Poll Res. 41 (3) : 1008-1015 (2022)

ISSN 0257–8050
DOI No.: http://doi.org/10.53550/PR.2022.v41i03.036

CHEMICAL FERTILIZATION AS POTENTIAL PATHWAYS OF HEAVY METAL CONTENTS IN AGRICULTURAL SOIL IN MEMARI II BLOCK, WEST BENGAL, INDIA

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(Received 16 December, 2021; Accepted 2 February, 2022)

ABSTRACT

The major purposes of this study were to measure the level of metal pollution, identify the highly polluting elements and the principal fertilizers as potential sources of metals concentration in the agricultural soil. Extracted heavy metals (As, Cd, Cr, Cu, Hg, Pb, and Zn) were measured by atomic absorption spectrophotometer (AAS VGB 210 System). Three identically different fields viz. bare land (Treatment A), bio-compost based fields (Treatment B) and chemical fertilizer-based fields (Treatment C), were selected to conduct this experiment. The findings show that Treatment C was identified as a critical condition for Cd (5.2 µg/g), Pb (4.1 µg/g) and Zn (3.9 µg/g), exceeding the contamination factor limit (Cf =1) and also having the highest value (16.4) of the degree of contamination (Cd=16) among the treatments. Pollution Load Index (PLI) also reconfirmed that treatment C was the major pathway of heavy metals (PLI=1.96) and crossed the standard limit (PLI=<1) of metals accumulation in soil. In the case of fertilizers, analysis came up with the fact that DAP, superphosphate and zinc sulphate were the maximum potential contributor for primary pollutant metals (Cd, Pb, and Zn). The mentioned fertilizers were also used to apply more than the recommended doses suggested by the National Academy of Agricultural Sciences (NAAS) India.

KEY WORDS: Heavy metals, Agricultural soil, Chemical fertilizers, Contamination, Treatment fields

INTRODUCTION

In agricultural land, the major contributors of heavy metals have been identified as municipal wastes (King *et al.,* 1974; Hanay *et al.,* 2008), industrial wastes (Murtaza *et al*., 2010), agricultural fertilizers (Atafar *et al.,* 2010; Singh *et al*., 2010) and pesticides (Davydov *et al.,* 2018) etc. Apart from these, degraded rock particles (Zhao *et al*., 2014) and atmospheric dust (Doabi *et al.,* 2018) are also considered as sources of metals in soil. However, fertilizer seems to be the major source of heavy metals, which is directly, influenced the soil (Savci *et al.* 2012). Agricultural fertilizers are usually two types, organic (sewage sludge, cow dung compost, green manure etc) and inorganic (several chemical fertilizers like superphosphate, di-ammonium phosphate etc). Long-term application of excessive fertilizers causes metals accumulation in agricultural lands. Trace metals have been detected in paddy fields (Andreu *et al.,* 1999; Malidareh *et al*., 2014), wheat fields (Brus *et al*., 2004; Hassan *et al*., 2013) mustard fields (Barman *et al.,* 2000) and even massively in vegetable fields (Odai *et al.,* 2008; Gebeyehu *et al.,* 2020). In soil, heavy metals are up taken by plants cell and eventually these concentrate into the human body through the food chain (Sugiyama *et al*., 1994; Patra *et al.,* 2011). Several studies have stated that through the food chain, Arsenic (As), Cadmium (Cd) or even Lead (Pb) are consumed by humans and which call for several diseases (Luc *et al*., 2012).

Generally, fertilizers are commonly used to fill up the deficiency of particular nutrients in the soil.

However, due to the rapid growth of the population in India, farmers became more profit-oriented rather than taking into consideration the sustainability of the soil environment; consequently, they used to apply more amount of fertilizers in the soil, which further adversely affect the productivity of lands (Pacheco *et al*., 2001). The amount of metal concentration is significantly related to the amount of fertilizers to be applied (Atafar *et al*., 2010). Without taking the knowledge about the deficiency of a particular nutrient, application of fertilizers must be brought up with the reason of the massive amount of metals concentration that leads to decline of soil health (Parkpian *et al*., 2003). Each fertilizer has conveyed various metal pollutants and there are some standard background values (Hakanson, 1980) and assessment index (Qingjie *et al*., 2008)to determine the critical limit of metals concentration in soil.

