SEMINAR REPORT

BIOSOLID - A POTENTIAL SOIL AMENDMENT

By

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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DECLARATION

I, **Riaj Rahaman (2018-11-151)**hereby declare that the seminar entitled **'Biosolid - a potential soil amendment'** has been prepared by me, after going through various references cited at the end and has not copied from any of my fellow students.

Vellanikkara | Riaj Rahaman
20/01/2020 | 2018-11-151

CERTIFICATE

This is to certify that the seminar report entitled **'Biosolid - a potential soil amendment'** has been solely prepared by **Riaj Rahaman (2018-11-151)**under my guidance and has not been copied from fellow students.

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CERTIFICATE

Certified that the seminar report entitled '**Biosolid - a potential soil amendment'** is a record of seminar presented by **Riaj Rahaman (2018-11-151)**on 07/11/2019and is submitted for the partial fulfilment of the course SOILS 591.

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1. Introduction

The population of India is increasing exponentially, much of the population has been concentrating in large urban centres. This continuing concentration creates serious waste problems.A huge volume of waste water is generated every day by the cities and towns of India. In the year 2015, the country generated sewage at the rate of 61754 million liters per day (CPCB, 2016). About 37 per cent of the sewage generated is treated in about 522 Sewage Treatment Plants (STPs) to remove contaminants and produce water that is safe for release into the environment(Kumar *et al*., 2017).Sludge produces from STPs are usually disposed to the landfill by which the nutrients and organic matter present in it is completely lost.The improper disposal of solid wastes pose a serious threat to the environmental quality leading to problems like groundwater contamination, degradation of soil quality etc. Sewage sludge that has undergone further stabilization treatment termed as biosolid, leading to sustainable waste management as well as recycling of essential plant nutrients.

2. Biosolids

Biosolids are nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility. When treated and processed, these residuals can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth (US EPA, 2019).

Table 1: Electro- chemical properties of biosolids

Properties	**Value**
pH	6.16–7.50
EC (dS/m)	2.28–2.70
Organic Carbon (%)	12.6 – 38.50
Total N (%)	1.6–1.73
Total P (%)	1.20 – 2.26
Total K (%)	0.8–1.26
Total calcium (%)	2.13
Total magnesium (%)	0.23
Total sulphur (%)	2.10

(Sharma *et al.,* 2017)

3.Constituents of biosolids

The suitability of a particular biosolid for land application can be determined by biological, chemical, and physical analyses. Biosolids composition depends on wastewater constituents and treatment processes.

a) Total solids: Total solids include suspended and dissolved solids and are usually expressed as the concentration present in biosolids.

b) Volatile solids: Provide an estimate of the readily decomposable organic matter in biosolids and are usually expressed as a percentage of total solids.

c) Organic chemicals: Organic chemicals are complex compounds that include chemicals from industrial wastes, as a result of incomplete combustion of fossil fuel such as polycyclic aromatic hydrocarbon (PAH), pentachlorophenol (PCP), household pollutants like detergent and pharmaceutical residues.

d) Elements: Biosolids contains all major plant nutrients N, P, K, Ca, Mg, S and trace elements such as Cd, Cr, Cu, Zn, Ni, Pb, the content of whichvaries depending upon the sources of wastes.Concentration of heavy metals above permissible limit restrict the use of biosolids.

(Evanylo, 2005)

4. Comparison between sewage sludge and biosolid

Biosolids are treated sewage sludge and must be used in accordance with regulatory requirements. Different treatment processes increase total solid proportion, reduce moisture content, chemical oxygen demand, dynamic respiration index, volatile solid and odour in bioisolids. But a significant change in heavy metals concentration is not observed by Uggetti*et al.*(2012).

Table 2:Comparison between sewage sludge and biosolid

Parameters	**Sewage sludge**	**Biosolid**
Total solid (%)	1.1	25.8
Volatile solid (% TS)	51.5	42.9
COD (g/kg TS)	709	494
DRI_{24h}(mg O_2/g TS /h)	6.7	3.7
Odour ($ou_E m^2/s$)	41	6.5
Ni (mg/kg)	39	32
Cu (mg/kg)	252	213
Zn (mg/kg)	719	641
Cd (mg/kg)	1.7	0.8
Hg (mg/kg)	<1.5	<1.5

TS: Total Solid, COD: Chemical Oxygen Demand, DRI: Dynamic Respiration Index

Persistence of pathogens like *Salmonella* sp.,Enterococci, *Escherichia coli*is extremely reduced in biosolid(Nielsen, 2007)

Table 3: Pathogen content in sewage sludge and biosolid

Pathogen content	**Sewage sludge**	**Biosolid**
Salmonella sp. (Number/100g)	10–300	<2
Enterococci (CFU/g)	7×10^3 - 25×10^3	<10
Escherichia coli	8×10^5 - 10×10^6 CFU/100 g	<200 number/100 g

5. Application of biosolids

Biosolids can be apply for several purposes such as

- Land application in agriculture
- Power production/energy recovery
- Road base
- Landfill
- Composting

6. Land application in agriculture

Biosolids can be applied as a fertiliser to improve and maintain productive soils and stimulate plant growth.

Benefits of land application:

- Rich source of organic matter
- Recycle essential plant nutrients
- Slow release, less water soluble organic amendment
- Improves soil structure
- Reduce the potential for erosion
- Reduce ground water contamination
- Biosolids are an endlessly renewable resource

(Qin *et al.*, 2012)

7. Application rate of biosolid

Quantity of biosolid to be applied is determined based on the crop nutrients requirement (generally N). Soil should be tested to find out the residual nutrient present in the soil. The residual value is deducted from the required nutrient by the crop to get adjusted biosolid rate(Evanylo, 2005).

Dry tonnes biosolid required /ha = Adjusted biosolid N rate (kg/ha) ÷ PAN /dry ton biosolid

Where,

Adjusted biosolid N rate = Required N – residual N

PAN /dry ton biosolid = NO_3-N + K_{vol} (NH_4^+-N) + K_{min} (Org-N)

PAN: Plant Available Nitrogen
K_{vol} : Volatilization factor
K_{min}: Mineralization factor

Table 4: Mineralization factor

	Non - irrigated				**Irrigated**			
Year	1	2	3	4	1	2	3	4
K_{min}	0.42	0.14	0.14	0.07	0.42	0.21	0.14	0.07

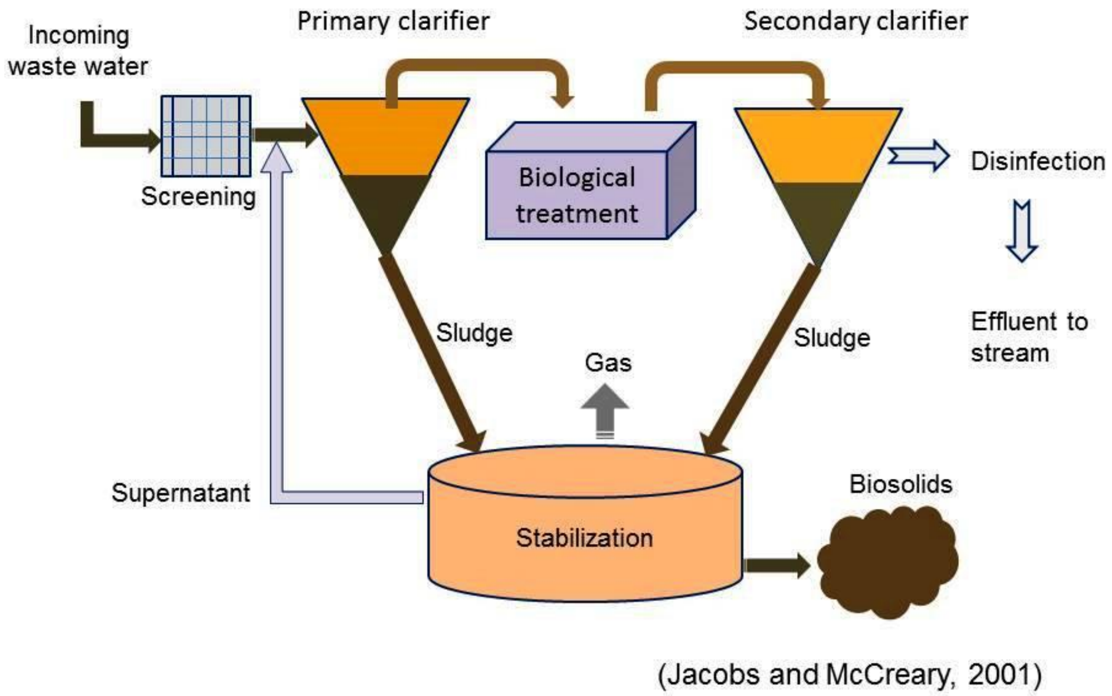
Table 5: Volatilization factor

Incorporation	**Biosolid with pH < 10**	**Biosolid with pH >10**
	Available NH_3 (%)	
Within 24 hours	85	75
Within 1-7 days	70	50
After 7 days	50	25

8. Production technology

A. Municipality waste water is being collected in sewage treatment plant
B. A screener removes the stones, pebbles and other physical pollutants and transfer waste water to primary clarifier
C. In primary clarifier solid portion settled down due to gravity and collected into stabilization tank. Supernatant is carried for biological treatment.
D. In biological treatment waste is aerated by a mechanical agitator to separate solid from liquid and to oxidize pathogens
E. Liquid portion is filtered, disinfected and discharged to stream
F. Solid portion undergo different stabilization processes

Production technology of biosolid



9. Stabilization processes

A. Digestion

Digestion is a biological process that uses bacteriato convertvolatile solids into carbon dioxide and methane. Solid waste is treated for 15 days at 35–55°C and thereafter 60 days at 20°C. This reduce pathogen density and attractiveness of the material to vectors, reduce bulkiness of materials, mineralize N and narrowed down C:N ratio. Digestion can be aerobic or anaerobic(Al-Gheethi*et al.*, 2018).

