MONGOLIAN HEAVY METAL POLLUTED SITES AND THEIR VEGETATION

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G. Disan from UB and I Lichtscheidl from UNIVIE combined to investigate heavy metal tolerant plants and to exploit their potential for remediation of mine spoil dumps. Their main goals and achievements were:

Research

We analyzed the vegetation of mine dumps in Mongolia and in Austria in the frame of field work and excursions, in combination also with students courses because of our focus in education. Selected plants were further investigated in the laboratories of UB and UNIVIE.

In Mongolia, we visited: Active copper mine in Erdenet, Active zinc mine in Tsairt, abonded gold mine in Boro, and coal mine in Tavan Togul.

We selected plants which grow in the most polluted areas for further investigation. They were classified with the help of Dr. Urgamal Magsar (MAS) and Dr. Oyun Batlai, taxonomists in the National University of Mongolia. Prof- Katarzyna Turnau from Krakow University/Poland joined in the second excursion to Mongolia and shared her expertise about microbes in soils and plants.

Laboratory work on plants collected in the areas included analysis of the morphology and anatomy of the selected plants, tolerance of plant cells towards hm and expression of stress symptoms, and uptake or exclusion of hm from the plant body, as well as isolation and characterization of plant endophytes and soil microbes.

Education

In Austria:

IL together with Wolfram Adlassnig and Brigitte Schmidt gave a project practicum about heavy metal stress in plants, from which 2 Bachelor Theses resulted and 4 normal protocols. In several excursions in Austria, IL supervised research projects of Master students in Ecology and Botany.

In Mongolia:

Plenary talks were given in both Symposia about state-of-the-art techniques and research trends. Protocols were and are exchanged about analysis of soils and plants, research papers were and are discussed and best practice of instruments is evaluated.Young Mongolian researcher Ulziinyam Rentsendorj was awarded with an Ernst Mach Stipendium and spends her research stay with IL, UNIVIE to learn and work about the aims of MOVE.

Communication

Communication with and among researchers in Mongolia was achieved by organizing two meetings in UB, one smaller kick-off meeting at the start of the project and one large Symposium at the end of the meeting. A book of abstract resulted. In Austria, research was extended to cooperation with Polish microbiology colleagues in the frame of the WTZ TrinumPerfectum and common excursions and meetings shaped our common research.

In Mongolia, contact to mining companies was very important for the environmental miners who got information about possibilities of phytoremediation, and for us because we plan now some experimental fields in the mining areas where we can bring our lab results into practice. In addition, also contact to environmental officers of the Communities effected by mining proved very important and yielded start of cooperation between Mongolian researchers and Mining Communities.

We are thankful to EPU/ÖAD for the possibilities offered and the results achieved by this project and attach a detailed report.

General Goals of the project

High concentrations of heavy metals (hm) in soil are highly toxic for organisms. Accordingly, metal mining dumps represent a big danger for the local population. In Mongolia, mining activities in the last two decades have led to seriously destroyed land and dangerous health situation for the population. Environment and eco-systems have suffered strongly due to reckless exploitation of metal mining sites, leaving large contaminated areas with barren soil, leading to contaminated water and making soils disabled for agricultural use and animal husbandary. However, some plants and microbes developed resilience to metal contamination, they can grow in toxic mine spoil heaps. They are candidates for phytoremediation, i.e. growing new healthy vegetation over toxic ground.

Also in Austria, similar as in other middle-European countries, mine waste has remained from earlier exploitation. This is however often not a danger for the environment, because areas are small and in remote regions, but they are, on the contrary, hot spots for plants that are tolerant to hm.

Accordingly, G. Disan from Institute of Chemical Ecology in Academy of Sciences of Mongolia (GD/UB), and I Lichtscheidl from Cell Imaging and Ultrastructure Research, University of Vienna (IL/UNIVIE) combined to investigate heavy metal tolerant plants and to exploit their potential for remediation of mine spoil dumps.

Soil is the basis of terrestrial life, particularly for agriculture, forestry, and general land-use by man. We therefore focused in the frame of this project on the terrestrial ecosystem in heavy metal polluted land and the biota within, it is plants and their root systems. They interact and also actively shape their environment. We investigated the vegetation of hm contaminated areas in Mongolia and in Austria for hm tolerant plants that can be used either for stabilizing hm in the soil, hence preventing uptake by plants and seepage into groundwater (“phyto-stabilization”), or for extracting hm from soil by plants specialized in hyper-accumulating hm (“phyto-extraction”, “phyto-mining”), or for the production of high biomass gain from growth of short-rotation plants for bio-energy production. It is of importance that plants are studied and selected, which have their origin in the areas of interest, because they are adapted to the ecological situation and they cause no harm considering invasiveness and replacement of native vegetation.Plants and soils are also heavily influenced by soil microbes such as fungi and bacteria, as well as by endophytic microbes. Big efforts have been started to improve plant growth in difficult ecologic situation by supplementing them with beneficial microbes (eg UMBRELLA, Wernitznig et al.2013). We therefore invited Prof Katarzyna Turnau from University of Krakow in Poland to cooperate in our project and she thankfully accepted. She has joined us so far in our research and field work, in our symposium and communication efforts, and in our teaching and education goals.

