Title	**Lindane uptake and translocation by rice seedlings (Oryza sativa L.) under different culture patterns and triggered biomass re-allocation**
Author Name	Shidi Huang, G. Daniel Sheng
Journal Name	Chemosphere
Year	2021
Volume and Issue	262
Article No.	127831
Abstracts	The study was conducted to investigate the influence of the culture pattern on plant uptake and translocation of an organic chemical and the resultant acute response of plants, and to further reveal the interconnection. Plant exposure experiments were performed using a conventional rice seedling (*Oryza sativa L. subsp. indica*) under two kinds of culture patterns (viz., hydroponics and soil-based culture) with various culture matrices for a period of 7 days. The exposure concentration of lindane was ~450 μg L^{-1} in the aqueous-phase matrices, and 200.1–756.0 μg kg^{-1} in the solid matrices. Lindane accumulation and its distribution in plant tissues were quantified, as well as the tissue biomass. The results showed the accumulation of lindane in all exposure groups were comparatively close over the period, confirming that the soil-bound lindane was scarcely available to plants. Similar trend of lindane uptake and translocation in seedlings was found among the groups under the same kind of cultivation pattern. In the hydroponic groups, lindane was mostly distributed in roots (about 60% at the end of exposure), whereas more lindane was translocated to shoots (approximate 70%) under the soil-based culture pattern. Allometric analysis demonstrated that the tissue part (root or shoot) with more lindane accumulation had a relatively higher growth rate over 7 days. Correspondingly, biomass allocation presented a slight trend of mutual proximity to lindane distribution. It was inferred that plants altered their allometric growth pattern to realize biomass re-allocation in response to the short-term lindane exposure, which could be considered as a plant defense strategy.
Keywords	Plant uptake; Organic pollutant; Culture pattern; Biomass re-allocation; Allometric growth; Matrixmicrobiomes; organochlorine

Title	**Successful remediation of soils with mixed contamination of chromium and lindane: Integration of biological and physico-chemical strategies**
Author Name	Juan Daniel Aparicio, Rafael G.Lacalle, Unai Artetxe, Erik Urionabarrenetxea, José María Becerril, Marta Alejandra Polti, Carlos Garbisu, Manuel Soto
Journal Name	Environmental Research
Year	2021
Volume and Issue	194
Article No.	110666
Abstracts	Soils contaminated by organic and inorganic pollutants like Cr(VI) and lindane, is currently a main environmental challenge. Biological strategies, such as biostimulation, bioaugmentation, phytoremediation and vermiremediation, and nanoremediation with nanoscale zero-valent iron (nZVI) are promising approaches for polluted soil health recovery. The combination of different remediation strategies might be key to address this problem. For this reason, a greenhouse experiment was performed using soil without or with an organic amendment. Both soils were contaminated with lindane (15 mg kg^{-1}) and Cr(VI) (100 or 300 mg kg^{-1}). After one month of aging, the following treatments were applied: (i) combination of bioaugmentation (actinobacteria), phytoremediation (*Brassica napus*), and vermiremediation (*Eisenia fetida*), or (ii) nanoremediation with nZVI, or (iii) combination of biological treatments and nanoremediation. After 60 days, the wellness of plants and earthworms was assessed, also, soil health was evaluated through physico-chemical parameters and biological indicators. Cr(VI) was more toxic and decreased soil health, however, it was reduced to Cr(III) by the amendment and nZVI and, to a lesser extent, by the biological treatment. Lindane was more effectively degraded through bioremediation. In non-polluted soils, nZVI had strong deleterious effects on soil biota when combined with the organic matter, but this effect was reverted in soils with a high concentration of Cr(VI). Therefore, under our experimental conditions bioremediation might be the best for soils with a moderate concentration of Cr(VI) and organic matter. The application of nZVI in soils with a high content of organic matter should be avoided except for soils with very high concentrations of Cr(VI). According to our study, among the treatments tested, the combination of an organic amendment, biological treatment, and nZVI was shown to be the strategy of choice in soils with high concentrations of Cr(VI) and lindane, while for moderate levels of chromium, the organic amendment plus biological treatment is the most profitable treatment.
Keywords	Biostimulation; Bioaugmentation; Phytoremediation; Vermiremediation; nZVI, Ecotoxicity