$H_2O + CH_3CH_2OH \rightarrow CH_3COO^- + 5H^+ + 4e^-$

$2e^- + 2H^+ \rightarrow H_2$

$H_2O + ½ CO_2 \rightarrow ½ CH_4 + H_2O$

$H^+ + CH_3COO^- \rightarrow CH_4 + CO_2$

B. Heat Drying

Heat drying involves using active or passive dryers todestroy pathogens and remove water from biosolids. In thisprocess, biosolids are dried with hot gases at temperaturesgreater than 80 °C to reduce the moisture content to 10% orlower.Pathogenic bacteriaare inactivated during exposure to heat, above their optimumgrowth temperature. The period of exposure is depended onthe temperature as well as the bacterial.The total inactivation of pathogenic bacteria in biosolidsrequires a holding time of 4.78 h at 60 °C comparedto 30 min at 70 °C (US EPA 1994).

C. Composting

Composting is aerobic, thermophilic, biological stabilization in a windrow, aerated static pile or vessel. In the case of within-vessel composting method or the static aerated pile composting method, the temperatureof sewage sludge is maintained at 55 ^{0}C or higher for three consecutive days. But using the windrow compostingmethod, treatment is continued for 15 consecutive days orlonger at the same temperature. During the period there shall be a minimum offive turnings of the windrow. Compostingdestroys pathogens and converts sludge to humus-like material(Al-Gheethi*et al.*, 2018).

D. Alkaline stabilization

The principle objectives of alkaline stabilization are toreduce the activity of pathogenic bacteria and inhibit theirregrowth and thus reduce the health hazard associated withthe biosolids as well as to immobilize heavy metals at higher pH.The most commonly used alkalineis the quick lime (calcium oxide, CaO) and its derivativehydrated lime or slaked lime (calcium hydroxide, $Ca(OH)_2$)which are used due to their low cost. Adding adequate volumeof CaO to the biosolids leads to increase of pH to 12(or higher) and temperature to be between 55 and 70 ^{0}C, andas results for these conditions the pathogenic bacteria areinactivated or destroyed (Evanylo, 2005).

10. Pathogen Treatment Processes

a) Heat treatment: Biosolid is heated to a temperature of 180 ^{0}C or higher for 30 minutes.
b) Beta ray irradiation: Irradiation with beta rays from an electron accelerator at dosages of at least 1.0 mega rad at room temperature (20 ^{0}C).
c) Gamma ray irradiation: Irradiation with ^{60}Co and ^{137}Cs isotopes , at the dose of 1.0 mega rad at room temperature (20 ^{0}C)

(Al-Gheethi*et al.*, 2018)

11. Classification of biosolid

Based on stabilization process, pathogen density and suitability for applicationbiosolids are classified into Class A and Class B (Foess and Fredericks, 1995).

I.Class A biosolid

The objective of Class A biosolid is to reduce pathogen content below detectable levels.This can be applied to land without any pathogen-related site restrictions.The treatment methods followed to produce Class A biosolids are alkaline stabilization, heat drying and composting. As per regulation of US EPA, Class A biosolidshould contain faecal coliform less than 1000 Most Probable Number (MPN) / g of solids, *Salmonella* sp. less than 3 MPN / 4g of solids and materials should be treated above 52^{0}C temperature for 12 hours or longer at pH 12.

II.Class B biosolid

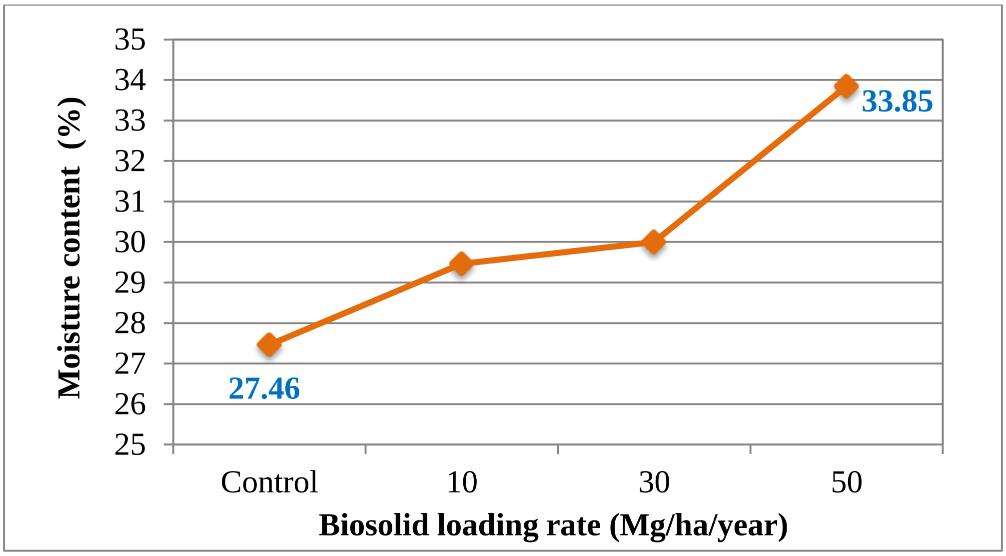
The goal of Class B biosolidis toensure that pathogens have been reduced to levels that are unlikely to cause a threat to public health and the environment under specified use conditions. Digestion and alkaline stabilization are followed to produce Class B biosolids which are exclusively applied to agricultural land away from public access area.As per regulation of US EPA, Class Bbiosolid should contain faecal coliform less than 2,000,000 Most Probable Number (MPN) /g of solids or, 2,000,000 Colony Forming Unit (CFU) /g of solid. Food crops shall not be harvested for at least 14 months after application and animals shall not be grazed on the land for 30 days after application.

12. Effect of biosolidson soil physical properties

a. Effect on soil moisture content

Tsadilas*et al.* (2005) conducted an experiment in a clay loam soil to study the influence ofbiosolids application on physical properties ofsoil. The experiment was done with four biosolids rate (0, 10, 30, and 50 t/ha/year) and four replicates. It was found that after three years ofbiosolids application, water retention capacity of soil at field capacity, increased from 27.46 per cent to 33.85 per cent on control plot and maximum dose of biosolid applied plot respectively (Figure 1).

Figure 1 : Effect of biosolid on soil moisture content



b. Effect on bulk density

The same experiment conducted by Tsadilas*et al.*(2005) also reported that bulk density of soil decreased from 1.41 Mg /m^3 to 1.27 Mg /m^3(Figure 2) on control plot and maximum dose of biosolid applied plot respectively. Soil physical properties affected by the addition of biosolidswere significantly correlated with organic matter content.

c. Effect on infiltration rate

Salazar *et al.* (2005) reported that infiltration rate of soil is increased as a result of biosolids application. Different doses (30, 60 and 90 t/ha) of biosolid was applied on andisoland accumulated infiltration (cm) was measured using ainfiltrometer at different time interval. After 155 min accumulated infiltration observed was 12.7 cm and 30.9 cm on control and maximum dose of biosolid applied soil respectively (Figure 3).

