Ecological and human health risks appraisal of metal(loid)s in agricultural soils: a review

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ABSTRACT
Agriculture is one of the major human activities that changed the landforms, water resources and the biogeochemical cycles. Pollution of agricultural soils by metal(loid)s is a serious and global hazard but worldwide studies related to metal(loid)s pollution in agricultural soils are very limited. To fulfil this gap, metal(loid)s content in agricultural soils from 2001 to 2019 all over the world was reviewed. Multivariate statistical techniques, contamination indices and human health risk assessment were determined for the metal(loid)s. Among the analysed metal(loid)s, the average contents of Zn, Cu, Pb, Cr, Cd, As and Ni exceeded the Canadian, and China soil guidelines limits. The results of contamination factor indicated that Cr, Pb, Cd, As and Zn are the key pollution contaminants. As and Cd had the highest enrichment among the analysed metal(loid)s according to the enrichment factor. The potential and modified ecological risk index showed that Cd is the foremost contaminant responsible for ecological threats. The non-carcinogenic risk for ingestion pathway indicated that As, Pb and Cr are the foremost contaminants responsible for affecting human health, while dermal pathway results showed less risk of metal(loid)s in the agricultural soils. The carcinogenic risk revealed that As, Pb and Cr are the key contaminants that affect human health.

1. Introduction
Agriculture is one of the major human activities that changed the landforms, water resources, and the biogeochemical cycles (Rodrigo-Comino, Senciales, Cerdà, & Brevik, 2018; Sharma et al., 2017). It is also a key driver of the land degradation processes (and desertification) and within the processes that are responsible for the soil pollution (Cernansky, 2015). Agricultural activities are also responsible for enrichment of metal(loid)s in the soils is widely accepted by the scientific community. Soil is the main reservoir of metal(loid)s in the biosphere and has an imperative impact in cycling of metal(loid)s in nature (Cao et al., 2010). The significant expansion of urbanization is planting stress on the soil ecosystem (Guan et al., 2018). Particularly, in agricultural soils metal(loid)s pollution has drawn increasing attention to scientists and to the public throughout the globe owing to its harmful influence on the food safety (Toth et al., 2016; Liu et al., 2017; Keshavarzi & Kumar, 2018; Kumar et al., 2019a, Dogra et al., 2019). Soil quality resources are greatly affected by metal(loid)s content and have a significant impact on the human health through the food chain (Toth et al., 2016). The analysis of soil pollutants accompanied by China’s Ministry of Environmental Protection and Ministry of Land and Resources, revealed that about 19.4% agricultural soils samples are contaminated by metal(loid)s, which surpassed the standard limits (MEPPRC and MLRPRC, 2014).

