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14th International HCH and Pesticides Forum

Phytoremediation of POPs-contaminated soils: solutions and development potential in Kazakhstan

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The problem of obsolete pesticides in Kazakhstan (case study of Almaty region)

Table 1 - Inventory of obsolete pesticides in Almaty region

Districts	# of storehouses	Pesticide amount, kg		
		Ministry of Ecology of Kazakhstan, 2005	IPBB, **2010**	IPBB, IGG&C, **2018-2020**
Karasay	6	1 350	600	NA
Talgar	7	121 449	31 150	450
Zhambyl	5	13 245	100 700	NA
Enbekshikazakh	9	25 000	7 970	NA
Uygur	7	3 250	3 830	NA
Balkhash	7		500	NA
Ile	3	17 550	107 150	NA
Eskeldi	12	60 000	100 750	NA
Kerbulak	8		0	NA
Koksu	0	0	0	NA
TOTAL	**64**	**436 049**	**352 650**	**450** (disposed 2019)

350 kg of banned pesticides (sayfos, metaphos) out of 352 t of obsolete pesticides, 21 % are pesticides in packaging, remaining 79 % are mixed unknown pesticides.

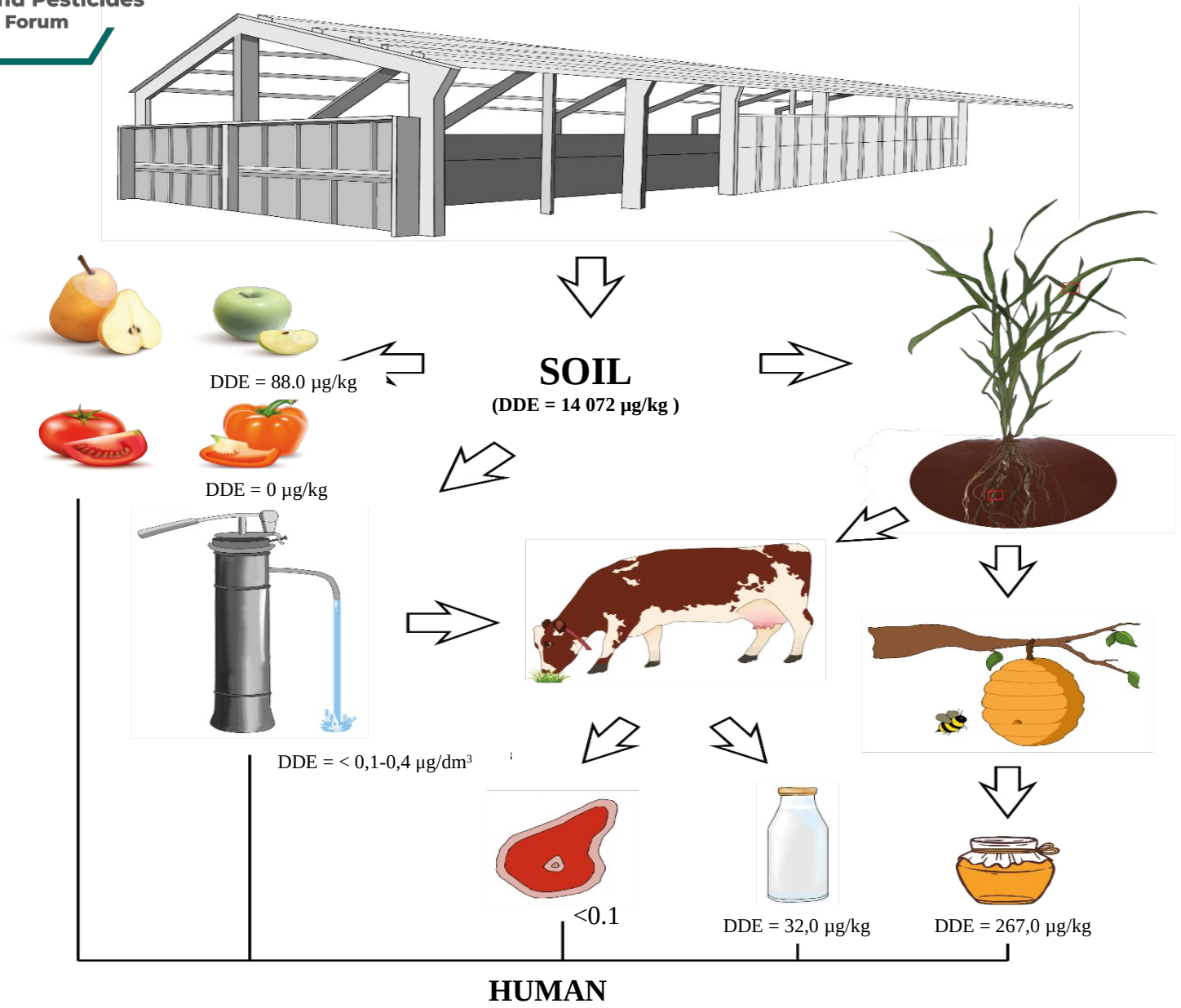
Pesticide concentrations in 780 soil samples from former pesticide storehouses in Almaty region (2008-2010)

