INFLUENCE OF SEWAGE SLUDGE APPLICATION ON UPTAKE OF NUTRIENTS AND HEAVY METALS (HM) IN MARIGOLD CROP

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ABSTRACT

Purpose *- Pot culture experiment was carried out at Horticulture farm, ANGRAU- Hyderabad to assess the influence of sewage sludge on uptake of nutrients and heavy metals in Marigold plant and flowers.*

Methods *- Sewage sludge obtained from NMK-STP, Hyderabad analysed for physico-chemical properties and used in the study along with Red soil in different fractions. A total of seven potting media were prepared containing soil, sewage sludge and different ratios of soil + sewage sludge. Plant and flower samples were analysed for nutrients and heavy metals uptake.*

Results *- The physico-chemical and biological characteristics of sewage sludge presented in the Table 1., indicated that sewage sludge can be safly used as a rich organic matter for realizing marig-old yield instide of inorganic fertilizers with ecofriendlly manners. Among treatments, T_5 (100% sewage sludge) was found to be significantly supirior in all observed parameters, however the heavy metals uptake in these treatment were beyond the maximum permisible limites.*

Conclusion*- The NPK content of sewage sludge used in the present experiment was high along with organic carbon content. The content of heavy metals Pb, Ni, Co and Cd was within maximum permissible limits.*

Key Words: Marigold, Heavy Metals, Waste Management, Ecofriendlly Manure.

I. INTRODUCTION

India has a long tradition of floriculture. The commercial activity of production and marketing of floriculture products with low cost technology is a source of gainful agri-business option and could generate quality employment to scores of people. In India, flowers are cultivated in area of 2.72 lakh ha with annual production of about 16.8 lakh million tones during the year 2013, earning 17.7 lakh million rupees by their export (Indian Statistical Data Base 2013). Marigold is one of the most important decorative flowers. In several states of India they are grown commercially in fields where they are claimed by some to be more profitable than any other crops. Marigold is even helping to play a vital role as a cash crop to poor farmers in the north of India.

Solid wastes are the organic and inorganic wastes generated by rapid increased production, consumption and other human and animal activities of the urban society, normally discarded as useless or unwanted or those which have lost their value to the first user and are a major cause of pollution (Mee and Topping, 1998) In developing countries, increasing waste production accompanies to urbanization (Ahmed and Ali, 2004) and the waste produced generally has high moisture content and a low combustible fraction (Ali, 2003) and found to be composed of vegetative matter (44%) and inert materials (42%) in a developing country like India (Damodaran *et al*. 2003). Sewage sludge is a residual mixture of organic and inorganic solids derived from municipal waste water treatment. It contains large amount of major and micro nutrients besides having high organic matter content. Hence, it can improve soil physical, chemical and biological properties Singh and Agrawal (2009). Thus, it can be explored as an alternative organic source to supplement chemical fertilizers in crop production. The major interest to use this sewage sludge for growing crops is to promote the concept of wealth out of waste in order to have green and clean Earth. It also makes better earning by investing less as low cost technology.

Waste management has become a major environmental challenge, and land application of sewage sludge is generally considered the best option for disposal of sewage sludge because it offers the possibility of recycling plant nutrients, provides organic material, improves soil fertility along with physical properties and enhances crop yields (Robert *et al.*, 2011). Agricultural and horticultural applications of sewage sludge are becoming popular as a means of nutrient recycling in many areas of the world (Jacobs, 1981). Guidelines on application of sewage sludge should take account of many factors, such as sludge type, time and method of application (Shepherd, 1996). Because of a growing need to apply municipal sewage sludge on agricultural lands, there is a developing urgency to have criteria for disposal practices that will preserve the productivity of these lands and enhance the productivity and quality of crops (Chaney *et al*., 1987). Land application could utilize the valuable components in sludge, making it an attractive and feasible option for sludge disposal. Among the valuable components of sewage sludge, phosphorus (P) is an important nutrient that stimulates the growth of crops and other photosynthetic microorganisms (Xie *et al*., 2010).

