Phytoremediation Applied to Pesticide-Contaminated Soil in Kazakhstan

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Research Tasks

- Task 1: Inventory former obsolete pesticide warehouses to document obsolete pesticide stockpiles and to characterize levels of soil contamination
- Task 2: Study genotoxicity of organochlorine pesticides
- Task 3: Identify pesticide tolerant plant species using surveys of plant community structure at selected "hot points"
- Task 4: Describe physiological and biochemical characteristics of pesticide tolerant plants grown in pesticide contaminated soil

Research Tasks

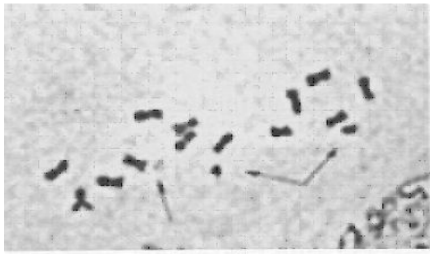
- Task 5: Document pesticide accumulation patterns in pesticide tolerant plants
- Task 6: Study the fate and transport of pesticides in soil and plants in the greenhouse using soil collected from hot points
- Task 7: Study the effect of fertilization on phytoremediation potential in the greenhouse and field

Pesticide – Tolerant Species Identified

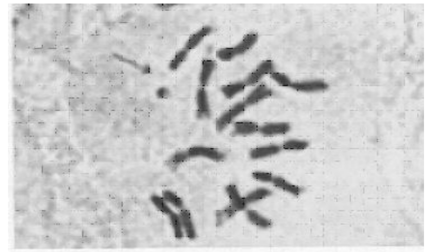
- *Artemisia annua* L.
- *Artemisia absinthium* L.
- *Agropyron pectiboformis* L.
- *Artemisia proceraeformis* L.
- *Amaranthus retroflexus* L.
- *Ambrosia artemisiifolia* L.
- *Barbareae vulgaris* W. T. Aiton
- *Bromus tectorum* L.
- *Erigeron canadensis* L.
- *Kochia scoparia* (L.) Schrad
- *Kochia sieversiana* L.
- *Lactuca tatarica* (L.) C.A. Mey
- *Onopordon acanthium* L.
- *Polygonum aviculare* L.
- *Rubus caesius* L.
- *Rumex confertus* Willd.
- *Solanum dulcamara* L.
- *Xanthium strumarium* L.

Table 1. Quantities of obsolete, forbidden and unidentified pesticides in former warehouses in Almaty and Akmola oblast of the Republic of Kazakhstan.

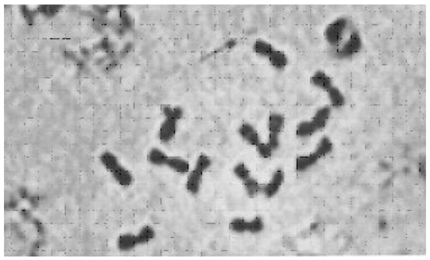
Rayon	No. Sites	Identified olsolete pesticides (kg)	Banned pesticides (kg)	Unidentified substances (kg)
Almaty Oblast				
Karasajsk	6			1,150
Talgar	7	30,600		
Dzhambul	5	200		100,500
Enbekzhi-Kazakh	9	2,950	350	4,570
Uigur	3	970		2,860
Balkazh	7			500
Ulisk	7	1,450		105,700
Eskeldinsk	8	50		100,700
Kerbulak	12	0	0	0
Koksuisk	0			
Total	**64**	**36,620**	**350**	**315,980**
Akmola Oblast				
Atbasar	3			26,430
Buladinsk	2			5,345
Enbekshilder	2			900
Zharkain	1			700
Shortandi	4			2,670
Total	**12**			**36,045**



