Project Summary:

Metal(loid) contamination of terrestrial ecosystems is a global concern. The metal(loid)s such as As, Cd, Cr, Co, Cu, Pb, Ni, etc. originate from different sources which include both natural as well as anthropogenic. But anthropogenic sources such as agrochemicals based agriculture, contaminated irrigation sources, vehicular emissions, industrial inputs, solid waste dumping, aerial depositions from point and non-point sources etc. cause excessive increase in metal(loid)s concentrations in soils under different land uses. The situation of soil contamination in urban areas are under severe threat of metal(loid)s contamination due to multitude of contamination sources (such as solid waste dumping, industrial inputs, vehicular emission etc.). The excessive contamination of these soils pose serious ecological and human health risks. In Punjab also, the soils contamination is a significant problem in the big cities (Amritsar, Jalandhar and Ludhiana) selected under Smart City Project of government of India. In order to decontaminate these soils, sustainable, low cost and green remediation measures are required. In this regard, phytoremediation can as a possible solution. Phytoremediation is the technique of using growing those plant species on contaminated soils which an accumulate large quantities of these metal(loid)s. Traditionally, many food, fodder and ornamental crops have been analyzed for their metal(loid) accumulation potential. But, these crops require high nutrient inputs and considerable human care. After accumulation of large quantities of metal(loid)s these crops become unusable which can result in economic loss. Thus, for phytoremediation plant species which are low cost, fast growing, high in biomass and requiring least human care are required. In this regard, grasses can act as a sustainable choice. Grasses are ubiquitously present, have high growth rate, significant biomass and require negligible human care. Keeping this in view, the proposed study has been planned with the aim to identify native grass species growing in contaminated urban areas of Amritsar and Jalandhar having high metal(loid) accumulation potential. The study will further focus on enhancing the metal(loid)s accumulation potential of selected grass species using amendments such as biochar and earthworms.

Keywords: Phytoremediation, Grasses, Metal(loid)s, Smart Cities, Amendments

Sustainable Development Goals Targets: SDG 3 (Good Health and Well Being)
SDG 11 (Sustainable Cities and Communities)
SDG 13 (Climate Action)

Other technical details

1.Origin of the Proposal:

Contamination of soils due to anthropogenic activities (extensive agrochemical based agriculture, industrialization, urbanization etc.) is severe cause of concern in India and throughout the globe (Liang et al., 2019). Among the different contaminants, metal(loid)s are one of the most significant threats due to their persistence and mobility. Although some of the metals such as Co, Cu, Fe, Mn, Zn etc. are required by living beings in trace amounts for their metabolic requirements, but at contents above the permissible limits, these metals can cause deleterious effects on living beings (Jose and Ray, 2018). Some other metal(loid)s such as As, Cd, Hg, Pb etc. are toxic for living beings even at very low concentrations (Antoniadis et al., 2017). Although metal(loid) contamination of terrestrial ecosystems is a ubiquitous problem, but it is more severe in case of urban areas due to the multiplicity of the sources which include vehicular emissions, industrial emissions, solid waste deposition, electric waste disposal, intensive agricultural practices etc.

In case of Punjab, metal(loid) contamination of agricultural and urban soils has been highlighted by many researchers in the past (Katnoria et al., 2011; Kumar et al. 2016; Bhatti et al., 2018a). The primary reasons for it includes intensive agrochemical based agriculture, industrial waste depositions, aerial deposition from vehicular and industrial sources, contaminated irrigation sources etc. In case of Punjab the situation more severe in case of urban areas as compared to rural ones. Especially, in the three cities which falls under Smart City project of government of India i.e. Amritsar, Jalandhar and Ludhiana (Bhatti et al., 2018b; Kaur et al., 2022). Among these three cities Ludhiana faces maximum pollution threat as it is the industrial center of Punjab, but soil pollution is also a significant issue in Amritsar and Jalandhar.

The remedial measures for metal(loid)s pollution of soils involves several physical and chemical methods such as surface capping, encapsulation, landfilling, soil flushing, soil washing, electrokinetic extraction, vitrification etc (Liu et al., 2018). But, phytoremediation is considered one of the most sustainable approach for metal(loid) decontamination of soils (Bhatti et al., 2018a; Sharma et al., 2023). In addition to that vermiremediation and biochar based remediation are also very popular methods among researchers. 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 (Li et al., 2019). Biochar is basically carbon enriched black solid made by pyrolysis or gasification of organic/biomass materials. In the past, biochar has been effectively used for decontamination of water due to its excellent adsorption potential, but in recent years, researchers have started to use it for soil cleanup also (Tang et al., 2023). Vermiremediaation on the other hand is one of the old and effective method for soil and industrial solid waste decontamination (Borah and Deka, 2023). In the past these

three method have been used separately as remediation tools. But their combined effect has rarely been studied in India.