Figure 2 : Effect of biosolid on bulk density of soil

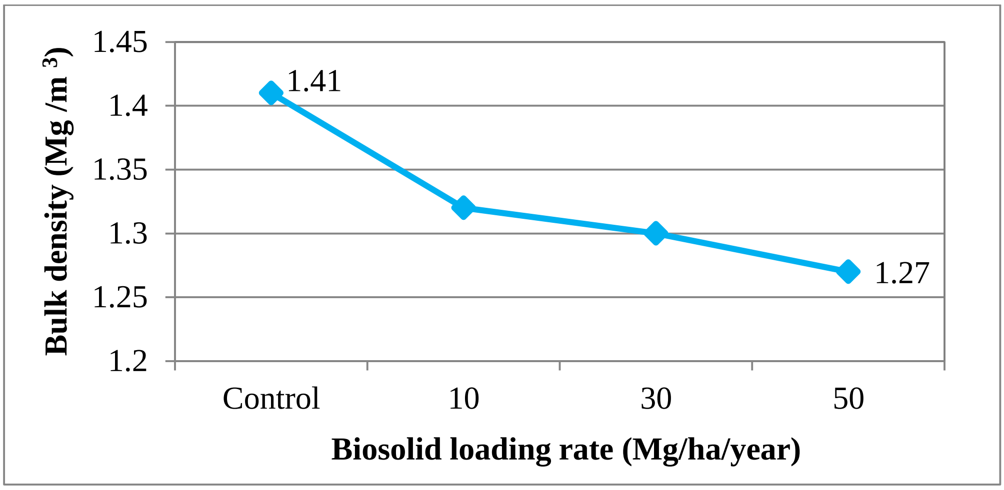
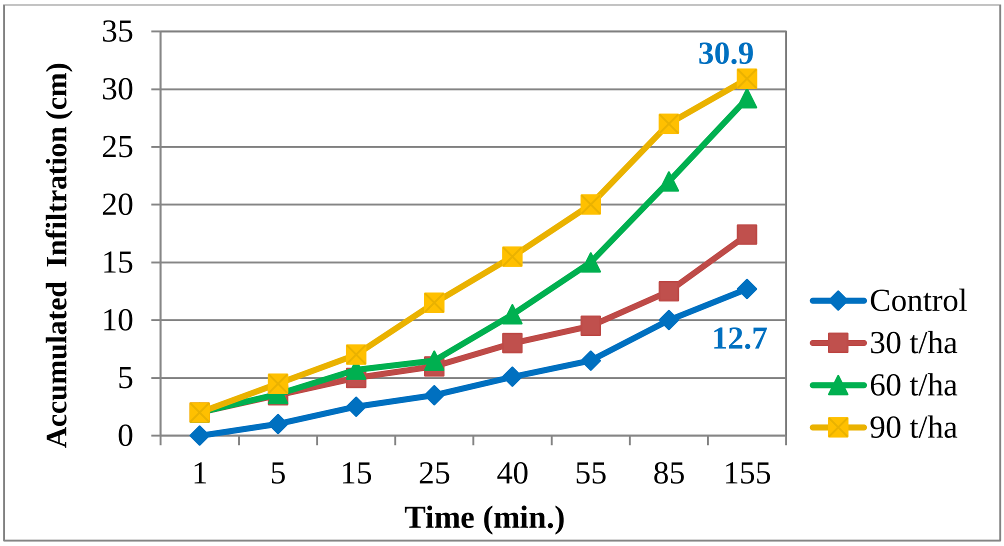


Figure 3 : Effect of biosolid on infiltration rate



13. Effect of biosolidon soil chemical properties

a. Effect on Soil pH

Sloan and Basta (1995) conducted an experiment on strongly acidic mollisol to study the effect of biosolid on soil pH. Alkaline stabilized biosolid was applied in different doses as per lime requirement of soil (10.7, 15.4 and 20.1 g /kg soil). After six months of incubation pH of the soil was increased from 3.7 to 5.22 at highest amendment rate (Figure 4).

b. Effect on soil electrical conductivity

There was no significant change in soil electrical conductivity in different depths and different doses of biosolid,reported by Cogger*et al.* (2014).

Figure 4 : Effect of biosolid on soil pH

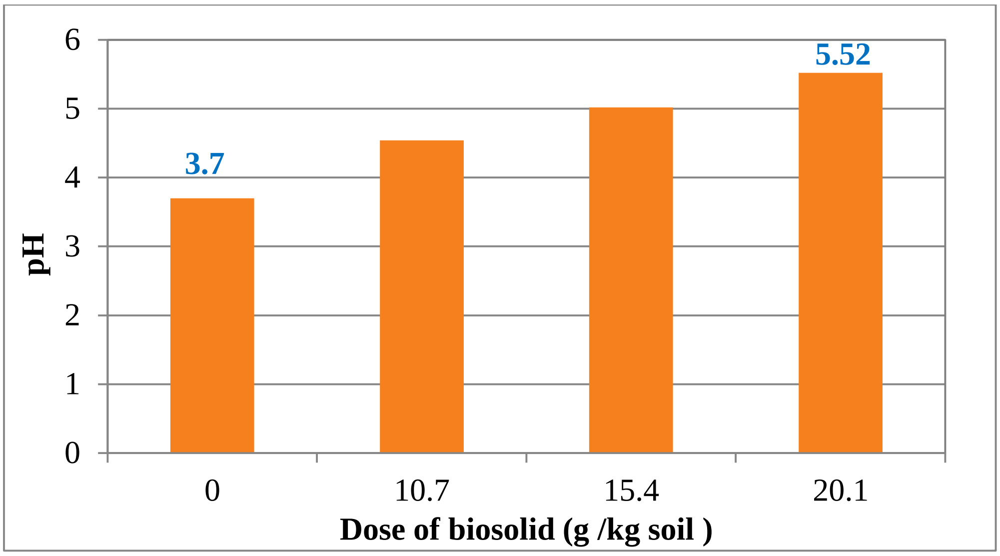


Figure 5 : Effect of biosolid on soil electrical conductivity (EC)

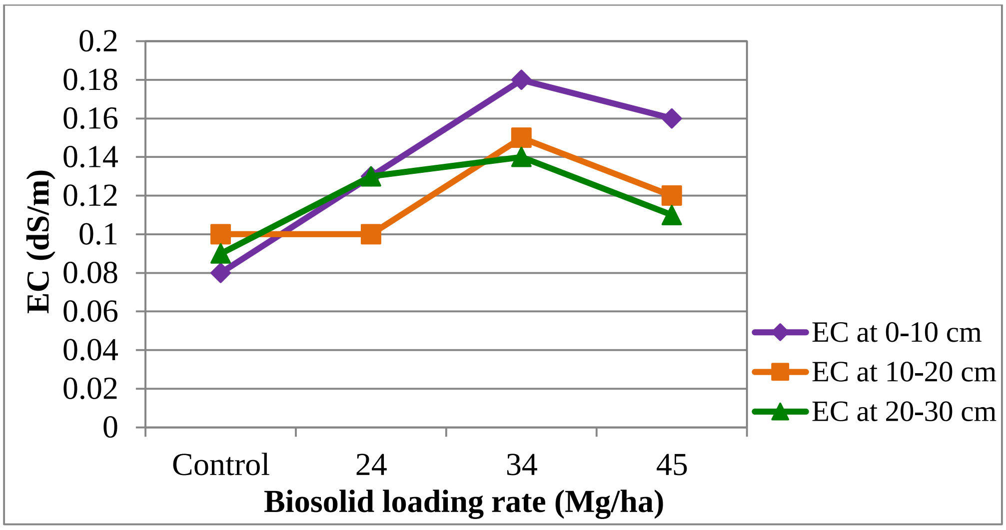
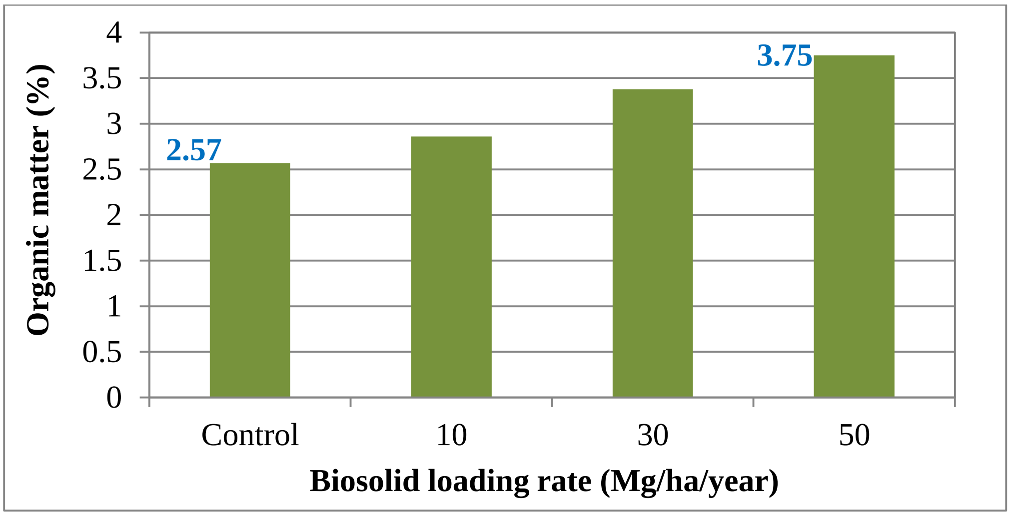


