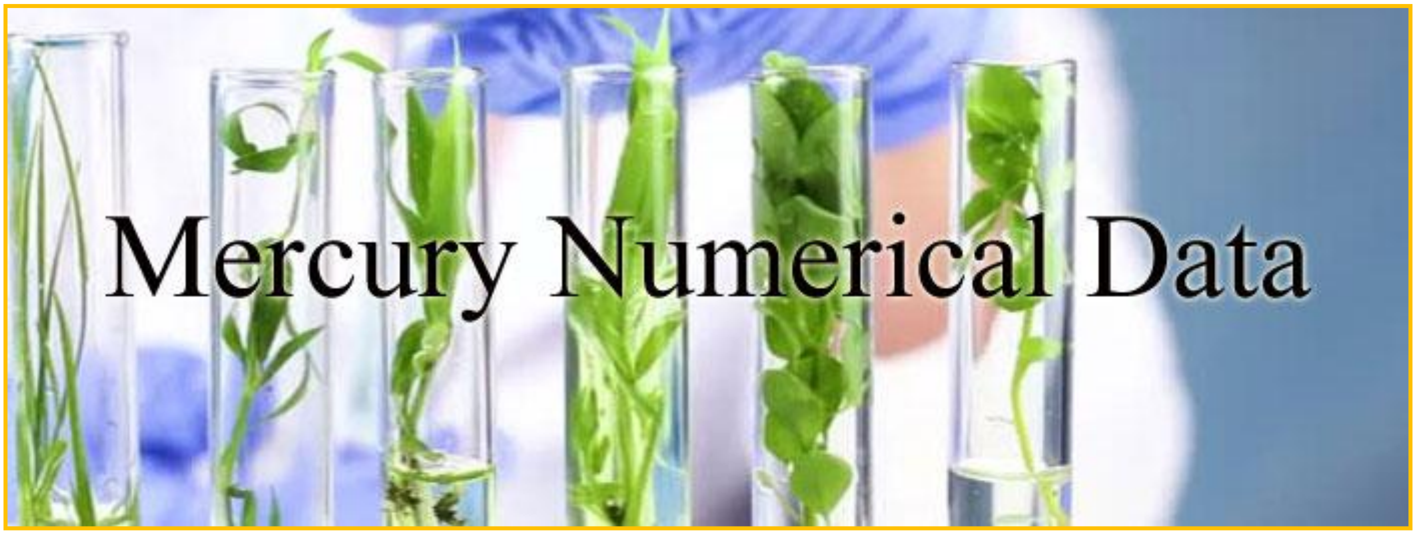

Phytoremediation and Microorganisms-Assisted Phytoremediation of Mercury-Contaminated Soils: Challenges and Perspectives (2021)

Table 1: Summary of research on Hg phytoremediation potential and toxicity of Hg promising (hyper) accumulator species, wide-range heavy metal accumulator, and crop plants.

Type	**Plant sp.**	**Growth Conditions**	**Phytotoxic Concentration**	**Growth Parameters(Phytotox. Conc.) ***	**Hg Accumulation (BAF, BCF and TF)**	**References**
potential Hg (hyper)accumulator native species	Vigna unguiculata L. Walp	Soil pots—3 m old ecotypes: 1. native genotype 2. commercial line L-019 3. commercial line L-042	5 and 8 mg kg^{-1} $Hg(NO_3)_2$ (added to 0.2 mg Hg kg^{-1} contaminated soil)	Negligible biomass decrease withˆHg	root > leaf > stem; BCF < 1 (all genotypes); $BAF_{stem/soil}$ < 0.5, $BAF_{seed/soil}$ < 0.5; 1. TF < 1 for native genotype 2. TF~1.5 (for 0.2 mg Hg kg^{-1} dw) for both commercial lines	[102]
	Phragmites australis	Plant samples were taken from gold mine contaminated wetland (wet and dry season)			root[Hg]—806 µg kg^{-1} dw stem[Hg]—495 µg kg^{-1} dw leaves[Hg]—833 µg kg^{-1} dw BAF—0.73/0.22 TF—0.57/1.99	
	Cyperus eragrostis				BAF—0.22/0.35 TF—1.99/3/60	
	Datura stramonium				BAF—0.20/0.61 TF—4.26/8.30	
	Panicum coloratum				BAF—0.11/0.13 TF—3.70/10.94	[55]
	Persicaria lapathifolia				BAF—0.11/0.20 TF—3.10/3.07	
	Melilotus alba				BAF—0.13/0.21 TF—0.54/0.60	
	Lathyrus pratensis	Aerial parts of plants growing in the area of an abandoned gold mine in the Czech Republic were collected (0.207–15.0 mg total Hg kg^{-1} soil)			Shoot[Hg]—0.108 mg kg^{-1} dw	[54]
	Epipactis sp.				Shoot[Hg]—0.152 mg kg^{-1} dw	

* (Growth parameters recorded in regard to the control treatments).

Table 2: Summary of research on Hg phytoremediation potential and toxicity of Hg promising (hyper) accumulator species, wide-range heavy metal accumulator, and crop plants. * (Growth parameters recorded in regard to the control treatments).

Type	**Plant sp.**	**Growth Conditions**	**Phytotoxic Concentration**	**Growth Parameters (Phytotox. Conc.) ***	**Hg Accumulation (BAF, BCF and TF)**	**References**
	Axonopus compressus	Plant samples were taken from soil contaminated by artisanal small-scale gold mines (arbuscular mycorrhizal fungi (AMF) colonization was aslo determined	--	--	root[Hg]—0.15 mg kg^{-1} dw shoot[Hg]—0.33 mg kg^{-1} dw BAFroot/leaves—0.03/0.06 TF—2.16	[103]
	Erato polymnioides				root[Hg]—3.56 mg kg^{-1} dw shoot[Hg]—1.48 mg kg^{-1} dw BAFroot—0.80; TF—0.42	
	Miconia zamorensis				root[Hg]—2.06 mg kg^{-1} dw shoot[Hg]—0.98 mg kg^{-1} dw BAFroot—0.47; TF—0.47	
	Cyrtomium macrophyllum	60 d old seedlings from uncontaminated sites (grown 1st hydroponically) 1. 225.73 mg total Hg kg^{-1} soil or 2. 0, 5, 10, 20, 50, 100, 200, 500 and 1000 mg $HgCl_2$ kg^{-1} soil	500 and 1000 mg kg^{-1} $HgCl_2$	20.2% biomass reduction	1. shoot[Hg]—36.44 mg kg^{-1} dw root[Hg]—13.90 mg kg^{-1} dw BCF—0.061; TF—2.62 2. for treatments up to 200 mg kg^{-1}: BCF > 1; TF > 1	[53]
	Manihot esculenta Crantz	1. soil pots with	mixtures with 50, 75,	significant root	1. Hg not determined in	[104]

		mixtures of mine tailings and biosolids; 4 w old cuttings (11.67 mg total Hg kg^{-1} mine tailings); 2. hydroponic solution with 50 or 100 µM HgCl$_2$; 5 w old plants	or 100% mine tailings	biomass decrease	plants 2. root[Hg]—6.836 and 12.13 g kg^{-1} dw (50 and 100 µM Hg)	
	Dillenia suffruticosa	Plants were cultivated on 2 ex-gold mine tailings areas: (i) tailings site where last mining activity was 2 years prior (0.5 mg Hg kg^{-1}) (ii) tailings site where last mining activity was 10 years prior (0.02 mg Hg kg^{-1})	none observed	no significant decrease in plant growth (height and diameter)	BCF—15.5; TF—3.0	[50]
	Vitex pinnata				BCF—40; TF—0.6	
	Archidendron pauciflorum				BCF—11.0; TF—0.1	
	Anacardium occidentale				BCF—6.5; TF—0.3	
	Shorea leprosula				BCF—7.5; TF—0.5	
	Alstonia scholaris				BCF—45.0; TF—1.3	
	Hevea brasiliensis				BCF—13.5; TF—0.1	
	Alyssum saxatile L.	Plant samples were collected from 41 sites in an active mining district in Western	--	--	root[Hg]/soil[Hg]—0.10 shoot[Hg]/soil[Hg]—0.04 Mean TF—0.85	[52]
	Anchusa arvensis L.				root[Hg]/soil[Hg]—0.06 shoot[Hg]/soil[Hg]—0.06 Mean TF—1.03	

	Centaurea cyanus L.	Turkey (mean 6.609 µg Hg kg^{-1} soil)			root[Hg]/soil[Hg] < 0.5 shoot[Hg]/soil[Hg] < 0.5 Mean TF > 1	
	Cynoglossum officinale				root[Hg]/soil[Hg] < 1 shoot[Hg]/soil[Hg] < 1 Mean TF < 1	
	Glaucium flavum				root[Hg]/soil[Hg]—0.09 shoot[Hg]/soil[Hg]—0.02 Mean TF—0.25	
	Isatis sp. L.				root[Hg]/soil[Hg]—0.02 shoot[Hg]/soil[Hg]—0.02 Mean TF—0.63	
	Onosma sp.				root[Hg]/soil[Hg] < 0.5 shoot[Hg]/soil[Hg] < 0.5 Mean TF > 1	
	Phlomis sp.				root[Hg]/soil[Hg]—0.21 shoot[Hg]/soil[Hg]—0.56 Mean TF—2.05	
	Silene compacta				root[Hg]/soil[Hg] < 0.5 shoot[Hg]/soil[Hg] < 0.5 Mean TF—1.66	
	Tripleurospermum maritimum				root[Hg]/soil[Hg]—0.02 shoot[Hg]/soil[Hg]—0.01 Mean TF—0.59	
	Verbascum thapsus L.				root[Hg]/soil[Hg]—0.03 shoot[Hg]/soil[Hg]—0.06 Mean TF—2.47	
	Sesbania grandiflora	17 d old seedlings in hydroponic solution	50 and 60 mg L^{-1} $HgCl_2$	56% growth decrease 19% biomass reduction	mostly in roots; TF—low.	[91]