The fertilizers like superphosphate or even lime contains necessary nutritional elements for plant growth, although these fertilizers accumulate the maximum amount of Cd in agricultural soils (Atafar *et al.,* 2010). The metals concentration were like triple super phosphate>sulphate>potassium>urea in paddy fields of North Iran (Malidareh *et al.,* 2014). It is also proved that urea contains lesser amounts of metals. In Bangladesh, Phosphorous (P) content in triple superphosphate (TSP) samples was much higher than the maximum allowable limit (MAL) and so was di-ammonium phosphate (DAP) (Mohiuddin *et al*., 2017).

The present study is mainly concentrated on the assessment of metal pollutants based on the degree of contamination (C_d) and pollution load index (PLI) contamination factors (C_f) of heavy metals have been calculated by the average earth values listed by Hakanson (1980). To execute the experiment, three separate treatment fields viz. fellow lands or bare soil field, organic-based field and inorganic based field have been selected as sampling sites. In concern fields, soil samples and applied fertilizers have been collected for further analysis for heavy metals concentration.

MATERIALS AND METHODS

Collection of samples

According to the soil testing and chemist department, Kalna (2019-2020), Memari-II Block has

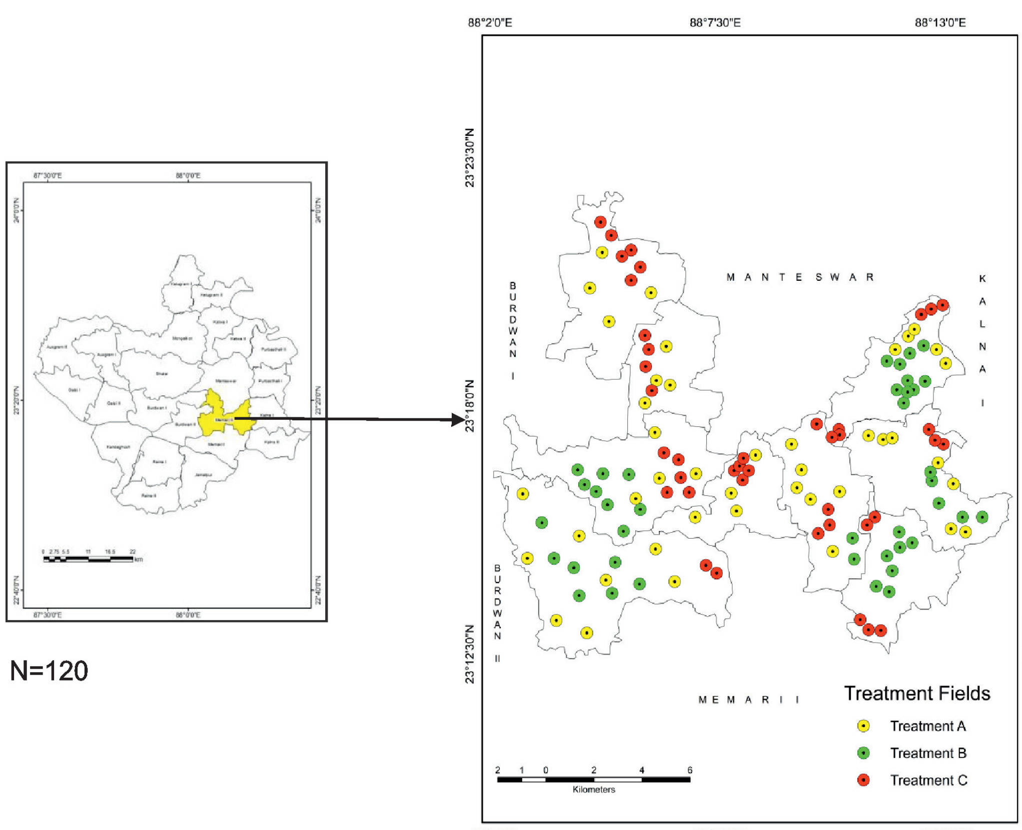

Fig. 1. Sampling sites of three identically different treatment fields, Treament A, B and C