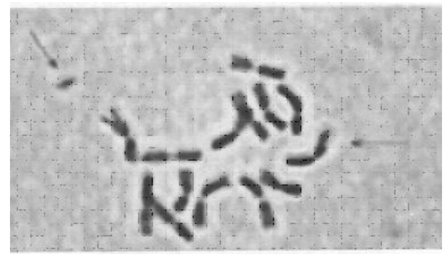
Isolocus break



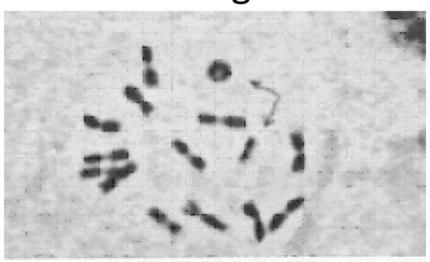
Chromosomal deletion



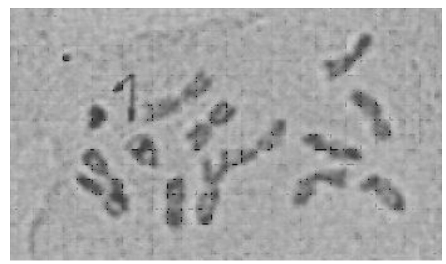
Microfragment



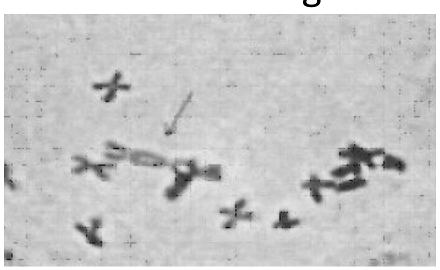
Chromatid deletion



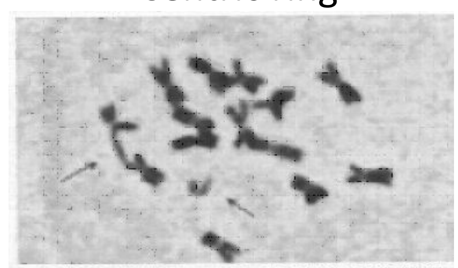
Acentric ring



Centric ring



Dicentric chromosome



Asymetric translocation

Figure 16, Structural chromosome aberrations Hordeum vulgare L. induced by seed treatment with HCH isomers and DDT metabolites.

Table 2. Frequency of chromosome aberrations in barley seed treated with HCH isomers and DDT metabolites compared to control treatments with water and hexane.

Treatment	Pesticide conc. µg/kg	No. cells	Metaphase cells with aberrant chromosomes		Total aberrations	Aberrations per 100 metaphases
			No.	%		
Control (water)		344	10	2.9 ± 0.9	10	2.9 ± 0.9
Control (hexane)		415	13	3.2 ± 0.7	14	3.5 ± 0.7
α-HCH	3	312	15	4.8 ± 1.2	15	4.8 ± 1.2
	50	304	25	8.2 ± 1.6	26	8.6 ± 1.6*
	200	302	45	14.9 ± 2.1	47	15.6 ± 2.1*
β-HCH	100	305	14	4.6 ± 1.2	14	4.6 ± 1.2
	200	318	14	4.4 ± 1.2	16	5.0 ± 1.2
	800	323	37	11.5 ± 1.8	38	11.8 ± 1.8*
γ-HCH	5	316	15	4.8 ± 1.2	17	5.4 ± 1.3
	100	301	39	13.0 ± 1.9	42	14.0 ± 2.0*
	200	314	47	15.0 ± 2.0	49	15.6 ± 2.1*
4,4 DDT	200	318	15	4.7 ± 1.2	17	5.4 ± 1.23
	1000	302	17	5.6 ± 1.3	20	6.6 ± 1.4
	5000	324	49	15.1 ± 2.0	52	16.1 ± 2.0*
2,4	5	317	16	5.1 ± 1.2	17	5.4 ± 1.3
	50	302	32	10.6 ± 1.8	37	12.3 ± 1.9*
	150	306	39	12.8 ± 1.9	40	13.1 ± 1.9*
4,4 DDE	100	381	48	12.6 ± 1.7	48	12.6 ± 1.7*
	800	312	27	8.7 ± 1.6	29	9.3 ± 1.6.*
	1800	321	45	14.0 ± 1.9	46	14.3 ± 2.0*