Figure 6 : Effect of biosolid on soil organic matter content



Total biosolid was applied 24,34 and 45 Mg/ha in a two years experiment. Soil sample was collected from 0-10, 10-20, and 20-30 cm depth. In all cases electrical conductivity was found less than 0.2 dS /m(Figure 5) with statistically significant but biologically unimportant.

c. Effect on soil organic matter content

Nearly half of the solid portion of biosolid is organic matter. After three years of biosolid application on clay loam soil, organic matter content of soil increases from 2.57 per cent in the control to 3.75 per cent in biosolid treated (50 Mg/ha/year) plot, reported by Tsadilas*et al.* (2005) (Figure 6).

d. Effect on soil primary macro nutrients

Increase in total soil N and available P as a result of long term biosolid application on sandy loam soil was observed by Cogger*et al.* (2014). Total N in the soil increases from 800 mg/kg (control) to 1500 mg/kg in highest dose of biosolid (45 Mg/ha) (Figure 7, a). Biosolids had a large effect on bicarbonate-extractable P, increasing from 15 mg/kg at the 0-10 cm depth in the control to 128 mg /kg at high rate (45 Mg/ha) of biosolids (Figure 7,b).

TotalKcontent increases from 2019 mg/kg in control to 2140 mg/kg in the biosolid treatment(5.8Mg/ha) on sandy loam soil after two years of application,reported by Banuelos*et al.* (2007) (Figure 7, c).

e. Effect on secondary nutrients

Application of biosolid significantly increased total concentration of secondary macro nutrients in sandy loam soil observed by Banuelos*et al*., (2007). Concentration of Ca, Mg and S increased from 2539, 2657 and 155 mg/kg in the control to 4641, 3051 and 480 mg/kg in high dose of biosolid treatment (5.8 Mg/ha) respectively (Figure 8).

f. Effect on concentration of Al and Mn

Efficacy of alkaline stabilized biosolids for neutralizing soil acidity and preventing Al and Mntoxicity in strongly acid soils was evaluatedby Sloan and Basta (1995). Biosolids are capable of forming complex and detoxify Al and Mn in acid soil. Concentration of Al in soil solution decreased from 285 µM to 0.2 µM whereas Mn decreased from 53.3mg/L to 13.1mg/L in the control and biosolid treatment respectively (Figure 9).

g. Effect on soil Cation Exchange Capacity (CEC)

Biosolid increase cation binding sites in the soil system.Zare*et al*. (2010) reported that, after one year of biosolids application at the rate 100 Mg/ha in fine loamy soil cation exchange capacity of soil increased from 13.2 to 15.9 cmol(+)/kg (Figure 10).

