailed study on the impact of brick kilns in Thadagam valley, Nilgiris. They reported that the deep soil excavations had resulted in the formation of big ravines which affected the hydrology and water dynamics of that area. Brick industries even excavated soil from dried out streams and then blocking any chance of rejuvenation. The dropping water table had further resulted in the change in vegetation pattern as wet and dry tropical forests were replaced by them and secondary forests.

Suraj and Neelakandan (2014) conducted a study on the impact of clay mining over hydrologic ecosystem in Thrissur. They reported that the hydrology in the mining area was severely affected. Water scarcity in wells adjacent to mining sites during summer seasons became a serious problem in those areas. Ground water level fluctuations were also reported in the 27 mining sites studied.

Singh *et al.* (2015) reported that the increase in desurfaced area has resulted in increase in water bodies. They noticed an increase from 840 ha to 1814 ha of water bodies in National capital (NCL) during 5 years. This might be due to the uneven top soil excavation resulting in large water filled pits.

There is an increasing trend of deterioration of surface water quality in areas of brick production (Jamatia *et al.,* 2014). They carried out a case study to identify potential contribution of pollution on the surface water sources by brick industries in Tripura state. The turbidity of the water samples was higher which reached upto 36.4 NTU (Nephalometric Turbidity Units). The hardness of the water was found to be in the range of 50.5 - 141 mg L^{-1} whereas alkalinity ranged between 59 to 146 mg L^{-1}.The Total dissolved solids (TDS) level was found to be higher than normal value with a highest value of 180 mg L^{-1}. The chloride content was found to be in the range of 9-14 mg L^{-1}. The disposal of brick industry waste water into the natural water bodies alter the quality of water. The disposal of waste water from brick industry into the natural water bodies alters the physicochemical properties of water.

Studies conducted by Dey and Dey (2015) proved that there was a huge variation in various physico-chemical parameters such as water temperature, pH, conductivity, total alkalinity, dissolved oxygen, carbon dioxide, nitrate, phosphate and transparency in the selected water bodies. The studied ponds were found to be in degrading state with less productivity.

2.2 RECLAMATION STUDIES

Larney *et al.* (1995) reported that the application of beef feed lot manures was effective in improving the carbon and N fractions in the desurfaced soil. In long term, the application of manure also improved the physical properties of soil such as water stable aggregates.

Larney *et al.* (2000) conducted simulated erosion approved to quantity erosion and effects of amendments on soil quality. They concluded that application of manure is the best amendment for enhancing soil productivity. The productivity enhancing effect of manure depends on the organic carbon status of the soil.

Under an experiment conducted by Larney *et al.* (2003) to reclaim abandoned natural gas well sites, it was reported that top soil replacement along with organic amendment is very effective. One-time application of organic amendments had short term (4 year) benefits to the reclamation process. They reported that organic amendments like manure and compost can be used as a substitute for top soil for short term.

Zhang and Fang (2007) conducted an experiment in abundant brick making site to study the effect of tillage, fertilizers and green manures in improving the soil quality. They reported that deep tillage reduced bulk density and increased water infiltration rate of soils whereas application of organic manures increased the accumulation or organic carbon and nitrogen and formation of water soluble aggregates. They recommended that the management of degraded topsoils can be done by deep tillage along with the application of organic manure with green manure cropping.

Rutherford and Arocena (2011) studied the effect of organic amendments such as saw dust, sewage sludge and paper sludge and addition of earthworms in the reclamation of non-acidic mine tailings in Canada. It was reported that the concentrations of NO_3-N (1050 mg kg^{-1}) and Bray P (487 mgP kg^{-1}) were found to be higher in the mine tailings in the presence of earthworms.

Singh *et al.* (2015) investigated the role of different measures to reclaim and improve the productivity of desurfaced soils due to brick kilns activity. Use of organic amendments like farm yard manure, animal waste, poultry manure, vermicompost and crop residues increase the biological activity of the soil and thus enhances the rejuvenation process to an extent. It also decreases bulk density of the soil thus improving water holding capacity and hydraulic conductivity of the soil. Use of biochar as a soil amendment improves the soil carbon content and the physical and biological properties. They also pointed out that green manuring, deep tillage and soil replacement process are beneficial for reclamation of degraded soils.

Knap *et al.* (2016) studied the physico-chemical properties of sulphur mine reclaimed with large amounts of ground, post floatation lime, mineral fertilizers and sewage sludge. They reported that the reclaimed soil had showed higher amounts of organic carbon and total N than that of non-reclaimed soil. There was a trend to increase the contents of available forms of P, K and Mg observed in reclaimed soils. Apart from this, the reclaimed soils were characterized by more favourable properties such as pH close to neutral, lower acidity and better sorption capacity as compared to non-reclaimed soils.

Wei Zhou *et al.* (2016) studied the development of top soil properties in open cast coal mine under different reclaimed land uses such as cultivated soil, forest, grassland and barren soil. They pointed out that the type of land use has a significant role in the reclamation process. The top soil properties like organic carbon, N, P and K were found to be highest in cultivated soil followed by forest, grass land and barren soils. The reclamation age also influences the soil properties.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil" was conducted at College of Horticulture, Vellanikkara, Thrissur, Kerala during 2017-2018. This chapter deals with the detailed information of materials and methods adopted during the experimental period.

3.1 EXPERIMENT I

Evaluation of physical, chemical and biological properties of soil and water samples

3.1.1 Location and physiography of the experimental site

Alathur Taluk is located in the central plains of Palakkad District in Kerala. It lies between $10^0$38'53"N and $76^0$32'18"E. The study area belonged to Bhavanjinagar series proposed by Soil Survey Organization, Kerala. The soil is fine, mixed, isohyperthermic, Typic Haplustalf. The climate is humid tropical with mean annual temperature of 27.3°C and average annual rainfall of 1174 mm. The soil is heavy textured, near neutral subjected to severe moisture stress. Calcium carbonate nodules are reported in the subsoils of this region. These soils are suitable for the cultivation of coconut, cotton, groundnut and sugarcane with a medium productivity potential.

3.1.2 Site selection

A comprehensive survey was conducted in Alathur Taluk in the soil mining areas and identified 10 desurfaced (mined) lands for small scale brick production. The small scale brick production units were identified in Thenkurissi village situated in the border of Alathur-Chitur Taluks (Plate 1). Most of the small scale brick production units has been leased out to brick producers from different locations in the state. Each individual sampling location had an area of 1 acre and mined to a depth of 1 m. A control site was also identified where no mining activity was prevalent till date. The sites which were close to agricultural lands and water bodies were selected. The sampling sites were georeferenced using GPS device (Table 1).

Plate 1: Map of study area

Table 1: Details of soils collected from the study area

Sl. No.	Sample number	Name of farmer	GPS values
1.	S_1	Kesavan	76^{0}42’41.63” E 10^{0}35’20.89”N
2.	S_2	Nandakumar	76^{0}42’43.08” E 10^{0}35’06.14”N
3.	S_3	Krishnankutty	76^{0}42’56.10” E 10^{0}34’50.70”N
4.	S_4	Sojesh	76^{0}42’56.10” E 10^{0}34’43.88”N
5.	S_5	Meghanathan	76^{0}42’41.63” E 10^{0}35’20.89”N
6.	S_6	Kunjumon	76^{0}43’27.41” E 10^{0}35’20.38”N
7.	S_7	Krishnakumar	76^{0}43’41.63” E 10^{0}35’20.89”N
8.	S_8	P. Iyer	76^{0}42’48.69” E 10^{0}35’20.89”N
9.	S_9	Santhosh	76^{0}42’41.49” E 10^{0}34’20.89”N
10.	S_{10}	Manoj	76^{0}42’41.63” E 10^{0}34’20.19”N
11.	S_{11} (Control site)	Nadarajan	76^{0}43’41.23” E 10^{0}35’40.19”N

3.1.3 Collection and characterisation of sample

3.1.3.1 Soil samples

Soil samples were collected randomly at a depth of 30 cm and 8 composite soil samples were collected from each site within the mined area. A control site with no previous history of soil mining was also selected for the study. A total of 88 composite soil samples were collected from 11 selected sites under study. The soil samples were collected during the period from August to September, 2017. The common problems observed in the mined sites included the formation of undulated soil surface resulting in water logging and soil erosion, invasion of weeds and finally conversion of fertile agricultural lands into waste lands (Plate 3 to Plate 7).

The collected soil samples were properly air dried and pulverised using wooden mallet. These were then passed through 2 mm sieve and labelled and packed in air tight polythene covers. The soil samples were subsequently used for the characterisation of physical, chemical and biological properties.

3.1.3.2 Characterisation of soil samples

3.1.3.2.1 Physical properties

The methods used for the physical characterisation of soil samples are given in Table 2. The texture of the mined soils was found based on the mean values of textural analysis of samples from S_1 to S_{10}.

3.1.3.2.2 Chemical properties

The methods followed in the characterisation of chemical properties of soil samples are given in Table 3.

Table 2: Methods of physical characterisation of soil samples

Sl. No.	Parameter	Method	Reference
1.	Soil temperature	Soil thermometer	Jennifer, 1945
2.	Soil moisture	Gravimetry	Black, 1965
3.	Bulk density	Keen Raczkowski brass cup method	Piper, 1942
4.	Water holding capacity		
5.	Soil texture	International pipette method	Robinson, 1922

Table 3: Methods of chemical characterisation of soil samples

Sl. No.	Characteristics	Method		Reference
		Extraction	Estimation	
1.	pH	1:2.5 soil water suspension	Potentiometry	Jackson, 1958
2.	Electrical conductivity		Conductometry	
3.	Organic carbon	Wet digestion		Walkely and Black, 1934
4.	Available nitrogen	Alkaline permanganometry		Subbiah and Asija, 1956
5.	Available phosphorus	Extraction using Bray No.1/ Olsen reagent and estimation calorimetrically by reduced molybdate ascorbic acid blue colour method	Colorimetry	Bray and Kurtz, 1945 Watanabe and Olsen, 1965
6.	Available potassium	Extraction by neutral normal ammonium acetate	Flame photometry	Jackson, 1958
7.	Available calcium		Atomic Absorption Spectrophotometer	
8.	Available magnesium			
9.	Available micronutrients (Fe, Mn, Cu, and Zn)	Extraction using 0.1M HCl	ICP-OES	Sims and Johnson, 1991
10	Heavy metals (Ni, Cd, Cr and Pb)	Extraction using 0.1M HCl	ICP-OES	Sims and Johnson, 1991

Plate 2: Soil sample collection from study area

Plate 3. View of mined area showing uneven soil surface

Plate 4. View of mined area invaded with weeds

Plate 5. View of mined area subjected to soil erosion

Plate 6. Mined area converted to waste land

Plate 7. Water logging in mined soils of study area

3.1.3.2.3. Biological properties

3.1.3.2.3.1. Microbial biomass carbon

The microbial biomass carbon was estimated using the procedure laid down by Jenkinson and Powlson (1976). A total of five sets of 10 g soil samples were taken. One set was kept in an oven at 105º C and the moisture was determined using gravimetric method. Vacuum was created inside desiccator using a vacuum pump. Two sets of soil samples and a beaker with ethanol free chloroform were kept in vacuum desiccator for 24 hrs. These were extracted using 0.5 M potassium sulphate to determine organic carbon. Potassium dichromate (0.2 M), concentrated sulphuric acid and ortho phosphoric acid were added to 10 ml extract. It was kept in a hot plate at 100 ºC for half an hour under refluxing condition followed by adding of water and titrated against standard ferrous ammonium sulphate.

3.1.3.2.3.2. Dehydrogenase enzyme activity

The dehydrogenase activity of the collected soil samples were analysed using the procedure given by Casida *et al*. (1964). About 1 g of air dried soil was taken in a screw capped test tube of 15 mL capacity and was saturated with 0.2 mL of 3 per cent triphenyl tetrazolium chloride solution. An accurate quantity of 0.5 mL of 1 per cent glucose solution was added to the test tube. The test tubes were gently tapped so as to remove the air trapped between the soil particles and thus a water seal was created in the test tube so as to prevent the formation of air bubbles. It was then incubated at 28ºC for 24 hours. After incubation, 11 mL methanol was added to test tubes and incubated for another 6 hours after vigorous shaking. The clear pink coloured supernatant solution was read at 485 nm wavelength in spectrophotometer.

3.1.3.2.3.3. Earth worm count

Earth worm count was recorded by hand sorting method (Plate 8). From each site, 5 random spots were identified and 1 m^2 area was delineated. The number of earthworms from each spots were counted and the mean values were found out.

3.1.3.2.3.4. Termite mound

The number of termite mounds in the sampling site was obtained by surveying and visual examination of whole area at each location (Plate 9).

a) Presence of worm casts in control site

b) A single worm cast (enlarged)

c) Presence of earthworm

Plate 8. Earthworm activity in the control site

Plate 9. View of termite mound in control site

3.1.3.2 Water samples

Water samples were collected from the selected farm pond, open well and other water bodies from the earlier identified sites for soil sampling. Three composite water samples were collected from each site (Table 4 and Plate 10). Each sample was filtered and stored in clean, labelled polythene bottles of 500 mL capacity. Few drops of toluene was added into each sample in order to prevent the growth of microorganisms and kept for further analysis.

3.1.3.3 Characterisation of water samples

The methods followed to assess the quality of water samples for irrigation are listed in the Table 5.

Table 4: Details of water samples collected from study area

Sl. No.	Sample No.	Name of farmer	Source of water
1.	W_1	Kesavan	Well
2.	W_2	Nandakumar	Well
3.	W_3	Krishnankutty	Pond
4.	W_4	Sojesh	Pond
5.	W_5	Meghanathan	Canal
6.	W_6	Kunjumon	Canal
7.	W_7	Krishnakumar	Pond
8.	W_8	P. Iyer	Pond
9.	W_9	Santhosh	Well
10.	W_{10}	Manoj	Well
11.	W_{11} (Control site)	Nadarajan	Well

a) Canal water from mined site

b) Water from farm pond near mined site

d) Water from open well of control site

Plate 10. Sources of water samples collected

Table 5: Methods of analysis of physico- chemical properties of water

Sl. No	Parameter	Method	Reference
1.	Temperature	Thermometer	Jennifer, 1945
2.	pH	Potentiometry	Jackson, 1958
3.	Electrical conductivity	Conductometry	Wilcox, 1950
4.	Total dissolved salts	Evaporation method	Ayers and Westcot, 1985
5.	Potassium	Direct reading using flame photometer	Jackson, 1958
6.	Sodium		
7.	Calcium	Direct reading in atomic absorption spectrophotometer	Jackson, 1958
8.	Magnesium		
9.	Nitrate	Reduction by Devarda's alloy and Kjeldahl distillation	AOAC, 1950
10.	Phosphate	Extraction using Bray No.1 and estimation colorimetrically by reduced molybdate ascorbic acid blue colour method	Bray and Kurtz, 1945
11.	Carbonate	Acidimetric titration	AOAC, 1950
12.	Bicarbonate		
13.	Chloride	Mohr's titration method	Motsara and Roy,2008

3.2 EXPERIMENT II

Study on reclamation of soils in areas of soil mining for brick production

After the physico-chemical characterisation of the soil samples, the soil sample with lowest nutrient status in terms of organic carbon and major nutrients was selected for further studies. From this area, bulk soil samples (0-30 cm) were collected for detailed reclamation study. A pot culture experiment was conducted to study the effect of organic manures and chemical fertilizers on the reclamation of these soils. Sixty three pots were used for this study involving 7 treatments and 3 replications each. Each replication consisted of 3 pots with one seedling per pot.

Location: College of Horticulture, Vellanikkara

Period: April – July / August, 2018

Crop: Chilli

Variety: Anugraha

Experimental design: CRD

No. of treatments: 7

No. of replication: 3

No. of pots/replication: 3

Total number of pots: 63

Treatment details:

T_1: Soil test based NPK + FYM @ 20 t ha^{-1}

T_2: Soil test based NPK + Poultry manure equivalent to N in 20 t ha^{-1}of FYM

T_3: Soil test based NPK +Vermicompost equivalent to N in 20 t ha^{-1}of FYM

T_4: Soil test based NPK +Coir pith compost equivalent to N in 20 t ha^{-1} of FYM

T_5: FYM @ 20 t ha^{-1}

T_6: NPK + FYM @ 20 t ha^{-1} (KAU POP, 2016)

T_7: Absolute control

Treatments T_1 to T_4 were given on the basis of soil test based recommendations. The treatment, T_6 *i.e.*, NPK + FYM @ 20 t ha^{-1} (KAU POP, 2016) was applied as a blanket recommendation as mentioned in package of practices (KAU POP, 2016). The recommended dose of fertilizers for chilli crop cultivation was 75:40:25 kg N: P_2O_5: K_2O per hectare. The collected soil samples were air dried and mixed thoroughly. A quantity of 5 kg per each pot was mixed with respective treatments and the pots were filled. The amount of organic manures and chemical fertilizers required for each treatment is mentioned in Table 15. The nutrient contents of different organic manures are given in Appendix I.

The experiment was conducted in the Plant Propagation and Nursery Management Unit field adjacent to College of Horticulture, Vellanikkara. The seeds of chilli were sown during the month of February and transplanted during April 2018.

The following biometric observations as well as yield of chilli were taken during the crop period.

1. Plant height (cm)
2. Number of branches
3. Number of leaves
4. Number of flowers
5. Number of fruits
6. Per cent fruit set
7. Yield (Weight of fruits per plant)

The biometric observations such as plant height, number of leaves, number of branches and number of leaves were taken at 60 days after transplanting (DAT). Observations on the total number of flowers and fruits during the whole period of crop growth were also recorded.

After the harvest of the crop, the soil in the pots was further utilized for the analysis of major physical and chemical properties. This was done to assess the changes in the nutrient status and physical and biological properties of soil after management of soil using various organic amendments and inorganic fertilizers. The soils were air dried, processed and passed through 2 mm sieve and kept for analysis.

3.3 STATISTICAL ANALYSIS

The statistical analysis was performed with statistical software WASP 2.0 (Completely randomised design).

a) Pots filled with soil and manures

b) Pots after the transplantation of chilli crop

Plate 11. General view of pot culture experiment

Results

4. RESULTS

The results of the study on 'Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soils' are presented in this section.

The present study was divided mainly into two experiments. The experiment I dealt with laboratory experiments in characterising the soil and water samples collected from the study area. Based on the results of soil characterisation, experiment II was conducted. The experiment II was pot culture study which aimed at the reclamation of degraded soils. The results pertaining to the experiments are discussed as follows.

4.1 EXPERIMENT I

Evaluation of physical, chemical and biological properties of soil and water samples

Based on the comprehensive survey conducted in Alathur block, 10 locations were identified where small-scale mining has been taking place. A mining free area was also identified as the control site. A total of 88 soil samples (8 from each location) were collected and used for soil characterisation. Also 11 water samples (1 from each site) were collected from selected ponds and wells and were analysed for physical and chemical properties.

4.1.1 Characterisation of soil samples

4.1.1.1 Physical properties

4.1.1.1.1 Bulk density

The mean values of bulk densities of soil samples are given in Table 6. The samples collected from location 5 (S_5) had shown the highest bulk density (1.73 Mg m^{-3}). The bulk density of the control site (S_{11}) was found to be the lowest (1.22 Mg m^{-3}).

4.1.1.1.2 Soil moisture

The average values of soil moisture of the samples are given in Table 6. The soil sample, S_{11} had the highest moisture (14.60 per cent) content whereas the soil sample, S_5 had the lowest moisture content (3.50 per cent).

4.1.1.1.3 Soil temperature

Table 6 depicts the mean value of soil temperature obtained from each sampling site. The sampling location S_{11} (the control site without mining operation) exhibited the lowest soil temperature (25.60°C). The sampling site S_5 recorded the highest temperature (29.30°C).

4.1.1.1.4 Water holding capacity

The average values of soil moisture of the samples are given in Table 6. The soil sample, S_{11} had the highest water holding capacity (29.60 per cent) content whereas the soil sample, S_5 had the lowest water holding capacity (9.35 per cent).

4.1.1.1.4 Soil texture

Soil texture was analysed for two samples from each site. The soils in the mined area were of sandy loam texture whereas the soil sample from control site was clayey loam in texture (Table 7).

Table 6. Physical properties of soil samples for initial characterisation

Sample No.	Bulk density (Mg m^{-3})	Soil moisture (%)	Water holding capacity (%)	Soil temperature (°C)
S_1	1.61	5.70	15.90	27.30
S_2	1.61	9.60	25.30	26.80
S_3	1.62	6.30	16.80	27.60
S_4	1.62	6.50	17.20	27.50
S_5	1.73	3.50	9.35	29.30
S_6	1.70	4.80	12.60	26.90
S_7	1.61	5.30	13.20	27.80
S_8	1.66	7.20	20.10	28.10
S_9	1.57	7.70	20.50	28.00
S_{10}	1.45	12.50	27.50	27.70
S_{11}	1.22	14.60	29.60	25.60

Table 7. Textural analysis of soil samples

Soil Separate	Mined soil	Control soil
Sand (%)	65.30	46.73
Silt (%)	24.72	14.77
Clay (%)	9.98	38.50
Soil texture	Sandy loam	Clay loam

4.1.1.2 Chemical properties

The major chemical characteristics of the selected soils such as pH, EC, contents of organic carbon, major and micro nutrients and heavy metals were analysed. The results of the analysis are given in Tables from 8 to 10.

4.1.1.2.1 pH

The mean values of pH of the soil samples are given in Table 8. The range of pH of soil samples from mined areas was neutral to slightly alkaline in nature. The highest pH was shown by soil samples S_5 (7.70) whereas lowest pH was shown by the control site (6.33).