* $p<0.001$ in comparison with control values

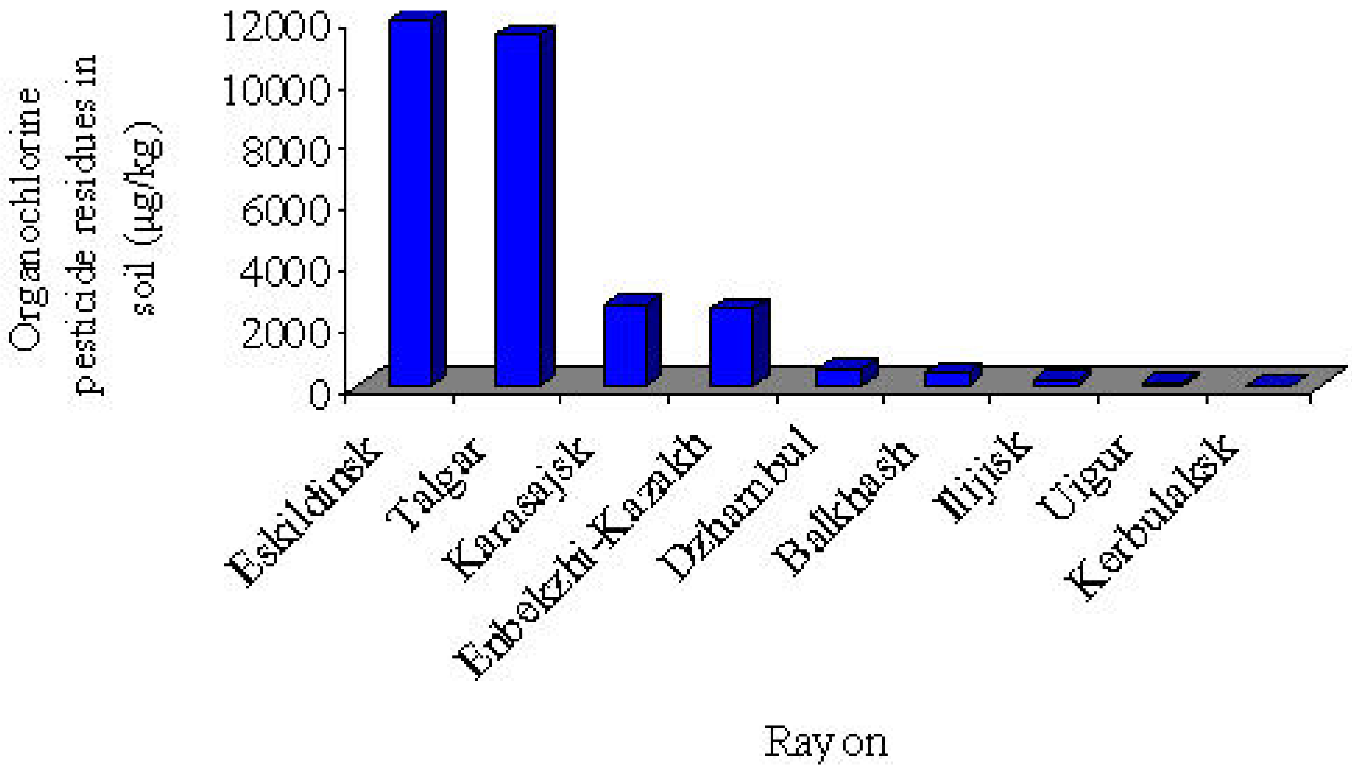


Figure 15. Total soil concentrations of isomers of HCH and metabolites of DDT from former pesticide storehouses in Almaty oblast.

