International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 930-934

Received: 04-05-2019
Accepted: 06-06-2019

K Ramya Krishna
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

PK Sharma
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Correspondence
K Ramya Krishna
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Physico: Chemical characterization in chromium contaminated soil with application of FYM and vermicompost in rice (*Oryza sativa*)

K Ramya Krishna and PK Sharma

Abstract
Contamination of chromium is considered a serious environmental pollutant due to wide industrialization. A pot experiment was conducted in net house of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during 2015-16 to study the effect of FYM and vermicompost on soil physico-chemical properties in chromium contaminated soil in rice. The Physico-Chemical properties of soil is based on various parameters like pH, Electrical Conductivity(EC), Organic Carbon, Available Nitrogen (N), Available Phosphorus (P2O5) and available Potassium (K2O).Five levels of chromium viz. 0, 20, 40, 60 and 80 ppm with and without vermicompost @ 5 ton ha^{-1} and farm yard manure @ 10 ton ha^{-1} were taken. Results indicated that the organic carbon, available NPK was recorded highest with the treatment Cr0+ VC followed by treatment Cr0+FYM and then Cr0 i.e., not- amended the soil. Rice crop can withstand up to 80 ppm of chromium with vermicompost and can tolerate up to 60 ppm with FYM. Hence, physico-chemical properties of post-harvest soil of rice contaminated with chromium are more effectively increased with application of vermicompost and FYM application and reduce the risk of health hazards for human beings and animals.

Keywords: Chromium, physico-chemical properties, FYM, VC

Introduction
In the present industrialized world, the toxic waste products are released to the environment at each and every moment. Even after recycling and reusing, many of the chemicals find their way to the pollution of environment because of poor planning of waste disposal and treatment and hence the industrial sites and waste disposal sites are contaminated with many pollutants (Watanabe *et al*., 2001; White *et al*., 2004) [30]. Among these pollutants heavy metals constitute a major part and they severely affect all the compounds of ecosystem in the soil (Selim *et al*., 1999) [20]. Cr is one of the most important such pollutants which enter the ecosystem mainly due to the human activities (Gómez *et al*., 2000) [3]. In particular, it is observed that Cr (III) and Cr (VI) are the most stable and hexavalent Cr is more toxic (Sinha *et al*., 2004). Cr is mainly used due to its properties such as resistance to corrosion, temperature, wear, and decay as well as strength, permanence, hygiene, hardness, and color in the many industries like electroplating, cement, dye, steel, leather tanning, wood, and so forth (Gómez *et al*., 2000) [3].

Numerous efforts have been taken in recent days for removing heavy metals of soil (Igwe *et al*., 2006) [5] of which metal-polluted soil can be treated by physical, chemical, or biological methods which are costly (McEldowney *et al*., 1993) [12]. For chemically contaminated soil, vegetation plays progressively more vital ecological and hygienic role (Antonkiewicz *et al*., 2002) and the correct management of green plants in such areas may contribute considerably to restore the natural environment (Keller *et al*., 2003) [8]. Phytoremediation is a well matched green tool that can be considered for remediation of impure sites because of its price effectiveness, visual advantages, and long term applicability.

Farm yard manure (FYM) is being used as the major source of organic manure in field crops. Limited availability of this manure is, however, an important constraint on its use as a source of nutrients. FYM positively controls the crop production and recovers properties of soil and it can be used to decrease heavy metal stress in plants. Farm yard manure (FYM) positively influence crop production, improved soil physical, chemical, and biological properties (Ould Ahmed *et al*., 2010; Alam *et al*., 2014) and can be used to reduce heavy metal hazards in plants (Yassen *et al*., 2007). Farm yard manure application to the soil could be used as an effective Measure for reducing Cr toxicity to crop plants in Cr contaminated soils (Singh *et al*., 2007) [21]. The limited information is available in the literature related to the effect of FYM application on immobilization and detoxification of Cr in soil, bioavailability of Cr, crop yield, and Cr uptake (Singh *et al*., 2007) [21].