				(60 mg Hg L^{-1})		
	Jatropha curcas	Pots with Hg-contaminated soil (1.76 mg kg^{-1}) spiked with 1, 5 or 10 mg Hg(NO$_3$)2 kg^{-1}; 1, 2, 3 or 4 m old seedlings (seeds of plants from uncontaminated soil)	none observed	--	plant[Hg]—max. 7.25 mg kg^{-1} dw (for 10 mg Hg kg^{-1} soil) BCF—good, with increased exposure (4th month); TF~1 (after 2 months, then decreased)	[105]
	Lepidium sativum L.	Soil pots (spiked with 10 or 100 mg HgCl2 kg^{-1} dw) with/without different fractions of uncontaminated compost; 10 d seedlings	(a) 10 and 100 mg kg^{-1} HgCl$_2$; (b) none observed for compost amended soil	(a) 27% decrease in shoot length; 53% decrease in root (10 mg Hg kg^{-1})	mostly in roots; add. compost—ˆ accumulation; BCF—high for 10 mg Hg kg^{-1} dw in 2/1 compost	[106]
	Flueggea tinctoria (L.) G.L. Webster	Aerial plant parts were collected from a riparian area in the mining district of Almadén (122—385 mg total Hg kg^{-1} soil)	--	--	BCF—5.9	[49]
	Tamarix canariensis Willd.				BCF—10.72	
	Nerium oleander L.				BCF—6.2	
	Typha domingensis Pers.				BCF—4.3	
	Phragmites australis Cav.				BCF—32.2	
	Atriplex	25	no	Biomass,	shoot[Hg]—1.09	[107]

	conodocarpa	seeds/species were sown in pots with Hg spiked potting mix (17.3 mg Hg kg^{-1} soil)	phytotoxic symptoms were observed	leaf area and number remained unchanged (in regards to unspiked soil)	mg kg^{-1} dw translocation %—19%	
	Australodanthonia caespitose				shoot[Hg]—1.20 mg kg^{-1} dw translocation—15.9%	
	Chilopsis linearis	2 w old seedlings in Hoagland solution	50, 100, 200 µM $(CH_3COO)_2$ Hg	49% decrease in root length	root[Hg]—ˆ with Hg conc. TF—low	[108]
	Medicago sativa	4 d old seedlings in 1/4 Hoagland solution	20 µM $HgCl_2$	54% decrease in root biomass	--	[88]
	Eichornia crassipes	30 d old plants in spring water tanks (0, 0.5, 2 mg L^{-1} $HgSO_4$)	--	--	root[Hg]—26.2 mg kg^{-1} dw (for 2 mg Hg L^{-1})	[101]
	Pistia stratiotes				root[Hg]—83.2 mg kg^{-1} dw	
	Scirpus tabernaemontani				root[Hg]—3.88 mg kg^{-1} dw	
	Colocasia esculenta				root[Hg]—6.99 mg kg^{-1} dw	
	Sesbania drummondii	15 d old seedlings in 1/2 Hoagland solution	50 and 100 mg L^{-1} $HgCl_2$	36.8% biomass reduction (100 mg Hg L^{-1})	root[Hg] > shoot[Hg]	[89]
	Rumex induratus	Field experiment; Whole plants were collected from sites with: 122.4 mg total Hg kg^{-1} dw (0.006% available Hg)	--	--	root[Hg]—8.3 mg kg^{-1} dw shoot[Hg]—7.3 mg kg^{-1} dw TF—0.96 Phytoextraction efficiency 12.9 g Hg ha^{-1} year^{-1}	[109]
	Marrubium vulgare	550.1 mg total Hg kg^{-1} dw (0.032%			root[Hg]—67.2 mg kg^{-1} dw shoot[Hg]—23.0 mg kg^{-1} dw	

		available)			TF—0.34 Phytoextraction efficiency 27.6 g Hg ha^{-1} year^{-1}	
	Medicago sativa	12 d old seedlings in a beaker-size hydroponic system	30 µM HgCl2	abrupt 30–40% growth inhibition (first 24 h)	--	[87]
	Myriophylhum aquaticum *Ludwigina palustris* *Mentha aquatica*	21 d old plants in water solution with hydroponic fertilizer	--	--	average removal efficiency—99.8% (all 3 plants); removal rate—0.0787–0.0002 mg Hg L^{-1} d^{-1}	[100]
	Nicotiana miersii	5 w old plants in 1/4 Hoagland	1. 1.0 mg Hg0 m3 2. 1.0 µg HgCl$_2$ mL^{-1}	1. Visible signs of stress 2. Inhibition of root and shoot	1. only in shoots 2. mostly in roots	[110]
broad-spectrum heavy metal (hyper)accumulator species	*Brassica juncea Long-standing and Florida Broad Leaf cultivars*	2 and 4 w old plants grown hydroponically	1.96, 4.11, 12.2, and 16.7 mg L^{-1} Hg(NO$_3$)$_2$	25% biomass decrease	BCFroot—750–1100; BCFshoots—82–104; roots[Hg]/shoot[Hg]—8–100	[111]
	Brassica juncea	36 d old seedlings grown hydroponically	5 and 10 mg L^{-1} HgCl$_2$	5.1-fold reduced transpiration rates	BCFroot—100–270; BCFshoot—0.31–1.07; shoots[Hg]/root[Hg]–0.3–0.76	[112]
crop plant species	*Hordeum vulgare* *Lupinus albus* *Lens esculenta* *Cicer aretinum*	Soil pots—3 soil compositions: 1. 8.35 mg HgCl2 kg^{-1} dw; 2. 32.16 mg total Hg kg^{-1} dw;	--	--	1. shoot[Hg]—1.51–5.13 mg kg^{-1} dw; (L. esculenta and L. albus the highest); 2. shoot[Hg]—0.16–1.13 mg kg^{-1} dw; 3. shoot[Hg]—6×	[113]

		3. 32.16 mg total Hg kg^{-1} dw + 1 mg $HgCl_2$ kg^{-1}; 150 d old plants			L. albus, 5× C. aretinum, 3.5× H. vulgare and L. esculenta (* regards to 2nd treatment)	
	Cucumis sativus	10 and 15 d old seedlings in 10% MS media	250–500 µM $HgCl_2$	96% root length reduction (10 d old seedlings) 98% root length reduction (15 d old seedlings)		
	Oryza sativa	3 w old seedlings in Long Ashton modified nutrient solution	0.5 mg L^{-1} $HgCl_2$	50% shoot biomass reduction		
	Lycopersicon esculentum	30 d old seedlings in modified Hoagland	50 µM $HgCl_2$	suppressed biomass production (roots and shoots)		
	Pisum sativum	seedlings in solution culture	5 and 10 mg L^{-1} $HgCl_2$ or $^{203}HgCl_2$	growth inhibition: 50% shoot and root length decrease (10 mg Hg L^{-1})	mostly in roots; linearly increase with [Hg]; TF—low	[116]
	Mentha spicata	cuttings in solution culture				

BCF = Bioconcentration Factor (plant[Hg]/corresponding soil or media[Hg]; depending on study, plant[Hg] can refer to root[Hg]);
BAF = Bioaccumulation Factor (shoot[Hg]/corresponding soil or media[Hg]);
TF = Translocation Factor (shoot[Hg]/root[Hg]); ˆ = increase; d = days; w = weeks; m=months; [Hg] = Hg concentration.

Source: https://www.mdpi.com/1660-4601/18/5/2435

Table 1: Bio-Mercury Remediation Suitability Index for the tested strains.

Strain	**69-II**	**80**	**74**	**130**	**146**	**25**	**18**	**69-I**	**211**	**212**	**11**	**43**	**95**	**20**	**79**
BMRSI	8.51	8.42	8.07	8.01	7.99	7.89	7.87	7.85	7.74	7.73	7.69	7.68	7.57	7.55	**7.55**
Strain	**10**	**31**	**57**	**55**	**21**	**50**	**175**	**37**	**98**	**76**	**23**	**204**	**1**	**48**	**173**
BMRSI	7.42	7.4	7.26	7.23	7.21	7.08	7.08	7.07	7.05	7.04	6.97	6.8	6.68	6.62	**6.6**
Strain	**122**	**9**	**58**	**56**	**159**	**70**	**214**	**114**	**160**	**75**	**149**	**186**	**35**	**168**	**166**
BMRSI	6.59	6.56	6.46	6.43	6.38	6.35	6.34	6.32	6.32	6.3	6.26	6.23	6.21	6.09	**6.03**
Strain	**178**	**167**	**217**	**104**	**26**	**133**	**213**	**19**	**22**	**118**	**121**	**151**	**155**	**112**	**161**
BMRSI	6.00	5.93	5.93	5.86	5.84	5.83	5.82	5.81	5.75	5.71	5.69	5.63	5.61	5.61	**5.6**
Strain	**47**	**14**	**16**	**154**	**200**	**88**	**223**	**203**	**174**	**190**	**199**	**206**	**195**	**126**	**68**
BMRSI	5.58	5.51	5.47	5.46	5.46	5.41	5.35	5.34	5.33	5.33	5.32	5.31	5.3	5.29	**5.25**
Strain	**224**	**30**	**189**	**128**	**162**	**137**	**117**	**216**	**5**	**197**	**191**	**196**	**109**	**180**	**192**
BMRSI	5.23	5.23	5.2	5.2	5.2	5.17	5.16	5.15	5.11	5.05	5.00	4.94	4.91	4.9	**4.86**
Strain	**201**	**124**	**134**	**45**	**106**	**135**	**96**	**108**	**142**	**145**	**82**	**153**	**91**	**143**	**210**
BMRSI	4.82	4.79	4.79	4.77	4.76	4.75	4.73	4.71	4.69	4.55	4.53	4.52	4.47	4.44	**4.39**
Strain	**125**	**132**	**139**	**188**	**4**										
BMRSI	**4.34**	**4.34**	**4.32**	**4.3**	**4.26**										

Table 2: Bio List of the thirty-nine strains selected in the second screen based on their PGPR activity. No.: strain number, SL: bulk soil, A: *Rumex induratus*, B: *Rumex bucephalophorus*, C: *Avena sativa*, D: *Medicago sativa*, E: *Vicia bengalensis*. BMRSI: Bio-Mercury Remediation Suitability index; “ND” not described strain.

