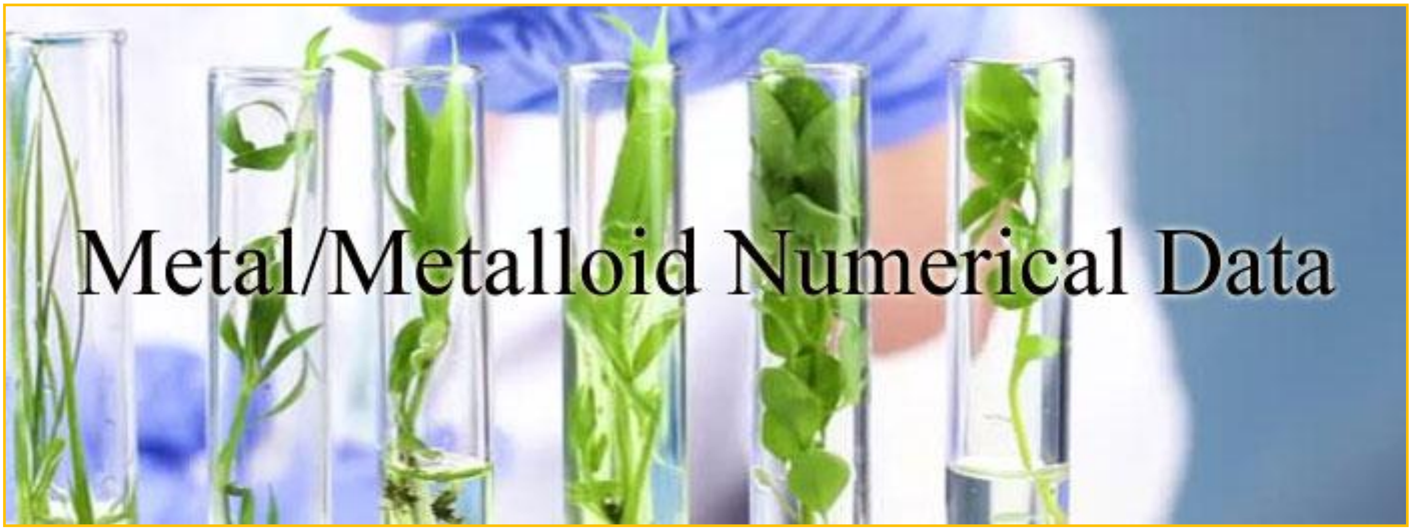



Impacts of heavy metals and medicinal crops on ecological systems, environmental pollution, cultivation, and production processes in China (2021)

Table 1: Impact of heavy metal ions in risk-inducing herbal medicines on humans and values of EDI (estimated daily intakes) and CR (carcinogenic risks) based on literature review.

| **y metals** | **$RfD_0$ (US EPA, 2000)** | **Representative herbs (118 kinds, 1902 samples)** | | | | **Health effects** | **References** |
|---|---|---|---|---|---|---|---|
| | | **Max EDI** | **Related examples** | **Max CR** | **Related examples** | | |
| | **(mg kg$^{-1}$ day$^{-1}$ bw)** | | | | | | |
| **Pb** | 0.004 | 0.004 | *Lonicera confusa* DC., *Tetradium ruticarpum* (A. Juss.) | 1.23E-07 | *Tetradium ruticarpum* (A. Juss.) | Adverse effect on the blood, nervous, immune, renal, skeletal, muscular, reproductive, and cardiovascular systems causing, poor muscle coordination, gastrointestinal symptoms, brain and kidneys damage, hearing and vision impairments, reproductive defects, slowed cognitive development, learning deficits, can damage the testicles in men, ultimately cause death. | (Dghaim et al., 2015, Martin and Griswold, 2009, Luo et al., 2021) |
| | | 0.005 | *Lonicera japonica* Thunb. | 1.15E-07 | *Plantago asiatica* L. | | |
| | | 0.008 | *Grona styracifolia* (Osbeck) H. Ohashi and K. Ohashi | 8.07E-08 | *Lonicera japonica* Thunb. | | |
| | | 0.024 | *Plantago asiatica* L. | 4.54E-08 | *Lonicera confusa* DC. | | |
| **As** | 0.0003 | 0.002 | *Cornus officinalis* Siebold and Zucc., *Taraxacum officinale* (L.) Weber ex | 1.34E-06 | *Plantago asiatica* L. | Decreased production of hemoglobin, red blood cells and white blood cells, abnormal heart rhythm, hypertension, diabetes, cardiovascular disease, skin lesions, hyperpigmentation, keratosis, and neurodegenerative disorders. | (Kapaj et al., 2006, Rana et al., 2018, Ray et al., 2014, Luo et al., 2021) |
| | | | | 1.09E-06 | *Cornus officinalis* Sieb. et Zucc. | | |
| | | 0.007 | *Plantago asiatica* L. | 9.20E-07 | *TaraxacMm mongolicum Hand. -Mazz.* | | |
| | | | | 7.43E-07 | *Andrographis paniculate* (Burm. f.) | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nees | | |
| **Cd** | 0.001 | 0.001 | *Andrographis paniculata* (Burm.f.) Nees, *Curcuma longa* L., *Lonicera confusa* DC. | 1.55E-06 | *Curcuma longa* L. | Irreversible impairment of the renal tract; serious damage of liver, lungs, vascular and immune system; fragile bones, irritates the stomach, leading to vomiting and diarrhea. | (Dghaim et al., 2015, Li et al., 2012, Martin and Griswold, 2009, Maobe et al., 2012, Luo et al., 2021) |
| | | | | 1.39E-06 | *Rheum palmatum* L. | | |
| | | | | 1.23E-06 | *Houttuynia cordata* Thunb. | | |
| | | 0.002 | *Houttuynia cordata* Thunb. | 1.12E-06 | *Lonicera confusa* DC. | | |
| **Hg** | 0.0001 | 0.001 | *Chrysanthemum indicum* L., *Forsythia suspensa* (Thunb.) Vahl, *Tussilago farfara* L. | 2.18E-06 | *Andrographis paniculata* (Burm. F.) Nees | Numerous deleterious effects on various organisms of the body within the digestive, immune, urinary, nervous systems, arrhythmias, cardiomyopathy, respiratory failure and kidney damage. | (Luo et al., 2021, Rana et al., 2018, Khan et al., 2019) |
| | | | | 1.72E-06 | *Plantago asiatica* L. | | |
| | | | | 1.64E-06 | *Cornus officinalis* Sieb. et Zucc. | | |
| | | | | 1.60E-06 | *Curcuma longa* L. | | |
| **Cu** | 0.04 | 0.015 | *Plantago asiatica* L. | – | – | Dermatitis, irritation of the upper respiratory tract, abdominal pain, nausea, diarrhea, vomiting, liver damage. | (Dghaim et al., 2015, Luo et al., 2021, Kohzadi et al., 2018) |
| | | 0.012 | *Desmodium styracifolium* (Osb.) Merr. | | | | |
| | | 0.008 | *Houttuynia cordata* Thunb. | | | | |
| **Zn** | 0.3 | 0.100 | *Zantedeschia aethiopica* (L.) Spreng., *Viola odorata* L. | – | – | Toxic effects on the immune system, blood lipoprotein levels, and copper level. | (Dghaim et al., 2015, Luo et al., 2021, Kohzadi et al., 2018) |
| **Fe** | 0.7 | 0.850 | *Viola odorata* L., *Matricaria chamomilla* L. | – | – | Gastrointestinal effects such as gastrointestinal bleeding, nausea and vomiting, dizziness, diarrhea, joints pain, shock, and liver damage, hypotension, lethargy, tachycardia, hepatic necrosis, metabolic acidosis and sometimes dead. | (Dghaim et al., 2015, Luo et al., 2021, Kohzadi et al., 2018) |

RfDo: International oral reference dose values for the heavy metals, EDI: Estimated daily intake (theoretical value without being corrected for % solubilization and bioavailability), CR: Carcinogenic risks. Acceptable risk levels for CR range from $10^{-4}$ (risk of developing cancer over a human lifetime is 1 in 10,000) to $10^{-6}$ (risk of developing cancer over a human lifetime is 1 in 1,000,000). (Adusei-Mensah et al., 2019). The EDI and CR scores in this table were calculated with maximal concentrations of each herbal medicine.

Table 2: The comparison between studies about heavy metal pollution to soils in China and elsewhere in the world (Huang et al., 2019b).

| Element (mg/kg) | Cd | Cr | Hg | As | Pb | Cu | Zn | Ni | Review/scope of monitoring | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| **Chinese agricultural soils** | 0.24 | 62.2 | 0.13 | 10.7 | 32.1 | 28.3 | 83.3 | 28.2 | Review (336 articles) | (Huang et al., 2019b) |
| **Chinese agricultural soils** | 0.43 | 58.9 | 0.24 | 10.2 | 37.6 | 31.7 | 117.2 | 27.5 | Review (12 articles) | (Wei and Yang, 2010) |
| **Chinese agricultural soils** | 0.25 | 65.3 | 0.16 | 9.5 | 34.9 | 30.7 | 85.3 | 30.7 | Field (138 samples) | (Song et al., 2013) |
| **Chinese farmland soils** | 0.17 | 60.7 | – | – | – | 26.6 | 85.6 | 29.5 | Field (131 samples) | (Niu et al., 2013) |
| **North China soils** | 0.56 | 31.5 | 0.07 | 4.18 | 33.3 | 16.3 | 129.8 | 16.4 | Field (4445 samples) | (Peng et al., 2019) |
| **South China soils** | 0.62 | 12.6 | 0.08 | 2.47 | 18.9 | 18.8 | 88.6 | 4.89 | | |
| **Chinese soil** | 0.23 | 68.5 | 0.09 | 12.1 | 31.2 | 27.1 | 79.0 | 29.6 | Field (38,393 samples) | (Chen et al., 2015) |
| **China urban soil** | 0.39 | 68.5 | 0.31 | 12.2 | 55.2 | 40.4 | 109.0 | 24.9 | Review (21 cities) | (Luo et al., 2012) |
| **China mining areas** | 3.76 | 67.3 | 0.18 | 20.6 | 196.4 | 88.8 | 241.9 | 45.4 | Review (72 mines) | (Li et al., 2014) |
| **World soils** | 0.35 | 40 | 0.07 | 7.2 | 2–300 | 30 | 90 | 20 | Review | (Adriano, 2001) |
| **England and Wales** | 0.33 | 68 | – | 15 | 49 | 19 | 76 | 21 | Field (131 samples) | (Rawlins et al., 2012) |
| **Europe** | 0.18 | 64 | – | 7 | 21 | 15 | 62 | 21 | Field (5691 samples) | (Reimann et al., 2012) |
| **Australia** | 0.04 | 48 | – | 3 | 13 | 11 | 31 | 15 | Field (2211 samples) | |
| **United States of America** | 0.34 | – | – | – | 15 | 30 | 75.8 | 27.1 | Field (3045 samples) | (Holmgren et al., 1993) |
| **Peninsular Malaysia** | 0.12 | 25.9 | 0.15 | 16.8 | 26.4 | 16.4 | 38.0 | 13.7 | Field (241 samples) | (Zarcinas et al., 2004a) |
| **Thailand** | 0.03 | 25.2 | 0.04 | 7.5 | 17.5 | 7.5 | 23.9 | 13.5 | Field (318 samples) | (Zarcinas et al., 2004b) |

Table 3: Examples of national limits for heavy metals in herbal medicine and medicinal products (mg/kg, dry weight).

| ountry/Region | Scope | Cu (mg/kg) | Pb (mg/kg) | As (mg/kg) | Cd (mg/kg) | Hg (mg/kg) | References |
|---|---|---|---|---|---|---|---|
| **ISO international standards** | CHM | – | 10.0 | 4.0 | 2.0 | 3.0 | ISO (International Organization for Standardization) 18664:2015 (2015) |
| **World Health Organization (WHO)** | HM | – | 10.0 | 1.0 | 0.3 | – | Guidelines for Assessing Quality of Herbal Medicines with Reference to Contaminants and Residues (WHO, 2007) |
| **European Union** | HM | – | 5.0 | – | 1.0 | 0.1 | European Union Pharmacopeia, EP 10.2 (European Pharmacopoeia Committee, 2019) |
| **China** | CHM | 20.0 | 5.0 | 2.0 | 0.3 | 0.2 | Pharmacopoeia of the Peoples Republic of China (China Pharmacopoeia Commission, 2015) |
| | | | | | 1.0 | | Pharmacopoeia of the Peoples Republic of China (China Pharmacopoeia Commission, 2020) |
| **Chinese green standards** | HM | 20.0 | 5.0 | 2.0 | 0.3 | 0.2 | Green standards of medicinal plants and preparations for foreign trade and economy, WM/T2-2004 (Liu et |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | al., 2018a) |
| **Hong Kong, China** | CHM | 150.0 | 5.0 | 2.0 | 1.0 | 0.2 | Hong Kong Chinese Materia Medica Standards 2018 (Yang et al., 2021) |
| **Macau, China** | CHM/RM | 150.0 | 20.0 | 5.0 | – | 0.5 | Macau Technique Directive 02-2003 Despacho No. 10/SS/2013 (Li et al., 2018b) |
| **Taiwan, China** | CHM | – | 5.0 | 3.0 | 1.0 | 0.2 | Taiwan Herbal Pharmacopeia (2019) |
| | HP | – | 10.0 | 3.0 | 0.5 | 0.5 | Regulation for Registration of Medicinal Products (Liu et al., 2015) |
| **Poland** | RM | 20 | 1.0 | – | 0.1 | – | Polish Ministry of Health Act 1993 (Krejpcio et al., 2007) |
| **Italy** | RM | – | 3.0 | – | 0.5 | 0.3 | Italian Pharmacopeia (FUI) 2002 (Chowdhary and Raj, 2020) |
| **United Kingdom** | HM | – | 5.0 | 5.0 | 1.0 | 0.1 | British Herbal Pharmacopoeia (2018) |
| **Germany** | HM | – | 5.0 | – | 0.2 | 0.1 | German Pharmacopoeia (Deutsches Arzneibuch – DAB) (2018) |
| **Australia** | HM | – | 5.0 | – | 1.0 | 0.1 | Therapeutic Goods Administration (TGA) (Li et al., 2018b) |
| **Singapore** | CHM/RM | 150.0 | 20.0 | 5.0 | 5.0 | 0.5 | Health Sciences Authority (HSA), Health Products (Therapeutic Products) Regulations 2016 (Vohora and Singh, 2018) |
| | HP | – | 20.0 | 5.0 | – | 0.5 | (Liu et al., 2015) |
| | | – | 10.0 | 5.0 | 0.3 | 0.5 | Health Sciences Authority (HSA (2020)) |
| **India** | HM | – | 10.0 | 3.0 | 0.3 | 1.0 | The Ayurvedic Pharmacopoeia of India 2019 (Debnath et al., 2020) |
| **Japan** | RM | 20.0 | 20.0 | 5.0 | – | – | The Japanese Pharmacopoeia (2016) |
| **Malaysia** | TPP | – | 10.0 | 5.0 | 0.3 | 0.5 | Drug Registration Guidance Document (DRGD), (National Pharmaceutical Regulatory Division, Ministry of Health Malaysia, 2019) |
| **South Korea** | RM | – | 5.0 | 3.0 | 0.3 | 0.2 | The Korea Pharmacopoeia (Jeong et al., 2020b) |
| **Thailand** | HM | – | 10.0 | 4.0 | 0.3 | – | Thai Herbal Pharmacopoeia, Traditional Formularies of Herbal Medicines (Mukherjee, 2019) |
| **Vietnam** | HM | – | 10.0 | 4.0 | 1.0 | 0.5 | Vietnamese Pharmacopoeia 2005 (Zhao et al., 2009) |
| **United States of America** | DS | – | 10.0 | 5.0 | 0.3 | 0.2 | National Sanitation Foundation International (NSFI) Draft Standard 173-2008 (Harris et al., 2011) |
| | HM | – | 5.0 | 2.0 | 0.3 | 0.2 | NSFI Draft Standard 173-2001 (2001) |
| | RM | – | 0.5 | 1.5 | 2.5 | 1.5 | The United States Pharmacopeia (US Pharmacopoeia Convention, 2012) |
| | DS | – | 1.0 | 1.5 | 0.5 | 1.5 | USP 2232 (Liu et al., 2015) |
| **Canada** | HM | – | 10.0 | 5.0 | 0.3 | 0.2 | (Gupta et al., 2010) |

CHM: Chinese herbal medicine, DS: Dietary supplements, HM: Herbal medicine, HP: Herbal products, RM: Raw material, TPP: Traditional pharmaceutical preparation.

