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Analysis and Evaluation of Heavy Metal Content in Remixing Soil by Feldspathic Sandstone and Sand in Mu Us Sandy Land, China

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Abstract. In order to ensure the quality of cultivated land with the technology of remixing soil by feldspathic sandstone and sand, the concentrations of eight heavy metals were measured, and the degree of heavy metal pollution in the soil was assessed by Nemerow index and potential ecological risk index. The results showed that, compared with feldspathic, the concentrations of Cr, Ni, Cu, Zn, As, Cd and Pb in the remixing soil decreased by 12.8%, 40.7%, 44.1%, 49.3%, 49.8%, 37.6% and 14.1% respectively. The concentrations of eight heavy metals in sandstone and remixing soil were not significantly different in space, but in sand vary greatly. There was very significant positive correlation among the contents of Ni, Cu, Zn, As, Cd and Pb in the remixing soil, which indicates that the heavy metals have obvious homology. The single pollution index of heavy metals in remixing soil, feldspathic sandstone and sand were all less than one, and the comprehensive pollution index were 0.611, 0.980 and 0.395 respectively. The potential ecological risk index (RI) of heavy metals in remixing soil, feldspathic sandstone and sand were all less than 150, indicating that the soils with three textures showed low ecological risks. After three years of planting, the potential ecological risk index of heavy metals in the remixing soil increased slightly, but the single pollution index was also less than one. The research shows that the remixing soil in Mu Us Sandy Land can ensure the quality of soil environment and the safety of agricultural products.

1. Introduction

Mu Us Sandy Land is one of four major deserts in China. It has been faced with serious ecological and environmental problems such as desertification and ecological degradation for a long time (Runnström 2010). In Mu Us Sandy Land, there is an area of more than 1.67×10^6 ha covered by a kind of special



Feldspathic Sandstone (also called Pisha sandstone or Soft rock). When the feldspathic sandstone is dry, it is hard as stone, and soft as mud when wet (Vlastelica et al. 2016). The feldspathic sandstone area is the most eroded area in the Loess Plateau, and it is known as "the most serious soil erosion in the world" and "environmental cancer". Although feldspathic sandstone has low intensity, easy weathering, poor cementation and bad permeability, it has high water holding capacity which can provide water for plant growth. The structure of sandy is loose, and its water holding capacity is poor. By taking advantage of the complementary nature of the feldspathic sandstone and the sand, combining sand and feldspathic sandstone into a new soil can not only reduce and prevent water seepage in sandy land, but also weaken the hard plate knot of the arsenic sandstone, so as to improve the physical characteristics of the soil and achieve the purpose of controlling desertification (Han et al. 2012).

Currently, a number of studies have focused on the technology of remixing soil by feldspathic sandstone and sand from different perspectives. WANG et al. introduced the new model of controlling and developing the sandy land by using the technology of remixing soil by feldspathic sandstone and sand on the basis of experiments (WANG et al. 2013). She et al. studied the effect of feldspathic sandstone amendment on the water retention and water absorption of sand (She et al. 2014). Zhang et al. studied the soil properties such as texture, particle composition, hydraulic parameters and so on (Zhang et al. 2015). Guo et al. studied the cementation force of feldspathic sandstone, sand and remixing soil of Mu Us sandy land by confocal laser raman micros (Guo et al. 2017). Wang et al. set up a water-fertilizer management system suitable for different crops in different growth stages of Mu Us sandy land (Wang et al. 2017). Luo et al. Studied the characteristics of nitrogen leaching on remixing soil by feldspathic sandstone and sand (Luo et al. 2013). Li et al. Studied the effects of the remixing soil by feldspathic sandstone and sand on the photosynthetic physiology and yield of wheat (Juan et al. 2014). Zhang et al. studied the application of the technology of remixing soil by feldspathic sandstone and sand in Mu Us Sandy Land (Zhang et al. 2015).

