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EMJM PROMISE – The New International Erasmus Mundus Joint Master in Sustainable Mineral and Metal Processing Engineering

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Abstract: The challenge of attracting young people to the field of mineral processing as well as the ever-growing worldwide demand for minerals and metals together with lower-grade deposits and shortages of energy and water triggered the establishment of the new Erasmus Mundus Joint Master Program PROMISE. The consortium of four mining universities in Europe and Chile aims at master level education on engineering and sustainability issues in mineral processing. The first academic year of PROMISE will start in September 2022.

Keywords: Mineral processing, Engineering, Sustainable, Erasmus Mundus Joint Master, PROMISE

EMJM PROMISE – Das neue internationale Erasmus Mundus Joint Master Programm für nachhaltige Aufbereitungs- und Veredlungstechniken von mineralischen und metallischen Rohstoffen

Zusammenfassung: Die Herausforderung, junge Menschen für den Fachbereich „Aufbereitung und Veredlung“ zu interessieren, wie auch der stetig steigende weltweite Bedarf an mineralischen Rohstoffen und Metallen bei gleichzeitiger Verarmung der Lagerstätten sowie Energie- und Wasserknappheit waren der Auslöser zur Einrichtung des neuen Erasmus Mundus Joint Master Programms PROMISE. Das Konsortium von vier Bergbauuniversitäten in Europa

und in Chile zielt bei der Masterausbildung auch auf Nachhaltigkeitsaspekte in der Aufbereitungssparte ab. Der erste Jahrgang von PROMISE wird bereits im September 2022 starten.

Schlüsselwörter: Mineralaufbereitung, Engineering, Nachhaltig, Erasmus Mundus Joint Master, PROMISE

1. The Consortium of EMJM Promise

The Erasmus Mundus Joint Master (EMJM) programs are delivered by international consortia with specific expertise and interest in the concerned study areas and professional domains. They are intended for students at master's level from all over the world. Besides providing excellent education, “mobility” of the students—i.e. spending at least two semesters at universities outside their own country of residence—is one of the key incentives. This shall enable them to build a worldwide network and thus contribute to connecting people globally.

In order to promote these goals, the European Union provides a number of substantial scholarships to selected students of the first four cohorts. Successful EMJMs build up a reputation during the funded project runtime and can continue as a self-sustaining Master's program afterwards by continuously attracting self-funded students. Currently, 163 EMJMs are listed in the Erasmus Mundus Catalogue at https://www.eacea.ec.europa.eu/scholarships/erasmus-mundus-catalogue_en.

EMJM PROMISE, offering an excellence academic content in the area of mineral processing, will start its first academic year in September 2022 and is organized by four university partners in four countries:

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- University of Zagreb, Croatia

Due to the program being a joint master's, all graduating students will be awarded a separate master's degree from both University of Oulu and Montanuniversität Leoben. Depending on their chosen pathway in the third semester, they may also get the degree from Federico Santa María.

2. The Motivation for EMJM Promise

The complete name of the program presented here is "Erasmus Mundus Joint Master in Sustainable Mineral and Metal Processing Engineering"—in short: PROMISE.

The program is built on the strengths and the complementary areas of expertise of the four partner universities in recovery and extraction of minerals and metals, such as comminution, metallic and industrial minerals physico-chemical processing, wet and dry processes, mineral and metal recycling and circular economy. Their involvement in a single program enables integration of the whole chain of mineral processing required for the mining industry.

The presented program reflects the future demands of mining and mineral processing engineering, the needs of the industry, disruptive innovation and mobility (triggered by key economic, incremental and societal trends), and required competences and knowledge that a mineral processing engineer should have to cope with those challenges.

The aim of PROMISE is to bear first-class mineral processing engineers at master's level. Mineral processing represents a unique combination of engineering, chemistry, and mathematics. Mineral processors use their specialized knowledge of the chemical and physical properties of minerals to extract the valuables from their natural ores and from anthropogenic sources. They maximize production whilst minimize the overall environmental impact through sustainable practices. Additionally, great savings of resources (water and energy) and time can be achieved if mineral processing professionals know and apply mathematical modelling and simulation in plant design and unit operation (like comminution, sizing and classifying, separation techniques).