Table 4: Statistics of heavy metal pollution in different medical sites.

| parts of CHM | Pb | | | As | | | Hg | | | Cd | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Size (num) | x ± s (mg/kg) | Over-limit ratio (%) | Size (num) | x ± s (mg/kg) | Over-limit ratio (%) | Size (num) | x ± s (mg/kg) | Over-limit ratio (%) | Size (num) | x ± s (mg/kg) | Over-limit ratio (%) |
| Root and rhizome[I] | 1245 | 2.58 ± 29.86 | 2.17 | 1032 | 0.89 ± 2.59 | 3.97 | 988 | 0.11 ± 0.43 | 0.71 | 1168 | 0.31 ± 0.92 | 2.23 |
| Flower[II] | 144 | 7.92 ± 25.85 | 6.94 | 115 | 4.45 ± 13.15 | 9.71 | 98 | 0.45 ± 1.18 | 5.10 | 135 | 0.68 ± 1.87 | 8.89 |
| Leaf[III] | 40 | 3.80 ± 3.50 | 7.50 | 28 | 1.10 ± 1.43 | 10.71 | 19 | 1.68 ± 6.17 | 10.53 | 36 | 0.29 ± 0.34 | 0 |
| Whole herb[IV] | 207 | 13.66 ± 2.64 | 3.86 | 175 | 1.95 ± 5.26 | 7.88 | 134 | 0.17 ± 0.60 | 2.24 | 196 | 0.44 ± 0.67 | 5.10 |
| Fruit and seed[V] | 364 | 1.38 ± 2.64 | 1.10 | 284 | 0.43 ± 1.72 | 1.05 | 270 | 0.19 ± 1.53 | 1.11 | 331 | 0.09 ± 0.13 | 0 |
| Stem[VI] | 39 | 6.02 ± 7.95 | 15.38 | 41 | 0.80 ± 1.81 | 2.56 | 34 | 0.31 ± 1.14 | 2.94 | 38 | 1.15 ± 2.18 | 13.16 |
| Peel and bark[VII] | 121 | 2.48 ± 3.00 | 3.31 | 109 | 0.36 ± 0.53 | 0 | 101 | 0.07 ± 0.10 | 0 | 93 | 0.16 ± 0.19 | 0 |

Examples of the medical parts of CHM based on Pharmacopoeia of the Peoples Republic of China: I – Notoginseng Radix et Rhizoma of Panax notoginseng (Burk.) F. H. Chen, Zingiberis Rhizoma of Zingiber officinale Rosc., Panacis Quinquefolii Radix of Panax quinquefolium L., Corydalis Rhizoma of Corydalis yanhusuo W. T. Wang, Ophiopogonis Radix of Ophiopogon japonicus (L. f) Ker-Gawl, Polygonati Rhizoma of Polygonatum sibiricum Red., Glycyrrhizae Radix Et Rhizoma of Glycyrrhiza uralensis Fisch., Puerariae Lobatae Radix of Pueraria lobata (Willd.) Ohwi; II – Chrysanthemi Flos of Chrysanthemum morifolium Ramat., Lonicerae Japonicae Flos of Lonicera japonica Thunb., Croci Stigma of Crocus sativus L., Albiziae Flos of Albizia julibrissin Durazz., Sophorae Flos of Sophora japonica L., Caryophylli Flos of Eugenia caryophyllata Thunb., Gossampini Flos of Gossampinus malabarica (DC.) Merr., Rosae Chinensis Flos of Rosa chinensis Jacq.; III – Isatidis Folium of Isatis indigotica Fort., Mori Folium of Morus alba L., Ginkgo Folium of Ginkgo biloba L., Epimedii Folium of Epimedium brevicornu Maxim., Lophatheri Herba of Lophatherum gracile Brongn., Sennae Folium of Cassia angustifolia Vahl; IV – Centellae Herba of Centella asiatica (L.) Urb., Taraxaci Herba of Taraxacum mongolicum Hand.-Mazz., Prunellae Spica of Prunella vulgaris L., Solidaginis Herba of Solidago decurrens Lour., Plantaginis Herba of Plantago asiatica L.; V – Canavaliae Semen of Canavalia gladiate (Jacq.) DC., Anisi Stellati Fructus of Illicium verum Hook. f., Crataegi Fructus of Crataegus pinnatifida Bge., Schisandrae Chinensis Fructus of Schisandra chinensis (Turcz.) Baill., Cuscutae Semen of Cuscuta chinensis Lam., Ziziphi Spinosae Semen of Ziziphus jujuba Mill. var. spinosa (Bunge) Hu ex H. F. Chou, Coicis Semen of Coix lacryma-jobi L. var. mayuen (Roman.) Stapf; VI – Dendrobii Officinalis Caulis of Dendrobium officinale Kimura et Migo, Ephedrae Herba of Ephedra sinica Stapf, Perillae Caulis of Perilla frutescens (L.) Britt.; VII – Pseudolaricis Cortex of Pseudolarix amabilis (Nelson) Rehd., Acanthopanacis Cortex of Acanthopanax gracilistylus W. W. Smith, Mori Cortex of Morus alba L., Ailanthi Cortex of Ailanthus altissima (Mill.) Swingle.

**Source:** https://www.sciencedirect.com/science/article/pii/S0147651321004474#tbl0005

Table 1: Soil properties in the sites; site 1 (S1), site 2 (S2), site 3 (S3) and control site (SC).

| | S1 | S2 | S3 | SC |
|---|---|---|---|---|
| **pH** | 8.62 ± 0.07$^{a}$ | 8.10 ± 0.09$^{b}$ | 8.12 ± 0.06$^{b}$ | 7.34 ± 0.08$^{c}$ |
| **EC (µs cm$^{-1}$)** | 648.37 ± 5.06$^{b}$ | 680.2 ± 11.54$^{a}$ | 372.56 ± 10.16$^{c}$ | 212.56 ± 3.30$^{d}$ |
| **OM (%)** | 12.98 ± 3.45$^{c}$ | 24.05 ± 1.91$^{b}$ | 33.97 ± 0.95$^{a}$ | 39.20 ± 1.03$^{a}$ |
| **$CaCO_3$ t (%)** | 34.07 ± 0.03$^{a}$ | 18.57 ± 0.99$^{b}$ | 10.49 ± 0.04$^{c}$ | 8.80 ± 0.06$^{d}$ |
| **CaCO3a (%)** | 29.91 ± 1.52$^{a}$ | 20.03 ± 1.99$^{b}$ | 14.90 ± 1.18$^{c}$ | 4.48 ± 0.48$^{d}$ |
| **Cr (ppm)** | 18.92 ± 0.10$^{a}$ | 2.77 ± 0.11$^{b}$ | 1.31 ± 0.14$^{d}$ | 1.72 ± 0.02$^{c}$ |
| **Co (ppm)** | 2.20 ± 0.03$^{a}$ | 0.20 ± 0.05$^{c}$ | 0.47 ± 0.06$^{b}$ | 0.23 ± 0.02$^{c}$ |
| **Zn(ppm)** | 14.96 ± 0.03$^{a}$ | 7.47 ± 0.06$^{b}$ | 6.76 ± 0.04$^{c}$ | 3.42 ± 0.04$^{d}$ |
| **Pb (ppm)** | 83.86 ± 0.97$^{a}$ | 11.82 ± 0.07$^{b}$ | 5.17 ± 0.03$^{c}$ | 3.14 ± 0.04$^{d}$ |

*EC: Electrical Conductivity, OM: Organic Matter, $CaCO_{3T}$: Total carbonates, $CaCO_3$: Active carbonates.Data represent mean values ± SD

Table 2: Perennial species density (n = 12) (mean ± SD) in the sites; site 1(S1), site 2 (S2), site 3 (S3) and control site (SC).

| **Species** | **Sites** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **SC** | ***p-value*** |
| ***Annarhinum brevifolium*** | 0.00 ± 0.00$^{c}$ | 0.45 ± 0.05$^{b}$ | 0.92 ± 0.07$^{a}$ | 0.00 ± 0.00$^{c}$ | * |
| ***Argylobum uniflorum*** | 0.00 ± 0.00$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.03 ± 0.02$^{a}$ | 0.00 ± 0.00$^{a}$ | ** |
| ***Aristada ciliata*** | 0.02 ± 0.01$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.00 ± 0.00$^{a}$ | ** |
| ***Artemisia compestris*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.07 ± 0.03$^{a}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Artemisia herba alba*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 2.12 ± 0.37$^{a}$ | * |
| ***Astragalus armatus*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.07 ± 0.02$^{a}$ | ** |
| ***Atractylis serratuloides*** | 0.43 ± 0.05$^{a}$ | 0.32 ± 0.10$^{ab}$ | 0.28 ± 0.10$^{b}$ | 0.07 ± 0.04$^{c}$ | * |
| ***Deverra tortuosa*** | 0.00 ± 0.00$^{b}$ | 0.38 ± 0.06$^{a}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Erodium glaucophyllum*** | 0.15 ± 0.03$^{b}$ | 0.28 ± 0.06$^{ab}$ | 0.35 ± 0.06$^{a}$ | 0.30 ± 0.16$^{ab}$ | * |
| ***Gymnocarpos decander*** | 0.82 ± 0.09$^{a}$ | 0.87 ± 0.08$^{a}$ | 0.05 ± 0.04$^{c}$ | 0.63 ± 0.06$^{b}$ | * |
| ***Helianthemum kahiricum*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.45 ± 0.06$^{a}$ | * |
| ***Helianthemum seliimit*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.13 ± 0.06$^{a}$ | * |
| ***Haloxylon scoparium*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.12 ± 0.04$^{b}$ | 0.28 ± 0.09$^{a}$ | * |
| ***Helianthemum ellipticum*** | 0.00 ± 0.00$^{b}$ | 0.28 ± 0.04$^{a}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Helianthemum fontanesi*** | 0.02 ± 0.01$^{c}$ | 0.00 ± 0.00$^{c}$ | 0.48 ± 0.01$^{a}$ | 0.13 ± 0.02$^{b}$ | * |
| ***Helianthemum intricatum*** | 0.85 ± 0.07$^{a}$ | 0.50 ± 0.30$^{a}$ | 0.78 ± 0.21$^{a}$ | 0.32 ± 0.24$^{a}$ | ** |
| ***Helianthemum sessi*** | 0.01 ± 0.00$^{a}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Hernaria fontanesi*** | 0.02 ± 0.01$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.48 ± 0.44$^{a}$ | 0.13 ± 0.07$^{a}$ | ** |
| ***Launaea residifolia*** | 0.65 ± 0.07$^{a}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Lygeum spartum*** | 0.92 ± 0.06$^{b}$ | 1.03 ± 0.06$^{b}$ | 0.07 ± 0.03$^{c}$ | 1.23 ± 0.02$^{a}$ | * |
| ***Plantago albicans*** | 0.07 ± 0.02$^{a}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Reaunuria vermiculata*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.42 ± 0.06$^{a}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Stipa tenassicima*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.27 ± 0.06$^{a}$ | * |
| ***Stipa plumosa*** | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | 0.03 ± 0.02$^{a}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Thymus capitatus*** | 0.00 ± 0.00$^{b}$ | 0.2 ± 0.14$^{a}$ | 0.00 ± 0.00$^{b}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Zygophyllum album L.*** | 0.08 ± 0.02$^{b}$ | 0.55 ± 0.02$^{a}$ | 0.07 ± 0.06$^{c}$ | 0.00 ± 0.00$^{b}$ | * |
| ***Total*** | 4.04 | 5.18 | 4.15 | 6.13 | |

Data represent means of twelve measures at the limit 95% of confidence,
*$p < 0.05$

Table 3: Annual species density (mean ± SD) in the sites; site 1 (S1), site 2 (S2), site 3 (S3) and control site (SC).

| *Species* | Sites | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | SC | *p*-value |
| ***Asteriscus pygmaeus*** | $0.00 \pm 0.00^{c}$ | $0.00 \pm 0.00^{c}$ | $2.33 \pm 0.23^{b}$ | $4.33 \pm 0.32^{a}$ | * |
| ***Astragalus tenuifolius*** | $0.00 \pm 0.00^{b}$ | $1.00 \pm 0.21^{a}$ | $0.83 \pm 0.15^{a}$ | $0.00 \pm 0.00^{b}$ | * |
| ***Atractylis flava*** | $0.00 \pm 0.00^{c}$ | $0.00 \pm 0.00^{c}$ | $2.33 \pm 0.10^{a}$ | $0.67 \pm 0.30^{b}$ | * |
| ***Bromus madritensis*** | $0.00 \pm 0.00^{b}$ | $0.50 \pm 0.21^{a}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | * |
| ***Diplotaxis harra*** | $0.17 \pm 0.05^{c}$ | $1.17 \pm 0.12^{b}$ | $3.33 \pm 0.08^{a}$ | $1.50 \pm 0.31^{b}$ | * |
| ***Euphorbia retusa*** | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $1.50 \pm 0.18^{a}$ | * |
| ***Ericaria pinnata*** | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $1.83 \pm 0.14^{a}$ | * |
| ***Fagonia glutinosa*** | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.67 \pm 0.26^{a}$ | * |
| ***Hippocrepis bicontortalois*** | $0.17 \pm 0.10^{c}$ | $1.00 \pm 0.20^{b}$ | $2.67 \pm 0.30^{a}$ | $0.00 \pm 0.00^{c}$ | * |
| ***Koelpimia linearis*** | $1.17 \pm 0.41^{a}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | * |
| ***Kolerea pubescens*** | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $1.50 \pm 0.19^{a}$ | $0.00 \pm 0.00^{b}$ | * |
| ***Launaea angustifolia*** | $2.33 \pm 0.10^{a}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | * |
| ***Launaea quercifolia*** | $2.83 \pm 0.17^{b}$ | $4.66 \pm 0.38^{a}$ | $2.50 \pm 0.84^{b}$ | $0.83 \pm 0.16^{c}$ | * |
| ***Lotus halophilus*** | $0.00 \pm 0.00^{c}$ | $1.33 \pm 0.18^{a}$ | $1.00 \pm 0.02^{b}$ | $0.00 \pm 0.00^{c}$ | * |
| ***Medicago minima*** | $0.17 \pm 0.01^{a}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | * |
| ***Paronychia arabica*** | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.83 \pm 0.10^{a}$ | * |
| ***Plantago coronopus*** | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.00 \pm 0.00^{b}$ | $0.50 \pm 0.03^{a}$ | * |
| ***Plantago ovata*** | $0.33 \pm 0.11^{c}$ | $0.83 \pm 0.03^{b}$ | $2.33 \pm 0.09^{a}$ | $0.00 \pm 0.00^{d}$ | * |
| ***Schismus barbatus*** | $1.00 \pm 0.03^{b}$ | $0.83 \pm 0.04^{c}$ | $0.00 \pm 0.00^{d}$ | $4.50 \pm 0.04^{a}$ | * |
| ***Total*** | 8.17 | 11.32 | 18.82 | 17.10 | |

Data represent means of twelve repetitions measures at the limit 95% of confidence,
$p < 0.05$, the variance between sites is significant

Table 4: Change indices of α-diversity (H’ and R) (±SD) in the sites S1, S2, S3 and SC.

| **Sites** | **H’ (n = 12) Shannonand Wiener Index ± SD** | **Evenness (R) (n = 12) (equitability)±SD** |
|---|---|---|
| **1** | 2.31*±0.01 | 0.68* ± 0.04 |
| **2** | 2.91*±0.01 | 0.55* ± 0.03 |
| **3** | 2.49*±0.02 | 0.43* ± 0.02 |
| **Control** | 2.99*±0.05 | 0.46* ± 0.01 |

Data represent means of α-diversity index in the four sites at the limit 95% of confidence,
* = $p < 0.05$.