No.	**RF/SL**	**MBC (µg/mL)**	**BMRSI**	**IAA (µg/mL)**	**ACCd (p/a)**	**SID. (cm)**	**SOL. PO_4^{3-}**	**IDENTIFICATION**
1	SL	50	6.68	4.63	-	1	**-**	***Bacillus toyonensis***
9	SL	75	6.56	5.59	+	-	**-**	***Bacillus toyonensis***
10	SL	200	7.42	6.12	-	1.1	**-**	**ND**
11	SL	87.5	7.69	5.61	-	1	**-**	***Bacillus toyonensis***
18	SL	100	7.87	6.28	+	0.5	**-**	***Bacillus toyonensis***
20	SL	100	7.55	5.96	+	0.5	**-**	***Bacillus toyonensis***
21	SL	100	7.21	5.31	+	0.8	**-**	***Bacillus toyonensis***
22	SL	87.5	5.75	4.57	+	0.1	**-**	***Bacillus toyonensis***
23	SL	175	6.97	4.89	+	0.9	**-**	***Pseudomonas moraviensis***
25	SL	150	7.89	5.85	+	0.9	**-**	***Bacillus toyonensis***
31	A	100	7.4	5.6	+	0.7	**_**	***Pseudomonas brassicacearum subsp. brassicacearum***

37	A	87.5	7.07	5.58	-	0.5	-Bacillus aryabhattai
43	A	87.5	7.68	5.7	+	0.9	-Bacillus toyonensis
48	A	100	6.62	4.92	+	0.6	-ND
50	A	100	7.08	5.29	+	0.7	-Bacillus toyonensis
55	A	87.5	7.23	5.56	-	0.8	_Pseudomonas brassicacearum sbups. neoaurantiaca
56	B	200	6.43	4.43	+	0.8	_Pseudomonas brassicacearum subsp. brassicacearum
57	B	175	7.26	6.38	+	0.6	_Pseudomonas syringae pv. phaseolicola
58	B	100	6.46	5.56	+	0.7	_Pseudomonas brassicacearum subsp. brassicacearum
69-I	B	75	7.85	6.08	-	0.7	-Pseudomonas corrugata
69-II	B	350	8.51	5.71	+	0.7	+Pseudomonas corrugata
74	B	100	8.07	6.27	+	0.7	_Pseudomonas syringae pv. phaseolicola
76	B	350	7.04	4.99	+	0.7	_Pseudomonas syringae pv. phaseolicola
79	B	87.5	7.55	5.27	+	0.4	_Pseudomonas syringae pv. phaseolicola
80	B	80	8.42	6.47	+	0.8	_Pseudomonas syringae pv. phaseolicola
95	C	80	7.57	4.69	-	2.8	-Brevibacterium frigoritolerans
98	C	160	7.05	5.29	+	0.6	-Pseudomonas baetica
112	C	150	5.61	4.36	+	0.1	-Pseudomonas corrugata
122	D	87.5	6.59	4.51	+	-	+Brevibacterium frigoritolerans
130	D	160	8.01	5.85	+	1	-Pseudomonas corrugata
146	E	80	7.99	6.09	+	0.8	-Pseudomonas fluorescens
151	E	87.5	5.63	4.38	+	0.2	-Bacillus aryabhattai
168	A	87.5	6.09	4.00	+	-	+Bacillus aryabhattai
173	A	175	6.6	5.53	+	-	-Bacillus toyonensis
175	A	80	7.08	6.00	+	-	-ND
204	D	80	6.8	5.72	-	-	+ND
211	D	80	7.74	6.16	+	0.5	-Bacillus drentensis
212	D	80	7.73	6.16	+	0.4	-Bacillus drentensis
217	**E**	**100**	**5.93**	**4.88**	**+**	**2**	+Bacillus nealsonii

Source: https://www.mdpi.com/1660-4601/18/8/4213

Mercury resistance and plant growth promoting traits of endophytic bacteria isolated from mercury-contaminated soil (2021)

Table 1: Soil chemical properties at the sampling site.

Soil properties	Mean ± SD
pH	7.26 ± 0.11
C-organic (%)	0.24 ± 0.01
Total-N (%)	0.034 ± 0.00
Available-P (mg/kg)	11.69 ± 0.09
Available-K (me/100g)	0.56 ± 0.04
Hg (mg/kg)	23.19 ± 0.03

Note: C = carbon; N = nitrogen; P = phosphorus; K = potassium.

Table 2: Mercury concentration and endophytic bacteria density in grass biomass.

Parameter	Grass species			
	Cynodon dactylon		***Eleusine indica***	
	Root	**Shoot**	**Root**	**Shoot**
Hg concentration (mg/kg)	43.43 ± 0.86	24.21 ± 0.94	82.08 ± 1.09	29.52 ± 0.92
Total	67.65 ± 1.64		111.29 ± 0.29	
Endophytic bacteria density (CFU/g)	3.8 (± 0.09) x 10^5	4.2 (± 0.19) x 10^5	6 (± 0.84) x 10^5	0.36 (± 0.02) x 10^5
Total	8 (± 0.28) x 10^5		6.36 (± 0.86) x 10^5	

Note: CFU = Colony Forming Unit; Mean ± Standard Deviation.

Table 3: Mercury resistance of endophytic bacterial isolates.

Isolate	Concentration of $HgCl_2$ (mg/L) on Nutrient Agar (NA)								
	0	**10**	**100**	**150**	**200**	**250**	**500**	**750**	**1000**
CD1	+	+	–	–	–	–	–	–	–
CD2	+	+	+	+	+	+	+	–	–
CD3	+	+	+	+	+	–	–	–	–
CD4	+	+	–	–	–	–	–	–	–
CD5	+	+	+	+	–	–	–	–	–
CD6	+	+	+	+	+	+	+	+	+
CD7	+	+	+	+	+	+	+	+	+
EI1	+	+	–	–	–	–	–	–	–
EI2	+	+	–	–	–	–	–	–	–
EI3	+	+	–	–	–	–	–	–	–
EI4	+	+	–	–	–	–	–	–	–
EI5	+	+	+	+	+	+	+	–	–
EI6	+	+	+	+	+	+	–	–	–

Note: CD = *Cynodon dactylon*; EI = *Eleusine indica*; (+) survive; (-) not survive. Highlighted isolates were selected for futher plant growth-pomoting trait tests.

Table 4: Siderophore production of isolated endophytic bacteria.

Isolate	
CD1	–
CD2	–
CD3	–
CD4	–
CD5	–
CD6	+
CD7	–
EI1	+
EI2	–
EI3	–
EI4	–
EI5	–
EI6	+

Note: CD = *Cynodon dactylon*; EI = *Eleusine indica*; (+) can produce siderophore; (-) can not produce siderophore.

Source: https://www.tandfonline.com/doi/full/10.1080/10889868.2021.1973950

Nodulated White Lupin Plants Growing in Contaminated Soils Accumulate Unusually High Mercury Concentrations in Their Nodules, Roots and Especially Cluster Roots (2021)

Table 1: Characterization of Almadenejos (AH) and Las Cuevas (LC) soils.

Soil	pH	Organic Matter (%)	C (%)	N (%)	Bioavailable Fe (μg g^{-1})	P (μgg^{-1})	Total Hg (μgg^{-1})	Bioavailable Hg (μg g^{-1})
AH	6.87	8.59	3.33	0.26	106.3	11.2	21,845	**2.69**
LC	**5.09**	**9.85**	**3.82**	**0.35**	**158.9**	**3.6**	**2622**	**0.82**

Table 2: Mercury bioaccumulation factors (BAF) of nodules, roots and cluster roots of L. albus G1 and N1 plants grown in Almadenejos (AH) or Las Cuevas (LC) soils. BAFs were calculated as the ratio between the Hg concentration in the organ tissue and the bioavailable Hg concentration in the soil. Means for each cultivar (inoculated plus non-inoculated plants) ± SD are shown. Asterisks (*) indicate significant differences between soils.

Tissue	**Almadenejos**		**Las Cuevas**	
	G1	N1	G1	N1
Nodules	443.5 ± 98.1	441.6 ± 107.8	787.2 ± 215.7 *	624.1 ± 117.6 *
Roots	889.2 ± 313	1046 ± 202.1	675.7 ± 241.4	927.0 ± 406.5
Cluster roots	1676.8 ± 318.4	1519 ± 308.3	3139.3 ± 900.9*	2390.9 ± 932.9*

Table 3: Mercury bioaccumulation factors (BAF) of nodules, roots and cluster roots of L. *albus* G1 plants grown hydroponically. BAFs were calculated as the ratio between the Hg concentration in the organ tissue and the bioavailable Hg concentration in the substrate. Means ± SD are shown.