Title	Bioremediation of lindane contaminated soil: Exploring the potential of actinobacterial strains
Author Name	Zeba Usmani, Maria Kulp, Tiit Lukk
Journal Name	Chemosphere
Year	2021
Volume and Issue	278
Article No.	130468
Abstracts	Lindane, an organochlorine pesticide, causes detrimental impacts on the environment and human health owing to its high toxicity, low degradation, and bioaccumulation. Its toxic nature can be overcome by biological and eco-friendly approaches involving its degradation and detoxification. The biodegradation of lindane was assessed using actinobacterial species *Thermobifida cellulosilytica* TB100 (*T. cellulosilytica*), *Thermobifida halotolerans* DSM 44931 (*T. halotolerans*) and *Streptomyces coelicolor* A3 (*S. coelicolor*). The degradation conditions of Lindane such as pH, temperature, inoculum volume, glucose concentration and number of days were optimized under broth conditions. Lindane degradation at different concentrations was studied in soil using reverse phase-high performance liquid chromatography over a 30 day period. A bioassay test was performed on seeds of Lactuca sativa (Lettuce) to assess the success of bioremediated soil. Maximum lindane degradation in soil was observed using *T. cellulosilytica* sp. The degradation trend for different concentrations of lindane using *T. halotolerans* in sterilized soil was 55 mg kg^{-1} (82%) > 155 mg kg^{-1} (75%) > 255 mg kg^{-1} (70%) after an incubation period of 30 days. Lindane degradation in soil followed the first order reaction kinetics. Phytotoxicity test on seeds of Lactuca sativa showed considerably good vigor index values for the bioremediated sterilized and non-sterilized soil by *T. cellulosilytica*, *T. halotolerans* and *S. coelicolor* in comparison to the contaminated soil without bacteria. This confirms that these actinobacterial species can be implemented in bioaugmentation of contaminated sites to efficiently remediate high lindane concentrations.
Keywords	Lindane; Actinobacteria; Bioremediation; Optimization; Soil; Phytotoxicity assay

Title	Lindane degradation in wet-dry cycling soil as affected by aging and microbial toxicity of biochar
Author Name	Anfei He, Zilan Zhang, Qi Yu, Kan Yang, G. Daniel Sheng
Journal Name	Chemosphere
Year	2021
Volume and Issue	219
Article No.	112374
Abstracts	This study determined the degradation of lindane in soil amended with biochar to evaluate the effects of biochar aging and microbial toxicity. Two biochars were prepared at 400 and 600 °C (BC_{400} and BC_{600}) and subjected to acid washing to remove nutrition (WBC_{400} and WBC_{600}). After 89 days of incubation under the alternate "wet–dry" conditions, scanning electron microscopy showed that acid washing rendered biochars especially susceptible to aging with structural collapse and fragmentation, with less surface covering. Aging impeded the release of toxic substances in BC_{400} and BC_{600} with reduced toxicity to degrading microorganisms. Lindane degradation was somewhat stimulated by biochar nutrition but mainly inhibited by adsorption. Acid washing facilitated the release of toxic substances and additionally reduced lindane degradation. The variations in fatty acid saturation degree (SFA/UFA) in soils confirmed the microbial toxicity of 5% WBC_{400} > 5% BC_{400} > 5% BC_{600} > 5% WBC_{600}. High-throughput DNA sequencing showed that biochar delayed the formation of dominant degrading microbial communities in soil. Lindane degradation was completed by joint *Sphingomonas*, *Flaviolibacter*, *Parasegetibacter*, *Azoarcus*, *Bacillus* and *Anaerolinaea*. These findings are helpful for better understanding the effect of biochar in soil on long-term degradation of persistent organic pollutants.
Keywords	Biochar; Soil; Lindane; Aging; Microbial community; Wet-dry cycling

Title	**Assessment of the *Streptomyces-plant* system to mitigate the impact of Cr(VI) and lindane in experimental soils**
Author Name	María Zoleica Simón Solá, Carolina Prado, Mariana Rosa, María Victoria Coll Aráoz, Claudia Susana Benimeli, Marta Alejandra Polti, Analia Alvarez
Journal Name	Environmental Science and Pollution Research
Year	2021
Volume and Issue	28
Pages	51217–51231
Abstracts	Phytoremediation techniques have been proposed as ecological methods to clean up contaminated sites. This study is aimed to evaluate the effect of the *Streptomyces sp*. Waksman & Henrici and *Zea mays L*. plant system on the dissipation of Cr(VI) and/or lindane from a co-contaminated soil, being 2 mg kg^{-1} of lindane and 150 mg kg^{-1} of chromium used. Lindane dissipation was improved in the presence of plant-microorganism association; however, Cr(VI) removal was higher when plants or the micro-organism were separately. In co-contaminated systems, chromium content in plant tissues was lower than metal content in plants grown only with Cr(VI), suggesting that lindane could interfere with metal accumulation in the plant. The high malondialdehyde (MDA) concentration detected in non-inoculated plants grown with chromium could be consequence of high metal concentration in plant tissues. Interestingly, plants inoculated with *Streptomyces sp*. Z38 growing with Cr(VI) showed decrease in MDA concentration, indicating that the bacterium could activate defense mechanisms in the plant. Also, inoculated plants showed the highest value of superoxide dismutase activity. Lettuce plants used as bioindicators grew better in biologically treated soils compared with lettuce grown on non-treated soil. The results presented in this work provide the basis that will allow the optimization of future trials on a larger scale.
Keywords	Chromium; Lindane; Phytoremediation; Actinobacteria; Mixed contamination; Soil