the highest concentration of NPK ratio among 23 Blocks of Purba Bardhaman District with 459.56 kg/ha (medium) available Nitrogen (N), 34.83 kg/ha (high) available Potassium (K) and 345.45 kg/ha (high) available Phosphorous (P). Three different types of land management fields have been covered in order to understand the potential pathways of heavy metals and determine the major metal pollutants in agricultural lands. These selected treatment fields are i. agricultural fallow lands ii organic fertilizers based lands iii. Chemical fertilizers and sludge-based lands. Total 120 soil samples have been taken from 0-15 cm depth (Fig. 1). To compare the temporal variation of the amount of detected trace elements, two different time frames, before and after fertilization, have been considered for the final study. May-June and August-September months have been determined as the season before and after fertilization respectively. The opinion of local farmers had kept in view during the time of season selection.

Samples treatments and metals analysis

Collected soil samples have been dried in oven-dry machine at 70 ^{0}C. Heavy metals have been extracted by acid digestion method using HNO_3, HCl and H_2O_2 in soil. Extracted heavy metals (As, Cd, Cr, Cu, Hg, Pb and Zn) in soil have been measured by Atomic Absorption Spectrophotometer (AAS VGB 210 System) (Malidareh *et al*., 2014).

Pollution assessment indexes and statistical analysis

Contamination factor (C_f), degree of contamination (C_d) and pollution load index (PLI) have been applied to measure the level of pollution. The formula of Contamination factor (C_f) is

$$C_f^i = \sum_{i=0}^{7} \frac{C_{0-1}^i}{C_n^i}$$

Where,

C_f^i= the contamination of factor

C_{0-1}^i= mean content of heavy metals (sample)

C_n^i= background value of heavy metals

C_f^i<1, low contamination factor; 1≤C_f^i<3, moderate contamination factors; 3≤C_f^i<6, considerable contamination factors; and C_f^i≥6, very high contamination factor (Hakanson, 1980).

$$C_d = \sum_{i=0}^{7} C_n^i$$

Where,

C_d= the degree of Contamination

C_d is calculated by using the value of all contamination factors. It is the summation value of all contamination factors

C_d< 8= low degree of contamination; 8 ≤ C_d< 16 = moderate degree of contamination; 16 ≤ C_d< 32 = considerable degree of contamination, C_d≥ 32 very high degrees of contamination indicating serious anthropogenic pollution (Hakanson, 1980)

Pollution Load Index (PLI)= $(Cf_{1+} Cf_{1+} Cf_{1+....} Cf_n)^{1/n}$

Values of PLI=1 indicates heavy metal loads close to the background level, and values above 1 indicate pollution (Cabrera *et al*., 1999)

ANOVA has been applied to observe the significant differences in the level of pollution in these treatment fields.

RESULTS AND DISCUSSION

Metals analysis

The variation in the amount of seven different metals, Mercury (Hg), Cadmium (Cd), Arsenic (As), Copper (Cu), Lead (Pb), Chromium (Cr) and Zinc (Zn) have been observed among the treatment fields (Table 2). After direct observation and conversation with farmers, it was confirmed that treatment fields were treated differently. Treatment A, the bare lands, was left for a long time (> 5 years) barring any agricultural activities. These fields are free from the accumulation of hazardous chemicals or sludge

Table 1. Pre-industrial background level (mg/g) of heavy metals in soil by Håkanson (1980)

Elements	As	Cd	Cr	Cu	Hg	Pb	Zn
Background level	15	1.0	90	50	0.25	70	175

water. The findings reveal that the detected metals have been measured as non-pollutant. All the detected metals have been recorded under the pollutant limit. The C_f (contamination factor) values of metals are below 1 and C_d (degree of contamination) value has recorded below 8 (1.7), which is considered a low degree of contamination. Thus the Treatment A has been considered as pollution-free from hazardous metals (Fig. 2a).