Vermicompost (VC) is an important source of rapidly emerging organic input. It is produced from various organic wastes and it is a rich source of enzymes, antibiotics, immobilized micro flora and growth hormones like gibberellins which regulate the growth of plants and microbes. Vermicompost is a rich source of microorganisms and nutrients and used a soil fertilizer or conditioner. It has a greatest ability to enhance the quality of growing plants and also increases biomass which could suggest that more metal toxicity is improved. However, information is hardly available on the phytotoxicity of Cr in cereals and its remedy. So, the pot experiment was taken for the study of toxic effects of Cr with amendments viz., FYM and Vermicompost to reduce the adverse effects of Cr on the growth, quality and yield of rice. The vermicompost contain high nutrient value, increases fertility of soil and maintains soil health (Suthar *et al*., 2005) [24]. Application of vermicompost in contaminated soil improves soil fertility and physical properties as well as helps in successful approach to phytoremediation (Zheljazkov and Warman, 2004; Jadia and Fulekar, 2008) [7]. Rice is the most widely consumed staple food crop and a primary food source for 50%of the world's population (Wang *et al*., 2013; Ramzani *et al*., 2016) [17]. At present, soil contamination of heavy metals including Cr renders a great threat to rice production and subsequently affects food safety. High Cr concentration in soil is toxic to rice, resulting in reduced growth, yield, and dry matter production (Qiu *et al*., 2010) [16]. In rice, most of the Cr was accumulated in roots, but still, a significant fraction can be transported into above ground tissues, including grains, which causes a health issue to human via food chain (Qiu *et al*., 2011) [15]. However very few comparative studies have been performed so far and the choice of a particular organic amendment in assisted phytostabilization strategies often remain empirical (Hattab *et al*., 2015) [4]. So, for improvement of soil physico –chemical properties in chromium contaminated soil, we have used certain organic amendments like Farm Yard Manure and vermicompost in this study.

Material and Methods

Pot experiment was conducted in Net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi taking rice as a test crop in 2016-17 during kharif season, to study the effect of different Cr concentrations (0, 20, 40, 50, 60, 80 ppm) with and without application of FYM and Vermicompost. Processed 10 kg soil was filled in each polythene lined pots. The pots were irrigated up to field capacity and moisture level is maintained. Pots were treated with required amount of Cr through potassium dichromate ($K_2Cr_2O_7$) i.e. Cr (VI), with five different levels like (0, 20, 40, 60, 80 mg/kg soil) and maintained contamination for 15 days. After 15 days of application of chromium, the organic farmyard manure (FYM) i.e., as 50gm/10kg soil and vermicompost (25g/10kg soil) applied to the soil and mixed thoroughly. Pots were incubated for 15 days with organic amendments and watered at field capacity and four week old-seedlings were transplanted on august 1st and five seedlings were transplanted in each pot. All the pots received uniform dose of NPK, and irrigation had supplied to maintain field capacity. The crop was grown up to maturity. Growth parameters, yield attributes and yield were studied before and after harvesting as per investigation required. Physico – chemical properties was analysed in the post-harvest soil of rice. The Physico-Chemical properties of soil is based on various parameters like pH, Electrical Conductivity (EC), Organic Carbon, Available Nitrogen (N), Available Phosphorus (P_2O_5) and available Potassium (K_2O).

1) Soil pH

A soil-water suspension was prepared in the ratio of 1:2.5 (10 g soil with 25 mL of distilled water) and pH was measured with the help of pH meter.

2) Electrical conductivity

The soil water suspension prepared for determination of pH was used to determine the electrical conductivity of the soil. Soil suspension was allowed to settle till supernatant become clear. Electrical conductivity was measured with the help of EC meter and expressed as dSm^{-1}.