Title	**Development of artificial consortia of microalgae and bacteria for efficient biodegradation and detoxification of lindane**
Author Name	Moni Kumari, Pooja Ghosh , Swati, Indu Shekhar Thakur
Journal Name	Bioresource Technology Reports
Year	2020
Volume and Issue	10
Article No.	100415
Abstracts	Bacterial, algal and bacto-algal cultures were set up with 50 ppm lindane to study the degradation and detoxification potency of the strains. Several intermediate metabolites like pentachlorocyclohexenes, tetrachlorocyclohexenes, trichlorocyclohexane, dichlorocyclohexane, aliphatic chlorinated compounds, phenols were detected using GC–MS. It was observed that after 120 h, lindane was efficiently degraded after treatment with bacteria-algal culture. To assess the detoxification extent in different modes of lindane degradation, methyl tetrazolium (MTT) assay for cytotoxicity and 7-ethoxyresorufin-O-deethylase (EROD) assay for xenobiotics were determined using human hepato-carcinoma cell line HepG2. After 168 h treatment by bacto-algal co-culture, LC50 was increased by 1.89 folds and 3.1-fold decrease in EROD induction confirmed the reduction in toxicity. Integrated toxico-chemical analysis clearly indicated that the artificial bacterial and algal consortia could be considered as a prospective approach for degradation and detoxification of environments contaminated with lindane and other organochlorinated pesticides.
Keywords	Bacto-algal; Co-culture; Biodegradation; Detoxification; Dechlorination; MTT assay; EROD assay

Title	**Insights Into the Biodegradation of Lindane (γ-Hexachlorocyclohexane) Using a Microbial System**
Author Name	Wenping Zhang, Ziqiu Lin, Shimei Pang, Pankaj Bhatt, and Shaohua Chen
Journal Name	Frontiers in Microbiology
Year	2020
Volume and Issue	11
Article No.	522
Abstracts	Lindane (γ-hexachlorocyclohexane) is an organochlorine pesticide that has been widely used in agriculture over the last seven decades. The increasing residues of Lindane in soil and water environments are toxic to humans and other organisms. Large-scale applications and residual toxicity in the environment require urgent Lindane removal. Microbes, particularly Gram-negative bacteria, can transform Lindane into non-toxic and environmentally safe metabolites. Aerobic and anaerobic microorganisms follow different metabolic pathways to degrade lindane. A variety of enzymes participate in Lindane degradation pathways, including dehydrochlorinase (LinA), dehalogenase (LinB), dehydrogenase (LinC), and reductive dechlorinase (LinD). However, a limited number of reviews have been published regarding the biodegradation and bioremediation of lindane. This review summarizes the current knowledge regarding lindane-degrading microbes along with biodegradation mechanisms, metabolic pathways, and the microbial remediation of lindane-contaminated environments. The prospects of novel bioremediation technologies to provide insight between laboratory cultures and largescale applications are also discussed. This review provides a theoretical foundation and practical basis to use Lindane-degrading microorganisms for bioremediation.
Keywords	Lindane, biodegradation, metabolic pathway, mechanisms, bioremediation