Districts	Number of storage facilities			
	Total	Without contamination	Contaminated, MPC <100	Contaminated, MPC >100
Karasay	6	0	0	6
Talgar	7	1	1	5
Zhambyl	5	1	2	2
Enbekshikazakh	9	0	2	7
Ile	3	1	1	1
Uygur	7	4	3	0
Balkhash	7	2	4	1
Kerbulak	8	8	0	0
Eskeldi	12	4	6	2
Koksu	0	0	0	0
Total	**64**	**21**	**19**	**24**

The soil around 24 former pesticide storehouses is contaminated with organochlorine pesticides and concentrations of these compounds exceed the limits of Kazakhstan's maximum permissible concentrations (MPC) (for organochlorine pesticides MPC is 100 µg/kg). The most common contaminants were **α-HCH, β-HCH, 4,4-DDE, and 4,4-DDT**. The depth of soil contamination was 30 cm.

Nurzhanova A., Kalugin S., Zhambakin K. Obsolete pesticides and application of colonizing plant species for remediation of contaminated soils in Kazakhstan // *Environ Sci Pollut Res* – 2013. – Vol. 20. – P. 2054-2063

Residuals of highly hazardous pesticides in food



According to the World Health Organization (WHO), everyone's health depends 25-30 % on the condition of the natural environment

Nurzhanova A., Jansugurova L.B., Zhapbasov R.Zh., Vsevolodov E.B., Zhubanova A.A. et al. Cadaster of obsolete pesticides in Almaty Region (Case Study of Talgar District) - Almaty: Kazakh University, 2022 - 116 p.