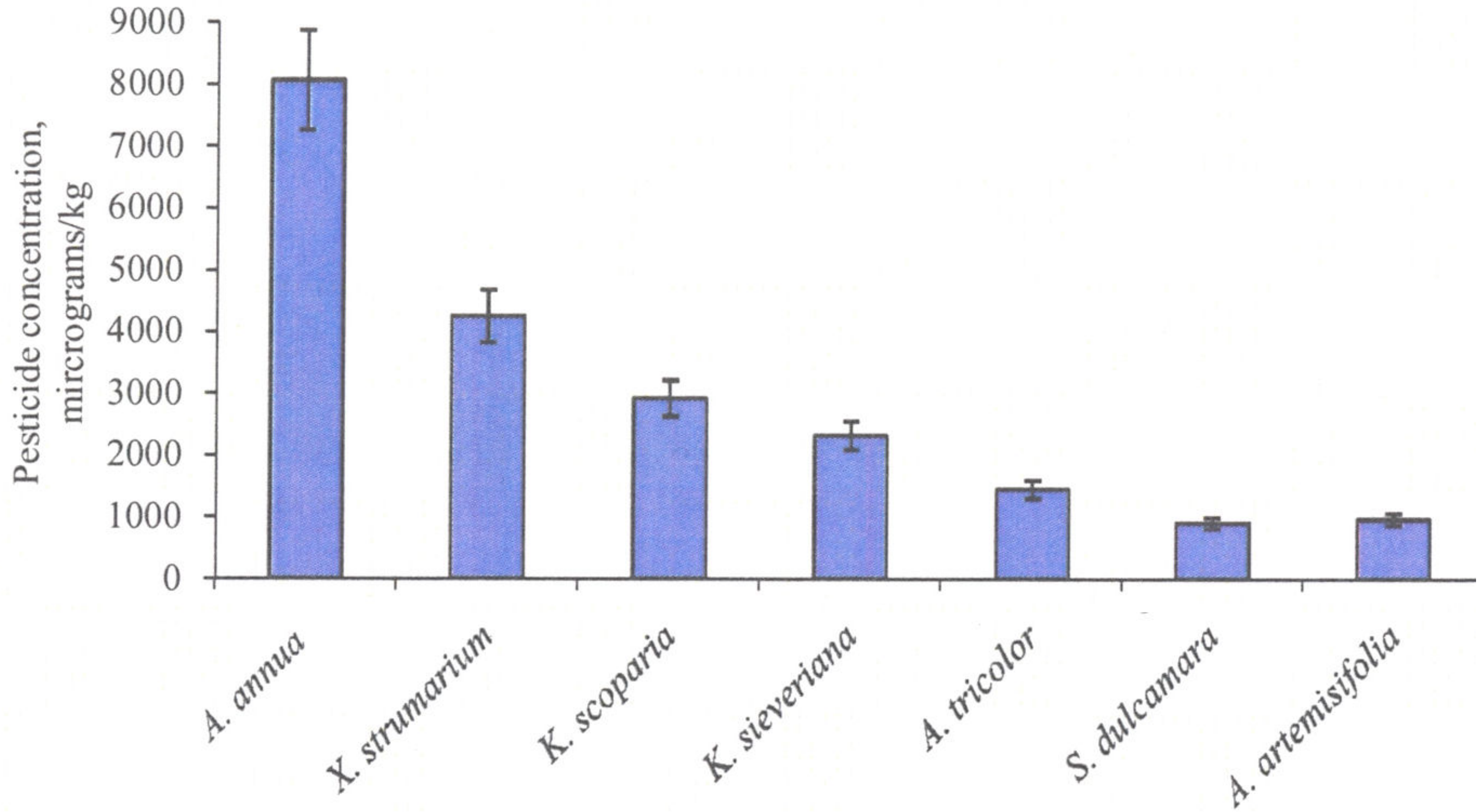


Figure 18. Total pesticide residuals accumulated in plant tissue for seven annual plant species grown in soil from Hot Point 2.

