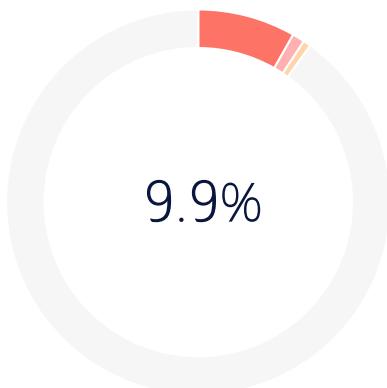


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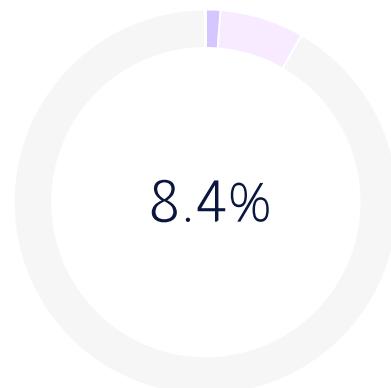
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Technical Details for Full ARG Proposal titled “Assessment of Phytoremediation potential of grass species growing in Smart cities of Punjab: improvement using earthworm and biochar assistance”

Principal Investigator: Dr. Sandip Singh Assistant Professor (Environmental Sciences) Department of Chemistry, Lovely Professional University, Phagwara, Punjab

Co- Investigator: Dr. Jaswinder Singh Associate Professor, Department of Zoology, Khalsa College, Amritsar, Punjab

Co- Investigator: Dr. Ashok Kumar Assistant Professor Department of Botany, Central University of Jammu, Jammu

1. Origin of the Proposal:

Metal(loid) contamination of soils represents a critical environmental threat globally, particularly in India due to extensive agricultural, industrial, and urban activities. Punjab faces severe contamination, especially in Smart Cities—Amritsar, Jalandhar, and Ludhiana—with Ludhiana experiencing maximum pollution as Punjab's industrial hub. Traditional physical and chemical remediation methods for soils (surface capping, soil washing, electrokinetic extraction, vitrification) are costly and unsustainable. But, Phytoremediation is a method which involves uptake and accumulation of metal(loid)s in different parts of plants and considered as the most sustainable method of remediation. Although, phytoremediation offers eco-friendly alternatives, the current approaches using crop and tree species for phytoremediation have significant drawbacks including lengthy remediation periods, intensive care requirements, and potential financial losses when edible crops become unsuitable for consumption due to metal accumulation.

This research addresses critical knowledge gaps by investigating indigenous grass species (Poaceae family) for phytoremediation in contaminated urban soils of Punjab. Grasses offer unique advantages: ubiquitous presence, rapid growth, high biomass production, and resistance to environmental stress. Being non-edible, they eliminate consumption risks and financial concerns associated with crop-based phytoremediation. The current study will focus on Amritsar and Jalandhar, evaluating grass species' phytoremediation potential both independently and in combination with rice husk biochar and vermicomposting technologies. This integrated approach represents novel research in India, where these three sustainable methods have rarely been studied collectively.

This research will identify optimal indigenous grass species for urban soil remediation while establishing enhanced remediation protocols through biochar and vermicomposting integration. The findings will contribute substantially to sustainable remediation technologies, offering cost-effective, environmentally friendly solutions for metal(loid)-contaminated soils in urban environments, particularly relevant for Smart City initiatives addressing industrial and urban pollution challenges. The project will also be helpful in achievement of SDGs 11 (Sustainable Cities and Communities) and 13 (Climate Action).

Aims/Objectives of the work:

- Monitoring of metal(loid) contaminated areas of Amritsar and Jalandhar (in the vicinity of industries, roadsides, solid waste dumpsites

etc.) to collect soil and native grass samples.

- Analysis of metal(loid)s in soil and grass samples to identify the species having high phytoremediation potential.
- Evaluation of the potential of rice husk biochar and vermicomposting to enhance the phytoremediation capacity of selected grass species in two modes of laboratory experimentation i.e. separately and in combination.

2. Review of status of Research and Development in the subject

2.1. International Status:

Although a lot of research had been carried out in the field of phytoremediation of metal(loid)s in the past and multiple review papers have also been published regarding the concept, application and developments in the field of phytoremediation (Sharma et al., 2023). But majority of the research work focused on use of food, fodder and commercially important plant species. These plant species require significant economic investment in the form of agrochemicals, irrigation and dedicated labor force. And accumulation of excessive metals in these traditional plant species lowers their quality and can ultimately cause financial losses. Therefore, now the focus is on using non-commercial plant species such as grasses for phytoremediation. The research work in this regard is in initial stages and following review focuses on the use of grass species for phytoremediation in different parts of world other than India.

Albornoz et al. (2016) analyzed Pb and Zn phytoaccumulation potential of two grass species i.e.

Festuca arundinacea and

Cynodon dactylon growing in naturally developed (*in situ*) and experimentally contaminated (*ex situ*) soils in Tandil city, Argentina. They observed that both the species had high remediation potential of Pb with Bioaccumulation values reaching upto 0.72.

Soils contaminated with Cr (VI) at different concentrations (with and without Ethylene diamine tetra acetic acid (EDTA) (4 mM) chelation) were treated with hybrid Napier grass (

Pennisetum americanus L. ×

Pennisetum purpureum Schumach) for analysis of its phytoremediation potential by Ram et al. (2019). With bioaccumulation factor > 1, the study indicated that hybrid napier grass is a potential source for phytoremediation. In this study, superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activities indicated that napier grass exhibited strong resistance at highest Cr (VI) concentration.

The arsenic (As) phytoaccumulation potential of two grass species i.e.

Holcus lanatus and

Agrostis capillaris was analyzed by Dradach et al. (2020) in former As mining sites of Sudetes, Poland. First a field study was conducted to determine the grass species with high As accumulation capacity. Among the different grass species, the above mentioned species were selected for greenhouse experimentation. In greenhouse experimentation, the grass species were exposed to different concentrations (394-19,600 mg/kg, untreated and fertilized). The results indicated that these plant species were unable to grow at high As concentration in soil without fertilization. But, with fertilization, these grass species showed significant improvement in their As uptake potential.

Vetiver grass (

Chrysopogon zizanioides) was analyzed for its Cr and Ni phyto-accumulation potential in a treatment based (50, 150, and 300 ppm concentrations in soils) experimentation by Chintani et al. (2021). The results revealed that *C. zizanioides* showed better phytoremediation potential for Cr in comparison to Ni with above for in several treatments translocation factor (TF) bioconcentration factor (BCF), biological absorption coefficient (BAC), and values.

Rolka et al. (2023) investigated the heavy metal phytoremediation potential of *Calamagrostis acutiflora*, an ornamental grass growing along streets of Olsztyn, Poland. The metals analyzed were Fe, Mn, Zn, Cu, Pb, Cd, Ni, Cr and Co. The results of the study indicated that *C. acutiflora* showed biological accumulation coefficient (BAC) in the range of 1.117–3.631, thus proving the grass species as an efficient candidate for phytoremediation. Table 1 shows other studies in which phytoremediation potential of grass species were analyzed to remove metal(lloid)s by researchers in recent years.

