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Bioassessment of Heavy Metals in Wheat Crop from Soil and Dust in a Coal Mining Area

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ABSTRACT: Coal mining and related industry can increase heavy metals (HMs) concentrations in soil, atmosphere and wheat, thereby posing metal-associated human health risk via food ingestion. In this study, 58 samples of soil, wheat, and dust were collected from Xuzhou coal mine eastern China, six kinds of HMs Pb, Cd, Cu, Zn, As and Cr were studied for their spatial distribution in wheat, enrichment in different wheat organs (roots, stem leaf, glumes, and grains), pollution level and potential human health risks. Results show that the spatial distribution of HMs in wheat grains were likely to coal while dissimilar to soil. Most of heavy metals enrichment in wheat organs retained in glume and stem leaf after roots, and followed by grains, indicating that HMs was accumulated more from atmospheric dust as compared to other sources. Meanwhile, 71% of wheat grains were contaminated by HMs comprehensively in Xuzhou coal mine area. The potential health risk indicated that ingestion of food was the main exposure route causing non-carcinogenic and carcinogenic risk for inhabitants. This study provides basic information to control HMs enrichment from atmospheric dust and human health risk management policies in the mining area.

Keywords: heavy metals; wheat organs; coal mining; health risk; atmospheric dust.

INTRODUCTION

Toxic metals or metalloids are of huge environmental concern due to the fact that they are harmful to living things and endanger the ecological environment safety through food chain transmission. Several studies (Doabi et al., 2018; Huang et al., 2008; Mahdavian et al., 2017; Masto et al., 2017; Yang et al., 2018) have shown that coal mining regions are one of the major pollution sources for these toxic metals. In these regions, a large proportion of cultivable land has been contaminated with heavy metals (HMs) (Quartacci et al., 2006). These HMs influence the local community life through plant–human interaction (Hussein et al., 2005; Zhang et al., 2003). They may enter human body through dietary intake, inhaling, or skin contact; and cause damage to the cellular level by initiating oxidative stress, that leads to the growth of various diseases and health problems (Jaishankar et al., 2014; Mahurpawar, 2015; USEPA, 2007). This

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may cause adverse effects on nervous, immune, endocrine, and urine system of human beings (Doabi et al., 2018; Hong et al., 2014; WHO, 2018, 2010). There are more than twenty kinds of HM trace elements, that are found in coal regions (Finkelman, 1994; Swaine, 2000). These trace elements are released into the environment during coal exploration, mine ventilation, washing, transportation, and other coal processing steps (Lough et al., 2005; Zhang et al., 2016).

Despite of environmental and human health impacts as mentioned above, coal is still one of the mostly used energy resource in the worldwide, that contribute 70% in China, India followed by 56% and USA 25 % by total energy production (The World Bank, 2007). Xuzhou is the most excessive mining activities region in china, which have more than 120 year history of mining activities and peak production was 25 million tons per year (Hu et al., 2018). Mining activities pose a huge health risk to local inhabitant; this makes Xuzhou an important study area for environmentalists. Consequently, elevated concentrations of HMs are found in soil of Xuzhou and suburbs area (Wang et al., 2013; Wang and Fu, 2014). In addition to soil pollution, air is also polluted by fly ash and dust, originating from coal mining activities (de Souza et al., 2015). Few studies were carried out to assess the impact of HMs pollution (Dai et al., 2017; Huang et al., 2009; Wang, 2013). The authors (Du et al., 2019; Guan et al. 2018; Wang et al., 2018) estimated heavy metals pollution index and assess the heavy metals health risk impact. However, these studies did not assess the carcinogenic risk due to heavy metals in the area. Therefore, a study is required to investigate the health problems associated with HMs pollution in detail of formulating environmental policy subject area.

On the other side, it is reported in several studies (Ishtiaq et al. 2018; Ying et al 2016) carried out in other coal mining regions, that these HMs are consumed by human beings which results in huge health risk. Thus is has become necessary to analyze the soil-plant-human and air-plant-human interaction in terms of HMs transfer, as these HMs may enter human body via dietary intake of food crops or vegetables (Chen et al., 2018; Sumczynski et al., 2018). The authors (Bashir et al., 2009; Liao et al., 2016; Thakur et al., 2016) have reported that the HMs accumulated in plants through soil or acid mine drains i.e. their absorption has direct or indirect relation with soil. The studies (Chibuike et al., 2014; Dikinya and Areola, 2010) have found that HMs are adsorbed readily in wheat, vegetables, and rice. According to studies (Du et al., 2012; Yabanli et al., 2014), the distribution of heavy metals in plant organs is found in order as roots >stem and leaf> husk >grains, which indicates that a large proportion of HMs area transferred from soil through roots, in contrast, few other studies (Dehghani et al., 2017; Doabi et al., 2018; Ma and Singhirunnusorn, 2012) reported that a large proportion of HMs are transferred from atmospheric dust. These contradictory results have necessitated the investigation of HM accumulation in detail.