Table 5: Variation of Jaccard Index (β diversity) of similarity between sites.

| **Jaccard Index (βdiversity)(n = 12) **** | **Sites** | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **Control** |
| **1** | 1 | | | |
| **2** | 0.12 | 1 | | |
| **3** | 0.11 | 0.13 | 1 | |
| **Control** | 0.15 | 0.07 | 0.09 | 1 |

Data represent means of β-diversity index in the four sites at the limit 95% of confidence,
** = $p > 0.05$.

Table 6: Variance, , being a given variable under analysis, and the relative percentage ascribable to the intra-site and inter-site contributes.

| **Δ** | V(Δ) | **intra-site contribution (%)** | **inter-site contribution (%)** |
|---|---|---|---|
| **pH** | 0.21 | 0. 61 | 99.39 |
| **EC** | 37,888 | 0.05 | 99.95 |
| **OM** | 101 | 1.07 | 98.03 |
| **$CaCO_3$ t** | 99 | 0.06 | 99.94 |
| **CaCO3a** | 84 | 0.60 | 99.40 |
| **Cr** | 54 | 0.20 | 99.80 |
| **Co** | 0.68 | 0.60 | 99.40 |
| **Zn** | 18 | 0.33 | 99.67 |
| **Pb** | 1128 | 0.01 | 99.99 |
| **Species Richness** | 25 | 3.71 | 96.29 |
| **Perennial Species Richness** | 59 | 1.94 | 98.06 |
| **Annual Species Richness** | 0.07 | 3.09 | 96.81 |
| **Alpha Diversity** | 0.01 | 3.23 | 96.77 |
| **Evenness** | 578 | 0.08 | 99.02 |
| **Vegetation Cover** | 153 | 0.68 | 99.28 |

Table 7: Loading factors for the first two principal component of the soil properties and the ecological indicators.

| **Original Variable** | **$PC^S_1$** | **$PC^S_2$** | **Original Variable** | **$PC^I_1$** | **$PC^I_2$** |
|---|---|---|---|---|---|
| **pH** | 0.32 | 0.26 | Species Richness | 0.44 | −0.08 |
| **EC** | 0.28 | 0.63 | Perennial Species Richness | 0.43 | 0.21 |
| **OM** | −0.34 | −0.17 | Annual Species Richness | 0.42 | −0.13 |
| **$CaCO_3$ t** | 0.35 | −0.04 | Alpha Diversity | 0.33 | 0.78 |
| **CaCO3a** | 0.34 | 0.25 | Evenness | −0.37 | 0.56 |
| **Cr** | 0.33 | −0.37 | Vegetation Cover | 0.45 | −0.12 |
| **Co** | 0.32 | −0.43 | | | |
| **Zn** | 0.35 | −0.06 | | | |
| **Pb** | 0.32 | −0.33 | | | |

**Source:** https://www.sciencedirect.com/science/article/pii/S1470160X21001734#t0005

Table 1: Impacts of HMs on plants and humans.

| HMs | Effects of plants and humans | Reference |
|---|---|---|
| **Copper** | 1.Prevents the development of plants<br>2.Lower biomass in plants<br>3.Displays chlorotic effect in plants<br>4.Kidney and brain damage to humans<br>5.Intestinal and stomach pain | (Yruela, 2005)(Wuana and Okieimen, 2011) |
| **Mercury** | 1.Disrupts the activity of mitochondria and causes oxidative stress<br>2.Immune mediated disorders, loss of hairs, visual disorder, failure of lung and kidney | (Gulati et al., 2010, Messer et al., 2005) |
| **Lead** | 1.Reduces the amount of seed germination<br>2.Interrupts nutrition of minerals<br>3.Reduces division of cell<br>4.Memory loss for short time<br>5.Coordination and learning difficulties | (Ghani, 2010) |
| **Nickel** | 1.Growth and development inhibited<br>2.Induced leaf chlorosis<br>3.Disorder of allergic skin like scratching<br>4.Neurotoxic, immunotoxic effects<br>5.Loss of hairs | (Chen et al., 2009) |
| **Chromium** | 1.Decreases the proportion of growth of plants and buds<br>2.Reduces growth of roots, shoots and leaves<br>3.Nose infections, nasal congestion, issues with breathing<br>4.Fall of hairs | (Salem et al., 2000, Shanker et al., 2005) |
| **Cobalt** | 1.Reduces biomass and growth of shoot<br>2.Limits chlorophyll, and protein concentration | (Nagajyoti et al., 2010) |
| **Arsenic** | 1.Impacts of primary mechanisms in cells | (Tripathi et al., 2007) |
| **Barium** | 1.Caused cardiac arrhythmias<br>2.Gastrointestinal disorder<br>3.Cause adverse effects on the respiratory system | (Jacobs et al., 2002) |

Table 2: Group of radiotoxicities from radionuclides of a very high level of radiotoxicity to a low and minimal level.

| Radionuclides | Radiotoxicity Group |
|---|---|
| **$^{210}$Po, $^{210}$Pb, $^{230}$Th, $^{232}$Th, $^{226}$Ra, $^{232}$U, $^{238}$Pu, $^{237}$Np, $^{241}$Am and others.** | Group A (The level of radiotoxicity of radionuclides is particularly high) |
| **$^{106}$Ru, $^{224}$Ra, $^{235}$U, $^{238}$U, $^{234}$U, $^{152}$Eu, $^{144}$Ce, $^{210}$Bi, $^{90}$Sr, $^{230}$Th, $^{241}$Pu, $^{130}$I, $^{131}$I, and others** | Group B (High-radiotoxicity radionuclides) |
| **$^{32}$P, $^{22}$Na, $^{36}$Cl, $^{35}$S, $^{60}$Co, $^{59}$Fe, $^{89}$Sr, $^{93}$Mo, $^{90}$Y, $^{140}$Ba, $^{125}$Sn, $^{234}$Th and others** | Group C (Average radio-toxicity radionuclides) |
| **$^{14}$C, $^{40}$K, $^{7}$Be, $^{51}$Cr, $^{18}$F, $^{64}$Cu, $^{55}$Fe, $^{129}$Te, $^{197}$Pt, $^{131}$Cs, $^{197}$Hg, $^{210}$Pb, $^{200}$Tl, and others.** | Group D (Low- and minimal radiotoxicity radionuclides) |

Table 3: Mechanisms of tolerance to HMs ions in active microbes.

| Heavy metals ions | Microorganisms | Mechanism of resistance | Resistance molecular | Reference |
|---|---|---|---|---|
| **Zinc (II), Copper (II), Cadmium (II)** | *Desulfovibrio desulfuricans* | Extracellular sequestration | Extracellular polymeric elements | (Yue et al., 2015) |
| **Chromium (II), Cadmium (II), Nickel (II)** | *D. desulfuricans* | Extracellular sequestration | Hydrogen sulfide | (Joo et al., 2015) |
| **Copper (II)** | *Sulfolobus solfataricus* | Intracellular sequestration | Polyphosphates | (Remonsellez et al., 2006) |
| **Zinc (II), Cadmium (II)** | *Synechococcus* sp. | Intracellular sequestration | Metallothionein | (Blindauer et al., 2008) |
| **Copper (II)** | *S. solfataricus* | Active export | P-type efflux ATPase | (Soto et al., 2019) |
| **Mercury (II)** | *Pseudomonas* sp. | Enzymatic detoxification | Mercuric reductase | (Giovanella et al., 2016) |

Table 4: Difference between in-situ bioremediation and ex situ bioremediation.

| In situ bioremediation | Ex situ bioremediation |
|---|---|
| It enables processing of hazardous, contaminated, and waste products at the location of the genesis. | It includes the disposal of toxic products or waste material from the site, accompanied by transport and treatment to another place. |
| In in-situ bioremediation techniques includes: phytoremediation, bioventing, biosparging, bioaugmentation, etc. | In ex situ bioremediation techniques includes :biopiles, landfarming, bioreactors, etc. |
| For in-situ bioremediation, the treatment of polluted soil in the site were found to be quite efficient. There is no need to uncover the polluted soil, results in less expensive. | While this decontamination approach involves soil removal before treatment, it can be quicker, possible to manage, and generally allows the treatment of a wider range of soils and pollutants. |
| The disadvantage of in situ bioremediation is, it is less manageable, it can take longer time to decontaminate. | The disadvantage of ex situ bioremediation is the expenses of packaging, transportation, and management. |

Table 5: Some plant species for bioremediation of heavy metals.

| Plant species | Metals | Reference |
|---|---|---|
| ***Polygonum hydropiperoides*** | Cu, Pb | (Kamal et al., 2004) |
| ***Hydrocotyle umbellata*** | Pb, Zn, Cu, Cd, As | (Sharma and Agrawal, 2005) |
| ***Juncus effusus*** | Cd, Zn, Ni, Al, Co, Cr, Pb, Cu | (Archer and Caldwell, 2004) |
| ***Carex buchananii*** | Cd, Zn, Ni | (Ladislas et al., 2014) |
| ***Kyllinga brevifolia*** | U, Th, Sr, Ba, Ni, Pb | (Li et al., 2011) |
| ***Gratiola bogotensis*** | Pb, Zn, Cu, Cd, As | (Del Río et al., 2002) |
| ***Elsholtzia splendens*** | Cu | (Chen et al., 2005) |
| ***Salix viminalis, Salix fragilis*** | Zn, Cd, Cu, P | (Meers et al., 2007) |

Table 6: HMs elimination with the help of microorganisms

| Heavy metals | Selected microorganisms | References |
|---|---|---|
| **Lead, Cadmium** | *Saccharomyces cerevisiae* | (Farhan and Khadom, 2015, Lívia de and Benedito, 2015) |
| **Chromium (VI)** | *Bacillus subtilis* | (Balamurugan et al., 2014) |
| **Chromium (VI)** | *Pseudomonas putida* | (Balamurugan et al., 2014) |
| **Cadmium, Zinc, Copper** | *Pseudomonas veronii* | (Coelho et al., 2015) |
| **Chromium (VI)** | *Bacillus cereus* strain XMCr-6 | (Dong et al., 2013) |
| **Chromium, Lead, Zinc** | *Bacillus licheniformis, Escherichia coli* | (Basha and Rajaganesh, 2014) |
| **Copper, Chromium, Iron** | *B. licheniformis* | (Samarth et al., 2012) |
| **Nickel, Copper** | *Aspergillus versicolor* | (Coelho et al., 2015) |
| **Chromium (VI)** | *Rhizopus oryzae* | (Sukumar, 2010)(Mittal et al., 2010) |
| **Copper, Manganese, Zinc** | *Aspergillus brasiliensis, Penicillium cirtinum* | (Pereira et al., 2014) |
| **Lead, Nickel, Chromium** | *Aspergillus niger, Aspergillus flavus* | (Dwivedi, 2012) |
| **Lead (II), Copper (II)** | *Spirogyra* sp., *Cladophora* sp. | (Coelho et al., 2015; Lee and Chang, 2011) |
| **Chromium, Copper, Manganese, Zinc** | *Spirogyra* sp-., *Spirulina* sp. | (Coelho et al., 2015) |
| **Cadmium, Lead** | *Chlorella vulgaris* | (Aung et al., 2012) |
| **Copper, Zinc** | *Spirulina maxima* | (Chan et al., 2014) |
| **Lead, Cadmium** | *Saccharomyces cerevisiae* | (Farhan and Khadom, 2015, Lívia de and Benedito, 2015) |
| **Copper** | *Candida utilis* | (Zu et al., 2006) |

Table 7: Microbial remediation mechanism of radionuclides.

| Microbes involved | Heavy metal/ Radionuclide | Mechanism | Reference |
|---|---|---|---|
| ***Klebsiella planticola, Salmonella enterica, Citrobacter* sp, *Pseudomonas aeruginosa, E. coli*** | Phosphates, Chromium and Arsenic sulphides | Biomineralization | (Francis and Dodge, 2009, Prakash et al., 2013) |
| ***Thiobacillus ferrooxidans, Streptomyces* sp., *Pseudomonas putida*** | Mercury (II) | Detoxification | (Ozdemir et al., 2017, Yin et al., 2017) |
| ***Rhizopus arrhizus, Pseudomonas mendocina, Arthrobacter* sp., *Bacillus subtilis*** | Cadmium (II), Zinc (II), Lead (II), Uranium (IV), Thorium | Bioaccumulation, Biotransformation, Biosorption | (Ozdemir et al., 2017, Yin et al., 2017) |
| ***E. coli, Deinococcus radiodurans* R1** | Mercury (II), Uranyl nitrate | Genetically modified organisms | (Alexandrova et al., 2011, Prakash et al., 2013, Priya et al., 2014) |
| ***Deinococcus. radiodurans*** | Uranyl phosphate | Bioprecipitation | (Suzuki and Banfield, 2004) |
| ***Arthrobacter ilicis, Geobacter* sp.** | Uranium (VI), Plutonium (IV), Technetium (VII) | Bioaugmentation, Biostimulation | (Francis and Dodge, 2009, Merroun and Selenska-Pobell, 2008, Prakash et al., 2013) |

Table 8: Genes encoding metal transporters for improved HMs phytoextraction and phytostabilization.

| Gene | Organisms | Metal transformation | Effect | Reference |
|---|---|---|---|---|
| ***AtATM3*** | *Brassica juncea / Arabidopsis thaliana* | ABC (ATP-binding cassette | Enhanced Cd and Pb aggregation in the shoots | (Bhuiyan et al., 2011) |
| ***YCF1*** | *Saccharomyces cerevisiae* | ABC | Enhanced Zn and Cd aggregation in the shoots | (Shim et al., 2013) |
| ***PgIREG1*** | *Arabidopsis thaliana, Psychotria gabriellae* | Ferroprotein/Regulator iron (FNP/IREG) | Enhanced Ni aggregation in the shoots | (Merlot et al., 2014) |
| ***OsMTP1*** | *Nicotiana tabacum/Oryza sativa* | Metal tolerance protein (MTP) | Enhanced Cd aggregation in the shoots | (Das et al., 2016) |
| ***copC*** | *Pseudomonas* sp. | Copper resistance protein (Cop) | Cu hyperaccumulation in the shoots | (Rodríguez-Llorente et al., 2012) |
| ***AtHMA4*** | *Nicotiana tabacum* | CDF, P-1b-ATPase | From the roots to the shoots constricted transfer of Cd | (Siemianowski et al., 2014) |
| ***AtMTP1, AtZIP1*** | *Manihot esculenta* | ZIP | Aggregation of Zn at the roots, with limited transportation to the shoots | (Gaitán-Solís et al., 2015) |

Table 9: Low-cost adsorbents material for HMs removal.

| **Adsorbents** | **Adsorption Capacity (mg/g)** | | | | **Reference** |
|---|---|---|---|---|---|
| | **$Ni^{2+}$** | **$Zn^{2+}$** | **$Pb^{2+}$** | **$Cu^{2+}$** | |
| **Clay/poly(methoxyethyl)acrylamide** | 80.9 | 20.6 | 81.02 | 29.8 | (Solener et al., 2008) |
| **Zeolite, clinoptilolite** | 0.4 | 0.5 | 1.6 | 1.64 | (Babel and Kurniawan, 2003) |
| **HCl-treated clay** | – | 63.2 | 83.3 | – | (Vengris et al., 2001) |
| **Activated phosphate** | – | – | 4 | – | (Pan et al., 2007) |
| **Modified zeolite, MMZ** | – | – | 123 | – | (Nah et al., 2006) |

**Source:** https://www.sciencedirect.com/science/article/pii/S2590262821000095#t0005

Effects of heavy metals and organic matter fractions on the fungal communities in mangrove sediments from Techeng Isle, South China. (2021)