The results of our One Year project MOVE can be summarized according to the following main goals: Research – Education - Communication

Research

In the main focus of our research was the investigation of plants that are tolerant to soil pollution by hm. Accordingly, we analyzed the vegetation of mine dumps in Mongolia and in Austria in the frame of field work and excursions, in combination also with students courses because of our focus in education. Selected plants were further investigated in the laboratories of UB and UNIVIE.

Field work was carried out in Austria and in Mongolia in order to analyze the vegetation in hm rich soil investigate the reactions of plants to hm develop measures how to mitigate toxic environmental situations.

In Austria, we focused on abandoned silver and zinc mines in Ramingstein/Sbg and Arzberg/Stmk abandoned copper mine in Reichenau/NÖ natural nickel and chromium rich Serpentinite areas in Redlschlag/Bgld, Kraubath/Stmk, Pernegg/Stmk abandoned copper mines in Hüttschlag/SalzburgWe attach vegetation lists and students' reports. They were/will be incorporated into our BIOREM database www.biorem.univie.ac.at.

In Mongolia, we visited active copper mine in Erdenet Active zinc mine in Tsairt abonded gold mine in Boro coal min in Tavan Togul.

We could not make a complete list of vegetation, but we selected plants which grow in the most polluted areas for further investigation. They were classified with the help of Dr. Urgamal Magsar (MAS) and Dr. Oyun Batlai, taxonomists in the National University of Mongolia.

The ecologic situation of the areas will be taken up into the BIOREM data base. Pictures of the classified plants were communicated to colleagues from Greifswald University and will be incorporated into the website of Virtual Guide to the Flora of Mongolia by the University of Greifswald (https://floragreif.uni-greifswald.de/floragreif/).

Laboratory work on plants collected in the areas included:Analysis of the morphology and anatomy of the selected plants (eg hairs, glandular cells, special kinds of root re-inforcements …)

Tolerance of plant cells towards hm and expression of stress symptoms uptake or exclusion of hm from the plant body: acid digestion of soils and plants, measuring the hm content chemically by ICP-OES localize hm in plant tissue by EDX in the scanning electron microscope.

In a further step, GD started to analyze stress metabolites in Zinc- and Nickel hyper accumulating plants by LCMS-QTOF instruments.

Education

We are well aware that we need the experience and dedication of young researchers to do active research in the field and promote progress for bioremediation. We therefore both have a strong motivation to teach in the frame of organized courses and in the frame of Bachelor- and Master Theses.

In Austria

IL together with Wolfram Adlassnig and Brigitte Schmidt gave a project practicum about heavy metal stress in plants, from which 2 Bachelor Theses resulted about Noccaea caerulescens in serpentinite and about different species of Silene in copper, nickel and zinc rich soil. Also 4 normal protocols were made from those participants who had their Bachelor Thesis already finished.In several excursions, IL went with the students to Hirschwang/Rax (copper mine waste), Ramingstein and Arzberg (zinc waste), and to the natural serpentinite areas in Redlschlag, Kraubath and Pernegg.

Both, practicum and excursions were organized together with Stephan Krämer and Jan Wiederhold from the Geological Department in the frame of their Master student course about heavy metals in soils, and with strong cooperation of GD.

For understanding of the cooperation of soil microbes in plant tolerance towards copper, IL worked in the abandoned copper spoil heap “Schwarzwand” together with Katarzyna Turnau from Institute of Environmental Sciences, University of Krakow/Poland.

In the frame of a specific research project for Ecologists and for Botanists, hands-on training in plant cell physiological techniques was given and 3 small projects were finished about the copper tolerant plant Saxifraga stellaris from a copper mine waste in Schwarzwand/Sbg, about Rumex acetosella from copper and zinc rich areas, and about different species of Noccaea in nickel and zinc rich soil.

In the frame of the Department Seminar of IL, topics and results were presented and discussed.In the frame if Ernst Mach program, the young researcher Ulziinyam Rentsendorj was awarded to spend a research stay at CIUS, UNIVIE. In her currently running research in Vienna, Mrs. Ulziinyam Rentsendorj specializes in various techniques e.g. SEM-EDAX, ICP as well as wet chemistry sample processing. Up to date, she is analyzing samples collected during this particular project with above techniques and a separate report will follow with fine details of her results at the end of scholarship period. Preliminary observations show a positive and reproducible data well following the current environmental conditions and their vegetation. Participation in excursions, lectures/seminars and project related discussions is an essential part of her stay.

In Mongolia

Plenary talks were given in both Symposia about state-of-the-art techniques and research trends. Protocols were and are exchanged about analysis of soils and plants, research papers were and are discussed and best practice of instruments is evaluated.