In above contexts, a comprehensive study is carried out in Xuzhou coal mining region to investigate heavy metals distribution in wheat organs and to assess their impacts on human health. The study has following objectives: 1) determination of spatial distribution of HMs (Pb, Cd, Cu, Zn, As, and Cr) in wheat plants, 2) assessment of HMs enrichment in wheat organs (root, stem, leaf, glumes, and grains) from soil and air dust, 3) estimation of non-carcinogenic (nCR) and carcinogenic (CR) risk assessment of HMs in wheat.

MATERIALS AND METHODS

The study was conducted in a coal mining and industrial region of China the northwest of Xuzhou, Jiangsu Province, China (34°15′–34°20′ N and 117°04′–

117°7′ E, Figure 1). The annual mean precipitation, temperature, and wind in the study area are 900mm, 14°C and 3.5m/s, respectively. Our study area covers more than 98km^2 which contains around 56 number of pollution source including coal mines, heavy machinery industries, steel structure, and processing plants, building materials plants, coal fire plant, and fly ash yard that promulgates HMs into the soil and atmospheric dust. One-third of area is under agricultural practices, and surrounded by pollution source.

A total of 24 soil samples were collected from 0 to 20cm depth across the area on the basis of crop distribution, agriculture practicing area and surroundings of the pollution source. All samples were taken from the marked location, using a stainless-steel auger. At each sampling point, five subsamples were taken and mixed together to make one sample. A similar criterion followed for both soil and wheat. These composite soil samples were transferred to the laboratory for chemical analyses. All soil samples were dried in the air at room temperature (25°C). Afterwards, 40g of each soil sample was grind then sieved through 0.15mm. Furthermore, at harvest time (June 2015) 24 sample of wheat were collected within 2m of the soil sample marked the location. All wheat samples were washed with deionized water to remove soil and other debris, then each wheat sample separated into four wheat organs as root, stem leaf, glume, and grains and transferred to the laboratory. All wheat samples were dried at room temperature, dried wheat grains crushed by a grinder, and other wheat cut into small pieces with scissors, then grind into fine powder, put in an envelope and stored in a dry place.

A total 10 dust samples was collected in the temporal range of July 1st, 2014 to March 30th, 2015, each sample load-standing 270 days in a different location. The selected sampling point have the following characteristic, they were not shaded by buildings or trees and protected against human and animals interruption. Dust collector polyethylene container was installed on artificially mounted roof 4m above from ground level, with a mouth of 0.15m diameter, and covered with polyethylene screen to retard from large particles entering. Dust samples were collected rainwater and settled particles, sealed plastic bag, tagged and transferred to the laboratory. All dust collected sample were dried in oven for 24 hours at 102°C, passed through 2mm nylon sieve mechanically to remove large debris then sieved through 100μm nylon. In addition, fine particles are associated with environmental and health risk instead of coarser particles (Liu et al., 2014; Zhao and Li, 2013).

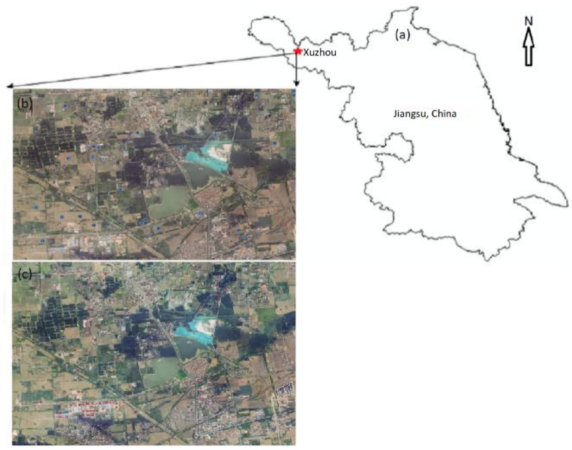

Fig. 1. Location of study area 34°15′–34°20′ latitude and 117°04′–117°07′ longitude (a), Sample points shows in Blue Color (b), and Pollution Source shows in Red Color (c)

To determine HMs, an accurately weighed amount 0.2g of soil and dust were filled in a 100ml test tube, 24ml of tetra-acid mixture (of 99.9% pour regents HCl, HNO_3, HF, and $HClO_4$ with 5:1:5:1 ratio) added to each tube, and mixture was placed overnight at room temperature. Moreover, the controlled heat applied to each test tube for 2 hours at 150°C temperature and material was dried. The concentration of Pb, Cd, Cu, Zn, As, and Cr were determined by using inductively coupled plasma atomic emission spectrometry (PerkinElmer Optimal 8000, USA). Same process repeats for HMs determination in wheat roots, stem leaf, glume, and grains as mentioned above. All samples experimented in triplicate.