Table 1: Microbial remediation mechanism of radionuclides.

| Samples | As | Co | Cr | Cu | Mn | Ni | Pb | V | Zn | TOC | TN | TS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | µg/g | | | | | | | | | % | % | % |
| Ac1 | 5.2 | 1.2 | 17.7 | 18.9 | 112.2 | 4.5 | 52.8 | 24.6 | 10.6 | 1.6 | 0.12 | 0.19 |
| Ac2 | 4.8 | 1.0 | 17.4 | 16.8 | 105.9 | 3.9 | 51.6 | 25.5 | 10.2 | 1.3 | 0.08 | 0.11 |
| Ac3 | 4.0 | 1.6 | 16.5 | 18.2 | 117.3 | 3.6 | 56.4 | 27.6 | 11.6 | 1.4 | 0.12 | 0.12 |
| Ac-AV | 4.67 ± 0.61$^{a}$ | 1.27 ± 0.31$^{a}$ | 17.20 ± 0.62$^{c}$ | 17.97 ± 1.07$^{b}$ | 111.80 ± 5.71$^{c}$ | 4.00 ± 0.46$^{b}$ | 53.60 ± 2.50$^{c}$ | 25.90 ± 1.54$^{c}$ | 10.80 ± 0.72$^{b}$ | 1.43 ± 0.15$^{a}$ | 0.11 ± 0.02$^{a}$ | 0.14 ± 0.04$^{b}$ |
| Am1 | 10.8 | 4.6 | 18.3 | 21.0 | 156.3 | 8.7 | 54 | 26.7 | 20.4 | 2.3 | 0.21 | 0.08 |
| Am2 | 12.0 | 5.0 | 18.9 | 21.7 | 171.3 | 6.6 | 52.8 | 24.9 | 21.4 | 1.8 | 0.18 | 0.05 |
| Am3 | 10.4 | 4.4 | 19.8 | 23.1 | 157.8 | 8.7 | 58.8 | 25.8 | 20.4 | 1.9 | 0.15 | 0.13 |
| Am-AV | 11.07 ± 0.83$^{b}$ | 4.67 ± 0.31$^{c}$ | 19.00 ± 0.75$^{d}$ | 21.93 ± 1.07$^{c}$ | 161.80 ± 8.26$^{d}$ | 8.00 ± 1.21$^{c}$ | 55.20 ± 3.17$^{c}$ | 25.80 ± 0.90$^{c}$ | 20.73 ± 0.58$^{d}$ | 2.00 ± 0.26$^{ab}$ | 0.18 ± 0.03$^{ab}$ | 0.09 ± 0.04$^{ab}$ |
| Bg1 | 9.6 | 3.0 | 12.3 | 18.9 | 71.4 | 4.5 | 37.2 | 18.6 | 13.4 | 2.9 | 0.24 | 0.11 |
| Bg2 | 8.4 | 2.6 | 12.0 | 19.6 | 75.3 | 3.9 | 36.0 | 18.3 | 13.4 | 2.4 | 0.19 | 0.16 |
| Bg3 | 10.0 | 3.2 | 12.3 | 17.5 | 65.4 | 3.6 | 39.6 | 20.1 | 14.0 | 2.8 | 0.27 | 0.14 |
| Bg-AV | 9.33 ± 0.83$^{b}$ | 2.93 ± 0.31$^{b}$ | 12.20 ± 0.17$^{b}$ | 18.67 ± 1.07$^{b}$ | 70.70 ± 4.99$^{b}$ | 4.00 ± 0.46$^{b}$ | 37.60 ± 1.83$^{b}$ | 19.00 ± 0.96$^{b}$ | 13.60 ± 0.35$^{c}$ | 2.70 ± 0.26$^{b}$ | 0.23 ± 0.04$^{bc}$ | 0.14 ± 0.03$^{b}$ |
| Rs1 | 4.0 | 1.0 | 5.4 | 4.9 | 40.2 | 0.9 | 9.6 | 8.1 | 4.2 | 3.1 | 0.26 | 0.03 |
| Rs2 | 3.2 | 0.8 | 5.1 | 4.2 | 42.6 | 0.9 | 8.4 | 8.1 | 4.4 | 3.9 | 0.38 | 0.05 |
| Rs3 | 1.2 | 0.6 | 5.4 | 5.6 | 41.1 | 1.2 | 10.8 | 8.7 | 4.6 | 3.5 | 0.37 | 0.03 |
| Rs-AV | 2.80 ± 1.44$^{a}$ | 0.80 ± 0.20$^{a}$ | 5.30 ± 0.17$^{a}$ | 4.90 ± 0.70$^{a}$ | 41.30 ± 1.21$^{a}$ | 1.00 ± 0.17$^{a}$ | 9.60 ± 1.20$^{a}$ | 8.30 ± 0.35$^{a}$ | 4.40 ± 0.20$^{a}$ | 3.50 ± 0.40$^{c}$ | 0.34 ± 0.07$^{c}$ | 0.04 ± 0.01$^{a}$ |

Different letters indicate significant differences between the four samples at same factor ($P < 0.05$). TOC, total organic carbon; TN, total nitrogen; TS, total sulphur

Table 2: comparisons of microbial sequences, the estimated OTUs richness, Shannon's indexes of the fungal ITS1 sequences (97% sequences similarity) detected in the mangrove sediments from four sites (Ac, Am, Bg and Rs) on Techeng Isle, Zhanjiang, China.

| Samples | Sequences | Observed OTUs | Chao 1 | Shanon |
|---|---|---|---|---|
| **Ac1** | 16372 | 124 | 122 | 2.91 |
| **Ac2** | 20147 | 135 | 137 | 3.12 |
| **Ac3** | 17820 | 137 | 142 | 3.01 |
| **Am1** | 15210 | 166 | 168 | 3.35 |
| **Am2** | 21034 | 170 | 175 | 3.46 |
| **Am3** | 15336 | 150 | 146 | 3.30 |
| **Bg1** | 18357 | 243 | 237 | 4.21 |
| **Bg2** | 20891 | 221 | 220 | 4.01 |
| **Bg3** | 18997 | 238 | 235 | 4.15 |
| **Rs1** | 20048 | 258 | 259 | 4.61 |
| **Rs2** | 21921 | 279 | 284 | 4.81 |
| **Rs3** | 19854 | 276 | 279 | 4.77 |

**Source:** https://www.sciencedirect.com/science/article/pii/S0147651321006576#tbl0005

Long-Term Effect of Heavy Metal–Polluted Wastewater Irrigation on Physiological and Ecological Parameters of *Salicornia Europaea L.* (2020)

Table 1: Mean, minimum, and maximum values and standard deviation of heavy metal concentrations in sewage (n = 4)

| Metals | Mean | Minimum | Maximum | St. dev. |
|---|---|---|---|---|
| **Zn (mg $L^{-1}$)** | 2.45 | 0.158 | 3.8 | 2 |
| **Fe (mg $L^{-1}$)** | 3.60 | 0.61 | 5.4 | 3 |
| **Cu (mg $L^{-1}$)** | 0.44 | 0.058 | 0.90 | 0.2 |
| **Cd (mg $L^{-1}$)** | 0.096 | 0.028 | 0.17 | 0.05 |
| **Pb (mg $L^{-1}$)** | 2.54 | 0.174 | 3.82 | 1 |
| **Ni (mg $L^{-1}$)** | 2.77 | 0.074 | 4.62 | 2 |

Table 2: Growth parameters of *Salicornia europaea* as affected by time and duration of wastewater application

| Irrigation | Duration | Time (days) | Nodes on the main stem | Number of pairs of side branches | Diameter of the branched area (cm) |
|---|---|---|---|---|---|
| **Control** | Short term | 2 | 1.75 ± 0.50b | 1.00 ± 0.00d | **7.87 ± 2.57b** |
| | | 4 | 1.75 ± 0.50b | 1.50 ± 0.57d | **9.20 ± 2.54b** |
| | Average term | 2 | 4.25 ± 0.95a | 3.00 ± 1.41bc | **19.42 ± 6.31a** |
| | | 4 | 5.25 ± 0.95a | 4.50 ± 1.29a | **21.17 ± 6.51a** |
| | Long term | 2 | 4.75 ± 1.50a | 3.50 ± 1.29ab | **20.62 ± 3.08a** |
| | | 4 | 5.50 ± 0.57a | 4.00 ± 1.15ab | **21.30 ± 3.58a** |
| **Wastewater** | Short term | 2 | 2.00 ± 0.00b | 1.00 ± 0.00d | **8.90 ± 2.47b** |
| | | 4 | 2.50 ± 0.57b | 1.75 ± 0.50 cd | **10.10 ± 2.32b** |
| | Average term | 2 | 4.50 ± 1.29a | 4.25 ± 0.95ab | **20.50 ± 6.26a** |
| | | 4 | 4.75 ± 1.25a | 4.25 ± 1.50ab | **23.10 ± 5.77a** |
| | Long term | 2 | 4.75 ± 1.50a | 3.75 ± 1.50ab | **20.70 ± 3.69a** |
| | | 4 | 4.25 ± 2.06a | 3.75 ± 1.50ab | **22.60 ± 5.98a** |
| **ANOVA** | Irrigation (I) | | ns | ns | ***** |
| | Duration (D) | | ** | ** | ****** |
| | Time (T) | | ns | * | ****** |
| | I×D | | ns | ns | **ns** |
| | I×T | | ns | ns | **ns** |
| | D×T | | ns | ns | **ns** |
| | **D×T×I** | | **ns** | **ns** | **ns** |

[ns, *, **] show non-significant and significant differences at 0.05, 0.01 probability level, respectively. Short term, 20 days after sowing (at vegetative stage); average, 30 days after sowing (at flowering stage); long term, 40 days after sowing (at reproductive stage)

Table 3: Root and shoot length and plant biomass (dry weight) of *Salicornia europaea* as affected by time and duration of wastewater application

| **Irrigation** | **Duration** | **Time (days)** | **Shoot length (cm)** | **Root length** | **Shoot weight** | **Root weight** | **Plant biomass** |
|---|---|---|---|---|---|---|---|
| | | | | (cm) | (mg) | (mg) | **(mg)** |
| **Control** | Short term | 2 | 7.6 ± 1.06f | 3.80 ± 1.06e | 270 ± 60e | 14 ± 3.0d | **284 ± 60.7e** |
| | | 4 | 9.0 ± 1.29ef | 4.70 ± 1.06de | 380 ± 85de | 53 ± 75ab | **433 ± 154.1d** |
| | Average term | 2 | 23.9 ± 3.24d | 12.30 ± 1.16c | 590 ± 69c | 41 ± 6.6a-d | **631 ± 99.7c** |
| | | 4 | 25.1 ± 3.70 cd | 13.10 ± 1.52bc | 600 ± 95bc | 47 ± 6.9abc | **647 ± 93.77bc** |
| | Long term | 2 | 24.3 ± 2.93d | 14.40 ± 1.21ab | 750 ± 54a | 54 ± 6.3ab | **804 ± 40.2a** |
| | | 4 | 25.4 ± 4.04bcd | 14.72 ± 0.68a | 710 ± 120ab | 52 ± 10.0ab | **762 ± 123.46ab** |
| **Waste water** | Short term | 2 | 10.4 ± 2.68ef | 4.42 ± 0.75de | 350 ± 69de | 17 ± 0.81 cd | **367 ± 68.9de** |
| | | 4 | 11.7 ± 2.34e | 5.30 ± 1.29d | 460 ± 47d | 23 ± 3.1bcd | **483 ± 47.5d** |
| | Average term | 2 | 27.9 ± 2.68abc | 12.62 ± 1.83c | 670 ± 86abc | 46 ± 7.5abc | **716 ± 93.2abc** |
| | | 4 | 28.5 ± 2.89ab | 13.47 ± 2.05abc | 690 ± 95bc | 54 ± 2.1ab | **744 ± 132abc** |
| | Long term | 2 | 27.5 ± 2.67bc | 13.37 ± 1.89abc | 740 ± 41a | 57 ± 9.8a | **797 ± 51.91ab** |
| | | 4 | 29.5 ± 2.85a | 13.47 ± 2.03abc | 780 ± 40a | 56 ± 10.0a | **836 ± 29.72a** |
| | Irrigation (I) | | ** | ns | ** | ns | ** |
| | Duration (D) | | ** | ** | ** | ** | ** |
| **ANOVA** | Time (T) | | ** | ** | * | ns | * |
| | I × D | | ns | ** | * | ns | * |
| | I×T | | ns | ns | ns | ns | **ns** |
| | D × T | | ns | ns | * | ns | * |
| | **D×T×I** | | **ns** | **ns** | **ns** | **ns** | **ns** |

$^{ns}$ and $^{*, **}$ show non-significant and significant differences at 0.05, 0.01 probability level, respectively Short term, 20 days after sowing (at vegetative stage); average, 30 days after sowing (at flowering stage); long term, 40 days after sowing (at reproductive stage)

Table 4: Chlorophyll content, carotenoid, total soluble protein and electrical conductivity of *Salicornia europaea* as affected by time and duration of wastewater application

| **Irrigation** | **Duration** | **Time (days)** | **Chlorophyll a** | **Chlorophyll b** | **Total Chlorophyll** | **Carotenoids** | **Total soluble protein** | **EC** |
|---|---|---|---|---|---|---|---|---|
| | | (mg $g^{-1}$ FW) | | | | | | **(μS $m^{-1}$)** |
| **Control** | Short term | 2 | 5.21 ± 1.10 cd | 2.24 ± 0.17a | 7.45 ± 0.94bc | 0.155 ± 0.099de | 25.92 ± 0.95f | **167.75 ± 8.18de** |
| | | 4 | 6.75 ± 1.87ab | 1.97 ± 0.28abc | 8.73 ± 1.75ab | 0.176 ±0.056cde | 26.76 ± 0.60ef | **164.50 ± 5.44e** |
| | Average term | 2 | 6.94 ± 1.34ab | 1.95 ± 0.14abc | 8.90 ± 1.27a | 0.246 ± 0.11bc | 27.61 ± 1.28de | **169.50 ± 2.88de** |
| | | 4 | 7.72 ± 1.21a | 1.80 ± 0.35bc | 9.51 ± 1.00a | 0.316 ± 0.058ab | 28.31 ± 0.70 cd | **170.75 ± 2.21de** |
| | Long term | 2 | 5.02 ± 1.73de | 2.14 ± 0.47ab | 7.17 ± 1.69 cd | 0.162 ± 0.056de | 27.61 ± 0.69de | **170.25 ± 3.77de** |
| | | 4 | 3.49 ± 0.33e | 1.97 ± 0.41abc | 5.47 ± 0.39e | 0.148 ± 0.046e | 28.10 ± 0.48cde | **168.50 ± 4.50de** |
| **Waste water** | Short term | 2 | 6.70 ±1.17abc | 2.06 ± 0.16abc | 8.76 ± 1.07ab | 0.218 ±0.050cde | 27.75 ± 1.74de | **165.50 ± 3.31e** |
| | | 4 | 7.37 ± 1.99ab | 1.98 ± 0.26abc | 9.36 ± 1.73a | 0.233 ± 0.078 cd | 28.10 ± 1.65cde | **167.50 ± 2.08de** |
| | Average term | 2 | 8.19 ± 1.44a | 1.89 ± 0.22abc | 10.08 ± 1.24a | 0.383 ± 0.047a | 29.30 ± 0.60bc | **173.50 ± 5.06 cd** |
| | | 4 | 8.29 ± 1.09a | 1.74 ± 0.35 cd | 10.04 ± 1.06a | 0.385 ± 0.041a | 30.29 ± 1.18ab | **179.75 ± 8.65bc** |
| | Long term | 2 | 5.72 ± 1.73bcd | 1.35 ± 0.34d | 7.08 ± 1.41 cd | 0.226 ±0.076cde | 31.06 ± 0.87a | **184.75 ± 3.40ab** |
| | | 4 | 4.20 ± 1.95de | 1.69 ± 0.15 cd | 5.90 ± 1.44de | 0.158 ± 0.046de | 31.27 ± 0.72a | **187.00 ± 2.94a** |
| **ANOVA** | Irrigation (I) | | * | ** | * | ** | ** | ** |
| | Duration (D) | | ** | ** | ** | ** | ** | ** |
| | Time (T) | | ns | ns | ns | ns | * | **ns** |
| | I × D | | ns | * | ns | ns | * | ** |
| | I×T | | ns | ns | ns | ns | ns | * |
| | D × T | | ** | ns | ** | * | ns | **ns** |
| | **D×T×I** | | **ns** | **ns** | **ns** | **ns** | **ns** | ns |