Title	**Gentle remediation options for soil with mixed chromium (VI) and lindane pollution: biostimulation, bioaugmentation, phytoremediation and vermiremediation**
Author Name	Rafael G. Lacalle, Juan D. Aparicio, Unai Artetxe , Erik Urionabarrenetxea , Marta A. Polti, Manuel Soto , Carlos Garbisu, José M. Becerril
Journal Name	Heliyon
Year	2020
Volume and Issue	6 (8)
Article No.	e04550
Abstracts	Gentle Remediation Options (GROs), such as biostimulation, bioaugmentation, phytoremediation and vermiremediation, are cost-effective and environmentally-friendly solutions for soils simultaneously polluted with organic and inorganic compounds. This study assessed the individual and combined effectiveness of GROs in recovering the health of a soil artificially polluted with hexavalent chromium [Cr(VI)] and lindane. A greenhouse experiment was performed using organically-amended vs. non-amended mixed polluted soils. All soils received the following treatments: (i) no treatment; (ii) bioaugmentation with an actinobacteria consortium; (iii) vermiremediation with *Eisenia fetida*; (iv) phytoremediation with *Brassica napus*; (v) bioaugmentation + vermiremediation; (vi) bioaugmentation + phytoremediation; and (vii) bioaugmentation + vermiremediation + phytoremediation. Soil health recovery was determined based on Cr(VI) and lindane concentrations, microbial properties and toxicity bioassays with plants and worms. Cr(VI) pollution caused high toxicity, but some GROs were able to partly recover soil health: (i) the organic amendment decreased Cr(VI) concentrations, alleviating toxicity; (ii) the actinobacteria consortium was effective at removing both Cr(VI) and lindane; (iii) *B. napus* and *E. fetida* had a positive effect on the removal of pollutants and improved microbial properties. The combination of the organic amendment, *B. napus*, *E. fetida* and the actinobacteria consortium was the most effective strategy.
Keywords	Soil health; Actinobacteria; *Brassica napus*; *Eisenia fetida*; Organic amendment; Metal pollution; Ecotoxicity; Phytomanagement; Bioremediation; Ecological restoration; Soil biology; Soil chemistry Soil microbiology; Soil pollution; Environmental chemistry; Sustainable development; Environmental pollution; Chemistry; Microbiology; Environmental science

Title	**Bioremediation of lindane-contaminated soils by combining of bioaugmentation and biostimulation: Effective scaling-up from microcosms to mesocosms**
Author Name	Enzo E.Raimondo, Juliana M.Saez, Juan D.Aparicio, María S.Fuentes, Claudia S.Benimeli
Journal Name	Journal of Environmental Management
Year	2020
Volume and Issue	276
Article No.	111309
Abstracts	The scaling-up of lindane-contaminated soils bioremediation from microcosms to mesocosms bioaugmentated with an actinobacteria quadruple culture and biostimulated with sugarcane filter cake (SCFC) was surveyed. Mesocosms of silty loam soil, clayey soil, and sandy soil were polluted with the pesticide, bioaugmented with the mixed culture, biostimulated with adequate amounts of 0.5 mm SCFC particles, and assessed during 63 days maintaining environmental parameters with minimal intervention. Samples were taken to determine residual lindane, heterotrophic microorganisms, enzymatic activities, and bioremediation effectiveness using ecotoxicity tests with *Raphanus sativus*, *Lactuca sativa*, and *Lycopersicon esculentum*. The bioaugmentation and biostimulation of the three soils improved lindane removal, microbial counts, and enzymatic activities, and reduced pesticide T1/2, regarding the values obtained in non-bioremediated controls. The removal process was significantly affected by the soil type, and the highest pesticide dissipation (82.6%) was detected in bioremediated sandy soil. Ecotoxicity tests confirmed the bioremediation success through a rise in the vigor index of seedlings compared to non-treated soils (*R. sativus: 12–22%; L. sativa: 12–20%; L. esculentum: 30–45%*). Finally, scanning electron microscopy corroborated soil colonization by actinobacteria. Successful scaling-up of the combined application of an actinobacteria quadruple culture and SCFC as an appropriate strategy for restoring lindane-polluted soils at mesocosms-scale was confirmed.
Keywords	Bioremediation scaling-up; Lindane; Actinobacteria consortium; Sugarcane filter cake; Ecotoxicity tests

Title	**Enhanced bioremediation of lindane-contaminated soils through microbial bioaugmentation assisted by biostimulation with sugarcane filter cake**
Author Name	Enzo E.Raimondo, Juan D.Aparicio, Ana L.Bigliardo, María S.Fuentes, Claudia S.Benimeli
Journal Name	Ecotoxicology and Environmental Safety
Year	2020
Volume and Issue	190
Article No.	110143
Abstracts	Lindane is a toxic and persistent organochlorine pesticide, whose extensive use generated its accumulation in different environmental matrices. Bioremediation is a promising technology that can be used combining bioaugmentation and biostimulation processes to soil restoration. The aim of the present work was to determine the conditions of maximum lindane removal by bioaugmentation with an actinobacteria consortium and biostimulation with sugarcane filter cake (SCFC). The assays were carried out on lindane-contaminated silty loam (SLS), clayey (CS), and sandy (SS) soils. Through complete factorial designs, the effects of three abiotic factors (moisture content, proportion and size of SCFC particles) were evaluated on lindane removal. In addition, a response optimizer determined the optimal conditions for pesticide removal in bioaugmented and biostimulated soils, in the range of levels studied for each factor. In these conditions, bioaugmentation of biostimulated soils increased the pesticide removal (SLS: 61.4%, CS: 70.8%, SS: 86.3%), heterotrophic microbial counts, and soil enzymatic activities, and decreased lindane T1/2, regarding the non-bioaugmented biostimulated controls, after 14 days of assay. The values of these parameters confirmed the efficiency of the bioremediation process. Finally, the viability of the four strains was demonstrated at the end of the assay. The results indicate that the simultaneous application of bioaugmentation with the actinobacteria consortium and biostimulation with SCFC constitutes a promising tool for restoring soils contaminated with lindane, by using the optimal conditions obtained through the factorial designs.
Keywords	Lindane, Bioaugmentation, Actinobacteria, Biostimulation, Sugarcane filter cake