The objective of this study, therefore, was to investigate the effect of sewage sludge on nutrients and HM uptake in marigold (*tagetes erecta*) to combat the scarcity of chemical fertilizers and their negative residual impact on soil phisico-chemical properties. Results indicated that sewage sludge can be safly used as a rich organic matter for realizing marigold yield instide of inorganic fertilizers with ecofriendlly manners. Among treatments, T_5 (100% sewage sludge) was found to be significantly supirior in all observed parameters, however the HM uptake in these treatment were within meximum permisible limites.

II. MATERIALS AND METHODS

2.1 Study site- A pot culture experiment was conducted on alfisols (red soil) at green house farm of the Department of Horticulture, College of Agriculture, Rajendranagar, Hydeabad during *kharif* 2013 to study the innovative approache of effect of sewage sludge application on nutrients and HM uptake in marigold.

2.2 Treatments- The experiment was laid out in Completely Randomized Design (CRD) with three replications and necessary data was collected whenever required. There were seven treatments consisting of T_1 (20% sewage sludge), T_2 (40% sewage sludge), T_3 (60% sewage sludge), T_4 (80% sewage sludge), T_5 (100% sewage sludge), T_6 (RDF - Inorganic N, P and K @ 100, 100 and 100 kg ha^{-1}, respectively) and T_7 (Control).

2.3 Experimental protocol- Before starting of experiment the silent properties of sewage sludge were analysed using standard methods, which are presented in the Table 1.

2.4 Sewage Sludge Chemical Analysis- Sewage sludge used in the pot culture experiment was analyzed for physico-chemical and biological properties by using standard procedures. The pH was determined in 1:10 sewage sludge (1 mm sieved) and water suspension by using combined glass electrode pH meter (Jackson, 1973). Electrical conductivity was determined in 1:20 sewage sludge and water suspension by using Electrical Conductivity meter (Jackson, 1973) and expressed in dS m^{-1}. Organic carbon content of sewage sludge was estimated by the wet digestion method (Walkley and Black, 1934). Nitrogen content of the sewage sludge was determined following Bremner (1965) method.

2.4.1 Digestion of Sewage Sludge for P, K and Zn- Finely ground sample (0.5 gm) was digested with 20 ml triacid mixture consisting of HNO_3: H_2SO_4: $HClO_4$ in 9:4:1. The digest was kept on the hot plate for about two hours at $160^{O}C$, until a clear digest was obtained. The intensity of yellow colour was determined by using double beam UV Spectrophotometer model UV5704SS at 420 nm (Piper, 1966). The potassium content in the triacid digest was determined by using Flame photometer model CL 361(Jackson, 1973). Zinc in the triacid extract was determined by using the Atomic Absorption Spectrophotom-eter (AAS) model NOVAA300 and expressed as mg kg^{-1} (Lindsay and Norwell, 1978).

2.4.2 Digestion of sewage sludge for HM (Cd, Co, Ni and Pb)- Finely ground sample (1 gm) was digested with 20 ml diacid mixture consisting of HNO_3: $HClO_4$ in 9:4. The digest was kept on the hot plate for about two hours at $160^{O}C$, until a clear digest was obtained. The diacid extract was used for analysis of HM (Cd, Co, Ni and Pb) using the Atomic Absorption Spectrophotometer (AAS) model NOVAA300 and expressed as mg kg^{-1} (Swarajya *et al*., 2010).

2.4.3 Sludge volume index (SVI)- The sludge volume index is the volume in milliliters occupied by one gram of a suspension after 30 minutes settling (Dick and Vesilind, 1969). SVI determined through used standard laboratory test method (Davis *et al*., 2008). The procedure involves measuring the Mixed Liquor Suspended Solids (MLSS) value and also the sludge settling rate.

$$\text{SVI (mL g}^{-1}\text{)} = \frac{\text{SSV (mL L}^{-1}\text{)}}{\text{MISS (mg L}^{-1}\text{)}} \times 1000$$

2.5 Chemical analysis of plant and flower- Plant **s**amples collected for recording dry matter production (DMP) at 45 and 90 days after transplanting (DAT) were dried, powdered and utilized for chemical analysis.