3) Organic Carbon

Organic Carbon in the soil was determined using Walkley and Black method (Walkley and Black, 1934). One gram of soil was taken in a 500 mL of conical flask. Ten mL of 1 N $K_2Cr_2O_7$ solution was added and mixed. Then 20 mL of concentrated H_2SO_4 was added, the flask was swirled 2-3 times and allowed to stand for 30 minutes in dark. The suspension was diluted with 200 mL of distilled water. Ten mL of 85% H_3PO_4 and 1 mL of diphenyl indicator were added and titrated against the solution of 0.5 N Ferrous Ammonium Sulphate till color changed from violet to bright green. A blank titration was also carried out.

4) Available nitrogen

Available Nitrogen content in soil was determined using Kjeltec Semi-Auto Nitrogen Analyzer by alkaline Potassium permanganate method as proposed by Subbiah and Asija (1956). The method has been adopted widely in order to get a reliable index of Nitrogen availability in soil due to its rapidity and reproducibility. Five gram of soil sample was weighed and transferred in a distillation tube. Twenty five mL 0.32% $KMnO_4$ was added to it and the distillation tube was set to the instrument. In a 250 mL conical flask, 20 mL of 2 % boric acid mixed indicator was taken and placed under the receiver tube. Twenty five mL of 2.5% NaOH was sucked and added to the distillation tube. Then it was put on distillation for 9 min. During this process the N released in the form of ammonia is trapped in the boric acid, which develops green color. The flask containing the distillate was removed. The distillate was then titrated against 0.02 N H_2SO_4 until pink color developed.

5) Available Phosphorus

Available phosphorus content of soil was determined by Olsen's method (Olsen *et al*., 1954). Firstly reagent A was prepared by using ammonium molybdate, antimony potassium tartarate and H_2SO_4. Then reagent B was prepared with the help of reagent A.2.5 gram of soil was taken in a 100 mL conical flask, a pinch of Darco G-60 and 50 mL of Olsen's reagent (0.5 M $NaHCO_3$) was added to it. It was then shaken for 30 minute on mechanical shaker and the suspension was filtered through Whitman No. 1 filter paper.

Five mL of filtrate was transferred in a 25 mL volumetric flask and was acidified with 2.5 M H_2SO_4 to pH 5.0 and 20 mL distilled water was added followed by 4 mL of reagent B. After waiting for 10 min the intensity of blue colour was measured on spectrophotometer at 660 nm. Simultaneously a blank was also run. First standard reading was taken followed by sample reading.

6) Available Potassium

Flame Photometer is used to determine available potassium in soil by using (1 N ammonium acetate extract) by using a method Jackson (1973) [6]. Five gram soil was transferred in a 100 mL conical flask and 25 mL of 1 N ammonium acetate solution was added and it was shaken for 5 minutes. The suspension was then filtered through Whatman No. 1 filter paper and potassium concentration in the filtrate was measured using flame photometer. First standard reading was taken followed by sample reading.

Results and Discussion

1) Effect of FYM and Vermicompost on physico-chemical properties of post-harvest soil

1.2) Soil pH

The results indicated that the initial pH of soil was 7.9.The data pertaining to pH of the post-harvest soil showed that pH varied from 8.3 to 8.5.Maximum pH(8.5) was observed with treatment Cr80 +VC followed by Cr0+FYM treated soil (8.43)and minimum was observed with the treatment Cr0(8.3). Application of organic amendments in chromium contaminated pots showed a slight change in pH of the soil. Soil pH is the most important factor responsible for affecting metal availability. High pH under vermicompost and FYM amended soil increased adsorption sites by increasing negative charges on the soil surface and reducing competing for metal cations similar results reported by Alamgir *et al.* (2011). Availability of all metals was significantly higher in non - amended soil due to lower soil pH. With the increase in soil pH, the bioavailability of Cd decreased given by Kim *et al*. (2009) [9]. In the present study, initial soil samples did not show a significant difference in pH (Table 1), but at the time of harvest, pH was significantly higher in vermicompost and FYM amended the soil as compared to the control soil. The increase in pH of soil is due to the addition of FYM in the soil similar results was reported by Zaller and Kopke (2004) Interaction of organic manure with heavy metals causes the changes in soil pH which determine immobilization or mobilization of metals. The pH levels were expected to rise with the addition of the organic manure due to release of ammonia from the decomposing organic manures. The environment around the completing site will affect metal complexation by soil organic matter, particularly pH and the metal species taking part in the process (Ross, 1994) [19].