[ns] and [*, **] show non-significant and significant differences at 0.05, 0.01 probability level, respectively Short term, 20 days after sowing (at vegetative stage); average, 30 days after sowing (at flowering stage); long term, 40 days after sowing (at reproductive stage)

**Source:** https://link.springer.com/article/10.1007/s42729-020-00299-7

Risk assessment of heavy metal toxicity by sensitive biomarker δ-aminolevulinic acid dehydratase (ALA-D) for onion plants cultivated in polluted areas in Kosovo (2020)

Table 1: Statistical data of Cd, Cr, Ni, Pb and Zn concentrations (mg $kg^{-1}$) in soil samples from some polluted locations of the Mitrovica region (Shupkovc and City of Mitrovica) and Obiliqi region (Kryshevc, Leshkoshiq, Plementin and Mazgit) and non-polluted localtion Kraishtë (Control).

| Polluted regions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Mitrovica region** | | **Obiliqi region** | | | | **Non-polluted region** |
| **Elements** | | **Shupkovc** | **Mitrovica** | **Kryshevc** | **Leshkoshiq** | **Plementin** | **Mazgit** | **Control** |
| | | ***n*** **= 10** | ***n*** **= 10** | ***n*** **= 10** | ***n*** **= 10** | ***n*** **= 10** | ***n*** **= 10** | ***n*** **= 10** |
| **Cd** | Mean | **11.83**$^{A}$ | **6.09**$^{B}$ | ND | ND | ND | ND | ND |
| | Median | 11.99 | 6.65 | | | | | |
| | Range | 10.96-12.36 | 3.35-7.74 | | | | | |
| | St. dev. | 0.55 | 1.73 | | | | | |
| **Cr** | Mean | **79.58**$^{A}$ | **57.19**$^{B}$ | **42.37**$^{C}$ | **34.54**$^{D}$ | **40.17**$^{CD}$ | **33.28**$^{D}$ | **15.55**$^{E}$ |
| | Median | 74.04 | 54.23 | 42.57 | 34.33 | 40.52 | 33.26 | 15.50 |
| | Range | 73.51-93.22 | 47.85-72.60 | 40.89-44.25 | 33.68-35.69 | 38.65-41.22 | 32.26-34.25 | 14.67-16.82 |
| | St. dev. | 8.68 | 9.75 | 1.32 | 0.81 | 1.04 | 0.74 | 0.68 |
| **Ni** | Mean | **170.54**$^{B}$ | **181.44**$^{A}$ | **57.88**$^{D}$ | **33.96**$^{F}$ | **68.68**$^{C}$ | **49.05**$^{E}$ | **10.12**$^{G}$ |
| | Median | 165.74 | 179.55 | 57.55 | 33.93 | 68.36 | 49.88 | 10.03 |
| | Range | 162.66-184.83 | 169.32-196.10 | 48.65-66.45 | 30.26-37.59 | 66.45-71.98 | 44.40-55.36 | 8.72-11.49 |
| | St. dev. | 9.38 | 10.66 | 6.59 | 2.73 | 2.11 | 4.41 | 1.12 |
| **Pb** | Mean | **2516.54**$^{A}$ | **2122.09**$^{B}$ | **174.57**$^{C}$ | **145.81**$^{C}$ | **158.54**$^{C}$ | **166.31**$^{C}$ | **26.82**$^{D}$ |
| | Median | 2491.69 | 2065.87 | 174.26 | 146.99 | 159.45 | 165.41 | 26.67 |
| | Range | 2489-2576 | 1953-2365 | 171.52-178.96 | 138.52-155.45 | 155.62-160.25 | 155.85-174.96 | 24.45-29.32 |
| | St. dev. | 38.76 | 167.22 | 2.82 | 6.75 | 1.94 | 7.08 | 1.47 |
| **Zn** | Mean | **2284.92**$^{A}$ | **1927.44**$^{B}$ | **284.55**$^{C}$ | **163.16**$^{D}$ | **284.31**$^{C}$ | **170.75**$^{D}$ | **77.68**$^{E}$ |
| | Median | 2279.63 | 1925.39 | 285.61 | 164.28 | 284.63 | 170.77 | 78.45 |
| | Range | 2156-2402 | 1870-1980 | 278.95-288.74 | 154.56-170.28 | 280.61-288.65 | 167.32-174.21 | 69.13-88.33 |
| | St. dev. | 90.86 | 41.59 | 3.94 | 6.26 | 3.09 | 2.57 | 7.13 |

**Note:** Means in each row followed by same letters are not significantly different at P 0.05 by one-way ANOVA with Duncan's multiple range tests.

Table 2: Statistical data of Cd, Pb and Zn concentrations (mg $kg^{-1}$) in leaves of onion plants grown in soil samples from some polluted locations of Mitrovica region (Shupkovc and City of Mitrovica) and Obiliqi region (Kryshevc, Leshkoshiq, Plementin and Mazgit) and non-polluted localtion Kraishtë (Control).

| Polluted regions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Mitrovica region** | | **Obiliqi region** | | | | **Non-polluted region** |
| **Elements** | | **Shupkovc** | **Mitrovica** | **Kryshevc** | **Leshkoshiq** | **Plementin** | **Mazgit** | **Control** |
| | | ***n* = 10** | ***n* = 10** | ***n* = 10** | ***n* = 10** | ***n* = 10** | ***n* = 10** | ***n* = 10** |
| **Cd** | Mean | **2.02** | **1.03** | ND | ND | ND | ND | ND |
| | Median | 2.03 | 1.02 | | | | | |
| | Range | 1.85-2.21 | 0.98-1.12 | | | | | |
| | St. dev. | 0.13 | 0.05 | | | | | |
| **Pb** | Mean | **8.35**[A] | **5.69**[B] | **2.48**[D] | **1.85**[E] | **3.02**[C] | **2.69**[D] | ND |
| | Median | 8.58 | 5.65 | 2.49 | 1.85 | 3.01 | 2.71 | |
| | Range | 7.77-8.62 | 5.45-5.98 | 2.25-2.65 | 1.74-1.98 | 2.95-3.12 | 2.54-2.87 | |
| | St. dev. | 0.36 | 0.21 | 0.15 | 0.09 | 0.06 | 0.12 | |
| **Zn** | Mean | **29.72**[B] | **32.98**[A] | **17.95**[C] | **13.08**[D] | **19.69**[C] | **14.99**[D] | **10.26**[E] |
| | Median | 30.62 | 32.98 | 17.91 | 13.16 | 20.14 | 14.97 | 10.28 |
| | Range | 25.74-35.49 | 32.95-33.01 | 17.36-18.45 | 12.36-13.95 | 18.65-20.15 | 14.32-15.62 | 9.46-11.02 |
| | St. dev. | 4.02 | 0.02 | 0.42 | 0.61 | 0.66 | 0.48 | 0.55 |

**Note:** Means in each row followed by same letters are not significantly different at P 0.05 by one-way ANOVA with Duncan's multiple range tests.

Table 3: Correlation between Pb, Cr, Ni, Zn or Cd in soil and leaves of onion plants and in activity of δ-aminolevulinic acid dehydratase (ALA-D), δ-aminolevulinic acid (ALA) and total chlorophyll contents.

| | | **Pb** | **Cr** | **Ni** | **Zn** | **Cd** | **Pb** | **Cd** | **Zn** | **ALA-D** | **ALA** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Heavy metals in soil** | Cr | 0.91** | | | | | | | | | |
| | Ni | 0.95** | 0.85** | | | | | | | | |
| | Zn | 0.99** | 0.91** | 0.96** | | | | | | | |
| | Cd | 0.95** | 0.89** | 0.88** | 0.95** | | | | | | |
| **Heavy metals in plant** | Pb | 0.92** | 0.89** | 0.9** | 0.93** | 0.92** | | | | | |
| | Cd | 0.87** | 0.81** | −0.54 | 0.97** | 0.89** | 0.97** | | | | |
| | Zn | 0.80** | 0.70** | 0.90** | 0.83** | 0.72** | 0.89** | −0.39 | | | |
| **Biochemical parameters** | ALA-D | −0.49** | −0.50** | −0.62** | −0.52** | −0.44** | −0.71** | −0.32 | −0.83** | | |
| | ALA | 0.65** | 0.65** | 0.72** | 0.67** | 0.64** | 0.82** | 0.71* | 0.85** | −0.86** | |
| | Total chl. | −0.39* | −0.35* | −0.45** | −0.40* | −0.36* | −0.51** | −0.52 | −0.55** | 0.54** | −0.59** |

** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

Table 4: Activity of δ-aminolevulinic acid dehydratase (ALA-D), δ-aminolevulinic acid (ALA) and total chlorophyll contents in leaves of onion plants grown in soil samples from some polluted locations of Mitrovica region (Shupkovc and City of Mitrovica) and Obiliqi region (Kryshevc, Leshkoshiq, Plementin and Mazgit) and non-polluted localtion Kraishtë (Control).

| Location | | ALA-D (μmol PGB mg protein$^{-1}$ h$^{-1}$) | | ALA (μmol mg$^{-1}$ FM) | | Total chlorophyll (mg g$^{-1}$ FM) | |
|---|---|---|---|---|---|---|---|
| | | **Mean** | **St. dev.** | **Mean** | **St. dev.** | **Mean** | **St. dev.** |
| **Mitrovica region** | Shupkovc | **38.82**$^{C}$ | 7.71 | **237.82**$^{A}$ | 15.61 | **0.79**$^{C}$ | 0.01 |
| | Mitrovica | **41.72**$^{C}$ | 1.68 | **221.35**$^{B}$ | 2.11 | **0.80**$^{C}$ | 0.01 |
| **Obliqi region** | Kryshevc | **45.63**$^{C}$ | 3.55 | **209.73**$^{B}$ | 10.41 | **0.87**$^{AB}$ | 0.07 |
| | Leshkoshiq | **57.19**$^{B}$ | 3.63 | **187.23**$^{C}$ | 18.36 | **0.89**$^{AB}$ | 0.07 |
| | Plementin | **45.75**$^{C}$ | 4.75 | **196.28**$^{C}$ | 5.14 | **0.83**$^{C}$ | 0.16 |
| | Mazgit | **44.51**$^{C}$ | 5.27 | **213.65**$^{B}$ | 2.34 | **0.81**$^{C}$ | 0.10 |
| | Control | **80.36**$^{A}$ | 5.97 | **152.02**$^{D}$ | 4.96 | **0.97**$^{A}$ | 0.01 |

**Note:** Means in each column followed by same letters are not significantly different at P 0.05 by one-way ANOVA with Duncan's multiple range tests.

**Source:** https://www.tandfonline.com/doi/full/10.1080/03601234.2020.1721229

Deciphering metal toxicity responses of flax (*Linum usitatissimum L.*) with exopolysaccharide and ACC-deaminase producing bacteria in industrially contaminated soils (2020)

Table 1: Quantitative estimation of ACC-deaminase, EPS and IAA production under standard and stressed conditions.

| Bacterial Strains | Acc-deaminase (µM/mg protein/h) | | Exopolysaccharide (mg/ml) | | IAA production (µM/ml) | |
|---|---|---|---|---|---|---|
| | Without stress | With stress | Without stress | With stress | Without stress | With stress |
| **PM14** | 0.493 ± 0.097[c] | 1.829 ± 0.089[a] | 0.5933 ± 0.0[b] | 2.953 ± 0.04[a] | 107 ± 1.632[a] | 91 ± 0.816[c] |
| **PM11** | 0.489 ± 0.081[c] | 1.701 ± 0.008[b] | 0.58 ± 0.024[b] | 2.967 ± 0.04[a] | 96 ± 1.632[b] | 79 ± 1.632[d] |

Table 2: Physio-chemical properties of soil.

| Soil parameters | Soil 1 (non-contaminated) | Soil 2 (contaminated) |
|---|---|---|
| **Soil EC (dsm$^{-1}$)** | 0.005 | 0.015 |
| **Soil pH** | 6.35 | 7.60 |
| **Soil texture** | Loamy | Sandy loam |
| **Organic matter** | 0.74% | 0.92 |
| **Nitrate-Nitrogen (ppm)** | 7.24 | 5.32 |
| **Available k (ppm)** | 109 | 63 |
| **Available p (ppm)** | 7 | 12 |
| **Cd (ppm) 0.005** | 0.681 | 11.739 |
| **Cr (ppm)** | 0.869 | 128.15 |
| **Mn (ppm)** | 0.569 | 125.25 |
| **Zn (ppm)** | 0.249 | 90.55 |
| **Cu (ppm)** | 0.075 | 5.78 |

Table 3. Differential effects of *B. xiamenensis* and *B. gibsonii* in heavy metals uptake from contaminated industrial soil.

| Treatments | Zn | Mn | Cd | Cr | Cu | Ni | cPb |
|---|---|---|---|---|---|---|---|
| | | L. usitatissimum | | | | | |
| **C** | 12.4 ± 0.01[c] | 11.7 ± 0.23[c] | 6 ± 0.15[c] | 16.7 ± 0.28[c] | 16.1 ± 0.1[c] | 20 ± 0.41[c] | 56 ± 0.02[b] |
| **T1** | 38.17 ± 0.57[a] | 33.9 ± 0.47[a] | 10.5 ± 0.19[b] | 18.9 ± 0.3[b] | 23.1 ± 0.4[b] | 53 ± 0.19[a] | 86 ± 0.06[a] |
| **T2** | 22.58 ± 0.5[b] | 17 ± 0.36[b] | 14.8 ± 0.08[a] | 35.3 ± 0.81[c] | 31.4 ± 0.8[a] | 48.8 ± 0.3[b] | 85 ± 0.19[a] |

C= Control, T1 = *B. xiamenensis* PM14 T2 = *B. gibsonii* (n = 3).