Figure 7 : Effect of biosolid on soil primary macro nutrients

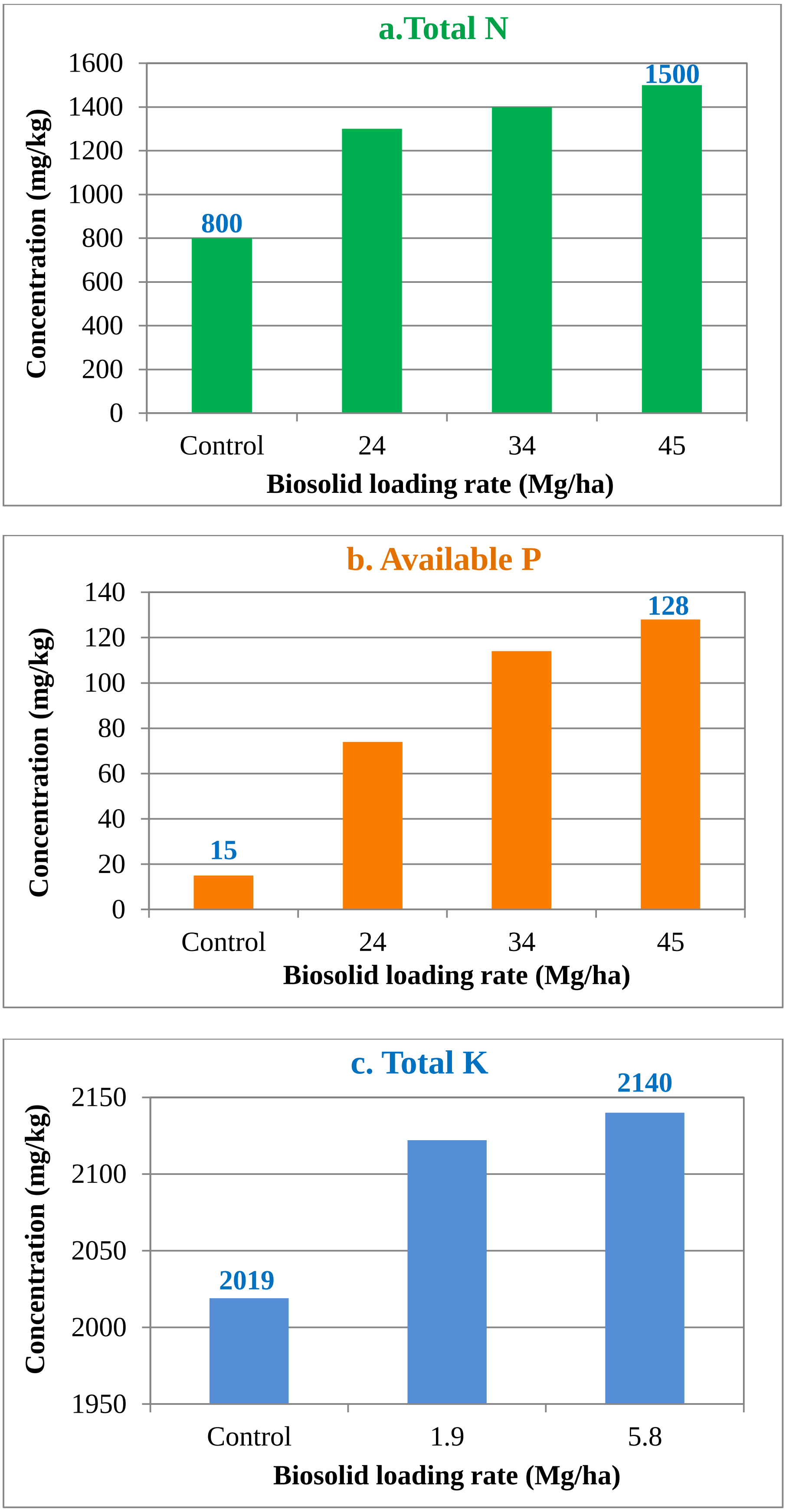


Figure 8 : Effect of biosolid on soil secondary macro nutrients

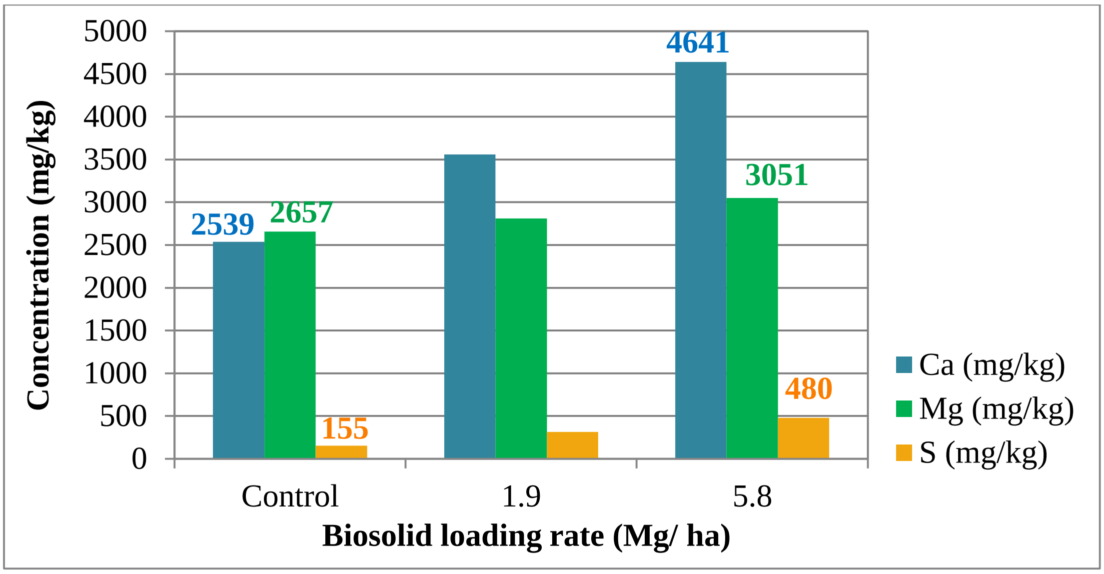


Figure 9 : Effect of biosolid on soil Al and Mn

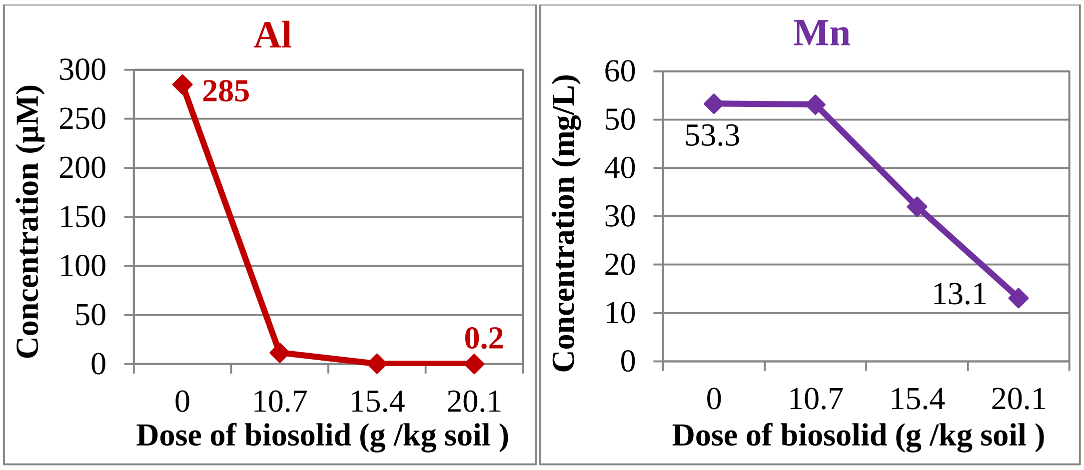
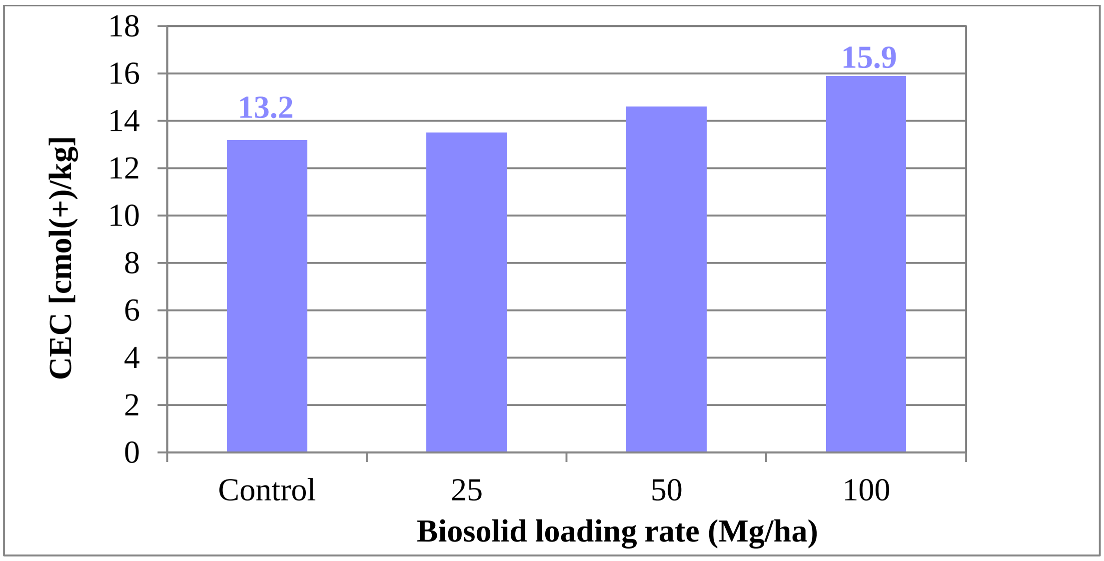


Figure 10 : Effect of biosolid on soil cation exchange capacity (CEC)



14. Effect on soil biological properties

Long-term applications of lime-stabilized anaerobicallydigested biosolid have consistently improved soil biological activity, increased soil organic matter content, andmicrobial biomass carbon–nitrogen–phosphorus poolshave enlarged with greater metabolic efficiency (lowqCO_2) by the impacts ofbiosolid application (Yucel*et al.*, 2015).

a. Effect on soil microbial biomass

Soil microbial biomass was significantly influenced by the temporal effects of biosolid application.The microbial biomass carbon (MBC)content at the 0-15cm depth was higher by 1.9 and 3.7 folds in the 5 and 25 years of biosolid applied fields respectively, than in the control (Figure 11). While microbial biomass nitrogen (MBN) and microbial biomass phosphorus (MBP) contents were higher in the 25 years of biosolid applied field by 3.2 and 3.3 folds respectively(Figure 12).

b. Effect on soil specific maintenance respiration (qCO_2)

Specific maintenance respiration (qCO_2) is the amount of C used by the metabolic activity of soil micro-organisms and expressed as μg CO_2 / g MBC / day. Reduce the value indicates stability of the materials.The qCO_2 was reduced by 20 to 53 % in the long-term (25 years)biosolid-applied fields compared with the control(Figure 13),which may be due to efficient anabolism of C and nutrients for microbial cell growth than respiratory catabolism.

c. Effect on soil enzyme activity

Cele and Maboeta, (2016) conducted an experiment to observe the effect of biosolid on soil enzyme activity.Three types of enzymes were investigated, namely b-glucosidase, alkaline phosphatase and urease. The estimation of b-glucosidaseand alkaline phosphatase was based on thedetermination of the released p-nitrophenol, after theincubation of soil with p-nitrophenylglucoside andp-nitrophenyl phosphate solution respectivelyfor 1 h at 37 ^{0}C. For the urease enzyme, the method wasbased on colorimetric determination of released ammoniaafter the incubation of soil samples with urea solution for 2 h at 37 ^{0}C. All the three enzymes showed increased activity and this was consistent with each increase in biosolidapplication (Figure 14).The observed increases in soil enzyme activities were attributed to improvements in soil physicochemical conditions,due to the application of biosolid.

15. Effect of biosolids on crop yield

Biosolids application at the rate 50Mg/ha/year for three year on clay loam soil, significantly increased cotton yield from 2.47 ton/ha in the control treatment up to 3.35 ton /ha (Tsadilas*et al.*, 2005) (Figure 15, a).

Increased soil N supply thereby increased wheat yield with repeated application of biosolidsreported by Cogger*et al.*(2014). Yield increased from 2350 kg/ha in the control to 3860 kg/ha in the biosolid treated plot at the rate 24Mg/ha(Figure 15, b). Thereafter any increase in biosolid dose reduced the crop yield, indicating that was the optimum requirement for the crop.

Figure 11 : Effect of biosolid on soil microbial biomass carbon (MBC)