In summary, the research on the technology of remixing soil by feldspathic sandstone and sand in Mu Us sandy land had been deeply studied, including the introduction of the overall technology, the study of soil characteristics, the influence of soil characteristics on the crop, engineering application and so on. However, less report has been made on the quality of new cultivated land and the safety of planting agricultural products by the remixing soil, and the changes of heavy metal content in remixing soil by feldspathic sandstone and sand with time is not clear. By collecting and analyzing the soil samples around the Yulin mining area in Northern Shaanxi, it was found that the soil in the mining area of Yulin was polluted by 8 kinds of heavy metals in different degrees (Liu et al. 2010). There are two main ways of the source of heavy metals in soil: natural disturbance and artificial disturbance (Tóth et al. 2017). Metals can accumulate in soil and residue in crops, enter the human body through the food chain, and bring potential hazards to the people health. Soil heavy metal pollution has the characteristics of universality, concealment, hysteresis, correlation and comprehensiveness (Díaz et al. 2013). Hence, the objective of this study is to determine the contents of heavy metals in farmland soil of Mu Us sandy land, and the ecological risk assessment was carried out by using the Nemerow index and the potential ecological risk index method, aiming at providing scientific reference for regional environmental protection and scientific reference for treatment and protection of heavy metal pollution in farmland soil in Mu Us Sandy Land.

2. Methods and Materials

The study area is located in Mengjiawan village (38°27'34", 109°33'15" E) of Yulin city, Mu Us Sandy Land of China. It uses the technology of remixing soil by feldspathic sandstone and sand to carry out desert treatment and land reclamation. The project, with an area of about 163 hm² and an altitude of 1206~1215m, is a typical mid-temperate semi-arid continental monsoon climate zone, four seasons, ample sunshine, warm and humid in summer, cold and dry in winter. The mean annual temperature is 8.1 °C, annual precipitation is 413.9 mm, annual frost-free period 154d. The long-term average climate data were obtained from the weather bureau in Yulin, which about 5 km far away from the experimental field.

The study area is divided into 7 zones on average, each zone is about 23.3 hm². The feldspathic sandstone and sand were only sampled once in 2013, and the remixing soil of the project area were sampled twice in 2013 and 2016. Surface soil samples (0~20 cm) from each region were collected by “S” sampling procedure (Mirzaei et al. 2014) and mixed into one sample. All the samples were ground after air-drying, passed through the 0.149-mm mesh screen for the analysis of heavy metal contents (Willscher et al. 2016). The concentrations of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) in soil were measured by inductively coupled plasma atomic emission spectrometry (ICP-MAS, Agilent 7700) (Buonocore et al. 2010). The concentration of mercury (Hg) was determined by atomic fluorescence spectrometry (AFS-7960, Haiguang) (Lu et al. 2015). The concentration of trace metals obtained from the reagents, glassware and Teflon containers used in the test was below the detection limit. Quality control of soil analysis was performed using standard reference materials (GSS-8, GSS-10, and GSF-3) obtained from the China National Standards Materials Center. The recovery of heavy metal content in the reference material is between 90% and 110%, and the pH value of the soil is determined by the glass electrode method.

The Nemerow index one of the most commonly used methods to calculate the comprehensive pollution index at home and abroad (Ramdani et al. 2018). The comprehensive pollution index (P_{ix}) is calculated as follows:

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

$$P_{ix} = \sqrt{\frac{(P_{iave})^2 + (P_{imax})^2}{2}}$$

Where: C_i is measured value of heavy metal concentration for the given metal of “i”; S_i is he background value of the risk screening value (pH > 7.5) stipulated in the soil environmental quality control standard for agricultural land pollution (GB 15618-2018) (Table 1). P_{iave} is the average value of soil single factor pollution index, and P_{imax} is the maximum value of soil single factor pollution index.