In case of phytoremediation, the major focus had been on use of different edible and non-edible crop and tree species. Although these plant and tree species are effective phytoremediators, but they require very long time and care. Also, if edible crops such as *Brassica juncea* are used as phytoremediators, the excessive accumulation of metal(loid)s in such crops can render these unsuitable for consumption and thus can cause financial loss also. Therefore, the need of the hour is to find those plant species which are fast growing, have high biomass and are non-edible so that they can be removed without any financial or health issues. In this regard, very less research has been done to analyze the phytoremediation potential of grasses (family: Poaceae). This research is negligible in case of India. But grasses are ubiquitously present, fast growing, high biomass and resistant members of plant kingdom (Morita et al., 2023). They can act as excellent candidates for phytoremediation, especially in urban areas. Therefore, the present research project is designed to analyze the potential of indigenous grass species for phytoremediation of metal(loid)s from contaminated urban soils of the two cities under Smart City Project of government of India i.e. Amritsar and Jalandhar. The project will further evaluate the potential of rice husk biochar and vermiremediation to enhance the phytoremediation capacity of selected grass species. This analysis will be done in two modes of experimentation i.e. separately and in combination. This work would be a significant contribution to the knowledge regarding sustainable remedial technologies for metal(loid)s contamination of soils.

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 vermiremediation 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 wirth 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 Dradrach 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 mention 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
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 log (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 is 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 zizaniodes* (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 Harimandir 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.

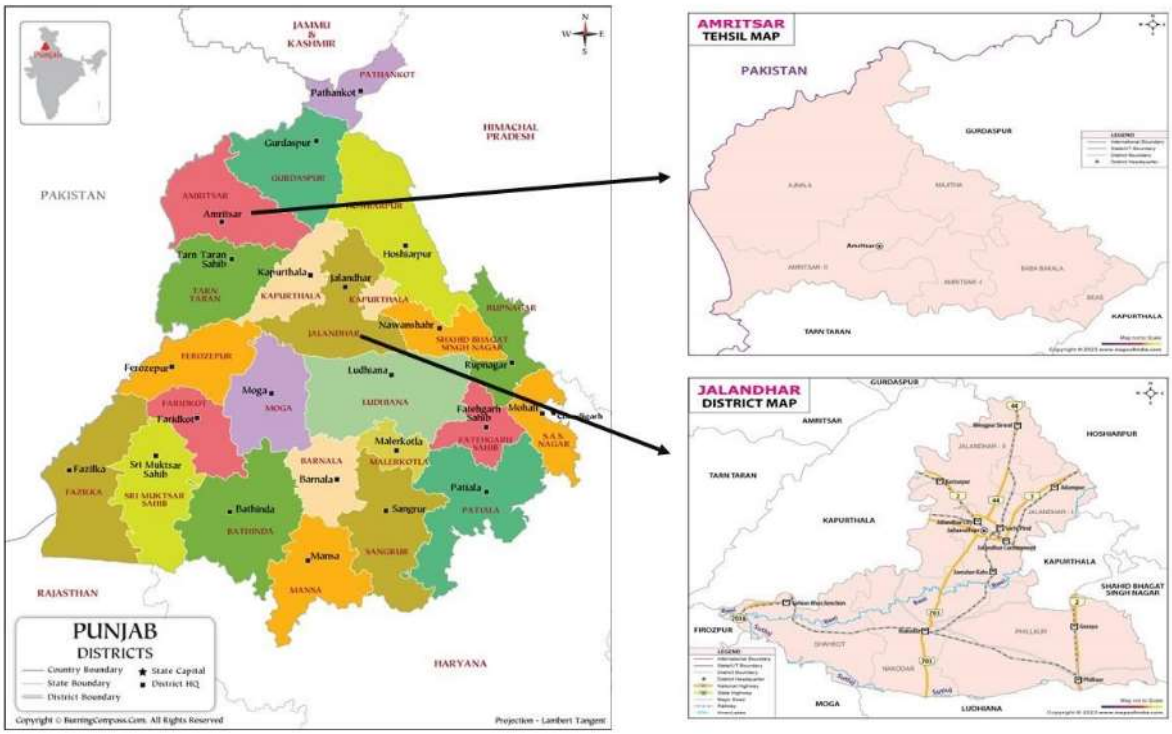

Fig. 1. Map to the study area (district Amritsar and Jalandhar)