4.1.1.2.2 Electrical conductivity

The average values of electrical conductivity are furnished in Table 8. The highest value of electrical conductivity was observed in S_2 (0.055 dS m^{-1}), whereas the lowest was in S_{11} (0.009 dS m^{-1}).

4.1.1.2.3 Organic carbon

The mean values of organic carbon is depicted in Table 8. The soil samples from top soil mined areas showed a very low status of organic carbon. The percentage of organic carbon in the mined soils were in a range of 0.08-0.46 per cent, whereas S_5 (0.08 per cent) showed the lowest organic content. The control site, S_{11} showed a medium range of organic carbon content (0.66 per cent).

4.1.1.2.4 Available nitrogen

The mean values of the available nitrogen of soil samples are given in Table 9. The available nitrogen content in soil samples from mined sites were ranged 87.81–196.00 kg ha^{-1}. The soil samples from S_5 marked the lowest content of available nitrogen (87.81 kg ha^{-1}). The available nitrogen content of the control site S_{11} was found to be the highest (250.88 kg ha^{-1}). The samples belonged to the “low” fertility class in which the control soil showed a value towards the upper limit of this class.

Table 8: Electrochemical properties and organic carbon content of soil samples

Sample No.	pH	Electrical conductivity (dS m^{-1})	Organic carbon (%)
S_1	7.14	0.036	0.30
S_2	7.58	0.055	0.28
S_3	7.47	0.029	0.16
S_4	7.19	0.019	0.26
S_5	7.70	0.017	0.08
S_6	7.02	0.019	0.15
S_7	7.32	0.024	0.36
S_8	7.22	0.026	0.20
S_9	7.20	0.025	0.33
S_{10}	6.61	0.014	0.46
S_{11} (Control soil)	6.33	0.009	0.66

4.1.1.2.5 Available phosphorus

The mean values of the available phosphorus level of the soil samples are presented in Table 9. High content of available phosphorus was observed in all the soil samples. The available phosphorus content ranged from 13.25 kg ha^{-1} to 92.32 kg ha^{-1}. The available phosphorus was the lowest in S_5 (13.25 kg ha^{-1}) and highest in S_{11} (92.32 kg ha^{-1}). All the soil samples belonged to the classes “medium” or “high”.

4.1.1.2.6 Available potassium

The mean values of available potassium content in the soil samples are depicted in Table 9. Comparatively, a lower status of available potassium content was observed in all the soil samples irrespective of top soil mining. The available potassium content ranged from 57.71 kg ha^{-1}(S_5) to 305.89 kg ha^{-1} (S_{11}).

4.1.1.2.7 Available calcium

The average values of available calcium content of the soil samples analysed are presented in Table 9. The available calcium content on the control site S_{11} was the lowest (105.11 mg kg^{-1}) whereas that of the S_2 was the highest (582.06 mg kg^{-1}).

4.1.1.2.8 Available magnesium

The mean values of available magnesium content of soil samples are given in Table 9. The available magnesium ranged from 35.19 mg kg^{-1} (S_5) to 129.28 mg kg^{-1} (S_{11}).

4.1.1.2.9 Available zinc

The mean values of available zinc content of the soil samples are furnished in Table 10. The average available zinc content ranged from 0.04 mg kg^{-1} to 0.22 mg kg^{-1}. The highest and lowest available zinc content were observed in S_5 (0.22 mg kg^{-1}) and S_{11} (0.04 mg kg^{-1}) respectively.

4.1.1.2.10 Available copper

The average values of available copper are presented in Table 10. The highest content of available copper was observed in S_9 (1.07 mg kg^{-1}) whereas lowest content of copper was observed in S_{11} (0.14 mg kg^{-1}).

4.1.1.2.11 Available iron

The average values of available iron are presented in Table 10. The highest content of available iron was observed in S_9 (36.14 mg kg^{-1}) whereas lowest content was observed in S_{11} (5.43 mg kg^{-1}).

4.1.1.2.12 Available manganese

The mean values of available manganese content of the soil samples are furnished in Table 10. The average available manganese content ranged from 4.22 mg kg^{-1}(S_{11}) to 15.54 mg kg^{-1} (S_6).

4.1.1.2.13 Available nickel

The average values of available nickel are presented in Table 10. The highest content of available nickel was observed in S_4 (0.95 mg kg^{-1}) whereas lowest content was observed in S_{11} (0.19 mg kg^{-1}).

4.1.1.2.14 Available chromium

The mean values of available chromium content of the soil samples are furnished in Table 10. The average available chromium content ranged from below detectable level (S_{11}) to 0.12 mg kg^{-1} (S_4).

4.1.1.2.15 Available lead

The average values of available lead content are presented in Table 10. The highest content of available lead content was observed in S_8 (0.46 mg kg^{-1}) whereas the lowest value was observed in S_{11} (0.15 mg kg^{-1}).

4.1.1.2.16 Available cadmium

The content of available cadmium in all the selected soil samples were below the detectable level (BDL) (Table 10).

Table 9: Content of available major and secondary nutrients of soil samples

Sample No.	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Calcium (mg kg^{-1})	Magnesium (mg kg^{-1})
S_1	172.48	15.67	207.40	299.20	72.01
S_2	177.18	15.44	147.07	582.06	72.01
S_3	120.74	33.27	89.66	279.08	88.76
S_4	134.85	26.05	158.30	387.75	73.08
S_5	87.81	13.25	57.71	182.41	35.19
S_6	108.19	57.67	124.77	304.88	52.19
S_7	127.01	23.11	88.17	269.08	47.46
S_8	112.90	15.24	70.39	156.83	47.04
S_9	175.62	48.40	225.88	148.72	35.58
S_{10}	196.00	41.58	156.94	157.89	49.77
S_{11}	250.88	92.32	305.89	105.11	129.28

Table 10: Content of available micronutrients and heavy metals of soil samples

Sample No.	Zinc (mg kg^{-1})	Copper (mg kg^{-1})	Iron (mg kg^{-1})	Manganese (mg kg^{-1})	Nickel (mg kg^{-1})	Chromium (mg kg^{-1})	Cadmium (mg kg^{-1})	Lead (mg kg^{-1})
S_1	0.09	0.31	10.82	13.40	0.25	0.05	BDL	0.34
S_2	0.17	0.49	13.40	8.80	0.33	BDL	BDL	0.25
S_3	0.14	0.74	17.23	13.92	0.65	0.09	BDL	0.16
S_4	0.20	0.76	23.37	12.26	0.95	0.12	BDL	0.24
S_5	0.22	0.42	15.83	14.68	0.41	0.09	BDL	0.19
S_6	0.17	0.40	11.76	15.54	0.42	0.10	BDL	0.19
S_7	0.15	0.20	8.28	10.03	0.36	BDL	BDL	0.40
S_8	0.16	0.22	15.85	11.46	0.36	BDL	BDL	0.46
S_9	0.44	1.07	36.14	10.06	0.76	0.08	BDL	0.20
S_{10}	0.15	0.26	13.38	6.49	0.30	0.02	BDL	0.22
S_{11}	0.04	0.14	5.43	4.22	0.19	BDL	BDL	0.15

*BDL - Below detectable level

4.1.1.3 Biological properties

The results of the biological properties of the selected soil samples are furnished in Table 11.

4.1.1.3.1 Microbial biomass carbon (MBC)

The microbial biomass carbon (MBC) content of the soil samples ranged from 100.14 µg g^{-1} soil (S_5) to 290.80 µg g^{-1} soil (S_{11}).

4.1.1.3.2 Dehydrogenase enzyme activity

The mean dehydrogenase enzyme activity of the selected samples are presented in Table 11. The minimum dehydrogenase activity was shown by S_5 (1.95 µg TPF g^{-1} day^{-1}) whereas maximum dehydrogenase activity was shown by S_{11} (3.69 µg TPF g^{-1} day^{-1}).

4.1.1.3.3 Earthworm count

The earthworms were absent in top soil mined areas. The control site from where the sample S_{11} was collected, 13 no. m^{-2} earthworms were obtained.

4.1.1.3.4 Termite mound

No termite mounds were observed in any of the top soil mined sites. But one termite mound was observed in the location from where the control soil sample (S_{11}) was collected.

Table 11: Biological properties of soil samples

Sample No.	Earthworm count (Number m^{-2})	Total termite mound (Number per area)	Microbial biomass carbon (MBC) ($\mu g\ g^{-1}$ soil)	Dehydrogenase activity (μg TPF g^{-1} day^{-1})
S_1	-	-	139.89	2.35
S_2	-	-	145.09	2.47
S_3	-	-	110.91	2.30
S_4	-	-	141.33	2.47
S_5	-	-	100.14	1.95
S_6	-	-	111.51	2.26
S_7	-	-	137.94	2.44
S_8	-	-	162.51	2.68
S_9	-	-	186.15	2.91
S_{10}	-	-	221.51	3.31
S_{11}	13	1	290.80	3.69

4.1.2 Characterisation of water samples

The water samples were analysed for their physico-chemical properties. The results of the analysis are given in Table 12 and Table 13.

4.1.2.1 Temperature

The mean values of temperature of the water samples are given in Table 12. The temperature of water samples from mined sites ranged from 21.3°C (W_{10}) to 23.9°C (W_5). The temperature of water sample from control site was 20.9°C(W_{11}) which was the lowest among all the water samples.

4.1.2.2 pH

The pH of water samples collected from topsoil mined area ranged between 6.08 (W_1) to 6.60 (W_{10}) (Table 12). The value for water sample from control site (W_{11}) was 6.36. As per FAO guidelines for interpretation of water quality for irrigation (1985) (Appendix III), the normal range of pH for irrigation water is 6.5-8.4. All the water samples from mined area except W_1 were in the suitable range of irrigation.

4.1.2.3 Electrical conductivity

The average values of electrical conductivity are furnished in Table 12. The highest value of electrical conductivity was observed in W_5 (0.136 dS m^{-1}) whereas lowest was observed in control sample, W_{11} (0.116 dS m^{-1}). As per FAO guidelines (1985) (Appendix III), the values of electrical conductivity from different sources remained below the permitted limit and can be used safely for irrigation.

4.1.2.3 Total dissolved solids (TDS)

The mean values of TDS of the water samples are given in Table 12. The TDS values were in low status where W_{10} (76.80 mg L^{-1}) showed the lowest value and W_5 (87.04 mg L^{-1}) showed the highest value among the samples from mined area. The TDS value of water sample from the control site, W_{11} was 74.24 mg L^{-1}. As per the FAO guidelines for irrigation water quality (1985) (Appendix III), all the water samples are safe to be used for irrigation purposes.

4.1.2.4 Potassium

The potassium content in water samples from mined areas ranged from 1.30 mg L^{-1} (W_5) to 4.1 mg L^{-1} (W_{10}). The potassium content in the water sample obtained from control site, (W_{11}) (0.7 mg L^{-1}) was the lowest among the different samples analysed (Table 12).

4.1.2.5 Sodium

The sodium content from the water samples of mined area ranged from 9.6 mg L^{-1} (W_9) to 53.4 mg L^{-1} (W_1) (Table 12). There was no regular pattern in the sodium content and the different sources showed extreme variation.

4.1.2.6 Calcium

The calcium content of water samples from mined soils varied from 7.31 me L^{-1} (W_{10}) to 21.97 me L^{-1} (W_5) and followed a relatively irregular pattern. The control sample (W_{11}) showed the lowest value of 4.83 me L^{-1} (Table 12).

4.1.2.7 Magnesium

The content of magnesium ions ranged from 1.13 me L^{-1} (W_6) to 1.63 me L^{-1} (W_3) for the water sources from mined area. Unlike other cations, the magnesium content of the control sample (W_{11}) was found to be having the highest value of 2.76 me L^{-1} (Table 12).

4.1.2.8 Nitrate

The mean values ranged from 3.02 me L^{-1} (W_3) to 4.23 me L^{-1} (W_5) in the case of water samples from mined area. The water sample from control site showed a nitrate content of 3.08 me L^{-1} (Table 13). All the water samples showed relatively more or less similar values for this parameter. As per FAO guidelines (1985), except the water sample, W_3, all the other samples from the mined area, came under the slight to moderate category of suitability as irrigation water.

4.1.2.9 Phosphate

The phosphate content from the mined areas varied from 0.09 me L^{-1} (W_4) to 0.81 me L^{-1} (W_5). The water sample from the control area, W_{11} recorded a comparatively very low value of 0.04 me L^{-1} (Table 13). The water samples from the mined area showed values 5-10 times greater than that of the control.

4.1.2.10 Sulphate

The sulphate content of water samples from mined areas varied from 0.25 me L^{-1} (W_{10}) to 0.94 me L^{-1} (W_5) and followed a relatively irregular pattern. The control sample (W_{11}) showed the lowest value of 0.19 me L^{-1} (Table 13).

4.1.2.11 Bicarbonate

The bicarbonate ion content from the mined areas varied from 4.16 me L^{-1} (W_1) to 9.71 me L^{-1} (W_7). The water sample from the control area, W_{11} recorded a comparatively very low value of 6.35 me L^{-1} (Table 13). All the samples (including the control sample) except W_7 came under the moderate category. The sample W_7 with a value of 9.71 me L^{-1} came under the toxic category.

4.1.2.12 Chloride

The chloride concentration of samples from mined area ranged from 4.5 me L^{-1} (W_8) to 5.5 me L^{-1} (W_5) more or less uniform values (Table 13). The control site (W_{11}) showed the lowest value (4.1 me L^{-1}). As per the FAO guidelines (1985), the mined sites can be classified under the moderate category with respect to suitability for irrigation.

Table 12. Physico-chemical properties of water samples

Sample No.	Temperature (°C)	pH	EC (dS m^{-1})	TDS (mg L^{-1})	K (mg L^{-1})	Na (mg L^{-1})	Ca (me L^{-1})	Mg (me L^{-1})
W_1	22.5	6.08	0.131	83.84	2.10	53.40	17.15	1.56
W_2	22.3	6.32	0.135	86.40	3.10	19.70	14.30	1.28
W_3	22.8	6.55	0.133	85.12	2.40	14.70	16.17	1.63
W_4	23.1	6.31	0.125	80.00	1.90	20.00	13.03	1.59
W_5	23.9	6.28	0.136	87.04	1.40	23.90	21.97	1.47
W_6	23.3	6.40	0.121	77.44	1.50	13.90	11.06	1.13
W_7	22.8	6.34	0.129	82.56	1.50	13.70	9.86	1.22
W_8	22.5	6.44	0.133	85.12	1.30	11.20	11.65	1.29
W_9	21.7	6.59	0.128	81.92	1.60	9.60	9.22	1.31
W_{10}	21.3	6.60	0.120	76.80	4.10	31.60	7.31	1.59
W_{11}	20.9	6.36	0.116	74.24	0.70	13.10	4.83	2.76

Table 13. Concentration of anions in water samples

Sample No.	Nitrate (me L^{-1})	Phosphate (me L^{-1})	Sulphate (me L^{-1})	Bicarbonate (me L^{-1})	Chloride (me L^{-1})
W_1	3.63	0.14	0.89	4.16	4.8
W_2	3.59	0.21	0.85	4.75	4.6
W_3	3.02	0.19	0.61	4.23	5.1
W_4	3.18	0.09	0.45	5.05	4.6
W_5	4.23	0.81	0.94	5.71	5.5
W_6	4.12	0.45	0.75	4.33	4.9
W_7	3.82	0.36	0.39	9.71	5.2
W_8	3.49	0.69	0.48	7.05	4.5
W_9	3.52	0.49	0.56	6.21	4.7
W_{10}	3.69	0.13	0.25	6.56	5.4
W_{11}	3.08	0.04	0.19	6.35	4.1

4.2 EXPERIMENT II

Study on reclamation of soils in areas of soil mining for brick production

Taking the result of the predecessor research on essential nutrients as a prelude, a steady state assessment of mined soils in the survey area under consideration was done and a data base was generated based on aforesaid parameters read out in the soil samples collected. A cursory inception of data revealed that the soil samples collected from fifth location (S_5) showed the lowest nutrient status (Table 8 and Table 9). The analytical results of the physical, chemical and biological properties of the selected soil sample (S_5) is given in Table 14. Hence for detailed investigation, as per the experiment II was planned, bulk soil samples were collected for the study as envisaged in the experiment with 7 ameliorants under study (Table 15). The results of the pot culture study on reclamation of soils in areas of soil mining for brick production is discussed in Tables from 16 to 20.

Table 14. Characteristics of soil sample selected (S_5) for pot culture study in chilli

Sl. No.	Soil properties	Result
1.	Bulk density (Mgm^{-3})	1.73
2.	Soil moisture (%)	3.50
3.	Water holding capacity (%)	9.35
4.	Soil temperature (°C)	29.30
5.	pH	7.26
6.	Electrical conductivity (dS $m^{-1)}$	0.017
7.	Organic carbon (%)	0.08
8.	Av. nitrogen (kg ha^{-1})	87.81
9.	Av. phosphorus (kg ha^{-1})	13.25
10.	Av. potassium (kg ha^{-1})	57.71
11.	Av. calcium (mg kg^{-1})	182.41
12.	Av. magnesium (mg kg^{-1})	35.19
13.	Av. zinc (mg kg^{-1})	0.21
14.	Av. copper (mg kg^{-1})	0.42
15.	Av. iron (mg kg^{-1})	15.83
16.	Av. manganese (mg kg^{-1})	14.68
17.	Av. nickel (mg kg^{-1})	0.41
18.	Av. chromium (mg kg^{-1})	0.09
19.	Av. cadmium (mg kg^{-1})	BDL
20.	Av. lead (mg kg^{-1})	0.19
21.	Microbial biomass carbon (µg g^{-1} soil)	100.14
22.	Dehydrogenase (µg TPF g^{-1} day^{-1})	1.95

Table 15: Nutrient requirement for the soil selected (S_5) for pot culture study in chilli

Sl.No.	Treatment	Requirement per pot (g)
1.	T_1 : Soil test based NPK + FYM @ 20 t ha^{-1}	N- 0.5 P- 0.14 K- 0.015 FYM – 45
2.	T_2 : Soil test based NPK + poultry manure equivalent to N in 20 t ha^{-1} of FYM	N- 0.5 P- 0.14 K- 0.015 Poultry manure – 33.75
3.	T_3 : Soil test based NPK +vermicompost equivalent to N in 20 t ha^{-1}of FYM	N- 0.5 P-0.14 K-0.015 Vermicompost – 45
4.	T_4 : Soil test based NPK +coirpith compost equivalent to N in 20 t ha^{-1}of FYM	N- 0.5 P- 0.14 K- 0.015 Coir pith compost- 45
5.	T_5 : FYM @ 20 t ha^{-1}	N- nil P- nil K- nil FYM – 45
6.	T_6 : NPK + FYM @ 20 t ha^{-1} (KAU POP, 2016)	N- 0.36 P- 0.56 K- 0.10 FYM – 45
7.	T_7 : Absolute control	Nil

4.2.1 Biometric observations

4.2.1.1 Plant height

The data pertaining to plant height at 60 DAT is given in Table 16. The treatments significantly influenced the plant height. The treatment receiving NPK+ poultry manure (T_2) (50.42 cm) recorded significantly highest plant height. The lowest value was noticed in absolute control, T_7 (21.96 cm) and all the other treatments were on par.

4.2.1.2 Number of branches

The highest number of branches at 60 DAT (6.11) was found in NPK+ poultry manure treated plots (T_2). The lowest number of branches found in absolute control, T_7 (3.11) and all the other treatments were on par (Table 16).

4.2.1.3 Number of leaves

The data regarding number of leaves at 60 DAT are presented in Table 16. The treatment receiving NPK+ poultry manure (T_2) recorded the highest number of leaves (221.78). The lowest numbers of leaves were recorded in absolute control T_7 (15.00). The treatments T_4 (NPK+ coir pith compost), T_5 (FYM @ 20 kg ha^{-1}) and T_6 (KAU POP, 2016) were on par with T_7 (Absolute control).

4.2.1.4 Number of flowers

The treatment T_2 (NPK+ poultry manure) recorded the highest number of flowers (95.33) and was on par with T_3 (NPK+ vermicompost) (86.00). Absolute control T_7 (3.33) recorded the lowest number of flowers. The treatment, T_6, blanket recommendation of NPK +FYM (KAU POP, 2016) (14.00) was on par with T_7 (Table 16).

4.2.1.5 Number of fruits

The treatment consisting of various different organic amendments had a significant effect on number of fruits. The number of fruits at 60 DAT was highest in T_2, soil test based NPK+ poultry manure (31.33) and lowest in absolute control, T_7 (0.00) which was on par with T_6, NPK +FYM (KAU POP, 2016) (1.67) (Table 16).

Plate 12 View of chilli crop at harvest

a) Absolute control (T_7)

b) Soil test based NPK + poultry manure equivalent to N in 20 t ha^{-1} of FYM (T_2)

Plate 13. Effect of poultry manure on chilli crop

4.2.1.6 Per cent fruit set

Table 16 represents the result of per cent fruit set significant variation was seen among the treatments. Per cent fruit set was highest (32.95 per cent) in treatment receiving NPK+ poultry manure (T_2). The absolute control T_7 had the lowest value (0.00 per cent).

4.2.1.7 Yield per plant

The data pertaining to yield per plant is given in Table 16. The yield per plant was recorded highest in T_2, soil test based NPK+ poultry manure (128.47 g) whereas the yield of absolute control, T_7 was nil. The lowest yield obtained in T_7 (0.00 g).

4.2.2 Soil analysis

The data regarding soil analysis of pot culture experiment after harvest of the crop are given in from Tables 17 to 19.