DDT degradation methods

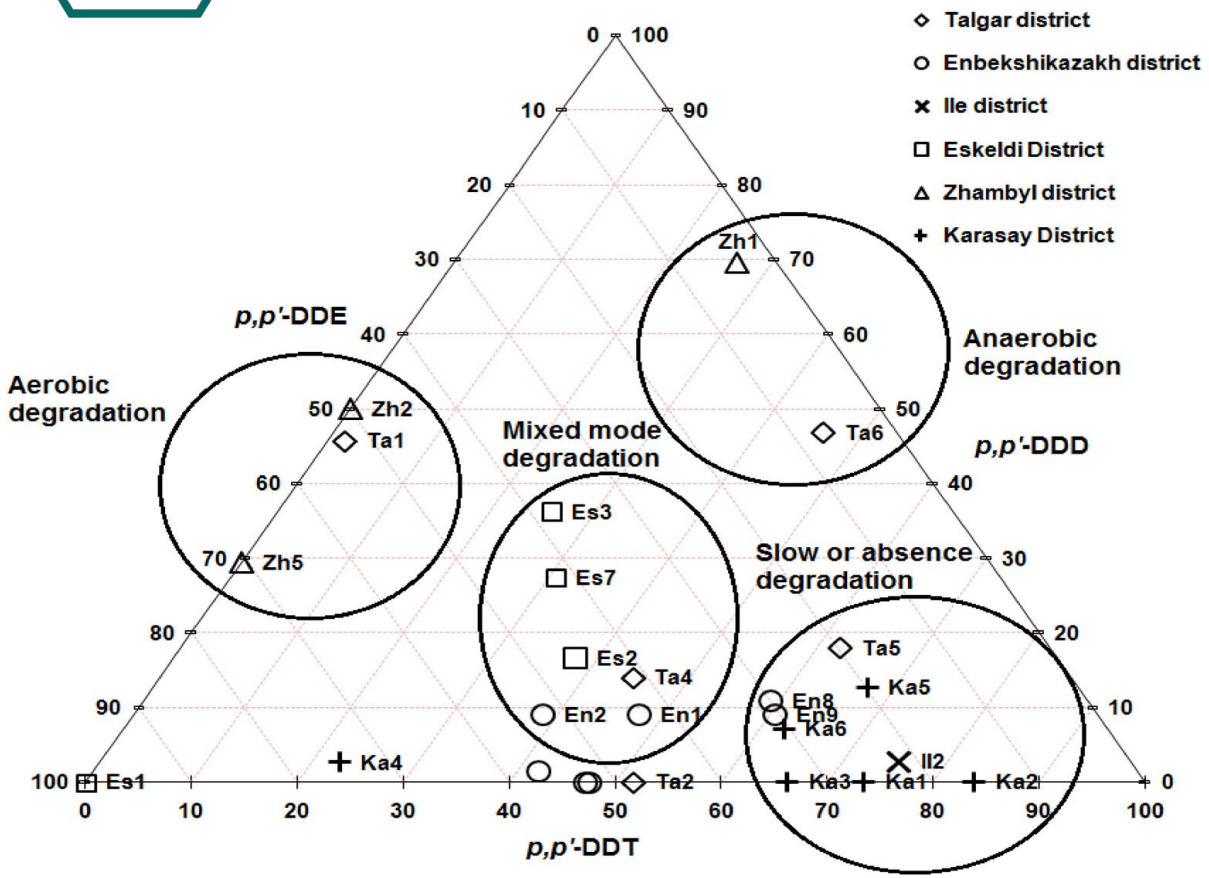


Fig. 1. Three-fold diagram illustrating p,p′-DDT degradation pathways in soil samples from various locations within Almaty Region, Kazakhstan.

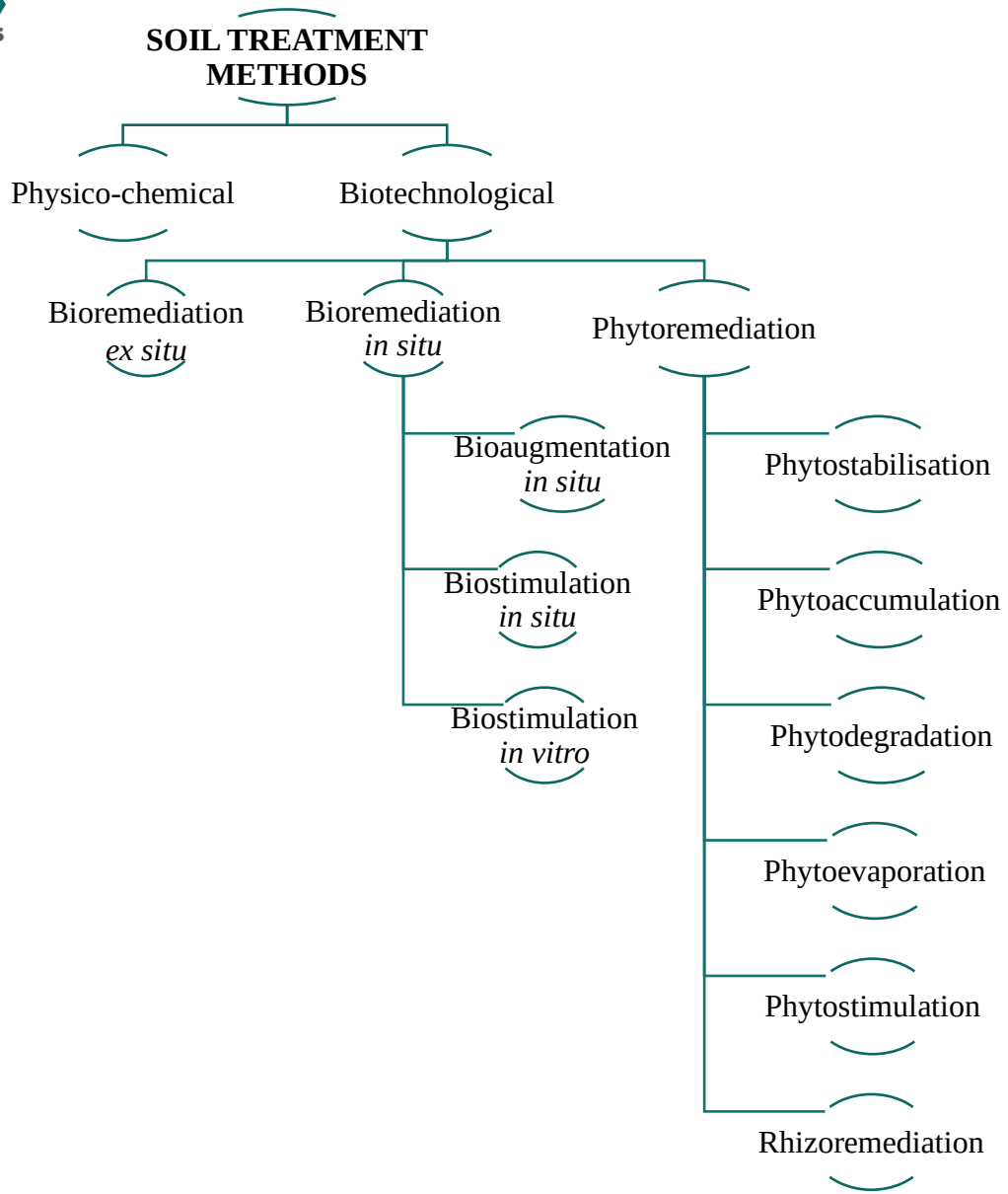
In Zhambyl and Talgar districts, points near DDT-DDE degradation axis indicate **aerobic degradation** of metabolites, points near DDT-DDD axis, on the contrary are associated with **anaerobic degradation pathway**.