The program takes into consideration the importance of minerals for the EU and the importance to improve their resource and energy efficiency. According to the European Commission, (https://ec.europa.eu/growth/sectors/raw-materials/industries/minerals/metalllic_en)[1], EU's metallic minerals sector produces a wide range of ores yielding metals or metallic substances and the EU is an important producer of chromium, copper, lead, silver, and zinc. However, most metallic ores that supply the European metallic industry are imported. Only a few EU countries, like Austria, Finland, Greece, Ireland, Poland, Portugal, and Sweden, have active mines. In those countries, metal mining contributes more than 1% to the global production of a particular metallic mineral.

Metal and mineral raw materials play a vital role in our everyday lives. There is an increasing demand in the quantity and diversity of minerals, metals, and materials, and this demand will accelerate as we move towards renewable energy, electromobility, communication, and other clean technologies, like full use of electric vehicles. The demand for finite resources will be enormous while supplies decline. Therefore, the need to reprocess old mine tailings and industrial deposits will increase. So will also the need to overcome the greatest challenge of all in the quest for a circular economy—recycling. Particularly the enormous quantities of metals tied up in Waste Electrical and Electronic Equipment (WEEE) call for action.

It is also a fact that the general future mobility requires sustainable materials and that low carbon technologies require lithium, cobalt, nickel, manganese, graphite and copper, and other metals, including rare earths. Therefore, the mining of metals and the sophistication of minerals processing that will support the technologies that operate alternatives to the large-scale mining of fossil fuels is of upmost importance.

Highly skilled mineral processing engineers are essential in a world that is dependent on an increasing supply of minerals to meet its needs for energy and materials. The skills of mineral processing engineers need to be broadened to follow the goal of a sustainable development strategy to increase employment competitiveness. For instance, with regard to sustainable development, the Association of Mineral Processing emphasized that the total resource recovery, recycling, by-product recovery, and objective and defensible measures of environmental impacts, particularly the ability to reconcile trade-offs between different social costs and benefits, must be reinforced and the educational curriculum should contain all these facets.

This awareness of increasing demand for metals and minerals and the responsiveness of continuous improvement by training of people is being addressed by the PROMISE consortium (Fig. 1). Its aim is to improve education and productivity whilst sustaining Earth's carrying capacity through the adoption of genuine business and sustainability frameworks.

Considering the increasing world population with its ever-growing demand for minerals and metals, on the one hand, and the shortage of high-grade deposits, water, and energy, on the other hand, it is obvious that the mining and mineral processing sector can have a substantial impact on the sustainability of today's lifestyle.



Fig. 1: Logo of EMJM PROMISE

TABLE 1
List of Associate Partners in PROMISE

Industry Partners			
Metso Outotec OY	Finland	PMT-Jetmill GmbH	Austria
Terrafame Group OY	Finland	CEMTEC Cement and Mining Technology GmbH	Austria
Agnico Eagle OY	Finland	Zementwerk LEUBE GmbH	Austria
Geopyörä	Finland	IFE Aufbereitungstechnik GmbH	Austria
Dragon Mining OY	Finland	Bernegger GmbH	Austria
Monolithos	Greece	Omya GmbH	Austria
BioSO4 OY	Finland	Binder & Co AG	Austria
Boliden	Sweden	RHI Magnesita GmbH	Austria
Copperstone Vicaria AB	Sweden	Corporación Chilena de Investigación del Agua, Cetaqua	Chile
Timegate Instruments OY	Finland	Centro Nacional de Pilotaje de Tecnologías para la Minería	Chile
Spectra—Media d.o.o.	Croatia	Minera Santo Domingo	Chile
Depos d.o.o.	Croatia	Saulo SpA	Chile
Holcim (Hrvatska) d.o.o.	Croatia	Seven-C Project SpA	Chile
FLSmidth GmbH	Austria	Maelgwyn Mineral Services	Germany
Kärntner Montanindustrie GmbH	Austria	–	–
Research Centers			
CETEM—Centro de Tecnologia Mineral	Brazil	GTK—Geologian tutkimuskeskus	Finland
Helmholtz Institute Freiberg for Resource Technology	Germany	–	–
Universities			
Universidad Politécnica de Madrid/E.T.S.I. de Minas y Energía	Spain	Universidad Católica del Norte	Chile
Copperbelt University	Zambia	–	–