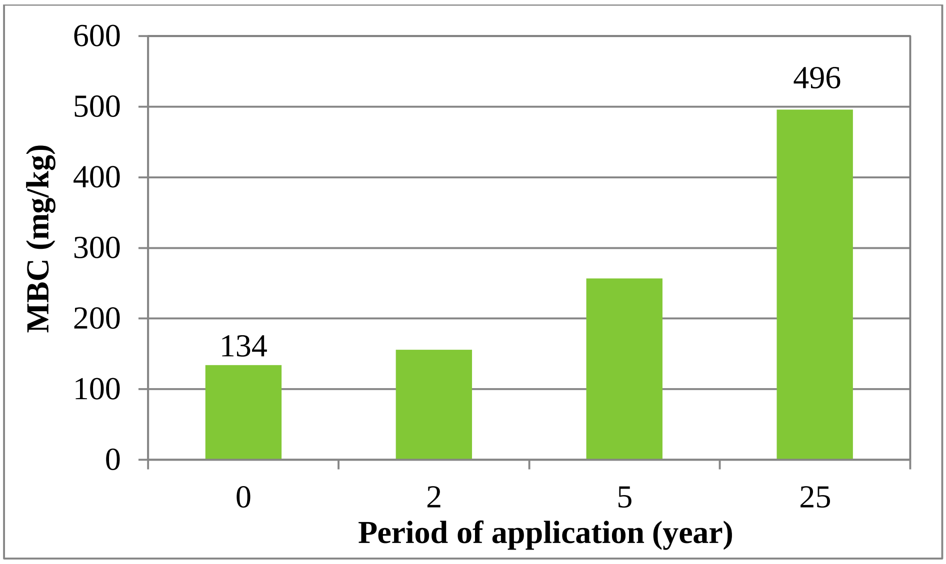


Figure 12 : Effect of biosolid on soil microbial biomass N and P

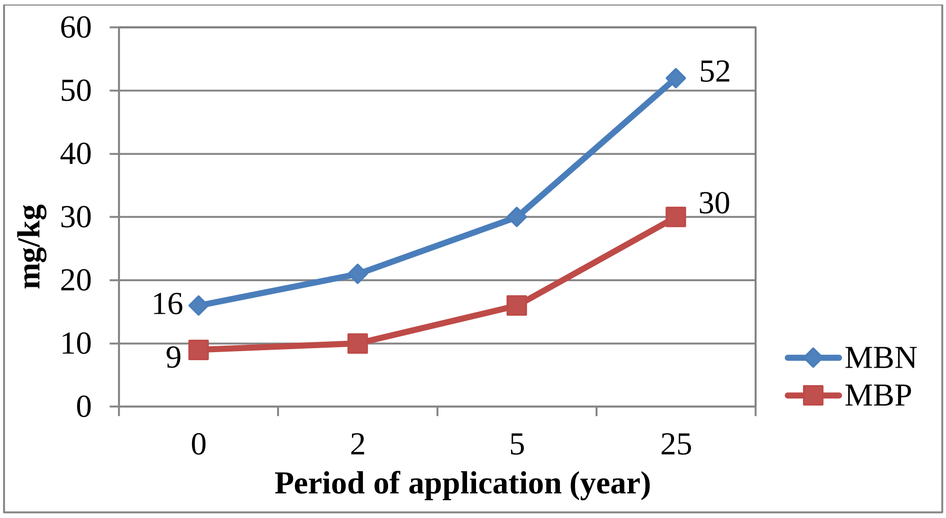


Figure 13 : Effect of biosolid on soilspecific maintenance respiration (qCO_2)

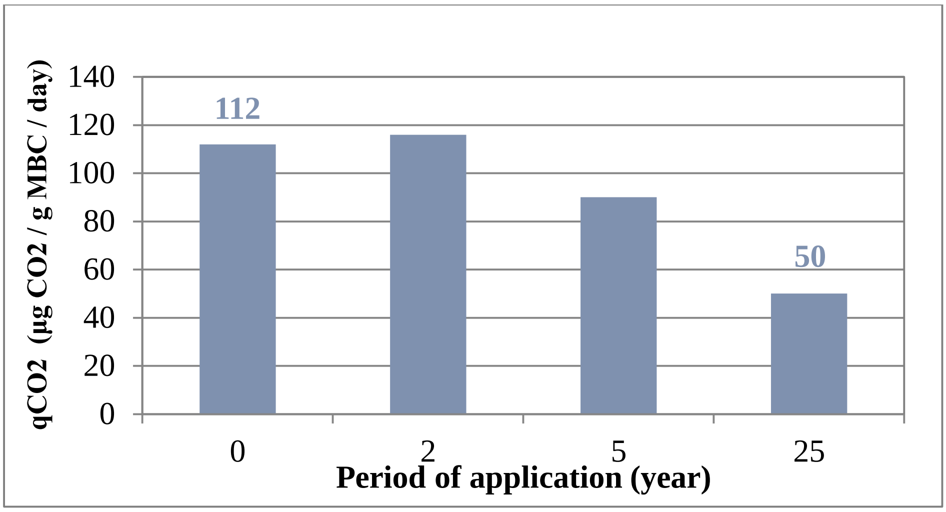


Figure 14 : Effect of biosolid on soil enzyme activity

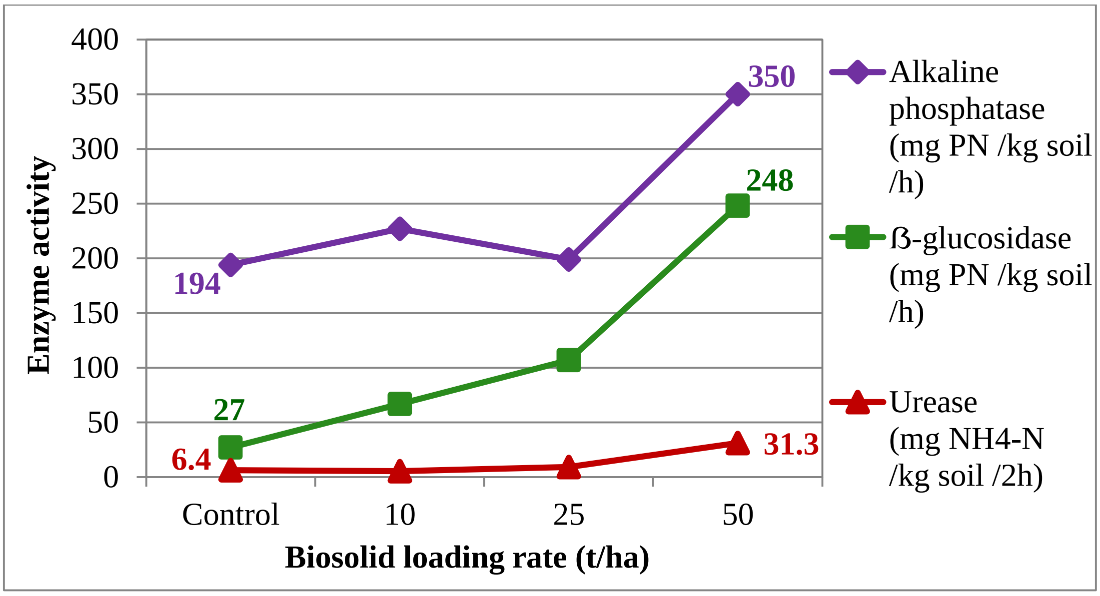
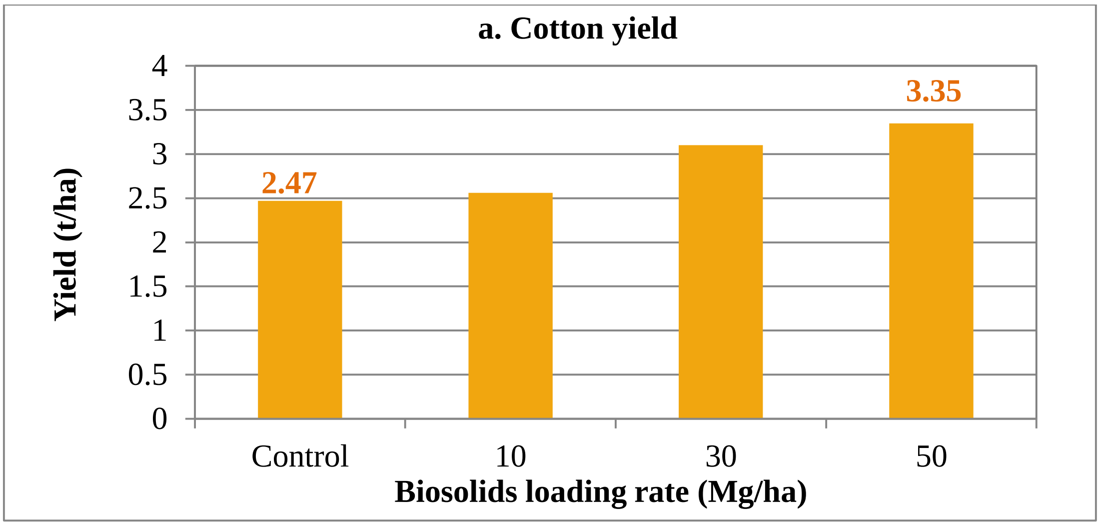
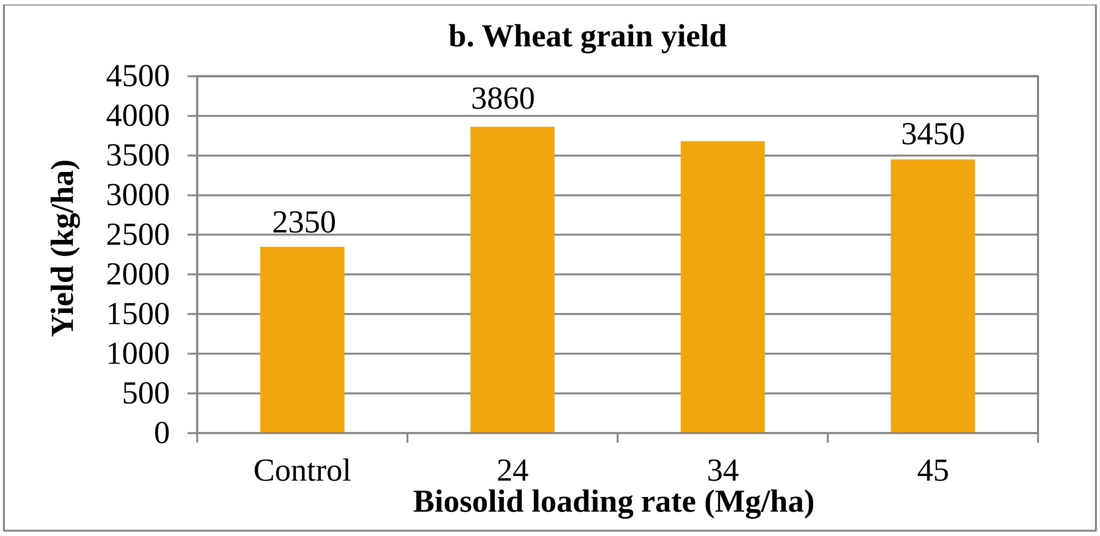


Figure 15 : Effect of biosolid on crop yield





Soil fertilisation with biosolids greatly benefits spring barley, increase yield up to 30 per cent (Arduini*et al.* 2018). The study evaluated the relative advantages of biosolid over inorganic fertilizer. Inorganic fertilizer was applied at the rate 120 kg N/ha (20 kg as basal and remaining top dressing) and rate of biosolid was 20 t/ha which contains almost equal amount of potentially mineralisable N available for plant uptakebut produced 40 per cent higher grain yield, due to the combination of a more constant release of N throughout the growth cycle, and the improvement of soil physical properties.