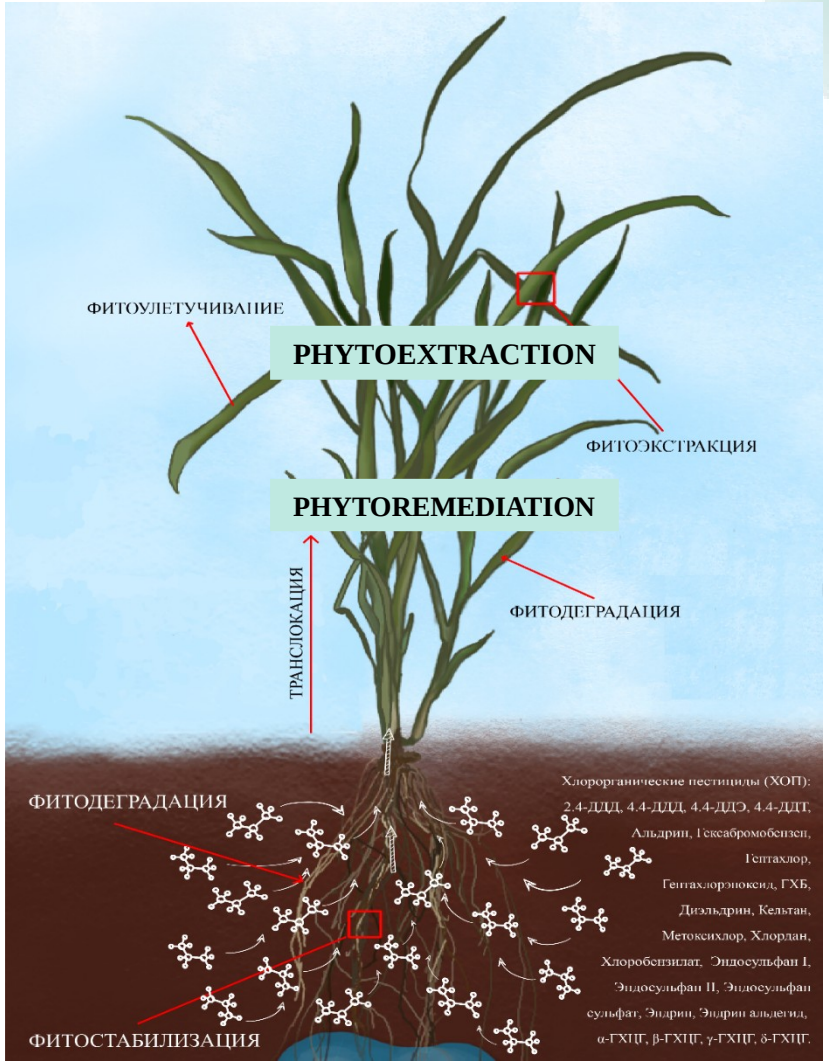
In the territory of Karasay, Ile, and Enbekshikazakh districts, DDT dominates in the soil, which reflects slow or even no degradation.

Sailaukhanuly Y, Nurzhanov Ch., Nurzhanova A., Carlsen L. Evaluation of the potential cancer risk of obsolete organochlorine pesticides in abandoned storehouses throughout the Almaty oblast, Kazakhstan // Int. J. Human and ecological risk assessment. – 2022. – 28(10). – P.1213-1227.

Biological methods of soil remediation

Phytoremediation is a promising technology in balance with the ecosystem.