2.5.1 Nitrogen uptake- For estimation of nitrogen in plant sample, 0.1 g of plant sample was added with conc. H_2SO_4. Later it was heated on flame by adding H_2O_2 (hydrogen peroxide) drop wise till it became colourless. The extract obtained was used to estimate nitrogen concentration in plant samples by using Kjelplus. The concentration was calculate in per cent and further expressed in g $plant^{-1}$ using following formula.

N uptake (g $plant^{-1}$) = N content (%) x DMP (g $plant^{-1}$)/100

3.5.2 Wet digestion- Diacid digestion was carried out using 9:4 mixtures of HNO_3 and $HClO_4$. One gram of pounded plant material was taken into 100 ml volumetric flask and 10 ml of diacid mixture was added to this flask and mixed by swirling. The extract was finally made up to 100 ml with double distilled water, filtered and suitable aliquots were used for estimation of the P, K, Zn, Cd, Co, Ni and Pb.

3.5.3 Phosphorus uptake- The phosphorus concentration in plant samples was determined by Vanado molybdo phosphoric yellow colour method (Piper, 1966). The intensity of the yellow colour was read using spectrophotometer (Model UV 5704SS).

3.5.4 Potassium uptake- The potassium concentration in plant samples was estimated by using flame photometer Model Elico CL 361 (Piper, 1966).

3.5.5 Zinc uptake- Zinc in the filtrate was determined using Atomic Absorption Spectrophotometer (AAS) and expressed in mg plant^{-1}.

Zn uptake (mg plant^{-1})=Zn content (µg g^{-1}) x DMP (g plant^{-1})/1000

3.5.6 HM uptake- HM (Cd, Co, Ni and Pb) in the filtrate were determined using Atomic Absorp-tion Spectrophotometer (AAS) and expressed in mg plant^{-1}.

HM uptake (mg plant^{-1})= HM content (µg g^{-1}) x DMP (g plant^{-1})/1000

2.6 Statistical Analysis- The results of pot culture study were subjected to statistical analysis as per the procedures outlined by Snedecor and Cochran (1967).

III. RESULTS AND DISCUSSION

3.1 Physico-chemical properties of sewage sludge- The sewage sludge was moderately acidic with pH of 5.81. It was slightly saline with EC value of 5.48 dS m^{-1}. Organic carbon was high (27.76%) and SVI was 482.71 mL g^{-1}. The available total nutrients *viz*., N, P and K in sewage sludge were 3.29, 1.23 and 2.98%, respectively. The N, P and K content of sewage sludge was more by 6.58, 6.15 and 5.96 times, respectively than Farm Yard Manure and compared with urban compost, available N, P and K was more by 6.58, 2.46 and 2.98 times, respectively. The triacid extractable zinc of sewage sludge was 27.72 mg kg^{-1} which was within the maximum permissible limits as per USEPA standards, 1993.

3.1.1 Diacid extractable HM (Cd, Ni, Co and Pb)- The diacid extractable contents of HM Cd, Ni, Co and Pb were 0.97, 1.69, 0.37 and 6.86 mg kg^{-1}, respectively. The heavy metal contents were within the maximum permissible limits. (USEPA standards 1993 and Water Research Commission 1997).