**Source:** https://www.sciencedirect.com/science/article/pii/S0981942820302084

Evaluation of in vivo sub-chronic and heavy metal toxicity of under-exploited seaweeds for food application (2020)

Table 1: Evaluation of Biochemical methods.

| Parameters | Method | Reference |
|---|---|---|
| **Hematological Haemoglobin RBC count WBC count<br>Packed Cell Volume (PCV)<br>Mean Corpuscular Volume (MCV)** | ABX pentra-120 Automated Haematology Analyzer | **Raghuramulu et al., 2003** |
| **Mean Corpuscular Hemoglobin (MCH)<br>Mean Corpuscular** | | |
| **Hemoglobin Concentration (MCHC)<br>Biochemical** | | |
| **Glucose** | Hexokinase method | **Shaw and Wolfe, 1989** |
| **Total protein** | Biuret method | **Shaw and Wolfe, 1989** |
| **Albumin** | BCG Dye binding method | **Bush and Reed, 1987** |
| **Calcium** | Arenazo III method | **Weissmann et al., 1980** |
| **Inorganic phosphorus** | Phosphomolydate method | **Daly and Ertingshausen, 1972** |
| **Electrolytes (Sodium, Potassium, Chloride)** | ISE method | **Tietz, 1987** |
| **Serum cholesterol** | CHOD PAP method | **Allain et al., 1974** |
| **ALT (SGOT)** | colorimetric method | **Reitman and Frankel, 1957** |
| **AST (SGPT)** | modified IFCC/UV kinetic method | **Reitman and Frankel, 1957** |
| **Alkaline phosphatase** | kinetic method | **Reitman and Frankel, 1957** |
| **Blood urea nitrogen** | Urease GLDH/UV kinetic method | **Tietz, 1987** |
| **Creatinine** | Jaffe/kinetic method | **Raghuramulu et al., 2003** |
| **Urine analysis (urine volume, pH and sodium, potassium, chloride)** | Flame photometer | **Schachter et al., 1980** |
| **Histopathology (liver and kidney)** | **conventional method-Microscope** | **Raghuramulu et al., 2003** |

Table 2: Hematological values of experimental rats on $90^{th}$ day

| Parameters | Reference value | Control group | Group I | Group II | Group III | Group IV | Group V | *f* value |
|---|---|---|---|---|---|---|---|---|
| **Haemoglobin (g/dl)** | 11–19 | 16.34 ± 3.42 | 16.10 ± 1.65 | 15.80 ± 1.41 | 15.40 ± 1.69 | 15.23 ± 1.89 | 15.2 ± 2.76 | **$0.27^{NS}$** |
| **RBC ($\times 10^6$ cells/mm³)** | 5.4–8.5<br>3.7–4.9 | 8.76 ± 0.32<br>7.32 ± 0.34 | 8.90 ± 0.85<br>6.90 ± 1.16 | 7.59 ± 1.22<br>6.12 ± 3.12 | 8.70 ± 1.37<br>6.10 ± 1.17 | 7.88 ± 1.21<br>7.12 ± 1.76 | 8.60 ± 0.88<br>7.30 ± 2.31 | **$1.6^{NS}$<br>$0.54^{NS}$** |
| **PCV(%)** | 37.6–50.6 | 45.89 ± 0.12 | 45.43 ± 3.09 | 48.64 ± 2.05 | 45.81 ± 2.87 | 49.20 ± 2.99 | 43.20 ± 3.35 | **4.2* ($p < 0.05$)** |
| **MCV (cumm)** | 57.3–66 | 62.70 ± 0.08 | 65.20 ± 0.76 | 62.00 ± 0.62 | 61.08 ± 4.32 | 60.14 ± 0.07 | 65.80 ± 0.76 | **9.1* ($p < 0.05$)** |
| **MCH (pg)** | 11–15 | 17.54 ± 0.99 | 18.20 ± 0.73 | 17.82 ± 0.39 | 17.60 ± 1.23 | 17.98 ± 1.33 | 17.50 ± 0.98 | **$0.47^{NS}$** |
| MCHC (%) | **30–35** | **32.90 ± 5.71** | **33.70 ± 3.98** | **33.32 ± 4.31** | **32.50 ± 2.76** | **33.65 ± 5.74** | **31.20 ± 2.76** | **$0.28^{NS}$** |

NS-Not significant, *$p < 0.05$, Dunnett's Multiple Comparison Test, all values are expressed as mean ± SD for 6 albino rats in each group.

Table 3 Biochemical values of experimental rats on 90th day

| Parameters | Standard Value | Control group | Group I | Group II | Group III | Group IV | Group V | *f* value |
|---|---|---|---|---|---|---|---|---|
| **Glucose (mg/dl)** | 85–132 | 89.32 ± 5.08 | 83.51 ± 9.08 | 80.28 ± 13.69 | 83.43 ± 9.18 | 88 ± 12.39 | 90.15 ± 3.47 | **1.0NS** |
| **Cholesterol (mg/dl)** | 46–92 | 51.60 ± 1.80 | 74.01 ± 3.77 | 62.00 ± 0.89 | 70.00 ± 4.33 | 63.00 ± 15.14 | 67.00 ± 2.10 | **8.0*** |
| **Blood urea nitrogen (mg/dl)** | 15–21 | 15.86 ± 1.56 | 16.10 ± 0.90 | 18.70 ± 2.63 | 19.25 ± 3.39 | 17.80 ± 2.76 | 16.60 ± 7.26 | **(P < 0.05) 0.88NS** |
| **Total protein (g/dl)** | 6.3–8.7 | 7.20 ± 1.56 | 6.60 ± 0.93 | 6.90 ± 0.63 | 6.60 ± 1.54 | 6.50 ± 0.91 | 6.50 ± 1.01 | **0.35NS** |
| **Albumin (g/dl)** | 3.3–4.9 | 4.38 ± 0.36 | 4.70 ± 1.0 | 4.38 ± 0.63 | 4.70 ± 0.52 | 4.30 ± 0.96 | 4.70 ± 1.19 | **0.31 NS** |
| **SGOT (AST) (U/L)** | 37–92 | 79.89 ± 0.26 | 90.12 ± 0.72 | 84 ± 2.34 | 89.78 ± 3.26 | 89.56 ± 0.76 | 90.12 ± 0.36 | **38*** |
| **SGPT (ALT) (U/L)** | 17–50 | 48.03 ± 5.60 | 51.75 ± 13.31 | 47.66 ± 11.07 | 48.36 ± 6.27 | 42.00 ± 7.84 | 47.00 ± 9.03 | **(p < 0.05) 0.70NS** |
| **Sodium (mEq/L)** | 140–150 | 143 ± 2.47 | 138.0 ± 8.13 | 139.0 ± 7.70 | 144.0 ± 13.44 | 138.0 ± 6.15 | 141.0 ± 10.25 | **0.53NS** |
| **Potassium (mEq/L)** | 5.2–7.8 | 6.39 ± 0.43 | 6.9 ± 0.75 | 5.6 ± 0.62 | 7.4 ± 1.19 | 6.7 ± 1.22 | 5.4 ± 0.91 | **4.41*** |
| **Calcium (mg/dl)** | 10.7–13.7 | 10.92 ± 0.64 | 11.80 ± 2.18 | 11.9 ± 3.45 | 12.6 ± 4.25 | 11.8 ± 1.88 | 11.9 ± 1.17 | **(p < 0.05) 0.25 NS** |
| **Creatinine (mg/dl)** | 0.9–1.5 | 1.57 ± 0.146 | 1.49 ± 0.103 | 1.50 ± 0.10 | 1.37 ± 0.05 | 1.45 ± 0.23 | 1.78 ± 0.12 | **0.13 NS** |
| **Alkaline Phosphatase (U/L)** | **39–216** | **120.72 ± 2.98** | **132.06 ± 6.71** | **131.00 ± 6.00** | **116.16 ± 5.30** | **126.36 ± 22.65** | **115.95 ± 10.58** | **2.48 NS** |

Values are significantly different from the control group at *p < 0.05 Dunnett's Multiple Comparison Test, all values are expressed as mean ± SD for 6 albino rats in each group.

Table 4: Mean weight of vital organs of experimental rats.

| Organs | Control group | Group I | Group II | Group III | Group IV | Group V | *f* value |
|---|---|---|---|---|---|---|---|
| **Liver** | 3.21 ± 0.07 | 3.18 ± 1.07 | 3.34 ± 3.03 | 3.48 ± 2.04 | 3.21 ± 1.89 | 3.27 ± 2.23 | **0.019NS** |
| **Spleen** | 0.34 ± 2.83 | 0.28 ± 1.24 | 0.37 ± 8.07 | 0.34 ± 3.24 | 0.28 ± 4.13 | 0.26 ± 1.25 | **0.067NS** |
| **Heart** | 0.4 ± 3.16 | 0.34 ± 1.18 | 0.37 ± 2.12 | 0.42 ± 1.06 | 0.44 ± 3.04 | 0.41 ± 4.06 | **0.011NS** |
| **Kidney** | 1.46 ± 2.14 | 1.29 ± 1.03 | 1.24 ± 3.12 | 1.98 ± 1.26 | 1.92 ± 2.31 | 1.31 ± 1.98 | **0.15NS** |
| **Brain** | **0.48 ± 1.91** | **0.63 ± 2.01** | **0.59 ± 3.03** | **0.32 ± 2.26** | **0.49 ± 4.42** | **0.45 ± 1.76** | **0.097NS** |

NS-not significant, Dunnett's multiple comparison test, all values are expressed as mean ± SD for 6 albino rats in each group.

Table 5: Urine electrolytes of experimental rats.

| Parameter | Control Group | Group I | Group II | Group III | Group IV | Group V | *f* value |
|---|---|---|---|---|---|---|---|
| **pH** | 7.87 ± 1.14 | 7.56 ± 2.23 | 7.54 ± 1.18 | 7.9 ± 2.45 | 8.1 ± 1.32 | 7.86 ± 2.12 | **0.084$^{NS}$** |
| **Na (mEq/l)** | 140.2 ± 1.23 | 138 ± 2.34 | 140 ± 2.78 | 136 ± 1.29 | 142 ± 3.29 | 140 ± 3.2 | **1.9$^{NS}$** |
| **K (mEq/l)** | 2.8 ± 2.42 | 2.5 ± 1.21 | 3.17 ± 1.78 | 3.02 ± 1.28 | 3.12 ± 1.67 | 2.98 ± 2.48 | **0.10$^{NS}$** |
| **Cl (mEq/l)** | **170 ± 1.34** | **168 ± 2.02** | **173 ± 1.98** | **180 ± 1.71** | **174 ± 1.05** | **176 ±2.56** | **32** (P < 0.01)** |

NS-not significant, Dunnett's multiple comparisons Test, all values are expressed as mean ± SD, n = 6 in each group.

$^{**}$ p < 0.01 significance level.

Table 6: Heavy metals accumulation in vital organs of experimental rats.

| | **Control** | | | **Group I** | | | **Group II** | | **Group III** | | **Group IV** | | | **Group V** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | As | Cd | Pb | As | Cd | Pb | As<br>Cd | Pb | As<br>Cd | Pb | As | Cd | Pb | As<br>Cd | **Pb** |
| **Kidney** | 0.00<br>0.024 | 28 | 0.17 | 0.21 | 0.012 | 0.06 | 0.79<br>0.04 | 0.6 | 0.72<br>0.031 | 0.8 | 0.78 | 0.04 | 0.079 | 0.98<br>0.012 | **0.12** |
| **Liver** | 0.20<br>8 | 0.01 | 0.437 | 0.09 | 0.039 | 0.08 | 0.51<br>0.037 | 0.29 | 0.236<br>0.012 | 0.57 | 0.156 | 0.025 | 0.12 | 0.76<br>0.04 | **0.08** |
| **Brain** | **0.17** | **nd** | **0.057** | **0.28** | **0.002** | **0.10** | **0.491**<br>**nd** | **0.08** | **0.396**<br>**nd** | **0.27** | **0.011** | **nd** | **0.03** | **0.05**<br>**nd** | **nd** |

nd- not deducted.

**Source:** https://www.sciencedirect.com/science/article/pii/S1018364719317926

Effects of EDTA and plant growth-promoting rhizobacteria on plant growth and heavy metal uptake of hyperaccumulator Sedum alfredii Hance (2020)

Table 1: Physico-chemical characteristics and heavy metal content of the studied soils.

| Property | Soil for pot experiment |
|---|---|
| pH | 6.3 |
| OM (g/kg) | 35.6 |
| CEC (cmol/kg) | 11.2 |
| Total N (g/kg) | 2.5 |
| Total P (g/kg) | 0.9 |
| Total K (g/kg) | 22.2 |
| Total Cd (mg/kg) | 46 |
| Total Pb (mg/kg) | 790 |
| Total Zn (mg/kg) | 4131 |
| Total Cu (mg/kg) | 29 |
| OM: organic matter; CEC: cation exchangeable capacity. | |

Table 2: Effects of different treatments on photosynthetic parameters of Sedum alfredii Hance.

| Treatment | Pn | Tr | WUE |
|---|---|---|---|
| | mmol/(m$^2$$sec)) | (g/(m$^2$$hr)) | (g/kg) |
| **CK** | 38.40 ± 0.10 b | 0.07 ± 0.04 b | 619.84 ± 332.44 ab |
| **EDTA** | 39.23 ± 0.12 a | 0.04 ± 0.02 bc | 1246.44 ± 622.61 a |
| **EDTA + D54** | 38.80 ± 0.17 b | 0.15 ± 0.01 a | 255.18 ± 10.48 c |
| **EDTA + D41** | 37.83 ± 0.15 c | 0.07 ± 0.01 c | 582.17 ± 88.93 ab |

Mean values are presented as mean ± SD (standard deviation). Different letters indicate significant differences between treatments ($p < 0.05$). Pn: net photosynthetic rate; Tr: transpiration rate; WUE: water use efficiency, WUE¼ Pn/Tr.

Table 3: Effects of different treatments on cysteine, gluthatione and phytochelatin content of Sedum alfredii Hance.

Table 3 e Effects of different treatments on cysteine, gluthatione and phytochelatin content of *Sedum alfredii* Hance.

| Treament | Cys | GSH | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|---|
| | (nmol/g) | (nmol/g) | (nmol/g) | (nmol/g) | (nmol/g) | (nmol/g) |
| CK | 0.000 ± 0.000 c | 11.662 ± 1.401 b | 0.626 ± 0.071 c | 0.363 ± 0.097 c | 0.050 ± 0.015 b | 0.009 ± 0.001 b |
| EDTA | 0.142 ± 0.043 b | 15.128 ±1.967 a | 4.712 ± 1.050 b | 2.085 ± 0.482 b | 0.111 ±0.034 a | 0.015 ±0.003 a |
| EDTA + D54 | 0.380 ± 0.366 ab | 15.063 ±1.851 a | 7.879 ±1.567 a | 3.221 ±0.509 a | 0.117 ± 0.054 ab | 0.012 ±0.002 a |
| EDTA+D416 | 0.549 ± 0.273 a | 10.935 ± 0.722 b | 5.732 ± 2.135 ab | 2.894 ±0.082 a | 0.154 ± 0.106 ab | 0.013 ± 0.004 ab |

Mean values are presented as mean ± SD (standard deviation). Different letters denote significant difference from the corresponding control and other treatments ($p < 0.05$).

Cys: cysteine; GSH: glutathione; PC: phytochelatins.

**Source:** https://www.sciencedirect.com/science/article/abs/pii/S1001074219316377

Effects of long-term fertilizer applications on peanut yield and quality and plant and soil heavy metal accumulation (2020)

Table 1: Changes in pH, organic matter (OM) content, and available nutrients (mean ± SD) in soil after long-term fertilization.

| Treatment | pH | OM (mg• kg-1) | N mg• kg-1 | P mg· $kg^{-1}$ | K mg· $kg^{-1}$ |
|---|---|---|---|---|---|
| **Initial soil** | 3.90 ± 0.12 c | 8.44 ± 0.72 c | 0.043 ± 0.0024 c | - | **0.084 ± 0.013 b** |
| **F** | 5.38 ± 0.14 b | 19.51 ± 0.76 b | 0.073 ± 0.0032 b | 0.015 ± 0.00078 b | **0.58 ± 0.054 a** |
| **FT** | 5.25 ± 0.20 b | 20.52 ± 0.60 b | 0.078 ± 0.0038 b | 0.016 ± 0.00081 b | **0.63 ± 0.062 a** |
| **M** | 6.03 ± 0.21 a | 22.58 ± 0.84 a | 0.090 ± 0.0022 a | 0.062 ± 0.0018 a | **0.60 ± 0.050 a** |
| **MB** | 5.76 ± 0.18 a | 22.62 ± 0.69 a | 0.090 ± 0.0026 a | 0.059 ± 0.0025 a | **0.57 ± 0.047 a** |
| **MBT** | **5.83 ± 0.11 a** | **23.05 ± 0.80 a** | **0.092 ± 0.0029 a** | **0.065 ± 0.0016 a** | **0.56 ± 0.052 a** |

Different lowercase letters within columns indicate significant differences ($P < 0.05$, Student–Newman–Keuls multiple comparison test). F: chemical fertilizer; FT: F + trace elements; M: organic fertilizer (pig manure); MB: M + effective microorganisms; MBT: MB + trace elements.