According to the cultivators, though organic fertilizer has maintained sustainability as well as productivity in nature but it has not been used conventionally than chemical fertilizers. The compost pits were built in their houses. Farmers also used to apply sewage sludge water containing humus and relevant nutrients, which is useful for healthy and productive soil. Sludge water-based organic fields have been chosen as treatment B. These fields are based on organic fertilizers. The metals are too minimal to detect in AAS. In the case of metals analysis, the calculated C_f of detected metals are less than 1 and also the C_d values (4.3) are belong to the low degree of contamination (<8) (Fig. 2b). In comparison to before the fertilization period, the values have been detected below the pollution level (Table 2). While treatment C, where chemical fertilizer, pesticides and sewage sludge have been used. Before the fertilization, the single index C_f and integrated indices C_d values are belonging below the pollution limit. Whereas, after fertilization, the values of C_f are indicated towards critical in the case of Cadmium (Cd; $C_{f=}$5.2), Lead (Pb; C_f=4.1) and Zinc

Table 2. Comparative analysis of heavy metals among the three treatment fields

Treatments		Hg	Cd	As	Cu (mg/g^{-1})	Pb	Cr	Zn	C_d
Treatment A		0.2	0.6	0.3	BDL*	0.4	BDL	0.2	1.7
Treatment B	Before fertilization	0.1	0.3	0.2	BDL	0.5	0.1	0.3	1.5
	After fertilization	0.4	0.9	0.6	0.4	0.7	0.5	0.8	4.3
Treatment C	Before fertilization	0.4	1.5	0.6	0.2	0.9	0.2	1.8	5.6
	After fertilization	0.7	5.2	0.9	0.8	4.1	0.8	3.9	16.4

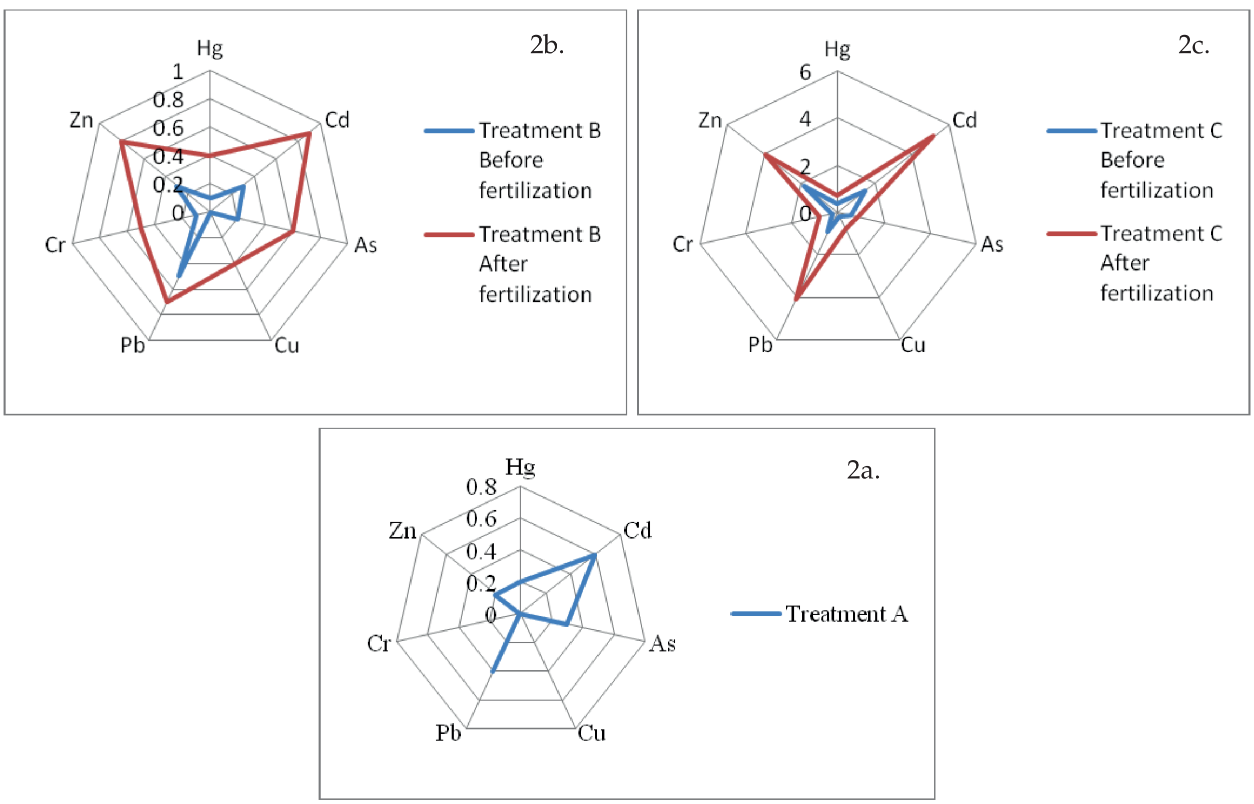

Fig. 2. The radar diagram shows temporal variation 2a. Treatment A 2b. Treatment B and 2c. Treatment C after and before fertilization. Comparatively higher concentrations of Cd, Pb, Zn contents in agricultural soil