Tissue	**0.05 mM P**	**0.5 mM P**
Nodules	131.9 ± 33	142 ± 48.5
Roots	137.4 ± 45.7	146.8 ± 29.7
Cluster roots	309.4 ± 66.1	345 ± 40.2

Source: https://www.mdpi.com/2311-7524/7/9/302

Describing the toxicity and sources and the remediation technologies for mercury-contaminated soil (2020)

Table 1: Common remediation technologies for contaminated soil

	Technology	Operation	Reagent
Physical remediation	Soil replacement	Cleanning soil replaces contaminated soil	—
	Soil vapour extraction	Reduction of the vapor pressure of soil pores	—
	Thermal desorption	Separation of pollutants from soil by heating	$MgCl_2$, *etc.*
	Electric remediation	Establish electric field gradient	KI, EDTA, *etc.*
Chemical remediation	Soil washing	Extraction and separation of contaminants from soil by eluent	HCl, HNO_3, H_2SO_4, H_3PO_4, NaCl, $Na_2S_2O_3$, KI, *etc.*
	Chemical stabilization	Addition of chemical reagents or chemical materials	Sulfide, phosphate, *etc.*
Biological remediation	Phytoremediation	The use of plants and their associated rhizospheric microorganisms to remove contaminants	Hyperaccumulators, *etc.*
	Microbial remediation	Control contaminants in soil by introducing microorganisms	Bacteria, *etc.*
	Animal remediation	Utilizing the activities of some lower animals to enhance bioremediation	Earthworm

Table 2: Desorption temperatures of different Hg phases

Phase	Desorption temperature of phases Hg (°C)
Hg^0	119 ± 9
$HgCl_2$	135 ± 5
$Hg–FeS_2$	169 ± 5
HgS metacinnabar	190 ± 11
Hg-OM (Hg bound toorganic matter)	217 ± 7
HgS cinnabar	303 ± 13
HgO	308 ± 1; 471 ± 5
$HgSO_4$	580 ± 19
$Hg(NO_3)_2 \cdot H_2O$	215 ± 4; 280 ± 13; 460 ± 25
Hg_2Cl_2	170
Hg in pyrite	>450
Hg in sphalerite	600
Hg matrix-bound	200–300

Source: https://pubs.rsc.org/en/content/articlelanding/2020/ra/d0ra01507e#!divAbstract

Effect of soil mercury pollution on ginger (*Zingiber officinale Roscoe*): Growth, product quality, health risks and silicon mitigation (2020)

Table 1: The effect of mercury stress level on the growth of ginger

Treatment days (d)	Treatment	Plant height (cm)	Stem diameter (cm)	Shoot number	Leaf number	Root FW (g)	Stem FW (g)	Leaf FW (g)	Rhizome FW (g)
40	CK	49.7 ± 1.5^{a}	1.2 ± 0.1^{a}	3.7 ± 0.6^{a}	56.7 ± 1.5^{a}	17.6 ± 0.8^{ab}	61.4 ± 1.1^{a}	32.5 ± 0.6^{a}	72.6 ± 0.6^{a}
	T1	50.6 ± 2.0^{a}	1.2 ± 0.1^{a}	3.3 ± 0.6^{a}	57.7 ± 1.5^{a}	18.3 ± 0.4^{a}	59.2 ± 2.6^{ab}	32.1 ± 0.6^{a}	70.6 ± 2.5^{a}
	T2	49.5 ± 1.3^{a}	1.1 ± 0.1^{b}	3.3 ± 0.6^{a}	55.3 ± 1.5^{a}	17.2 ± 0.3^{ab}	56.7 ± 3.8^{b}	31.4 ± 1.1^{a}	67.7 ± 6.0^{a}
	T3	47.8 ± 0.8^{a}	1.1 ± 0.1^{b}	2.3 ± 0.6^{b}	50.0 ± 1.7^{b}	16.5 ± 0.6^{bc}	45.6 ± 0.4^{c}	27.8 ± 0.8^{b}	53.7 ± 5.7^{b}
	T4	44.8 ± 0.8^{b}	1.0 ± 0.1^{c}	2.0 ± 0.0^{b}	46.3 ± 2.1^{c}	15.9 ± 0.6^{c}	40.9 ± 0.4^{d}	23.9 ± 0.6^{c}	45.9 ± 0.9^{c}
80	CK	61.2 ± 1.3^{a}	1.3 ± 0.1^{a}	5.7 ± 0.6^{a}	62.0 ± 1.0^{a}	30.5 ± 0.9^{a}	86.0 ± 1.3^{a}	45.7 ± 1.0^{a}	94.8 ± 1.5^{a}
	T1	61.7 ± 1.5^{a}	1.3 ± 0.1^{a}	5.3 ± 0.6^{a}	61.0 ± 2.0^{a}	29.4 ± 0.9^{ab}	80.7 ± 5.8^{ab}	44.4 ± 0.7^{a}	89.8 ± 3.3^{b}
	T2	59.8 ± 1.4^{a}	1.3 ± 0.1^{b}	4.7 ± 0.6^{ab}	59.3 ± 3.2^{a}	27.5 ± 2.2^{b}	74.9 ± 7.7^{b}	39.0 ± 3.6^{b}	84.7 ± 4.5^{c}
	T3	54.4 ± 1.0^{b}	1.2 ± 0.1^{c}	3.7 ± 0.6^{bc}	52.3 ± 1.2^{b}	23.9 ± 0.5^{c}	49.2 ± 1.0^{c}	31.1 ± 1.0^{c}	59.8 ± 0.8^{d}
	T4	47.0 ± 1.0^{c}	1.1 ± 0.1^{d}	3.3 ± 0.6^{c}	48.7 ± 1.2^{c}	20.2 ± 1.3^{d}	43.8 ± 0.9^{c}	26.2 ± 0.7^{d}	50.8 ± 0.8^{e}
120	CK	66.7 ± 1.2^{a}	1.4 ± 0.2^{a}	8.3 ± 0.6^{a}	81.3 ± 1.5^{a}	42.6 ± 2.2^{a}	126.1 ± 1.7^{a}	60.3 ± 3.8^{a}	148.9 ± 6.4^{a}
	T1	65.3 ± 2.1^{ab}	1.4 ± 0.1^{a}	7.7 ± 0.6^{ab}	79.3 ± 1.5^{ab}	41.3 ± 0.3^{ab}	119.8 ± 5.1^{b}	55.3 ± 1.5^{b}	142.7 ± 5^{ab}
	T2	61.3 ± 2.3^{b}	1.4 ± 0.1^{a}	7.7 ± 0.6^{ab}	76.7 ± 4.7^{b}	39.5 ± 2.2^{ab}	112.7 ± 4.7^{c}	52.3 ± 3.3^{b}	137.7 ± 6.4^{b}
	T3	56.2 ± 2.6^{c}	1.3 ± 0.1^{ab}	7.3 ± 0.6^{bc}	68.7 ± 1.2^{c}	36.9 ± 0.2^{b}	94.4 ± 1.9^{d}	45.2 ± 1.8^{c}	119.6 ± 1.3^{c}
	T4	50.7 ± 2.3^{d}	1.2 ± 0.1^{b}	6.7 ± 0.6^{c}	53.0 ± 2.0^{d}	32.2 ± 1.6^{c}	87.7 ± 0.8^{e}	38.3 ± 1.5^{d}	110.3 ± 1.2^{d}

Table 2: The effect of mercury stress level on yield and quality of ginger rhizome.

Treatment	Yield (g plant^{-1})	Soluble sugar (%)	Crude cellulose (mg g^{-1})	Soluble protein (mg g^{-1})	Free amino acid (mg g^{-1})	Vitamin C (%)	Gingerol (%)	Naphtha (%)
CK	148.93^{a}	0.79^{a}	0.24^{c}	2.96^{a}	0.52^{a}	2.78^{a}	0.58^{a}	4.35^{a}
T1	142.67^{ab}	0.78^{a}	0.23^{c}	2.86^{b}	0.48^{b}	2.72^{b}	0.53^{b}	4.13^{b}
T2	137.67^{b}	0.62^{b}	0.31^{b}	2.68^{c}	0.37^{c}	2.63^{c}	0.41^{c}	3.97^{c}
T3	119.63^{c}	0.55^{c}	0.38^{a}	2.21^{d}	0.26^{d}	2.59^{d}	0.35^{d}	3.75^{d}
T4	110.27^{d}	0.48^{d}	0.39^{a}	2.08^{d}	0.21^{e}	2.31^{e}	0.26^{e}	3.67^{e}

Note: Under the same column, values followed with the same letter was not significant at P = 0.05.

Source: https://www.sciencedirect.com/science/article/pii/S0147651320303110?via%3Dihub

Table 1: Promoting effect of chemical accelerators for accumulating and transferring Hg by plants.