The methods used for HMs pollution assessment were conducted, Enrichment factor (EF), Single factor index method, and Nemerow comprehensive index method.

Enrichment factor (EF) is also termed as Bioconcentration factor (BCF). The EF of the crop is the ratio of element content in a certain part of the plant to the content of corresponding geochemical background of an element, which reflects the strains of elemental migration in the soil-plant system to a certain extent, and shows the enrichment of HMs in plant orangs (González-Macías et al., 2006). Therefore, EF is calculated by using the following relationship in Eq. (1):

$$EF = \frac{C_p}{C_s} \tag{1}$$

where, Cp = Heavy metal concentration in plants organs (wheat roots, stem leaf, glume, and grains) (mg/kg); C_s =Heavy metal concentration in geochemical background of element (soil) (mg/kg).

The single factor index method was used to estimate the pollution level of one pollutant in the examined sample. It stresses that which pollutant contributes the most to pollution at each sample in an obvious way. Single factor index method reflects the contamination factor (CF) against the anthropogenic input. The single factor index is calculated for a single pollutant according to following relationship (Hakanson, 1980) in Eq. (2):

$$P_i = \frac{C_i}{S_i} \tag{2}$$

where P_i = single pollution index of HMs in wheat; C_i=measured concentration of the heavy metal in wheat (mg/kg); S_i= standard value of heavy metal (mg/kg). If $P_i < 1$ means clean or unpolluted; $1 < P_i \le 2$ means light or low polluted; $2 < P_i \le 3$ means moderate or medium polluted; $P_i > 3$ means high or severe polluted (Dong et al., 2012).

The Nemerow pollution index method was used to estimate the comprehensive (or combined) pollution level of all HMs present in sample. As different HMs may have varied effects on one site, this method might provide a rational analysis of HMs pollution at each site on the whole. It can be calculated (Yan et al., 2016) by Eq. (3):

$$P_N = \sqrt{\frac{\left(Ci_{max}/Si_{max}\right)^2 + \left(Ci_{avg}/Si_{avg}\right)^2}{2}} \tag{3}$$

where, P_N= Nemerow pollution index $(C_i\ max\ /Si\ max)$ =the maximum value of pollution index of heavy metals in the crop; $(C_i\ avg/S_i\ avg)$ = the average pollution index of heavy metals in crops. If $P_N < 1$ means clean or unpolluted; $1 < P_N \le 2$ means light or low polluted; $2 < P_N \le 3$ means moderate or medium polluted; $P_N > 3$ means high or severe polluted (Dong et al., 2012).

Inhabitant are exposed to metals over the dominate pathway direct ingestion or chronic daily intake (CDI) of substrate particles. CDI of wheat evaluated using Eq. (4) (USEPA, 1989):

$$CDI = \frac{Ci \times IR \times ED \times EF}{BW \times AT \times 365} \tag{4}$$

where, C_i= the average heavy metal content in wheat grains (*mglkg); IR*=ingestion rate (daily appetite) for adults

(0.*389mg/kg.day*(Ministries of Health and Science and Technology and the National Bureau of Statistics of the People's Republic of China, 2004)); *ED*=exposure duration (*27year* (Ministries of Health China, 2004)); *EF*=exposure frequency(*365 day/year* (Yeganeh et al., 2013)); *BW*= average body weight of an adult (*62.7kg* (Ministries of Health China, 2004)); *AT*= average time (*70year* (USEPA, 1989)).

Based on Environmental Protection Agency (EPA) guidelines for risk assessment, carcinogenic and non-carcinogenic impacts assessed separately because different methods are used for these two modes toxic elements. In this study, hazard indexes (HI) quantified for both non-carcinogenic and carcinogenic impacts were applied on dietary intake (CDI) pathway by dividing the doses of reference dose (RfD) for non- carcinogenic and multiple doses by slope factor (SF) for carcinogenic. Based on IARC (International Agency for Research on Cancer) As and Cr are intended to have carcinogenic effect(Cao et al., 2014). Lack of carcinogenic slope factor for Pb, Cd, Cu and Zn, the carcinogenic risk of As and Cr were assessed through ingestion. Hazard index (HI) is the sum of more than one hazard quotient (HQ). If the HI or HQ value is less than unity, it is affirmed that tolerable non-carcinogenic effects. If the HI or HQ value is more than unity, it consider as serious and momentous chances of non-carcinogenic effects (Huang et al., 2008; Masto et al., 2017; USEPA, 2002). The non-carcinogenic and carcinogenic risks for each metal calculated by following Eq. (6) and (7) respectively:

$$HQ = \frac{CDI}{RfD} \quad (5)$$

$$HI = \sum HQ_i \quad (6)$$

$$CR = CDI \times SF \quad (7)$$

RfD for Pb, Cd, Cu, Zn, As, and Cr are 0.0035, 0.001, 0.04, 0.3, 0.0003, and 1.5 mg/kg.day, respectively(USEPA, 2000). SF for As and Cr are 1.5 and 0.501 mg/kg.day, respectively (Cao et al., 2014; USEPA, 1988). USEPA recommends that the value of CR less than 1×10^{-6} can be regarded as negligible, range from 1×10^{-6} to 1×10^{-4} tolerable risk and more than 1×10^{-4} are tend to be more harmful effect to human (Dehghani et al., 2017).