Table 1. National pollutant control standard, environmental background values and toxicity factor of heavy metals in the sediments

Element	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
S_i (mg/kg)	0.3	200	2.4	30	120	100	250	100
C_n^i (mg/kg)	0.76	62.5	0.063	11.1	21.4	21.4	69.4	28.8
T_r^i	30	2	40	10	5	5	1	5

Potential Ecological Risk Index Method (Hkanson Method) is a commonly used risk assessment method for soil (sediment) heavy metal pollution research. This method not only reflects the influence of a single pollutant in a specific environment, but also reflects the comprehensive influence of various pollutions (Protano et al. 2014). The RI could be calculated by the following equation (Rana et al. 2016):

$$P_r^i = \frac{C_s^i}{C_n^i}$$

$$E_r^i = T_r^i P_r^i$$

$$RI = \sum_{i=1}^n E_r^i$$

Where: T_r^i is the toxic response factor for the given metal of “i”, which demonstrate their toxic and ecological sensitivity levels; this study adopted the T_r^i proposed by Hakanson (Table 1(Zhu et al. 2018)). C_s^i is measured value of heavy metal concentration; C_n^i is he background value of soil

environment in Shaanxi Province; E_r^i is a single factor potential ecological hazard factor and RI is a multi-factor integrated potential ecological hazard index.

Statistical analyses were conducted using SPSS 10.01. The difference of heavy metal contents was tested using one-way analysis of variance (ANOVA).

3. Results and Discussion

The results of sampling and testing in 2013 show that the average values of pH of feldspathic sandstone, sand and remixing soil are 8.35, 8.29 and 8.41, respectively, indicating that the remixing soil, feldspathic sandstone and sand are alkaline, so the risk screening value ($\text{pH} > 7.5$) stipulated in the soil environmental quality control standard for agricultural land pollution (GB 15618-2018) was taken as the evaluation standard.

The heavy metal concentrations of feldspathic sandstone, sand and remixing soil are shown in Table 2. It can be seen from the table that the Cr, Ni, Cu, Zn, As, Cd and Pb in the remixing soil decreased by 12.8%, 40.7%, 44.1%, 49.3%, 49.8%, 37.6% and 14.1%, respectively, compared with the feldspathic sandstone, indicating that the soil contaminating degree and the harm to human beings can be reduced by the physical measures for remixing soil. In the three kinds of soil, the concentrations of Hg from high to low are remixing soil, feldspathic sandstone and sand, and the other seven elements are feldspathic sandstone, remixing soil and sand. The mean concentrations of heavy metals in feldspathic sandstone, sand and remixing soil were all lower than the risk screening value ($\text{pH} > 7.5$) stipulated in the soil environmental risk control standard (GB 15618-2018).

Table 2. Grades of Nemerow index of heavy metal pollution

Scope of Nemerow comprehensive pollution index (P_{ix})	Pollution grade	Pollution level
$P_{ix} \leq 0.07$	Security	Soil and crops are clean
$P_{ix} < P \leq 1$	Warning	Soil and crops are still clean
$1 < P_{ix} \leq 2$	Light pollution	Soil and crops are slightly polluted
$2 < P_{ix} \leq 3$	Moderate pollution	Soil and crops are moderately polluted
$P_{ix} > 3$	Heavy pollution	Soil and crops are seriously polluted