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

The collected soil and grass plants samples would be acid digested in Laboratory fume hood using aqua regia ((HNO$_3$: HCl in 3:1 ratio) and triacid mixture (HNO$_3$:H$_2$SO$_4$:HClO$_4$ in 5:1:1 ratio) by method of Allen et al. (1986). Different metal(loid)s would be analyzed in soil and grass samples using techniques such as ICPMS and AAS and grass species having maximum metal(loid) 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(loid) concentration in plant tissue to soil (Ali et al., 2013):

$$BAF = C_{plant\ tissue} / C_{soil} \quad (1)$$

where $C_{plant\ tissue}$ and C_{soil} are the concentrations of metal(loid) 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):

$$TF = C_{stem/leaves} / C_{roots} \quad (2)$$

$$TF = C_{leaves} / C_{stem} \quad (3)$$

where C_{leaves}, C_{stem} and C_{roots} are the concentrations of the metal(loid) 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(loid) accumulation potential would be grown in pots/fields having metal(loid) (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(loid) 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(loid) 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(loid) Amelioration potential analysis grasses with amendments

Metal(loid) contents would be analyzed in soils pre and post treatments with grasses+biochar, grasses+earthworm and grasses+biochar+earthworm determine the remediation potential. Metal(loid) 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(loid)s.

• Estimation of metal(loid)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(loid) removal.

• Carrying out pot based experimentation to analyze the maximum metal(loid) 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(loid)s												
Estimation of metal(loid)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(loid) removal												
Carrying out pot based experimentation to analyze the maximum metal(loid) 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(loid) 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(loid) 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(loid)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 phytomining 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 contaminated soils.

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 vermiremediation and solid waste management, and Dr. Astha Bhatia (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. Astha Bhatia (Co-PI)	(i) Identification of grass plant species (ii) Analysis of key plant parameters involved in phytoremediation (iii) Assistance in pot based experimental study

References

Albornoz, C. B., Larsen, K., Landa, R., Quiroga, M. A., Najle, R., & Marcovecchio, J. (2016). Lead and zinc determinations in *Festuca arundinacea* and *Cynodon dactylon* collected from contaminated soils in Tandil (Buenos Aires Province, Argentina). *Environmental Earth Sciences*, *75*, 742.

Ali, H., Khan, E., & Sajad, M. A. (2013). Phytoremediation of heavy metals—concepts and applications. *Chemosphere*, *91*(7), 869-881.

Allen, S. E., Grimshaw, H. M., & Rowland, A. P. (1986). Chemical analysis. In: Moore, P.D., Chapman, S.B. (Eds.), Methods in Plant Ecology. Blackwell, Scientific Publication, Oxford, London, pp. 285–344.

Antoniadis, V., Golia, E. E., Liu, Y. T., Wang, S. L., Shaheen, S. M., & Rinklebe, J. (2019). Soil and maize contamination by trace elements and associated health risk assessment in the industrial area of Volos, Greece. *Environment International*, *124*, 79-88.

Balsamo, R. A., Kelly, W. J., Satrio, J. A., Ruiz-Felix, M. N., Fetterman, M., Wynn, R., & Hagel, K. (2015). Utilization of grasses for potential biofuel production and phytoremediation of heavy metal contaminated soils. *International Journal of Phytoremediation*, *17*(5), 448-455.

Banerjee, R., Goswami, P., Lavania, S., Mukherjee, A., & Lavania, U. C. (2019). Vetiver grass is a potential candidate for phytoremediation of iron ore mine spoil dumps. *Ecological Engineering*, *132*, 120-136.

Bhatti, S. S., Bhat, S. A., Kumar, V., Kaur, M., Minakshi, Sambyal, V., ... & Nagpal, A. K. (2018b). Ecological risk assessment of metals in roadside agricultural soils: A modified approach. *Human and Ecological Risk Assessment: An International Journal*, *24*(1), 186-201.

Bhatti, S. S., Kumar, V., Sambyal, V., Singh, J., & Nagpal, A. K. (2018a). Comparative analysis of tissue compartmentalized heavy metal uptake by common forage crop: a field experiment. *Catena*, *160*, 185-193.

Borah, G., & Deka, H. (2023). Vermiremediation of heavy metals (HMs)-contaminated agricultural land: synergistic changes in soil enzyme activities and earthworm's growth parameters. *Environmental Science and Pollution Research*, 30, 115266–115278.