2) EC

It is evident that the EC of the soil ranged between 0.38 to 0.49 dSm^{-1}. The EC of the soil increased significantly with the application of organic amendments. The interaction effect of chromium and organic amendments was non -significant. Metal content in the soil is directly associated with plant uptake, which is indirectly associated with physicochemical characteristics of soil and plant species similar results reported by Tariq and Rashid (2013) [25].

3) Organic Carbon

Highest Organic Carbon was recorded with the treatment Cr0+VC (0.48%) followed by Cr0+FYM (0.41%) and then Cr0 (0.33%) i.e., not- amended the soil, respectively. At the time of harvest, organic C increased by 31% in vermicompost and 19% in FYM amended the soil when compared to the control Cr0.With the increase in chromium concentration, the organic carbon decreased. The minimum organic carbon found at treatment Cr80.Upon addition of organic amendments like FYM and vermicompost used as fertilizers will stimulate the soil biological activity, consequently increases the organic C content in the soil. So we have increased organic carbon upon addition of amendments compared to control. The application of organic amendments resulted in Cr (VI) reduction either from an enhancement of the microbial population and microbial activity. In addition, it enhanced the abiotic process of Cr (VI) reduction by supplying organic carbon supported by Losi *et al.* (1994).

4) Available N

Highest available N were recorded with the treatment Cr0+VC (210kg ha^{-1}) followed by Cr0+FYM (202 kg ha^{-1}) and then Cr0 (181 kg ha^{-1}) i.e., non- amended the soil, respectively. At the time of harvest, available N increased by 13% in vermicompost amended soil and 10% in FYM amended the soil, as compared to the control Cr0 (Table 2 Fig 2).Cr 20+VC is at par with Cr0+VC.Interaction effect of organic amendments and chromium was found non-significant. The treatment Cr0+VC is at par with Cr20+VC.

The available nitrogen in the soil was generally found lower in range. Upon increasing chromium concentration at first N content increase but upon the higher concentration of chromium, the nitrogen content further decreased. so in order to make nitrogen available in the soil we are adding organic amendments. These organic amendments will supply all macronutrients. But upon an increase in chromium concentration even in the amended soil, we find a decrease in available Nitrogen. The interaction between chromium and organic amendments found non -significant.

5) Available P

A critical perusal data presented showed that available P in soil was in medium range. A significant increase was recorded with the application of FYM and Vermicompost. The available P ranged from 21 to 19.11kg hac^{-1}.Minimum in control maximum in organic amended pots i.e., with the treatment Cr0+VC followed by Cr0+FYM.

The connections with the soil mechanism to increase phosphorus uptake by the plants are most important given by Whalen (2001) [29]. The exchangeable cations (Na^+, K^+, and Ca^{2+}) were highest for vermicompost followed by FYM amended soil. Vermicompost treated pots have more available P than farmyard manure (FYM),this might be due to the reason that more exchangeable cations were found highest in vermicompost followed by FYM amended soil compared to the control (Kundu *et al*. 2007) [7]. FYM improved the availability of N, Fe, and Zn and P in soil similar results reported by Ranganathan and Salvseelan (1997) [18].

6) Available K

Highest available K was recorded with the treatment Cr0+ VC (219 kg ha^{-1}) followed by treatment Cr0+FYM (215 kg ha^{-1}) and then Cr0 (213 kg ha^{-1}) i.e., non- amended the soil, respectively. At the time of harvest, available P increased by 2.7% in vermicompost and 0.9% in FYM soil compared to the control (Table 2). Interaction effect of organic amendments and chromium was found non -significant.