Title	**Assembly and variation of root-associated microbiota of rice during their vegetative growth phase with and without Lindane pollutant.**
Author Name	Jiayin Feng, Ashley E. Franks, Zhijiang Lu, Jianming Xu, Yan He
Journal Name	Soil Ecology Letters
Year	2020
Volume and Issue	3 (3)
Pages	207-219
Abstracts	Soil-derived micro biota associated with plant roots are conducive to plant growth and stress resistance. However, the spatio-temporal dynamics of micro biota in response to organochlorine pollution during the unstable vegetative growth phase of rice is not well understood. In this study, we focused on the rice (*Oryza sativa L.*) micro biota across the bulk soil, rhizosphere and endosphere compartments during the vegetative growth phase in two different soils with and without lindane pollutant. The results showed that the factors of growth time, soil types and rhizo-compartments had significant influence on the microbial communities of rice, while lindane mostly stimulated the construction of endosphere micro biota at the vegetative phase. Active rice root-soil-microbe interactions induced an inhibition effect on lindane removal at the later vegetative growth phase in rice-growth-dependent anaerobic condition, likely due to the root oxygen loss and microbial mediated co-occurring competitive electron-consuming redox processes in soils. Each rhizocompartment owned distinct microbial communities, and therefore, presented specific ecologically functional categories, while the moderate functional differences were also affected by plants species and residual pollution stress. This work revealed the underground micro-ecological process of micro biota and especially their potential linkage to the natural attenuation of residual organochlorine such as Lindane.
Keywords	Lindane pollutant; Rice (*Oryza sativa L.*); Root-associated micro biota; Root–microbe–soil interaction; Vegetative growth phase; Metagenome functions

Title	**Assembly of root-associated microbiomes of typical rice cultivars in response to lindane pollution**
Author Name	Jiayin Fenga, Yan Xua, Bin Ma, Caixian Tang, Philip C. Brookes, Yan He & Jianming Xu
Journal Name	Environment International
Year	2019
Volume and Issue	131, 104975
Abstracts	Organochlorine pesticides have been extensively used for many years to prevent insect diseases of rice (Oryza sativa L.), but little is known about their residual impacts on the underground micro-ecology in anaerobic environment. In this glasshouse study, we characterized the lindane effects on the assembly of root-associated microbiomes of commonly used indica, japonica and hybrid rice cultivars, and their feedback in turn, in modifying lindane anaerobic dissipation during 60 days' rice production. The results showed that rice growth inhibited the anaerobic dissipation of lindane, but was not affected apparently by lindane at initial spiked concentration of 4.62 and 18.54 mg kg−1 soil. Suppressed removal of lindane in rice planted treatments as compared with that in unplanted control was likely due to inhibited reductive dechlorination induced by a comprehensive effect of radial O2 secretion of rice root and co-occurring Fe (III) reduction that consumed electron competitively in rice rhizosphere. However, the hybrid cultivar exhibited a less suppression than the conventional cultivars in high polluted soils. Bacteria was more sensitively responded to lindane pollution than fungal taxa, and Actinobacteria, Chloroflexi, Verrucomicrobia and Proteobacteria were the main different phyla between hybrid and conventional cultivars, with a more stable community structure exhibited in the hybrid rice under lindane stress. Our study highlights the assembly and variation of root-associated microbiomes in responses of lindane pollution, and suggests that hybrid rice cultivar might be most competent for cultivation in paddy fields polluted by lindane and other organochlorine pesticides, especially in the area with high residual levels.
Keywords	Lindane; glasshouse; anaerobic; dechlorination; rhizosphere; microbiomes; organochlorine