Strategies for the development of phytotechnology

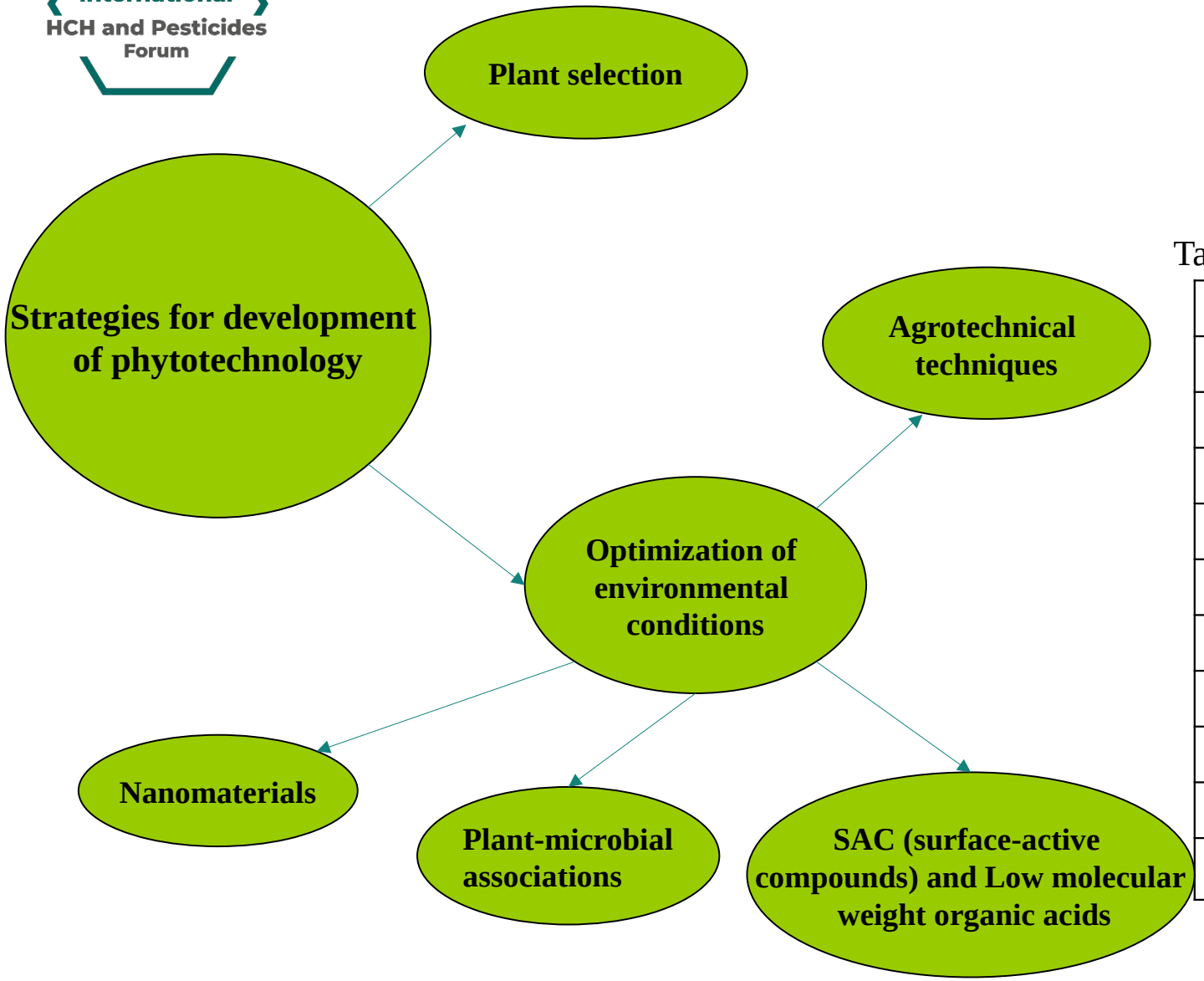


Table 2 - Phytoremediation plants of Kazakhstan's flora

Pollutants	woody	perennial	annual
Petroleum hydrocarbons	9	18	5
Pesticides	**5**	**10**	**5**
POPs-Pesticides	**3**	**7**	**11**
Radionuclides	8	26	3
Explosives	0	3	2
Chlorinated solvents	4	3	1
Arid zones	19	0	0
Plants with large biomass	9	0	0
Bioenergy species	2	4	3
Total	**65**	**102**	**40**

A. Nurzhanova Phytoremediation plants of the Kazakhstan's flora. - 2019. Almaty. IE N.A.Volkova - 227 p.

Advantages and disadvantages of phytotechnology

USE OF CONTAMINATED SOILS

PHYTOREMEDIATION	PHYTOMANAGEMENT
The process of soil **remediation** from xenobiotics for further use.	The process of growing energy crops on contaminated sites to **produce clean biomass.**

PHYTOREMEDIATION		PHYTOMANAGEMENT	
Advantages	Disadvantages	Advantages	Disadvantages
Eco-friendliness Economic efficiency Can be applied to a wide range of contaminants	Access to land use in the long run Long time Continuous monitoring and control	Use of marginal and contaminated sites Profitability Eco-friendliness Can be combined with phytostabilisation	Lack of quality standards for input raw materials Strict requirements for the output product

Phytoremediation of soil polluted with pesticides

Table 3 - Organochlorine pesticides concentrations in soil before phytoremediation