Table 6: Effect of biosolid on yield of barley *(Hordeumvulgare)*

Treatment	Mean kernel weight (mg)	Kernel / spike	Spike / plant	Grain N (%)
Control	37.4	15.3	1.6	1.3
Mineral fertilizer (120 kg N/ha)	43.4	21.4	4.1	**1.6**
Biosolid (20 t/ha)	**45.6**	**24**	**4.9**	1.5

16. Limitations

Biosolid often contains higher concentration of heavy metals, organic pollutants like polycyclic aromatic hydrocarbon (PAH), pentachlorophenol (PCP), detergent residue, pharmaceutical; pathogenic agents such as *Salmonella* spp., enterococci, *Escherichia coli*etc.

Smith (2009) reported that, the most toxic compounds cannot be detected inbiosolids, and they are also influenced by a variety of physico-chemical and biologicalattenuation mechanisms that prevent transfer to crop tissues and the human foodchain, including:

(i) rapid volatilization and loss to the atmosphere

(ii) rapid biodegradation and minimal or no persistence or

(iii) strong adsorption of persistent compounds

According to National Research Council(2002),there has been no outbreaks of infectious disease associated with human exposure, either directly or through food consumption pathways, from land applied biosolids.In spite of having potential problem, there were no incidences of disease from land application of biosolids detected, reported by Al-Gheethi*et al*.(2018)

17. Standards for the use of biosolids

United States Environmental Protection Agency (US EPA, 1994) has given some standards to regulate land application of biosolid.Application of biosolid should immediately stop to a particular site when the standards reach to the maximum limit.

Ceiling Concentration (CC): Maximum permissible concentrations of trace elements for land application of biosolids (mg/kg)

Cumulative Pollutant Loading Rate (CPLR): Total amount of a pollutant that can be applied to a site (kg/ha).

Monthly Average Concentration (MAC): Permissible limit for addition in one month (mg/kg/month).

Annual Pollutant Loading Rate (APLR): Permissible limit for addition in a year (kg/ha/year).

Table 7:Pollutant limits, Code of Federal Regulations - Part 503, US EPA

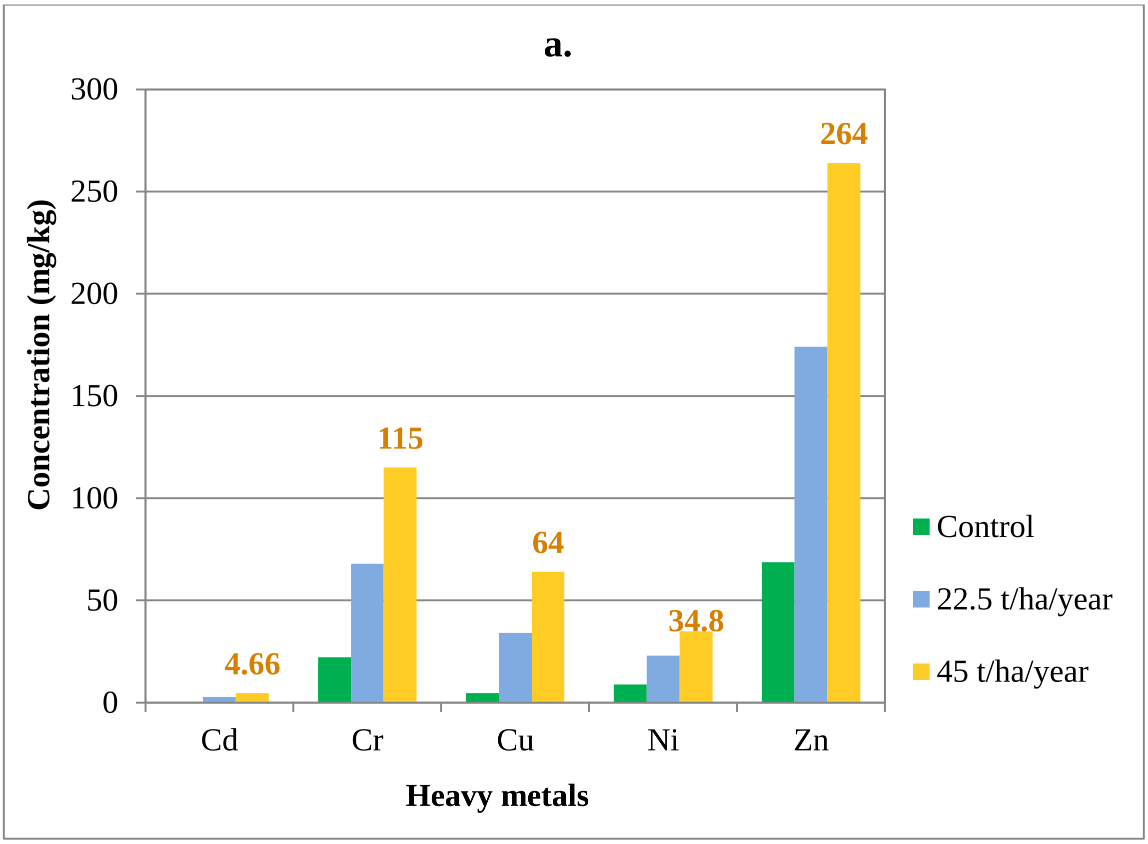
Pollutant	CC (mg/kg)	CPLR (kg/ha)	MAC (mg/kg)	APLR (kg/ha/year)
As	75	41	41	2.0
Cd	85	39	39	1.9
Cu	4300	1500	1500	75
Pb	840	300	300	15
Hg	57	17	17	0.85
Ni	420	420	420	21
Se	100	100	100	5.0
Zn	7500	2800	2800	140

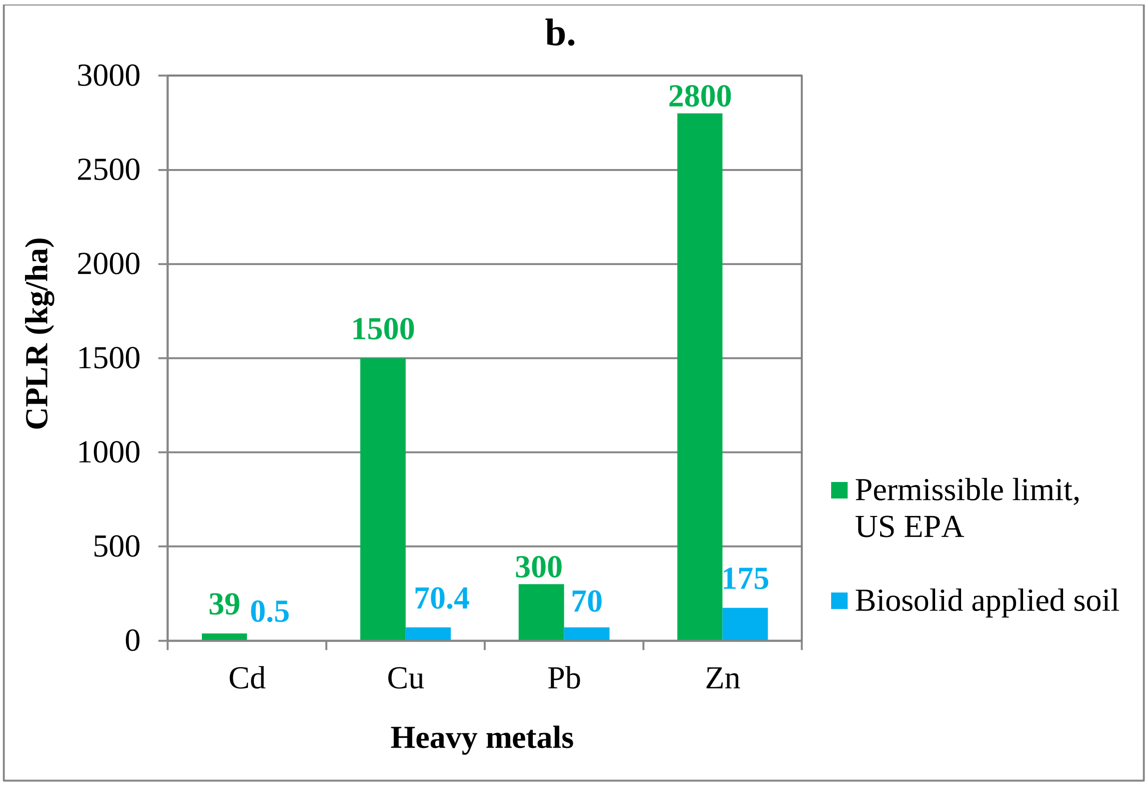
18. Heavy metal content in biosolid amended soil