Title	Testing different strategies for the remediation of soils polluted with lindane
Author Name	J.Vidal, M.Carvela, C.Saez, P.Cañizares, V.Navarro, R.Salazar, M.A.Rodrigo
Journal Name	Chemical Engineering Journal
Year	2019
Volume and Issue	381, 122674
Abstracts	This work attempts to clarify the remediation processes involved in the treatment of soil spiked with non-soluble species like lindane. To achieve this goal, the remediation of spiked soil is evaluated coupling electro-kinetic soil flushing (EKSF) with three types of permeable reactive barriers (PRB) which consist of soil merged with nanoparticles of ZVI (n-ZVI), granular particles of ZVI (m-ZVI) or granular activated carbon (GAC). Likewise, the effect of reverse polarity in EKSF will be assessed. Results show that, for a given electric field applied, the intensity reached depends on the size and materials of the reactive particles contained in the PRB and decreases in the sequence EKAB-EKmZVIB-EKnZVIB. Additionally, water content and pH and conductivity profiles between rows of electrodes are also affected by the presence of PRB, mainly because ZVI particles can behave as bipolar electrodes and, thus amend current lines and water flux. In terms of lindane mobilization, the differences are even more remarkable since iron particles promote lindane dehalogenation and activated carbon shows a very good adsorption capacity for lindane. After 720 h of operation, the percentage of lindane extracted is below 2% in all EK-strategies while the percentage retained in soil depends on the strategy used: REKSF seems to prevent lindane removal while EKSF and EKAB lead to higher removal. Results are significant for the design of full-scale applications for the remediation of soils polluted with non-soluble species.
Keywords	Soil remediation; Electrokinetic soil flushing; Permeable reactive barriers; Lindane

Title	**Lindane Bioremediation in Soils of Different Textural Classes by an Actinobacteria Consortium**
Author Name	Enzo E. Raimondo, Juan D. Aparicio, Gabriela E. Briceño, María S. Fuentes, Claudia S. Benimeli
Journal Name	Journal of Soil Science and Plant Nutrition
Year	2019
Volume and Issue	19, 1
Pages	29-41
Abstracts	Lindane is a highly chlorinated and recalcitrant insecticide, capable to accumulate in soil and groundwater. Despite lindane has been banned in many countries, numerous sites still remain contaminated. The present work studies the bioremediation of soils of different textures contaminated with lindane by bioaugmentation with a quadruple Streptomyces consortium. In the three evaluated soils, silty loam soil (SLS), sandy soil (SS), and clayey soil (CS), heterotrophic microbial populations increased during the 14 days of the assay and CFU counts were higher in bioaugmented than in non-bioaugmented soils. Lindane removal was detected in all contaminated treatments, with higher removal percentages in the bioaugmented microcosms (SS 70.3%, SLS 36.3%, and CS 30.7%), than in non-bioaugmented ones (SS 40.4%, SLS 9.3%, and CS 12.2%). The pesticide half-life decreased by 77.3, 50.3, and 10.7 days, in bioaugmented SLS, CS, and SS, respectively. Lindane had an inhibitory effect on soil enzyme activities such as dehydrogenase, fluorescein diacetate hydrolysis, acid and alkaline phosphatases and increased the catalase activity, in non-bioaugmented controls; however, no effect on urease activity was observed. Bioaugmentation of soil microcosms with actinobacteria increased all enzymatic activities. Finally, the survival of the four strains of the consortium was demonstrated at the end of the bioremediation assay. Bioremediation using the Streptomyces sp. A2-A5-A11-M7 consortium represents a promising tool to restore different types of soils contaminated with organochlorine pesticides.
Keywords	Pesticide; Streptomyces consortium; Bioaugmentation; Soils Enzymes

Title	**Perspectives of lindane (γ-hexachlorocyclohexane) biodegradation from the environment: a review**
Author Name	Dharmender Kumar and Rochika Pannu
Journal Name	Bioresources and Bioprocessing
Year	2018
Volume and Issue	5:29
Abstracts	This review describes the biodegradation of Lindane *(γ-hexachlorocyclohexane*, γ-HCH) from the diverse sources. Environmental degradation of γ-HCH has been described in terms of integrated biological approaches such as *metagenomics*, cloning, *phytoremediation*, *nanobiodegradation*, and *biosrfactants*, genes and enzymes responsible for γ-HCH degradation and exploration of new strains of γ-HCH-degrading microbes from different environmental sources. *Metagenomics-based* approaches help in the identification and isolation of new genes from the uncultivable sources and provide insights for future research. There is potential in the elucidation of pathways of degradation of persistent organic pollutants (POPs) from environment by the microorganisms. This is possible by means of new/improved microbial species. The *behavior* of isolated strains and the microorganisms when present in community is altogether different. Therefore, there is a need to develop new technology which will identify the minor component of the microbial community involved in degradation because the minor part might have profound effect on degradation. This is mediated by the biological activity of the microbial system.
Keywords	Microbial degradation; Metagenomics; Phytoremediation; Microbial Community; Lindane (γ-hexachlorocyclohexane, γ-HCH)