Generally, initial soils are medium in available K content in the soil. Upon addition of organic amendments, there was an increase in soil available K. But with an increase in chromium concentration, the available K decreased in both amended and non-amended soil.

Conclusion

The experiment depicted that the pH, EC of post-harvest soil changed with application of chromium along with amendments (VC &FYM). The Organic Carbon, available NPK content of post-harvest soil decreased with increase in the levels of chromium i.e., maximum decrease was observed in treatment Cr80. However, the treatment of Cr20 and Cr40 were found statistically at par with treatment Cr0. The addition of these organic amendments has significantly increased available NPK content in soil. The highest NPK content found in vermicompost treated pots followed by FYM treated pots. Organic Carbon, available NPK was recorded highest with the treatment Cr0+VC followed by Cr0+FYMand then Cr0 i.e., not- amended the soil.

Table 1: Effect of FYM and Vermicompost on chemical properties of post-harvest soil in chromium contaminated soils.

Treatments	pH	EC	OC
Cr 0	8.3	0.38	0.33
Cr20	8.4	0.40	0.32
Cr 40	8.4	0.4	0.31
Cr 60	8.43	0.4	0.27
Cr 80	8.43	0.38	0.25
Cr0+FYM	8.43	0.46	0.41
Cr 20+FYM	8.4	0.44	0.40
Cr 40+FYM	8.43	0.43	0.39
Cr60+FYM	8.43	0.42	0.38
Cr 80+FYM	8.47	0.41	0.36
Cr0+VC	8.55	0.49	0.48
Cr20+VC	8.43	0.46	0.47
Cr40+VC	8.53	0.44	0.46
Cr60+VC	8.5	0.43	0.44
Cr80+VC	8.57	0.42	0.42
SEm ±	0.07	0.01	0.01
CD	0.20	0.02	0.02

Table 2: Effect of FYM and VC on NPK (Kg ha^{-1}) content in post-harvest chromium contaminated soil

Treatments	N	P	K
Cr 0	191.0	18.13	213.1
Cr20	196.3	19.17	214.2
Cr 40	194.0	19.74	210.3
Cr 60	191.1	19.49	209.5
Cr 80	187.0	19.11	205.4
Cr0+FYM	202.4	20.37	215.6
Cr 20+FYM	205.1	20.95	218.8
Cr 40+FYM	206.1	20.12	217.6
Cr60+FYM	204.1	19.85	216.4
Cr 80+FYM	202.2	19.62	214.1
Cr0+VC	210.3	20.85	219.5
Cr20+VC	212.8	21.48	220.1
Cr40+VC	209.0	21.05	219.0
Cr60+VC	207.6	20.65	216.3
Cr80+VC	206.3	20.29	215.7
SEm ±	0.7	0.16	0.4
CD	2.0	0.46	1.2

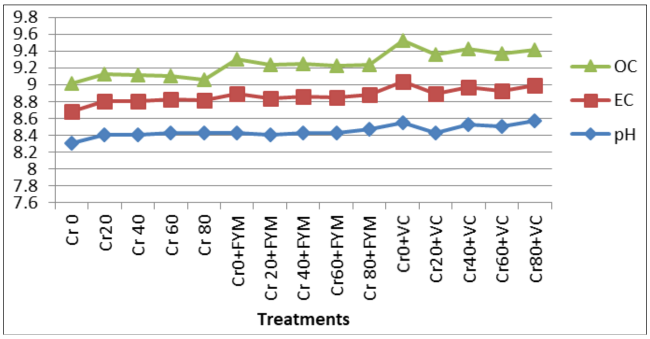

Fig 1: Effect of FYM and Vermicompost on chemical properties of post-harvest soil in chromium contaminated soil