Table 1. Summary of research studies which analyzed phytoremediation potential of grass species for metal(lloid)s in soils

Grass species	Country	Type of study	Metal(lloid)s analyzed	References
Switchgrass (<i>Panicum virgatum</i>) and Timothy grass (<i>Phleum pretense</i>)	USA	Treatment based study	(50, 80, 120, 200, or 500 mg Pb/kg of soil)	Pb Balsamo et al. (2015)
<i>Sporobolus virginicus</i>	Australia	Field based study on industrially contaminated sediments	Zn, Cu, Pb, Cd and Se	Tran et al. (2020)
Bermuda grass (<i>Cynodon dactylon</i> (L.) pers.)	China	Pot based experimentation in combination with PAHs	Cd	Song et al. (2022)
Barnyard grass (<i>Echinochloa crusgalli</i> L.)	Bangladesh	Pot based experimentation on industrially contaminated soils	As, Pb, Cr, Fe, and Mn	Sultana et al. (2022)
<i>Megathyrsus maximus</i> , <i>Urochloa brizantha</i> and <i>Urochloa decumbens</i>	Brazil	Treatment based greenhouse study	(0, 45, 90 and 270 mg kg ⁻¹)	Pb Farnezi et al. (2023)
<i>Pennisetum purpureum</i> (elephant grass), <i>Brachiaria decumbens</i> (brachiaria grass), <i>Vetiveria zizanioides</i> (vetiver)	Brazil	Field study in case of elephant and brachiaria grass; Treatment based study for vetiver grass (soils collected from contaminated sites)	Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Pb, Co, Cu, Cr, Sn, Sr, Fe, P, Li, Mg, Mn, Hg, Mo, Ni, K, Ag, Se, Na, Tl, Ti, U, V, Zn	Morita et al. (2023)
<i>Poa pratensis</i> , <i>Lolium perenne</i> , <i>Festuca rubra</i> , <i>Festuca pratensis</i> , <i>Deschampsia caespitosa</i>	Poland	Pot based experimentation on industrially contaminated soils	Zn	Korzeniowska and Stanislawska-Glubiak, 2023

The review of literature suggests that the analysis of phytoremediation potential of grass species is an emerging research field. Main focus till now is on some famous grass species such as vetiver grass and napier grass. But now globally, researchers are trying to focus on other indigenous grass species for their phytoremediation potential. Overall grass species are emerging as effective instruments for phytoremediation of existing and emerging contaminants.

2.2. National Status:

In India, significant amount of work has been done on phytoremediation potential of food and fodder crops, ornamental plants, tree species, herbs and shrubs, weeds etc. in last two decades. But, most of this work focused on economically important plant species. These species require significant economic and labor investment. And once the contaminant is accumulated in the aerial parts of these plant

species, it renders them as waste which can cause economic loss. Also in case of tree species the time taken for effective phytoremediation is very long (2-4 years). So now focus is shifting to fast growing, high biomass and economically viable plant species for phytoremediation. In this regard, grasses can act as a viable option. But, till now research on phytoremediation potential of native Indian grass species has still been in preliminary stage. Very few research reports are available regarding phytoremediation potential of grasses in India for which summary is presented below.

Kumar and Maiti (2015) analyzed the phytoremediation potential of two aromatic grass species i.e.

Cymbopogon citratus and

Chrysopogon zizanioides to remove metal(loid)s from mining waste collected from Roro hills, West Singhbhum, Jharkhand. For analysis they amended the mine waste with different proportions of chicken manure, farmyard manure and garden soil. Analysis of metal(loid)s (Cr, Ni, Mn, Zn, Co, Cu, Pb and Cd) accumulation in these grass species indicated that the amendments enhanced the phytoremediation capability of both grass species, especially for Cr and Ni.

In addition to food crops and tree species, two grass species (

Cynodon dactylon and

Sorghastrum nutans) were analyzed by Kumar et al. (2017) for their heavy metal (Cr, Ni, Zn, Mn, Co, Cu, Pb and Cd) accumulation potential in a monitoring study in chromite-asbestos mining area of Roro region, Chaibasa, Jharkhand. The analysis revealed that both *C. dactylon* and

S. nutans acted as excellent accumulators of Cr and Ni with above 1 Translocation Factor (TF) values.

Chandra et al. (2018) carried out a monitoring study to analyze the heavy metal phytoremediation potential of weed and grass species growing in distillery sludge contaminated soils of Unnao, Uttar Pradesh. The grass species analyzed were

Saccharum munja (munja),

Cynodon dactylon (Bermuda grass), and

Pennisetum purpureum (elephant grass), while the metals tested were Fe, Zn, Cu, Mn, Ni, and Pb. The researchers observed that the grass species exhibited excellent metal accumulation potential with > 1 values of bioaccumulation coefficient factor (BCF) and translocation factor (TF). Thus, it was concluded that these native grass species can act as efficient remediation tools for heavy metal contaminated soils.

In addition to the above mentioned studies, few other researchers carried out phytoremediation studies on grass species in India including Banerjee et al. (2018) on

Chrysopogon zizanioides (L.) Roberty (vetiver grass), Iyer et al. (2022) on

Cynodon sp., Kumar and Fulekar (2022) on Deenanath grass (

Pennisetum pedicellatum), Sinduja et al. (2023) on Cumbu Napier hybrid grass. But, still there is huge paucity of research work on phytoremediation potential of native grass species growing in varying contaminated conditions.

2.3 Importance of the proposed project in the context of current status

In the current scenario of excessive contamination of terrestrial ecosystems due to multitude of anthropogenic activities, finding low cost sustainable remedial solutions is a necessity. Several, physical and chemical methods for remediation have been applied by researchers in the past, but they are high cost and unsustainable processes. Phytoremediation on the other hand provides a low cost, green and sustainable solution for removal of contaminants from polluted soils. And now, in case of phytoremediation the focus is on fast growing,

high biomass and low cost plant species. In this regard, grasses can act as ideal candidates. In last few years, researchers have started analyzing the phytoremediation potential of grasses around the globe as shown in Section 2.1. In India also, some of the research focus has shifted from traditional crops to grasses for their phytoremediation potential. But, this work is in preliminary stage. And, in case if Punjab, negligible reports are available regrading phytoremediation potential of native grass species. Punjab is among the better performing states on economic front. In addition to agriculture, industry and tourism are also main pillars of economy of Punjab. But, these economic activities also lead to severe contamination of soils of Punjab. The situation is worse in the three cities (Amritsar, Jalandhar and Ludhiana) designated under smart city project of government of India. Although, several reports are available regarding phytoremediation potential of different food and fodder species. But, there are negligible research reports on phytoremediation potential of grass species for heavy metal contaminated soils of Punjab. Considering this, the present research study was planned to analyze the phytoremediation potential of native grass species growing in Amritsar and Jalandhar to decontaminate metal(loid)s contaminated soils. This research study can help to identify best performing native grass species which can be used for phytoremediation of the contaminated sites in urban and rural areas. Since grass species ubiquitously grow without any nutritional aid, this work would be very beneficial for designing low cost, sustainable and green strategy to decontaminate out urban terrestrial ecosystems.

2.4. If the project is location specific, basis for selection of location be highlighted:

Yes, this work would be location specific. The main locations of this work would be urban areas of Amritsar and Jalandhar, Punjab (two cities under smart city project of Government of India). These two cities are selected because a lot of economic activity happens in these two cities. Amritsar is one of the most famous tourist sites of India because of religious and historical landmarks such as Harmandir Sahib, Jaliawala Bagh, Durgiana mandir, Wagha Border etc. In addition to that, significant industrial establishments (food, textile, dairy) are also located in Amritsar. Jalandhar on the other hand is one of the economic hubs of Punjab, with significant industrial activity including leather tanning, textile, sports goods, distillery etc. In cases of both Amritsar and Jalandhar soil environments get contaminated with metal(loid)s due to agricultural, traffic and industrial inputs and it is necessary to find sustainable remedial solution for decontamination these soils in order to achieve the targets of sustainable city project of government of India.

3. Work Plan

3.1. Methodology of the work:

The proposed research work would be carried out in following steps:

3.1.1. Collection of soils and grass species from contaminated areas

The metal(loid) accumulation potential of native grass species growing in contaminated sites of Amritsar and Jalandhar would be analyzed by carrying out monitoring studies in contaminate areas (roadsides, industrial areas, solid waste dumpsites etc.) in first part of the project. Fig. 1 presents the study area. Samples of grass plants growing in contaminated sites will be collected with soil samples of those contaminated areas.

Fig. 1. Map to the study area (district Amritsar and Jalandhar)

3.1.2. Analysis of metal(lloid) contents in soil and grass samples

The collected soil and grass plants samples would be acid digested in Laboratory fume hood using aqua regia ((HNO₃: HCl in 3:1 ratio) and triacid mixture (HNO₃:H₂SO₄:HClO₄ in 5:1:1 ratio) by method of Allen et al. (1986). Different metal(lloid)s would be analyzed in soil and grass samples using techniques such as ICPMS and AAS and grass species having maximum metal(lloid) accumulation potential would be determined by using equations such as Bioaccumulation factor (BCF) and Translocation factor (TF).