Chandra, R., Kumar, V., Tripathi, S., & Sharma, P. (2018). Heavy metal phytoextraction potential of native weeds and grasses from endocrine-disrupting chemicals rich complex distillery sludge and their histological observations during in-situ phytoremediation. *Ecological Engineering*, *111*, 143-156.

Chintani, Y. S., Butarbutar, E. S., Nugroho, A. P., & Sembiring, T. (2021). Uptake and release of chromium and nickel by Vetiver grass (*Chrysopogon zizanioides* (L.) Roberty). *SN Applied Sciences*, *3*, 285.

Dradrach, A., Karczewska, A., & Szopka, K. (2020). Arsenic uptake by two tolerant grass species: *Holcus lanatus* and *Agrostis capillaris* growing in soils contaminated by historical mining. *Plants*, *9*(8), 980.

Farnezi, M. M. D. M., Silva, E. D. B., Santos, L. L. D., Silva, A. C., Grazziotti, P. H., Alleoni, L. R. F., ... & Miranda, L. C. (2022). Potential of forage grasses in phytoremediation of lead through production of phytoliths in contaminated soils. *Land*, *12*(1), 62.

Iyer, N. S., Mandaliya, D. D., & Dave, S. R. (2022). *In situ* microbial and phytoremediation of crude oil contaminated soil by *Cynodon* sp. *International Journal of Phytoremediation*, *24*(3), 235-244.

Jose, A., & Ray, J. G. (2018). Toxic heavy metals in human blood in relation to certain food and environmental samples in Kerala, South India. *Environmental Science and Pollution Research*, *25*, 7946-7953.

Katnoria, J. K., Arora, S., Bhardwaj, R., & Nagpal, A. (2011). Evaluation of genotoxic potential of industrial waste contaminated soil extracts of Amritsar, India. *Journal of Environmental Biology*, *32*(3), 363.

Kaur, J., Bhat, S. A., Singh, N., Bhatti, S. S., Kaur, V., & Katnoria, J. K. (2022). Assessment of the heavy metal contamination of roadside soils alongside Buddha Nullah, Ludhiana, (Punjab) India. *International Journal of Environmental Research and Public Health*, *19*(3), 1596.

Korzeniowska, J., & Stanislawska-Glubiak, E. (2023). The phytoremediation potential of local wild grass versus cultivated grass species for zinc-contaminated soil. *Agronomy*, *13*(1), 160.

Kumar, A., & Maiti, S. K. (2015). Effect of organic manures on the growth of *Cymbopogon citratus* and *Chrysopogon zizanioides* for the phytoremediation of chromite-asbestos mine waste: a pot scale experiment. *International Journal of Phytoremediation*, *17*(5), 437-447.

Kumar, A., Maiti, S. K., Tripti, Prasad, M. N. V., & Singh, R. S. (2017). Grasses and legumes facilitate phytoremediation of metalliferous soils in the vicinity of an abandoned chromite–asbestos mine. *Journal of Soils and Sediments*, *17*, 1358-1368.

Kumar, P., & Fulekar, M. H. (2022). Cadmium phytoremediation potential of Deenanath grass (*Pennisetum pedicellatum*) and the assessment of bacterial communities in the rhizospheric soil. *Environmental Science and Pollution Research*, *29*(2), 2936-2953.

Kumar, R., Kumar, R., Mittal, S., Arora, M., & Babu, J. N. (2016). Role of soil physicochemical characteristics on the present state of arsenic and its adsorption in alluvial soils of two agri-intensive region of Bathinda, Punjab, India. *Journal of soils and sediments*, *16*, 605-620.

Li, C., Ji, X., & Luo, X. (2019). Phytoremediation of heavy metal pollution: A bibliometric and scientometric analysis from 1989 to 2018. *International journal of environmental research and public health*, *16*(23), 4755.

Liang, J., Liu, Z., Tian, Y., Shi, H., Fei, Y., Qi, J., & Mo, L. (2023). Research on health risk assessment of heavy metals in soil based on multi-factor source apportionment: A case study in Guangdong Province, China. *Science of The Total Environment*, 858, 159991.

Liu, J., Xin, X., & Zhou, Q. (2018). Phytoremediation of contaminated soils using ornamental plants. *Environmental Reviews*, *26*(1), 43-54.

Morita, A. K. M., Niviadonski, L. M., Leite, M. B., & Wendland, E. (2023). Using plants to manage uncontrolled dumpsites: metal phytoremediation by endemic species from subtropical

sites. *International Journal of Environmental Science and Technology*, 1-12. https://doi.org/10.1007/s13762-023-05306-9

Ram, B. K., Han, Y., Yang, G., Ling, Q., & Dong, F. (2019). Effect of hexavalent chromium [Cr (VI)] on phytoremediation potential and biochemical response of hybrid Napier grass with and without EDTA application. *Plants*, *8*(11), 515.