Table 2: Effects of fertilization on crude protein and crude lipid content (mean ± SD) (%) in peanut kernels

| Treatment | F | FT | M | MB | MBT |
|---|---|---|---|---|---|
| **Crude protein** | 28.78 ± 0.12c | 29.06 ± 0.18c | 32.71 ± 0.21b | 33.02 ± 0.22b | **34.76 ± 0.22a** |
| **Crude lipid** | **52.81 ± 0.11b** | **52.38 ± 0.86b** | **54.81 ± 1.19a** | **54.19 ± 0.52a** | **56.6 ± 0.42a** |

Different lowercase letters within columns indicate significant differences ($P < 0.05$, Student–Newman–Keuls multiple comparison test). F: chemical fertilizer; FT: F + trace elements; M: organic fertilizer (pig manure); MB: M + effective microorganisms; MBT: MB + trace elements.

Table 3: Effect of fertilization on amino acid contents (mean ± SD) (%) in peanut kernels

| Treatment | F | FT | M | MB | MBT |
|---|---|---|---|---|---|
| **Threonine** | 1.30 ± 0.03 c | 1.36 ± 0.04 c | 1.45 ± 0.04 b | 1.51 ± 0.05 b | **1.84 ± 0.08 a** |
| **Valine** | 1.57 ± 0.03 c | 1.63 ± 0.03 c | 1.76 ± 0.04 b | 1.79 ± 0.04 b | **1.91 ± 0.05 a** |
| **Methionine** | 0.10 ± 0.02 c | 0.14 ± 0.02 c | 0.38 ± 0.03 b | 0.42 ± 0.04 b | **0.51 ± 0.04 a** |
| **Isoleucine** | 1.59 ± 0.02 c | 1.59 ± 0.02 c | 1.68 ± 0.03 b | 1.71 ± 0.03 b | **1.83 ± 0.04 a** |
| **Leucine** | 3.12 ± 0.02 c | 3.17 ± 0.03 c | 3.38 ± 0.03 b | 3.43 ± 0.03 b | **3.64 ± 0.05 a** |
| **Phenylalanine** | 2.92 ± 0.02 c | 2.97 ± 0.2 c | 3.17 ± 0.03 b | 3.21 ± 0.03 b | **3.36 ± 0.04 a** |
| **Lysine** | 2.66 ± 0.02 c | 2.71 ± 0.03 c | 2.83 ± 0.03 b | 2.86 ± 0.03 b | **3.21 ± 0.05 a** |
| **Total amino acids** | **54.14 ± 0.21 c** | **54.59 ± 0.23 c** | **55.73 ± 0.26 b** | **56.01 ± 0.28 b** | **58.55 ± 0.27 a** |

Different lowercase letters within columns indicate significant differences ($P < 0.05$, Student–Newman–Keuls multiple comparison test). F: chemical fertilizer; FT: F + trace elements; M: organic fertilizer (pig manure); MB: M + effective microorganisms; MBT: MB + trace elements.

Table 4: Effect of fertilization practice on fatty acid content and composition (mean ± SD) (%)

| Treatment | F | FT | M | MB | MBT |
|---|---|---|---|---|---|
| **Palmitic acid** | 8.40 ± 0.12 b | 8.43 ± 0.13b | 8.73 ± 0.13 a | 8.78 ± 0.14a | **8.77 ± 0.13 a** |
| **Stearic acid** | 2.51 ± 0.02 b | 2.53 ± 0.02b | 2.62 ± 0.03 a | 2.59 ± 0.03a | **2.63 ± 0.03 a** |
| **Oleic acid** | 48.32 ± 0.13c | 48.53 ± 0.13c | 50.52 ± 0.16 b | 50.93 ± 0.1 b | **51.57 ± 0.17 a** |
| **Linoleic acid** | 29.75 ± 0.11b | 29.76 ± 0.12b | 30.13 ± 0.14 a | 30.15 ± 0.16a | **30.15 ± 0.15 a** |
| **Linolenic acid** | 0.33 ± 0.01 b | 0.35 ± 0.02b | 0.44 ± 0.03 a | 0.47 ± 0.03a | **0.45 ± 0.03 a** |
| **Eicosanoic acid** | 1.41 ± 0.01 b | 1.45 ± 0.02b | 1.58 ± 0.03 a | 1.63 ± 0.03a | **1.65 ± 0.03 a** |
| **Arachidonic acid** | 0.79 ± 0.02 b | 0.81 ± 0.02b | 0.86 ± 0.02 a | 0.87 ± 0.03a | **0.89 ± 0.03 a** |
| **Docosanoic acid** | 2.12 ± 0.02 b | 2.15 ± 0.02b | 2.25 ± 0.03 a | 2.31 ± 0.03a | **2.25 ± 0.03 a** |
| **Tetracosanoic acid** | 1.23 ± 0.02 b | 1.26 ± 0.02b | 1.36 ± 0.03 a | 1.42 ± 0.03a | **1.43 ± 0.03 a** |
| **O/ L ratio** | **1.62** | **1.63** | **1.67** | **1.68** | **1.71** |

Different lowercase letters within columns indicate significant differences (*P* < 0.05, Student–Newman–Keuls multiple comparison test). F: chemical fertilizer; FT: F + trace elements; M: organic fertilizer (pig manure); MB: M + effective microorganisms; MBT: MB + trace elements.

Table 5: Metal contents (mean ± SD) in pig manure and inorganic fertilizers

| Amendment | Cu | Zn | Pb | Cd |
|---|---|---|---|---|
| **Pig manure (dry weight)** | $mg\cdot kg^{-1}$ 20.57 ± 0.34 | $mg\cdot kg^{-1}$ 81.57 ± 0.43 | $mg\cdot kg^{-1}$ 27.64 ± 0.13 | **$mg\cdot kg^{-1}$ 7.91 ± 0.06** |
| **Urea** | 17.78 ± 0.14 | 70.83 ± 0.32 | 2.51 ± 0.02 | **0.08 ± 0.001** |
| **Calcium magnesium phosphate** | 1.02 ± 0.01 | 4.47 ± 0.02 | - | **0.12 ± 0.01** |
| **Potassium chloride** | **3.18 ± 0.03** | **14.17 ± 0.15** | **-** | **0.08 ± 0.001** |

**Source:** https://www.sciencedirect.com/science/article/abs/pii/S1002016017604570

Efficiency of Heavy Metals-Tolerant Plant Growth Promoting Bacteria for Alleviating Heavy Metals Toxicity on Sorghum (2019)

Table : Effect of heavy metals on photosynthetic pigments in sorghum leaves

| Treatments | | Chlo.A | | Chlo. B | | Carotenoids | |
|---|---|---|---|---|---|---|---|
| | | Inoculation with HMT-PGPB | | | | | |
| | | Without | With | Without | With | Without | With |
| **Control** | | $0.9^{h}$ | $2.1^{b}$ | $0.5^{e}$ | $1.2^{bc}$ | $1.3^{f}$ | $3.1^{ab}$ |
| **$Cu^{2+}$ (mg/kg)** | 100 | $1.9^{b}$ | $0.7^{i}$ | $1.1^{a}$ | $1.3^{b}$ | $3.1^{ab}$ | $3.2^{a}$ |
| | 200 | $1.4^{d}$ | $2.1^{b}$ | $0.7^{cd}$ | $1.2^{bc}$ | $2.6^{bc}$ | $2.9^{cd}$ |
| | 400 | $1.3^{de}$ | $1.9^{c}$ | $0.6^{de}$ | $0.5^{i}$ | $2.1^{cde}$ | $2.6^{e}$ |
| **$Cd^{2+}$ (mg/kg)** | 10 | $1.4^{d}$ | $1.4^{g}$ | $0.9^{b}$ | $1.3^{b}$ | $2.6^{bc}$ | $3.2^{a}$ |
| | 20 | $1.3^{de}$ | $2.9^{a}$ | $1.2^{a}$ | $1.1^{cd}$ | $2.2^{cd}$ | $2.8^{d}$ |
| | 40 | $1.3^{de}$ | $1.7^{de}$ | $1.2^{a}$ | $0.6^{hi}$ | $2.0^{de}$ | $2.3^{f}$ |
| **$Pb^{2+}$ (mg/kg)** | 200 | $2.2^{a}$ | $1.5^{gf}$ | $1.2^{a}$ | $1.0^{de}$ | $3.4^{a}$ | $3.1^{ab}$ |
| | 400 | $1.7^{c}$ | $1.2^{h}$ | $0.8^{bc}$ | $1.6^{a}$ | $2.6^{bc}$ | $2.9^{cd}$ |
| | 800 | $1.1^{fg}$ | $1.4^{g}$ | $0.6^{de}$ | $0.7^{gh}$ | $1.3^{f}$ | $2.5^{e}$ |
| **$Zn^{2+}$ (mg/kg)** | 250 | $1.8^{bc}$ | $1.8^{cd}$ | $1.2^{a}$ | $0.9^{ef}$ | $3.2^{a}$ | $3.1^{ab}$ |
| | 500 | $1.2^{ef}$ | $1.6^{ef}$ | $0.7^{cd}$ | $0.8^{gf}$ | $1.8^{def}$ | $2.1^{f}$ |
| | 1000 | $1.0^{gh}$ | $1.1^{h}$ | $0.9^{b}$ | $0.6^{hi}$ | $1.6^{ef}$ | $1.9^{g}$ |
| **Mixture (mg/kg)** | | $1.3^{de}$ | $2.2^{b}$ | $0.5^{e}$ | $0.9^{ef}$ | $1.9^{de}$ | $3.0^{bc}$ |

**a,b, c Means with different superscript in the same column are significantly different at ($P<0.05$).**

Data presented in Table indicates that photosynthetic pigments increased in inoculated plants than uninoculated ones. This due to the beneficial effects of HMT-PGPB for alleviation the toxic effects of heavy metals. In this respect, Popova et al. (2012) demonstrated the relationship between total chlorophyll content in heavy metal exposed and bacterial treated plants. He proved that because the ability of the bacteria to metabolize heavy metal, the chlorophyll content was affected and cause increase in photosynthetic activity followed by increase in plant growth.

**Source:** https://www.sciencedirect.com/science/article/abs/pii/S0098847219302497

Efficiency of Heavy Metals-Tolerant Plant Growth Promoting Bacteria for Alleviating Heavy Metals Toxicity on Sorghum (2019)

Table: Effect of different heavy metals concentrations on oxidative enzymes in sorghum

| **Treatments** | | **PO (Abs. at 425 nm/g FW/15 min.)** | | **PPO (Abs. at 420 nm/g FW/ 30 min.)** | |
|---|---|---|---|---|---|
| | | **Inoculation with HMT-PGPB** | | | |
| | | **Without** | **With** | **Without** | **With** |
| **Control** | | 4.048[a] | 4.550[a] | 1.034[g] | 1.293[h] |
| **$Cu^{2+}$** (mg/kg) | 100 | 4.133[a] | 4.280[c] | 1.792[b] | 2.014[b] |
| | 200 | 3.751[a] | 3.775[k] | 1.145[e] | 1.168[j] |
| | 400 | 3.076[b] | 3.483[m] | 0.571[k] | 1.079[l] |
| **$Cd^{2+}$** **(mg/kg)** | 10 | 4.113[a] | 4.327[b] | 1.910[a] | 1.912[c] |
| | 20 | 3.978[a] | 4.252[d] | 0.833[i] | 0.977[m] |
| | 40 | 3.693[a] | 4.038[e] | 0.830[i] | 0.933[n] |
| **$Pb^{2+}$** (mg/kg) | 200 | 4.102[a] | 3.828[i] | 0.910[h] | 1.761[d] |
| | 400 | 3.979[a] | 3.818[j] | 0.830[i] | 1.531[f] |
| | 800 | 3.956[a] | 3.763[l] | 0.806[j] | 1.173[i] |
| **$Zn^{2+}$** **(mg/kg)** | 250 | 4.154[a] | 3.998[f] | 1.473[c] | 1.566[e] |
| | 500 | 4.000[a] | 3.954[h] | 1.315[d] | 1.492[g] |
| | 1000 | 3.948[a] | 3.245[n] | 1.317[d] | 1.081[k] |
| **Mixture (mg/kg)** | | 3.859[a] | 3.987[g] | 1.091[f] | 2.583[a] |

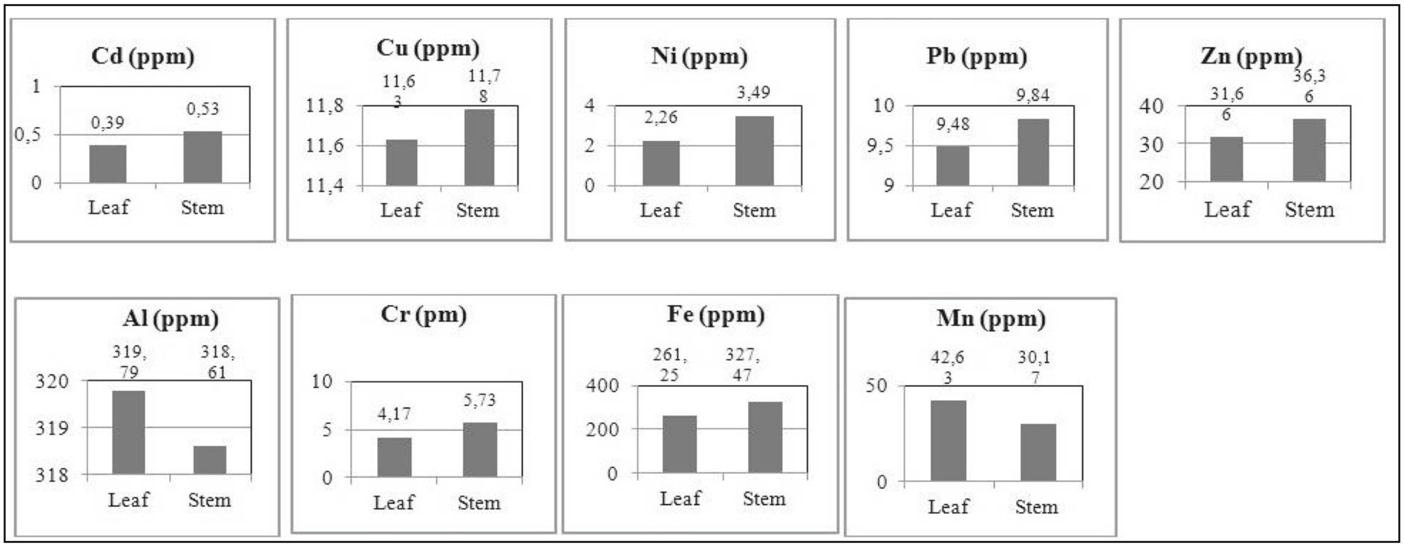
**[a, b, c] Means with different superscript in the same column are significantly different at ($P<0.05$).**

**PO: peroxidase, PPO: polyphenol oxidase**

Respecting the effect of heavy metals mixture on sorghum growth, it was clear that all estimated parameters were lower in uninoculated plants than inoculated plants. This could be because the toxic effect of heavy metals and role of HMT-PGPB which possess many strategies (salicylic acid, proline, exopolysaccharide, biosurfactant and sidrophores) to alleviate the toxic effect of heavy metals as previously confirmed and as many researchers demonstrated.

**Source:** http://sci-hub.tw/https://doi.org/10.1016/j.envexpbot.2019.03.005

## Heavy metal accumulation in rosemary leaves and stems exposed to traffic-related pollution near Adana-İskenderun Highway *(Hatay, Turkey)* (2019)



Accumulation level of heavy metals in the plants' leaves and stem (ppm)

**Source:** https://link.springer.com/content/pdf/10.1007%2Fs10661-019-7714-7.pdf

## Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils (2019)

Table: Maximum permissible limits for toxic heavy metals concentration in irrigation water, soil and plants.

| Metal | Irrigation water (µg/mL) | Soil (µg/g) | Plant (µg/g) |
|---|---|---|---|
| **Lead (Pb)** | 0.015 | 300 | 0.30 |
| **Cadmium (Cd)** | 0.01 | 3 | 5 |
| **Chromium (Cr)** | 0.10 | 150 | 0.2 |
| **Arsenic (As)** | 0.01 | 20 | 0.1 |
| **Nickel (Ni)** | 1.40 | 50 | 67 |
| **Mercury (Hg)** | 0.01 | 30 | 0.03 |
| **Copper (Cu)** | 0.20 | 80 | 40 |
| **Iron (Fe)** | 0.50 | 50,000 | 450 |
| **Zinc (Zn)** | 2.0 | 300 | 60 |
| **Manganese (Mn)** | 0.20 | 140 | 500 |

Lead and cadmium can influence the absorption of $Cu^{2+}$, $Fe^{2+}$, $Zn^{2+}$ and $Mn^{2+}$ through competition for sites or processes shared by these cations (Xu and Shi, 2000). Hence, metal contaminated crops mainly vegetables are not safe for human edible purpose due to their network of roots in upper layer of soil (Smolen et al., 2010; Qureshi et al., 2016; Gupta et al., 2019). The maximum permissible limits of toxic heavy metals in irrigation water, soil and plants are presented in the table.