Title	**Lindane dissipation in a biomixture: Effect of soil properties and bioaugmentation**
Author Name	Juliana M.Saez, Ana L.Bigliardo, EnzoE.Raimondo, Gabriela E.Briceño, Marta A.Polti&Claudia S.Benimeliae
Journal Name	Ecotoxicology and Environmental Safety
Year	2018
Volume and Issue	Volume 156
Pages	97-105
Abstracts	The *biomixture* is the major constituent of a *biopurification* system and one of the most important factors in its efficiency; hence the selection of the components is crucial to ensure the efficient pesticides removal. Besides, *bioaugmentation* is an interesting approach for the optimization of these systems. A mixed culture of the fungus *Trametesversicolor* SGNG1 and the *actinobacteria Streptomyces* sp. A2, A5, A11, and M7, was designed to inoculate the *biomixtures*, based on previously demonstrated *ligninolytic* and pesticide-degrading activities and the absence of antagonism among the strains. The presence of *lindane* and/or the *inoculum* in the *biomixtures* had no significant effect on the development of *culturable* microorganisms regardless the soil type. The consortium improved *lindane* dissipation achieving 81–87% of removal at 66 d of incubation in the different *biomixtures*, decreasing *lindane* half-life to an average of 24 d, i.e. 6-fold less than t1/2 of *lindane* in soils. However, after recontamination, only the *bioaugmentedbiomixture* of *silty* loam soil enhanced *lindane* dissipation and decreased the t1/2 compared to *non-bioaugmented*. The *biomixture* formulated with silty loam soil, sugarcane *bagasse*, and peat, inoculated with a *fungal-actinobacterial* consortium, could be appropriate for the treatment of *agroindustrial* effluents contaminated with *organochlorine* pesticides in *biopurification* systems.
Keywords	Biomixture; Pesticides; Bioaugmentation; Biopurification system; Actinobacteria; Fungi

Title	**Microbial-enhanced lindane removal by sugarcane (Saccharumofficinarum) in doped soil-applications in phytoremediation and bioaugmentation**
Author Name	Jaseetha Abdul Salam, Mohammed A.A.Hatha&Nilanjana Das
Journal Name	Journal of Environmental Management
Year	2017
Volume and Issue	193
Pages	Pages 394-399
Abstracts	The aim of this study was to examine the effect of *lindane*-degrading yeast on the growth and lindane uptake by *Saccharum* sp., in doped garden soils. The rhizosphere of *Saccharum* plant was amended with yeast Candida VITJzN04 by root-inoculation. The bio-augment yeast was applied in two different forms viz., *planktonic* form and cells immobilized on sugarcane-bagasse, in the pot experiments. Garden soils (lindane∼100 mg/kg) exposed to various treatments were monitored for a period of 30 days, for residual *lindane* by gas-chromatography analysis. The *lindane*-removal rates in soil were expressed in terms of half-life period and were recorded as 13.3 days (yeast), 43.3 days (*Saccharum)*, 9.8 days (free yeast-plant) and 7.1 days (immobilized yeast-plant). Additionally, Candida sp., was also identified as a plant growth promoting yeast due to its ability to produce growth hormone and *solubilize* insoluble phosphates in the soil for better uptake by the plant species. Bio-stimulation of the soil with yeast immobilized on sugarcane *bagasse* further enhanced the total yeast activity in the soil which in turn had a positive influence on *lindane*-removal. Combined treatment with *bagasse* immobilized yeast and plant showed the best *lindane* degradation. Results suggested that the synergistic activity of plant and yeast resulted in fast and efficient degradation of *lindane*. Thus, it can be concluded that *Saccharum* plant in combination with Candida VITJzN04 is an effective alternative for the conventional remediation strategies.
Keywords	Bioaugmentation; Candida VITJzN04; Immobilization; Lindane; Phytoremediation; Saccharum sp.