3.2 Chemical analysis of plant (Marigold)

3.2.1 Nitrogen uptake (g plant^{-1})- The nitrogen uptake by marigold plants at mid stage (45 DAT) and harvesting stage (90 DAT) was estimated, which was significantly different at both the stages of analysis. The nitrogen uptake increased with advancement in crop age. The highest nitrogen uptake (1.98) was recorded at mid stage in T_5 followed by T_4 (1.38) and T_3 (0.97). The lowest nitrogen uptake (0.15) was observed in T_7 followed by T_1 (0.39). The increase in nitrogen uptake was significantly more by 43.48% in T_5 than T_4. Nitrogen uptake at harvesting stage ranged from 0.23 in T_7 to 2.02 in T_5. In T_5 it was significantly more by 36.49% than T_4, similar to nitrogen uptake that noticed at 45 DAT. The lowest nitrogen uptake (0.23) was recorded in T_7 followed by T_1 (0.41) and T_2 (0.88). Similar finding was reported by Singh and Agrawal (2010) that, nutrients concentration of N, P, K, Ca, Na and Mg in seeds of *Vigna radiata* linearly increased at all application rates of sewage sludge (3, 9 and 12 kg m^{-2}) which suggests better translocation of nitrogen due to sewage sludge amendment application.

Table1. Silent properties of Sewage Sludge

Parameters	Units	Sewage Sludge
Physio-chemical properties		
Soil reaction	pH	5.81
EC	dS m^{-1}	5.48
OC	%	25.76
Total major nutrient status		
Nitrogen	%	3.29
Phosphorus	%	1.23
Potassium	%	2.98
Micro nutriente		
Zinc	mg kg^{-1}	27.72
Total heavy metals		
Cadmium	mg kg^{-1}	0.97
Cobalt	mg kg^{-1}	0.37
Nickel	mg kg^{-1}	1.69
Lead	mg kg^{-1}	6.86
SVI	mL g^{-1}	482.71

3.2.2 Phosphorus uptake (g plant^{-1}) Phosphorus uptake by plant recorded at mid stage and harvesting stage. The phosphorus uptake recorded at mid stage ranged from 0.30 in T_7 to 1.23 in T_5. The increase in phosphorus uptake in T_5 it was significantly more by 8.85% and 61.84%, respectively as compared with T_4 and T_6, similar to the trend of nitrogen uptake that recorded in same crop. The phosphorus uptake recorded in 20% sewage sludge (0.470 g plant^{-1}) and Control (0.30 g plant^{-1}) was on par with each other. The highest phosphorus uptake (2.25) at harvesting stage was observed in T_5 followed by T_4 (1.95) and T_3 (1.47), unlike to that observed at mid stage. The lowest phosphorus uptake (0.21) was recorded in T_7 followed by 20% sewage sludge treatment (0.49). The uptake recorded in 60% sewage sludge (1.47) and T_6 (1.24) was on par with each other, unlike to the nitrogen uptake. More availability of phosphorus and soil organic carbon in the soil and favorable soil pH for phosphorus availability in T_5 at mid and harvesting stages in marigold as compared with rest of the treatments can be attributed to maximum phosphorus uptake. Higher uptake and translocation of P to pods in *Vigna radiata* might have led to higher P content in seeds at increasing sewage sludge application rates from 3 to 12 kg m^{-2} (Singh and Agrawal, 2009).

3.2.3 Potassium uptake (g plant^{-1} - The uptake of potassium increased with crop age. Significantly highest potassium uptake of 1.46 at mid stage was observed in T_5 followed by T_4 (1.06) and T_3 (0.75), similar to nitrogen and phosphorus uptake. The lowest potassium uptake of 0.11 was observed in T_7 followed by 20% sewage sludge treatment (0.28). The potassium uptake recorded in T_6 (0.53) was significantly more than 40% sewage sludge treatment (0.45), unlike that nitrogen and phosphorus uptake observed in same crop. Potassium uptake at harvesting stage (90 DAT) ranged from 0.20 in T_7 to 2.96 in T_5. In T_5 it was significantly more by 49.49% than T_4, similar to nitrogen uptake trend noticed in marigold. The potassium uptake in T_2 was significantly more than T_1. The potassium uptake in RDF (T_6) was 1.01 g plant^{-1}. The highest potassium uptake in T_5 at mid and harvesting stages in marigold as compared with rest of the treatments was due to more availability of potassium and soil organic carbon in the soil. Stark and Clapp (1980) showed that, crop yield and K uptake increased in potato with application of sewage sludge as compared with other treatments that did not receive sludge. Similar opinion was expressed by Soon (1981) and Singh and Agrawal (2010).