Bioaccumulation factor (BAF):

Bioaccumulation Factor (BAF) is a ratio of metal(lloid) concentration in plant tissue to soil (Ali et al., 2013):

$$\text{BAF} = \text{C}_{\text{plant tissue}} / \text{C}_{\text{soil}} \quad (1)$$

where C_{plant tissue} and C_{soil} are the concentrations of metal(lloid) in plant tissues (roots, stems and leaves) and soil, respectively, on a dry weight basis.

Translocation factor (TF):

Translocation Factor (TF) is the ability of a plant to move the accumulated heavy metal from roots to above ground tissues (stems, leaves and inflorescences) (Ali et al., 2013):

$$\text{TF} = \text{C}_{\text{stem/leaves}} / \text{C}_{\text{roots}} \quad (2)$$

$$\text{TF} = \text{C}_{\text{leaves}} / \text{C}_{\text{stem}} \quad (3)$$

where Cleaves, Cstem and Croots are the concentrations of the metal(lloid) in plant leaves, stem and roots, respectively on a dry weight basis.

3.1.3. Biochar formation

Simple biochar would be formed by pyrolysis of organic wastes (mainly rice husk) for using in the study.

3.1.4. Pot experimentation setup

In first set up, the three grass species determined in the preliminary study having maximum metal(lloid) accumulation potential would be grown in pots/fields having metal(lloid) (As, Cd, Cr, Ni and Pb salts at different concentrations for different periods of times) spiked soils for determination of their phytoremediation potential. In second setup, pots having metal(lloid) spiked soils would be amended with biochar (at varying concentrations) and earthworms (

Eisenia fetida) in separate treatments for assessment of their remediation potential. The third setup would include grass plants grown in pots/fields having metal(lloid) spiked soils with amendment of biochar (at varying concentrations) and earthworms to determine their

potential to enhance phytoremediation of grass species.

3.1.5. Metal(lloid)

Amelioration potential analysis grasses with amendments

Metal(lloid) contents would be analyzed in soils pre and post treatments with grasses+biochar, grasses+earthworm and grasses+biochar+earthworm determine the remediation potential. Metal(lloid) contents would be analyzed in soils and plant parts at different times for 15-30 days to analyze the phytoremediation potential of grasses under different treatments.

3.2 Time Schedule of activities giving milestones through BAR diagram.

1st financial Year

- Purchase of equipment, necessary chemicals and glassware.
- Appointment of Junior Research Fellow (JRF)
- Identification of contaminated sites for sampling in the two cities
- Collection of soil and grass samples from the contaminated sites.
- Analysis of soil for physico-chemical characteristics and metal(lloid)s.
- Estimation of metal(lloid)s in grass samples grown and identification of best performing grass species.

2nd financial year

- Standardization of protocol for rice husk biochar for determining optimal conditions for its application in metal(lloid) removal.
- Carrying out pot based experimentation to analyze the maximum metal(lloid) accumulation potential of selected grass species alone and in combination of biochar and earthworms.

3rd financial year

- Continuation of the pot based experimentation
- Compilation of data.
- Publications of research articles

- Preparation of final report

Plan of work and targets to achieve

First financial year 1 2 3 4 5 6 7 8 9 10 11 12

Purchase of equipment, chemicals and glassware.

Appointment of Staff (JRF & TA)

Identification of contaminated sites for sampling in the two cities

Collection of soil and grass samples from the contaminated sites

Analysis of soil for physico-chemical characteristics and metal(lloid)s

Estimation of metal(lloid)s in grass samples and identification of best performing species

Second financial year

Standardization of protocol for rice husk biochar for determining optimal conditions for its application in metal(lloid) removal.

Carrying out pot based experimentation to analyze the maximum metal(lloid) accumulation potential of selected grass species alone and in combination of biochar and earthworms.

Third financial year

Continuation of the pot based experimentation

Compilation of data

Publications of research articles

Preparation of final report

3.3 Suggested Plan of action for utilization of research outcome expected from the project

This research project has been designed to identify the best performing native grass species of Punjab for phytoremediation of metal(lloid) contaminated soils of urban areas which are contaminated due to various anthropogenic activities. The research work also focuses on performance of these grass species in combination with physical (biochar) and biological (earthworm) amendments in order to enhance their phytoremediation potential. The research data from this project can provide valuable information about the possible metal(lloid) hyper-accumulator native grass species which can be grown in contaminated soils of Punjab and other parts of India for their decontamination. Therefore, this project can provide a low cost, low maintenance, sustainable and green solution for our soil pollution with metal(lloid)s and the results can be beneficial for following departments of the state:

- Pollution control

- Urban development

- Health

- Agriculture

· Academics and Research Institutes

· For general public awareness

3.4 Environmental impact assessment and risk analysis

The present research work focuses on determining the native grass species which can accumulate metal(loid)s from contaminated soils of urban areas of Punjab and effects of physical and biological amendments for their performance enhancement. The results of this project would be very beneficial for pollution control, urban development and agriculture departments, since soil pollution is a critical issue for Punjab and finding a sustainable, low cost solution is a necessity. In phytoremediation, the plants have the capability to absorb large quantities of metal(loid)s and accumulate in different body parts in non-toxic forms. The metal(loid)s accumulated can be acquired back for commercial purposes by phyto-mining which can help the economy of the state. The results of this study can also guide other states to adopt local, low maintenance plant species (such as grasses) as effective tools for remediation of the contaminated soils.

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4. Expertise:

4.1 Expertise available with the investigators in executing the project

The present research work has the trans-disciplinary relevance because it is framed to utilize the expertise of investigators from different disciplines viz., Environmental Sciences, Botany and Zoology. All investigators will be working jointly towards creating translational innovations that can integrate to address a common problem like soil pollution and its sustainable remediation using grasses. Dr. Sandip Singh (PI) has the expertise in the field of Environmental monitoring and phytoremediation while Dr. Jaswinder Singh (Co-PI) has the expertise in vermicoremediation and solid waste management, and Dr. Ashok Kumar (Co-PI) has the expertise in plant taxonomy and metabolism.

4.2 Summary of roles/responsibilities for all Investigators:

S.No. Name of the Investigators Roles/Responsibilities

1. Dr. Sandip Singh (PI) (i) Identification of contaminated sites (ii) Collection of soil and grass samples (iii) Biochar formation and amendment analysis (iv) Analysis of metal(lloid) contents in soil and grass samples (iv) Compilation of data and report formation
2. Dr. Jaswinder Singh (Co-PI) (i) Collection of soil and grass samples (ii) Analysis of earthworm assisted remediation (iii) Analysis of metal(lloid) contents in soil and grass samples
3. Dr. Ashok Kumar (Co-PI) (i) Identification of grass plant species (ii) Analysis of key plant parameters involved in phytoremediation (iii) Assistance in pot based experimental study

4.3. Key Publications by investigators:

Principal Investigator: Dr. Sandip Singh

Papers:

Bhatti SS, Kumar V, Sambyal V, Singh J, Nagpal AK (2018). Comparative analysis of tissue compartmentalized heavy metal uptake by common forage crop: A field experiment. *Catena*, 160:185-193. DOI: 10.1016/j.catena.2017.09.015.