The coefficient of variation reflects the mean degree of variation of each sample. Generally, the coefficient of variation is weak mutation in 0-10%, moderate mutation in 10-100% and strong mutation in over 100% (Rana et al. 2016). It can be seen from Table 3 that the mean variation degree of the contents of eight heavy metals in the remixing soil in the study area from large to small were As, Cu, Zn, Hg, Ni, Cd, Cr and Pb with the coefficient of variation of 10.75% ~ 68.17%. The variation degree of the concentrations of eight heavy metals in the feldspathic sandstone from large to small were Zn, Cr, Ni, Cu, Cd, Pb, Hg and As with the coefficient of variation of 0.76 %~ 26.87%. The mean variation degree of the concentrations of eight heavy metals in the sand from large to small were As, Cu, Ni, Hg, Cd, Zn, Cr, and Pb with the coefficient of variation of 3.14 %~96.13%. The concentrations of eight heavy metals in sandstone and remixing soil were not significantly different in space, but the concentrations of eight heavy metals in sand vary greatly. Sand has the characteristics of strong fluidity and easy to migrate with the wind (Rittner et al. 2016), which results in great difference of pollution degree among different sites. Except for Zn and Cr, the coefficient of variation of the content of heavy metals in the feldspathic sandstone is the smallest compared with the remixing soil and sand. The coefficients of variation of Cr, Ni and Cu (4.38%, 3.69 % and 3.34%, respectively) in the feldspathic sandstone were close, and those of As, Cd, Hg and Pb (0.76 %, 1.58% and 1.12%, respectively) were close. This suggests that human activities contribute similarly to the pollution of these heavy metals, or that heavy metals have homology (Adokoh et al. 2011).

Table 3. Grades of potential ecological risk index of heavy metal pollution

Scope of potential ecological risk index (E_r^i)	Scope of integrated potential ecological risk index (RI)	Ecological risk level
<40	<150	low
40~80	150~300	moderate
80~160	300~600	Considerable
160~320	600~1200	high
≥ 320	≥ 1200	Significantly high

Heavy metals in the soil are derived from the parent material and human activities, and there is a correlation among heavy metals from the same sources (Lalah et al. 2008). The correlation between soil heavy metal concentrations and soil properties is not only affected by the nature of the element themselves, but also greatly related to the environment the source of the elements (Desenfant et al. 2004). The correlation coefficient of soil heavy metal concentrations in remixing soil is shown in Table 8. It could be seen from Table 8 that Cu-Ni, Zn-Ni, As-Cu, Cd-Zn, Cd-As, Pb-Ni, and Pb-As had a very significant correlation at $p = 0.01$ level, and Cr-Ni, Cr-As, Cr-Cd, Ni-Zn, Ni-Cd, Ni-Hg, Cu-Cd, Cu-Hg, Cu-Pb, Zn-As, Cd-Pb, Hg-Pb had a significant correlation at $p = 0.05$ level. The analysis shows that the five heavy metals of As, Cd, Cu, Pb, and Zn have high homology. If there is a high correlation between heavy metals, it indicates that these heavy metals have the same source in the migration and transformation process, and these heavy metals are interdependent with the similar mechanisms of migration and transformation (Shou et al. 2012). If the correlation between heavy metals is low, it indicates that these heavy metal elements are not only affected by a single factor, but also by the combination of geochemical behavior and its own properties (Mici et al. 2013). From the above analysis, it is known that heavy metals in remixing soil were combined pollution and had the same source. On the one hand, it comes from the parent material of soil formation; on the other hand, it comes from the chemical fertilizer applied by local farmers to improve the fertility of remixing soil.

Table 4. The heavy metal concentrations in feldspathic sandstone, sand and remixing soil in 2013

Sample type		Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
Remixing soil	Min(mg/kg)	0.184	16.64	0.05	2.48	15.79	2.34	2.41	6.273
	Max(mg/kg)	0.327	27.23	0.14	15.5	21.44	8.79	6.92	14.55
	Mean(mg/kg)	0.253	21.73	0.074	6.28	17.91	4.86	4.97	9.37
	Standard deviation	0.056	3.11	0.032	4.28	1.93	2.5	2.43	3.14
	Coefficient of variation	22.07	14.31	43.55	68.17	10.75	51.50	48.90	33.57
Feldspathic sandstone	Max(mg/kg)	0.401	24.15	0.062	12.45	20.61	8.5	7.95	15.39
	Min(mg/kg)	0.41	25.7	0.063	12.59	21.06	8.91	11.66	16.21
	Mean(mg/kg)	0.406	24.93	0.063	12.52	20.84	8.7	9.81	15.8
	Standard deviation	0.006	1.09	0.001	0.1	0.32	0.29	2.64	0.58
	Coefficient of variation	1.58	4.38	1.12	0.76	1.53	3.34	26.87	3.69
Sand	Max(mg/kg)	0.155	18.88	0.035	0.39	15.27	2.15	0.643	5.38
	Min(mg/kg)	0.173	20.06	0.04	2.06	15.96	2.52	0.706	6.24
	Mean(mg/kg)	0.164	19.47	0.038	1.22	15.62	2.34	0.675	5.81
	Standard deviation	0.013	0.83	0.004	1.18	0.49	0.27	0.045	0.61
	Coefficient of variation	7.74	4.28	9.33	96.13	3.14	11.42	6.60	10.46