**Source:** https://www.sciencedirect.com/science/article/pii/S0147651319302271

## Multi-criteria decision analysis of optimal planting for enhancing phytoremediation of trace heavy metals in mining sites under interval residual contaminant concentrations (2019)

Table: The comparison of measured and simulated cumulative metal uptake for all scenarios (t ¼ 180 days; values ¼ averaged data, n ≤ 4).

| **Samples** | **Measured** | **values** | **Simulated** | **values** | **RMSE(Zn)** | | **RMSE(Pb)** | **RMSE(Cd)** |
|---|---|---|---|---|---|---|---|---|
| | Zn | Pb | Cd | Zn | Pb | Cd | | |
| ***Setaria viridis*** | 85.86 | 75.74 | 8.05 | 87.2 | 75.21 | 7.77 | 1.61 | **4.16** |
| ***Phragmites australisis*** | 119.74 | 40.71 | 4.28 | 115.7 | 41.21 | 4.22 | 1.27 | **2.04** |
| ***Echinochloa crus-galli*** | **228.65** | **37.36** | **11.44** | **240.21** | **38.67** | **11.22** | **1.12** | **1.43** |

Table shows the growth characteristics of the 3 plant species (Setaria viridis, Echinochloa crus-galli and Phragmites australis) in this area.

Table compared the modeled solute plant uptake with those observed values in the surveyed area (t 180 days). Due to the complexity of predicting the rate of degradation and transportation of trace metal contaminants in the unsaturated zone, it was considered accept- able if root mean square error was less than 50%. The average values of RMSE between the predicted and observed Zn, Pb and Cd uptake is shown in Table, where the highest RMSE is 1.61(Zn), 4.16(Pb) and 6.01(Cd). Nevertheless, a maximum concentration croot for Pb uptake was modified to 0.21. This requirement was used due to (1) extremely low Pb translocation from the study area and (2) a relatively high initial Pb concentration.

**Source:** https://sci-hub.tw/10.1016/j.envpol.2019.113255

## Assessment of Metalloid and Metal Contamination in Soils from Hainan, China.(2018)

Table: Statistics of studied elements (mg.kg$^{-1}$) in soils (0–20 cm) of Hainan Island

| | **As** | **Cd[a]** | **Cr** | **Cu** | **Hg[a]** | **Ni** | **Pb** | **Se** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|
| **N** | 8713 | 8713 | 8713 | 8713 | 8713 | 8713 | 8713 | 8713 | 8713 |
| **Minimum** | 0.01 | 2 | 0.1 | 0.25 | 1 | 0.1 | 1 | 0.02 | 2 |
| **Maximum** | 988.04 | 3064 | 860.3 | 192.9 | 3540 | 327.1 | 619.6 | 4.68 | 800 |
| **Geometrical mean** | 2.17 | 60.19 | 26.50 | 9.43 | 33.34 | 8.74 | 22.20 | 0.26 | 39.64 |
| **Variation coefficient** | 4.05 | 1.16 | 1.58 | 1.35 | 1.77 | 1.91 | 0.67 | 0.88 | 0.74 |
| **Std. Deviation** | 21.42 | 93.61 | 96.32 | 23.34 | 75.20 | 48.18 | 17.51 | 0.30 | 37.91 |
| **Skewness** | 24.91 | 10.52 | 2.65 | 2.35 | 29.30 | 2.74 | 7.79 | 3.39 | 2.51 |
| **Kurtosis** | 858.68 | 219.08 | 7.09 | 4.97 | 1127.52 | 6.93 | 191.20 | 22.67 | 22.31 |
| **China BK[b]** | 9.20 | 74.00 | 53.90 | 20.00 | 40.00 | 23.40 | 23.60 | 0.22 | 67.70 |
| **Threshold of the first grate[c]** | 15 | 200 | 90 | 35 | 150 | 40 | 35 | | 100 |
| **Canadian soil quality guidelines[d]** | 12 | 10000 | 64 | 63 | 6600 | 45 | 140 | 1 | 200 |
| **Target value of Dutch soil guidelines[e]** | 29 | 800 | 100 | 36 | 300 | 35 | 85 | | 140 |

[a] µg.kg$^{-1}$; [b]Background values of Chinese soils, A layer (0–20 cm), more than 4000 samples; [c]Class I value of the Environmental Quality Standard for Soils in China; [d] Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (Residential); [e] Values for soil remediation proposed by Dutch Ministry of Housing, Spatial Planning and Environment.

**Source:** https://www.mdpi.com/1660-4601/15/3/454

## Heavy Metals bio-adsorption by *Hibiscus Sabdariffa l.* from contaminated water.(2018)

| Mean Cd content (mg/L) | Time of contact | | | | | |
|---|---|---|---|---|---|---|
| | 1 min | 5 min | 10 min | 15 min | 30 min | 40 min |
| sepal + 1 % black tea residue | | | | | | |
| 0.2 % bio-adsorbent H. sabdariffa L. | 48.04 $^{a}$ | 42.338 $^{b}$ | 33.217 $^{c}$ | 32.574 $^{c}$ | 32.111 $^{c}$ | 26.788 $^{d}$ |
| sepal + 2 % black tea residue | | | | | | |
| 0.3 % bio-adsorbent H. sabdariffa L. | 47.03 $^{a}$ | 38.195 $^{b}$ | 32.067 $^{c}$ | 28.974 $^{c}$ | 26.571 $^{c}$ | 17.454 $^{d}$ |
| sepal + 3 % black tea residue | | | | | | |
| 0.5 % bio-adsorbent H. sabdariffa L. | 44.12 $^{a}$ | 34.187 $^{b}$ | 30.107 $^{c}$ | 27.651 $^{c}$ | 14.092 $^{d}$ | 8.732 $^{d}$ |
| sepal + 3 % black tea residue | | | | | | |
| untreated contaminated Effluent | 50.032 $^{a}$ | 50.021 $^{a}$ | 49.868 $^{a}$ | 49.866 $^{a}$ | 49.964 $^{a}$ | 49.866 $^{a}$ |
| Mean Co content (mg/L) | 1 min | 5 min | 10 min | 15 min | 30 min | 40 min |
| 0.1 % bio-adsorbent H. sabdariffa L. | 103.42 $^{a}$ | 97.106 $^{a}$ | 95.602 $^{a}$ | 93.116 $^{a}$ | 93.217 $^{a}$ | 91.181 $^{b}$ |
| sepal + 1 % black tea residue | | | | | | |
| 0.2 % bio-adsorbent H. sabdariffa L. | 100.88 $^{a}$ | 98.419 $^{a}$ | 94.333 $^{a}$ | 91.018 $^{b}$ | 89.806 $^{b}$ | 88.112 $^{b}$ |
| sepal + 2 % black tea residue | | | | | | |
| 0.3 % bio-adsorbent H. sabdariffa L. | 100.01 $^{a}$ | 90.154 $^{b}$ | 89.094 $^{b}$ | 86.731 $^{b}$ | 80.556 $^{c}$ | 78.667 $^{c}$ |
| sepal + 3 % black tea residue | | | | | | |
| 0.5 % bio-adsorbent H. sabdariffa L. | 98.65 $^{a}$ | 87.28 $^{b}$ | 86.564 $^{b}$ | 83.211 $^{b}$ | 78.444 $^{c}$ | 70.193 $^{c}$ |
| sepal + 3 % black tea residue | | | | | | |
| untreated contaminated Effluent | 110.21 $^{a}$ | 110.45 $^{a}$ | 109.89 $^{a}$ | 109.88 $^{a}$ | 110.23 $^{a}$ | 110.35 $^{a}$ |
| Mean Ni content (mg/L) | 1 min | 5 min | 10 min | 15 min | 30 min | 40 min |
| 0.1 % bio-adsorbent H. sabdariffa L. | 106.52 $^{a}$ | 100.03 $^{a}$ | 95.556 $^{b}$ | 93.213 $^{b}$ | 90.617 $^{b}$ | 82.187 $^{c}$ |
| sepal + 1 % black tea residue | | | | | | |
| 0.2 % bio-adsorbent H. sabdariffa L. | 102.89 $^{a}$ | 97.632 $^{a}$ | 92.206 $^{b}$ | 90.111 $^{b}$ | 85.345 $^{c}$ | 78.432 $^{d}$ |
| sepal + 2 % black tea residue | | | | | | |
| 0.3 % bio-adsorbent H. sabdariffa L. | 95.498 $^{a}$ | 91.222 $^{b}$ | 89.704 $^{b}$ | 84.532 $^{c}$ | 80.556 $^{c}$ | 76.562 $^{d}$ |
| sepal + 3 % black tea residue | | | | | | |
| 0.5 % bio-adsorbent H. sabdariffa L. | 90.478 $^{b}$ | 80.778 $^{c}$ | 74.306 $^{d}$ | 68.092 $^{d}$ | 60.232 $^{d}$ | 50.32 $^{f}$ |
| sepal + 3 % black tea residue | | | | | | |
| untreated contaminated Effluent | 110.15 $^{a}$ | 111.9 $^{a}$ | 110.16 $^{a}$ | 110.87 $^{a}$ | 110.34 $^{a}$ | 110.28 $^{a}$ |

Mean value ±SD of Cadmium, Cobalt and Nickel contents (mg /L) after addition of different percentages of H. sabdariffa L. sepal and black tea residue

**Source:** http://repositsc.nuczu.edu.ua/bitstream/123456789/6848/1/22-32-Parisa%20Ziarati.pdf

Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. (2017)

Table 1: Heavy metal levels in air reported in different countries

| **Country** | **Poland** | **Pakistan** | **Spain** | **Algeria** | **Iran** | **India** | **UK** | **Nigeria** |
|---|---|---|---|---|---|---|---|---|
| Metal | Concentration | Concentration in | Concentration in | Concentration in | Concentration in | Concentration | Concentration | Concentration |
| | In air(ng/$m^3$) | air (ng/$m^3$) | air (ng/$m^3$) | air(ng/$m^3$) | air(ng/$m^3$) | in air (ng/$m^3$) | in air (ng/$m^3$) | in air(ng/$m^3$) |
| Pb | 23.6 | 16.24 | 9.24 | 299 | 120.92 | - | 10.22 | 0.832 |
| Cd | 0.806 | 31.66 | 0.25 | 21.2 | 0.33 | 0.02 | 0.2 | - |
| Zn | 66.5 | 0.85 | 354 | - | 164.58 | 7.13 | - | 1.712 |
| Ni | 2.15 | 65.78 | 3.38 | 42.4 | 5.33 | 0.29 | 1.74 | 0.478 |
| As | 0.534 | - | 0.55 | - | 7.77 | - | 0.91 | - |
| Fe | - | - | | 639.8 | 652.41 | 20.81 | - | 1.081 |
| Co | 0.271 | 12.69 | | 37.7 | 5.13 | | - | - |
| Al | 0.058 | 3.01 | - | - | 241.51 | 13.89 | - | - |

Table 2: Foliar heavy metal uptake by vegetables and associated health risks near industrial areas

| **Metal** | | **Vegetable** | **Concentration in atmospheric fallouts (mg $cm^{-2}$)** | **Concentration in plant shoot (mg /kg)** | **Concentration in grains** | **GEF** | **DIM (mg kg/ day)** | **HRI** |
|---|---|---|---|---|---|---|---|---|
| Cd | | Spinach | | 317.3 | - | 396.6 | 0.127 | 25.493 |
| Cd | | Rice | | 30.1 | 2 | 0.1 | 0.012 | 2.418 |
| Cd | | Lettuce | 0.9 | 1.7 | | 1.9 | 0.001 | 0.137 |
| Pb | | Lettuce | | 335 | | 300.1 | 0.135 | 26.915 |
| Pb | | Lettuce | | 171.5 | | 248.7 | 0.069 | 13.779 |
| Pb | | Lettuce | 456.2 | 122 | | 0.3 | 0.049 | 9.802 |
| Pb | | Spinach | | 485 | - | 79.5 | 0.195 | 38.966 |
| Zn | | Lettuce | 6.9 | 29.1 | | 4.2 | 0.012 | 2.338 |
| Zn | | Wheat | | 31.68 | 43.61 | 1.4 | 0.013 | 2.545 |
| Zn | | Spinach | | 144.2 | - | 5.7 | 0.058 | 11.585 |
| Zn | | Wheat | | 86.8 | 43.4 | 0.5 | 0.035 | 6.974 |
| Sb | | Lettuce | 1.9 | 1.4 | | 0.7 | 0.001 | 0.112 |
| Sb | | Spinach | | 276.3 | - | 50.2 | 0.111 | 22.199 |
| Ni | | Birch | 58.2 | 4.8 | | 0.1 | 0.002 | 0.386 |
| Cu | | Ryegrass | 1.7 | 7 | | 4.1 | 0.003 | 0.562 |
| As | | Lettuce | 0.2 | 1.1 | | 5.5 | 0 | 0.088 |

GEF; Global Enrichment Factor, DIM; Daily Intake of Metals, HRI; Health Risk Index

**Source:** https://sci-hub.tw/10.1016/j.jhazmat.2016.11.063

# Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia (2016)

Table 1: Daily intakes of metals (DIM) (mg $kg^{-1}$ $person^{-1}$ $d^{-1}$) and the Health Risk Index (HRI) for individual heavy metals in food crops irrigated with sewage water

| **Metals** | **Translocation factor AF**[a] | **Risk assessment index** | | | **RDA**[b] **(mg day $^{1}$)** | **RfD**[c] **(mg kg $^{1}$ day $^{1}$)** |
|---|---|---|---|---|---|---|
| | | DIM | HRI | THQ | | |
| **Cu** | 0.0122–0.0246 | 3.30E-03 | 2.20E-03 | 0.873 | 6.0–9.0 | 0.2 |
| **Ni** | 0.1265–0.1489 | 3.20E-03 | 1.62E-01 | 0.902 | 2.0–8.0 | 0.4 |
| **Mn** | 1.0777–1.0964 | 4.06E-02 | 2.90E-01 | 1.164 | 1.8–2.3 | 0.14 |
| **Pb** | 1.0124–1.0429 | 2.85E-02 | 8.14E-00 | 1.803 | 2.0–6.5 | 0.6 |
| **Cd** | 0.0991–0.1820 | 1.70E-03 | 1.67E-00 | 2.904 | 1.8–6-8 | 0.5 |
| **Zn** | 1.1422–1.1622 | 4.00E-04 | 3.00E-04 | 0.065 | 8.0–11.0 | 0.3 |
| **Fe** | 0.6162–0.8354 | 1.90E-03 | 9.68E-02 | 0.442 | 8.0–18.0 | 0.8 |
| **Cr** | 1.6730–1.8240 | 2.28E-02 | 1.63E-01 | 2.279 | 5.0–9-0 | 0.3 |

The accumulation factors of the metals in the consumed parts of the plants were less than the values obtained for Fe and Cr. Chromium, with AF values in the range of 1.6730–1.8240, was the most accumulated. Thus, the bio-concentration factor (BCF) values of metals in the food crops showed a trend in the order of Cr > Zn > Ni > Cd > Mn > Pb > Cu ≈ Fe. The best accumulators for Cr are okra plants that preferentially concentrate metals in their leaves, the consumable part of the plant.

**Source:** https://www.sciencedirect.com/science/article/pii/S1319562X15002181