By designing a master's program for mineral processing that explicitly addresses these topics to a substantial extent, the consortium contributes to the solution of this global challenge. Besides the necessary lectures on the basics and fundamentals of mineral processing, many courses aim directly at sustainability issues as described later. PROMISE is based on existing study programs and courses at the partner universities and integrates them in a joint curriculum. It also contains new courses to address the problems faced by mineral processing plants and the needs of mineral processing students.

In order to provide real-life context for the lectures, the consortium currently also comprises 35 associated partners (APs), like mining companies, equipment manufacturers, research centers, or further universities (Table 1). They contribute mainly by bringing up the topics and environments for doing the master's theses and providing students with internships.

3. Timeline, Modules, and Curriculum

As an EU funded project, PROMISE is scheduled to run for five years and teach four cohorts of students. The program is designed for 25 new students each year. For these, 21 scholarships are available, while the remaining four will be self-funded students. Thus, 100 master's degrees are expected to be awarded during the project's primary runtime.

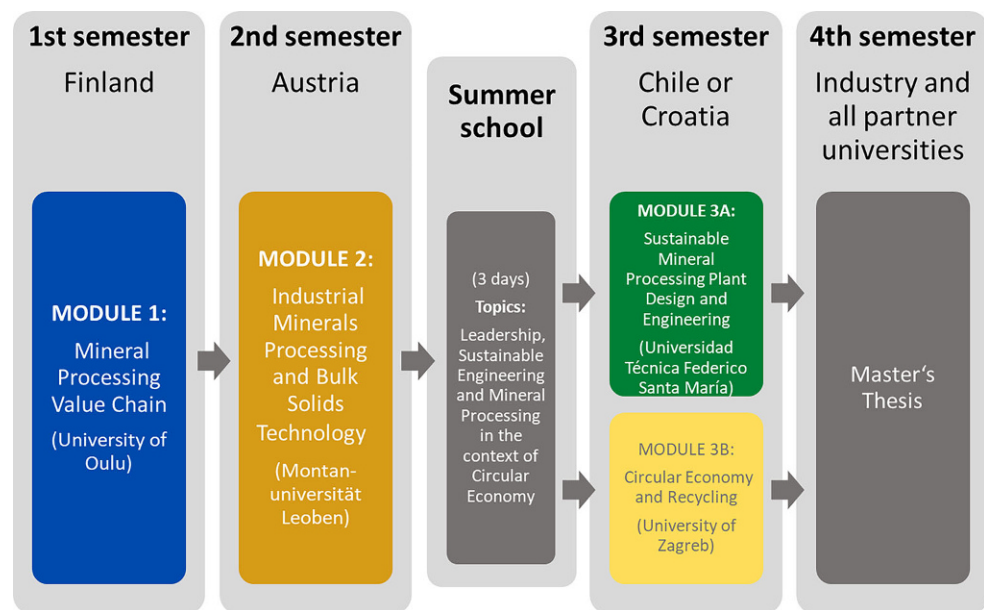
During the two years of the PROMISE master's, the students will be awarded 120 ECTS credits from four modules. Three modules provide the lectures, lab courses, and field trips, while the last is dedicated to the thesis. Between the second and third semesters, a Summer School will be held that serves to promote the students' soft skills. Participation in at least one Summer School is obligatory. The master's program will be taught entirely in English.

All participants will spend the first semester in Finland and the second in Austria. In the third semester, about half of them will continue in Croatia, the other half will go to Chile. The thesis can be done at any of the four partner universities. The timeline of the program is outlined in Fig. 2.