4.2.2.1 Bulk density

The treatment receiving NPK+ vermicompost (T_3) recorded the lowest bulk density (1.60 Mg m^{-3}) and was on par with NPK+ coir pith (T_4) (1.61 Mg m^{-3}). The highest bulk density was noted in absolute control, T_7 (1.73 Mg m^{-3}) (Table 17) and was on par with T_1 which was treated with NPK+FYM (1.72 Mg m^{-3}).

4.2.2.2 Soil pH

The treatment receiving NPK+ poultry manure (T_2) recorded the highest soil pH (7.53). The absolute control, T_7 recorded the lowest pH (7.27) and was on par with T_6, KAU POP, 2016 (7.28) (Table 17).

4.2.2.3 Electrical conductivity

The highest electrical conductivity (0.03 dS m^{-1}) was recorded in NPK+ poultry manure (T_2) whereas the lowest (0.017 dS m^{-1}) was observed in absolute control (T_7) (Table 17).

4.2.2.4 Organic carbon

The treatment NPK+ poultry manure (T_2) showed the highest organic carbon value (0.15 per cent). The absolute control, T_7 recorded the lowest organic carbon 0.10 per cent. The treatment, T_1 (NPK+FYM) (0.11 per cent) and T_6 (0.11 per cent) (KAU POP, 2016) were on par with T_7 (absolute control) (Table 18).

4.2.2.5 Available nitrogen

The treatments significantly influenced the available nitrogen content of the soil in the pot culture experiment. The treatment receiving NPK+ poultry manure (T_2) recorded the highest available nitrogen content (102.17 kg ha^{-1}). The lowest available nitrogen content was observed in absolute control, T_7 (82.13 kg ha^{-1}). The initial content of available nitrogen before pot culture experiment was 87.81 kg ha^{-1} (Table 18).

4.2.2.6 Available phosphorus

The data regarding the available phosphorus content of the soil is given in Table 18. The treatment, T_2 which received NPK+ poultry manure showed a significantly higher available phosphorus content (31.40 kg ha^{-1}). The absolute control, T_7 recorded the lowest available phosphorus content (12.52 kg ha^{-1}). The initial available phosphorus content of the soil was 15.24 kg ha^{-1}.

4.2.2.7 Available potassium

The treatments had a significant influence on available potassium of the soil. The treatment receiving NPK+ poultry manure (T_2) marked the highest available potassium content (212.07 kg ha^{-1}). The absolute control, T_7 had the lowest value of available potassium (137.20 kg ha^{-1}) (Table 18).

4.2.2.8 Microbial biomass carbon

Various organic amendments had significant influence on the microbial biomass carbon of the soil. The treatment with NPK+ poultry manure (T_2) recorded the highest amount of microbial biomass carbon (374.13 μg g^{-1} soil) and was on par with NPK+ vermicompost (T_3) (373.17 μg g^{-1} soil). The absolute control had the lowest microbial biomass carbon content (159.40 μg g^{-1} soil) (Table 18).

4.2.2.9 Dehydrogenase activity

The dehydrogenase enzyme which represents the microbial activity was positively influenced by various treatments. The treatments with NPK+ coir pith (T_4) recorded the highest dehydrogenase activity (3.63 µg TPF g^{-1} day^{-1}). This was on par with T_2 (NPK+ poultry manure) (3.56 µg TPF g^{-1} day^{-1}). The absolute control T_7 marked the lowest dehydrogenase activity (2.10 µg TPF g^{-1} day^{-1}). This was on par with T_6 which was KAU POP, 2016 (2.26 µg TPF g^{-1} day^{-1}) (Table 18).

Table 16: Biometric observations and yield attributes of chilli crop in pot culture study

Treatments		Plant height (cm)	Number of branches	Number of leaves	Number of flowers	Number of fruits	Fruit set (%)	Yield/ plant (g)
T_1	NPK + FYM @ 20t ha^{-1}	26.59^{b}	4.00^{bc}	122.22^{b}	33.00^{c}	4.67^{d}	13.95^{d}	19.13^{d}
T_2	NPK + poultry manure equivalent to N in 20t ha^{-1} of FYM	50.42^{a}	6.11^{a}	221.78^{a}	95.33^{a}	31.33^{a}	32.95^{a}	128.47^{a}
T_3	NPK + vermicompost equivalent to N in 20t ha^{-1} of FYM	30.21^{b}	4.66^{b}	86.89^{c}	86.00^{a}	20.33^{b}	23.85^{b}	83.37^{b}
T_4	NPK + coir pith compost equivalent to N in 20t ha^{-1} of FYM	30.97^{b}	4.00^{bc}	43.33^{d}	68.00^{b}	10.33^{c}	15.44^{cd}	42.37^{c}
T_5	FYM @ 20t ha^{-1}	29.72^{b}	3.56^{bc}	26.33^{d}	46.00^{c}	9.67^{c}	21.16^{bc}	39.63^{c}
T_6	NPK + FYM @ 20t ha^{-1} (KAU POP, 2016)	26.68^{b}	3.44^{bc}	21.44^{d}	14.00^{d}	1.67^{de}	12.64^{d}	5.33^{de}
T_7	Absolute control	21.96^{b}	3.11^{c}	15.00^{d}	3.33^{d}	0.00^{e}	0.00^{e}	0.00^{e}

Means followed by common letters do not differ significantly at 5 per cent level of DMRT

Table 17: Physical and electrochemical properties of soil after pot culture study

Treatments		Bulk density (Mg m^{-3})	pH	EC (dS m^{-1})
T_1	NPK + FYM @ 20 t ha^{-1}	1.72^{ab}	7.35^{c}	0.02^{c}
T_2	NPK + poultry manure equivalent to N in 20 t ha^{-1} of FYM	1.70^{b}	7.53^{a}	0.03^{a}
T_3	NPK + vermicompost equivalent to N in 20 t ha^{-1} of FYM	1.60^{c}	7.42^{b}	0.03^{b}
T_4	NPK + coir pith compost equivalent to N in 20 t ha^{-1} of FYM	1.61^{c}	7.45^{b}	0.03^{b}
T_5	FYM @ 20 t ha^{-1}	1.70^{b}	7.35^{c}	0.02^{c}
T_6	NPK + FYM @ 20 t ha^{-1} (KAU POP, 2016)	1.70^{b}	7.28^{d}	0.02^{c}
T_7	Absolute control	1.73^{a}	7.27^{d}	0.017^{d}

Means followed by common letters do not differ significantly at 5 per cent level of DMRT

Table 18: Major chemical and biological properties of soil after harvest of chilli

Treatments		Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Microbial biomass carbon (µg g^{-1} soil)	Dehydrogenase activity (µg TPF g^{-1} day^{-1})
T_1	NPK + FYM @ 20 t ha^{-1}	0.11^{d}	94.10^{c}	22.57^{c}	174.80^{d}	200.73^{d}	2.84^{c}
T_2	NPK + poultry manure equivalent to N in 20 t ha^{-1} of FYM	0.15^{a}	102.17^{a}	31.40^{a}	212.07^{a}	374.13^{a}	3.56^{ab}
T_3	NPK + vermicompost equivalent to N in 20 t ha^{-1} of FYM	0.14^{b}	98.20^{b}	28.23^{b}	197.23^{b}	373.17^{ab}	3.38^{b}
T_4	NPK + coir pith compost equivalent to N in 20 t ha^{-1} of FYM	0.13^{c}	97.10^{b}	27.53^{b}	190.87^{c}	358.10^{b}	3.63^{a}
T_5	FYM @ 20 t ha^{-1}	0.12^{c}	87.20^{d}	20.57^{d}	160.40^{e}	300.60^{c}	2.48^{d}
T_6	NPK + FYM @ 20 t ha^{-1} (KAU POP, 2016)	0.11^{d}	93.00^{c}	20.53^{d}	161.67^{e}	206.67^{d}	2.26^{de}
T_7	Absolute control	0.10^{d}	82.13^{e}	12.52^{e}	137.20^{f}	159.40^{e}	2.10^{e}

Means followed by common letters do not differ significantly at 5 per cent level of DMRT

Discussion

5. DISCUSSION

The experiment on ‘Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soils’ was carried out at College of Horticulture, Vellanikkara during 2017-2018. The major research findings of the above study are discussed below.

5.1. EXPERIMENT I

Evaluation of physical, chemical and biological properties of soil and water

5.1.1. Characterisation of soil samples

5.1.1.1. Physical properties

The soil samples were subjected to analysis of temperature, bulk density, water holding capacity, moisture content and texture.

Bulk density is the measure of physical health of soil. It is the major indicator of soil air and compaction. The soils with bulk densities above 1.6 Mg m^{-3} restrict the plant growth by restricting the root penetration and decreasing the soil aeration. In the study area, the bulk densities of the mined soil varied from 1.45 to 1.73 Mg m^{-3} (Fig.1). The bulk density of the unmined soil was 1.22 Mg m^{-3} (Table 7). The higher bulk densities in the desurfaced soil might be due to the loss of organic carbon in the process of top soil removal. Another reason for the higher bulk density might be due to the migration and loss of finer particles like clay, silt and $CaCO_3$ during mining.

The loss of clay and organic matter had resulted in lowering the moisture content (Fig.2) and water holding capacity (Fig.3) of mined soils (Table 6). This had further resulted in elevating the soil temperature (Fig.4). The loss of clay was reflected in the change in soil texture from clay loam to sandy loam (Table 7 and Fig. 5). Similar results in the variation of physical properties were also obtained by Indorante *et al.* (1981), Gollany *et al.* (1992), Singh *et al.* (2015) and Abdullahi (2018).

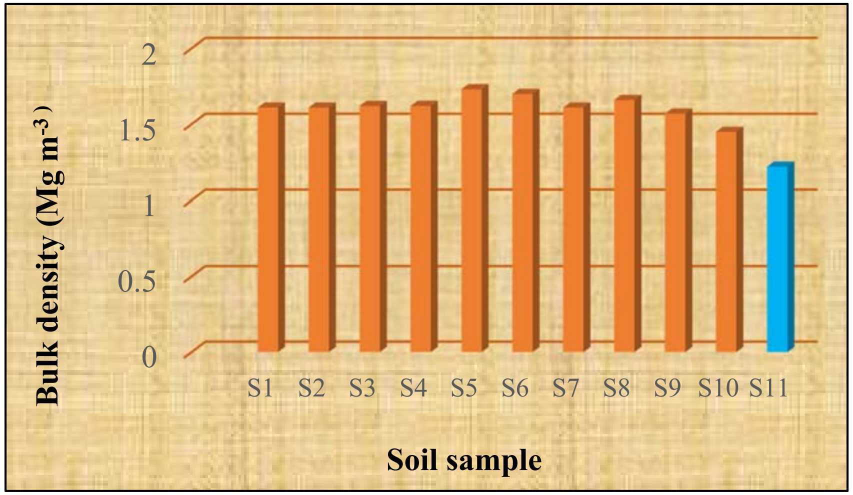

Fig. 1. Bulk density of soil samples

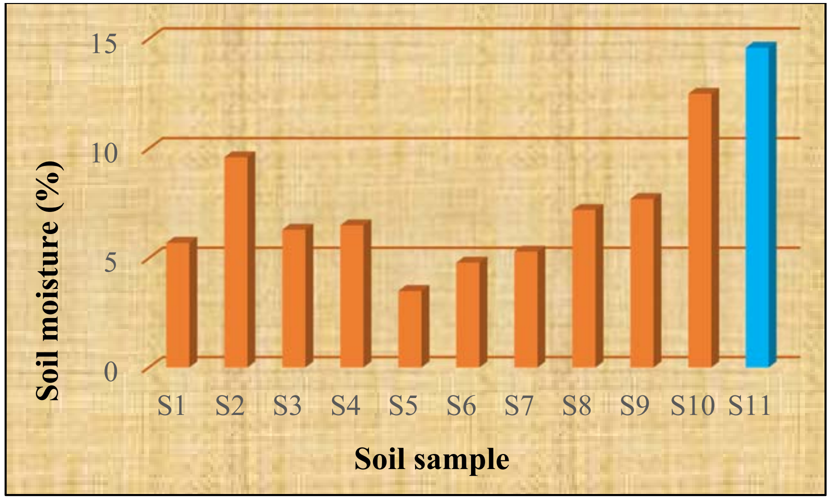

Fig. 2. Moisture content of soil samples

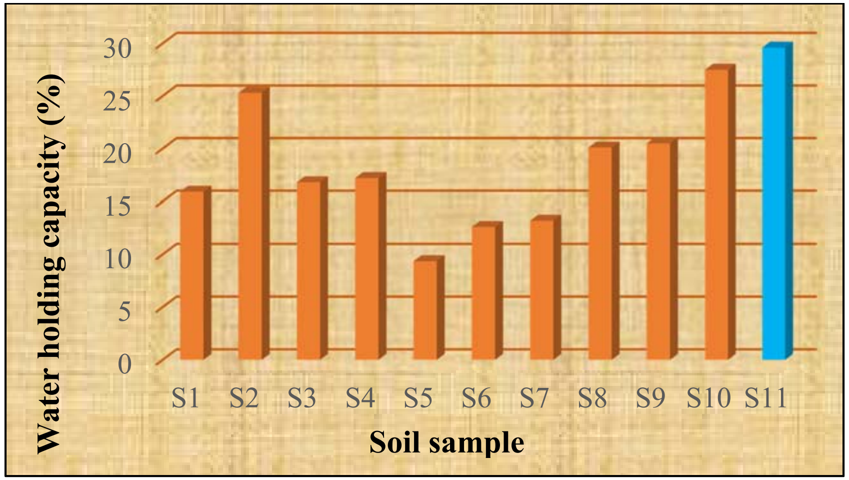

Fig.3. Water holding capacity of soil samples

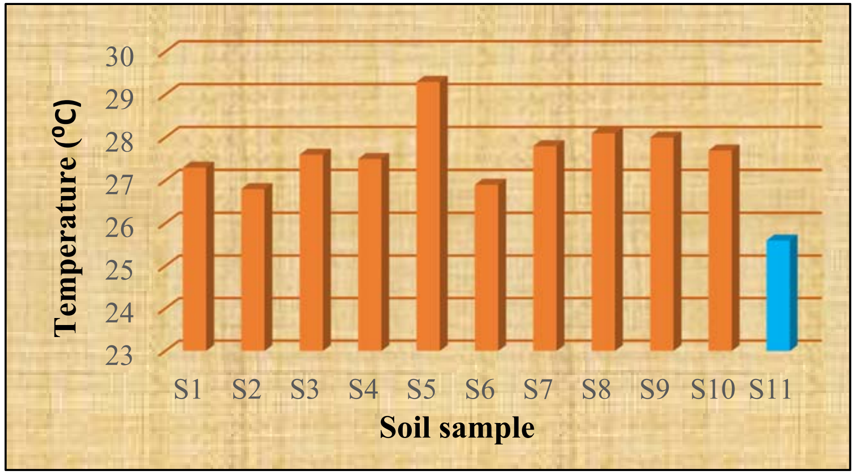

Fig.4. Temperature of soil samples

5.1.1.2. Chemical properties

5.1.1.2.1. pH

Soil pH can be referred to as a master variable as it holds the key for variation in physical, chemical and biological properties of soil. Any change in the soil pH directly affects the ecology of the soil. It influences the availability of nutrients as well as the activity of soil micro fauna and flora. It acts as an indicator of the chemical composition of soil. The ideal soil pH ranges from 6.5 to 7.5 in which most of the nutrients are available to plants.

The pH of the control soil which was not mined was slightly acidic (6.33). The pH of the desurfaced soils of the study area ranged from 6.61 – 7.59 and were near was neutral in nature (Table 8). Most of the crops come well in this range of pH. The presence of $CaCO_3$ nodules soil may have attributed to the rise in pH in mined soils. The result is in conformity with studies of Grewal and Kuhad (2002), Singh *et al.* (2015) and Islam *et al.* (2017).

5.1.1.2.2. Electrical conductivity

Soil electrical conductivity is the measure of amount of salts in the soil. The optimum value of electrical conductivity is essential for the proper growth of plants. It always correlate very well with the other soil physical and chemical properties. Lower value of EC was observed in control soil (0.009 dS m^{-1}) compared to desurfaced soils (Table 8). It may be attributed to the fact that due to high soil temperature and capillary rise, the salt got accumulated in the surface of the mined soils. Similar results were observed by Grewal and Kuhad (2002).

5.1.1.2.3. Organic carbon

Organic matter is the store house of plant nutrients. Apart from providing habitat, organic matter improves soil physical properties. Overall, soil organic matter play a crucial role in soil health. Soil organic carbon is a measure of soil organic matter. Soil organic carbon is greatly influenced by anthropogenic activities. In heavily exploited soils, organic carbon may be very low.

In the desurfaced soils of the study area, the organic carbon was in the range of 0.08 – 0.46 per cent with mean of 0.26 per cent (Table 8). The organic carbon content in the unmined soil (0.66 per cent) was slightly higher than desurfaced soil. About 61 per cent reduction of soil carbon was observed.

This significant reduction in organic carbon is due to fact that top soil was lost completely during the process of desurfacing and thus exposing the lower horizons which are low in organic matter. The organic matter is always added to the top soil which creates a huge difference in the organic carbon levels across the horizons. So when top soil is removed the newly formed surface soil is deprived of organic matter (Tressen *et al*., 1994).

Similar results were obtained by Singh *et al.* (2015) where the percentage reduction of soil organic carbon was 47.43 per cent. These results are also in conformity with the studies of Khan *et al.* (2007) and Islam *et al.* (2017).

5.1.1.2.4. Available nitrogen

Among nutrient elements, nitrogen is the most important element which influences the productivity and health of the soil. The amount of available nitrogen in the soil is a direct indication of the fertility status of the soil. The process of desurfacing adversely affected the available nitrogen in the soil. In the control soil, the available nitrogen content was 250.88 kg ha^{-1} and in desurfaced soil, it was in the range of 87.81–196 kg ha^{-1} with a mean of 141.28 kg ha^{-1}) (Table 9). Net decline amounted to about 43.70 per cent (Appendix II).

The loss of organic matter can be attributed to the lower levels of available nitrogen as organic matter and organic carbon plays a crucial role in nitrogen dynamics of the soil. The nitrogen fixing microbes are also lost during the process of desurfacing. The results are in conformity with the studies of Islam *et al*. (2015).

5.1.1.2.5. Available phosphorus

Phosphorus is the second most important nutrient element next to nitrogen. It is the important component in nucleic acids, as well as in the production of ATP, the energy currency of the cell. It is associated with the energy transformation in the cell. It stimulates the root development and is responsible for crop maturity. Overall, phosphorus is crucial for growth and development of plants.

In the study area, the concentration of available phosphorus in mined soil ranged from 13.25 to 57.67 kg ha^{-1} whereas in normal soil, it was 92.32 kg ha^{-1} (Table 9). Both mined and control soils were having high concentration of available phosphorus. About three fourth of the available phosphorus content (74.5 per cent) was lost due to top soil mining. The diminishing trend of available phosphorus may be due to the loss of organic matter in the subsoil where biological activity is less. High bulk density and change in pH also affect the phosphorus dynamics by creating an unfavourable environment for phosphorus availability.

5.1.1.2.6. Available potassium

Potassium plays a unique function in plants as a regulator of metabolic activities. It is the activator of many enzymes and is the only element which remains in plant fluids in soluble state. It is known for its ability to improve the drought resistance in plants.

The available potassium in the mined soils of study area ranged between 57.71 – 225.88 kg ha^{-1} (Table 9). The percentage reduction in the available potassium content was about 43.36 per cent (Brookes *et al.*, 1982) and Singh *et al.* (2015) had reported similar results in their studies.

Bramble – Brodhal *et al.* (1985) reported that in desurfaced soils both organic carbon and exchangeable potassium followed a similar trend. The exposure of subsoil with low organic matter content and poor biological activity can be the cause for the diminishing trend of exchangeable potassium. Another reason may be the lack of proper weathering process in subsoil resulting in the inefficient release of potassium from potassium rich minerals. The surface soil with ample amount of clays which accelerate the process of potassium conversion was lost due to soil desurfacing.

5.1.1.2.7. Available calcium

Calcium is a key element to both plants as well as soil. In plants, it is essential to maintain cell structure and proper growth. In soil, it acts as the major flocculating agent in binding soil particles and organic matter thus improving the soil structure and porosity. This in turn affects all the physical properties of the soil. In the study area, the calcium content of the mined soils were higher than that of the control soils. In mined soils, the available calcium content ranged from 148.72 to 582.06 ppm (Table 9). The increase in the available calcium content due to desurfacing is about 62 per cent (Appendix IV). The elevation in the available calcium content may be due to the presence of free $CaCO_3$ on the surface as well as throughout the profile of the near neutral soils as reported by Gollany *et al.*, 1992.