Pesticides	MPC, µg/kg		Amangeldy	Belbulak	Beskainar	Kyzylkairat
	KZ	EU				
2.4-DDD	100	10.0	487	176	848	14 072
4.4-DDD	100	10.0	654	198	824	11 434
4.4-DDE	100	10.0	784	576	34 215	777
4.4-DDT	100	10.0	1 237	62	6 274	10 023
α-HCH	100	220.0	7.30	< LOD	7.33	45.1
β-HCH	100	92.0	6.5	< LOD	13.4	25.5
γ-HCH	100	0.01	97.0	9.50	251	488
Endrin	1	2.9	859	23.9	32548	4485
Aldrin	2.5	7.0	12.2	< LOD	64.0	230
Chlordane	100	4.3	30.1	4.1	< LOD	48.1
Chlorobenzilate	20	-	277	25.7	4 067	32 061
Dibutyl chlorendate	-	-	511	154	1 285	2 134
Dicofol	100	-	11.9	< LOD	14.7	21.9
Dieldrin	0.5	7.0	42.3	22.0	194	< LOD
Endosulfan α	100	0.003	83.1	5.06	4.40	< LOD
Endosulfan β	100	0.003	27.8	< LOD	77.8	253
Endosulfan sulfate	-	-	654	258	266	119

< LOD

< MPC

> MPC (< 5)

> 5 × MPC

> 10 × MPC

> 50 × MPC

>100 × MPC

>500 × MPC

Miscanthus sinensis

Miscanthus sinensis – energy species

(Area – Altai)

CANNOT

Absorb and accumulate in tissues (BCF < 1) following pesticides **9 OCPs out of 24**

- 2.4-DDD
- 4.4-DDD
- Chlorobenzylate
- *α*-HCH
- *δ*-HCH
- Heptachlor epoxide
- Endosulfan α
- Endrin
- Dibutyl chlorendate

OCPs - organochlorine pesticides

CAN

- **Bioconcentrate** (BCF >1) **15 OCPs out of 24**
  4.4-DDE, 4.4-DDT, Methoxychlor, *γ*-HCH, Aldrin, Heptachlor, Endosulfan *β*, Endrin aldehyde, and Hexabromobenzene
- **Hyperaccumulation 6 OCPs out of 15**
  Dicofol, *β*-HCH, Dieldrin, Chlordane, Endosulfan sulfate, and HCB
- **Phytostabilization** (TLF < 1) **3 OCPs out of 15**
  4.4-DDE, Dicofol, and Chlordane
- **Phytoextraction** (TLF > 1) **5 OCPs out of 15**
  β-HCH, *γ*-HCH, Heptachlor, Hexabromobenzene, and HCB)
- **Evenly distributed in plant tissues** (TLF ~ 1) **7 OCPs out of 15**
  4.4-DDT, Methoxychlor, Aldrin, Dieldrin, Endosulfan *β*, Endosulfan sulfate, and Endrin aldehyde

Mamirova, A., Pidlisnyuk, V., Amirbekov, A., Ševců, A., & **Nurzhanova, A.** (2021). Phytoremediation potential of *Miscanthus sinensis* And. in organochlorine pesticides contaminated soil amended by Tween 20 and Activated carbon. // Environmental Science and Pollution Research. - 2021. – Vol. 28, Is. 13. – P. 16092–16106