3.2.4 Zinc uptake (mg plant^{-1}) The uptake of zinc was linearly increased with crop age. Significantly highest zinc uptake (19.740) at mid stage was recorded in T_5 as compared with rest of the treatments, similar to uptake of major nutrients *viz*., nitrogen, phosphorus and potassium. Zinc uptake ranged from 0.438 in T_7 to 19.740 in T_5. The increase in zinc uptake was more by 40.17% in T_5 than T_4. Zinc uptake recorded in T_2 (4.629) and T_6 (3.330) was on par with each other, similar to phosphorus uptake that observed in marigold. Zinc uptake at harvesting stage (90 DAT) ranged from 1.995 in T_7 to 53.311 in T_5. In T_5 it was significantly more by 17.81% than T_4. This trend was similar to nitrogen and potassium uptake. Similarly the zinc uptake in T_2 was significantly more than T_1. The uptake of zinc in T_1 (8.493) and T_6 (10.412) were on par with each other, similar to potassium uptake trend that noticed in marigold at harvesting stage. The Zn uptake was at adequacy level in 80% and 100% sewage sludge treatments and it was deficient in rest of the treatments. Observation of maximum zinc uptake in T_5 treated pot at mid and harvesting stages in marigold was due to more zinc availability in soil, favorable soil pH and presence of more soil organic carbon in the soil. This finding can be supported by the observations made by Singh and Agrawal (2008) that, macronutrients in the sewage sludge serve as a good source of plant nutrients and the organic constituents provide beneficial soil conditioning properties thus, due to more favourable conditions, the uptake of nutrients also would be more. Highest zinc concentration (22.07 mg kg^{-1}) was recorded in mung bean seeds at higher dose (12 kg m^{-2}) of sewage sludge application (Singh and Agrawal, 2010).

3.2.5 Heavy metals uptake- The HM was estimated in both plants and flowers of marigold. The details are as follows.

3.2.5.1 Lead (Pb mg plant^{-1}) Significantly highest lead uptake of 7.685 was recorded at 45 DAT in T_5 followed by T_4 (5.321) and T_3 (3.853). The lowest Pb uptake of 0.237 was observed in T_7 followed by T_1 (1.102) and T_6 (1.271). The increase in Pb uptake was 44.43% more in T_5 than T_4. This trend was similar to nitrogen, phosphorus, potassium and zinc uptake trend that observed in same crop at mid stage. The Pb uptake at harvesting stage ranged from 0.618 in T_7 to 8.069 in T_5. Lead uptake recorded in T_5 was significantly more by 41.44% than T_4, which was similar to nitrogen, potassium and zinc uptake. The uptake noticed in 80% sewage sludge treatment (5.705) was on par with 60% sewage sludge (4.237). Similarly, 40% sewage sludge (2.971) and 20% sewage sludge (1.586) were on par with each other, unlike to nitrogen and potassium uptake.

3.2.5.2 Lead (Pb mg flower^{-1})- Flowers collected at harvesting stage were used for analysis of Pb uptake and expressed in terms of mg flower^{-1}. The highest Pb uptake (0.523) was found in T_5 followed by T_4 (0.499). The lowest Pb uptake (0.016) was recorded in T_7. The T_5 was recorded significantly highest uptake when compared with other treatments. The uptake observed in T_5 was 4.81% more than T_4. This trend was similar to Pb uptake that seen in plants of the same crop. The trend of lead (Pb) uptake was beyond the maximum permissible limits in T_4 and T_5 in plants as per the WHO standards (1996) and it was within the maximum permissible limits in rest of the treatments. In contrast, the uptake in flowers was within the maximum permissible limits in all treatments. Similar results were reported by Singh and Agrawal (2010) in *Vigna radiata* seeds that, sewage sludge amendment increased the concentration of Pb at increased application dose of sewage sludge. Begum (2011) also reported in tomato that, the maximum concentration of Pb in fruits, leaves and roots were 6.5, 13.8 and 15.9 mg kg^{-1}, respectively @ 20 t ha^{-1} municipal sewage sludge vermicom-post.