(Zn; C_f=3.9) (Fig. 2c). The values are exceeding the critical limit of 1 which is indicated as considerable contamination factor. In the case of the degree of contamination (C_d), the value (16.4) has been measured as more than the considerable degree of contamination (16). So C_d indices have confirmed that the chemical fertilization with sludge-based fields are comparatively more contaminated and harmful for soil health. After analysing the collected data from the field, it has been found that treatment c, especially after the fertilization is the worst contaminated site for Cd, Pb and Zn than the other sites. Improper application of fertilizers for a longer period could be a reason for it.

Pollution load index (PLI)

Pollution load index is an example of integrated indices, which are calculated by the product of C_f values of heavy metals in sediments or water (Gohera *et al.*, 2017). PLI is useful to estimate the level of contamination for more than one component. PLI of >1 indicates soil pollution due to a higher concentration of heavy metals. While PLI of ≤1 indicates as close to the background values or non-pollution soil due to metals (Cabrera *et al.*, 1999). However, in the present study, PLI has been calculated among three different fields and the results are varied significantly (Table 3). In the case of Treatment A, the PLI was recorded as 0.43 that considered as non-polluted fields as it is under the critical value (<1). Thus the result after C_d, PLI concludes that fallow lands are non-polluted due to metal concentration. The PLI value of treatment B has been computed as 0.59, indicating not exceeding that critical limit. So, according to PLI, bio-fertilizers along with sewage sludge enriched fields are less polluted. The last experiment, treatment C has been identified as modernised fields, where chemical fertilizers, pesticides and sewage sludge were applied for intensified the productivity of the field. The PLI value of these concern fields has been measured as 1.95 which exceeds the critical limit of PLI in soil (Fig. 3). Thus, it shows that chemical-based fields are more vulnerable to heavy metals accumulation.

Table 3. Pollution load index of three treatment fields

Treatments	PLI
Treatment A	0.43
Treatment B	0.59
Treatment C	1.96

ANOVA

The result of ANOVA supports the outcomes of contamination degree as it shows a significant difference (P=<0.05) among the treatment fields (Table. 4a). It indicates that the metal contents are significantly varied in amount per unit of soil. Apart from the overall result of ANOVA, it also shows the differences between treatments. And the result indicates that there are significant differences between treatment C with treatment A (p<0.05) and treatment B (p<0.05) (Table. 4b). Thus it has been revealed from the analysis that chemical fertilizers act as the major contributor of heavy metals in agricultural lands.

Table 4a. Significant differences of metal contents among the three treatment fields

	ANOVA				
Heavy metals	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	27.894	2	13.947	7.958	.003*
Within Groups	31.549	18	1.753		
Total	59.443	20			

Table 4b. Significant differences between the treatment groups, treatment C with treatment A and treatment B

a. Agricultural fields	b. Agricultural fields	Mean Difference (a-b)	Std. Error	Sig.
Treatment A	Treatment B	-.12857	.67047	1.000
	Treatment C	-2.67143*	.67047	.003*
Treatment B	Treatment A	.12857	.67047	1.000
	Treatment C	-2.54286*	.67047	.004*
Treatment C	Treatment A	2.67143*	.67047	.003
	Treatment B	2.54286*	.67047	.004

*p<0.05

Status of inorganic fertilizers

The experiment among the three different fields has reconfirmed the fact that chemical fertilizers are the primary pathways of heavy metals in agricultural soils. Now it is essential to know about the amount of applied fertilizers and metals combination.