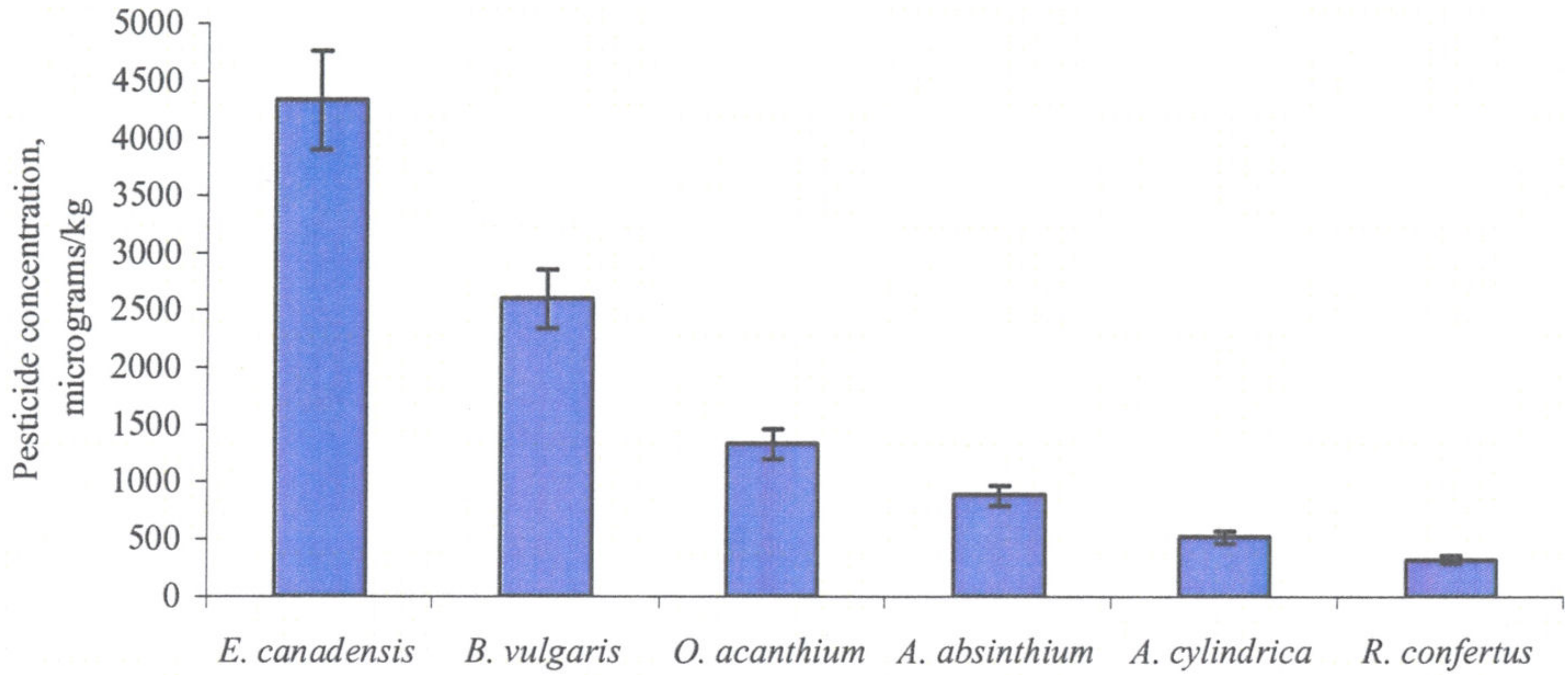


Figure 19. Total pesticide residuals accumulated in plant tissue for six biannual plant species grown in soil from Hot Point 2.

Table 3. Localization of pesticides residues in plant tissues based on histological analysis.

Species	Mosophyll type	Location of pesticide residues in plant tissue		
		Root	Stem	Leaf
Xanthium strumarium L	dorsiventral	parenchymous cells and xylem walls	xylem walls	palisade mesophyll
Ambrosia artemisiafolia L.	isolateral	parenchymous cells and xylem walls	xylem walls	palisade mesophyll
Erigeron canadensis L.	dorsiventral	parenchymous cells and xylem walls	xylem walls	palisade mesophyll
Artemisia annua L.	homogeneous	parenchymous cells and xylem walls	xylem walls	around conducting bunches.
Kochia scoparia L.	homogeneous	parenchymous cells and xylem walls	xylem walls	around conducting bunches.
Barbarea vulgare L.	dorsiventral	parenchymous cells and xylem walls	xylem walls	palisade mesophyll

Observed Patterns of Pesticide Accumulation

1. Pesticide accumulating plants: The concentration of pesticides in plant tissue exceeds the MAC up to 400 times. The MAC for plant tissue in Kazakhstan is 20 µg/kg. Species in this category include: *Xanthium strumarium, Kochia scoparia, Artemisia annua,* and *Kochia sieversiana*.
2. Accumulators of HCH isomers. The concentration of HCH isomers in plant tissue exceeds the MAC up to 90 times. Four representatives of family *Asteraceae* are in this category including *Artemisia annua*, *Ambrosia artemisifolia*, *Xanthium strumarium*, and *Erigeron canadensis*.

Observed Patterns of Pesticide Accumulation

3. Accumulators of metabolites 2,4 DDD and α-HCH. These compounds do not have a maximum allowable concentration (MAC) for plants or soil. These species accumulate trace metabolites of DDT and α-HCH in plant tissues in which the residual concentration of pesticides exceeds the MAC for other compounds. These species include *Ambrosia artemisifolia*, *Xanthium strumarium*, *Artemisia annua*, *Solanum dulcamara*, *Medicago sativa*, and *Barbarea vulgaris*.

Observed Patterns of Pesticide Accumulation

4. Ability to accumulate and to translocate pesticide from roots to aboveground plant tissue. Most pesticide accumulated is in the root system; however some species demonstrated capability to translocate pesticides from roots to aboveground tissues. These included *Kochia scoparia*, *Artemisia annua*, *Barbarea vulgari*, and *Ambrosia artemisifolia.* For these plants concentration of pesticide in aboveground tissue exceeded the concentration in root tissue giving a translocation factor of greater than one.

Observed Patterns of Pesticide Accumulation

5. Non-accumulators. Two species, *Solanum dulcamara* and *Rumex confertus*, did not accumulate significant concentrations of pesticides in plant tissues despite growing in the most contaminated areas of the hot points. These species may have practical value for phytostabilization or phytodegradation technologies that seek to stabilize or enhance degradation of organochlorine pesticides in soil.

Table 4. Pesticide concentrations and mass in soil and *Xanthium strumarium* plants from two test plots at Hot Point 2. One test plot had no added fertilizer and one test plot was fertilized with ammonium phosphate and potash chloride.