Spatial distribution of HMs content of wheat grains was prepared by using Neighborhood interpolation method in ArcGIS (10.2 version). The data processing of heavy metal content in each part of wheat was completed by Origio9. Pearson correlation coefficient used for correlation analysis of wheat grains between HMs to HMs and between soils, other wheat organs (roots, stem leaf, and glume) and descriptive statistical analysis were performed using SPSS19 (IBM®).

RESULTS AND DISCUSSIONS

The soil has moderate fertility rate with soil pH 8.22 and the dust flux was observed 8.62 $g/m^2/month$. As can be seen in Table 1, HMs content were noticeably different in soil and atmospheric dust with subsequently as Zn>Cr>Cu>Pb>As>Cd and Zn>Pb>Cu>Cr>As>Cd, respectively. The heavy metal contents were appreciably within permissible limits (Chinese Standard, 1995) except particularly high Cd in soil and slightly As content. Cd content arises in the soil as well as dust ascribed to excessive use of phosphate fertilizer of that area and might be the geogenic background of Cd in the regional soil, most important would be mining of Cd-rich coals (Liu et al., 2013). Although results showed that most of HMs content in soil under limits but the correlation analysis between different HMs and soil indicated the most of elements have a significant relationship with soil, Table 2 and 3. There seems to be tendency of HMs accumulation from soil which was enriched with coal particle. HMs content in atmospheric dust was extremely high as compared in the entire study area, Table 1. HMs dominant contributor to atmospher are road dust and traffic congestion with rapidly increasing of vehicles (Wei and Yang, 2010; Yuen et al., 2012). The extremely high Zn in the atmospheric dust among all other HM, dust generated from wear and tear of vehicle tyres to the poor roads and high traffic density could be source of Zn (Masto et al., 2017). The atmospheric Cr was caused by anthropogenic activity that produces from the metallurgical industry, and followed by coal combustion in that area.

A contour map of HMs content in wheat grains were generated, it recognized that Pb, Cd, Cu, Zn, As, and Cr shows distribution in blocks, Figure 2. The distribution of Pb and Zn seems to be similar, both shows high content at the northeast and northwest side of study area. The Cd content seems to be high at northwest side, Cr content seems to be high at northeast and southeast side, As content seems to be high at northeast, and Cu content high in southwest. The higher content of HMs in wheat grain might be existence of fly ash and coal dust, Cu content is high in the southeast direction due to electrochemical industries. The results indicate that HMs content existence in atmospheric dust is due to coal combustion and associated mining activities in that area.

Table 1. Descriptive statistics of heavy metals in content in wheat grains, soil, dust, and other wheat organs (mg/kg)

	HMs	Pb	Cd	Cu	Zn	As	Cr
Wheat grains(n=24)	Median	0.38	0.10	5.38	25.24	0.12	1.84
	Range	0.11-1.41	0.05-0.22	3.03-9.72	13.5-33.40	0.01-0.38	0.5-6.98
	Chinese standard for food	0.2(n=18)	0.1(n=13)	10(n=0)	50(n=0)	0.5(n=0)	1.0(n=17)
Soil(n=24)	Median	19.00	0.88	22.90	128.32	17.11	58.14
	Range	12.58-28.15	0.33-190	16.06-44.05	80.69-205.52	6.64-31.18	43.17-93.58
	Chinese standard for soil	80(n=0)	0.5(n=20)	100(n=0)	250(n=0)	30(n=2)	200(n=0)
Dust(n=10)	Median	170.51	1.87	135.08	684.53	35.29	103.56
	Range	59.59-650.33	0.52-3.96	38.42-794.88	209.9-1715.21	12.49-113.44	55.71-231.14
HMs Enrichment in wheat organs	Root	0.17	0.74	0.36	0.32	0.08	0.27
	Stem leaf	0.12	0.31	0.17	0.11	0.04	0.35
	Glumes	0.14	0.46	0.17	0.15	0.06	0.36
	Grains or Seeds	0.03	0.13	0.22	0.19	0.01	0.04

Table 2. Correlation analysis of within heavy metals in wheat grains

HM in Grains	Pb	Cd	Cu	Zn	As	Cr
Pb	1	0.544*	-0.231	0.33	0.728*	0.798*
Cd		1	-0.38	0.366	0.695*	0.443†
Cu			1	-0.136	-0.331	-0.173
Zn				1	0.213	0.17
As					1	0.718**
Cr						1

* Significant correlation at level 0.01 (bilateral).
† Significant correlation at level 0.05 (bilateral).