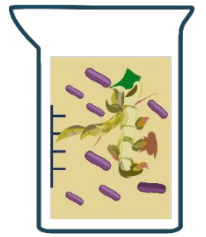
RESEARCH PERSPECTIVES

Contaminated soil

Microorganisms

Screening for growth-stimulating properties

Reproduction of the target microorganism



Inoculation of plant rhizomes

Miscanthus sinensis

Miscanthus × *giganteus*

Planting on contaminated soil

Soil remediation

PHYTOREMEDIATION

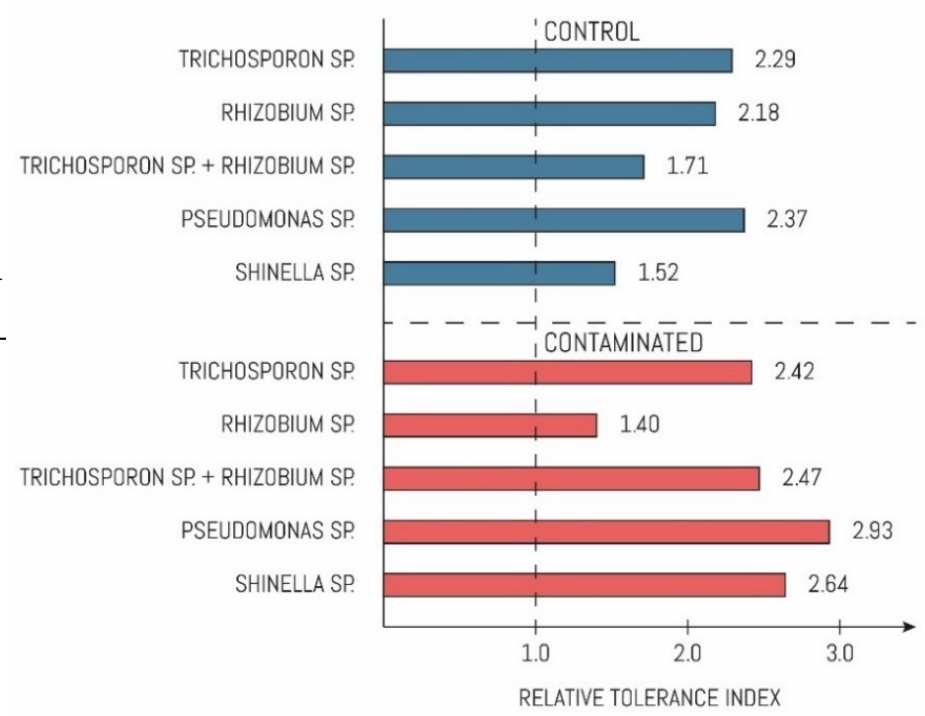
Nurzhanova A., Mukasheva T., Berzhanova R., Kalugin S., Omirbekova A., Mikolasch A. Optimization of microbial assisted phytoremediation of soils contaminated with pesticides // Int. J. Phytoremediation. Taylor & Francis, 2021.Vol. 23 (5): 482–491

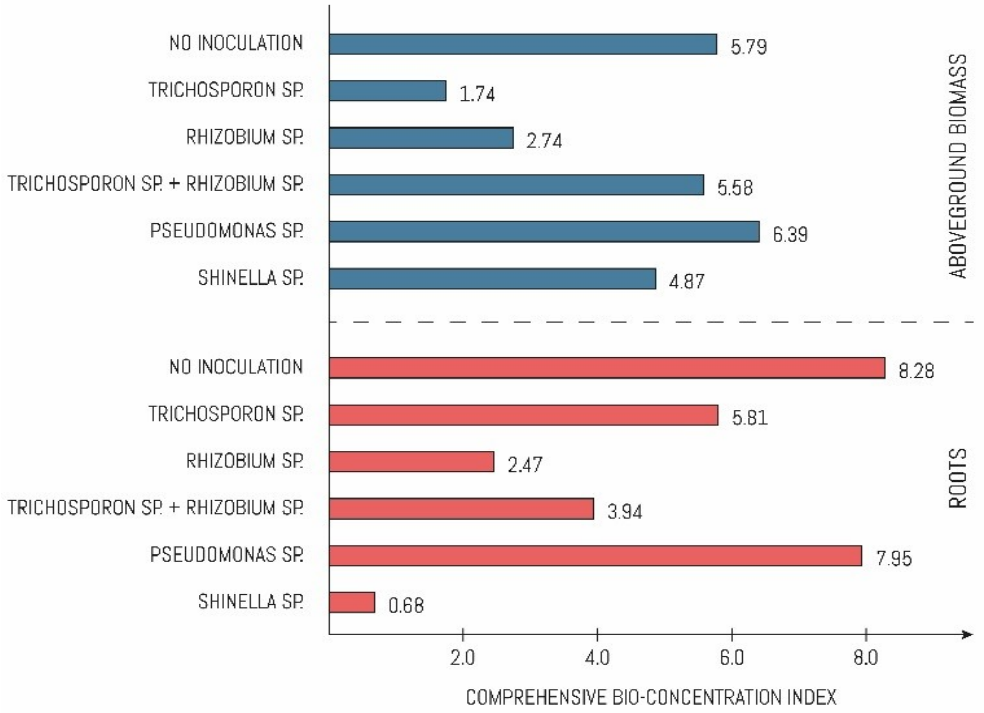
Phytoremediation of soil polluted with trace elements (heavy metals)

Miscanthus × *giganteus* is an allotriploid, bioenergetic, highly productive, sterile hybrid (Area – East Asia)

Plant growth promoting rhizobacteria (PGPR)