Plant species	**Chemical accelerators**	**Promoting effect**	**Reference**
Willow	KI	6.46-8.26 μg/g↑ (Hg accumulation in soils), 1.03-1.55%↑ (Hg accumulation in plants)	**Wang and Greger, 2006**
Lepidium sativum **L.**	Compost and KI	32%-41%↑ (Hg accumulation in plants)	**Smolinska and Szczodrowska, 2017**
Brassica juncea	(NH4)2SO4	25-fold↑ (Hg accumulation in roots), ≈control plants (Hg accumulation in shoots)	**Wang et al., 2017**
Brassica juncea	NH4Cl	≈control plants (Hg accumulation in roots), ≈control plants (Hg accumulation in shoots)	**Wang et al., 2017**
Brassica juncea	NaNO3	≈control plants (Hg accumulation in roots), ≈control plants (Hg accumulation in shoots)	**Wang et al., 2017**
Brassica juncea	EDTA	≈control plants (Hg accumulation in roots), ≈control plants (Hg accumulation in shoots)	**Wang et al., 2017**
Brassica juncea	(NH4)2S2O3	49-fold↑ (Hg accumulation in roots), about 32 and 3.8 mg/kg↑ (Hg accumulation in stems and leaves)	**Wang et al., 2017**
Brassica juncea	Na2SO3	62-fold↑ (Hg accumulation in roots), about 21 and 4.3 mg/kg↑ (Hg accumulation in stems and leaves)	**Wang et al., 2017**
Brassica juncea	Na2S2O3	37-fold↑ (Hg accumulation in roots), 13-fold and 0.2 mg/kg↑ (Hg accumulation in stems and leaves)	**Wang et al., 2017**
Chenopodium glaucum **L.**	(NH4)2S2O3	1100%, 600% and 200%↑ (Hg accumulation in roots, stems and leaves)	**Wang et al., 2011**
Poa annua	(NH4)2S2O3	About 2.66 mg/kg↑ (Hg accumulation in shoots), about 236.39 mg/kg↑ (Hg accumulation in roots)	**Pedron et al., 2013**
Brassica juncea	(NH4)2S2O3	About 44.66 mg/kg↑ (Hg accumulation in shoots), about 116.39 mg/kg↑ (Hg accumulation in roots)	**Pedron et al., 2013**
Helianthus annuus	(NH4)2S2O3	About 4.66 mg/kg↑ (Hg accumulation in shoots), about 96.39 mg/kg↑ (Hg accumulation in roots)	**Pedron et al., 2013**
Lepidium sativum **L.**	Na2S2O3	0.55-0.611↑ (TF)	**Smolinska and Rowe, 2015**
Oxalis corniculata **L.**	Na2S2O3	302.29-310.7↑ (TF)	**Liu et al., 2018b**
Lupinus albus	HCl	1.94-2.47 μg/plant↑ (Hg accumulation in plants)	**Rodríguez et al., 2016**
Lupinus albus	EDTA	0.42 μg/plant↑ (Hg accumulation in plants)	**Rodríguez et al., 2016**
Oryza sativa **L.**	Sulfur fertilizer	3.59-31.43 μg/kg↑ (MeHg accumulation in grains), about 4-15 μg/kg↑ (IHg accumulation in grains), about	**Li et al., 2019c**
		0.3-1 mg/kg↑ (IHg accumulation in straw), about 10-28μg/kg↑ (IHg accumulation in	

		roots)	
Brassica juncea	$(NH_4)_2S_2O_3$	71.5 mg/kg↑ (Hg accumulation in roots), 41.5 mg/kg↑ (Hg accumulation in shoots)	**Moreno et al., 2005**
Brassica juncea	NH_4SCN	0.1 mg/kg↑ (Hg accumulation in roots), 0.1 mg/kg↑ (Hg accumulation in shoots)	**Moreno et al., 2005**
Helianthus annuus	Cytokinin	9.1×10^{-3}↑ (TF)	**Cassina et al., 2012**
Helianthus annuus	$(NH_4)_2S_2O_3$	3.4×10^{-3}↓ (TF)	**Cassina et al., 2012**
Helianthus annuus	Cytokinin+$(NH_4)_2S_2O_3$	4.4×10^{-3}↑ (TF)	**Cassina et al., 2012**
Brassica juncea	Cytokinin	3.6×10^{-3}↓ (TF)	**Cassina et al., 2012**
Brassica juncea	$(NH_4)_2S_2O_3$	5.3×10^{-3}↑ (TF)	**Cassina et al., 2012**
Brassica juncea	Cytokinin+$(NH_4)_2S_2O_3$	20.2×10^{-3}↑ (TF)	**Cassina et al., 2012**
Solanum nigrum L.	Attapulgite	About 0.04, 0.1, 0.125 and 0.15 mg/kg↑ (Hg accumulation in roots after four, five, six and seven months)	**Li et al., 2019a**
Solanum nigrum L.	Biochar	About 0.01, 0.05, 0.09 and 0.1 mg/kg↑ (Hg accumulation in roots after four, five, six and seven months)	**Li et al., 2019a**
***Lepidium sativum* L.**	**Compost**	**0.054-0.119↑ (BAF)**	**Smolinska, 2015**

↑: increasing compared to no chemical accelerators addition; ↓: decreasing compared to no chemical accelerators addition; ≈: similar to no chemical accelerators addition.

Table 2: Promoting effect of transgenic plants for accumulating and transferring Hg.

Plant species	Gene	Promoting effect	Reference
Tobacco	*merA/B*	100-fold↑ (Hg accumulation in leaves)	**Hussein et al., 2007**
Arabidopsis thaliana	*merC*	About 6-23 ng/mg↑ (Hg accumulation in leaves)	**Sasaki et al., 2006**
Arabidopsis thaliana	*merP*	About 5.35 µg/g↑ (Hg accumulation in plants)	**Hsieh et al., 2009**
Arabidopsis thaliana	*MerC*	About 5-200 ng/g↑ (Hg accumulation in plants)	**Kiyono et al., 2013**
Arabidopsis thaliana	MerC-SYP121	About 0.03-0.21↑ (TF)	**Uraguchi et al., 2019**
Alfalfa	GST, CYP2E1	About 3.0-4.2 times↑ (Hg accumulation in plants)	**Zhang et al., 2013**
Arabidopsis	*PtABCC1*	26-72%↑ (Hg accumulation in plants)	**Sun et al., 2018**
Poplar	***PtABCC1***	**53-136%, 26-160% and 7-31%↑ (Hg accumulation in roots, stems and leaves)**	**Sun et al., 2018**

↑: increasing compared to untransformed plants.

Source: https://www.sciencedirect.com/science/article/abs/pii/S0304389420311274

Transgenic *merA* and *merB* expression reduces mercury contamination in vegetables and grains grown in mercury-contaminated soil (2020)

Table 1: Mercury content in samples of lab soil with HgCl$_2$ added and soil collected from power plant

Samples	Mercury content in soil samples			
	Total Hg (μg/kg)[c]	Organic Hg (μg/kg)[d]	Inorganic Hg (μg/kg)[e]	Organic/total Hg (%)
Lab dry soil with HgCl$_2$ added[a]	258.86 ± 2.39	3.85 ± 0.61	255.01 ± 1.90	1.49
Lab paddy soil with HgCl$_2$ added[a]	259.10 ± 1.33	6.36 ± 3.16	252.74 ± 1.87	2.45
Dry soil from power plant[b]	379.23 ± 12.65	1.75 ± 0.58	377.48 ± 13.12	0.46
Paddy soil from power plant[b]	399.70 ± 7.65	4.89 ± 1.33	394.80 ± 8.59	1.22

[a] HgCl$_2$ was added to the dry and paddy soil to a final concentration of 260 μg/kg and the soil samples were analyzed after 2 months

[b] The dry and paddy soil samples were collected within 1 km from a coal-fired power plant in Nanjing, Jiangsu Province, China

[c] Total Hg samples were digested by in a Closed Microwave Sample Preparation System (ETHOS One; Milestone, Italy) as described in EPA method 7473 (USEPA 2007)

[d] Organic Hg samples was extracted as described by Boszke et al. (2007), and the samples was treated with bromating agent to oxidize organic Hg to Hg(II) for determination

[e] Inorganic Hg was calculated as difference between total mercury and organic mercury

Table 2: Mercury content in leaves of transgenic and WT Arabidopsis, tobacco, tomato and rice plants

Plant species	Mercury content in leaf samples (μg/kg)							
	Soil with no Hg(II) added		Soil with 80 μg/kg Hg(II) added		Soil with 260 μg/kg Hg(II) added		Soil with 1600 μg/kg Hg(II) added	
	WT	MB	WT	MB	WT	MB	WT	MB
Arabidopsis	5.62 ± 0.82	3.18 ± 0.25[a]	*37.18 ± 1.28*	7.82 ± 0.73[a]	*159.2 ± 9.28*	*38.72 ± 1.43*[a]	*456.04 ± 15.36*	*113.86 ± 1.93*[a]
Tobacco	4.28 ± 1.14	2.24 ± 0.79	*20.78 ± 1.54*	3.94 ± 0.87[a]	*98.95 ± 5.14*	*21.55 ± 1.48*[a]	*334.70 ± 4.47*	*73.81 ± 0.12*[a]
Tomato	3.83 ± 1.03	2.52 ± 0.66	*21.92 ± 0.48*	4.04 ± 0.31[a]	*93.50 ± 7.99*	*21.22 ± 2.96*[a]	*298.49 ± 7.02*	*72.05 ± 0.33*[a]
Rice	6.88 ± 1.32	5.13 ± 0.71	*40.11 ± 2.62*	8.81 ± 1.21[a]	*137.55 ± 7.40*	*32.91 ± 0.88*[a]	*301.93 ± 11.29*	*81.01 ± 3.59*[a]

Bolded and italic numbers indicate that the mercury concentrations in samples exceeded the maximum allowed mercury level of 10 μg/kg FW in vegetables (Food Safety Standard in China, GB 2762-2012) (CSEPA 2012)