3.2.5.3 Nickel (Ni mg plant^{-1})- The Ni uptake was significantly different at both the mid and harvesting stages and the uptake was increased with advancement in crop age. The highest Ni uptake of 2.559 recorded at mid stage was observed in T_5 followed by T_4 (1.996) and T_3 (1.499). The lowest Ni uptake of 0.174 was observed in Control (0.174) followed by 20% sewage sludge (0.634). The increase in Ni uptake was more by 28.21% in T_5 than T_4, unlike to the uptake trend that noticed in lead. Ni uptake at harvesting stage ranged from 0.558 in T_7 to 2.942 in T_5. In T_5 it was significantly more by 56.29% than T_3 but, was on par with T_4. Ni uptake recorded in T_1, T_6 and T_7 were on par with each other.

3.2.5.4 Nickel (Ni mg flower^{-1})- Ni uptake recorded in flowers are indicated that the Ni uptake was significantly different by different treatments of sewage sludge. The highest Ni uptake (0.401) observed in T_5 was significantly more by 43.73% and 146.01% as compared with T_4 and T_3, respectively. The lowest Ni uptake (0.004) was recorded in T_7 followed by T_1 (0.041) and T_2 (0.089) as similar to trend of Pb uptake noticed. The nickel (Ni) uptake was within the maximum permissible limits in plants and flowers in all treatments as per the WHO standards (1996). Higher nickel (Ni) uptake in flowers and plants of marigold in T_5 and T_4 was found to be due to more concentration and total Ni availability in these two treatments as compared with rest of the treatments.

3.2.5.5 Cobalt (Co mg plant^{-1})- The cobalt uptake at mid stage ranged from 0.110 in T_7 to 2.188 in T_5. The Co uptake recorded in 20% sewage sludge treatment (0.734) and RDF (0.745) were on par with other. The increase in cobalt uptake was significantly more by 12.44% in T_5 than T_4. The highest cobalt uptake 2.638 at harvesting stage was observed in T_5 followed by T_4 (2.346) and T_3 (1.998). The lowest cobalt uptake (0.310) was observed in T_7 followed by T_1 (0.834) and RDF (0.884). The Co uptake noticed in T_5 was significantly more than T_4. This trend was similar to trend of only Pb uptake at both the stage of observation.

3.2.5.6 Cobalt (Co mg flower^{-1})- Cobalt uptake recorded in flowers ranged from 0.003 in T_7 to 0.301 in T_5. The maximum Co uptake recorded in T_5 was significantly more by 68.16% than T_4. The Co uptake observed in 20% sewage sludge treatment (0.034), Control (0.003) and RDF (0.039) was on par with other, similar to trend of Pb and Ni uptake that seen in marigold flowers. The cobalt (Co) uptake was beyond the maximum permissible limits in 80% sewage sludge and 100% sewage sludge treatments in plants of both crops and it was within the maximum permissible limits in rest of the treatments. But, uptake in flowers was within the maximum permissible limits in all treatments (WHO standards, 1996). The higher uptake of cobalt (Co) was recorded in T_5 in flowers and plants marigold can be attributed to more concentration and total Co availability in T_5. Similar result was also expressed by Saruhan *et al*. (2010) in *Lotus corniculatus* that, the concentration of cobalt (Co) in plant increased (0.42, 0.56 and 0.63 mg kg^{-1}, respectively) with the increase in sewage sludge application rates (@ 3, 6 and 9 t ha^{-1}).

3.2.5.7 Cadmium (Cd mg $plant^{-1}$)- The highest Cd uptake (0.275) at 45 DAT recorded in T_5 was significantly different as compared with rest of the treatments. The uptake ranged from 0.003 in T_7 to 0.275 in T_5. The increase in Cd uptake was significantly more by 105.22% in T_5 than T_4, similar to uptake trend that noticed in Pb and Co. The trend observed in Cd uptake at harvesting stage (90 DAT) was similar to mid stage. Significantly highest uptake of 0.374 and lowest 0.004 were obtained in treatments of T_5 and T_7, respectively unlike to the trend of Pb uptake noticed.