Table 5. Correlation coefficients matrix among heavy metals in remixing soil in 2013

Element	Ni	Cu	Zn	As	Cd	Hg	Pb
Cr	1.00**						
Ni	0.77*	1.00**					
Cu	0.7	0.98**	1.00**				
Zn	0.61	0.81*	0.7	1.00**			
As	0.72*	0.93**	0.89**	0.71*	1.00**		
Cd	0.76*	0.83*	0.71*	0.90**	0.84**	1.00**	
Hg	0.61	0.75*	0.80*	0.26	0.77*	0.36	1.00**
Pb	0.56	0.87**	0.83*	0.67	0.96**	0.74*	0.77*

* $p < 0.05$, ** $p < 0.01$

Table 6. Assessment of Nemerow index of heavy metals in feldspathic sandstone, sand and remixing soil in 2013

Sample type	P_i								P_{ix}	Pollution assessment
	Cr	Ni	Cu	Zn	As	Cd	Hg	Pb		
Remixing soil	0.843	0.109	0.031	0.209	0.149	0.049	0.020	0.094	0.611	Warning
Feldspathic sandstone	1.353	0.125	0.026	0.417	0.174	0.087	0.039	0.158	0.980	Warning
sand	0.547	0.097	0.016	0.041	0.130	0.023	0.003	0.058	0.395	Warning

The single pollution index of heavy metals in remixing soil, feldspathic sandstone and sand were all less than one, indicating that the soils of three textures were not polluted by heavy metals, but needed to be warned. The pollution degree of the eight heavy metals in the remixing soil from large to small were Cd, As, Pb, Cr, Ni, Cu, Hg and Zn (0.843, 0.209, 0.156, 0.109, 0.094, 0.049, 0.031 and 0.020, respectively), and the comprehensive pollution index (P_{ix}) from large to small were remixing soil, feldspathic sandstone and sand (0.611, 0.980 and 0.395, respectively). Nemerow index method is one of the most commonly used methods for comprehensive pollution index calculation at home and abroad. This method is simple in concept, and the comprehensive environmental quality of the evaluation area can be known only by calculating the comprehensive index and comparing the corresponding grading standards according to this method. However, Nemerow index method is susceptible to the largest single pollution index, and does not consider the toxicity of heavy metals, so that its sensitivity to environmental quality assessment is not high enough. In some cases, its results are difficult to distinguish the degree of soil environmental pollution difference (Dawood 2017).

Table 7. Assessment of potential ecological risk of heavy metals in feldspathic sandstone, sand and remixing soil in 2013

Sample type		Cd	Cr	Hg	As	Pb	Cu	Zn	Ni	RI
Remixing soil	Min	7.26	0.53	31.75	2.23	3.69	0.55	0.03	1.09	47.14
	Max	12.91	0.87	88.89	13.96	5.01	2.05	0.10	2.53	126.32
	Mean	9.99	0.70	46.98	5.66	4.18	1.14	0.07	1.63	70.34
Feldspathic sandstone	Min	15.83	0.77	39.37	11.22	4.82	1.99	0.11	2.67	76.77
	Max	16.18	0.82	40.00	11.34	4.92	2.08	0.17	2.81	78.33
	Mean	16.03	0.80	40.00	11.28	4.87	2.03	0.14	2.74	77.89
Sand	Min	6.12	0.60	22.22	0.35	3.57	0.50	0.01	0.93	34.31
	Max	6.83	0.64	25.40	1.86	3.73	0.59	0.01	1.08	40.13
	Mean	6.47	0.62	24.13	1.10	3.65	0.55	0.01	1.01	37.54