Table 3. Correlation analysis of heavy metals between wheat grains, soil, and other wheat organs

HM in Grains/wheat organs	Pb	Cd	Cu	Zn	As	Cr
Root	0.23	0.259	0.788*	0.673*	-0.26	0.698*
Stem Leaf	0.302	0.303	0.410†	0.788*	-0.301	0.389
Glumes	0.302	0.277	0.790*	0. 594*	-0.239	0.523*
Soil	-0.088	0.112	0.790*	0.371	-0.369	-0.35

* Significant correlation at level 0.01 (bilateral).
† Significant correlation at level 0.05 (bilateral).

The heavy metal content in wheat grains compared with China food hygiene standard (Standard, 1988) and found that Pb, Cd, and Cr are exceptionally high, although Pb and Cr content under permissible limit in soil Table 1. The amount of Cd found less as compared to Pb and Cr though Cr amount exceeding in soil, more than half of the wheat grains are extremely contaminated of these metals (Pb, Cd, and Cr). The content of Cu, Zn, and As found to be under standard in soil as well as wheat grains which is predicted but content of Pb, Cd, and Cr shows contradiction. Results indicate that heavy metals accumulation in wheat grains not only rely on soil source also from other source like presence of high content of heavy metals in dust (influence of these metals on wheat grains).