MB mercury-breathing plants

[a] The mercury concentrations of WT and MB plant samples were significantly different at $P = 0.05$

Table 3: Mercury content in seeds of transgenic and WT Arabidopsis, tobacco and rice plants

Plant species	**Mercury content in seed samples (μg/kg)**							
	Soil without Hg(II) added		Soil containing 80 μg/kg Hg(II)		Soil containing 260 μg/kg Hg(II)		Soil containing 1600 μg/kg Hg(II)	
	WT	MB	WT	MB	WT	MB	WT	MB
Arabidopsis	1.1 ± 0.16	0.45 ± 0.03[a]	9.27 ± 1.02	1.06 ± 0.10[a]	*29.12 ± 1.62*[a]	5.16 ± 0.12[a]	*72.73 ± 4.72*	13.02 ± 0.37[a]
Tobacco	1.35 ± 0.08	0.69 ± 0.09[a]	10.9 ± 0.25	1.03 ± 0.04[a]	17.91 ± 0.13	4.31 ± 0.32[a]	*54.54 ± 1.32*	14.17 ± 0.42[a]
Rice	2.29 ± 0.48	1.35 ± 0.10[a]	11.33 ± 1.76	2.11 ± 0.31[a]	*39.81 ± 0.43*	9.41 ± 2.31[a]	*60.09 ± 2.29*	17.20 ± 2.35[a]

Bolded and italic numbers indicate that the mercury concentrations in samples exceeded the maximum allowed mercury level of 20 μg/kg FW in grains (Food Safety Standard in China, GB 2762–2012) (CSEPA 2012)

MB mercury-breathing plants

[a] The mercury concentrations of WT and MB plant samples were significantly different at *P* = 0.05

Source: https://link.springer.com/article/10.1007/s00299-020-02570-8

Responses of Nonprotein Thiols to Stress of Vanadium and Mercury in Maize (*Zea mays L.*) Seedlings (2019)

Table: V and Hg concentration in different parts of maize seedlings (µg/g, FW)

Hg	**V**	**V(µg/g, FW)**		**$(BF)_V$**	**$(TF)_V$**	**Hg (µg/g, FW)**	**$(BF)_{Hg}$**	**$(TF)_{Hg}$**
		Shoots	Roots			Shoots	Roots	
0	**0**	0.04 ± 0.00e	0.37 ± 0.04d	–	0.12	0.30 ± 0.01b	0.65 ± 0.02b –	**0.46**
	1	0.51 ± 0.03d	2.55 ± 0.24d	3.05	0.20	2.60 ± 0.47a	4.69 ± 0.21a –	**0.55**
	5	0.90 ± 0.04c	9.75 ± 0.52c	2.13	0.09	2.74 ± 0.05a	4.63 ± 0.07a –	**0.59**
	10	1.27 ± 0.08b	14.01 ± 0.23b	1.53	0.09	2.19 ± 0.03b	4.56 ± 0.08a –	**0.48**
	20	2.43 ± 0.16a	19.89 ± 0.41a	1.12	0.12	2.83 ± 0.05a	4.60 ± 0.02a –	**0.62**
5	**0**	0.31 ± 0.03d	1.53 ± 0.18d	0.37	0.20	4.39 ± 0.04c	19.84 ± 0.04c 4.85	**0.22**
	1	0.53 ± 0.03d	3.80 ± 0.31c	0.72	0.14	4.42 ± 0.12c	22.15 ± 1.07b 4.43	**0.20**
	5	1.14 ± 0.20c	17.85 ± 0.78a	1.90	0.06	18.97 ± 0.02a	132.15 ± 0.19a 15.11	**0.14**
	10	1.56 ± 0.16b	19.47 ± 0.58a	1.40	0.08	4.60 ± 0.05b	16.00 ± 0.10d 1.37	**0.29**
	20	1.95 ± 0.17a	16.82 ± 1.54ab	0.75	0.12	4.24 ± 0.00d	4.86 ± 0.12e 0.36	**0.87**
10	**0**	0.30 ± 0.01b	1.84 ± 0.08d	0.21	0.16	5.73 ± 0.08d	44.83 ± 0.03c 5.06	**0.13**
	1	0.46 ± 0.07b	4.96 ± 0.39c	0.49	0.09	6.50 ± 0.16c	45.34 ± 0.98c 4.71	**0.14**
	5	1.62 ± 0.19a	20.02 ± 0.15a	1.44	0.08	22.54 ± 0.32a	298.53 ± 1.03a 21.40	**0.08**
	10	1.66 ± 0.03a	19.78 ± 0.54a	1.07	0.08	8.41 ± 0.07b	63.31 ± 0.30b 3.59	**0.13**
	20	**1.70 ± 0.05a**	**9.79 ± 0.42b**	**0.38**	**0.17**	**6.63 ± 0.03c**	**11.34 ± 0.08d 0.60**	**0.58**

Values are means ± SD (n = 3). Different letters in the same column indicate a significant difference at the 5% level

Hg, V extraneous mercury and vanadium mg/L, BF bioconcentration factor, TF translocation factor

V and Hg concentrations in different parts of maize seedlings are shown in Table. It showed that when the Hg stress level was 0 mg/L, there was still a small amount of Hg in maize seedlings, but it was significantly lower than that under Hg stress. A small amount of Hg in plants may come from maize seeds or hydroponic environment. With single Hg stress, the bioconcentration factor of V ((BF) V in maize seedlings decreased with increasing the V stress level, while BF of V and Hg increased first and then decreased with V–Hg combined stress. In contrast, the transport coefficient (TF) of V showed a decreasing trend, while the TF of Hg decreased first and then increased.

Source: https://www.ncbi.nlm.nih.gov/pubmed/30683955

Spectral insight into thiosulfate-induced mercury speciation transformation in a historically polluted soil (2019)

Table: Bioavailable Hg content in the rhizosphere soils (ng g−1, mean ± sd, n = 3).

Treatments	**Initial soil (0 day)**	**Rape soil (191 days)**	**Corn soil (276 days)**	**Potato soil (365 days)**
Control	0.25 ± 0.02a	1.88 ± 0.04a	1.98 ± 0.04a	**1.60 ± 0.06a**
Ts0.5	0.18 ± 0.03a	2.54 ± 0.05b	1.77 ± 0.03b	**1.96 ± 0.04b**
Ts2	0.28 ± 0.01a	2.77 ± 0.06c	2.02 ± 0.06a	**1.91 ± 0.05b**
Ts5	**0.24 ± 0.01a**	**2.22 ± 0.08d**	**1.60 ± 0.02c**	**1.79 ± 0.08b**

The bioavailable Hg contents in the rhizosphere soils in different treatments are shown. The contents of bioavailable Hg in the initial soils ranged from 0.18 to 0.28 ng g^{-1}, which were significantly lower than those in the soils collected on days 191, 276, and 356 (1.60 to 2.77 ng g^{-1}) in both the control and thiosulfate treatments. This indicates that both the growth of plants and application of thiosulfate to the soil resulted in a mobilization of Hg in the soils compared to the initial soils. Further compared the bioavailable Hg contents in the soils between the control and thiosulfate treatments, which were took on days 191, 276, and 356, respectively, and did not observe a significantly increase in bioavailable Hg contents in thiosulfate treatments as compared to that in the control soils at each sampling campaign (except for days 191). It appears that the effect of thiosulfate treatments on Hg mobilization in the soils is of the same magnitude as the effect of the plants grown in the non-treated soils.

Source: https://www.sciencedirect.com/science/article/pii/S0048969718348502

Mercury mobility and effects in the salt-marsh plant Halimione portulacoides: Uptake, transport, and toxicity and tolerance mechanisms (2019)

Table: Ranges and average of bioaccumulation factor (roots/growth medium) and translocation factors (translocation factors: stems/roots; leaves/roots; leaves/stems), obtained during the exposure experiment, between the different plant organs of THg and MMHg, within H. portulacoides plants exposed to 199Hg(II) (1056 ng L^{-1}) and MM201Hg (24 ng L^{-1}) combined (n = 3; average ± SD).

Metal	**199Hg(II)**	**MM201Hg**
Bioaccumulation factor in roots	0.0025 ± 0.00020–3.5 ± 0.39 1.02 ± 1.2	0.025 ± 0.0083–34 ± 15 12 ± 11
Translocation factor stems/roots (TF S/R)	0.013 ± 0.00010–0.028 ± 0.0052 0.022 ± 0.011	0.0072 ± 0.0018–0.99 ± 0.17 0.12 ± 031
Translocation factor leaves/roots (TF L/R)	0.17 ± 0.11–4.03 ± 0.56 0.027 ± 0.059	0.038 ± 0.0055–0.59 ± 0.025 0.042 ± 0.11
Translocation factor leaves/stems (TF L/S)	0.0023 ± 0.0018–0.18 ± 0.0070 0.78 ± 0.14	0.00027 ± 0.000030–0.34 ± 0.0300.36 ± 0.19

Source: https://www.sciencedirect.com/science/article/pii/S0048969718333060

Responses of the grass *Paspalum distichum L.* to Hg stress: A proteomic study (2019)

Table: Effect of Hg stress on growth characteristics of *Paspalum distichum L.*

Physiological index (Hg/Control)	**Control**	**Hg contamination**	**Change fold (Hg/Control)**
Root length (cm)	19.0 ± 1.80	18.0 ± 0.51 *	1.06
Root fresh weight (g·plant^{-1})	0.83 ± 0.05	0.71 ± 0.03 *	1.17
Root dry weight (g·plant^{-1})	0.031 ± 0.001	0.027 ± 0.001	1.15

Statistically significant differences are indicated with asterisks: ( ) $p < 0.05$ or ( ) $p < 0.01$. Data are given as means ± standard deviation (Naghipour).