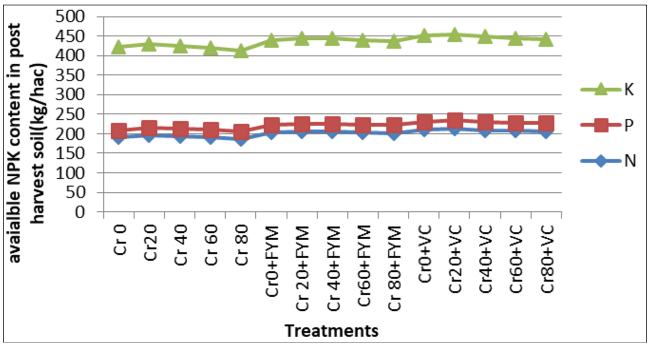

Fig 2: Effect of FYM and Vermicompost on NPK (Kg ha^{-1}) content in post-harvest chromium contaminated soil

References

1. Alamgir M, Kibria MG, Islam M. Effects of Farm Yard Manure on Cadmium and Lead Accumulation in Amaranth (*Amaranth usoleracea* L.). Journal Soil Sciences Environment Management. 2011; 2(8):237-240.
2. Antonkiewicz J, Jasiewicz C. The use of plants accumulating heavy metals for detoxification of chemically polluted soils. Electronic Journal of Polish Agricultural Universities. 2002; 5(1):121-143.
3. Gómez V, Callao MP. Chromium determination and speciation since. TrAC—Trends in Analytical Chemistry. 2006. 2000; 25(10):1006-1015.
4. Hattab N, Heino MM, Faure O, Bouchardon JL. Effect of fresh and mature organic amendments on the phytoremediation of technosols contaminated with high concentrations of trace elements. Journal of Environmental Management, Elsevier. 2015; 159:37-47.
5. Igwe JC, Abia AAA bioseparation process for removing heavy metals from waste water using biosorbents. African Journal of Biotechnology. 2006. 2015; 5(12):1167-1179.
6. Jackson ML. Soil chemical analysis. Prentice- Hall of India Pvt. Limited, New Delhi, India, 1973, 111-203.
7. Jadia CD, Fulekar MH. Phytoremediation: the application of Vermicompost to remove zinc, cadmium, copper, nickel and lead by sunflower plant. Environmental Engineering and Management Journal. 2008; 7(5): 547-558.
8. Keller C, Hammera D, Kayserb A. Phytoextraction of Cd and Zn with *Thalaspi aerulescens* and *Salix viminalis* in field trials. Proceedings of the Workshop Meeting on Phytoremediation of Toxic Metals; June Stockholm, Sweden, 2003.
9. Kim KR, Owens G, Naidu R. Heavy Metal Distribution, Bioaccessibility and Phytoavailability in Long-term