Metals accumulation in chemical fertilizers

In various cropping seasons, the major applied fertilizers are urea, DAP, superphosphate, zinc sulphate and potash. Along with chemical fertilizers, sewage sludge has predominantly been applied in these fields. Each fertilizer has been analysed to measure the concentration of the metals and also find the reason behind the particular metal which polluted the most (Cd, Pb and Zn). All the applied fertilizers have hazardous heavy metals with a variety of proportions. So the applied fertilizers were analysed through atomic absorption spectrophotometer (AAS) to find the proportion of the most pollutant metals identified as Cd, Pb and Zn (Fig. 3).

Urea

Urea is considered as least metals bearing fertilizer. Urea is the common source of nitrogen in agricultural soil as it contains 46% of nitrogen. Thus the standard level of nitrogen of ureain the soil is 46% (FRG, 2012). The only metal detected in Urea is Cd with a very low amount (0.8 $\mu g/g^{-1}$) and far below the maximum allowable limit (MAL; Cd=10). The metals like Pb and Zn have not been detected in urea.

Di-Ammonium Phosphate (DAP)

The major constituent of DAP is phosphorous (P) and the standard level of phosphorous content in DAP is 46%. In the case of metals analysis, Pb (108.14 $\mu g/g^{-1}$) and Zn (174.54 $\mu g/g^{-1}$) have been found over the MAL (Pb=100 and Zn=150). DAP is considered one of the main pathways of Pb and Zn. According to cultivators, DAP has been considered as the primary fertilizer applied in agricultural lands. The findings show that excessive use of DAP is reached in 30 kg/ha and it is carried with more heavy metals like Pb and Zn.

Superphosphate

Throughout the world, superphosphate fertilizer has been prepared by the particles of phosphate rock (Mohiuddin *et al*., 2017). Phosphate, superphosphate or triple superphosphate (TSP) all are conveyors of P Superphosphate contained a much higher percentage of Cd (12.35 $\mu g/g^{-1}$), Pb (128.47 $\mu g/g^{-1}$) and Zn (216.14 $\mu g/g^{-1}$) and this accumulation are higher than MAL (Table 5). Superphosphate is often used rather than triple superphosphate. The result is confirmed that more than 23 kg/ha amount of fertilizer has been applied in the fields compared to recommended and it is a definite cause for the addition of Cd, Pb and Zn.

Zinc sulphate

Zn is an essential trace element for soil productivity and plant nutrition. Zinc sulphate is one of the major pathways of Zn in agricultural soil. In the case of analysis of metals accumulation $ZnSo_4$ contributes all the mentioned contaminant trace elements (Cd, Pb and Zn) with a higher concentration of Pb (152.48 $\mu g/g^{-1}$) and Zn (234.17 $\mu g/g^{-1}$) exceeding the value of MAL (Pb= 100; Zn= 150). Zn is an essential nutrient for soil health and crop productivity. But similarly, its excessive accumulation causes various adverse impacts on soil health. Zinc sulphate is a major external source of Zn in soil. The present study has reported an excessive application that causes a massive concentration of Zn in soil.

Table 5. Proportional distribution of pollutant heavy metals with maximum allowable limit in applied chemical fertilizers

Chemical fertilizers	Nutrient Content (%)*			Mean Amount of heavy metals (ug/g^{-1})		
	N	P_2O_5	K_2O	Cd	Pb	Zn
Urea	46	0	0	BDL**	BDL	BDL
DAP	18	46	0	4.32	108.1	174.54
Superphosphate	0	16	0	12.35	128.5	216.14
Potash	0	0	48	6.25	54.36	BDL
Zinc sulphate	Zn (%) 21-22	ZnO (%) 50-80		3.52	152.5	234.17
***MAL				10	100	150

*Farmers handbook, 2016 **BDL= Below Detectable Limit ***Maximum Allowable Limit (Mohiuddin *et al*., 2017)

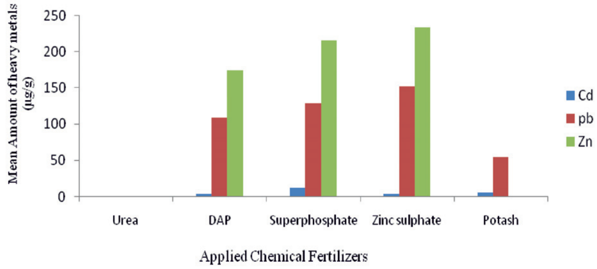

Fig. 3. Contribution of hazardous heavy metals through applied fertilizers in agricultural lands

Potash

Potash is well known as Potassium Oxide (K_2O), which contains a leading percentage (60%) of potassium (K). From the result of collected samples, it is confirmed that farmers apply less amount of potash from the recommended level. Hence, it can be concluded that the use of potash is so limited in the study area and it is not the major pathway of pollutant heavy metals (Cd, Pb and Zn). All the detected values are recorded lower than MAL.