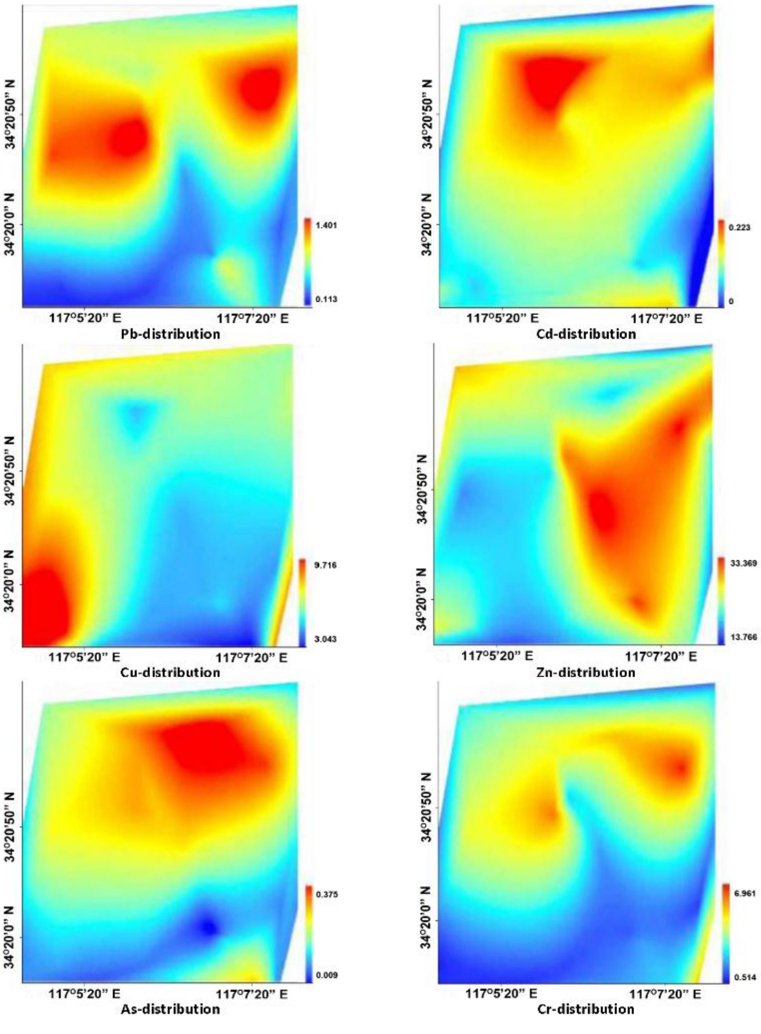

Fig. 2. Spatial distribution of heavy metals in wheat grains

The distribution of heavy metals in different wheat organs vary across the study area at mature stage (chosen this stage for distribution analysis because wheat consumed by habitant after maturity stage of wheat crop) as can be seen at each sample micro level Fig. 3. The distribution of HMs (Pb, Cd, Cu, Zn, As, and Cr) found to be more alike in wheat organs. The presence of HMs in wheat organs expressed as subsequently: root>glume>stem leaf> seeds or grains overall, Fig.4. HMs enrichment high in roots due to direct intake of HMs from soil source despite HMs enrichment found to be high in glumes which show contrary prediction, indicate that fly ash and coal dust great influence of enrichment through atmospheric dust. From other studies found that HMs distribution in different plant organ can be varies, and also depends upon heavy metal combination chemistry (Angelova et al., 2011; Dinulic, 2011). The enrichment pattern of Pb, Cd, and As found as similar with following sequence roots>glumes> stem leaf> seeds or grains, Table 1. The Cd content appear with high enrichment in each wheat organ among other HMs (Pb, Cu, Zn, As and Cr), linked to high content in soil as discussed earlier section 3.1, arise from high mobility and ease of translocation into plants (Liu et al., 2013). The enrichment of Cu in wheat organs as sequence roots>grains>glumes=stem leaf, Zn content found as sequence roots>grains>glumes> stem leaf, and singular enrichment of Cr was found in wheat organs as sequence glumes>stem leaf>roots> grains or seeds. The enrichment of all HMs in glumes found to be high with comparison of stem leaf that appreciably indicate that HMs enriched through dust exposure of wheat organ from atmosphere, Table 1.

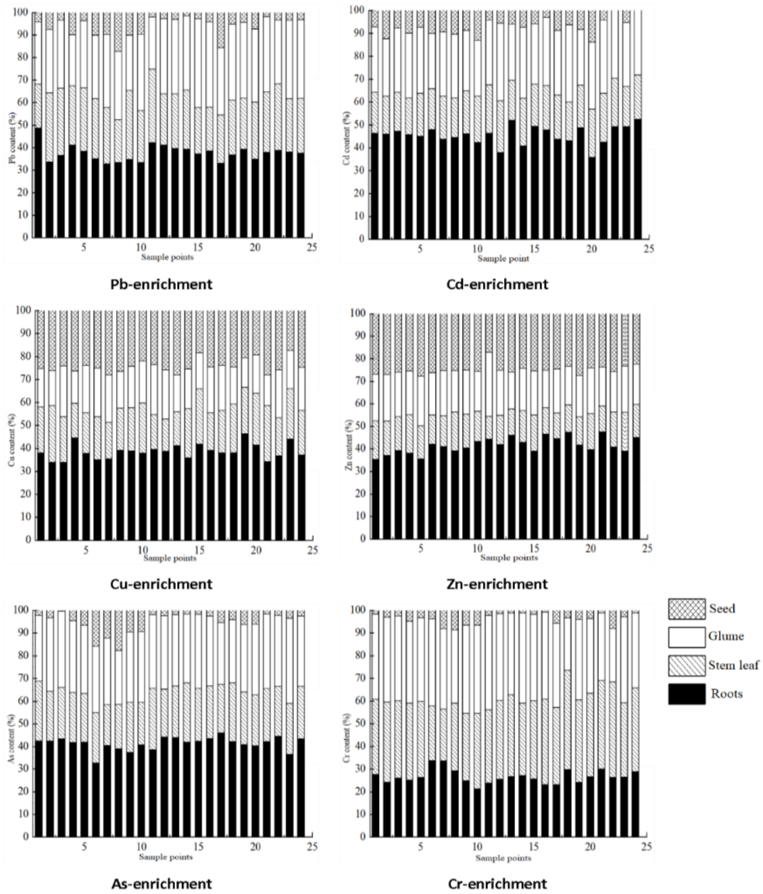

Fig. 3. Enrichment of heavy metals in different wheat organs (grains or seed, glume, stem leaf and roots)

The enrichment of Cd, Cu, and Zn found that high in grains or seeds as compared to remaining HMs, and high enrichment of Cu and Zn in grains or seeds between stem leaf and glumes strongly shows enrichment from atmospheric coal dust. However, the enrichment of Cr found as low in roots comparison with stem leaf and glumes, which shows weak relationship of HMs enrichment from soil and indicate enrichment through atmospheric dust, while enrichment of As is considerably low to other HMs (Pb, Cd, Cu, Zn, and Cr) shows consistency with other studies (Liu et al., 2005; Pu et al., 2018).

Single factor pollution index of HMs can be seen Fig. 5 with clean unpolluted, low polluted, moderate polluted, and high polluted degree of wheat grains. Pollution index value of Zn and Cu *Pi<1* are unpolluted degree, while Pb, Cd, As, and Cr $P_i>1$ which shows polluted with different degree.