Food crops are the vital sources of human oral contact to metal(loid)s (Zheng et al., 2013), as a consequence regular evaluation of metal(loid)s content in agricultural soils is of utmost significance in safeguarding its quality and certifying future sustainability (Keesstra et al., 2016; Wong, Li, Zhang, Qi, & Min, 2002). The natural content of metal(loid)s in soils was low due to natural processes (Shan et al., 2013), while substantial geogenic enrichment has been confirmed (Kumar, Sharma, Minakshi, & Thukral, 2018a). Metal(loid)s accumulation in agricultural soils leads to nutrient loss and soil function deterioration that have great impact on the production and quality of crops (Huamain, Chunrong, Cong, & Yongguan, 1999; Kong, 2014). Metal(loid)s showed harmful effects at low levels, while their excessive contents affected the human health (Alloway, 2013; Burges, Epelde, & Garbisu, 2015; Khan, Cao, Zheng,
Metal(loid)s sources in the agricultural soils assisted as a foundation for the management that ambition to attain good organisation of soil quality, which safeguards human health and soil environs (Kumar et al., 2019c; Heidari, Kumar, & Keshavarzi, 2019). Thus, it is very imperative to apportion the contamination of metal(loid)s in the agricultural soils. The natural processes like geological parent materials and anthropogenic activities (e.g., release of untreated industrial wastes, agronomic practices, etc.) are the foremost aspects responsible for contamination of agricultural soil by metal(loid)s (Huang et al., 2018a; Kumar et al., 2018b; Lu et al., 2012; Sun, Liu, Wang, Sun, & Yu, 2013). Cheng (2003) showed that the geological background content of metal(loid)s is low in China, but with human activities, air, soil, and water are polluted by the metal(loid)s, which also affects the human health directly or via the food chain. Numerous limits on metal(loid)s were defined to safeguard agricultural soils. Bioavailability is the crucial aspect responsible for metal(loid)s in association with environment and human beings (Lado, Hengl, & Reuter, 2008). Various investigations on agricultural soils have been reported throughout the world by different workers like Cai et al. (2012), Sun et al. (2013), Niu, Yang, Xu, Yang, and Liu (2013), Huang et al. (2018), Guan et al. (2018), and Cai, Wang, Wen, Luo, and Wang (2019) in China; Kumar et al. (2018a) and Dogra et al. (2019) in Keshavarzi and Kumar (2018, 2019) in Iran; and Antibachi, Kelepertzs, and Kelepertsis (2012), Skordas, Papastergios, and Filippidis (2013), and Kelepertzs (2014) in Greece. In the Mediterranean area, mainly Spanish agricultural soils have been evaluated (Micó, Recatalá, Peris, & Sánchez, 2006; Peris, Recatalá, Micó, Sánchez, & Sánchez, 2008; Franco-Uría, López-Mateo, Roca, & Fernández-Marcos, 2009; Martín, Ramos-Miras, Boluda, & Gil, 2013; Toth et al., 2016), while geochemical data are found for Italy (Abollino et al., 2002; Facchinelli, Sacchi, & Mallen, 2001) and Zagreb (Romic & Romic, 2003).

Various multivariate statistical techniques were also applied to the metal(loid)s content in agricultural soils to determine their sources of origin. Guan et al. (2018) while working on agricultural soils of Hexi Corridor, China used principal component analysis (PCA), and inferred that both natural as well as anthropogenic activities were responsible for the contribution of metal(loid)s in the agricultural soils. Keshavarzi and Kumar (2019) in their work on Northeastern Iran applied PCA and heatmap, and concluded that anthropogenic activities and natural factors are the main sources of metal(loids). Further, they also employed various contamination factors/indices like contamination factor, enrichment factor (EF), potential ecological risk and modified ecological risk, and showed that sampling sites are moderately to highly polluted by the metalloids. Kumar et al. (2019) in another on soils of India also applied multivariate analysis and contamination indices (CF), and concluded that metal(loid)s showed low to moderate contamination in the area. Krishna and Mohan (2016), in another study on soils of Hyderabad, India, applied contamination factor, EF and ecological risk index (RI), and concluded that soils were moderately to highly polluted by the metalloids. Further, they also computed human health risk assessment and revealed that As, Cr, and Pb showed average to high risks.

The key objective of this review paper is to appraisal the metal(loid)s (Fe, Cu, Cr, Co, Pb, Cd, As, Ni, Mn, and Zn) levels in agricultural soils throughout the globe from 2001 to 2019. Since the soil quality varies with the time, data for years before this time may not reveal the scope of this work. Furthermore, evaluation strategies are being updated each year, and to make the results equivalent, the selected period of work is regarded suitable. To evaluate the different results, and to incorporate them into a widespread dataset, multivariate techniques were used to find the possible sources of metal(loids) in the agricultural soils. Further CF, EF, potential ecological RI, and modified ecological risk index (MRI) were also applied to determine the pollution and ecological risk assessment of metalloid(s). Finally, the human risks associated with metalloid(s) of agricultural soils were determined by hazard quotient (HQ), hazard index (HI), and cancer index (CI). Our contribution will inform about the State-of-the-Art of metalloid(s) contamination and with this information the necessary policies should be developed to achieve a sustainable management that will help to accomplish the sustainable goals for development launched by the United Nations and soil science is relevant to reach the wished Land Degradation Neutrality (Keesstra et al., 2018; Keshavarzi, Kumar, Bottega, & Rodrigo-Comino, 2019).