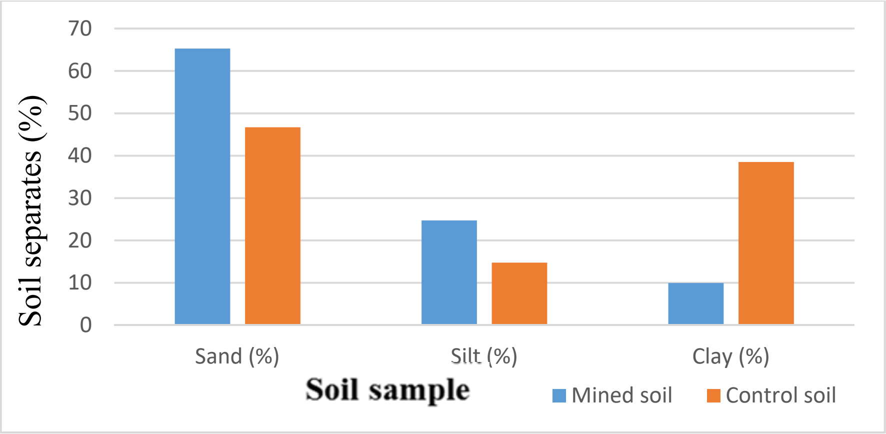

Fig.5. Textural analysis of mined and control soils

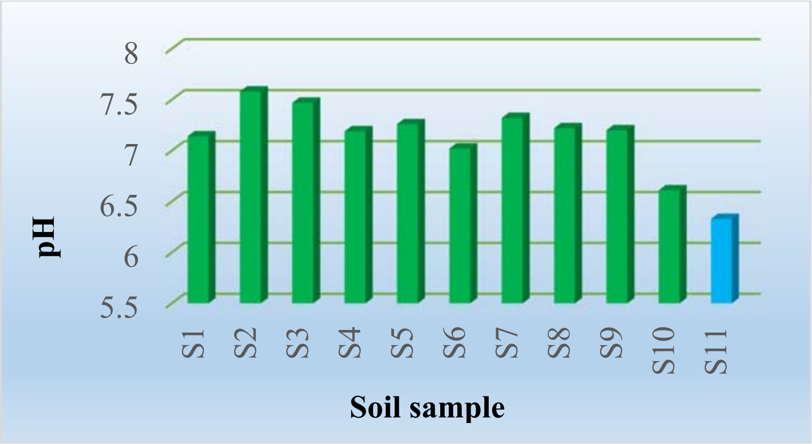

Fig.6. pH of soil samples

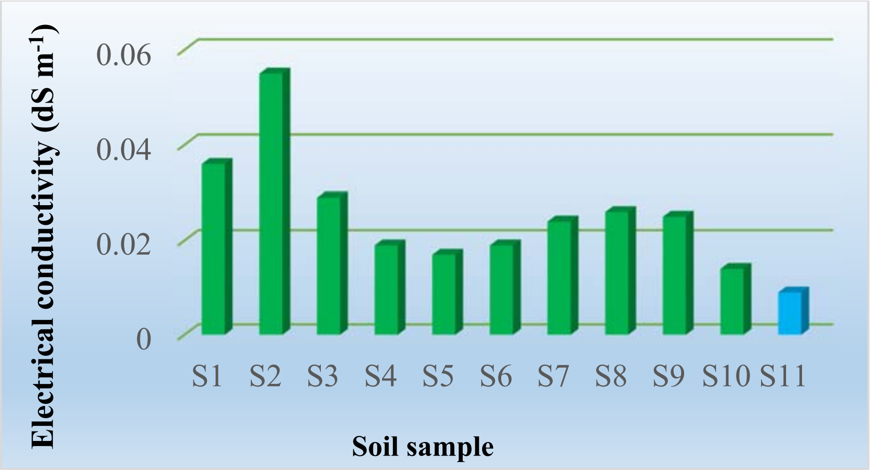

Fig.7. Electrical conductivity of soil samples

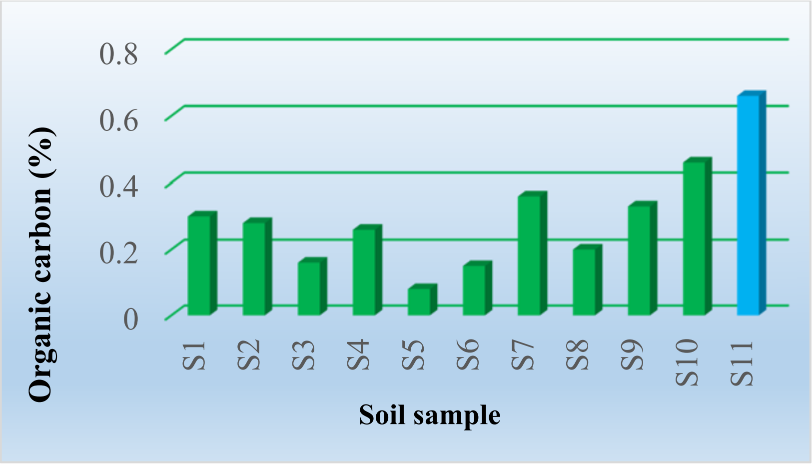

Fig.8. Organic carbon content of soil samples

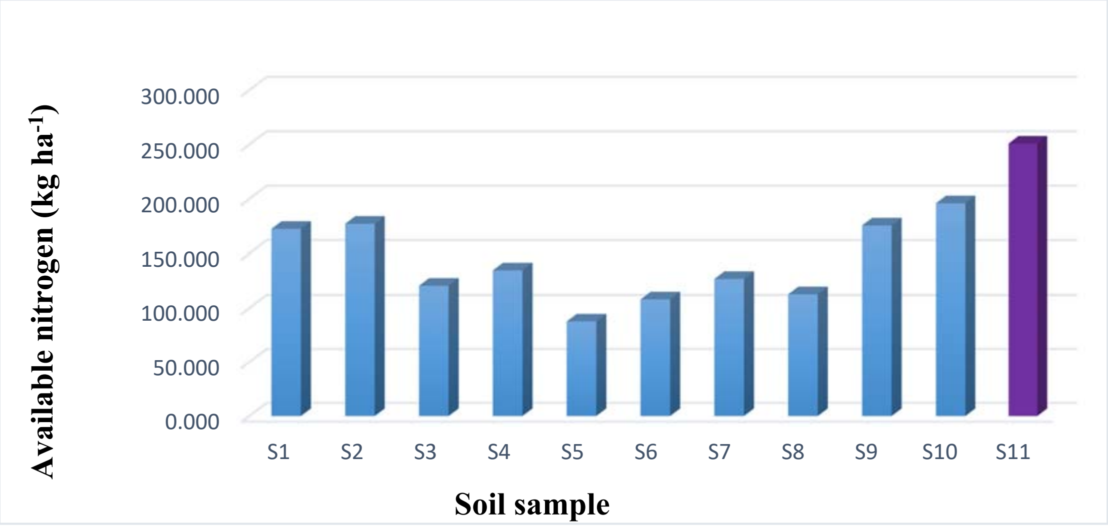

Fig 9. Available nitrogen content of soil samples

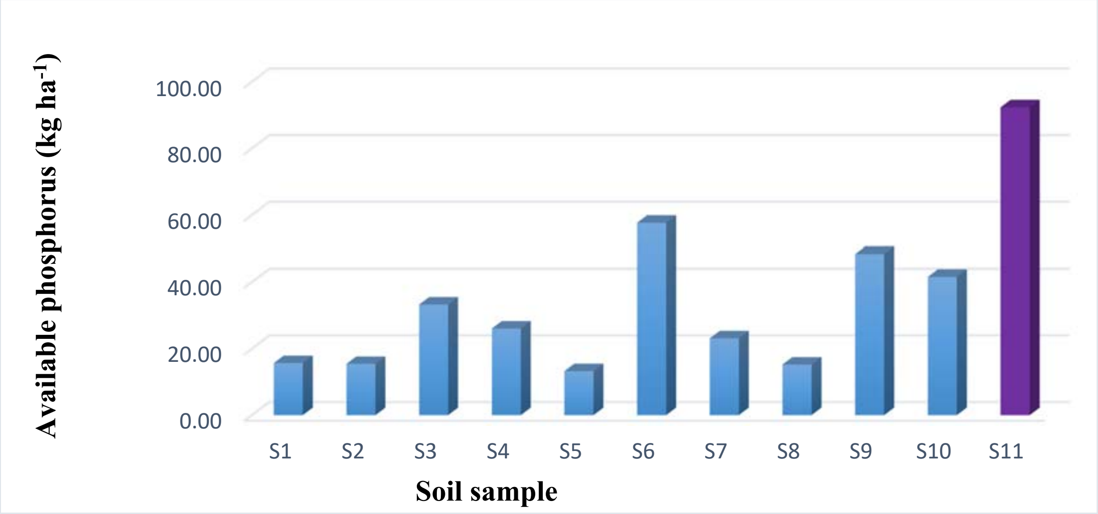

Fig 10. Available phosphorus content of soil samples

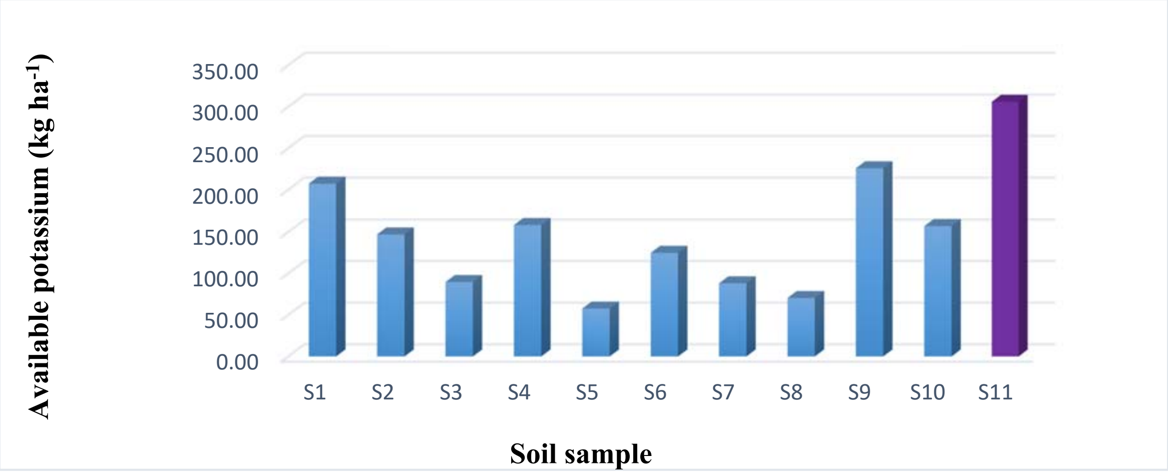

Fig 11. Available potassium content of soil samples

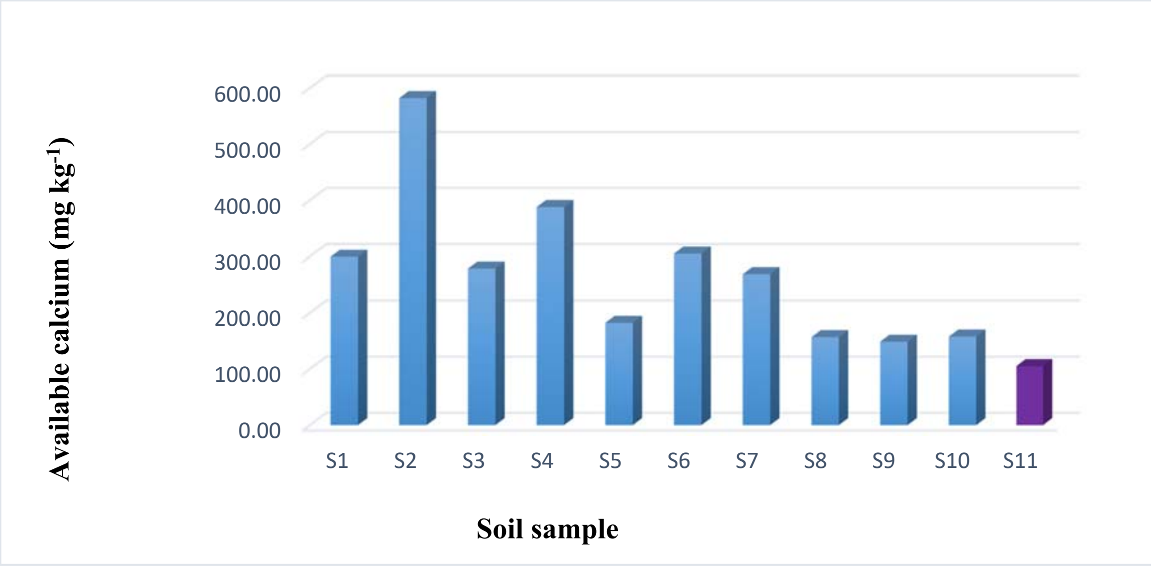

Fig 12. Available calcium content of soil samples

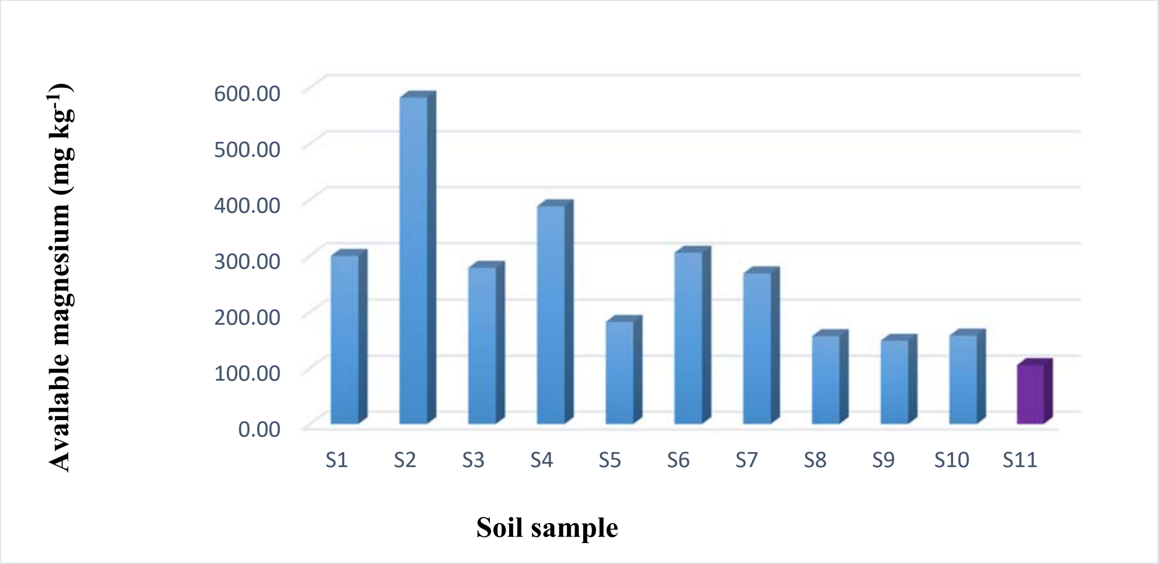

Fig.13. Available magnesium content of soil samples

5.1.1.2.8. Available magnesium

Magnesium is a crucial element for plants as it is present in chlorophyll. It is an active element in the metabolism of phosphorus. Even though it rarely affects the crop, magnesium is essential to maintain the nutritional quality of the crop.

In the present study, the available magnesium content in the desurfaced soils ranged from 35.19 to 73.08 ppm. The average magnesium content of mined soils was 129.28 ppm (Table 9). The percentage reduction in available magnesium content due to soil desurfacing accounted to 55.6 per cent (Appendix IV). The loss of organic matter in topsoil had resulted in the reduction in available magnesium content in desurfaced soils (Gollany *et al.*, 1992).

5.1.1.2.9. Available micronutrients (Zn, Cu, Mn and Fe)

The content of all the micronutrient, viz., Zn, Cu, Mn and Fe were found to increase in the mined soils compared to the control soil and percentage increase is shown in Appendix IV. The available zinc content in the desurfaced soil was in the range of 0.09 – 0.44 ppm. The available zinc content in the control soil is 0.04 ppm (Table 10). The percentage increase in available zinc content due to desurfacing is 14.41 per cent.

The available copper content in the top mined soil in the study area ranged from 0.20 to 1.07 ppm whereas that in normal soil was 0.14 ppm (Table 10). The percentage increase in available copper was about 71 per cent.

The available iron content in the normal soil was 5.43 ppm whereas in desurfaced soil it ranged from 8.28 to 36.14 ppm (Table 10). The desurfacing has resulted in the increase of 96.3 per cent.

The available manganese content also followed a similar trend. In desurfaced soils it ranged from 6.49 to 15.54 ppm whereas in normal soils, it was 4.22 ppm (Table 12). Net increase of 63.8 per cent was observed in desurfaced soils.

The higher levels of micronutrient content in soils samples from mined area may be primarily attributed to the depth of mining activities. The continuous deep mining of soil has resulted in the exposure of subsoil which are already rich in micronutrients leached from soil surface (Ishaq *et al.,* 2009).

5.1.1.2.10. Available heavy metals (Ni, Cd, Cr and Pb)

Heavy metals followed a similar trend as that of micronutrients with an increase (Appendix IV) in their content in mined soils compared to control soil.

The available nickel (ultra micronutrient) content of the desurfaced soils were in the range of 0.25 – 0.95 ppm whereas in the control soil, it is 0.19 ppm (Table 10). The net increase in the available nickel content due to desurfacing is about 61 per cent.

The available chromium content of the desurfaced soils in the study area ranged from below detectable limits to a maximum of 0.12 ppm. The available chromium values of normal soils were below detectable level (Table 10).

The available cadmium content of the desurfaced as well as control soils in the study area were so low that it could not be detected within the limits (Table 10).

The available lead also followed a similar trend. The available lead in desurfaced soil ranged from 0.16 to 0.46 ppm (Table 10). The value of available lead in normal soil was 0.15 ppm (Table 10). The percentage increase due to desurfacing was 44 per cent.

The result is in agreement with the findings of Ishaq *et al.* (2009). The higher concentrations of heavy metals in mined soils when compared to control soil may be due to the burning of fuel in brick kilns and subsequent pollution. The main fuel is wood from locally available trees along with other fuels like coal. The burning of wood and coal generate micronutrient and heavy metal pollutants which settles down in the soil. Another reason for higher concentrations of heavy metals is the depth of soil mining. Deep mining of soil results in the exposure of subsoil which are rich in heavy metal concentration (Singh *et al.* 2015).

5.1.1.3. Biological properties

The biological properties of soil such as microbial biomass carbon, dehydrogenase activity and the count of earthworm and termite mound were found to be significantly affected by soil mining activities.

Earthworms (13 numbers m^{-2}) and termite mound (1 number per area) were observed only in the control site. Microbial biomass carbon in control soil was found to be three times higher than that of mined soils. Similarly, the dehydrogenase activity was reduced to half in case of mined soil (S_5)) when compared with control soil (Table 11). The loss of organic carbon and higher bulk density contributed to this phenomenon. The elevated levels of soil temperature as well as increased pH also might have affected the biological properties of mined soils adversely.