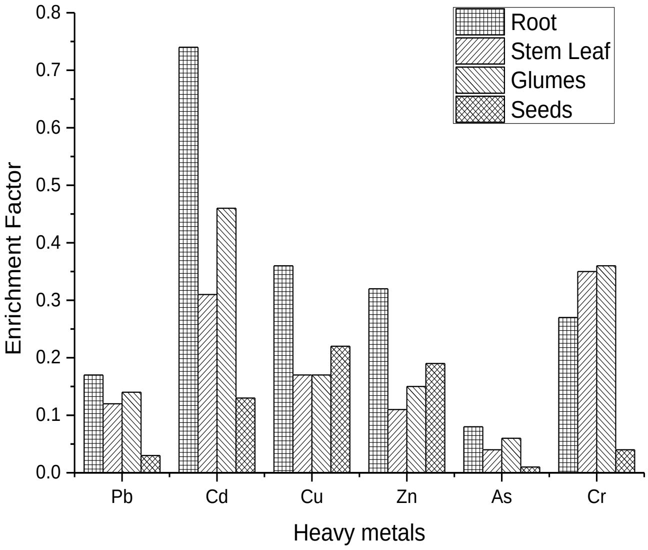

Fig. 4. Enrichment factor of heavy metals in different wheat organs

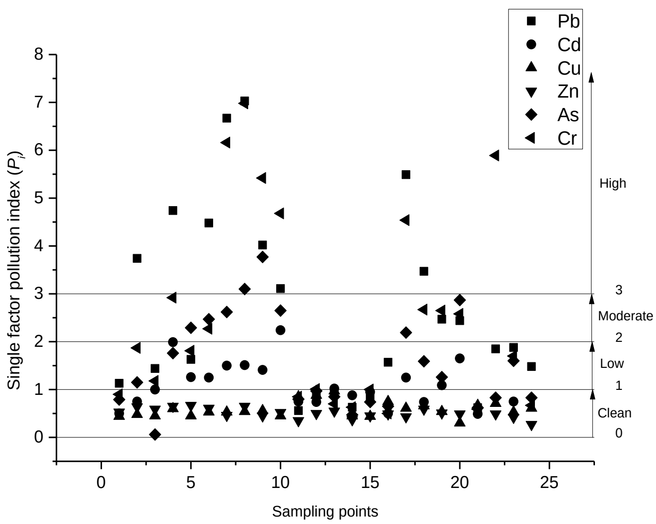

Fig. 5. Single factor pollution index of heavy metals in terms of sampling points.

Pb pollution index exist in 75% of study area (sampling points) which includes 37.5%, 8.3% and 29.2% with high polluted, moderate polluted, and low polluted area respectively. Cd pollution index exist in 45.8% study area including 4.2% and 41.6% with moderate polluted and low polluted area respectively. As pollution index exist in 54.2% study area including 8.4%, 25% and 20.8% with high polluted, moderate polluted, low polluted area respectively. Cr pollution index exist in 66.6% study area including 25%, 20.8% and 20.8% with high polluted, moderate polluted, low polluted area respectively. At study area Pb and Cr pollution was reached high pollution level which is serious in this place, while other metals has moderate or low pollution. The pollution degree of HMs decreasing in the subsequently Pb>Cr>As>Cd>Cu>Zn. Pb and Cr were main pollutants for their P_i values were relatively higher than other sampling area, reaching high or moderate pollution level. The Single pollution index has limitation only feasible for an area which affected by only single pollutant, in fact areas always affected by multiple pollutants, for this reason Nemerow pollution index could be applied to determine the comprehensive pollution level.

Nemerow pollution index shows 71% of area was comprehensively polluted including 16% and 20% of moderately and low polluted while 39% of area found as high polluted, and the rest of area under safe level Fig. 6. Comprehensive pollution found to be in those areas where Single pollution factor index of Pb and Cr have high index. Pollution assessment shows the wheat produced in the coal mining area polluted and dietary intake can pose health risk to the consumers of that region and it should be determined for health safety management practices.

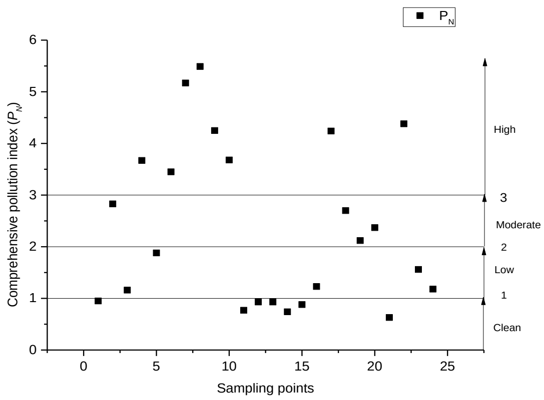

Fig. 6. Nemerow Comprehensive pollution index of heavy metals in terms of sampling points.