2. Material and methods

2.1. Data collection

Metalloid(s) data on agricultural soils throughout the world were assembled by the available published literature from 2001 to 2019 by searching the keywords “heavy metals in agricultural soils,” “heavy metal content in agricultural soils,” and “assessment of heavy metals in agricultural soils” from the ISI of the Web of Science, Science Direct, Google Scholar, Research
Data from 81 indexed journals were collected for metal(loids) in agricultural soils and converted into µg/g. Figure 1 illustrates the available data of metal(loids) in different regions of the world. China recorded maximum number of sites (94) followed by India (25) and Bangladesh (11) for collection of metal(loids) in agricultural soils. All the metal(loids) collected data are provided in the supplementary Table S1.

2.2. Quantification of soil pollution

A number of CF have been used to quantify the metal(loids) pollution in agricultural soils. The description of CF is as follows.

2.2.1. Contamination factor (CF)

CF is the ratio of metal(loids) present in the agricultural soils divided by metal(loids) in the background environment. It was determined by following Hakanson (1980):

\[ CF = \frac{C_n}{B_n} \]  

(1)

where \( C_n \) is the ith value of metal(loids) in the agricultural soils and \( B_n \) is the background values of ith metal(loids) taken from Taylor and McLennan (1995). The ratings applied for categorization of CF level are given in Table S2.

2.2.2. Enrichment factor (EF)

EF was conducted to evaluate the enrichment level, and to assess the human influence of metal(loids) on the agricultural soils (Loska, Wiechula, & Korus, 2004). It was computed by following Buat-Menard and Chesselet (1979):

\[ EF = \frac{\left( \frac{C_n}{C_{ref}} \right)_{sample}}{\left( \frac{B_n}{B_{ref}} \right)_{background}} \]  

(2)

where \( C_n \) and \( B_n \) are the ith metal(loids) in the agricultural soil and background environment respectively. \( C_{ref} \) and \( B_{ref} \) is the content of reference element used for normalization. Metals like Ti, Fe, Al, Mn, and Sc were taken as reference elements (Amil, Latif, Khan, & Mohamad, 2016; Hsu et al., 2016; Kara et al., 2014; Namaghi, Karami, & Saadat, 2011; Szolnoki, Farsang, & Puskás, 2013). Fe was chosen as reference element due to its comparatively high

Figure 1. Overview of collection of metal(loids) in different countries.
level and strength in the crust (Bhuiyan, Parvez, Islam, Dampare, & Suzuki, 2010). The grades used to find the enrichment level of metal(loid)s are presented in Table S2.

### 2.3. Ecological risk assessment

RI was suggested by Hakanson (1980) and conducted to determine the ecological risks posed by metal(loid)s in the agricultural soils (Cui, Zang, Zhai, & Wu, 2014; Maanan et al., 2015). This index considers four aspects: content, pollutant type, toxicity degree, and the sensitivity of metal(loid)s contamination in the agricultural soils. The RI was determined as:

\[ RI = \sum_{i=1}^{n} E_r T_i \times CF^i \]  

(3)

where \( E_r \) is the potential ecological RI of individual metal(loid)s and \( T_i \) is the toxicological response factor taken from Duodu, Goonetilleke, and Ayoko (2016). When RI is derived by employing EF, then it is called MRI and equation used to compute it are as follows:

\[ MRI = \sum_{i=1}^{n} mE_r T_i \times EF^i \]  

(4)

The toxicological response factor and grades used for classification of ecological risk assessment are provided in Table S3.

### 2.4. Human health risk assessment

It links the concentration of metal(loid)s in the agricultural soil with the possibility of harmful effects on the human health. The HQ and cancer risk (CR) were conducted to evaluate the non-carcinogenic and carcinogenic risk (CR) of each metal(loid)s in the agricultural soils (USEPA, 2011). In agricultural soils, three exposure routes were measured: ingestion, dermal contact, and inhalation. For non-carcinogens, the average daily intake (ADD) of metal(loid)s through different routes was determined (USEPA, 2011) as follows:

\[ ADD_{\text{ing}} = \frac{C_i \times IR_x \times EF \times ED}{BW \times AT} \]  

(5)

\[ ADD_{\text{dermal}} = \frac{C_i \times SA \times K_p \times ET \times EF \times ED \times CF}{BW \times AT} \]  

(6)

where \( ADD_{\text{ing}} \) and \( ADD_{\text{dermal}} \) are the ADD from ingestion and dermal pathways respectively (mg/kg/day). The other parameters used for determination of pathways are given in Table S4.