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Co-Principal Investigator: Dr. Jaswinder Singh

Papers:

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4.4. List of funded projects implemented/ being implemented:

S.No Project Title Funding Agency Budget (Rs) Duration Start date & End Date (MM/YYYY) Status (in Chronological order) (Ongoing/ completed/ Submitted) Role as PI/ Co- PI PCR evaluation grade it funded by (ANRF/ SERB) Summary of Result & Publication/ Patent

Dr. Sandip Singh (Principal Investigator)

No project NA NA NA NA NA NA NA NA NA

Dr. Ashok Kumar (Co-Principal Investigator)

No project NA NA NA NA NA NA NA NA NA

Dr. Jaswinder Singh (Co-Principal Investigator)

1. Bioremediation of Effluents Generated by Beverage and Paper Industries Using *Eisenia fetida* UGC 1,25,000/- 1 year 03/2010 -02/2011

Completed PI - 2

2. Ecological and taxonomic distribution of earthworms in punjab: effect of soil quality and heavy metals DST 27,27,360/- 3 years 11/2013 - 10/2026 Completed PI - 4

3 Management of Cattle Dung of Dairies of Amritsar and Ludhiana through Vermicomposting: Awareness and Training of Farmers and People of Punjab to Shift to Organic Farming Directorate of Environment and Climate Change, Government of Punjab 46,46000/- 2 years 03/2023 - 03/2025 Completed PI - -

4. Hands on Training Workshop for Vermicomposting Procedure and its Application PSCST 4,00,000/- 1 year 10/2023 - 09/2024

Completed PI - -

5. List of facilities available at host institute

5.1 Infrastructural Facilities

S. No. Infrastructural Facility Yes/No/ Not required Full or sharing basis

1. Workshop Facility Yes

2. Water & Electricity Yes

3. Laboratory Space/ Furniture Yes

4. Power Generator Yes

5. AC Room or AC Yes

6. Telecommunication including e-mail & fax Yes

7. Transportation No

8. Administrative/ Secretarial support Yes

9. Information facilities like Internet/Library Yes

10. Computational facilities No

5.2. Equipment available with the Institute/ Group/ Department/Other Institutes for the project

Equipment available with Specific Name of Equipment & detailed description Model, Make & year of purchase Remarks including

accessories available and current usage of equipment

PI institute (LPU) UV spectrophotometer Shimadzu, 2017 Accessories available and currently working

Dr. Jaswinder Singh (Co-PI) institute Microwave plasma atomic emission spectrometer (MP-AES) Agilent-4200, Agilent, 2017 Accessories available and currently working

Dr. Ashok Kumar (Co-PI) institute Atomic Absorption Spectrophotometer (AAS)* Agilent Accessories available and currently working

6. Name and address of experts/ institution interested in the subject/ outcome of the project.

S. No. Name of Expert/Affiliation Email Area of Expertise

1 Punjab Pollution Control Board epappcb@gmail.com Pollution control and management

2 Central Pollution Control Board ccb.cpcb@nic.in Pollution control and management

3 Punjab State Council for Science and Technology pritpal.pscst@gmail.com Promotion of Science

4 Ministry of Environment and Forest, Climate Change apccfcntral-npg-mef@gov.in Environmental protection

7. Current financial support, other than those mentioned in section 4.4.

No financial support to mention

8. Any other relevant information & supplementary documentation.

Complete Budget Details

Institution wise budget detail

Budget Head Lovely Professional University Total

Manpower 21,02,400 21,02,400

Consumables 5,00,000 5,00,000

Travel 1,50,000 1,50,000

Equipments 3,50,000 3,50,000

Contingencies 2,00,000 2,00,000

Other costs (outsourcing) 7,00,000 7,00,000

Overhead 4,00,000 4,00,000

Total 44,02,400 44,02,400

Year wise budget summary

Budget Head Year 1 Year 2 Year 3 Total

Manpower 6,76,800 6,76,800 7,48,800 21,02,400

Consumables 2,50,000 1,50,000 1,00,000 5,00,000

Travel 1,00,000 25,000 25,000 1,50,000

Equipments 3,50,000 0 0 3,50,000

Contingencies 1,00,000 50,000 50,000 2,00,000

Other costs (outsourcing) 1,50,000 3,50,000 2,00,000 7,00,000

Overhead 1,50,000 1,50,000 1,00,000 4,00,000

Total 17,76,800 14,01,800 12,23,800 44,02,400

Head-wise Budget details

1. Manpower

Designation Year 1 Year 2 Year 3 Total

Junior Research Fellow (JRF) (JRF will assist in carrying out experiment work) 5,32,800 5,32,800 6,04,800 16,70,400

Technical Assistant (TA) 1,44,000 1,44,000 1,44,000 4,32,000

2. Consumables

Justification Year 1 Year 2 Year 3 Total

For the purchase of chemicals, glassware, for the research work, etc., 2,50,000 1,50,000 1,00,000 5,00,000

3. Travel

Justification (Inland travel) Year 1 Year 2 Year 3 Total

For sample collection and their transportation to lab, visit to collaborating institution/lab, conference attending 1,00,000 25,000 25,000
1,50,000

4. Equipments

Generic Name, Model No., (Make)/ Justification	Quantity	Spare time	Estimated Cost
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Laboratory Fume Hood (50 L) New Tech Scientific Instruments For acid digestion of samples for metal analysis 1 50 % 1,00,000

Digital Weighing Balance Endeavour Instrument Private Limited For weighing of samples 1 50 % 20,000

Hot Plate S Lab Instruments For digestion of samples for metal analysis 1 50 % 10,000

Refrigerator RLR 300 Laboratory Refrigerator For storage of chemicals and samples 1 0 1,00,000

Laptop+Printer HP/Dell For data analysis and processing 1 0 1,00,000

pH meter Lab Junction Measurement of pH of samples 1 50 % 20,000

5. Contingency

Justification (Inland travel) Year 1 Year 2 Year 3 Total

Contingency will be used for miscellaneous expenditure which is not covered under other budget heads. For example, stationary, computer

related stationary and items, repair of existing equipment etc. 1,00,000 50,000 50,000 2,00,000

6. Other (outsourcing)

Justification Year 1 Year 2 Year 3 Total

Outsourcing of heavy metal/metal(Iloid) analysis to available facilities in host/other institutions on payment basis 1,50,000 3,50,000
2,00,000 7,00,000

6. Overhead

Justification Year 1 Year 2 Year 3 Total

Overhead charges are for providing facilities like infrastructure, staff, water, electricity, communications etc. 1,50,000 1,50,000 1,00,000
4,00,000

AI Content

8.4%

	Text Coverage	Words
AI Text	8.4%	381
Low Frequency		56
Medium Frequency		0
High Frequency		4
Human Text	91.6%	4,155
<hr/>		
Excluded		
Omitted Words		1,462

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3x  228x

228x care requirements, and potential

How frequently the phrase was found in our dataset:

AI Text	1.2 / 1,000,000 Documents
Human Text	0.01 / 1,000,000 Documents

53x offer unique advantages:

How frequently the phrase was found in our dataset:

AI Text	133.28 / 1,000,000 Documents
Human Text	2.5 / 1,000,000 Documents

38x research addresses critical

How frequently the phrase was found in our dataset:

AI Text	13.12 / 1,000,000 Documents
Human Text	0.34 / 1,000,000 Documents

19x and resistance to environmental

How frequently the phrase was found in our dataset:

AI Text	20.8 / 1,000,000 Documents
Human Text	1.09 / 1,000,000 Documents

19x in urban environments, particularly

How frequently the phrase was found in our dataset:

AI Text	1.88 / 1,000,000 Documents
Human Text	0.1 / 1,000,000 Documents

16x significant drawbacks including

How frequently the phrase was found in our dataset:

AI Text	8.29 / 1,000,000 Documents
Human Text	0.52 / 1,000,000 Documents

15x financial concerns associated with

How frequently the phrase was found in our dataset:

AI Text	1.66 / 1,000,000 Documents
Human Text	0.11 / 1,000,000 Documents

13x chemical remediation methods

How frequently the phrase was found in our dataset:

AI Text	1.05 / 1,000,000 Documents
Human Text	0.08 / 1,000,000 Documents

9x for Smart City initiatives

How frequently the phrase was found in our dataset:

AI Text	2.31 / 1,000,000 Documents
Human Text	0.27 / 1,000,000 Documents

8x globally, particularly in

How frequently the phrase was found in our dataset:

AI Text	16.38 / 1,000,000 Documents
Human Text	2.04 / 1,000,000 Documents

7x approach represents novel

How frequently the phrase was found in our dataset:

AI Text	1.79 / 1,000,000 Documents
Human Text	0.25 / 1,000,000 Documents

6x current approaches using

How frequently the phrase was found in our dataset:

AI Text	1.34 / 1,000,000 Documents
Human Text	0.24 / 1,000,000 Documents

6x 11 (Sustainable Cities and Communities) and

How frequently the phrase was found in our dataset:

AI Text	1.47 / 1,000,000 Documents
Human Text	0.26 / 1,000,000 Documents

5x The findings will contribute

How frequently the phrase was found in our dataset:

AI Text	2.94 / 1,000,000 Documents
Human Text	0.58 / 1,000,000 Documents

3x challenges. The project

How frequently the phrase was found in our dataset:

AI Text 7.61 / 1,000,000 Documents

Human Text 2.22 / 1,000,000 Documents

3x costly and unsustainable.