Communication

Communication between partners and also with companies, artisanal miners and authorities is of paramount importance for successful remediation. We therefore made more excursions and meetings than could be funded, but we paid from our own sources because we think that it was important to have two meetings in UB, one at the beginning so that we could start our plant work, and one in the end where we could explain also to stakeholders what we found and what could be done to improve the environmental situation. Meetings in Austria occurred in the frame of common excursions and invited guest seminars, where also our long-term colleagues Katarzyna Turnau and her post-doc assistants, Przemek Rysak and Piotr Rozpadek from University of Poland participated, and Marek Vaculik and his PhD student Jan Kovac from University of Bratislava/SK.

Communication with and among researchers in Mongolia

was started with a kick-off meeting in July 2017 in Ulaanbaatar at the start of the project year, in July 2017. Colleagues from the Academy of Sciences in UB and from the National University in Mongolia participated; they showed great interest and shared their experience with us.This led us to organize a 1st International Symposium about Mongolian heavy metal rich sites and their vegetation in UB at the end of the project year, in June 2018.

Communication with mining companies in Mongolia

In Mongolia, we were received by the Environmental Scientists of:

Boroo Gold Mine, a former open pit gold mine which was operated from 2004 through to 2015 until a severe environmental accident. The polluted area has been remediated since, and has led to good results. However, there is still a vast amount of arsenic in soil and waters. June 2017. Plants were further analysed in UNIVIE. Soil was analysed in UB.

Tsairt Mineral, the largest active zinc mine of the region, is a joint venture by the Mongolian and Chinese Investors. Ore is deposited in two large heaps before further processing. The company provided data of hm in soils and led us to various areas in order to investigate the vegetation. June 2018. Plants were further analysed in UNIVIE.

Tavan Tolgoi Coal Mine, is one of the world largest coking coal deposit (estimated 6.4 billion tons) located in South Gobi is under operation since 2010. Divided into six different operation sites all of them owned by Erdenes Tavan Tolgoi, a government owned company. Dust generated by operation especially, the amount of PM 10 and PM 2.5 particle tends to increase in the area. Excess use of ground water and its scarcity has a long term environmental effect according to the environmental department. Both plant and soil samples were analysed in UNIVIE.

Erdenet Copper-Molybdenum Mine, the largest active copper mine of the region, presents a serious threat for the environment due to the finely grounded ore remains as well as to mine drainage. The company, however, did not allow us to enter. We could observe and take samples only from outside of the fences. Samples were taken from the mining wastewater impoundment. Level of metalloids in mining discharge after ore concentration and its dust from tailing beach cause severe environmental pollution in the urban area. Plant and soil samples are under investigation in UNIVIE.

Communication with Communities in Mongolia

Erdenet City Department of nature, environment and tourism and the head and senior officers welcomed us. Visit of mining discharge area was guided by one of the environmental officers.Baruun-Urt City, is a seat of Tsairt Mineral LLC. Meeting with environmental specialists from the Sukhbaatar province department of nature, environment and tourism. Reports on local flora, environmental management reports etc. was kindly provided for our research purpose as a reference.

Ulaanbaatar is a seat of most academic organizations in Mongolia. Successful meetings with numerous scientists from the Mongolian Academy of Sciences (e.g. Secretary General Dr. Avid Budeebazar, Director of the Institute for chemistry and chemical technology. Dr. Jargalsaikhan Lkhasuren and colleagues e.g. Dr. Azzaya Tumendelger, Badgaa Amarsanaa) as well as Prof. Dr. Oyun Batlai (head of department for biology, National University of Mongolia), Assistant Prof. Dr. Buyan Chuluun (Department for Chemistry, NUM) et al. during official visit was held. Meeting with environmental offcials from the Minsitry of nature and green development, Dr. S.Bayarkhuu, former scientist in the field of gene banking was also held.

In media, a newspaper interview (D.Gunbilig, “Plants with potential for soil remediation” Daily News 2018 June 15 p.19) and a series of TV news and short interview with Prof. Dr. Irene Lichtscheidl in TV6 channel broadcasted (See Appendix 3).

Continuation and Sustainability of the Project MOVE

Our activities awoke sufficient interest so that the former colleague of G Disan from ICCT, Academy of Sciences, Amarsanaa Badgaa, considers to apply for financing for a research project on phytoremediation of industrial/oil polluted urban areas for the next fiscal year of 2019-2020.

In continuation of this project in the frame of EPU, we aply for MOVE-ON, the chemical and physiological analysis of Mongolian plants stressed by heavy meals and by water deficiency. This will also include again the cooperation of Katarzyna Turnau and her expertise about microbes in soils and in plants.

In Austria, we continue to analyse the collected samples in the laboratory in the frame of specific research projects with young researchers (Bachelor and Master students) in order to gain two, hopefully three publications.