The equation used to calculate HQ is as follows:

\[ HQ_i = \frac{ADD_{\text{ing}}}{RfD_{\text{ing}}} \]  

(7)

The sum of non-CR of each metal(loid)s was represented as HI for different exposure pathways, and determined as:

\[ HI = HQ_{\text{ing}} + HQ_{\text{dermal}} \]  

(8)

\[ CR_{\text{ing}} = \frac{ADD_{\text{ing}} \times SF}{RfD_{\text{ing}}} \]  

(9)

\[ CR_{\text{dermal}} = \frac{ADD_{\text{dermal}} \times SF}{RfD_{\text{dermal}}} \]  

(10)

\[ CI = \sum CR_{\text{ing}} + CR_{\text{dermal}} \]  

(11)

\[ CI = \sum CR_{\text{ing}} + CR_{\text{dermal}} \]  

(12)

### 2.5. Statistical analysis

The data was subjected to descriptive statistics by employing PAST v 3.21 software (Hammer & Harper, 2001). The correlation among the different metal(loid)s in agricultural soils was evaluated by using Pearson’s correlation using R software v 3.5.1 (Statistical Computing, Vienna, Austria). Cluster analysis (CA) was also conducted to find the association between the metal(loid)s. Finally, PCA was performed to evaluate the source apportionment of metal(loid)s in the agricultural soils (Kumar et al., 2017).

### 3. Results and discussion

#### 3.1. Descriptive statistics of metal(loid)s and vis-a-vis the soil guidelines

Metal(loid)s are frequently found in the soils. Among all the metal(loid)s Pb, As, Cd, and Hg are included in the top 20 hazardous substances of the ATSDR (ATSDR, 2012) and the USEPA (USEPA, 2007). Metals may reside in the soil for long duration based on type of metal and soil (Ghosh & Singh, 2005). The descriptive analysis of metal(loid)s is presented in Table 1. Among the analysed metal(loid)s, Fe content was the highest, while Cd content was found minimum. The mean content of metal(loid)s showed a trend, i.e., Fe > Zn > Mn > Cr > Pb > Ni > Cu > As > Co > Cd. The geometric mean of metal(loid)s followed a trend, viz., Fe > Mn > Zn > Ni > Pb > As > Cr
Table 1. Descriptive statistics of metal(loid)s in agricultural soils.

|       | µg/g          |       | µg/g          |       | µg/g          |       | µg/g          |       | µg/g          |       |
|-------|---------------|-------|---------------|-------|---------------|-------|---------------|-------|---------------|-------|
| Fe    | Min 0.1       | Max 68,700 | Mean 1314     | Std. error 667.71 | Median 13,149 | Coef. var 61.57 | CCME (2007)* - | CNEMC # - | 17 50.5 - | 36 0.056 8.9 14.4 - | 47.3 |
| Cu    | 0.004         | 1149   | 11.24         | 39.07 | 61.57         | -     | -             | 63    | 64 40 70 1.4 12 50 - | -     |
| Cr    | 0.026         | 7767.5 | 78.82         | 49.7  | 407.0         | 63    | -             | -     | -             | -     |
| Co    | 0.003         | 68.09  | 0.51          | 3.42  | 89.94         | 64    | -             | -     | -             | -     |
| Pb    | 0.02          | 6153   | 61.23         | 34.11 | 342.4         | 40    | -             | -     | -             | -     |
| Cd    | 0.03          | 216.79 | 1.25          | 1.04  | 272.1         | 70    | -             | -     | -             | -     |
| As    | 2.35          | 5.55   | 4.02          | 28.29 | 112.1         | 1.4   | -             | -     | -             | -     |
| Ni    | 0.27          | 43.44  | 15.99         | 50.96 | 190.2         | 12    | -             | -     | -             | -     |
| Mn    | 1.1           | 43.44  | 22.14         | 511.4 | 45.63         | 50    | -             | -     | -             | -     |
| Zn    | 0.25          | 588.22 | 22.14         | 511.4 | 455.1         | 50    | -             | -     | -             | -     |

*Canadian soil quality guidelines for the Protection of Environment and Human Health (2007).
#China National Environmental Monitoring Centre (1990).