How frequently the phrase was found in our dataset:

AI Text 1.62 / 1,000,000 Documents

Human Text 0.52 / 1,000,000 Documents

3x knowledge gaps by

How frequently the phrase was found in our dataset:

AI Text 3.67 / 1,000,000 Documents

Human Text 1.18 / 1,000,000 Documents

Technical Details for Full ARG Proposal titled “Assessment of Phytoremediation potential of grass species growing in Smart cities of Punjab: improvement using earthworm and biochar assistance”

Principal Investigator: Dr. Sandip Singh Assistant Professor (Environmental Sciences) Department of Chemistry, Lovely Professional University, Phagwara, Punjab

Co- Investigator: Dr. Jaswinder Singh Associate Professor, Department of Zoology, Khalsa College, Amritsar, Punjab

Co- Investigator: Dr. Ashok Kumar Assistant Professor Department of Botany, Central University of Jammu, Jammu

1. Origin of the Proposal:

Metal(loid) contamination of soils represents a critical environmental threat globally, particularly in India due to extensive agricultural, industrial, and urban activities. Punjab faces severe contamination, especially in Smart Cities—Amritsar, Jalandhar, and Ludhiana—with Ludhiana experiencing maximum pollution as Punjab's industrial hub. Traditional physical and chemical remediation methods for soils (surface capping, soil washing, electrokinetic extraction, vitrification) are costly and unsustainable. But, Phytoremediation is a method which involves uptake and accumulation of metal(loid)s in different parts of plants and considered as the most sustainable method of remediation. Although, phytoremediation offers eco-friendly alternatives, the current approaches using crop and tree species for phytoremediation have significant drawbacks including lengthy remediation periods, intensive care requirements, and potential financial losses when edible crops become unsuitable for consumption due to metal accumulation.

This research addresses critical knowledge gaps by investigating indigenous grass species (Poaceae family) for phytoremediation in contaminated urban soils of Punjab. Grasses offer unique advantages: ubiquitous presence, rapid growth, high biomass production, and resistance to environmental stress. Being non-edible, they eliminate consumption risks and financial concerns associated with crop-based phytoremediation. The current study will focus on Amritsar and Jalandhar, evaluating grass species' phytoremediation potential both independently and in combination with rice husk biochar and vermicomposting technologies. This integrated approach represents novel research in India, where these three sustainable methods have rarely been studied collectively.

This research will identify optimal indigenous grass species for urban soil remediation while establishing enhanced remediation protocols through biochar and vermicomposting integration. The findings will contribute substantially to sustainable remediation technologies, offering cost-effective, environmentally friendly solutions for metal(loid)-contaminated soils in urban environments, particularly relevant for Smart City initiatives addressing industrial and urban pollution challenges. The project will also be helpful in achievement of SDGs 11 (Sustainable Cities and Communities) and 13 (Climate Action).

Aims/Objectives of the work:

- Monitoring of metal(loid) contaminated areas of Amritsar and Jalandhar (in the vicinity of industries, roadsides, solid waste dumpsites etc.) to collect soil and native grass samples.
- Analysis of metal(loid)s in soil and grass samples to identify the species having high phytoremediation potential.
- Evaluation of the potential of rice husk biochar and vermicomposting to enhance the phytoremediation capacity of selected grass species in two modes of laboratory experimentation i.e. separately and in combination.

2. Review of status of Research and Development in the subject

2.1. International Status:

Although a lot of research had been carried out in the field of phytoremediation of metal(loid)s in the past and multiple review papers have also been published regarding the concept, application and developments in the field of phytoremediation (Sharma et al., 2023). But majority of the research work focused on use of food, fodder and commercially important plant species. These plant species require significant economic investment in the form of agrochemicals, irrigation and dedicated labor force. And accumulation of excessive metals in these traditional plant species lowers their quality and can ultimately cause financial losses. Therefore, now the focus is on using non-commercial plant species such as grasses for phytoremediation. The research work in this regard is in initial stages and following review focuses on the use of grass species for phytoremediation in different parts of world other than India.

Albornoz et al. (2016) analyzed Pb and Zn phytoaccumulation potential of two grass species i.e.

Festuca arundinacea and

Cynodon dactylon growing in naturally developed (*in situ*) and experimentally contaminated (*ex situ*) soils in Tandil city, Argentina. They observed that both the species had high remediation potential of Pb with Bioaccumulation values reaching upto 0.72.

Soils contaminated with Cr (VI) at different concentrations (with and without Ethylene diamine tetra acetic acid (EDTA) (4 mM) chelation) were treated with hybrid Napier grass (

Pennisetum americanus L. ×

Pennisetum purpureum Schumach) for analysis of its phytoremediation potential by Ram et al. (2019). With bioaccumulation factor > 1, the study indicated that hybrid napier grass is a potential source for phytoremediation. In this study, superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activities indicated that napier grass exhibited strong resistance at highest Cr (VI) concentration.

The arsenic (As) phytoaccumulation potential of two grass species i.e.

Holcus lanatus and

Agrostis capillaris was analyzed by Dradach et al. (2020) in former As mining sites of Sudetes, Poland. First a field study was conducted to determine the grass species with high As accumulation capacity. Among the different grass species, the above mentioned species were selected for greenhouse experimentation. In greenhouse experimentation, the grass species were exposed to different concentrations (394-19,600 mg/kg, untreated and fertilized). The results indicated that these plant species were unable to grow at high As concentration in soil without fertilization. But, with fertilization, these grass species showed significant improvement in their As uptake potential.

Vetiver grass (

Chrysopogon zizanioides) was analyzed for its Cr and Ni phyto-accumulation potential in a treatment based (50, 150, and 300 ppm

concentrations in soils) experimentation by Chintani et al. (2021). The results revealed that

C. zizanioides showed better phytoremediation potential for Cr in comparison to Ni with above for in several treatments translocation factor (TF) bioconcentration factor (BCF), biological absorption coefficient (BAC), and values.

Rolka et al. (2023) investigated the heavy metal phytoremediation potential of

Calamagrostis acutiflora, an ornamental grass growing along streets of Olsztyn, Poland. The metals analyzed were Fe, Mn, Zn, Cu, Pb, Cd, Ni, Cr and Co. The results of the study indicated that

C. acutiflora showed biological accumulation coefficient (BAC) in the range of 1.117–3.631, thus proving the grass species as an efficient candidate for phytoremediation. Table 1 shows other studies in which phytoremediation potential of grass species were analyzed to remove metal(loid)s by researchers in recent years.