Quantitative analysis showed that root length and root dry weight was significantly decreased by 14.7% and 16.0%, respectively ($p < 0.05$), compared with the control. No significant differences were observed in leaf length or leaf weight ($p > 0.05$).

Source: https://www.sciencedirect.com/science/article/pii/S0147651319308802

Sources, toxicity, and remediation of mercury: an essence review (2019)

Table: Global Hg concentration in vegetable and tree species growing on Hg-contaminated soil.

Country/regions	Vegetable/tree species	Hg (mg/kg)	References
China	*Solanum lycopersicum* *Cucumis sativus*	0.0718 ± 0.012 0.0384 ± 0.0014	**Li et al. 2017**
	Lactuca sativa	0.039 ± 0.0044	
China	Leafy vegetables (*n* = 28) Fruit vegetables (*n* = 62)	0.002 ± 0.001 0.0003 ± 0.0002	**Hu et al. 2017**
	Rootstalk vegetables (*n* = 30)	0.0003 ± 0.0001	
Cambodia	*Brassica oleracea var. capitata*	0.000256	**Cheng et al. 2013**
	Dacuscarota	0.00167	
	Cucumis sativus	0.00015	
Spain	*Agrocybeaegerita* *Boletus aereus*	0.20 ± 0.17 8.00 ± 3.24	**Ostos et al. 2015**
	Amanita caesarea	0.81 ± 0.14	
Saudi Arabia	*Allium cepa* *Brassica oleracea var. capitata*	0.027 ± 0.001 0.0143 ± 0.001	**Ali and Al-Qahtani 2012**
	Solanum tuberosum	0.0123 ± 0.001	
Serbia/Belgrade	*Aesculus hippocastanum*	0.1	**Tomašević et al. 2004**
	Tilia	0.2	
India/Korba coal basin, Chhattisgarh	*Mangifera indica* (*n* = 5)	0.17	**Patel et al. 2015**
	Butea monosperma (*n* = 5)	0.76	
	Tectona grandis (*n* = 5)	0.13	
	***Azadirachta indica* (*n* = 5)**	**0.36**	

n number of samples; mean ± standard deviation

Vegetables growing in Hg-contaminated soil become contaminated due to the uptake of Hg in their roots and edible parts. Several tree species growing on Hg contaminated soil are also affected by the deposition of Hg-laden FA and mine dust and the uptake of Hg from the soil. Li et al. (2017) reported Hg concentrations in vegetables growing near a coal-fired TPP region and found that the vegetable species *Solanum lycopersicum, Cucumis sativus,* and *Lactuca sativa* contained 0.0718, 0.0384, and 0.039 mg Hg/kg, respectively.

Source: https://www.ncbi.nlm.nih.gov/pubmed/31418123

Soil mercury speciation and accumulation in rice (*ORYZA SATIVA L.*) grown in wastewater-irrigated farms (2018)

Table 1: The detailed information of the studied catchments in Tianjin

Study site	**Wastewater irrigation area**	**Wastewater irrigation age**	**Crops of wastewater irrigation**	**Soil type**	**Wastewater sources**
BJR	8.35×10^{4}	20	Rice,wheat	Loamy and sandy fluvo-aquic soil; Salt clay fluvo- aquic soil in southeast	Wastewater is originated from Beijing, including industrial and demotic waste water.
BTR	1.20×10^{4}	25–34	Rice,wheat, vegetables	Loamy fluvo-aquic soil; Salt clay fluvo-aquic soil	Wastewater is originated from industrial waste water in Dongli.
DGR	2.33×10^{4}	15–43	Rice, dry crops, vegetables	Loamy fluvo-aquic soil in west; salt and clayey fluvo- aquic soil in west	Wastewater is originated from industrial and demotic waste water in urban district of Tianjin and Xiqing
HHR	Control area		Rice, wheat, vegetables	salt and clayey fluvo-aquic soil; Loamy and sandy fluvo-aquic soil	Wastewater is originated from demotic waste water urban district of Tianjin and Ninghe.

Table 2: List and analytical results of CRMs used in this study

Producer	**CRM**	**Matrix**	**n**	**Element (ng/g)**	**Obtained value**	**Certified value**	**Recovery (%)**
IGGE IRMA	GBW07403(GSS-3)	Yellow-brow soil	12	THg	598 ± 79	590 ± 80	**101 ± 13**
IGGE, CAGS	GBW10020	Citrus Leaves	15	THg	145 ± 11	150 ± 20	**97 ± 8**
NRCC	TORT-2	Lobster	8	MeHg	145 ± 8	152 ± 13	**96 ± 17**
IAEA	**IAEA-405**	**Sediment**	**5**	**MeHg**	**5.20 ± 0.31**	**5.49 ± 0.53**	**95 ± 6**

Table 3: The linear correlation coefficients (r) between different tissues of rice plants for their Hg concentrations by using Pearson's correlation matrix.

Item	**IHg**	**MeHg**						
	Soil	Root	Stem	Leaf	Soil	Root	Stem	**Leaf**
Root	0.91				0.98			
Stem	0.91	0.93			0.96	0.93		
Leaf	0.85	0.89	0.95		0.93	0.93	0.92	
Grain	**0.58**	**0.61**	**0.69**	**0.64**	**0.93**	**0.91**	**0.92**	**0.90**

Source: https://www.sciencedirect.com/science/article/pii/S0883292717303736#!

Table 1: Types of heavy metals, permissible level, health hazards and sources.

Metal contaminant	Permissible level (ppm)	Health hazards	Major sources
Lead, Pb	0.1	Mental retardation in children, Liver, Kidney, gastrointestinal damage(GIT), causes sterility, anemia, muscle and joint pains, Hypertension	Paint, pesticides, smoking, batteries, water pipes, automobile emission, mining, burning of coal, lamps
Mercury, Hg	0.01	Corrosive to skin, eyes and muscle membrane. Dermatitis, nervous and kidney damage, anorexia, protoplasm poisoning, severe muscle pain	Pesticides, batteries, paper and leather industry, thermometers, electronics, amalgam in dentistry, pharmaceuticals
Arsenic, As	0.02	Bronchitis, carcinogenic dermatitis, liver tumors, gastrointestinal damage (GIT)	Pesticides, fungicides, metal smelters, Coal fumes, Wood Preservatives
Zinc, Zn	5.0	Nervous membrane and skin damage, Causing short term illness called metal fume fever and restlessness	Refineries, brass manufacture, metal plating, plumbing
Cadmium, Cd	0.06	Kidney damage, bronchitis, carcinogenic, gastrointestinal disorder, bone marrow, cancer, weight loss	Welding, electroplating, pesticides, fertilizers, CdNi batteries, nuclear fission plant
Chromium, Cr	0.01	Allergic dermatitis, producing lung tumors, human carcinogens	Steel industry, mining, cement, paper, rubber, metal alloy paints
Copper, Cu	3.0	Long term exposure causes irritation of nose, mouth, eyes, headache, stomachache, dizziness, diarrhea	Brass manufacture, electronics, electrical pipes, additive for antifungal
Nickel, Ni	3.0	Causes chronic bronchitis, reduced lung function, nasal sinus, cancer of lungs	Steel industry, mining, magnetic industry

Table 2: Summary about phytoremediation techniques.

Phytoremediation techniques	Action mechanism	Medium treated	Contaminant
Phytoextraction	Direct accumulation of contaminants into plant shoots with subsequent removal of the plant shoots	Soil	Inorganics
Rhizofiltration	Absorb and adsorb pollutants in plant roots	Surface water and water pumped through roots	Inorganics/Organics
Phytostabilization	Root exudates cause metals to precipitate and biomass becomes less bioavailable	Groundwater, soil, mine tailings	Inorganics
Phytodegradation	Microbial degradation in the rhizosphere region	Groundwater within the rhizosphere and soil	Organics
Phytovolatilization	Plants evaporate certain metal ions and volatile organics	Soil, groundwater	Inorganics/Organics
Phytotransformation	Plant uptake of organic contaminants and degradation	Surface- and groundwater	Organics
Removal of aerial contaminants	Uptake of various volatile organics by leaves	Air	---

Table 3: Some examples of selective detoxification of mercury and lead by biosorbents as plant material.