> Cu > Co > Cd. Metal(loid)s ranged from 0.1 to 68,700 µg/g for Fe, 0.004 to 1149 µg/g for Cu, 0.003 to 68.09 µg/g for Co, 0.02 to 6153 µg/g for Pb, 0.03 to 96.9 µg/g for Cd, 2.35 to 276 µg/g for As, 0.27 to 1609.8 µg/g for Ni, 1.1 to 2492 µg/g for Mn, and 0.25 to 36,756 µg/g for Zn, respectively (Table 1). The standard error was found maximum for Fe followed by Zn and Cr. The coefficient of variation (CV) was found maximum for Zn followed by Cr and Pb, indicating higher degree of alteration of these metals in the agricultural soils. The CV reflects the variations in the data, representing the order to which agricultural soils are affected by the anthropogenic activities (Kumar et al., 2019a). According to Zhou, Feng, Pei, Meng, and Sun (2016), the CV range from 10 to 100 represents modest alterations in the samples. The mean concentrations of Cu, Cr, Pb, Cd, As, Ni, and Zn were found greater than the values of Canadian soil quality guidelines for Protection of Environment and Human Health (2007) and China National Environmental Monitoring Centre (1990).

3.2. Correlation analysis

Pearson’s correlation analysis was performed to determine the dimensions of similarity and to assess the associations among the metal(loid)s in the agricultural soils (Figure 2). From the results, it was revealed that Fe was positively correlated with Cr, As, Co, and Mn, while showed negative correlation with Cu. Co was positively correlated with Cd, and negative relationship of Co was found with As, Ni, and Mn. Mn and As also showed positive

Figure 2. Pearson’s correlation analysis of different metal(loid)s in agricultural soils.
correlation with each other. The high correlations among the metal(loid)s suggest that metal(loid)s have the same origin (Micó et al., 2006). Inter-element associations in the agricultural soil matrix give statistics on origin and pathways of metal(loid)s in the geoenvironment (Dragovic, Mihailovic, & Gajic, 2008).

3.3. Multivariate analysis

CA was done to determine the sources among the different metal(loid)s by employing Ward’s method and Euclidean distance (Kumar, Sharma, Bakshi, Bhardwaj, & Thukral, 2018c). CA demonstrated predominantly two groups (Figure 3): group I (Fe, As, Mn, and Cr), and group II (Cu, Zn, Pb, Ni, Co, and Cd). Further, group I is divided into Fe and As, and Mn and Cr. Group II is also divided into Cu and Zn, Pb and Ni, and Co and Cd. To determine the correlations among metal(loid)s, PCA was performed by decreasing the dataset to many influential aspects (Guan et al., 2016). For well elucidation of PCs, they were revolved using varimax rotation and chosen for consequent graphical presentations (Table 2). The Eigen values of first three components explained 43.9% of total variation. The loadings of PCA before varimax rotation indicated that PC1 explained 18.5% variation and demonstrated positive loadings of Fe, Cr, As, and Mn. PC2 demonstrated positive loadings of Co and Cd, while negative loading of Ni and 15% variation was explained by this PC. Cu and Pb contribute to PC3 and demonstrated 11.1% of variance. PCA loadings after varimax rotation showed that PC1 explained 17.5% followed by PC2 (15.3%) and PC3 (11%) of variance respectively. The PCA loadings after varimax rotation followed

![Figure 3. Cluster analysis of different metal(loid)s in agricultural soils.](image)

| Components | Eigen values | Extraction sums of squared loadings | Rotation sums of squared loadings |
|------------|--------------|------------------------------------|----------------------------------|
|            | Total        | % Variance | Cumulative % | Total | % Variance | Cumulative % | Total | % Variance | Cumulative % |
| 1          | 1.8          | 18.5       | 18.5         | 1.8   | 18.5       | 18.5         | 1.7   | 17.5       | 17.5         |
| 2          | 1.5          | 15.0       | 33.5         | 1.5   | 15.0       | 33.5         | 1.5   | 15.3       | 32.8         |
| 3          | 1.1          | 11.1       | 44.6         | 1.1   | 11.1       | 44.6         | 1.1   | 11.0       | 43.9         |
| 4          | 1.0          | 10.5       | 55.1         | 1.0   | 10.5       | 55.1         | 1.0   | 10.6       | 54.5         |
| 5          | 1.0          | 10.0       | 65.1         | 1.0   | 10.0       | 65.1         | 1.0   | 10.6       | 65.1         |