Table 1. Summary of research studies which analyzed phytoremediation potential of grass species for metal(loid)s in soils

Grass species	Country	Type of study	Metal(loid)s analyzed	References
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Switchgrass (*Panicum virgatum*) and Timothy grass (*Phleum pretense*) USA Treatment based study (50, 80, 120, 200, or 500 mg Pb/kg of soil) Pb Balsamo et al. (2015)

Sporobolus virginicus Australia Field based study on industrially contaminated sediments Zn, Cu, Pb, Cd and Se Tran et al. (2020)

Bermuda grass (*Cynodon dactylon* (L.) pers.) China Pot based experimentation in combination with PAHs Cd Song et al. (2022)

Barnyard grass (*Echinochloa crusgalli* L.) Bangladesh Pot based experimentation on industrially contaminated soils As, Pb, Cr, Fe, and Mn Sultana et al. (2022)

Megathyrsus maximus, *Urochloa brizantha* and *Urochloa decumbens* Brazil Treatment based greenhouse study (0, 45, 90 and 270 mg kg⁻¹) Pb Farnezi et al. (2023)

Pennisetum purpureum (elephant grass), *Brachiaria decumbens* (brachiaria grass), *Vetiveria zizanioides* (vetiver) Brazil Field study in case of elephant and brachiaria grass; Treatment based study for vetiver grass (soils collected from contaminated sites) Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Pb, Co, Cu, Cr, Sn, Sr, Fe, P, Li, Mg, Mn, Hg, Mo, Ni, K, Ag, Se, Na, Tl, Ti, U, V, Zn Morita et al. (2023)

Poa pratensis, *Lolium perenne*, *Festuca rubra*, *Festuca pratensis*, *Deschampsia caespitosa* Poland Pot based experimentation on industrially contaminated soils Zn Korzeniowska and Stanislawska-Glubiak, 2023

The review of literature suggests that the analysis of phytoremediation potential of grass species is an emerging research field. Main focus till now is on some famous grass species such as vetiver grass and napier grass. But now globally, researchers are trying to focus on other indigenous grass species for their phytoremediation potential. Overall grass species are emerging as effective instruments for phytoremediation of existing and emerging contaminants.

2.2. National Status:

In India, significant amount of work has been done on phytoremediation potential of food and fodder crops, ornamental plants, tree

species, herbs and shrubs, weeds etc. in last two decades. But, most of this work focused on economically important plant species. These species require significant economic and labor investment. And once the contaminant is accumulated in the aerial parts of these plant species, it renders them as waste which can cause economic loss. Also in case of tree species the time taken for effective phytoremediation is very long (2-4 years). So now focus is shifting to fast growing, high biomass and economically viable plant species for phytoremediation. In this regard, grasses can act as a viable option. But, till now research on phytoremediation potential of native Indian grass species has been still in preliminary stage. Very few research reports are available regarding phytoremediation potential of grasses in India for which summary is presented below.

Kumar and Maiti (2015) analyzed the phytoremediation potential of two aromatic grass species i.e.

Cymbopogon citratus and

Chrysopogon zizanioides to remove metal(loid)s from mining waste collected from Roro hills, West Singhbhum, Jharkhand. For analysis they amended the mine waste with different proportions of chicken manure, farmyard manure and garden soil. Analysis of metal(loid)s (Cr, Ni, Mn, Zn, Co, Cu, Pb and Cd) accumulation in these grass species indicated that the amendments enhanced the phytoremediation capability of both grass species, especially for Cr and Ni.

In addition to food crops and tree species, two grass species (

Cynodon dactylon and

Sorghastrum nutans) were analyzed by Kumar et al. (2017) for their heavy metal (Cr, Ni, Zn, Mn, Co, Cu, Pb and Cd) accumulation potential in a monitoring study in chromite-asbestos mining area of Roro region, Chaibasa, Jharkhand. The analysis revealed that both

C. dactylon and

S. nutans acted as excellent accumulators of Cr and Ni with above 1 Translocation Factor (TF) values.

Chandra et al. (2018) carried out a monitoring study to analyze the heavy metal phytoremediation potential of weed and grass species growing in distillery sludge contaminated soils of Unnao, Uttar Pradesh. The grass species analyzed were

Saccharum munja (munja),

Cynodon dactylon (Bermuda grass), and

Pennisetum purpureum (elephant grass), while the metals tested were Fe, Zn, Cu, Mn, Ni, and Pb. The researchers observed that the grass species exhibited excellent metal accumulation potential with > 1 values of bioaccumulation coefficient factor (BCF) and translocation factor (TF). Thus, it was concluded that these native grass species can act as efficient remediation tools for heavy metal contaminated soils.

In addition to the above mentioned studies, few other researchers carried out phytoremediation studies on grass species in India including Banerjee et al. (2018) on

Chrysopogon zizanioides (L.) Roberty (vetiver grass), Iyer et al. (2022) on

Cynodon sp., Kumar and Fulekar (2022) on Deenanath grass (

Pennisetum pedicellatum), Sinduja et al. (2023) on Cumbu Napier hybrid grass. But, still there is huge paucity of research work on phytoremediation potential of native grass species growing in varying contaminated conditions.

2.3 Importance of the proposed project in the context of current status

In the current scenario of excessive contamination of terrestrial ecosystems due to multitude of anthropogenic activities, finding low cost sustainable remedial solutions is a necessity. Several, physical and chemical methods for remediation have been applied by researchers in

the past, but they are high cost and unsustainable processes. Phytoremediation on the other hand provides a low cost, green and sustainable solution for removal of contaminants from polluted soils. And now, in case of phytoremediation the focus is on fast growing, high biomass and low cost plant species. In this regard, grasses can act as ideal candidates. In last few years, researchers have started analyzing the phytoremediation potential of grasses around the globe as shown in Section 2.1. In India also, some of the research focus has shifted from traditional crops to grasses for their phytoremediation potential. But, this work is in preliminary stage. And, in case of Punjab, negligible reports are available regarding phytoremediation potential of native grass species. Punjab is among the better performing states on economic front. In addition to agriculture, industry and tourism are also main pillars of economy of Punjab. But, these economic activities also lead to severe contamination of soils of Punjab. The situation is worse in the three cities (Amritsar, Jalandhar and Ludhiana) designated under smart city project of government of India. Although, several reports are available regarding phytoremediation potential of different food and fodder species. But, there are negligible research reports on phytoremediation potential of grass species for heavy metal contaminated soils of Punjab. Considering this, the present research study was planned to analyze the phytoremediation potential of native grass species growing in Amritsar and Jalandhar to decontaminate metal(loid)s contaminated soils. This research study can help to identify best performing native grass species which can be used for phytoremediation of the contaminated sites in urban and rural areas. Since grass species ubiquitously grow without any nutritional aid, this work would be very beneficial for designing low cost, sustainable and green strategy to decontaminate our urban terrestrial ecosystems.

2.4. If the project is location specific, basis for selection of location be highlighted:

Yes, this work would be location specific. The main locations of this work would be urban areas of Amritsar and Jalandhar, Punjab (two cities under smart city project of Government of India). These two cities are selected because a lot of economic activity happens in these two cities. Amritsar is one of the most famous tourist sites of India because of religious and historical landmarks such as Harmandir Sahib, Jaliawala Bagh, Durgiana mandir, Wagha Border etc. In addition to that, significant industrial establishments (food, textile, dairy) are also located in Amritsar. Jalandhar on the other hand is one of the economic hubs of Punjab, with significant industrial activity including leather tanning, textile, sports goods, distillery etc. In cases of both Amritsar and Jalandhar soil environments get contaminated with metal(loid)s due to agricultural, traffic and industrial inputs and it is necessary to find sustainable remedial solution for decontamination these soils in order to achieve the targets of sustainable city project of government of India.

3. Work Plan

3.1. Methodology of the work:

The proposed research work would be carried out in following steps:

3.1.1. Collection of soils and grass species from contaminated areas

The metal(loid) accumulation potential of native grass species growing in contaminated sites of Amritsar and Jalandhar would be analyzed by carrying out monitoring studies in contaminated areas (roadsides, industrial areas, solid waste dumpsites etc.) in first part of the project. Fig. 1 presents the study area. Samples of grass plants growing in contaminated sites will be collected with soil samples of those contaminated areas.

Fig.1. Map to the study area (district Amritsar and Jalandhar)

3.1.2. Analysis of metal(lloid) contents in soil and grass samples

The collected soil and grass plants samples would be acid digested in Laboratory fume hood using aqua regia ((HNO₃: HCl in 3:1 ratio) and triacid mixture (HNO₃:H₂SO₄:HClO₄ in 5:1:1 ratio) by method of Allen et al. (1986). Different metal(lloid)s would be analyzed in soil and grass samples using techniques such as ICPMS and AAS and grass species having maximum metal(lloid) accumulation potential would be determined by using equations such as Bioaccumulation factor (BCF) and Translocation factor (TF).