	Soil or Plant Mass kg	**Pesticide concentration µg/kg**	**Pesticide mass µg**
Contaminated soil without fertilizer			
Soil before experiment	402	489	196,598
Aboveground plant biomass	1.3	60	78
Root biomass	0.1	182	18
Soil after experiment	402	227	91,274
Contaminated soil with fertilizer			
Soil before experiment	402	420	168,840
Aboveground plant biomass	3.3	101	334
Root biomass	0.3	474	142
Soil after experiment	402	113	45,426

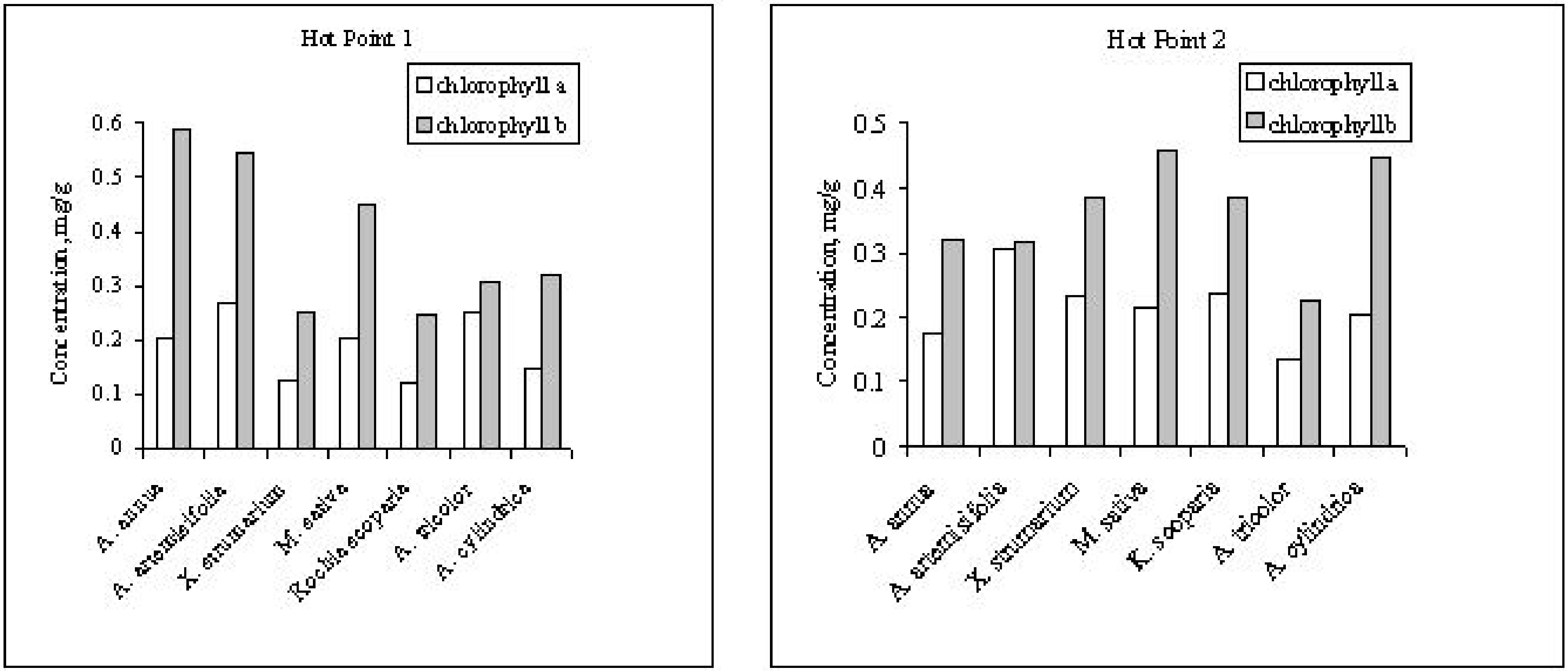


Figure 17. Concentrations of chlorophyll a and chlorophyll b in leaves of seven species growing in pesticide contaminated soil from hot point 1 and hot point 2.

Conclusions

1. Concentrations of DDT and HCH in soil exceeded MAC near former storehouses.
2. Many pesticide-tolerant plant species were found growing in the contaminated soil.

Conclusions

3. Pesticide uptake into roots and plant tissue was observed at concentration above the MAC.
4. Phytoremediation is an inexpensive technology that can be used to reduce pesticide concentrations in soil.