| Variables | PC1 | PC2 | PC3 |
|-----------|-----|-----|-----|
| Fe        | 0.69| 0.49| -0.13|
| Cu        | -0.16| 0.03| **0.79**|
| Cr        | **0.48**| 0.12| 0.22|
| Co        | -0.05| **0.70**| -0.27|
| Pb        | 0.05| -0.13| **-0.37**|
| Cd        | -0.34| **0.67**| 0.05|
| As        | **0.67**| 0.25| -0.15|
| Ni        | 0.11| -**0.43**| -0.28|
| Mn        | **0.55**| 0.30| 0.30|
| Zn        | -0.12| 0.08| -0.003|

| Variables | PC1 | PC2 | PC3 |
|-----------|-----|-----|-----|
| Fe        | **0.83**| 0.11| -0.12|
| Cu        | -0.11| 0.04| **0.89**|
| Cr        | **0.39**| -0.17| -0.006|
| Co        | -0.06| **0.84**| -0.166|
| Pb        | 0.13| -0.08| -0.006|
| Cd        | 7.10E-5| **0.79**| 0.16|
| As        | **0.73**| -0.02| -0.09|
| Ni        | -0.08| **-0.28**| -0.25|
| Mn        | **0.55**| -0.20| 0.37|
| Zn        | -0.09| -0.09| -0.13|
the same trend as observed for before varimax rotation of PCA loadings. Pb and Zn showed high content in the agricultural soils pose a great threat to human health, the environment and its biota; consequently, it is vital to determine the pollution origins of Pb and Zn (Dao, Morrison, Kiely, & Zhang, 2013). Pb is the foremost indicator of traffic emissions (Arditsoglou & Samara, 2005; Hjortenkrans, Bergbäck, & Häggerud, 2006). The roads contribute Pb beside the farmland, where traffic activities and agricultural equipment’s release exhaust with Pb, leading to pollution. While the manufacturing and practice of leaded petrol stopped since 2000, but still Pb occurred in the soil (Chen, Chang, Liu, Clevers, & Kooistra, 2016). The tire wear of car is the primary cause of Zn, as Zn-containing dust goes into the soil (Monaci, Moni, Lanciotti, Grechi, & Bargagli, 2000). Due to water scarcity and rising cost of fertilizers, farmers utilizing raw sewage to irrigate and fertilize the agricultural soil (Luo, Ma, Zhang, Wei, & Zhu, 2009). High content of Cr in soil suggested that anthropogenic activities are probably linked with sewage irrigation (Li, He, Han, & Gu, 2009; Liu et al., 2016). Cu and Zn content is primarily linked with livestock manures (Liang et al., 2017) since Cu and Zn are existed in the livestock diets as a stabilizer, providing great performance by giving antibacterial agents to the guts and governing post-weaning scours (Holm, 1990; Rosen & Roberts, 1996). Cu is generally regarded as an indicator metal of agricultural activities, which is associated with the usage of fertilizers (Acosta, Faz, Martínez-Martínez, & Arocena, 2011). Moreover, application of Cu-based fertilizers and fungicides on crops leads to enhanced level of Cu in the agricultural soils (Epstein & Bassein, 2001; Sun et al., 2013). The usage of P fertilizers is the vital source of Cd, and number of workers reported the enhancement of Cd content under extreme usage of P fertilizers in agricultural soils (Cai et al., 2012). P rocks are the crucial material for making the fertilizers, and contribute substantial level of Cd (Jiao, Chen, Chang, & Page, 2012). Escalated As content in agricultural soils has been attributed to the usage of mineral fertilizers (Nicholson, Smith, Alloway, Carlton-Smith, & Chambers, 2003).