3.1 Module 1: "Mineral Processing Value Chain" at University of Oulu

The Oulu Mining School, part of the University of Oulu, is currently the only national Finnish institution offering degrees in mineral processing, both at the undergraduate and postgraduate levels. This happens at a time when the world is increasing its demand for minerals and metals and the mining industry is becoming increasingly technology-driven and relies on a highly skilled workforce. The relevant study programs offered at the University of Oulu are:

Fig. 2: Timeline and modules of EMJM PROMISE



- MSc in Mineral Resources and Sustainable Mining with specialization in Mineral Processing
- BSc+MSc in Mining Engineering and Mineral Processing as a five-year degree program

This module deals with a wide area of the recovery of minerals, covering the whole chain from mineralogy to raw material for smelters. Students will learn about the major aspects of mineral processing, such as mineral characterization, geometallurgy, mineral separation processes, modelling and simulation, automation, and quality requirements of marketable concentrates.

The fundamentals are presented with a critical and applied look, considering technical and economic aspects. These are complemented with practical experience in specific laboratories for each unit operation and in an automated pilot plant, and also with visits of industrial plants. Modelling and simulation software dedicated to mineral processing makes it possible to integrate mineralogical/modal data into plant optimization (Table 2).

The University of Oulu has extensive knowledge in the field of mineral characterization and runs laboratories of optical microscopy, geochemistry, and geotechnics. MAKE, the Centre for Material Analysis, applies a range of characterization techniques, such as FESEM, EPMA, XRD, and XRF to

TABLE 2 List of courses in the first module	
Course	ECTS
Mineral Processing Technologies	5
Automation in Mineral Processing (focus on control)	5
Quality Requirements for Concentrates	5
Modelling and Simulation in Mineral Processing	5
Geometallurgy and Process Mineralogy	5
Elective	5

identify surface mineral properties, mineral liberation, minerals, microstructure, and textures by means of the latest available equipment.

3.2 Module 2: "Industrial Minerals Processing and Bulk Solids Technology" at Montanuniversität Leoben

Montanuniversität Leoben is a global center of excellence in its core disciplines that are oriented along the value-added life cycle from raw materials to high-performance materials. Part of this is delivered by the Chair of Mineral Processing at the Department Mineral Resources Engineering. It is the center for dry and wet processing of primary and secondary resources to marketable products by applying physical, physical-chemical and chemical methods. Montanuniversität is the only national institution in Austria delivering knowledge in mineral processing and is also an active part of the international scientific community in this respect.

The following programs regarding mineral processing are offered in Leoben:

- MSc in Raw Materials Engineering
- BSc in Mineral Resources Engineering
- University Course for Professionals: Processing Raw Materials

The second module focuses on industrial minerals and building materials. These comprise minerals that do not serve as sources of metals, although they may contain these elements but are used for the properties of these minerals. Some prominent examples are calcite, magnesite, and talc. The respective lecture is complemented by a hands-on course in the well-equipped laboratory that deals with selected topics from this range of minerals.

Course	ECTS
Processing of Industrial Minerals	3
Lab-Course on Processing of Industrial Minerals	3
Processing of Construction Raw Materials	2
Study Trip to Mineral Processing Plants	1
Project Study Mineral Processing	3.5
Bulk Solids Technology	4
Sampling and Homogenization	4
Sustainability in the Raw Materials Sector	3
Special Mineral Economics	1.5
Elective	5

This module also contains several supplementary topics, such as sampling and homogenization as a means for proper planning of test campaigns and providing a consistent feed to the plant. Another core element within the processing plant taught here is bulk solids technology. Obligatory lectures also cover sustainability concerning raw materials and mineral economics.

An important course in this module is the project study, where the students actively work on a concrete actual challenge within mineral processing. This requires literature study, application of prior knowledge in the subject, own lab work, and composition of a proper and concise report. (Table 3).