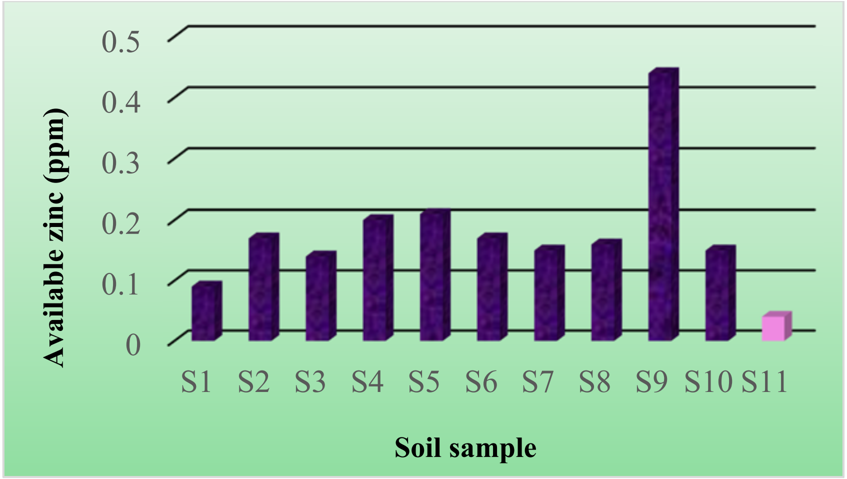

Fig.14. Available zinc content of soil samples

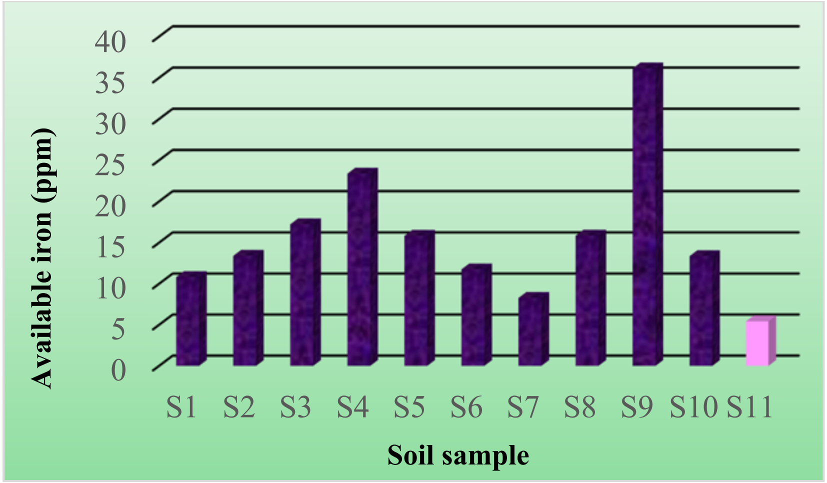

Fig.15. Available iron content of soil samples

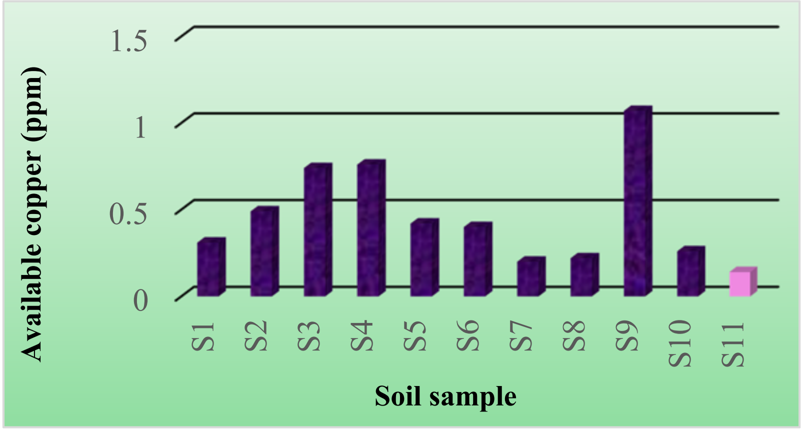

Fig.16. Available copper content of soil samples

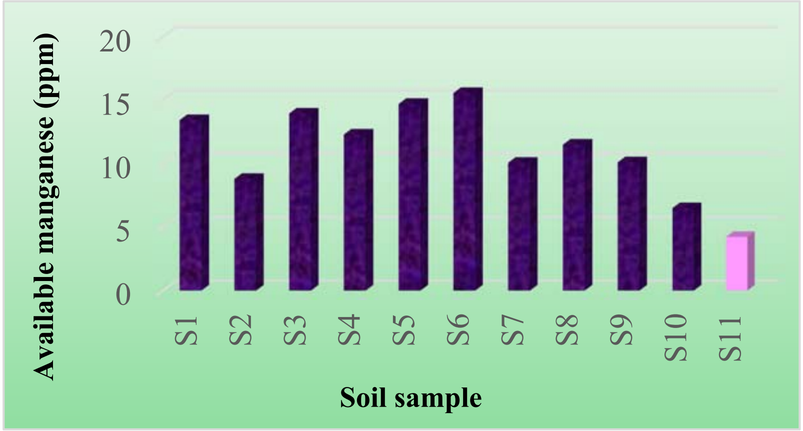

Fig.17. Available manganese content of soil samples

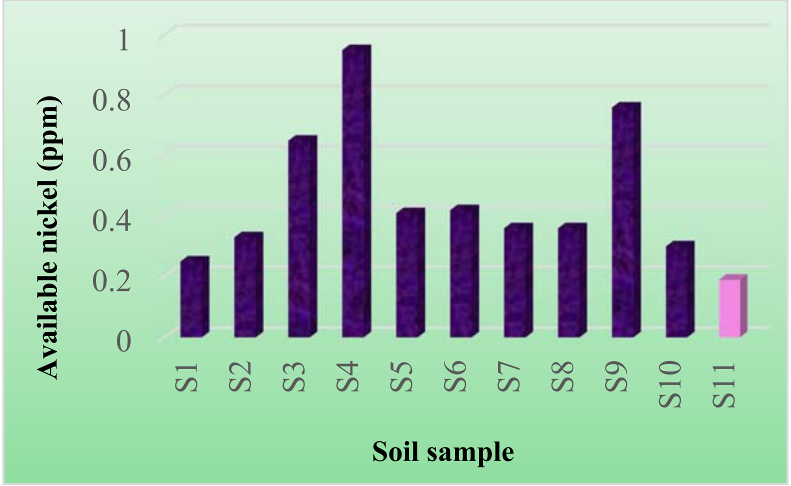

Fig.18. Available nickel content of soil samples

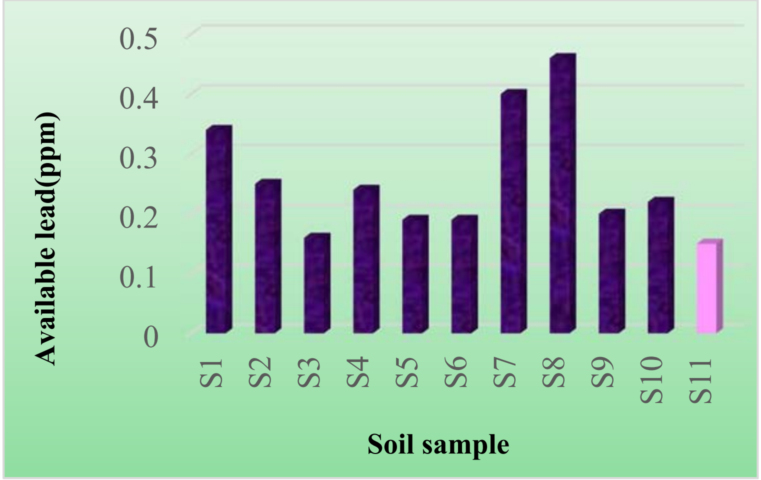

Fig.19. Available lead content of soil samples

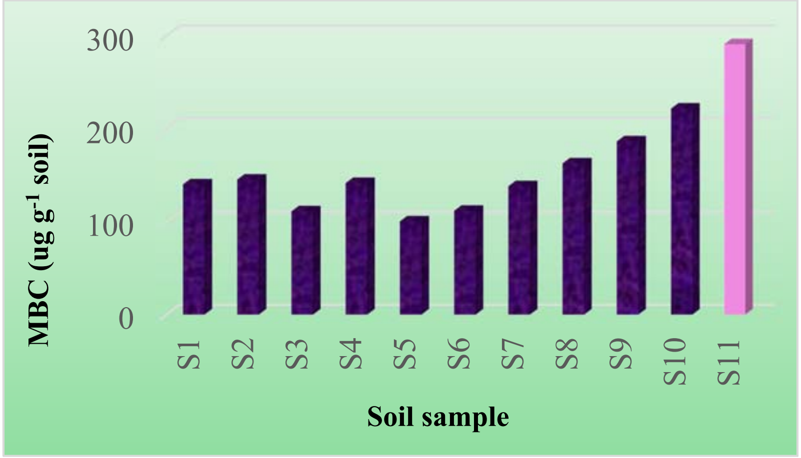

Fig.20. Microbial biomass carbon content of soil samples

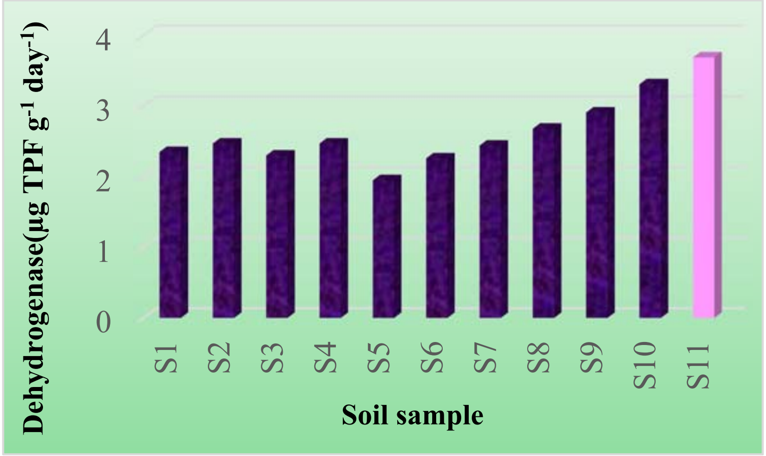

Fig.21. Dehydrogenase enzyme activity of soil samples

5.1.2 Water samples

5.1.2.1 Temperature

The temperature of water samples collected from mined areas were higher than that of control sample (Table 12). Water temperature of an aquatic body shows very close association with ambient temperature and plays important role in metabolism of different organisms. In the present study increase in water temperature might be due to the emissions of heat from the kilns which slightly raised the water temperature in nearby aquatic systems which was very much comparable with the heat losses from other brick kilns (Maithel *et al.*, 1999). The turbidity of water collected from might areas were also high which may have caused due to dumping of ash and cutting land resulting in high silt content in water bodies. The high turbidity might be responsible for high level of water temperature in the aquatic bodies near brick kiln industry because the suspended particles absorb the heat from the sunlight making the water warm (Tiwari, 2005; Mishra *et al.,* 2013)

5.1.2.2 pH

Measurement of pH indicates the level of acidic and basic nature of the aquatic system. During the study, pH was slightly acidic in water bodies close to the mined sites (Table 12). This might be due to leaching of some elements or acidic substances into the water bodies from the vicinity of the brick kilns (Khan *et al*., 2007). The fluctuations in pH was also related with input loads of pollutants in the aquatic systems (Sahu *et al.,* 1995).

5.1.2.3 Electrical conductivity and TDS

The fluctuations in electrical conductivity (Table 12) might be due to fluctuations in total dissolved solids and salinity (Boyd, 1981). Water conductivity is mainly attributed to the dissolved ions liberated from the decomposed plant matter (Sarwar and Irfan-Ul-Majid, 1997) and input of organic and inorganic waste (Wright, 1982). The elevated EC values in the mined soils can be associated with the increase in EC values in water bodies associated with them.

5.1.2.4 Potassium

The potassium content in water samples collected from mined areas were found to be higher than that of control sample (Table 12). It may be attributed to the burning of fuel wood for brick production were the resultant ash rich in potassium increased its concentration in water bodies. The run-off water rich in potassium from agricultural fields also increased the concentration of potassium in water from mined areas (Juned and Arjun, 2011).

5.1.2.5 Sodium

The sodium concentration in water samples showed an irregular trend. As per the results, the sodium concentration of water samples collected from mined areas except that of W_8 and W_9 were found to be higher than control sample (Table 12).

5.1.2.6 Calcium

The content of calcium in water samples of mined area was higher than that of control samples (Table 12). This might be due to the presence of calcium carbonate nodules in the soils of mined area.

5.1.2.7 Magnesium

Higher concentration of magnesium was found in water samples collected from control area. Unlike other cations, higher concentration of magnesium was found in water samples from control area (Table 12). This can be correlated to the lower content of magnesium in mined soils when compared to the unmined soils of study area.

5.1.2.8 Nitrate and phosphate

The presence of higher concentrations of nitrate and phosphate in water samples of mined areas may be attributed to the increase in soil erosion due to topsoil mining (Table 13). The topsoil mining resulted in reducing infiltration rate and increasing surface runoff thereby contributing towards the erosion of nutrients applied in agricultural fields. This had adversely affected the nitrate and phosphate contents in water bodies (Jamatia *et al.*, 2014).

5.1.2.9 Bicarbonate

The concentration of bicarbonate followed an irregular trend where all water samples were slightly to moderately toxic to be used as irrigation source (Table 13). This indicated the deterioration of water quality for irrigation in these sources.

5.1.2.10 Chloride

The chloride content in water samples collected from mined areas were higher than that of control sample (Table 13). This may be due to the disposal of waste water generated during brick production which later reached the water bodies.