### 3.4. Quantification of pollution in agricultural soils

The pollution level was determined by employing CF and EF for metal(loids) in the agricultural soils (Figure 4). CF results showed that CF values for Co were found less than one, indicating minimum contamination in the agricultural soils. CF values for Mn were found higher than the range of 1–3, while CF values for Cu and Ni were observed in the range of 3–6 grade for CF, representing moderate and substantial contamination of these metal(loids) in the agricultural soils, respectively. The CF of Cr, Pb, Cd, As, and Zn were found higher than 6, indicating higher contamination of these metal(loids) in the agricultural soils. The EF of metal(loids) in the agricultural soils have determined to distinguish metal(loids) originating from human aspects those from natural attribution. The EF showed that Cu, Cr, Co, Ni, and Mn values of EF were found higher than >5–20, demonstrating moderate agricultural soil contamination. Pb and Zn showed high contamination with EF values being higher than >20–40. EF values greater than 40 were found for Cd and As, representing extreme agricultural soil contamination.

### 3.5. Ecological risk evaluation of metal(loids) in agricultural soils

The RI of each metal(loids) and MRI were determined to evaluate the ecological risks of metal(loids) in the agricultural soils (Figure 5). Er values for Cu, Cr, Co, Ni, Mn, and Zn were less than 40, demonstrating low ecological risk in the agricultural soils. Pb and As demonstrated

![Figure 4. Contamination factor (CF) and enrichment factor (EF) of different metal(loids) in agricultural soils.](image-url)
modest ecological risks (Er 40–80). Er values higher than 320 were observed for Cd, representing very high ecological risk of Cd in the agricultural soils. The RI values for all metal(loid)s was 1883.3, indicating very high ecological risk in the agricultural soils. Moreover, the results of MRI indicated that mEr value of Cd was found greater than 320, showing high ecological risk in the agricultural soils. Cu, Cr, Co, Zn, and Mn showed less ecological risk, while mEr values of Pb and As showed substantial ecological risk in the agricultural soils. mEr values for Ni found higher than 40–80 representing adequate risk of Ni.

3.6. Human health risk assessment

Cu, Cr, Co, Pb, Cd, Ni, Zn, Mn, and As were taken into account for evaluation of human health risk as of their comparatively high toxicity to the human beings (USEPA, 2016). The results of non-CR showed by metal(loid)s in the agricultural soils for child and adults through ingestion and dermal pathways are represented in Table 3. The average daily dose values of metal(loid)s via ingestion pathway for child was found higher as compared to the adults for ingestion pathway. The maximum ADD values via ingestion pathway for child was found for Zn, Mn, Pb, and Cr, while maximum ADD values for adults were found for Zn, Mn, Pb, and Cr. The ADD values of metal(loid)s for both child and adults for dermal pathway were found very less as compared to ingestion pathway. The HQ was recorded maximum for As, Pb, and Cr in case of ingestion pathway for both child as well as adults. Similarly, the HQ values via dermal route were also found very less. The HI of Pb, Cr, and As were recorded maximum for child as compared to the adults. Children had more non-carcinogenic hazards as compared to the adults, representing they are vulnerable to environmental pollutants. The CR was determined for Ni, Cr, As, and Pb according to available SF of metal(loid)s. The results of CR are presented in Table 4. The CR values via ingestion pathway was found higher both for child and adults, whereas CR values via dermal pathway was recorded low for As, Pb, Ni, and Cr.

Remediation of polluted soils by metal(loid)s aims in cleaning up the soils used for agriculture, diminish the related risks, improve soil nutrients, and increase food production (Abdullahi, 2015). The removal processes used for recovery of metal(loid)s contaminated soils may be in-situ or ex-situ, and biological, physical and chemical (Ghosh & Singh, 2005; Khalid et al., 2017).