CONCLUSION

The study has revealed that excessive application of chemical fertilizer has significantly affected agricultural soil health. It is important to use the fertilizers, within the recommended doses suggested by local to the global standard agricultural institution. Excessive application of chemical fertilizer in the soil acts as a potential risk factor for human health as plant nutrients are consumed by a human directly or via the food chain. The study also revealed that Cd, Pb and Zn came up with moderately contaminated factors and chemical-based fields have been identified as the most contaminated site in the study area. It has been also observed that DAP, superphosphate and zinc sulphate fertilizer are major metals contributors in soil. Hence, some alternative fertilizers or mixed fertilizers, preferably, have to apply to minimize the heavy metals concentration and abating the risk factor for soil and human health as well.

ACKNOWLEDGEMENT

We are thankful to Dr. Sk. Md. Azizur Rahman, senior scientist and head, KVK-ICAR, Budbud, Burdwan and Dr. Dipankar Ghorai, technical staff, KVK-ICAR, Burdwan for their guide. We are also thankful to Sri Jagannath Chatterjee, the Deputy Director Agriculture for Burdwan (East) for providing relevant data and supportive maps. We are grateful to Pravat Ghosal, astaffof Soil Laboratory, Department of Geography, The University of Burdwan, for his constant help in soil testing and guide for using various soil testing machines.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Andreu, V. and Gimeno-Garcýa, E. 1999. Evolution of heavy metals in marsh areas under rice farming. *Environmental Pollution.* 104(2): 271-282.

Atafar, Z., Mesdaghinia, A., Nouri, J., Homaee, M., Yunesian, M., Ahmadimoghaddam, M. and Mahvi, A.H. 2010. Effect of fertilizer application on soil heavy metal concentration. *Environmental Monitoring and Assessment.* 160(1) : 83-89.

Brus, D.J. and Jansen, M.J.W. 2004. Uncertainty and sensitivity analysis of spatial predictions of heavy metals in wheat. *Journal of Environmental Quality.* 33(3) : 882-890.

Barman, S.C., Sahu, R.K., Bhargava, S.K. and Chaterjee, C., 2000. Distribution of heavy metals in wheat, mustard, and weed grown in field irrigated with industrial effluents. *Bulletin of Environmental Contamination and Toxicology.* 64(4): 489-496.

Cabrera, F., Clemente, L., Barrientos, E.D., López, R. and Murillo, J.M. 1999. Heavy metal pollution of soils affected by the Guadiamar toxic flood. *Science of the Total Environment.* 242(1-3) : 117-129.

Davydov, R., Sokolov, M., Hogland, W., Glinushkin, A. and Markaryan, A. 2018. The application of pesticides and mineral fertilizers in agriculture. *MATEC Web of Conferences.* (245) : 110-112.

Dhayagode, N.I., Shidhe N.G. and Pardeshi R.S. 2011. Disposal of municipal solid waste and its impact on agricultural soil property in Shelgi village of Solapurdistrict. *Geoscience Research.* (V2) : 61-69.

Doabi, S.A., Karami, M., Afyuni, M. and Yeganeh, M. 2018. Pollution and health risk assessment of heavy metals in agricultural soil, atmospheric dust and major food crops in Kermanshah province, Iran. *Ecotoxicology and Environmental Safety.* 163 : 153-164.

Gohera, M. E., Abdoa, M. H., Bayoumy, W.A. and Mansour, T.Y. 2017. Some heavy metal contents in surface water and sediment as a pollution index of El-Manzala Lake, Egypt. *J Basic Environ Sci.* 2 : 210-225.