Table 8. The heavy metal concentrations and potential ecological risk in remixing soil in 2016

Sample type		Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
Concentrations (mg/kg)	min	0.189	23.66	0.106	5.56	12.25	2.56	1.13	0.26
	max	0.321	42.15	0.131	15.12	19.36	5.33	3.22	1.12
	mean	0.225	35.42	0.126	8.54	16.31	3.26	2.13	0.57
Potential ecological risk	min	7.46	0.76	67.30	5.01	2.86	0.60	0.02	0.05
	max	12.67	1.35	83.17	13.62	4.52	1.25	0.05	0.19
	mean	8.88	1.13	80.00	7.69	3.81	0.76	0.03	0.10

In order to further evaluate soil environmental quality, the potential ecological risk index of heavy metals in the study area was calculated. The range of potential ecological risk index (RI) of remixing soil sand in the study area is 47.1~126.3, with an average of 70.3. The range of the potential ecological risk index (RI) of feldspathic sandstone is 76.8~78.3, with an average of 77.9. The range of the potential ecological risk index (RI) of sand is 34.3~40.1, with an average of 37.5. The potential ecological risk index (RI) of heavy metals of heavy metals in remixing soil, feldspathic sandstone and sand were all less than 150 (as shown in Table 7), indicating that the soils with three textures showed low ecological risks. The ecological risks of heavy metals in the remixing soil from high to low were Hg, Cd, As, Pb, Ni, Cu and Cr, and the range and means of the potential ecological risk index of Hg were the largest among these metals, ranging from 31.8 to 88.9, with an average value of 47.0, which needed to be noticed. Remixing soil is composed of feldspathic sandstone and sand, and its parent material is not essential different from feldspathic sandstone and sand. From the sources of heavy metals in soil, the heavy metals mainly come from human activities. Because of non-polluting enterprises around, the main pollution source may come from the chemical fertilizer applied by local farmers during the cultivation process.

In order to determine the effect of planting years on the content of heavy metals in the remixing soil, the concentrations of heavy metals in the remixing soil of the study area were measured and analyzed in 2016. The concentrations of heavy metals in the remixing soil after three years of planting were shown in Table 8. The concentrations of Cd, Cr, Hg, As, Pb, Cu, Zn and Ni were lower than the risk screening values stipulated in the soil pollution risk control standards for agricultural land. The mean concentrations of Cr, Hg and As in the remixing soil of the study area increased by 63.0%, 70.3% and 36.0% respectively, while the concentrations of Cd, Pb, Cu, Zn and Ni decreased by 11.1%, 8.9%, 32.9%, 57.1% and 93.9% compared with those in 2013. The range of the potential ecological risk of remixing soil calculated by the risk index (RI) was 84.1~116.8 with a mean value of 102.4 and revealed a low ecological risk in the study area, which will not cause harm to human and plant growth for the time being. However, it is worth noting that the average ecological risk index of the compounded soil in the project area increased by 45.6% compared with that in 2013. Chemical fertilizers and pesticides are the fruits of modern industrial development. They have played an irreplaceable role in promoting the development of grain and agricultural production. However, there are still problems such as excessive and blind application. Some chemical fertilizers and pesticides have residual risk of heavy metals due to production process defects (Divya 2012). With the application of fertilizers, heavy metals directly enter farmland soil and remain in farmland soil. Long-term accumulation of heavy metals in farmland soils and crops may lead to excessive levels of heavy metals, resulting in environmental pollution. It is suggested that in the future agricultural planting process, attention should be paid to protecting soil, avoiding heavy metal pollution and affecting crop cultivation, applying organic fertilizer and straw to improve soil fertility as far as possible, and minimizing the use of chemical fertilizers and pesticides.