| Heavy metals | ADD Ingestion | ADD dermal | ADD Ingestion | ADD dermal | HQ Ingestion | HQ dermal | HQ Ingestion | HQ dermal | HI Child | HI Adult |
|--------------|---------------|------------|---------------|------------|--------------|-----------|--------------|-----------|---------|----------|
| Cu           | 3.11          | 1.3609E-05 | 2.08          | 3.44322E-06| 77.77        | 1.7013E-06| 52.08        | 4.30403E-07| 77.77   | 52.08    |
| Cr           | 9.60          | 8.40348E-05| 6.43          | 2.12671E-05| 3201.32      | 0.001120464| 2143.7       | 0.000283489| 3201.3  | 2143.7   |
| Co           | 0.28          | 4.89732E-07| 0.19          | 1.23907E-07| 932.82       | 8.16219E-06| 624.6        | 2.06512E-06| 932.8   | 624.6    |
| Pb           | 8.87          | 3.88044E-05| 5.94          | 9.81791E-06| 2956.53      | 0.077     | 1979.8       | 0.019     | 2956.6  | 1979.8   |
| Cd           | 0.23          | 9.93425E-07| 0.15          | 2.51347E-07| 454.14       | 3.9737E-05 | 304.1        | 1.00539E-05| 454.1   | 304.1    |
| As           | 1.78          | 7.77556E-06| 1.19          | 1.9673E-06  | 5924.24      | 6.32159E-05| 3967.1       | 1.59943E-05| 5924.2  | 3967.1   |
| Ni           | 4.17          | 3.64685E-06| 2.79          | 9.22691E-07 | 208.39       | 4.55857E-06| 139.5        | 1.15336E-06| 208.3   | 139.5    |
| Mn           | 24.07         | 0.00011    | 16.12         | 2.66391E-05 | 1002.75      | 0.0001    | 671.4        | 2.77491E-05| 1002.7  | 671.4    |
| Zn           | 39.28         | 1.71843E-05| 26.3          | 4.3478E-06  | 130.93       | 2.86405E-07| 87.6         | 7.24633E-08| 130.9   | 87.6     |

ADD = average daily dose and HQ = Hazard quotient.
These strategies are frequently applied in intermingling of reasonable and cost-effective remediation of contaminated site. The overview of soil remediation techniques are presented in Figure 6. The utmost operative strategy on a lesser scale is soil exclusion and replacement. However, organizing of the soil and locating suitable news oil may be cost inefficient. Therefore, soil washing has been projected as a mode to eradicate metalloid(s) from soil but it can be applied mainly to small scale sites as it is a time taking and costly method (Ahmad, Najeeb, & Zia, 2015). Phytoremediation is environmental friendly and cheap method for soil clean up with low-to-moderate levels of metalloid(s) (Sabir et al., 2015; Sharma et al., 2018). It can be applied effectively in association with other traditional remediation strategies as a final step of the remediation process. The effectiveness of phytoremediation based on diverse aspects like physico-chemical properties of the soil, metalloid(s) bioavailability, microbial and plant exudates, and the capability of organisms to uptake, store and detoxify metalloid(s) (Khalid et al., 2017). Xu et al. (2019) in their work reported the design and demonstration of a removal approach based on idea of asymmetrical alternating current electrochemistry that accomplishes greatest level of pollutant removal for Cu, Pb and Cd at diverse initial levels from 100 to 10,000 ppm, all attaining equivalent regulation levels for domestic situation after rational treatment time from 30 min to 6 h. No unnecessary nutrient loss in treated soil is found and no secondary harmful product is generated. Long-durable experiment and plant assay indicates great sustainability of the approach and its possibility for agricultural purposes. Finally, we can conclude that more attention might be require to those zones or regions, where metalloid(s) content was very high. Since from the last few years, various studies have noted that local and national influence on the agricultural soils are the main aspects to understand ecological issues at worldwide level (Smith et al., 2015; Steffan, Brevik, Burgess, & Cerdà, 2018). Other researchers also studied that there is need to link the problems associated with soils to the public, although till date, it is not divulged properly to the public (Brevik et al., 2019).

**Conclusion**

This review revealed that the average content of Zn, Cu, Pb, Cr, Cd, As, and Ni from the data collected was found higher than the Canadian and China soil guidelines limit. The CF values indicated that As, Cd, Pb, Zn, and Cr showed high risk of contamination in
the agricultural soils. As and Cd showed greatest enrichment among the analysed metal(loid)s in the agricultural soils. The results of ecological risk assessment indicated that Cd is the main contaminant responsible for ecological threats in the agricultural soils, while As and Pb showed substantial ecological risk to the agricultural soils. The non-CR via ingestion pathway for both child and adults indicated that As, Pb, and Cr are the main metal(loid)s responsible for polluting the agricultural soils. As, Pb, and Cr may affect human health as indicated by the CR results. The data used and methods applied in this paper may be helpful for the policy and decision makers to develop strategies in mitigating the problems of metal(loid)s removal from the agricultural soils.

Disclosure statement
No potential conflict of interest was reported by the authors.

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