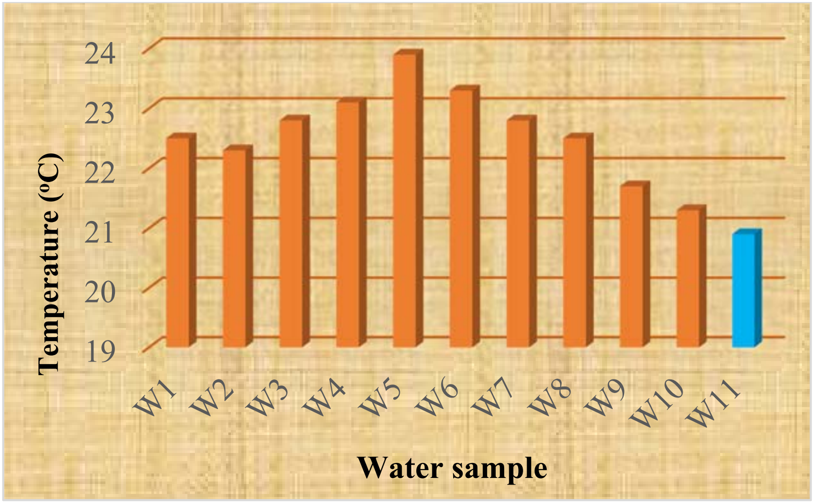

Fig.22.Temperature of water samples from different sources

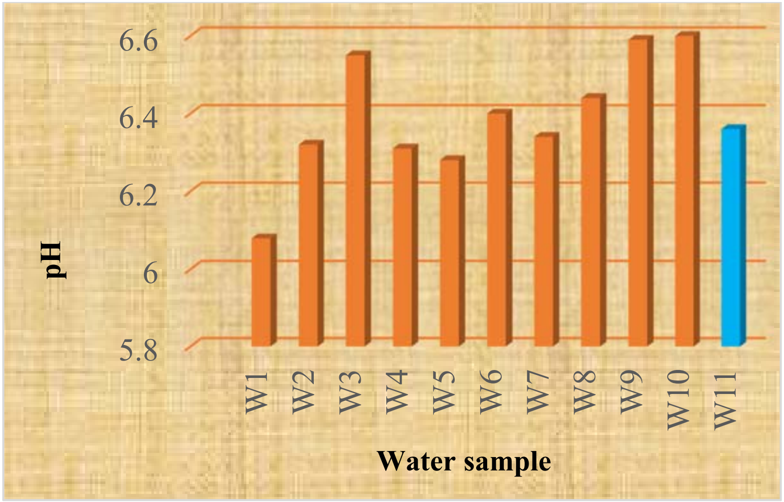

Fig.23. pH of water samples from different sources

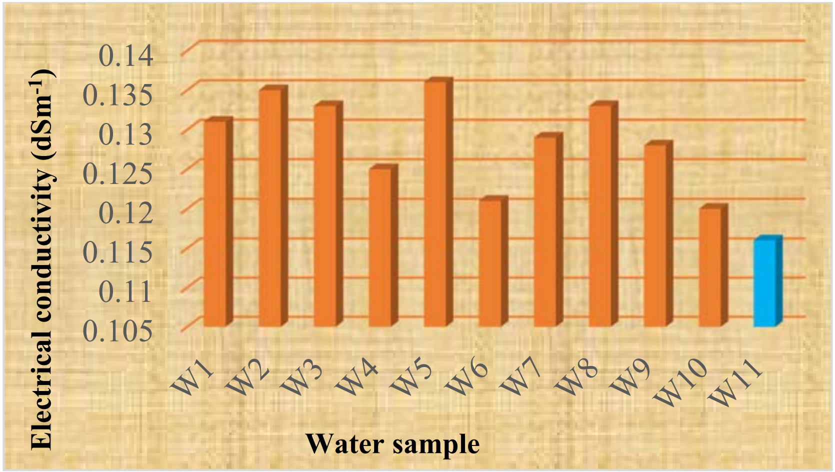

Fig.24. Electrical conductivity of water samples from different sources

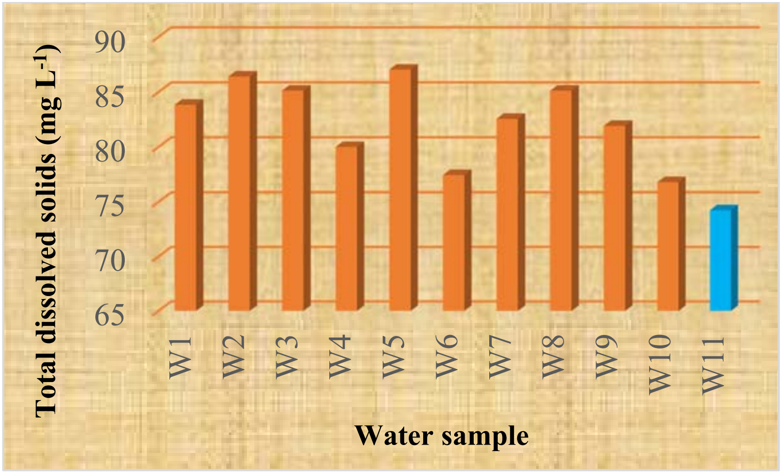

Fig.25. TDS of water samples from different sources

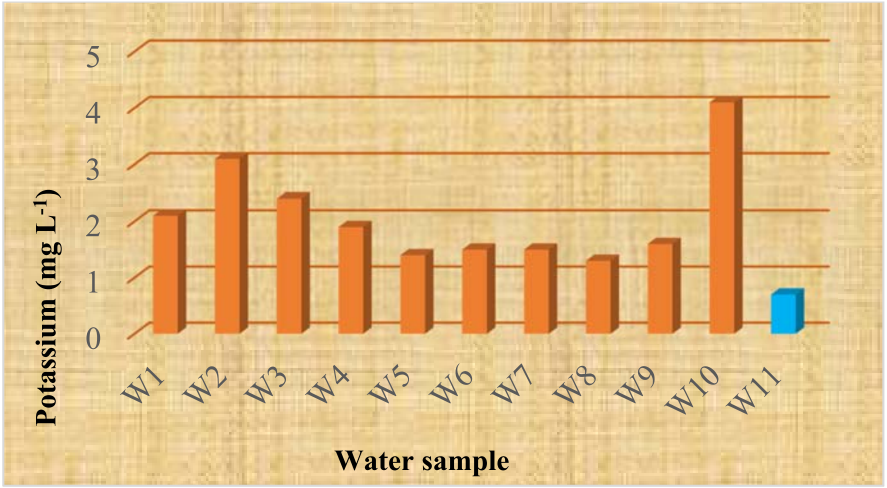

Fig.26. Potassium content of water samples from different sources

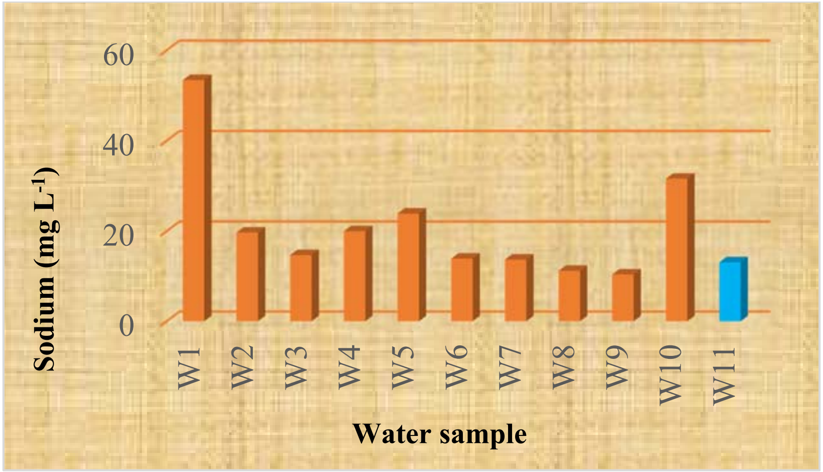

Fig.27. Sodium content of water samples from different sources

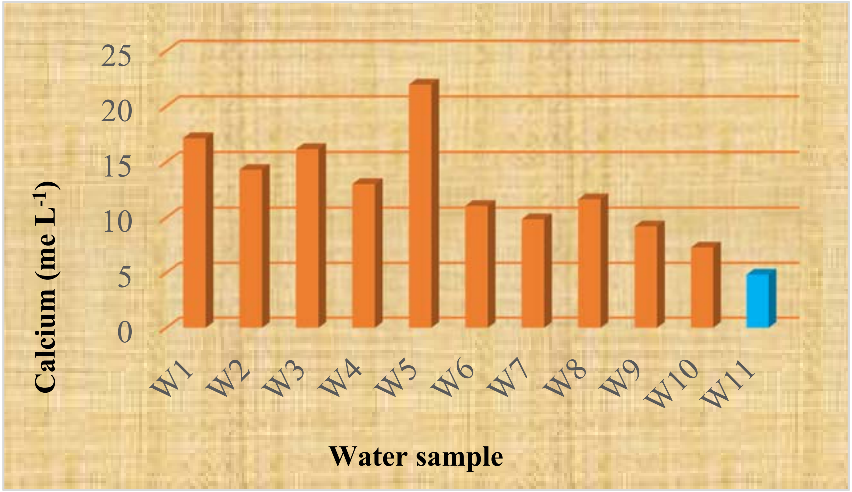

Fig.28. Calcium content of water samples from different sources

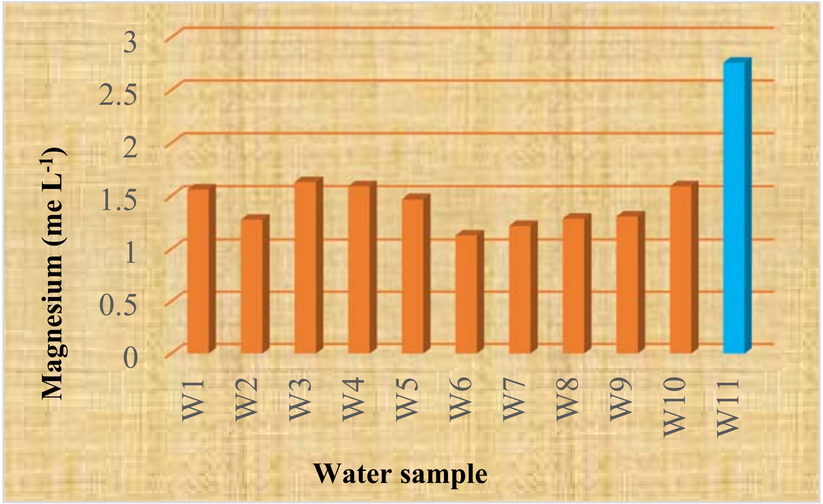

Fig.29. Magnesium content of water from different sources

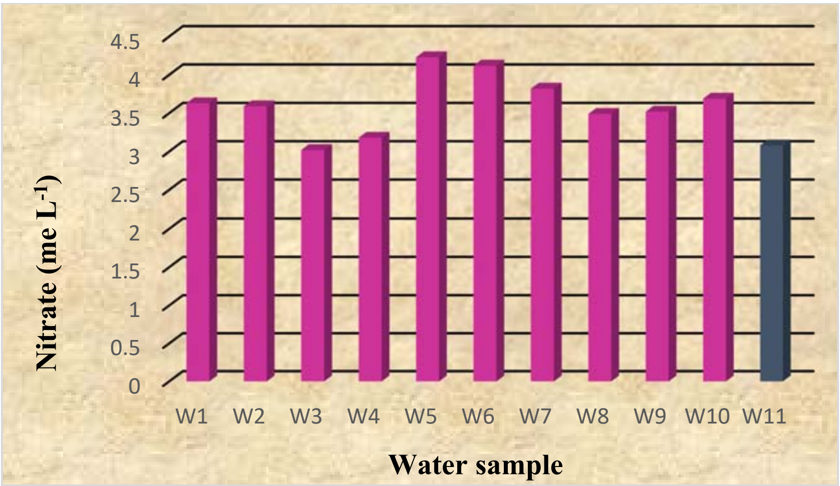

Fig.30. Nitrate content of water samples from different sources

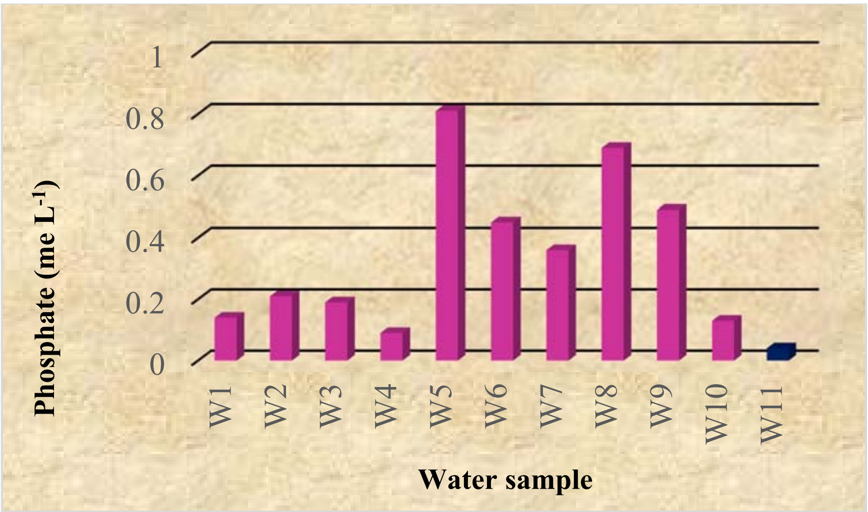

Fig.31. Phosphate content of water samples from different sources

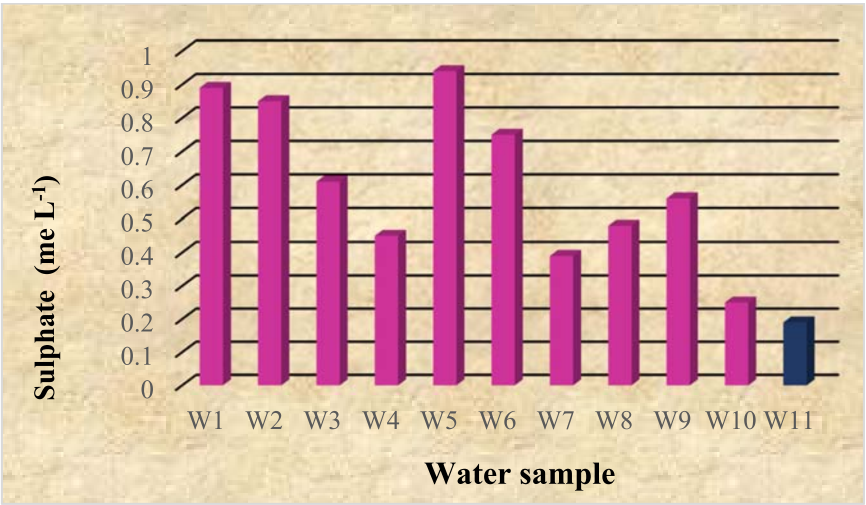

Fig.32. Sulphate content of water samples from different sources

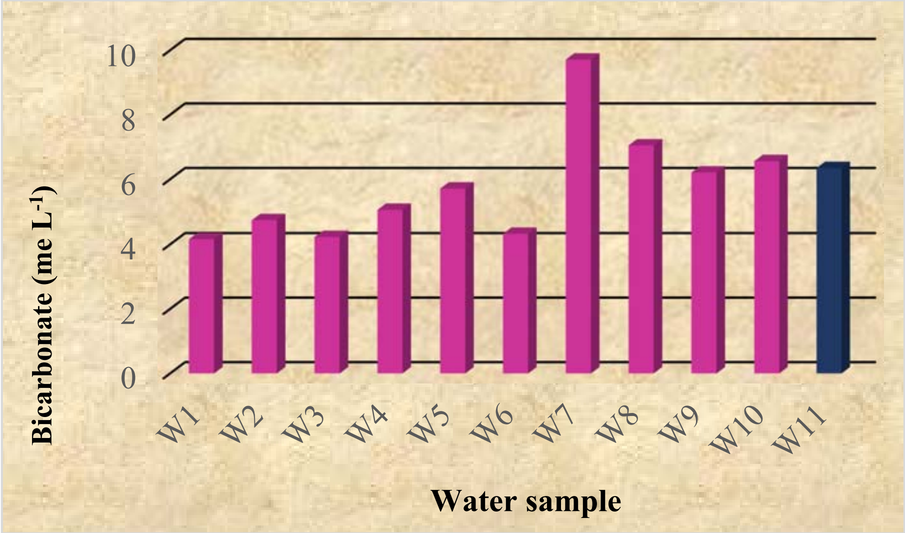

Fig.33. Bicarbonate content of water samples from different sources

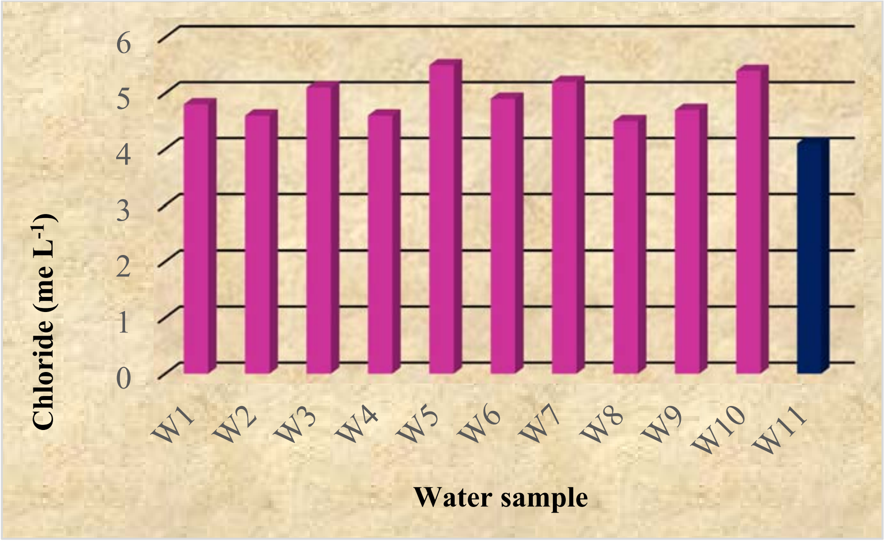

Fig.34. Chloride content of water samples from different sources

5.2. EXPERIMENT II

Study on reclamation of soils in areas of soil mining for brick production

The effect of various inorganic and organic fertilizers applied to the desurfaced soil is discussed in this section.

5.2.1. Biometric observations

During the pot culture experiment, plant height at 60 DAT, number of leaves at 60 DAT, number of branches, number of flowers, number of fruits, per cent fruit set and yield per plant were observed (Table 16). All the biometric observations followed similar trend in the effect of various treatments.

The plant height at 60 DAT was maximum for T_2, soil test based NPK+ poultry manure application (50.42 cm) whereas lowest was in absolute control, T_7 (21.96 cm) (Table 16). All the other treatments were found to be on par with the control treatment. Organic amendments are greatest source of plant nutrients. This further improves the physical condition of the soil. The biological activity of the soil is also enhanced. This results in the better plant growth and development. The finding of Detpiratmongkol *et al.* (2014) confirms with the result that application of the poultry manure has a positive effect on the plant growth and yield. This might be due to the improvement in soil physical condition for the plant growth along with increased availability of N, P and K at the early stage of crop growth (Patil *et al*., 2004). Nitrogen, phosphorus and potassium contained in organic fertilizer have great effects in plant growth and development. Plant need high concentration of this primary nutrient as any deficiency of these essential nutrients will prevent good plant growth (Gholizadeh *et al.*, 2009). Thus, sufficient nitrogen, phosphorus and potassium supplied by organic fertilizer help in producing sturdy and taller chilli plant.

The total number of branches at 60 DAT was found to be highest in T_2, soil test based NPK+ poultry manure (6.11) and lowest was in absolute control, T_7 (3.11). Similarly number of leaves at 60 DAT was the highest in T_2, soil test based NPK+ poultry manure (221.78) and was on par with T_3 where soil test based NPK was applied along with vermicompost. This finding is also in conformity with the work of Baloch *et al*. (2008), who reported the organic fertilizer contained most macro and micro nutrients along with NPK and mentioned that these fertilizers provide nutrients to the plant and had significant effect on branches per plant.

The lowest number of leaves were observed in absolute control, T_7 (15.00) which was on par with T_6 where blanket recommendation of NPK and FYM according to KAU POP, 2016 (21.44), T_5 with FYM 20 t ha^{-1} (26.33) and T_4 with soil test based NPK and coirpith compost (43.33) (Table 16). As nitrogen is an essential part of chlorophyll, helps in protein synthesis. Increase in leaves number per plant may be due to sufficient amount of nitrogen provided an ideal environment and balanced nutrition to plants, which increased number of leaves (Gholizadeh *et al.*, 2009).

5.2.2 Yield attributes

Total number of flowers was maximum in T_2, soil test based NPK+ poultry manure (95.33) and was on par with T_3, soil test based NPK + vermicompost (86.00). The lowest number of flowers was observed in absolute control, T_7 (0.00) along with T_6, NPK +FYM (KAU POP, 2016) (14.00).

Similarly number of fruits at 60 DAT was highest in T_2, soil test based NPK+ poultry manure (31.33) and lowest in absolute control, T_7 (0.00) which was on par with T_6, NPK +FYM (KAU POP, 2016) (1.67) (Table 16). The highest per cent fruit set was observed in T_2, soil test based NPK+ poultry manure (32.95) and lowest in absolute control, T_7 (0.00).

The yield per plant was recorded highest in T_2, soil test based NPK+ poultry manure (126.47 g) whereas the yield of absolute control, T_7 was nil. The lowest yield obtained in T_7 was on par with T_6, NPK +FYM (KAU POP, 2016) (5.33 g) (Table 16). The results were in agreement with the findings of Santhiya (2018) which studied the effect of different organic manures in Bhindi crop.

Khan *et al. (*2014), stated the highest number of fruits per plant might be due to vigour of plant and more number of leaves per plant. The results are in agreement with those of Roychaudhury *et al.* (1995), who reported that the number of fruit per plant increased with increasing nitrogen application. Application of poultry manure resulted in increasing of yield components due to increased photosynthetic activity and rate at which ultimately resulted in higher number of fruits per plant and seed yield per ha. Mogapi *et al.* (2014) reported the application of poultry or chicken manure which is the most widely used for growing crops increased the growth of crops, in line with the work of Adejoro *et al.* (2011)who found poultry manure to increase growth and yield of *Corchorus olitorius*. The individual weight was significantly higher in poultry manure treatment. For the control treatment, there was no fruit produced. The positive response of the fruit yield to the poultry manure treatment could be due to the synthesis of more assimilates that played significant role in the production of more and bigger economic chilli fruits. Application of organic fertilizer will increase values of fresh weights of the fruits per plant. Similar results were obtained by Khan *et al*. (2014) in chilli plants treated with organic fertilizers.

5.2.2. Soil characteristics

5.2.2.1. Bulk density

The lowest bulk density was recorded in NPK+ vermicompost (1.60 Mg m^{-3}) and highest was recorded in absolute control (1.73 Mg m^{-3}) (Table 17). Zaman *et al*. (2017) reported that the bulk density was decreased when compost was added to the soil.

5.2.2.2. Soil pH and electrical conductivity

The treatments significantly increased the soil pH. After pot culture study, the treatment with NPK + poultry manure recorded the highest pH (7.53) (Table 17). The increase may be due to release of organic anions in the residues that neutralize the hydrogen ions in the soil (Zaman *et al*., 2017).

The electrical conductivity was also found to be increased in NPK + poultry manure (0.029 dS m^{-1}) (Table 17). The poultry manure is rich in basic cations like Ca^{2+} and K^{+} compared to other organic manures. The electrical conductivity of poultry manure used for the study was also high compared to other manures (Appendix I). This might have further enhanced the pH and electrical conductivity of soils treated with poultry manure.

5.2.2.3. Organic carbon

The highest organic carbon content was observed in NPK + poultry manure treated soils (0.154 per cent) (Fig.45) whereas lowest was in absolute control (Table 18). The labile fraction of organic matter is the most degradable and therefore the most susceptible to mineralization. The poultry manure has a high content of easily mineralisable organic carbon content which in turn increased the soil organic carbon content followed by vermicompost. On comparison with other amendments, the organic carbon in farm yard manure was not easily mineralisable (Cook and Allen, 1992).

5.2.2.4. Available nutrients

The available nutrients like nitrogen, phosphorus and potassium were significantly influenced by different nutrients (Table 18). The highest available nitrogen was observed in NPK + poultry manure (102.17 kg ha^{-1}). This may be due to the increase in availability of nitrogen due to mineralization and biological activity. The level of available phosphorus (31.40 kg ha^{-1})and potassium (212.07 kg ha^{-1}) was also high in NPK + poultry manure applied soils (Fig.46-48).When compared with the other organic manures applied, the nutrient concentration in poultry manure was found to be higher (Appendix II). This has resulted in higher concentrations of plant available forms of N, P and K in soil after harvest. This observation is supported by the findings of Barth (1985) who reported that the benefits of poultry manure were due to their ability to improve soil physical characteristics and to supply micro and trace elements needed by plants but will increase the electrical conductivity of the soil. This can also be closely attributed to the type of feed these birds eat which will be high in oyster shell and other feed ingredients that are high in calcium.

5.2.2.5. Biological activity of soil

The highest microbial biomass carbon content (374.13 μg g^{-1} soil) and dehydrogenase enzyme activity (3.63 μg TPF g^{-1} day^{-1}) were obtained in treatments, NPK + poultry manure and NPK + coir pith compost respectively (Fig. 49 and Fig.50). This can be associated with the increase in microbial population and activity as a result of the application of organic matter which is rich in carbon nutrients (Appendix II). The supply of readily metabolisable C in the poultry manure is the most influential factor contributing to the biomass carbon increase. According to De Neve and Hofman (2000), Trinsoutrot *et al.* (2000), and Tejada and Gonzalez (2003, 2004, 2006), soil microbial biomass responded rapidly to additions of readily available carbon. The fact that soil microbial biomass and soil respiration were higher in poultry manure and vermicompost than in other organic manure amended soils may have been due to a greater labile fraction of organic matter in the former product. The labile fraction of organic matter is the most degradable and therefore the most susceptible to mineralization (Cook and Allen, 1992), acting as an immediate energy source for microorganisms.