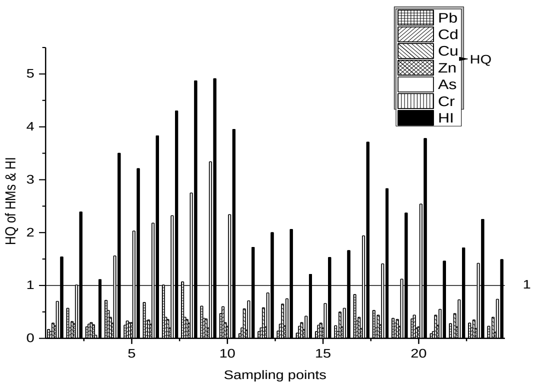

Fig. 7. Non-carcinogenic risk assessment of heavy metals in terms of HQ and HI in adults of study area

As can be seen Fig. 7, represent the non-carcinogenic risk assessment results of heavy metals (HMs) on human health through ingestion pathways in adults of wheat consumer in the study area. The HQ of for Cd, Cu, Zn, Cr were found less than unity of all the samples in study area and appreciably no risk of these metals in towards human health, while Pb have marginal risk found in few samples. In contrast, among all other HMs the HQ for As exceeds extremely in more than 50% samples of study area that is sever threat to human health of adults. The decreasing order of HQ as As>Pb>Cu>Cd>Zn>Cr respectively. Our study results shows consistency with other studies (Kim et al., 2014; Masto et al., 2017; Taylor et al., 2014).The contribution of HQ towards HI in wheat grains more shared from Pb, Cu, and As, thus diseases associated of these would be more dominant that wheat consumer (Adal 2018; Ghoreishy et al. 2018). Fig. shows HI representation for non-carcinogenic health risk among all sample points in study area wheat exposure to adults. HI of all samples points in the study area exceed from unity and average HI is 2.64 which indicate ingestion of wheat has potential health risk. Production of wheat in atmospheric dust and fly ash of coal mine area were found to be harmful for the consumer which can cause of diseases and immediate attention required in that area for healthy safety purposes.

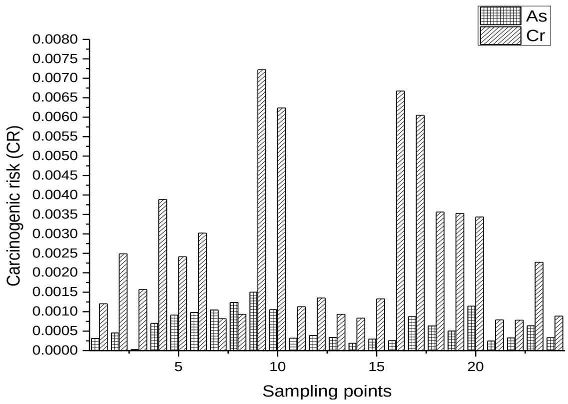

Fig. 8. Carcinogenic risk assessment of As and Cr in wheat grains

Fig. 8, represent the results of carcinogenic risk in adults of study area, it can be seen both CR values of As and Cr have exceeded from permissible limits 1×10^{-4}. Although Cr do not have non-carcinogenic risk in adults but found as carcinogenic risk across study area. The average carcinogenic (CR) values of As and Cr was calculated through ingestion of wheat grains which are 6.12×10^{-4} and 3.37×10^{-3}, respectively. Contrary, As content in wheat grains have not exceed from Standards but still having high carcinogenic risk while Cr content exceeds which shows consistency Table 1. It found that oral intake was the main cause of cancer to the consumer (Hu et al., 2017; Zhang et al., 2018).The results indicated adults have carcinogenic risk from wheat consumption in terms of As and Cr evaluation.

CONCLUSION

The heavy metals content in wheat grains produced from Xuzhou coal mining area compared with Chinese Standards, exceeded for PB, Cd, and Cr, while only Cd and As content exceeded in soil from permissible limits, which were not symmetrical, and other metals remains under permissible limits. The spatial distribution of heavy metals in wheat grains which were complementary related to coal enterprises in terms of coal mining and coal-fired power plant. Most of heavy metals enrichment in wheat organs retained in glume and stem leaf after roots, and followed by grains, indicating that metals were accumulated from atmospheric dust. The enrichment of Pb, As, and Cr are relatively low and heavy metals enriched through soil relatively are few, which caused by atmospheric dust. The correlation analysis of heavy metals in wheat grains shows Pb, Cd, As, and Cr were come from fly ash, coal dust, and other atmosphere pollution source, while Cu may come from soil source.

In non-carcinogenic risk (of Pb, Cd, Cu, Zn, As, and Cr) and carcinogenic risk (of As and Cr) all HI and CR values exceeded threshold values (HI>1, CR>10^{-4}) for adults via wheat oral intake, indicating that inhabitant of Xuzhou coal mining area might have a potential health risk, furthermore Pb, Cu, As, and Cr were contributed more in that risk. This risk increased when consuming wheat grains grown in coal dust, fly ash and atmospheric dust polluted area. To ensure food safety and minimize the damage in the bulk amount of atmospheric dust at coal mining area, more efforts need to make effectively mitigate heavy metals pollution and measures need be taken to reduce human health risk.

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