Plant material	Metal ion	Result	Reference
Carica papaya wood	Hg (II)	96%	Basha et al. (2009)
***Ricinus communis* L. (Castor) leaves**	Hg (II)	80%	Rmalli et al. (2008)
Sawdust (*Acacia arabica*)	Pb(II), Hg (II), Cr (VI), Cu(II)	Pb > Cr > Cu and Hg	Meena et al. (2008)
Oriza sativa husk	Pb(II)	98%	Zulkali et al.(2006)
Agricultural by product *Humulus lupulus*	Pb(II)	75%	Gardea-Torresdey et al. (1998)
Agro waste of black gram husk	Pb(II)	Up to 93%	Saeed et al. (2005)
Febrifuga bark	Pb(II)	100%	Bankar and Dara (1985)
Waste tea leaves	Pb (II)	92%	Ahluwalia and Goyal (2005)
Rice bran	Pb (II), Cd (II), Cu (II), Zn (II)	>80.0%	Montanher et al. (2005)
Saw dust of Pinus sylvestris	Pb (II), Cd (II)	96%, 98%	Taty-Costodes et al. (2003)
Maple saw dust	Pb (II), Cu (II)	80–90%	Yu et al. (2001)
Water hyacinth	Pb (II), Cu (II), Co (II), Zn (II)	70–80%	Kamble and Patil (2001)
Low cost sorbents (bark, dead biomass, chitin, sea weed, algae, peat moss, leaf mold, moss	Pb (II), Hg (II), Cd (II), Cr (VI),	Good results	Bailey et al. (1999)
Rice straw, soybean hulls, sugarcane bagasse, peanut and walnut shells	Pb (II), Cu (II), Cd (II), Zn (II),Ni (II)	Pb > Cu > Cd > Zn > Ni	Johns et al. (1998)

Source: https://www.sciencedirect.com/science/article/pii/S1878535213002712

Screening of mercury-resistant and indole-3-acetic acid producing bacterial-consortium for growth promotion of *Cicer arietinum L.* (2016)

Table: Effect of bacterial consortium on growth promotion of Chickpea (Cicer arietinum L.) grown in mercury amended and non-amended soil

Treatments growth attributes	**$-C + HgCl_2^{a}$ (Control)**	**$-C - HgCl_2^{b}$**	**$+C + HgCl_2^{c}$**	**$+C - HgCl_2^{d}$**
Germination	60 ± 0.5 (a)	70 ± 0.5 (b)	80 ± 0.6 (c)	90 ± 0.6 (d)
(%)				
Shoot length (cm)	46 ± 0.5 (a)	47 ± 0.6 (a)	56 ± 0.6 (b)	57 ± 0.5 (b)
Root length (cm)	14 ± 0.5 (a)	15 ± 0.6 (a)	21 ± 0.6 (b)	22 ± 0.6 (b)
Shoot fresh weight (g)	2.6 ± 0.5 (a)	3.6 ± 0.5 (a)	5.6 ± 0.6 (b)	6.6 ± 0.6 (b)
Root fresh weight (g)	0.2 ± 0.4 (a)	0.2 ± 0.5 (a)	0.3 ± 0.6 (b)	0.3 ± 0.4 (b)
No. of pods/plant	4 ± 0.5 (a)	5 ± 0.5 (a)	7 ± 0.6 (b)	8 ± 0.6 (b)
No. of seeds/pod	1 ± 0.3 (a)	1 ± 0.3 (a)	2 ± 0.3 (a)	2 ± 0.3 (a)
Weight of seed (g)	0.2 ± 0.05 (a)	0.2 ± 0.06 (a)	0.4 ± 0.05 (a)	0.4 ± 0.06 (a)

The results shown are mean of three independent experiments ± standard error. The $p < 0.05$ was calculated by ANOVA. The different letters (a–d) indicate significant difference between means of each treatments calculated by Duncan's multiple range test ($p = 0.05$).

[a] Without bacterial culture and with $HgCl_2$.

[b] Without bacterial culture and $HgCl_2$.

[c] With bacterial culture and $HgCl_2$.

[d] With bacterial culture and without $HgCl_2$.

Source: https://onlinelibrary.wiley.com/doi/full/10.1002/jobm.201600352

Moringa oleifera Lam. leaf extract as bioregulatorfor improving growth of maize under mercuricchloride stress (2016)

Table 1: Effect of MALE and $HgCl_2$on seed germination and seedling growth of maize

Treatments	Germination (%)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
Control	100 ± 5.01^{a}	1.148 ±0.065^{cd}	0.171 ±0.039^{bc}	0.677 ±0.098^{bcd}	0.156 ±0.014^{a}
1 mg/kg $HgCl_2$	76.0 ± 3.78^{c}	0.649 ±0.041^{d}	0.024 ±0.005^{d}	0.377 ±0.067^{d}	0.096 ±0.051^{bc}
0.5 mg/kg $HgCl_2$	90.67 ± 7.00^{b}	0.993 ±1.040^{d}	0.131 ±0.019^{c}	0.477 ±0.059c^{d}	0.050 ±0.078^{c}
5%MALE +1 mg/kg $HgCl_2$	100 ± 6.01^{a}	1.747 ±0.039a^{b}	0.242 ±0.037a^{b}	1.032 ±0.132^{ab}	0.143 ±0.091^{ab}
2.5%MALE+ 1 mg/kg $HgCl_2$	100 ± 8.09^{a}	1.591 ±0.071^{bc}	0.196 ±0.056^{bc}	0.814 ±0.093^{bc}	0.141 ±0.086^{ab}
5%MALE +0.5 mg/kg $HgCl_2$	100 ± 4.11^{a}	2.187 ±1.120^{a}	0.292 ±0.069^{a}	1.358 ±0.254^{a}	0.188 ±0.034^{a}
2.5%MALE+ 0.5 mg/kg $HgCl_2$	100 ± 5.00^{a}	1.993 ±0.065^{ab}	0.220 ±0.028^{ab}	1.408 ±0.142^{a}	0.186 ±0.076^{a}
LSD	4.347	0.540	0.084	0.413	0.056

Means sharing a common English letter are statistically similar. The ± represents value of standard error. MALE, Moringa oleifera aqueous leaf extract.

Table 2: Effect of MALE and $HgCl_2$ on leaf photosynthetic pigments and total soluble phenolics of maize.

Treatments	Chlorophyll (mg/g F.W)	Carotenoids (mg/g F.W)	Total soluble phenolics in roots (µg/g F.W)
Control	11.06 ± 0.581^{bc}	2.865 ± 0.014^{b}	28.93 ± 4.915^{d}
1 mg/kg $HgCl_2$	4.20 ± 1.712 ^{d}	2.867 ± 0.051^{b}	81.04 ± 5.912^{c}
0.5 mg/kg $HgCl_2$	6.93 ± 3.901^{cd}	3.354 ± 0.813^{b}	77.33 ± 7.990^{c}
5%MALE + 1 mg/kg $HgCl_2$	12.63 ± 2.001^{ab}	7.452 ± 1.253^{a}	138.54 ± 6.712^{a}
2.5%MALE + 1 mg/kg $HgCl_2$	13.63 ± 4.091^{ab}	3.225 ± 0.710^{b}	89.67 ± 5.312^{bc}
5%MALE + 0.5 mg/kg $HgCl_2$	16.88 ± 6.171^{a}	2.580 ± 0.513^{b}	104.33 ± 9.008^{b}
2.5%MALE + 0.5 mg/kg $HgCl_2$	13.56 ± 3.512^{ab}	3.422 ± 0.961^{b}	82.73 ± 7.012b^{c}
LSD	4.347	1.055	2.160

Notes: Means sharing a common English letter are statistically similar. The ± represents value of standard error. MALE, *Moringa oleifera* aqueous leaf extract.

Source: https://www.tandfonline.com/doi/full/10.1080/09064710.2016.1173225

Accumulation Of Mercury In Selected Plant Species Grown In Soils Contaminated With Different Mercury Compounds (2016)

Table 1: Biomass and mercury concentration in Chinese brake fern.

Treatment	Hg in shoots(mg/kg)	Hg in roots(mg/kg)	Shoot biomass (dry weight g)	Final Hg in soil (mg/kg)
F4HgT0 (Control)	0.38 (0.53) c†	BD#	6.1 (1.6)	BD
F4HgT1 (250mg/kg)	123 (88) b	749 (330) b	5.9 (1.6)	85 (23) c
F4HgT2 (500mg/kg)	540 (393) b	1525 (786) b	3.9 (1.1)	207 (43) b
F4HgT3 (1000mg/kg)	1469 (761) a	6802 (3325) a	3.9 (0.3)	413 (77) a

*The numbers in parenthesis indicate standard deviation.

BD-below detection limit.

† Means followed by a different letter are significantly different at the 0.05 probability level, grouped into classes a, b and c

Table 2: Mercury concentrations in Beard grass shoots and roots and soil (average with standard deviation).

Treatment	Hg in shoots(mg/kg)	Hg in roots(mg/kg)	Hg in soil(mg/kg)
G5HgT0(Control)	6.08(3.89)	9.73(10.7)	BD
G5HgT1(250 mg/kg)	40(27)	1579(855)	85(23)
G5HgT2(500 mg/kg)	26(12)	2241(1101)	207(43)
G5HgT3(1000 mg/kg)	65(40)	2298(468)	413(77)

Numbers in parenthesis indicate standard deviation. BD—below the detection limit.

Table 3: Mercury concentrations in shoots and roots of Indian mustard grown in aged soils contaminated by $Hg(NO_3)_2$, $HgCl_2$, and HgS (average with standard deviation).

Treatment	Hg in shoots (mg/kg)	Hg in roots (mg/kg)	Original Hg in soil (mg/kg)
$Hg(NO_3)_2$	2.1 (2.5)	24 (17)	100
$HgCl_2$–1	0.8 (0.8)	26 (11)	100
$HgCl_2$–2	12 (22)	110 (39)	250
$HgCl_2$–3	325 (287)	1775(1096)	1000
HgS–1	35 (29)	17 (11)	1000
HgS–2	79 (51)	87 (43)	2000

Table 3: Mercury concentrations in shoots and roots of plants grown in sunlit chamber. The plants were grown in mercury-contaminated soil, but the plant shoots were protected from gaseous mercury from soil.

Plant	Hg in shoots (mg/kg)	Hg in roots (mg/kg)
Indian mustard (Longstanding variety)	19.60 (20.00)	663.77 (34.03)
Indian mustard (Broadleaf variety)	11.23 (3.06)	230.56 (27.00)
Chinese brake fern	11.62 (7.87)	327.45 (121.74)

Source:
https://www.researchgate.net/publication/236475521_Accumulation_of_Mercury_in_Selected_Plant_Species_Grown_in_Soils_Contaminated_With_Different_Mercury_Compounds