Title	**Targeting of detoxification potential of microorganisms and plants for cleaning environment polluted by organochlorine pesticides**
Author Name	M.V.Kurashvili, G.S.Adamia, L.L.Amiranashvili, T.I.Ananiasvili, T.G.Varazi, M.V.Pruidze, M.S.Gordeziani&G.A.Khatisashvili
Journal Name	Annals of Agrarian Science
Year	2016
Volume and Issue	14,3
Pages	222-226
Abstracts	The goal of presented work is the development phytoremediation method targeted to cleaning environment polluted with organochlorine pesticides, based on joint application of specially selected plants and microorganisms. Initial degradation of pesticides carry out by microorganisms; the forming dehalogenated products easily uptake by the plants and undergo oxidative degradation via plant detoxification enzymes. This approach can complete degradation of toxicants and their mineralization into nontoxic compounds. In the presented work the results of using selected strains from genera Pseudomonas and plants phytoremediators in the model experiments are given. It has been shown that the using developed technological approach effectively decreased degree of pollution in artificially polluted soil samples.
Keywords	Detoxifidation potential; Organochlorine pesticides; Persistent organic; Pollutants; Phytoremediation technologies; Microorganisms

Title	**Is *Vigna radiata (L.) R. Wilczek* a suitable crop for Lindane contaminated soil?**
Author Name	Vishal Tripathi, Rama Kant Dubey, H.B. Singh, Nandita Singh, P.C. Abhilash
Journal Name	Ecological Engineering
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Abstracts	Lindane (γ-hexachlorocyclohexane) is an organochlorine pesticide recently included in the Stockholm list of persistent organic pollutants for global elimination. However, India is still allowed to use Lindane for combating vector borne diseases. Because of its large scale utilization during the last few decades, Lindane residue is reported from almost all agricultural soils of India. So there is an immediate need to monitor the accumulation of Lindane residue in crop plants growing in contaminated systems and suitable strategies should be taken to prevent the possible entry of Lindane in food chain. Therefore, in the present study, we studied the accumulation and translocation of Lindane in *Vigna radiata (L.) R. Wilczek* (Mung bean), a widely grown legume in India as a cheap source of protein. The test plant was grown in four different concentrations of Lindane viz. 5, 10, 15 and 20 μg g^{-1} soils and harvested at 15 and 45 days and at maturity. The experimental results showed that irrespective of the exposure days, the accumulation of Lindane in plant parts were linearly correlated (r2 = 0.915) with the Lindane concentration in soil. However, the Lindane concentration in soil significantly reduced the growth and yield (number of pods, pod length, number of seeds and seed weight) of the test plants at 95% confidence level (α = 5). At maturity, the concentration of Lindane in whole plant (root + shoot + leaf + seed) growing at four different concentrations were reached up to 3.8, 9.4, 13.5 and 17.79 μg g^{-1} dry matter, respectively. Worryingly, Lindane residue was found in the seeds of test plants grown at 10, 15 and 20 μg g^{-1} soils and the concentrations were detected as 0.2, 0.4 and 0.89 μg g^{-1} dry seed, respectively. Most importantly, the residue level detected in the edible part was higher than the maximum residue limit set by WHO and Codex Alimentarious Commission (0.1 μg g^{-1}). Thus our study suggests that Mung bean is not a suitable crop for medium to high level Lindane contaminated soil.
Keywords	Persistent organic pollutants; Organochlorine pesticide; Lindane; *Vigna radiata (L.) R. Wilczek*; Phytoaccumulation; Maximum residue limit

Title	**Phytoextraction and dissipation of Lindane by *Spinacia oleracea L.***
Author Name	Rama Kant Dubey, Vishal Tripathi, Nandita Singh, P.C. Abhilash
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Abstracts	Remediation and management of organochlorine pesticide (OCPs) contaminated soil is becoming a global priority as they are listed in the Stockholm list of persistent organic pollutants (POPs) for global elimination. Lindane is a OCPs candidate recently included in the Stockholm list. However, India has an exemption to produce Lindane for malaria control. Because of its widespread use during the last few decades, Lindane contaminated soils are found in almost all parts of India. Since phytoremediation is widely acknowledged as an innovative strategy for the clean-up of contaminated soils; the present study was aimed to evaluate the phytoextraction and dissipation of Lindane by a leafy vegetable *Spinacia oleracea L* (Spinach). The test plant was grown in different concentrations of Lindane (5, 10, 15 and 20 mg kg^{-1}) and harvested at 10, 30 and 45 days. At 45 days, the concentrations of Lindane in root and leaf of Spinach growing in four different concentrations were reached up to 3.5, 5.4, 7.6 and 12.3 mg kg^{-1} and 1.8, 2.2, 3 and 4.9 mg kg^{-1}, respectively. There was a significant difference ($p<0.01$) in the dissipation of Lindane in vegetated and non-vegetated soil. Moreover, the residual Lindane in four experiments was reduced to 81, 76, 69 and 61 percent, respectively. The experimental results indicate that Spinach can be used for the phytoremediation of Lindane. However, more studies are required to prevent the toxicity of harvested parts.
Keywords	Persistent organic pollutants; Organochlorine pesticide; Lindane; *Vigna radiata (L.) R. Wilczek*; Phytoaccumulation; Maximum residue limit