Potentially hazardous trace elements such as Cd, Cu, Cr, Ni and Zn are expected to accumulate in biosolids–amended soil andremain in the soil for a long period of time. After ten years of biosolid application at the rate 45 t/ha/year on sandy loam soil Bai*et al*.(2010) reported that, the concentration of heavy metals increased from the control consistently with increase of dose of biosolid but, found below the permissible limit at even maximum dose (Figure 16, a).

In another experiment Schroder *et al*.(2008) observed that, after 13 years of biosolid application at the rate 313 Mg/ha/year, the CPLR for Cd, Cu, Pb and Zn was below the permissible limit (Figure 16, b). Until CPLR reaches to permissible limit, biosolid can be used without causing adverse effects on plants, animals, and humans (US EPA, 1993).

Figure 16 : Heavy metal content in biosolid amended soil





19. Heavy metal content in vegetables from biosolid applied soil

Metal bioavailability in biosolids amended soils is dependent on the nature of the metal, biosolid, soil and plant. Plant availability of metals is depicted by a linear correlation between the concentration of metal in a given soil and sensitivity of plant towards metal ions. The plants absorbed adequate amounts of Cu which is essential for growth. The Cu concentrations of the edibletissues showed a slight yet consistent increasing trend inresponse to the metal loading levels. The same trend also observed in case of Cd and Zn.As per FAO the maximum permissible limit ofCd, Cu and Zn for edible portion of vegetablesare 0.3, 40, 60mg/kg respectively. Concentration of Cu and Zn didn't exceed the limit at higher dose (45 t/ha/year) after ten years of application but, the concentration of Cd was comparatively higher because, plantsweremore likely responding toCd, reported by Bai*et al*. (2010)

Table 8: Heavy metal content in vegetables from biosolid applied soil

Crop	**Treatment**	**Cd (mg/kg)**	**Cu (mg/kg)**	**Zn (mg/kg)**
Potato	Control	1.54	13.63	37.7
	22.5 t/ha/year	1.54	17.57	40.5
	45 t/ha/year	2.42	18.71	43.5
Tomato	Control	0.46	12.2	34.6

	22.5 t/ha/year	0.61	12.26	35.7
	45 t/ha/year	1.23	12.98	36.4
Cabbage	Control	0.5	3.26	25.9
	22.5 t/ha/year	0.87	5.08	47.4
	45 t/ha/year	1.08	6.09	60.1

20. Guidelines for application of biosolid

- Application should be based on crop nutrient requirement, generally based on crop N requirement. But if soil is rich in P, it is advisable to apply biosolid as per P requirement of the crop to avoid P contamination and remaining N requirement to be fulfil by inorganic fertilizer.
- Test soils before application and again when it is estimated that the soil trace element concentrations have reached approximately one half of the recommended maximum soil concentration.
- Soil pH of 6 or above should be maintained as long as the land to which sewage biosolids have been applied is used for crop production to keep trace elements in immobilized state.
- Alkaline-stabilized biosolid should be applied at rates of soil liming requirements.
- Incorporate materials within 24 h of application to reduce volatilization loss of ammonia (NH_3)
- Apply material that has consistent quality.

21. Summary

Biosolids are nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility. Treatment and stabilization improves physico-chemical properties which differs biosolids from sewage sludge and it is found to be the best disposal method. Based on stabilization process, pathogen density and suitability for application biosolids are classified into Class A and Class B. Biosolids can be apply for several purposes but agricultural land application has a potential advantage as it’s a rich source of essential plant nutrients. High content of organic matter present in biosoild improves physical properties of soil. Application of biosolids at agronomic rates to meet crop nitrogen requirement was found to positively effect soil fertility and produce higher crop yield than chemical fertilizers. Though biosolids contains several heavy metals, it’s application is regulated based on pollutant loading rate as per US EPA to minimize adverse effects.

22. Conclusion

The anxieties regarding the possible content of toxic pollutants, pathogens and heavy metals restrict its use in agriculture. Use of biosolids as a soil amendment is often driven by the intention of recycling nutrients while reducing the pressure on final deposal sites.

Discussion

1. What is the difference between activated sludge and biosolid? Which one is more cost effective?

The production of activated sludge includesphysical separation of sewage sludge and biological treatment in an aerator, further stabilization is not followed here but in case of biosolid, stabilization is an important step which reduces moisture content, pathogen level, foul smell and improves the quality of the materials.

Treatment of polluted water is mandatory and generated sewage sludge by the treatment plant has to be disposed. Up to biological treatment, the cost of production for activated sludge and biosolids are equal. Additional cost includes the instalment of stabilization tank and its maintenance. It is the best disposal method and compare to the advantages of treated biosolids, the cost is negligible.

2. Whether ligand can be used with biosolids to bind heavy metals?

Ofcourse, infactbiosolid itself acting as a chelating agent to bind heavy metals and to make them immobilise, additional ligand will increase the binding efficiency.

3. Can we completely remove heavy metals from soil?

Complete removal of heavy metals from the soil is very difficult, these can be immobilise by raising the pH of soil using liming materials. Application of alkaline stabilised biosolids in acid soil is found to be fruitful in this case. Moreover metalophytes can be used for phytoremediation of heavy metals and thereafter phytomining.

4. How does ‘NamamiGange’mission related to biosolid production?

'NamamiGange’ mission, is an integrated conservation mission, approved as 'Flagship Programme' by the Union Government in June 2014. Cleaning and purification of polluted water will generate huge quantity of sewage sludge which can be treated carefully to boost the production of biosolid in India.

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Abstract

A large volume of waste water is generated every day in the urban areas of India. According to the Central Pollution Control Board, the country is generating sewage at the rate of 61,754 million litres per day (CPCB, 2016). About 37 per cent of the sewage generated is treated in sewage treatment plants to remove contaminants and produce water that is safe for release into the environment.

Biosolid is the term given to sewage sludge that has undergone further stabilization treatment to enable beneficial reuse. Stabilization refers to the process that reduces the volatile solid content, pathogen load, vector attraction and odour. Based on suitability for soil application biosolids are categorized as Class A and Class B. While the former is suitable for use without limitation, the latter is restricted to application in agricultural land without public access (Foess and Fredericks, 1995).

High content of organic matter and essential plant nutrients particularly nitrogen and phosphorus make biosolid a potential soil amendment that can reduce the use of chemical fertilizers (Binder *et al*., 2002). The organic matter content in biosolid alters the physico-chemical and biological properties of soils. Tsadilas*et al*. (2005) observed significant improvement in soil porosity, bulk density, infiltration rate and water holding capacity in heavy textured and poorly structured soils. Increase in soil microbial population, soil respiration and enzymatic activity were also recorded (Sharma *et al.,* 2017). Alkaline stabilized biosolid could increase soil pH and reduce toxicity of Al and Mn in acidic soil (Sloan and Basta, 1995).

Application of biosolids at agronomic rates to meet crop nitrogen requirement was found to positively effect soil fertility and produce higher crop yield than chemical fertilizers (Arduini*et al*., 2018).

Apart from the beneficial constituents in biosolids, it is often characterized by the presence of toxic heavy metals, organic and inorganic chemicals and pathogens which may have adverse effect on the eco-system. As the indiscriminate use of biosolidscan be detrimental to soil health, it is regulated by monitoring the cumulative pollutant loading rate

in soil. Maintaining soil pH above the threshold limit of six can reduce the bio-availability of heavy metals (Sharma *et al.*, 2017).

Though the anxieties regarding the possible content of persistent and toxic pollutants, pathogens and heavy metals restrict its use in agriculture, use of biosolid as a soil amendment is often driven by the intention of recycling nutrients and ensuring sustainable waste management.

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