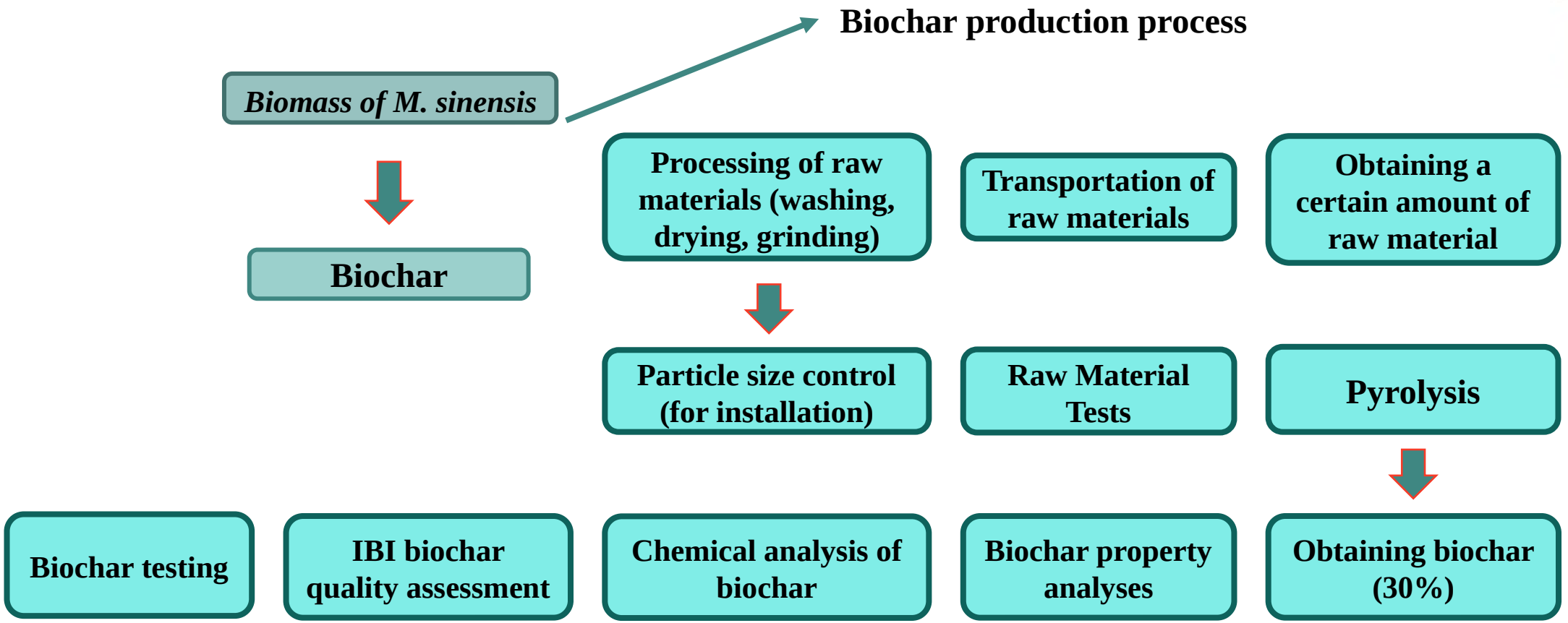
PGPR	N_2 fixation	P_2O_5 solubilization	Siderophore synthesis	IAA synthesis, μg mL^{-1}	Zn tolerance, mM	Pb tolerance, mM
Trichosporon sp. CA1	+	+	+	50.2 ± 1.2	4.0	4.0
Rhizobium sp. Zn1-1	+	+	±	12.0 ± 0.2	2.5	0.5
Pseudomonas sp. ChA1-4	+	+	±	31.0 ± 1.1	2.5	0.5
Shinella sp. Zn5-6	+	+	±	19.1 ± 0.1	2.5	0.5





Nurzhanova A., Pidlisnyuk V, Abit K., Nurzhanov Ch., Kenessov B., Stefanovska T., Erickson L. Comparative assessment of using *Miscanthus* × *giganteus* for remediation of soils contaminated by heavy metals: a case of military and mining sites // Environmental Science and Pollution Research. – 2019. – Vol. 26. – P.13320-13333

PROSPECTS FOR THE USE OF BIOMASS IN BIOENERGY



Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil (International Biochar Initiative).

New project supported by FAO

"Technical assistance in implementation of laboratory and field trials on bioremediation and phytoremediation of soils contaminated by POPs and heavy metals" 2023
as part of FAO project "Lifecycle Management of Pesticides and Disposal of POPs Pesticides in Central Asian countries and Türkiye"

Destroyed storage facilities of obsolete pesticides in villages of Enbekshi-Kazakh district, Almaty region: **Saimasai**

GPS coordinates: 43°27′19″ N 77°18′53″ E

Ownership: state property, can be used

Suspected soil contamination level based on inventory of 2010 (concentrations of DDT metabolites and HCH isomers): 23 × MPC.

Satellite pictures: since 2002

Tasks:

1 Site recultivation

2.1 Field trials on bio- and phytoremediation

2.2 Microbial preparation application on field scale

3 Cultivation of seeds/plants on OCP-contaminated soils in greenhouse

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THANK YOU FOR ATTENTION!

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