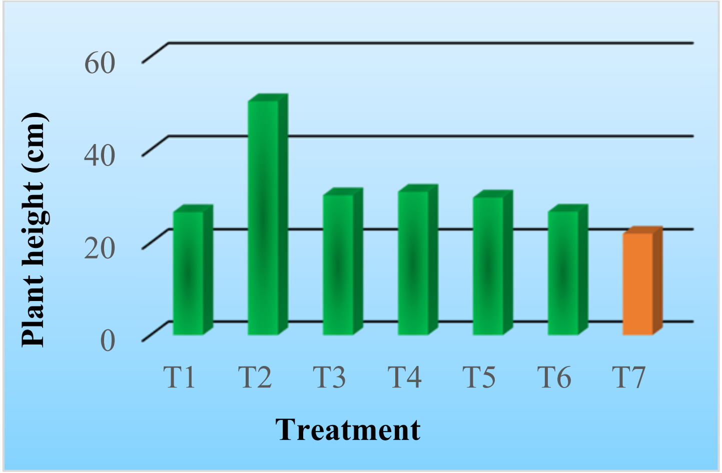

Fig.35. Plant height at 60 DAT in chilli crop

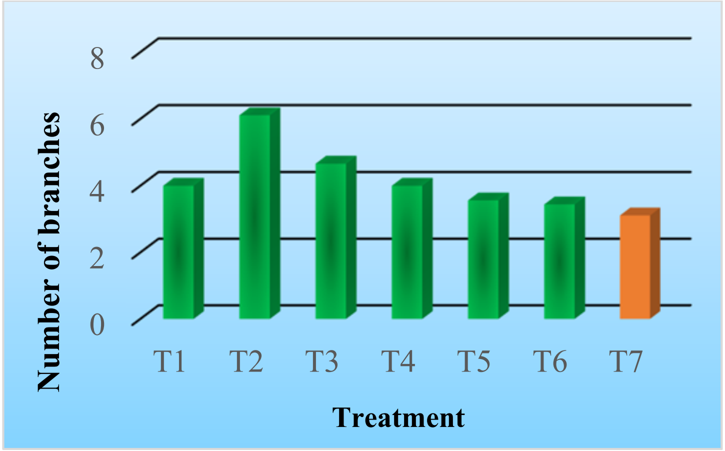

Fig.36. Number of branches at 60 DAT in chilli crop

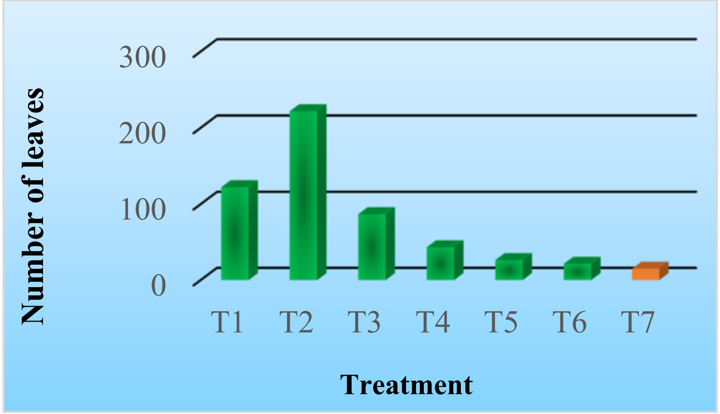

Fig.37. Number of leaves at 60 DAT in chilli crop

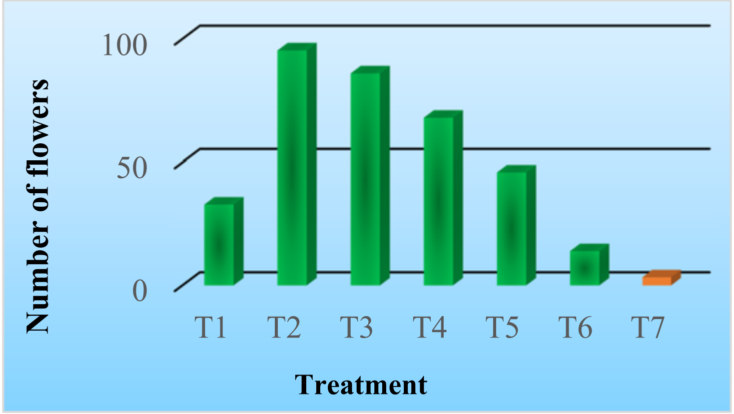

Fig.38. Number of flowers of chilli crop during the study

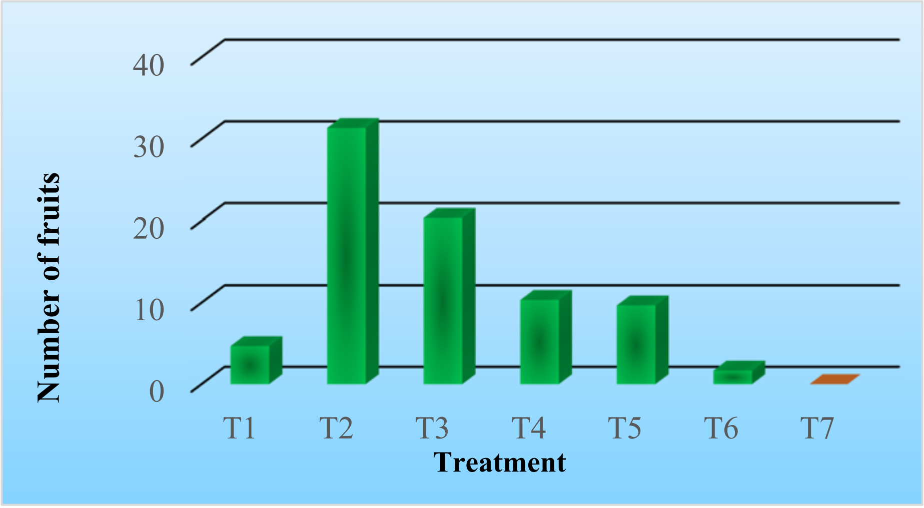

Fig.39.Number of fruits of chilli crop during the study

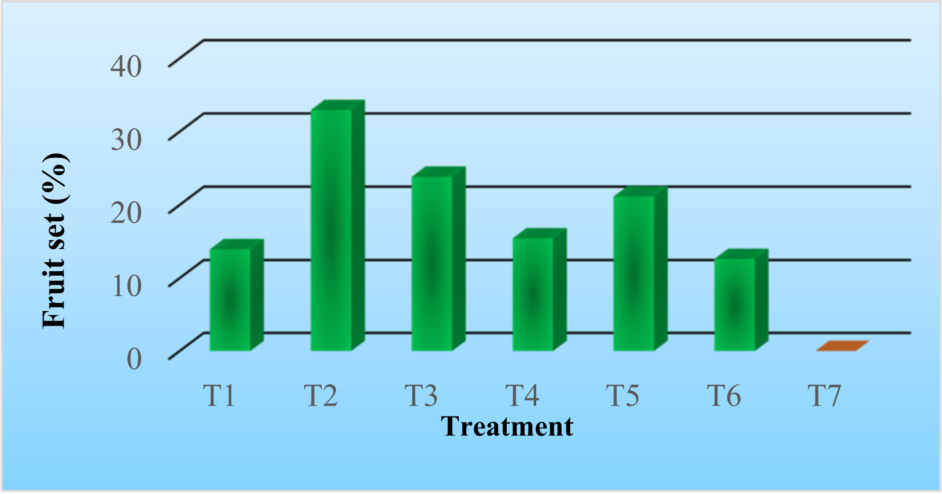

Fig.40. Fruit set in chilli plants of pot culture study

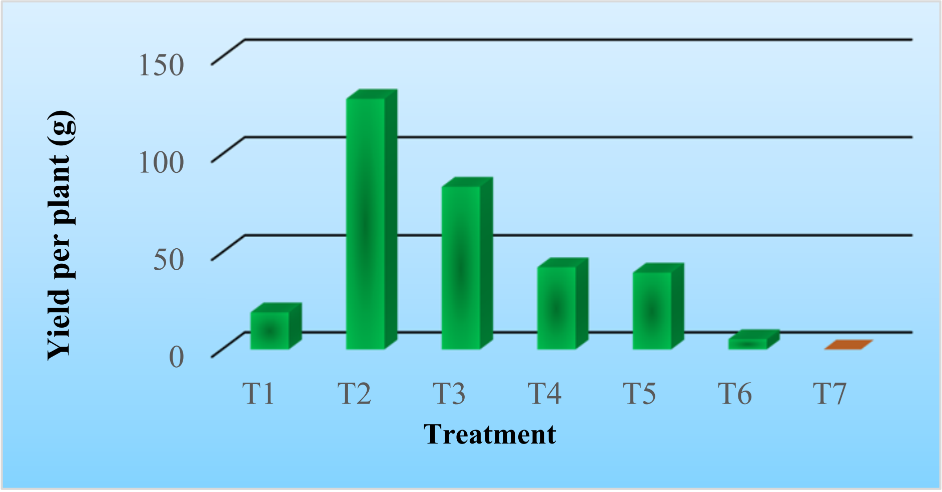

Fig.41. Yield of the chilli crop at harvest

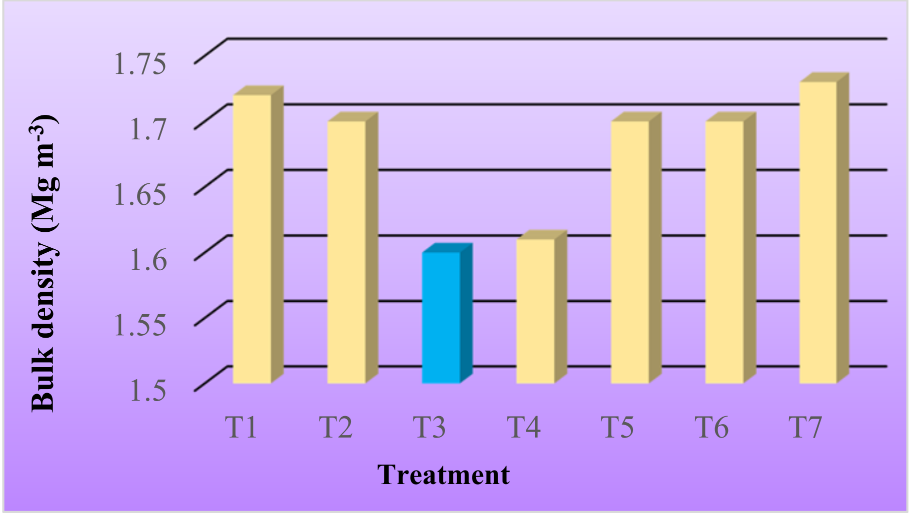

Fig.42. Bulk density of soil samples after harvest of chilli crop

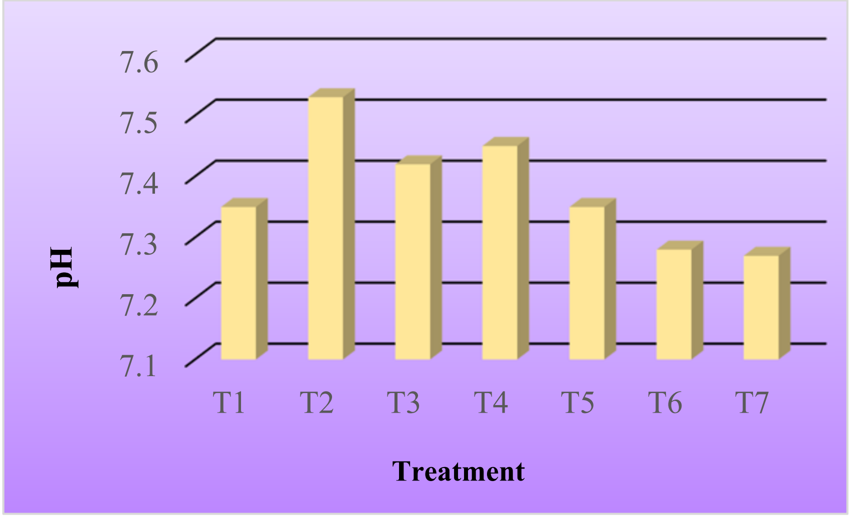

Fig.43. pH of soil samples after harvest of chilli crop

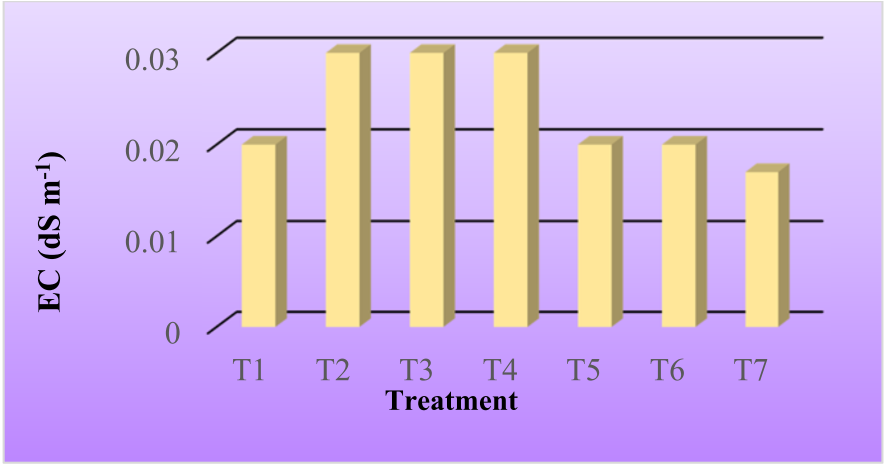

Fig.44. Electrical conductivity of soil samples after harvest of chilli crop

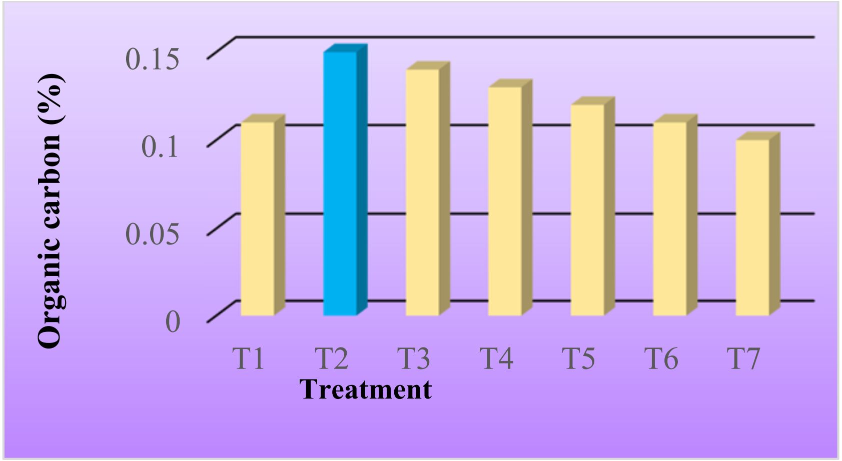

Fig.45. Organic carbon of soil samples after harvest of chilli crop

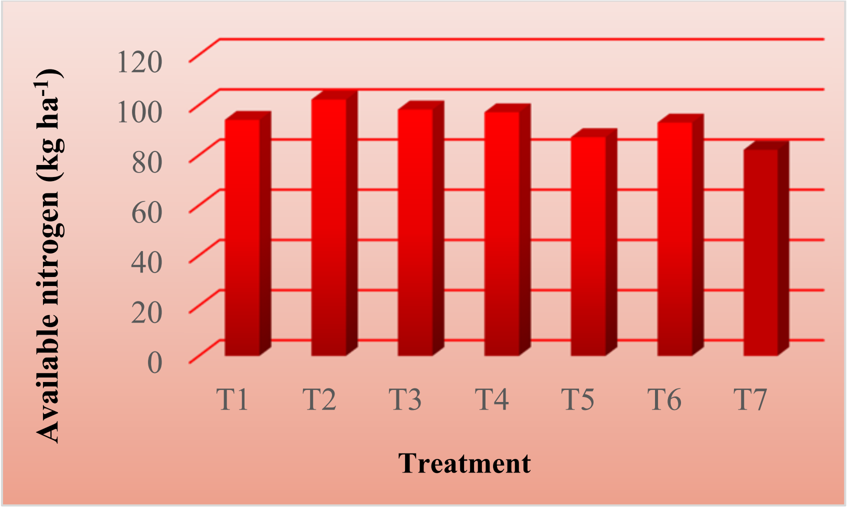

Fig.46. Available nitrogen content of soil samples after harvest of chilli crop

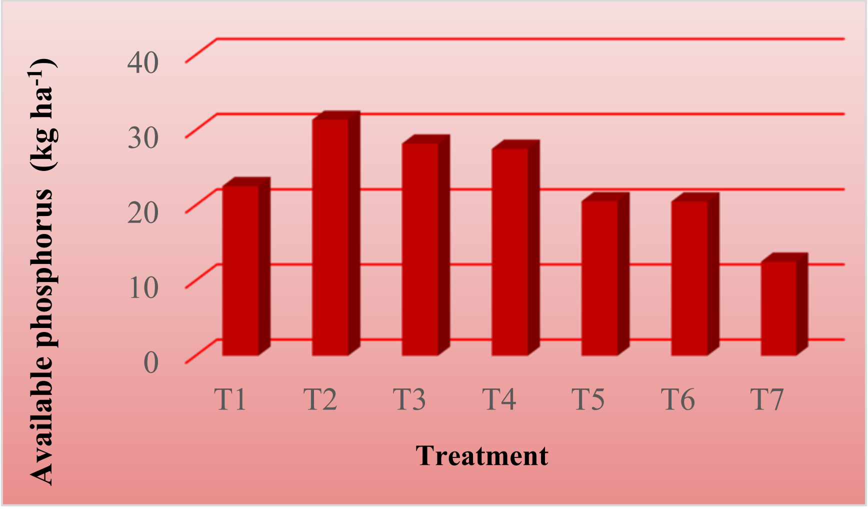

Fig.47. Available phosphorus content of soil samples after harvest of chilli crop

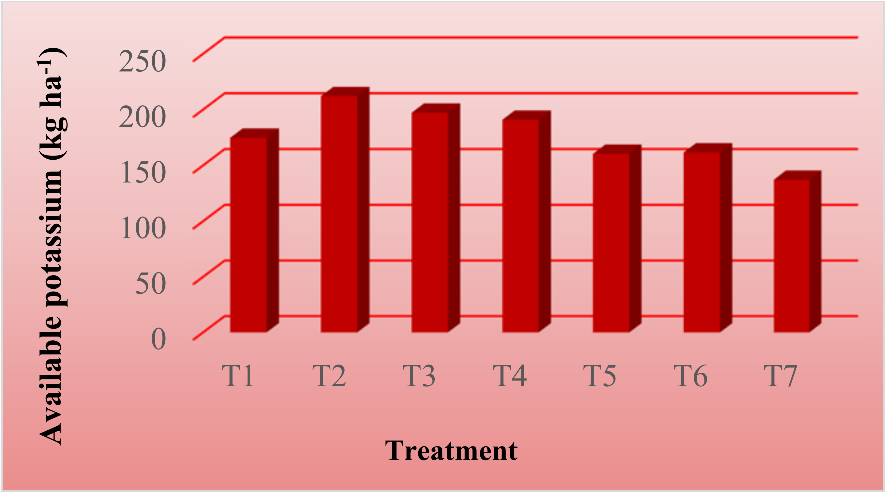

Fig.48. Available potassium content of soil samples after harvest of chilli crop

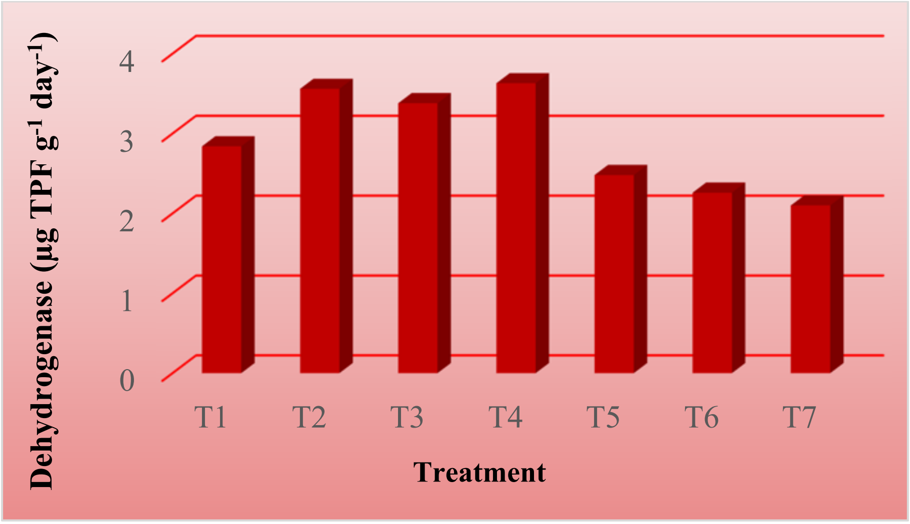

Fig.49. Dehydrogenase activity of soil samples after harvest of chilli crop

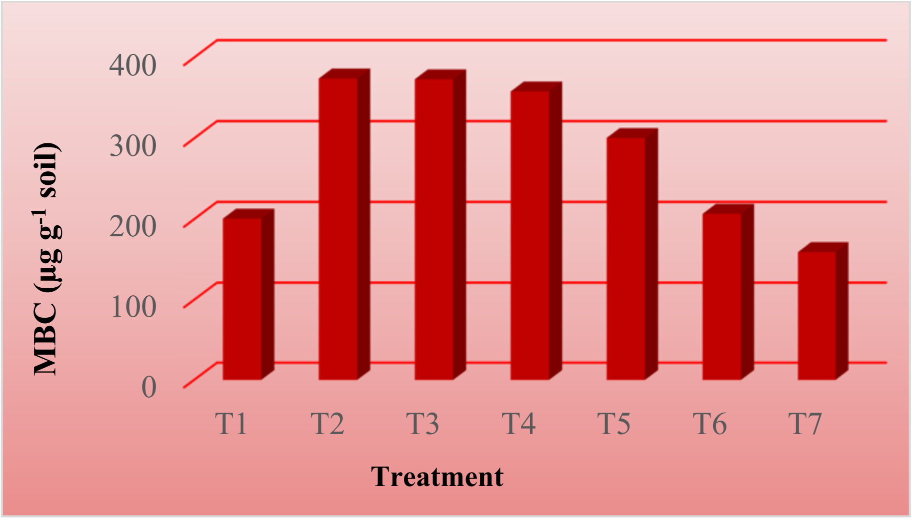

Fig.50. Microbial biomass carbon content of soil samples after harvest of chilli crop

Summary

6. SUMMARY

The study on 'Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soils' was conducted in Alathur taluk of Palakkad district and College of Horticulture, Vellanikkara, Thrissur, Kerala.

The present study was divided mainly into two experiments. The experiment I dealt with laboratory experiments in characterizing the soil and water samples collected from the study area. Based on the results of soil characterization, experiment II was conducted. The experiment II was a pot culture study which aimed at the reclamation of degraded soils. The conclusion of the study are presented here.

6.1 EXPERIMENT I

Evaluation of physical, chemical and biological properties of soil and water samples

- The sample collected from location 5 (S_5) had shown the highest bulk density (1.70 Mgm^{-3}) where as that of the control site (S_{11}) was the lowest (1.22 Mg m^{-3}).

- The loss of clay and organic matter had resulted in the decrease in moisture content and water holding capacity of mined soils. The lowest moisture content and water holding capacity was observed in sample S_5.

- The texture of soil sample in the control sample was clay loam while in mined soil it was sandy loam.

- The sampling location S_{11} (the control site without mining operation) exhibited the lowest soil temperature (25.6°C). The sampling site S_5, recorded the highest temperature (29.3°C).

- The content of organic carbon, available N, P and K decreased by 61.00, 43.70, 74.50 and 43.36 per cent in the mined soil over control.

- The biological activity of soil indicated by dehydrogenase enzyme activity and microbial biomass carbon were decreased in mined soils.

- Water samples were also affected by mining activities. The higher concentrations of pollutants such as nitrate and phosphate in mined area indicate the higher risk of water pollution.

6.2 EXPERIMENT II

Study on reclamation of soils in areas of soil mining for brick production

- The pot culture experiment was carried out in the soil with lowest nutrient status selected from the experiment I. Soil test based N, P, K and organic manures such us FYM, poultry manure, vermicompost and coirpith compost were applied as treatments. Chilli crop (*var*. Anugraha) was taken as the test crop.

- The treatment T_2 (soil test based NPK + poultry manure) recorded the highest plant height (50.42 cm), number of leaves (221.78) and number of branches (6.11) at 60 days after transplanting.
- The yield attributes such as total number of flowers (95.33), total number of fruits (31.33) and per cent fruit set (32.95 per cent) were found to be higher for the same.
- The bulk density of soil after harvest was lowest in treatment T_3 (soil test based NPK + vermicompost) and was on par with T_4 (soil test based NPK + coirpith compost).
- The content of organic carbon, available nitrogen, phosphorus and potassium recorded higher values in treatment T_2 (soil test based NPK + poultry manure) than the other treatments.
- The biological properties such as microbial biomass carbon (374.133 $\mu g\ g^{-1}$ soil) and dehydrogenase activity (3.630 μg TPF $g^{-1}\ day^{-1}$) after harvest of the crop were the highest in treatment T_2 (soil test based NPK + poultry manure) and T_4 (soil test based NPK + coirpith compost) respectively.
- The highest yield was obtained for the treatment T_2 (soil test based NPK + poultry manure).

- Integrated nutrient management using poultry manure and vermicompost along with NPK fertilizers is a suitable method of management of such soils.

- From the study, it can be concluded that the topsoil mining exhibits immediate adverse impacts on soil health and productivity which is a matter of serious concern and need immediate action. Desurfacing adversely affected the physical, chemical properties of soil and thereby hampered the biological activity of the soil. This practice should be checked legally and such degraded soils should be managed scientifically for sustainability.

Future line of work

1. More research should be conducted regarding the changes in physical properties of desurfaced soil.
2. The results of the pot culture study have to be validated by conducting field experiments utilizing other organic amendments like biochar.
3. As the loss of organic matter and clay had resulted in higher bulk density of the degraded soils, effect of application of coirpith in order to reduce bulk density can also be studied.
4. Agronomic practices like deep tillage and green manuring along with the application of bio fertilizers to enhance the aeration, nutrient status and microbial activity in these mined soils can also be attempted.
5. *In situ* microclimate management studies utilising suitable plantation crops can be taken up in order to avoid huge expenditure to reclaim the whole area of degraded soil.

References

REFERENCES

Abdullahi, A. 2018. Erosion effect on soil physical properties in selected farmlands in GidanKwano, Niger State. *J. Hortic. Plant Res.* 2:10-22.

Achakzai, K., Khalid, S. and Bibi, A. 2015. Determination of heavy metals in agricultural soil adjacent to functional Brick Kilns: a case study of Rawalpindi. *Sci. Technol. Dev.,* 34 (3): 122–129.

Adejoro, S. A., Okunlola, A. I., and Fakanlu, G. 2011. Evaluation of some manure types for the growth and yield of watermelon in southwestern Nigeria. *Researcher*, 3:393- 395.

Agera, S.I.N., Agbidye, F., and Ogwuche, J. S. 2018. Effect of burnt bricks production on soil bacteria and fungi at brick sites in Benue State, Nigeria. *J. Glob. Biosci.* 4: 3016-3023.

A.O.A.C. 1950. Official and Tentative Methods of Analysis of the Association of Official Analytical Chemists, Ed. 7: 910 pp. Washington.

Ayers, R. S. and Westcot, D.W. 1985. Water Quality for Agriculture, FAO Irrigation and Drainage Paper 29 rev 1. FAO, UN, Rome. 174pp.

Baloch, Q. B., Chachar, Q. I., and Tareen, M. N. 2008. Effect of foliar application of macro and micro nutrients on production of green chilies (*Capsicum annuum* L.), *J. Agric. Technol.*, 4(2):177-184.

Barth, C.L. 1985. Livestock characterization- A new approach in agricultural waste utilization and management. *Trans. ASAE.*4 (2): 286-291.

Bisht, G. and Neupane, S. 2015 Impact of brick kilns' emission on soil quality of agriculture fields in the vicinity of selected Bhaktapur area of Nepal. *Applied and Environ. Soil Sci.*, 2015, 8 p.