Contaminated Soils from Lake Macquarie, Australia. Australia Journal Soil Research. 2009; 47:166-176.
10. Kundu S, Bhattacharyya R, Prakash V, Ghosh BN, Pathak H, Gupta HS *et al.* Long-term Yield Trend and Sustainability of Rainfed Soy beanw heat System through Farmyard Manure Application in a Sandy Loam Soil of the Indian Himalayas. Biology Fertility Soils. 2007; 43:271-280.
11. Losi ME, Amrhein C, Frankenberger WT. Factors affecting chemical and biological reduction of hexavalent chromium in soil. Environmental Toxicology and Chemistry. 1994; 13(11):1727-1735.
12. McEldowney S, Hardman DJ, Waite S, Treatment technologies. In: McEldowney S, Hardman DJ, Waite S, editors. Pollution, Ecology and Biotreatment. Singapore: Longman Singapore Publishers, 1993, 48-58.
13. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. Circular U.S. Department of Agriculture, 1954, 939.
14. Ould Ahmed BA, Inoue M, Moritani S. Effect of saline water irrigation and manure application on the available water content, soil salinity, and growth of wheat. Agricultural Water Management. 2010; 97:165-170.
15. Qiu B, Zeng F, Xue D, Zhou W, Ali S, Zhang G *et al.* QTL mapping for chromium-induced growth and zinc, and chromium distribution in seedlings of rice DH population. Euphytica. 2011; 181:429-439.
16. Qiu BY, Zhou WH, Xue DW, Zeng FR, Ali S, Zhang GP *et al.* Identification of Cr-tolerant lines in a rice (*Oryza sativa*) DH population. Euphytica. 2010; 174:199-207.
17. Ramzani PMA, Khan WD, Iqbal M, Kausar S, Ali S, Rizwan M *et al.* Effect of different amendments on rice (*Oryza sativa* L.) growth, yield, nutrient uptake and grain quality in Ni-contaminated soil. Environmental Science and Pollution Research, 2016.
18. Ranganathan DS, Salvseelan DA. Effect of mushroom spent compost in combination with fertilizer application on nutrient uptake by potato in Ultic Tropudalf. Journal of the Indian Society of Soil Science. 1997; 45(3):515-519.
19. Ross SM. Retention, transformation and mobility of toxic metals in soils. In: Ross SM. (ed.), Toxic Metals in Soil Plant System, John Wiley and Sons, Chichester, 1994, 63-152.
20. Selim HM, Iskander IK. Fate and Transport of Heavy Metals in the Vadose Zone. CRC Press, 1999.
21. Singh G, Brar MS, Malhi SS. Decontamination of Chromium by Farm Yard Manure Application in Spinach Grown in Two Texturally Different Cr-Contaminated Soils. Journal of Plant Nutrition. 2007; 30:289-308.
22. Sinha S, Saxena R, Singh S. Chromium induced lipid peroxidation in the plants of *Pistia stratiotes* L.: role of antioxidants and antioxidant enzymes. Chemosphere. 2005; 58(5):595-604.
23. Subbaiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Current Science. 1956; 25:259-261.
24. Suthar SS, Watts J, Sandhu M, Rana S, Kanwal A, Gupta D *et al.* Vermicomposting of kitchen waste by using *Eisenia foetida* (*Savigny*). Asian Journal of Microbiology, Biotechnology and Environmental Sciences. 2005; 7:541-544.
25. Tariq SR, Rashid N. Multivariate analysis of metal levelsin paddy soil, rice plant, rice grains: case study from Sha-kargarh. Pakistan Journal of Chemical, 2013.
26. Walkey AJ, Black IA. Estimation of soil organic carbon by chromic acid titration method. *Soil Science.* 1934; 37:29-38.
27. Wang K, Gao F, Ji YX, Liu Y, Dan ZW, Yang PF *et al.* ORFH79 impairs mitochondrial function via interaction with a subunit of electron transport chain complex III in Honglian cytoplasmic male sterile rice. New Phytologist. 2013; 198:408-418.
28. Watanabe T, Hirayama T. Genotoxicity of soil. Journal of Health Science. 2001; 47(5):433-438.
29. Whalen JK, Chang C. Phosphorus accumulation in cultivated soils from long-term annual applications of cattle feedlot manure. Journal of Environmental Quality. 2001; 30(1):229-237.
30. White PA, Claxton LD. Mutagens in contaminated soil: a review. *Mutation Research—Reviews in Mutation Research*. 2004; 567(2-3):227-345.
31. Yassen AA, Nadia BM, Zaghloul MS. Role of some organic residues as tools for reducing heavy metals hazards in plant. World Journal of Agricultural Sciences. 2007; 3(2):204-209.
32. Zaller JG, Köpke U. Effects of Traditional and Biodynamic Farmyard Manure Amendment on Yields, Soil Chemical, Biochemical and Biological Properties in a Long-term Field Experiment. *Biology Fertility of Soils.* 2004; 40:222-229.
33. Zheljazkov VD, Warman PR. Application of high – Cu compost to dill and peppermint. Journal of Agricultural and Food Chemistry. 2004; 52:2615-2622.