Bioaccumulation factor (BAF):

Bioaccumulation Factor (BAF) is a ratio of metal(lloid) concentration in plant tissue to soil (Ali et al., 2013):

$$\text{BAF} = \text{C}_{\text{plant tissue}} / \text{C}_{\text{soil}} \quad (1)$$

where C_{plant tissue} and C_{soil} are the concentrations of metal(lloid) in plant tissues (roots, stems and leaves) and soil, respectively, on a dry weight basis.

Translocation factor (TF):

Translocation Factor (TF) is the ability of a plant to move the accumulated heavy metal from roots to above ground tissues (stems, leaves and inflorescences) (Ali et al., 2013):

$$\text{TF} = \text{C}_{\text{stem/leaves}} / \text{C}_{\text{roots}} \quad (2)$$

$$\text{TF} = \text{C}_{\text{leaves}} / \text{C}_{\text{stem}} \quad (3)$$

where Cleaves, Cstem and Croots are the concentrations of the metal(lloid) in plant leaves, stem and roots, respectively on a dry weight basis.

3.1.3. Biochar formation

Simple biochar would be formed by pyrolysis of organic wastes (mainly rice husk) for using in the study.

3.1.4. Pot experimentation setup

In first set up, the three grass species determined in the preliminary study having maximum metal(lloid) accumulation potential would be grown in pots/fields having metal(lloid) (As, Cd, Cr, Ni and Pb salts at different concentrations for different periods of times) spiked soils for determination of their phytoremediation potential. In second setup, pots having metal(lloid) spiked soils would be amended with biochar (at varying concentrations) and earthworms (

Eisenia fetida) in separate treatments for assessment of their remediation potential. The third setup would include grass plants grown in pots/fields having metal(lloid) spiked soils with amendment of biochar (at varying concentrations) and earthworms to determine their potential to enhance phytoremediation of grass species.

3.1.5. Metal(lloid)

Amelioration potential analysis grasses with amendments

Metal(lloid) contents would be analyzed in soils pre and post treatments with grasses+biochar, grasses+earthworm and grasses+biochar+earthworm determine the remediation potential. Metal(lloid) contents would be analyzed in soils and plant parts at different times for 15-30 days to analyze the phytoremediation potential of grasses under different treatments.

3.2 Time Schedule of activities giving milestones through BAR diagram.

1st financial Year

- Purchase of equipment, necessary chemicals and glassware.
- Appointment of Junior Research Fellow (JRF)
- Identification of contaminated sites for sampling in the two cities
- Collection of soil and grass samples from the contaminated sites.
- Analysis of soil for physico-chemical characteristics and metal(lloid)s.
- Estimation of metal(lloid)s in grass samples grown and identification of best performing grass species.

2nd financial year

- Standardization of protocol for rice husk biochar for determining optimal conditions for its application in metal(lloid) removal.
- Carrying out pot based experimentation to analyze the maximum metal(lloid) accumulation potential of selected grass species alone and in combination of biochar and earthworms.

3rd financial year

- Continuation of the pot based experimentation
- Compilation of data.

- Publications of research articles

- Preparation of final report

Plan of work and targets to achieve

First financial year 1 2 3 4 5 6 7 8 9 10 11 12

Purchase of equipment, chemicals and glassware.

Appointment of Staff (JRF & TA)

Identification of contaminated sites for sampling in the two cities

Collection of soil and grass samples from the contaminated sites

Analysis of soil for physico-chemical characteristics and metal(lloid)s

Estimation of metal(lloid)s in grass samples and identification of best performing species

Second financial year

Standardization of protocol for rice husk biochar for determining optimal conditions for its application in metal(lloid) removal.

Carrying out pot based experimentation to analyze the maximum metal(lloid) accumulation potential of selected grass species alone and in combination of biochar and earthworms.

Third financial year

Continuation of the pot based experimentation

Compilation of data

Publications of research articles

Preparation of final report

3.3 Suggested Plan of action for utilization of research outcome expected from the project

This research project has been designed to identify the best performing native grass species of Punjab for phytoremediation of metal(lloid) contaminated soils of urban areas which are contaminated due to various anthropogenic activities. The research work also focuses on performance of these grass species in combination with physical (biochar) and biological (earthworm) amendments in order to enhance their phytoremediation potential. The research data from this project can provide valuable information about the possible metal(lloid) hyper-accumulator native grass species which can be grown in contaminated soils of Punjab and other parts of India for their decontamination. Therefore, this project can provide a low cost, low maintenance, sustainable and green solution for our soil pollution with metal(lloid)s and the results can be beneficial for following departments of the state:

- Pollution control

- Urban development

- Health

- Agriculture
- Academics and Research Institutes
- For general public awareness

3.4 Environmental impact assessment and risk analysis

The present research work focuses on determining the native grass species which can accumulate metal(lloid)s from contaminated soils of urban areas of Punjab and effects of physical and biological amendments for their performance enhancement. The results of this project would be very beneficial for pollution control, urban development and agriculture departments, since soil pollution is a critical issue for Punjab and finding a sustainable, low cost solution is a necessity. In phytoremediation, the plants have the capability to absorb large quantities of metal(lloid)s and accumulate in different body parts in non-toxic forms. The metal(lloid)s accumulated can be acquired back for commercial purposes by phyto-mining which can help the economy of the state. The results of this study can also guide other states to adopt local, low maintenance plant species (such as grasses) as effective tools for remediation of the contaminated soils.

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4. Expertise:

4.1 Expertise available with the investigators in executing the project

The present research work has the trans-disciplinary relevance because it is framed to utilize the expertise of investigators from different disciplines viz., Environmental Sciences, Botany and Zoology. All investigators will be working jointly towards creating translational innovations that can integrate to address a common problem like soil pollution and its sustainable remediation using grasses. Dr. Sandip Singh (PI) has the expertise in the field of Environmental monitoring and phytoremediation while Dr. Jaswinder Singh (Co-PI) has the expertise in vermicoremediation and solid waste management, and Dr. Ashok Kumar (Co-PI) has the expertise in plant taxonomy and metabolism.

4.2 Summary of roles/responsibilities for all Investigators:

S.No. Name of the Investigators Roles/Responsibilities

1. Dr. Sandip Singh (PI) (i) Identification of contaminated sites (ii) Collection of soil and grass samples (iii) Biochar formation and amendment analysis (iv) Analysis of metal(loid) contents in soil and grass samples (iv) Compilation of data and report formation
2. Dr. Jaswinder Singh (Co-PI) (i) Collection of soil and grass samples (ii) Analysis of earthworm assisted remediation (iii) Analysis of metal(loid) contents in soil and grass samples
3. Dr. Ashok Kumar (Co-PI) (i) Identification of grass plant species (ii) Analysis of key plant parameters involved in phytoremediation (iii) Assistance in pot based experimental study

4.3. Key Publications by investigators:

Principal Investigator: Dr. Sandip Singh

Papers:

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Bhatti SS, Singh R (2020). Cadmium accumulation potential of Brassica species grown in metal spiked loamy sand soil. *Soil and Sediment Contamination: An International Journal*, 29(6):638-649.

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Bhatti SS, Bhat SA, Singh J (2020). Aquatic plants as effective phytoremediators of heavy metals. In *Contaminants and Clean Technologies* (pp. 189-199). CRC Press.

Bhatti SS*, Bhatia A, Bhagat G, Singh S, Dhaliwal SS, Sharma V, Verma V, Yin R, Singh J (2024). PAHs in Terrestrial Environment and their Phytoremediation. In *Bioremediation for Sustainable Environmental Cleanup* (pp. 67-85). CRC Press. (pp. 67-85). CRC Press.

Singh J,

Bhatti SS, Singh S, Balasubramani R (2023). Editorial: Vermiremediation in contaminated soils: An approach for soil stabilization. *Frontiers in Environmental Science*. DOI 10.3389/fenvs.2023.1137463.