3.3 Module 3A: “Sustainable Mineral Processing Plant Design and Engineering” at Universidad Técnica Federico Santa María

Santa María is the only technical university in Chile that specializes in teaching engineering. It has a Department of Mining, Metallurgy, and Materials Engineering. In addition, its chemical engineering department also addresses some aspects of mining and mineral processing. Both departments have well-established master's programs that focus on training professionals with skills that would help the local mining industry in Chile:

- MSc in Chemical Engineering
- MSc in Metallurgy

Aiming at advanced and sustainable mineral concentration, this module will cover innovative approaches to mineral and metal processing. In terms of particle size reduction (i.e. comminution), energy curves will be addressed, so those energy requirements will be specifically determined for the different stages of comminution. In terms of valuable particle separation, concepts such as incremental and step-change innovation will also be addressed. Fine particle flotation separation and trace valuable separation must be dealt with, since ore mineralogy is becoming more complex and making processing much harder.

Consequently, courses, such as process mineralogy, physical separation, and flotation innovations, are manda-

Course	ECTS
Energy Efficient Comminution	5
Water Efficient Mineral Processing	5
Sustainable Mineral Processing Plant Design	5
Digitalization and Smart Systems in Mineral Processing	5
Sustainable Mineral Processing Engineering	5
Elective	5

tory in postgraduate degree training. Environmental aspects must also be considered, since mineral and metal process engineering has very large water and energy footprints. In practical terms, postgraduate courses to be taught in this module are energy-efficient comminution, water-efficient mineral processing, sustainable mineral processing plant design, digitalization and smart systems in mineral processing, and sustainable mineral processing engineering. (Table 4).

3.4 Module 3B: “Circular Economy and Recycling” at University of Zagreb

The University of Zagreb is the only Croatian national institution to offer study programs in Mining Engineering, and the courses in Mineral Processing are an integral part of them. To ensure sustainability, the primary raw materials are being preserved and mineral processing methods have been widely used in the recycling of solid waste to obtain secondary raw materials. Accordingly, the University of Zagreb offers the following programs:

- BSc in Mining Engineering,
- MSc in Mining Engineering with the subprograms Mining Engineering, Geotechnical Engineering, Waste Treatment and Disposal

This module covers the transition from the traditional linear “take-make-dispose” concept to sustainable circular economy—“take-recycle.” Students will learn about sustainable mineral/waste resource management through maximizing yield and utilizing secondary raw materials by reuse, recycling and reprocessing minerals/waste.

The knowledge acquired through the first two modules will be upgraded by management and application of technological processes and procedures in the circular economy, solid waste recycling, tailings management and reprocessing, soil remediation, naturally occurring radioactive materials (NORM) residues processing and disposal. Theoretically acquired knowledge will be supplemented by laboratory exercises (Mineral Processing and Environmental Protection Laboratory, Geomechanical Laboratory, Lab-

TABLE 5
List of courses in module 3B

Course	ECTS
Recycling and Waste Treatment	5
Urban Mining and Circular Economy	5
Tailings Management and Reprocessing	5
Solid-Liquid Separation	5
Soil Remediation Technology	5
Elective	5

oratory for the analysis of geological materials—LaGEMA) and by visiting industrial plants. (Table 5).

3.5 Module 4: Master's thesis at any of the four locations

The thesis can be supervised by any partner university and will be executed at one of the cooperating companies. The 4th semester of the program is intended to be mostly “hands on,” enabling the trainees to have close contact with the practical aspects of sustainable mineral processing issues and collaborating with associate partners (industry, research centers or suppliers).

4. Current State, Outlook, and Further Information

In the application period for the first cohort, close to 200 students from 48 countries sent in their application files. Out of these, about 80 were considered to comply with all requirements and were thus evaluated. In total, 22 students selected by the consortium registered at University of Oulu.

They are expected to arrive in Finland at the end of August and to start their master's program on September 1st, 2022. The application window for the second cohort will open at the end of 2022; it will be announced well in advance on the PROMISE website.

In line with the international character of an EMJM, the first PROMISE students present a variety of nationalities: Bangladeshi, Brazilian, Chinese, Filipino, Ghanaian, Indonesian, Iranian, Mongolian, Nigerian, Pakistani, Peruvian, Thai, and Yemeni.

Detailed information on EMJM PROMISE are available at <https://www.master-promise.eu/>. For questions that are not covered there, please contact the consortium via e-mail to info@master-promise.eu, to promise@unileoben.ac.at or to the corresponding author.

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