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References

- [1] Adokoh CK, Obodai EA, Essumang DK, Serfor-Armah Y, Nyarko BJ, Asabere-Ameyaw A (2011) Statistical evaluation of environmental contamination, distribution and source assessment of heavy metals (aluminum, arsenic, cadmium, and mercury) in some lagoons and an estuary along the coastal belt of Ghana. *Archives of Environmental Contamination & Toxicology* 61: 389-400.
- [2] Buonocore M, Cardellicchio N, Leo AD (2010) Assessment of atmospheric heavy metal deposition in the Taranto urban area using the moss biomonitoring technique and ICP –MS analysis. *Journal of Biotechnology* 150: 567-567.
- [3] Díaz RO, Fonticiella MD, Arado López JO, Borrell Muñoz JL, D'Alessandro RK, López PN (2013) Spatial distribution and contamination assessment of heavy metals in urban topsoils from Las Tunas City, Cuba. *Bulletin of Environmental Contamination & Toxicology* 91: 29-35.
- [4] Dawood AS (2017) Using of Nemerow's Pollution Index (NPI) for Water Quality Assessment of Some Basrah Marshes, South of Iraq 25: 1708-1720.
- [5] Desenfant F, Petrovský E, Rochette P (2004) Magnetic Signature of Industrial Pollution of Stream Sediments and Correlation with Heavy Metals: Case Study from South France. *Water Air & Soil Pollution* 152: 297-312.
- [6] Divya J, Belagali SL (2012) Impact of chemical fertilizers on water quality in selected agricultural areas of Mysore district, Karnataka, India. *Agris On-line Papers in Economics and Informatics* 2: 1449-1458.
- [7] Guo H, Han J, Zhang Y, Wang H, Sun Y, Li X, Zhang H (2017) Cementation Force of Compound Soil Mixed by Soft Rock and Sand: Raman Spectrum Study[J]. *Laser & Optoelectronics Progress* 54(11):430-436
- [8] Han J, Xie J, Zhang Y (2012) Potential Role of Feldspathic Sandstone as a Natural Water Retaining Agent in Mu Us Sandy Land, Northwest China. *Chinese Geographical Science* 22: 550-555.
- [9] Juan LI, Han J, Xiaoming LI (2014) Effects of Remixed Soil with Soft Rock and Sand on Photosynthetic Characteristics and Yield of Winter Wheat. *Journal of Triticeae Crops* 34: 203-209.
- [10] Lalah JO, Ochieng EZ, Wandiga SO (2008) Sources of heavy metal input into Winam Gulf, Kenya. *Bulletin of Environmental Contamination & Toxicology* 81: 277-284.
- [11] Liu ZL, Zhao ZY, Yu-Miao LU (2010) Evaluation on Arsenic and Heavy Metal Pollution in Apple Orchard Soil in Shaanxi Province. *Arid Zone Research* 27: 273-277.
- [12] Lu S, Wang Y, Teng Y, Yu X (2015) Heavy metal pollution and ecological risk assessment of the paddy soils near a zinc-lead mining area in Hunan. *Environmental Monitoring & Assessment* 187: 627.
- [13] Luo LT, Cheng J, Wang HY, Han JC, Yan-Tao HU, Zeng-Hui MA (2013) Nitrogen Leaching Characteristics in the Compound Soil of Feldspathic Sandstone and Sand Under Corn Conditions. *Journal of Soil & Water Conservation* 27: 58-57.
- [14] Mici RiJ, Dimitrijevi DS, Kosti DA, Stojanovi GS, Miti SaS, Miti MN, Pavlovi AN, Ran?elovi SaS (2013) Content of Heavy Metals in Mulberry Fruits and Their Extracts-Correlation Analysis. *American Journal of Analytical Chemistry* 4: 674-682.
- [15] Mirzaei R, Ghorbani H, Moghaddas NH, Martín JAR (2014) Ecological risk of heavy metal hotspots in topsoils in the Province of Golestan, Iran. *Journal of Geochemical Exploration* 147: 268-276.