Rolka, E., Wyszkowski, M., Szostek, R., & Glinka, A. (2023). Role of feather reed grass (*Calamagrostis acutiflora*) in phytoremediation of urban soils. *International Journal of Phytoremediation*, *25*(7), 868-879.

Sharma, J. K., Kumar, N., Singh, N. P., & Santal, A. R. (2023). Phytoremediation technologies and their mechanism for removal of heavy metal from contaminated soil: An approach for a sustainable environment. *Frontiers in Plant Science*, *14*, 1076876.

Sinduja, M., Sathya, V., Maheswari, M., Dinesh, G. K., Dhevagi, P., Prasad, S., ... & Kalpana, P. (2023). Phytoextraction potential of Chrysanthemum and Cumbu Napier hybrid grass to remediate chromium-contaminated soils using bioamendments. *International Journal of Environmental Research*, *17*(1), 8.

Song, X., Li, C., & Chen, W. (2022). Phytoremediation potential of Bermuda grass (*Cynodon dactylon* (L.) pers.) in soils co-contaminated with polycyclic aromatic hydrocarbons and cadmium. *Ecotoxicology and Environmental Safety*, *234*, 113389.

Sultana, R., Ahmed, T., Islam, S. M. N., & Uddin, M. N. (2022). Barnyard grass (*Echinochloa crus-galli* L.) as a candidate plant for phytoremediation of arsenic from arsenic-amended and industrially polluted soils. *Frontiers in Soil Science*, *2*, 927589.

Tang, H., Chen, M., Wu, P., Faheem, M., Feng, Q., Lee, X., ... & Wang, B. (2023). Engineered biochar effects on soil physicochemical properties and biota communities: A critical review. *Chemosphere*, *311*, 137025.

Tran, T. K. A., Islam, R., Le Van, D., Rahman, M. M., Yu, R. M. K., & MacFarlane, G. R. (2020). Accumulation and partitioning of metals and metalloids in the halophytic saltmarsh grass, saltwater couch, *Sporobolus virginicus*. *Science of the Total Environment*, *713*, 136576.

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) *(TA will help in sampling, washing glassware, experimental setup etc.)*	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(loid) 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**

proposal

ORIGINALITY REPORT

14%	10%	11%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	coek.info Internet Source	1%
2	daneshyari.com Internet Source	1%
3	www.mdpi.com Internet Source	1%
4	Sandip Singh Bhatti, Vaneet Kumar, Anupama Kumar, Jason K. Kirby et al. "Potential carcinogenic and non-carcinogenic health hazards of metal(loid)s in food grains", Environmental Science and Pollution Research, 2020 Publication	1%
5	Sandip Singh Bhatti, Vaneet Kumar, Anupama Kumar, John Gouzos et al. "Potential ecological risks of metal(loid)s in riverine floodplain soils", Ecotoxicology and Environmental Safety, 2018 Publication	1%

6	Salwinder Singh Dhaliwal, P.K. Taneja, Jaswinder Singh, Sandip Singh Bhatti, Ravinder Singh. "Cadmium Accumulation Potential of Brassica Species Grown in Metal Spiked Loamy Sand Soil", Soil and Sediment Contamination: An International Journal, 2020 Publication	1 %
7	Ram Chandra, Vineet Kumar, Sonam Tripathi, Pooja Sharma. "Heavy metal phytoextraction potential of native weeds and grasses from endocrine-disrupting chemicals rich complex distillery sludge and their histological observations during in-situ phytoremediation", Ecological Engineering, 2018 Publication	1 %
8	GREEN CONSULT S.A.. "ITS de la Segunda MEIA-SD del Proyecto de Exploración El Padrino-IGA0009358", R.D. N° 024-2016-MEM-DGAAM, 2020 Publication	1 %
9	Kui Cai, Zefeng Song. "Bioconcentration, Potential Health Risks, and a Receptor Prediction Model of Metal(loid)s in a Particular Agro-Ecological Area", Applied Sciences, 2019 Publication	1 %

10	Submitted to Indian Institute of Management, Indore Student Paper	1 %
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12	Adarsh Kumar, Subodh Kumar Maiti, Tripti, Majeti Narasimha Vara Prasad, Raj Shekhar Singh. "Grasses and legumes facilitate phytoremediation of metalliferous soils in the vicinity of an abandoned chromite–asbestos mine", Journal of Soils and Sediments, 2015 Publication	<1 %
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