3.2.5.8 Cadmium (Cd mg $flower^{-1}$)- Cadmium uptake ranged from 0.001 in T_7 to 0.124 in T_5. The Cd uptake recorded in 100% sewage sludge treatment (0.124) was significantly more by 90.77% than T_4. The lowest Cd uptake (0.001) was recorded in T_7 followed by T_1 (0.012) and RDF (0.021). This trend was similar to trend of Pb, Ni and Co uptake that recorded in marigold flowers. The uptake observed in T_2 (0.022) and T_6 (0.021) was on par with each other. The trend of Cd uptake was beyond the maximum permissible limits only in 100% sewage sludge treatments in plants was within the maximum permissible limits in flowers in all the treatments as per the WHO standards (1996). Observation of maximum cadmium (Cd) uptake in T_5 treated flowers and plants of marigold were due to more concentration and total Cd availability in T_5 as compared with rest of the treatments. This finding can be corroborated by the observation made by Akdeniz *et al*. (2006) that, the concentration of Cd was increased linearly in sorghum leaves (0.56, 0.49, 0.49 mg kg^{-1}) and seeds (0.44, 0.46, 0.45 mg kg^{-1}) when sewage sludge (@ 7, 14, 21 Mg ha^{-1}, respectively) application rate increases linearly. The explanation given by Singh and Agrawal (2010) and Begum (2011) in the previous pages regarding other heavy metal like Pb were also stand good here.

IV. SUMMARY AND CONCLUSIONS

Uptake of major nutrients- The uptake of major nutrients *viz*., nitrogen, phosphorus and potassium by plants of marigold was linearly increased with increase in sewage sludge application rates. Significantly highest and lowest uptake of these nutrients was noticed, respectively in treatment of 100% sewage sludge application and Control (T_7) at both sampling done at mid and harvesting stages. Significantly highest Zn uptake by plants of marigold at mid and harvesting stages was recorded by the T_5. The lowest uptake of Zn recorded by the T_7 which was on par with T_1 at both mid and harvesting stages. The maximum uptake of Zn in plants was at adequacy level (Sailaja *et al*., 2011).

Uptake of heavy metals (Pb, Ni, Co and Cd)- The heavy metals were estimated in both plants and flowers mid and harvesting stages. The effect of sewage sludge on the uptake of heavy metals *viz*., Pb, Ni, Co and Cd was significantly highest in treatment of T_5. The Pb and Co uptake was beyond the maximum permissible limits in 80% sewage sludge and 100% sewage sludge in plants. But, the cadmium uptake was beyond the maximum permissible limits (WHO, 1996) in 100% sewage sludge in plants. In contrast, the uptake of Ni by plants was within the maximum permissible limits (WHO, 1996) in all treatments. Uptake of heavy metals *viz*., Pb, Ni, Co and Cd in flowers was within the maximum permissible limits in all treatments as per the WHO standards.

V. CONCLUSIONS

The NPK content of sewage sludge used in the present experiments was high along with organic carbon content. The content of heavy metals Pb, Ni, Co and Cd was within maximum permissible limits. Highest uptake of major nutrients (NPK), micronutrient (Zn) and heavy metal like Ni were within maximum permissible limits either in flowers and plants of marigold in 100% sewage sludge treatment (T_5). Uptake of heavy metals *viz*., Pb, Ni, Co and Cd in flowers and plante were within the maximum permissible limits as per WHO standards (1996).

Future scope of work

Thus, sewage sludge generated from Noor Mohammed Kunta Sewage Treatment Plant (NMK-STP) located near College of Agriculture was found to be a good organic source of fertilizer to cultivate flowers in peri-urban areas of Hyderabad. However, the trial needs further study to confirm the results before extensive and intensive use of sewage sludge in the field.

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