Gebeyehu, H.R. and Bayissa, L.D. 2020. Levels of heavy metals in soil and vegetables and associated health risks in Mojo area, Ethiopia. *PloS One*. 15(1) : e0227883.

Gimeno-García, E., Andreu, V. and Boluda, R., 1996. Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. *Environmental Pollution.* 92(1) : 19-25.

Hakanson, L. 1980. An ecological risk index for aquatic pollution control. A sedimentological approach. *Water Research.* 14(8) : 975-1001.

Hanay, Ö., Hasar, H., Kocer, N.N. and Aslan, S. 2008. Evaluation for agricultural usage with speciation of heavy metals in a municipal sewage sludge. *Bulletin of Environmental Contamination and Toxicology*. 81(1) : 42-46.

Hassan, N.U., Mahmood, Q., Waseem, A., Irshad, M. and Pervez, A. 2013. Assessment of heavy metals in wheat plants irrigated with contaminated wastewater. *Polish Journal of Environmental Studies.* 22(1).

King, L.D., Rudgers, L.A. and Webber, L. 1974. *Application of municipal refuse and liquid sewage sludge to agricultural land: I. Field Study*. 3, (4): 361-366). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Luc, K., Patrick, E.A., Lucien, A., Armelle, H.S. and Bernadin, E. 2012. Threat of the health quality of garden produces linked to pollution by toxic metals on some gardening sites of Benin. *American Journal of Environmental Sciences.* 8(3) : 248.

Malidareh, H.B., Mahvi, A.H., Yunesian, M., Alimohammadi, M. and Nazmara, S. 2014. Effect of fertilizer application on paddy soil heavy metals concentration and groundwater in North of Iran. *Middle East J Sci Res.* 20(12) : 1721-1727.

Mohiuddin, K.M., Era, F.R., Siddiquee, M.S.H. and Rahman, M.M. 2017. Quality of commonly used fertilizers collected from different areas of Bangladesh. *Journal of the Bangladesh Agricultural University.* 15(2) : 219-226.

Murtaza, G., Ghafoor, A., Qadir, M., Owens, G., Aziz, M.A. and Zia, M.H., 2010. Disposal and use of sewage on agricultural lands in Pakistan: A review. *Pedosphere.* 20(1) : 23-34.

Pacheco, J., Marín, L., Cabrera, A., Steinich, B. and Escolero, O. 2001. Nitrate temporal and spatial patterns in 12 water-supply wells, Yucatan, Mexico. *Environmental Geology*. 40(6) : 708-715.

Parkpian, P., Leong, S.T., Laortanakul, P. and Thunthaisong, N. 2003. Regional monitoring of lead and cadmium contamination in a tropical grazing land site, Thailand. *Environmental Monitoring and Assessment*. 85(2) : 157-173.

Patra, R.C., Rautray, A.K. and Swarup, D., 2011. Oxidative stress in lead and cadmium toxicity and its amelioration. *Veterinary Medicine International*, *2011*.

Odai, S.N., Mensah, E., Sipitey, D., Ryo, S. and Awuah, E. 2008. Heavy metals uptake by vegetables cultivated on urban waste dumpsites: case study of Kumasi, Ghana. *Res J Environ Toxicol.* 2(2) : 92-99.

Qingjie, G., Jun, D., Yunchuan, X., Qingfei, W. and Liqiang, Y. 2008. Calculating pollution indices by heavy metals in ecological geochemistry assessment and a case study in parks of Beijing. *Journal of China University of Geosciences.* 19(3) : 230-241.

Savci, S. 2012. Investigation of effect of chemical fertilizers on environment. *Apcbee Procedia*. 1 : 287-292.

Singh, A., Agrawal, M. and Marshall, F.M. 2010. The role of organic vs. inorganic fertilizers in reducing phytoavailability of heavy metals in a wastewater-irrigated area. *Ecological Engineering*. 36(12) : 1733-1740.

Sugiyama, M. 1994. Role of cellular antioxidants in metal-induced damage. *Cell Biology and Toxicology*. 10(1) : 1-22.

Zhao, Z., Jiang, G. and Mao, R. 2014. Effects of particle sizes of rock phosphate on immobilizing heavy metals in lead zinc mine soils. *Journal of Soil Science and Plant Nutrition.* 14(2) : 258-266.