Black, C.A. 1965. Methods of Soil Analysis: Part I Physical and mineralogical properties. American Society of Agronomy, Madison, Wisconsin.

Boyd C.E. 1981. Water Quality in Warm Water Fish Ponds. Craftmaster Printers, Inc. Opelika, Alabama.

Bramble-Brodhal, M., Fosberg, M. A., Walker, D. L., and Falen, A. L. 1985. Changes in soil productivity related to changing top soil depth on two Idaho Palaouse soils. P. 18-27 Int. Nat. Symp. *Erosion and soil productivity.* ASAE Publ. 8-85. ASAE, St. Joseph. MI.

Bray, R.H. and Kurtz, L.T. 1945. Determining total, organic and available forms of phosphate in soils. *Soil Sci*. 59: 39-45.

Brookes. P.C., Powlson, D.S., and Jenkinson, D.S. 1982. Measurement of microbial biomass and phosphorus in soil. *Biol. Biochem.* 14: 319-329.

Casida, L. E., Klein, D. A., and Santaro, T. 1964. Soil dehydrogenase activity. *Soil Sci*. 98: 371-376.

Cook, B.D., and Allen, D.L. 1992. Dissolved organic matter in old field soils: Total amounts as a measure of available resources for soil mineralization. *Soil Biol. Biochem*. 24:585–594.

Das, R. 2015. Causes and consequences of land degradation in and around the brick kilns of Khejuri cd blocks over coastal Medinipur in West Bengal. *Int. J. Innovative Res. Dev*. 4(2):185-194.

De Neve, S. and Hofman, G. 2000. Influence of soil compaction on carbon and nitrogen mineralization of soil organic matter and crop residues. *Biol. Fertil. Soils.* 30: 544-549.

Detpiratmongkol, S., Ubolkerd, T., and Yoosukyingstaporn, S. 2014. Effect of chicken, pig and cow manures on growth and yield of Kalmegh (*Andrographis paniculata* Nees). *J. Agric. Technol.* 10 (2): 475-482.

Dey, S. and Dey, M.2015. Deterioration and degradation of aquatic systems due to brick kiln industries – a study in Cachar district, Assam. *Curr. World Environ.* Vol. 10(2), 467-472.

Gholizadeh, A., Amin, M.S.M., Anuar, A.R. and Aimrun, W. 2009. Evaluation of SPAD chlorophyll meter in two different rice stages and its temporal variability. *Eur. J. Sci. Res.* 37(4):65-69.

Gollany, H., Schumacher, T. E., Lindstrom, M. J., Evenson, P. D., and Lemme, G. D. 1992. Topsoil depth and desurfacing effects on properties and productivity of a Typic Argiustoll. *Soil Sci. Soc. Am. J.* 56. 220-225.

Grewal, M. S. and Kuhad, M. S. 2002. The influence and management research of removing surface soil to productivity. *Soil and Water Conserv. in China*. 7: 20-20.

Gupta, S. and Narayan, R. 2010. Brick kiln industry in long-term impacts biomass and diversity structure of plant communities. *Curr. Sci.*, Vol. 99(1).

Haack, B. N. and Khatiwada, G. 2007. Rice and bricks: environmental issues and mapping of the unusual crop rotation pattern in the Kathmandu Valley, Nepal. *Environ. Manage*. 39, 774– 782.

Indorante, S. J., Jansen, I. J. and Boast, C.W. 1981. Surface mining and reclamation: initial changes in soil character. *J. Soil and Water Conserv.* 36. 347-351.

Ishaq, M., Khan, M. A., Jan, F. A., and Ahmad, I. 2009. Heavy metals in brick kiln located area using atomic absorption spectrophotometer: a case study from the city of Peshawar, Pakistan. *Environ. Monit. Assess*. 166:409–420.

Islam, M. S., Mamun, S. A., Muliadi, Rana, S., Tusher, T.R. and Roy, S. 2015. The impact of brick kiln operation to the degradation of topsoil quality of agricultural land. *Agrivita*. 37(3):204-209.

Ismail, M., Muhammad, D., Khan, F.U., Munsif, F., Ahmad, T., Ali, S., Khalid, M., Haq, N., and Ahmad, M. 2012. Effect of brick kilns emissions on heavy metal (Cd and Cr) content of contiguous soil and plants. *Sarhad J. Agric.* 28: 403–409.

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice Hall of India Private Ltd., New Delhi, 498p.

Jamatia, A., Chakraborty, S. and Chakraborti, S. 2014. Surface water quality assessment of the Jirania brick cluster – a case study. *Int. J. Eng. Res. Appl.*, 4(6):88-92.

Jenkinson, D. S. and Powlson, D. S. 1976. The effects of biological treatments on metabolism in soil.- A method measuring soil biomass. *Soil Biol. Biochem.* 8: 209-213.

Juned, A. S. and Arjun, B. B. 2011. Analysis of chloride, sodium and potassium in groundwater Samples of Nanded City in Mahabharata, India. *Eur. J. Exp. Biol.* 1 (1): 74-82.

KAU [Kerala Agricultural University] 2016. Package of practices recommendations: crops (15th Ed.). Kerala Agricultural University, Thrissur, 392p.

Khan, A., Shah, S.N.M., Rab, A., Sajid, M., Ali, K., Ahmed, A., and Faisal, S. 2014. Influence of nitrogen and potassium levels on growth and yield of chillies (*Capsicum annuum*L.). *Int. J. Farming and Allied Sci.*, 3(3): 260-264.

Khan, H. R., Rahman, K., AbdurRouf, A. J. M., Sattar, G. S., Oki, Y. and Adachi,T. 2007. Assessment of degradation of agricultural soils arising from brick burning in selected soil profiles. *Int. J. Enviorn. Sci. Technol.* 4 (4): 471-480.

Knap, R., Kaniuczak, J., Hajduk, E., and Szewczyk, A. 2016. Properties of degraded and reclaimed soils in the area of the abandoned 'Jeziórko' sulfur mine (Poland). *Soil Sci. Ann.* 67: 163-172.

Kumar. K. S., Jakkoji. S.C., Chinagodaba, S. B., Karne, K. and Kumar, G. V. 2015. Role of Soil Brick Industry in the Degradation of Land and Environment-A Case Study of Mallaram in Nizamabad, Telangana State. *Int. J. Civil and Struct. Eng. Res.* Vol. 3 (1): 222-227.

Larney, F. J., Akinremi, O. O., Lemke, R. L., Klaassen, V. E. and Janzen, H. H. 2003. Crop response to topsoil replacement depth and organic amendment on abandoned natural gas wellsites. *Can. J. Soil Sci.* 83: 415-423.

Larney, F. J., H. Janzen, H. and M' Olson, B. 1995. Efficacy of inorganic fertilizers in restoring wheat yields on artificially eroded soils. *Can. J. Soil Sci*. 369-377.

Larney, F., Olson, B. M., Janzen, H. and Lindwall, C. W. 2000. Early impact of topsoil removal and soil amendments on crop productivity. *Agron. J.,* 92: 948–956.

Maithel S., Uma R., Kumar R., and Vasudevan, N. 1999. Energy Conservation and Pollution Control in Brick Kilns. Tata Energy Research Institute, Habitat Place, Lodhi Road, New Delhi.

Mishra, M.K., Mishra, N., and Pandey, D.N. 2013. An assessment of physic-chemical characteristics of Bhamka Pond, Hanumana, Rewa District, India. *Int. J. Innovative Res. Sci. Eng. Technol.*2: 1781-1788.

Mogapi, E. M., Thembinkosi, M., Christopher, M., Ndapo, S., and Machach, S. 2014. Effect of chicken manure and commercial fertilizer on performance of jute mallow *(Corchorusolitorius*). *Agric. Biol. J. North Am.*; 4(6): 617-622.

Morgan, W. and Lal, R. 2003. Soil organic carbon in relation to cultivation and topsoil removal on sloping lands of Kolombangara, Solomon Islands. *Soil and Tillage Res.* 70: 19-27.

Motsara, M.R. and Roy, R.N. 2008. Guide to laboratory establishment for plant nutrient analysis. *Food and agricultural organisation of the United Nations FAO Fertilizer and Plant Nutrition Bulletin*. Rome. 219pp.

Patil, M. B., Mohammed, R. G. and Ghade, P. M. 2004. Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *J. Maharashtra Agric. University*. 29: 124-127.

Piper, C. S. 1942. Soil and Plant Analysis. Hans Publishers, Mumbai, India, 450p.

Pragatheesh, A and Jain, P. 2013. Thadagam - valley of brick kilns -lost river and disturbed wildlife. EIA Resource and Response Centre (ERC), Nilgiris, India. Article ID 409401, 8p. Available at https://www.hindawi.com/journals/aess/2015/409401/ 1/6.

Proshad, R., Kormoker, T., Mursheed, N., Islam, M.M., Bhuyan, M.I., and Islam, M.S. 2018. Heavy metal toxicity in agricultural soil due to rapid industrialization in Bangladesh: a review. *Int. J. Adv. Geosci.* 6: 83-88.

Robinson, G.W. 1922. A new method for the mechanical analysis of soils and other dispersions. *J. Agric. Sci.* 12: 306–321.

Roychaudhury A., Chatterjee, R., and Mitra, S.K. 1995. Effect of different doses of nitrogen, phosphorus, potassium, magnesium, calcium and iron on growth and development in chilli. Department of Horticulture Kalyani West Bengal India. 13: 96-99.

Rutherford, P.M. and Arocena, J. M. 2011. Organic amendments and earthworm addition improve properties of non-acidic mine tailings. *Appl. Environ. Soil Sci.,* 2012, 11p.

Sahu, B.K., Rao R.J., and Behera S.K. 1995. Studies of some physic-chemical characteristics of Ganga river water (Rishikesh-Kanpur) within twenty four hours during winter, 1994. *Ecol.Environ. Cons.* 1(1-4): 35-38.

Santhiya, K. 2018. Quality assessment of different organic manures and their effect on okra. MSc. Thesis. Kerala Agricultural University.

Sarwar S.K., and Irfan-Ul-Majid. 1997. Abiotic features and diatom population of Wular Lake, Kashmir. *Ecol.Environ. Cons.,* 3(3): 121-122.

Sims, J. R. and Johnson, G. V. 1991. Micronutrient soil tests. In: Mortvedt, J.J. (ed.), *Micronutrients in Agriculture* (2nd ed.). SSSA Book series 4, Soil Sci. Soc. Am. Madison, WI, USA. pp. 427–476.

Singh, P., Devi, R. and Hooda, R.S. 2015. Evaluation of spatiotemporal change of micronutrient status in parts of National Capital Region (NCR) of Haryana State (India). *Int. J. Sci. Res. Rev.,* 5(2), 01 – 19**.**

Subbiah, B.V. and Asija, G.L.A. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 25: 259-260.

Suraj, R. and Neelakantan, R. 2014. Clay mining areas and its impact over the hydrologic ecosystem in a mining district, South India. *Int. J. Advmt. Remote Sensing, GIS and Geogr.* Vol.2 (2):18-26.

Tejada, M., and Gonzalez, J.L. 2003. Effects of the application of a compost originating from crushed cotton gin residues on wheat yield under dryland conditions. *Eur. J. Agron.* 19:357–368.

Tejada, M., and Gonzalez, J.L. 2004. Effects of application of a byproduct of the two-step olive oil mill process on maize yield. *Agron. J.* 96:692–699.

Tejada, M., and Gonzalez, J.L. 2006. Effects of a crushed cotton gin compost on soil biological properties, nutrient leaching losses and maize yield. *Agron. J.*

Tiwari M. 2005. Assessment of physcio-chemical status of KhanpuraLake,Ajmer in relation to its impact on public health. *Ecol. Environ. Cons.* 11(3-4): 491-493.

Tressen, H., Cuevas, E., and Chacon, P. 1994. The role of soil organic matter in sustaining soil fertility. *Nature.* 371: 783-785

Trinsoutrot, J., Nicolardot, B., Justes, E., and Recous, S. 2000. Decomposition in the field of residues of oilseed rape grown at two levels of nitrogen fertilization. Effects on the dynamics of soil mineral nitrogen between successive crops. *Nutr. Cycling Agroecosyst.* 56: 125–137.

Vyas, H., Vyas, A., and Khan, R. 2009. A study of land degradation due to brick industries in Ujjain (India). *J. Environ. Res. Dev.* 3 (4).

Walkley, A.J. and Black, I.A. 1934. Estimation of soil organic carbon by chromic acid Titration method. *Soil Sci.* 31: 29-38.

Watanabe, F.S. and Olsen, S.R. 1965. Test of an ascorbic acid method for determining Phosphorus in water and sodium bicarbonate extracts from soil. *Soil Sci. Soc. Am. Proc.* 29: 39-45.

Wei Zhou, Cao Yingui, Zhang Gengjie, Liu Xiaoyang and Bai Zhongke. 2016. Changes in soil properties in the soil profile after mining and reclamation in an opencast coal mine on the Loess Plateau, China. *Ecol. Eng*. 98. 10.1016/j.ecoleng.2016.10.078.

Wilcox, L.V. 1950. Electrical Conductivity. *Amer. Water Works Assoc. J*. 42:775-776.

Wright R. 1982. Seasonal Variation in water Quality of a West African river (R. Jong in Sierra Leone). *Reveued Hydrobiologie Tropicale*. 15(3): 193-199.

Zaman, M.M., Chowdhury, T., Nahar, K. and Chowdhury, M. A. H. 2017. Effect of cow dung as organic manure on the growth, leaf biomass yield of *Stevia rebaudiana* and post-harvest soil fertility. *J. Bangladesh Agric. Univ*. 15 (2). 206-211.

Zhang, M.K. and Fang, L. 2007. Effect of tillage, fertilizer and green manure cropping on soil quality at an abandoned brick making site. *Soil and Tillage Res*. 93: 87–93.

Abstract

Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil

by

SOPHIA BABY

(2016-11-041)

ABSTRACT OF THE THESIS

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR 680656

KERALA, INDIA

2019

Assessment of soil degradation and water quality in areas of small scale brick production and management of the degraded soil

Abstract

The utilization of clay for construction of habitations and buildings dates back to the period of ancient civilizations. Even though centuries had passed and civilizations changed, the basic raw material for brick production remained the same. Brick production requires fine clayey loam soil with plenty of water supply. With the increasing demand for construction material, clay mining had shifted from river banks to fertile agricultural lands. This change in land use had resulted in the deterioration of soil health and decrease in crop production. The entry of large number of small scale brick production units is causing irreversible damages to the soil, hydrology and ecosystem. Hence, this study was taken up to characterise the desurfaced (mined) soils and water resources and to identify suitable management methods of these soils.

A comprehensive survey was conducted at Alathur Taluk of Palakkad District to identify locations with resurfaced soils. Soil and water samples were collected from 11 locations including a control location without mining activities during August to September, 2017. A total of 88 soil samples (eight samples per location) and 11 water samples (one sample per location) were collected for the study. Both soil and water samples were analysed for various physico- chemical properties. Biological properties of soil samples were also analysed.

The physical properties of soil such as temperature and bulk density were found to be higher in desurfaced soils when compared to control. The water holding capacity, porosity and moisture content were found to be reduced in desurfaced soils. The texture of the soil changed from clay loam to sandy loam. The organic carbon content of desurfaced soils were in the range of 0.08 – 0.46 per cent with a reduction of 61 per cent when compared with control soil. The content of available nitrogen, phosphorus and potassium were also reduced to the extent of 43.70, 74.50 and 43.36 per cent respectively. The available magnesium content was found to be lower in desurfaced soils (55.6 per cent reduction). The content of plant available micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Ni, Cr and Pb) were high in desurfaced soils. The presence of earthworms (13 nos. per m^2) and termite mound were observed only in the control soil. The microbial biomass carbon and dehydrogenase enzyme activity were highly reduced in desurfaced soils.

Water samples were also affected by small scale topsoil mining activity. The pH, electrical conductivity and TDS were in the safer limits for all water samples. The concentrations of sodium (W_1 andW_{10}) and calcium (W_1 andW_5) in certain water samples collected from mined areas were high and they were above safe limits to be used for irrigation purposes. Similarly the higher levels of nitrate, phosphate, bicarbonate and chloride in water samples from mined areas denote the possibility of the water bodies being polluted by mining activities.

Based on the status of organic carbon and major nutrients, the soil with the lowest nutrient status (S_5) was selected for pot culture study. The pot culture study was conducted with chilli (*var.* Anugraha) as the test crop. The effect of various organic and inorganic amendments on the properties of desurfaced soils were evaluated in this experiment. The treatment T_2 (soil test based NPK + poultry manure) recorded the highest plant height (50.42 cm), number of leaves (221.78) and number of branches (6.11) at 60 days after transplanting. The yield attributes such as total number of flowers (95.33), total number of fruits (31.33) and per cent fruit set (32.95 per cent) were found to be higher for the same. The highest yield was obtained for the treatment T_2 (soil test based NPK + poultry manure).

The soils were also analysed after the harvest of the crop. The bulk density of soil after harvest was the lowest in treatment T_3 (soil test based NPK + vermicompost) and was on par with T_4 (soil test based NPK + coirpith compost). The content of organic carbon, available nitrogen, phosphorus and potassium recorded higher values in treatment T_2 (soil test based NPK + poultry manure) than the other treatments. The biological properties such as microbial biomass carbon (374.133 µg g^{-1} soil) and dehydrogenase activity (3.630 µg TPF g^{-1} day^{-1}) were the highest in treatment T_2 (soil test based NPK + poultry manure) and T_4 (soil test based NPK + coirpith compost) respectively.

The study revealed that top soil mining for brick production predominantly affected bulk density, soil temperature and water holding capacity of the soils. The content of organic carbon and available nutrients such as N, P and K were also reduced. The biological properties like dehydrogenase enzyme activity and microbial biomass carbon reduced to a greater extent. Water samples from mined areas were polluted by cations like sodium and calcium and anions like nitrate, phosphate, bicarbonate and chloride to limited extent. Poultry manure application as an integrated nutrient management technique, followed by vermicompost application were found to be beneficial for the management of such desurfaced soils.

Appendix

Appendix I: physico-chemical characteristics of organic manure

Source	pH	EC (dS m^{-1})	Organic carbon (%)	Total N (%)	Total P (%)	Total K (%)
FYM	8.0	0.05	42.8	1.0	0.10	0.29
Poultry manure	8.4	0.12	35.3	1.7	0.68	0.78
Vermicompost	7.2	0.07	34.8	1.2	0.22	0.75
Coirpith compost	7.4	0.05	28.0	1.2	0.38	0.72

Appendix II: Fertility rating of soils

a) Organic carbon and major nutrients

Sl. No.	Category	OC (%)	Available nutrients		
			N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
1.	Low	<0.75	<280	<10	<115
2.	Medium	0.75-1.50	280-560	10-24	115-275
3.	High	>1.50	>560	>24	>275

(KAU POP, 2016)

b) Secondary nutrients

Sl. No.	Nutrient (mg kg^{-1})	Category	
		Deficiency	Sufficiency
1.	Calcium	<300	300
2.	Magnesium	<120	120
3.	Sulphur	<5.00	5.0-10.0

(KAU POP, 2016)

c) Critical limits for DTPA-extractable micronutrients

Sl. No.	Availability	Micronutrients (µg/g soil)			
		Zn	Cu	Fe	Mn
1.	Very low	0 – 0.5	0 – 0.1	0 – 2	0 – 0.5
2.	Low	0.5 – 1	0.1– 0.3	2– 4	0.5 –1.2
3.	Medium	1–3	0.3 – 0.8	4 – 6	1.2–3.5
4.	High	3 –5	0.8–3	6 –10	3.5 – 6
5.	Very high	> 5	> 3	> 10	> 6

(FAO, 2008)

Appendix III: Quality standards for irrigation water

Potential Irrigation Problem	**Units**	**Degree of Restriction on Use**		
		None	**Slight to Moderate**	**Severe**
Salinity*(affects crop water availability)*				
EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
TDS	mg/l	< 450	450 – 2000	> 2000
Specific Ion Toxicity *(affects sensitive crops)*				
Sodium (Na)				
Surface irrigation	SAR	< 3	3 – 9	> 9
Sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)				
Surface irrigation	me/l	< 4	4 – 10	> 10
Sprinkler irrigation	me/l	< 3	> 3	
Miscellaneous Effects *(affects susceptible crops)*				
Nitrogen (NO_3 - N)	mg/l	< 5	5 – 30	> 30
Bicarbonate (HCO_3)	me/l	< 1.5	1.5 – 8.5	> 8.5
pH	**Normal Range 6.5 – 8.4**			

(FAO, 1985)

Appendix IV: Per cent variation in nutrient status of mined soils

Sl. No.	Parameter	Per cent variation (%)
1.	Organic carbon	- 61.00
2.	Available nitrogen	-43.70
3.	Available phosphorus	- 74.50
4.	Available potassium	-43.36
5.	Available calcium	+ 62.00
6.	Available magnesium	- 55.60
7.	Available zinc	+ 14.41
8.	Available copper	+ 71.00
9.	Available iron	+ 96.30
10.	Available manganese	+ 63.80
11.	Available nickel	+ 61.00
12.	Available lead	+ 44.00

'- ' represents reduction in nutrient status

'+' represents increase in nutrient status

Appendix V: Soil reaction ratings

Sl. No.	pH range	Soil reaction ratings
1.	< 4.6	Extremely acidic
2.	4.6–5.5	Strongly acidic
3.	5.6–6.5	Moderately acidic
4.	6.6–6.9	Slightly acidic
5.	7.0	Neutral
6.	7.1–8.5	Moderately alkaline
7.	> 8.5	Strongly alkaline

(FAO, 2008)