Co-Principal Investigator: Dr. Jaswinder Singh

Papers:

Bhat SA,

Jaswinder Singh, Vig AP (2014). Genotoxic assessment and optimization of pressmud with the help of exotic earthworm *Eisenia fetida* *Environment Science & Pollution Research*, 21:8112-8123

Joshi R,

Singh J, Vig AP (2015). Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. *Reviews in Environmental Science and Biotechnology* 14: 137-159

Singh J, Singh S, Vig AP (2015). Extraction of earthworm from soil by different sampling methods: a review. *Environment Development & Sustainability*, 18: 1521-1539.

Phillips HRP et al., (2019). Global distribution of earthworm diversity. *Science*, 366: 480-485.

Singh J, Eisenhauer N, Schadler M, Ceszarz S (2021). Earthworm gut passage reinforces land-use effects on soil microbial communities across

Co-Principal Investigator: Dr. Ashok Kumar

Papers:

Kumar A, Chhillar RK, Gautam RC (2011). Nutrient requirement of winter maize (

Zea mays)-based intercropping systems. The Indian Journal of Agricultural Sciences, 76(5).

Kumar A, Soodan AS (2013). Taxonomic description of

Elytrophorus spicatus (Willd.) A campus (Poaceae: Arundinoideae, Arundineae) from the Shiwaliks of Northern India. Botany Research International, 6(3): 71-73.

Kumar A, Sharma S, Kaur R, Soodan AS (2015). A Study of Punjab Grasses as Indicators of Environmental Change. Botany Research

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Kumar A, Kaur R (2020). Morpho functional diversity of diaspores of some range grasses of Punjab (India). Proceedings of 23 international Grassland Congress (Sustainable use of Grassland Resources for Forage Production, Biodiversity and Environmental Protection).

Thakur A, Kumari R,

Kumar A, Chaudhary A (2024). Quantitative ethnobotanical study of medicinal plants used by native people of selected areas of Chhota Bhangal, Himachal Pradesh. Ethnobotany Research and Applications, 28, 1-34.

4.4. List of funded projects implemented/ being implemented:

S.No Project Title Funding Agency Budget (Rs) Duration Start date & End Date (MM/YYYY) Status (in Chronological order) (Ongoing/ completed/ Submitted) Role as PI/ Co- PI PCR evaluation grade it funded by (ANRF/ SERB) Summary of Result & Publication/ Patent
Dr. Sandip Singh (Principal Investigator)

No project NA NA NA NA NA NA NA NA

Dr. Ashok Kumar (Co-Principal Investigator)

No project NA NA NA NA NA NA NA NA

Dr. Jaswinder Singh (Co-Principal Investigator)

1. Bioremediation of Effluents Generated by Beverage and Paper Industries Using *Eisenia fetida* UGC 1,25,000/- 1 year 03/2010 -02/2011
Completed PI - 2

2. Ecological and taxonomic distribution of earthworms in punjab: effect of soil quality and heavy metals DST 27,27,360/- 3 years 11/2013 - 10/2026 Completed PI - 4

3 Management of Cattle Dung of Dairies of Amritsar and Ludhiana through Vermicomposting: Awareness and Training of Farmers and People of Punjab to Shift to Organic Farming Directorate of Environment and Climate Change, Government of Punjab 46,46000/- 2 years 03/2023 - 03/2025 Completed PI - -

Completed PI --

5. List of facilities available at host institute

5.1 Infrastructural Facilities

S. No. Infrastructural Facility Yes/No/ Not required Full or sharing basis

1. Workshop Facility Yes
2. Water & Electricity Yes
3. Laboratory Space/ Furniture Yes
4. Power Generator Yes
5. AC Room or AC Yes
6. Telecommunication including e-mail & fax Yes
7. Transportation No
8. Administrative/ Secretarial support Yes
9. Information facilities like Internet/Library Yes
10. Computational facilities No

5.2. Equipment available with the Institute/ Group/ Department/Other Institutes for the project

Equipment available with Specific Name of Equipment & detailed description Model, Make & year of purchase Remarks including accessories available and current usage of equipment

PI institute (LPU) UV spectrophotometer Shimadzu, 2017 Accessories available and currently working

Dr. Jaswinder Singh (Co-PI) institute Microwave plasma atomic emission spectrometer (MP-AES) Agilent-4200, Agilent, 2017 Accessories available and currently working

Dr. Ashok Kumar (Co-PI) institute Atomic Absorption Spectrophotometer (AAS)* Agilent Accessories available and currently working

6. Name and address of experts/ institution interested in the subject/ outcome of the project.

S. No. Name of Expert/Affiliation Email Area of Expertise

1 Punjab Pollution Control Board epappcb@gmail.com Pollution control and management

2 Central Pollution Control Board ccb.cpcb@nic.in Pollution control and management

3 Punjab State Council for Science and Technology pritpal.pscst@gmail.com Promotion of Science

7. Current financial support, other than those mentioned in section 4.4.

No financial support to mention

8. Any other relevant information & supplementary documentation.

Complete Budget Details

Institution wise budget detail

Budget Head Lovely Professional University Total

Manpower 21,02,400 21,02,400

Consumables 5,00,000 5,00,000

Travel 1,50,000 1,50,000

Equipments 3,50,000 3,50,000

Contingencies 2,00,000 2,00,000

Other costs (outsourcing) 7,00,000 7,00,000

Overhead 4,00,000 4,00,000

Total 44,02,400 44,02,400

Year wise budget summary

Budget Head Year 1 Year 2 Year 3 Total

Manpower 6,76,800 6,76,800 7,48,800 21,02,400

Consumables 2,50,000 1,50,000 1,00,000 5,00,000

Travel 1,00,000 25,000 25,000 1,50,000

Equipments 3,50,000 0 0 3,50,000

Contingencies 1,00,000 50,000 50,000 2,00,000

Other costs (outsourcing) 1,50,000 3,50,000 2,00,000 7,00,000

Overhead 1,50,000 1,50,000 1,00,000 4,00,000

Total 17,76,800 14,01,800 12,23,800 44,02,400

Head-wise Budget details

1. Manpower

Designation Year 1 Year 2 Year 3 Total

Junior Research Fellow (JRF) (JRF will assist in carrying out experiment work) 5,32,800 5,32,800 6,04,800 16,70,400

Technical Assistant (TA) 1,44,000 1,44,000 1,44,000 4,32,000

2. Consumables

Justification Year 1 Year 2 Year 3 Total

For the purchase of chemicals, glassware, for the research work, etc., 2,50,000 1,50,000 1,00,000 5,00,000

3. Travel

Justification (Inland travel) Year 1 Year 2 Year 3 Total

For sample collection and their transportation to lab, visit to collaborating institution/lab, conference attending 1,00,000 25,000 25,000
1,50,000

4. Equipments

Generic Name, Model No., (Make)/ Justification Quantity Spare time Estimated Cost

Laboratory Fume Hood (50 L) New Tech Scientific Instruments For acid digestion of samples for metal analysis 1 50 % 1,00,000

Digital Weighing Balance Endeavour Instrument Private Limited For weighing of samples 1 50 % 20,000

Hot Plate S Lab Instruments For digestion of samples for metal analysis 1 50 % 10,000

Refrigerator RLR 300 Laboratory Refrigerator For storage of chemicals and samples 1 0 1,00,000

Laptop+Printer HP/Dell For data analysis and processing 1 0 1,00,000

pH meter Lab Junction Measurement of pH of samples 1 50 % 20,000

5. Contingency

Justification (Inland travel) Year 1 Year 2 Year 3 Total

Contingency will be used for miscellaneous expenditure which is not covered under other budget heads. For example, stationary, computer related stationary and items, repair of existing equipment etc. 1,00,000 50,000 50,000 2,00,000

6. Other (outsourcing)

Justification Year 1 Year 2 Year 3 Total

Outsourcing of heavy metal/metal(lloid) analysis to available facilities in host/other institutions on payment basis 1,50,000 3,50,000
2,00,000 7,00,000

6. Overhead

Justification Year 1 Year 2 Year 3 Total

Overhead charges are for providing facilities like infrastructure, staff, water, electricity, communications etc. 1,50,000 1,50,000 1,00,000
4,00,000