- [16] Protano C, Zinnà L, Giampaoli S, Romano SV, Chiavarini S, Vitali M (2014) Heavy metal pollution and potential ecological risks in rivers: a case study from southern Italy. *Bulletin of Environmental Contamination & Toxicology* 92: 75-80.
- [17] Ramdani S, Amar A, Belhsaien K, Hajjaji SE, Ghalem S, Zouahri A, Douaik A (2018) Assessment of Heavy Metal Pollution and Ecological Risk of Roadside Soils in Tlemcen (Algeria) Using Flame-Atomic Absorption Spectrometry. *Analytical Letters*: 1-20.
- [18] Rana V, Maiti SK, Jagadevan S (2016) Ecological Risk Assessment of Metals Contamination in the Sediments of Natural Urban Wetlands in Dry Tropical Climate. *Bull Environ Contam Toxicol* 97: 407-412.
- [19] Rittner M, Vermeesch P, Carter A, Bird A, Stevens T, Garzanti E, Andò S, Vezzoli G, Dutt R, Xu Z (2016) The provenance of Taklamakan desert sand. *Earth & Planetary Science Letters* 437: 127-137.
- [20] Runnström MC (2010) Rangeland development of the Mu Us Sandy Land in semiarid China: an analysis using Landsat and NOAA remote sensing data. *Land Degradation & Development* 14: 189-202.
- [21] She X, Zhang X, Wei X (2014) Improvement of water absorbing and holding capacities of sandy soil by appropriate amount of soft rock. *Transactions of the Chinese Society of Agricultural Engineering* 30: 115-123.
- [22] Shou Z, Feng C, Yang Y, Niu J, Shen Z (2012) Risk assessment of sedimentary metals in the Yangtze Estuary: New evidence of the relationships between two typical index methods. *Journal of Hazardous Materials* 241-242: 164-172.
- [23] Tóth G, Hermann T, Szatmári G, Pásztor L (2017) Remarks to the debate on mapping heavy metals in soil and soil monitoring in the European Union. *Science of the Total Environment* 603.
- [24] Vlastelica G, Mišćević P, Pavić N (2016) Testing the shear strength of soft rock at different stages of laboratory simulated weathering. *Grđevinar* 68: 955-965.
- [25] WANG, Jianchang, Jichang (2013) A Sand Control and Development Model in Sandy Land Based on Mixed Experiments of Arsenic Sandstone and Sand: A Case Study in Mu Us Sandy Land in China. *Chinese Geographical Science* 23: 700-707.
- [26] Wang H, Han J, Tong W, Cheng J, Zhang H (2017) Analysis of water and nitrogen use efficiency for maize (*Zea mays* L.) grown on soft rock and sand compound soil. *Journal of the Science of Food & Agriculture* 97: 2553.
- [27] Willscher S, Jablonski L, Fona Z, Rahmi R, Wittig J (2016) Phytoremediation experiments with *Helianthus tuberosus* under different pH and heavy metal soil concentrations. *Hydrometallurgy* 168.
- [28] Zhang L, Han J, Ma Z, Luo L, Wang H (2014). Texture Character Study of Feldspathic Sandstone and Sand Compound "Soil". *Acta Agriculturae Boreali-Occidentalis Sinica* 4 :166-172
- [29] Zhang W, Han J, Wang H, Du Y, Tong W (2015) The improvement effects of softrock on sandy soil in Mu Us sandy land. *Journal of Arid Land Resources & Environment* 29 (10) :122-127
- [30] Zhu D, Wei Y, Zhao Y, Wang Q, Han J (2018) Heavy Metal Pollution and Ecological Risk Assessment of the Agriculture Soil in Xunyang Mining Area, Shaanxi Province, Northwestern China. *Bulletin of Environmental Contamination & Toxicology*: 1-7