The Pavia’s IUSS Master in Nuclear and Ionizing Radiations Technologies

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Department of General Chemistry - University of Pavia (Italy)

The problem of teaching and professional training in the field of “non power” nuclear technologies

The University Town of Pavia
- 15 miles south of Milan
- 70,000 inhabitants
- 25,000 students
- 17 University Colleges (Ghislieri and Borromeo founded in 1560)
- The second oldest University in Italy, founded in 1361 (first nucleus in 825 by Lotario)

Alessandro Volta
Camillo Golgi (Nobel prize in medicine)
Lazzaro Spallanzani

NUCLEAR FACILITIES AT THE UNIVERSITY OF PAVIA
• TRIGA MII Research Nuclear Reactor 0.25 MW
• 18 MeV D-D Cyclotrons
• 2 60-Co gamma cells (initially 4 kCi); X-ray generator (250 kV)
• Facilities for high energy physics experiments (partnership with CERN)
THE NATIONAL CENTRE FOR ONCOLOGICAL ADROTHERAPY

CNAO

Pavia is the location for the national centre for Oncological therapy using adrons beams (protons, deuterons, carbon and oxygen ions).

A synchrotrone for the production of the ion beams has already been installed and it will become operative within 2009.

The synchrotrone will also be a reference apparatus for research in radiobiology, material science, and medical physics.

INSTITUTIONAL AIMS OF THE MASTER

"Non-power" nuclear technologies are finding increasing success in strategic areas of human activities as Nuclear Medicine, Industrial Radiation Processing, Material Science, Cultural Heritage, Environmental Studies, Radioprotection and Nuclear Decommissioning.

Related to this technological advance is the need for high level professional education and training not yet fulfilled by traditional university courses or specialization Schools.

This is the institutional aim of the Master on NUCLEAR AND IONISING RADIATIONS TECHNOLOGIES (TNRI) which was lunched as a pioneering initiative in 1998 by IUSS-University of Pavia and it is now arrived at its 9th academic year.

ONE YEAR COURSE

- **1) BASIC NUCLEAR THEORY** (Radiation Physics, Radiation Chemistry, Radiation detection, Dosimetry, Radiobiology)
- **2) INDUSTRIAL APPLICATIONS OF IONIZING RADIATIONS**
- **3) RADIOCHEMISTRY AND RADIOISOTOPES TECHNIQUES**
- **4) RADIOPROTECTION**

- 40 ECTS
  - 48 FRONT THE THEORETICAL PART
  - 12 FROM THE STAGE

- **4 MODULES**
- **THEORETICAL LECTURES AND LABS: 400 hrs**
- **TRAINING STAGE: 6 MONTHS 60 ECTS**
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- **TRAINING STAGE: 6 MONTHS 60 ECTS**
ADMISSION TO THE COURSE
• MSc OR EQUIVALENT DEGREE IN PHYSICS, CHEMISTRY, ENGINEERING, PHARMACEUTICAL CHEMISTRY, BIOLOGY IS REQUIRED
• SELECTION IS BASED ON CURRICULA AND ORAL EXAMINATION

LECTURES
• THE ATTENDANCE TO THE COURSE IS MANDATORY
• THE OFFICIAL LANGUAGE OF THE COURSE IS ENGLISH
• LECTURES ARE DELIVERED BY THE BEST SPECIALISTS FROM ACADEMIC INSTITUTIONS, RESEARCH CENTRES AND INDUSTRIES.

EXAMINATIONS
• INTERMEDIATE WRITTEN EXAMINATIONS AT THE END OF EACH MODULE
• FINAL DISSERTATION BASED ON THE STAGE THESIS

FELLOWSHIPS
• ABOUT 50% OF THE STUDENTS ARE AWARDED TWINING FELLOWSHIPS AND REIMBURSEMENT OF LODGING EXPENSES.

QUALITY ASSESSMENT
Questionnaires for quality assessment are distributed to the students:
- when a teacher has completed his lectures cycle
- at the end of each module
- at the end of the theoretical part of the course
- at the end of the stage
- at the end of the course

The questionnaires are aimed to assess:
- the quality of the teaching,
- the quality of the examination
- the quality of the documentation delivered by the teachers to the students,
- the quality of the course organization,
- the achievement of the objectives of the master,
- the pertinence of the theoretical part with the training program in the stage,
- the logistics,
- the overall satisfaction.

Forms are also distributed to the Tutors responsible for the training stage in order to achieve an evaluation from them and their institution.

The overall performance Index obtained by the Master course in the past academic year was 3.3/4.

Prerequisites for the justification and success of the Master
• The existence in the country of a “non-power” nuclear economical and cultural substrate capable of affording specialists for teaching, placements for the training stages and job opportunities.
• Nuclear research (academic, private and state institutions)
• Industries operating with nuclear technologies
• Hospitals using nuclear methods (PET centres, radioprotection services)
• Government Agencies and Institutions (radiochemistry and radiation controls)
• International Character: English language, partnerships with foreign prestigious universities and research institutions; Support by IAEA
THE ITALIAN MINISTRY OF UNIVERSITY AND RESEARCH

THE UNIVERSITY OF PAVIA

THE UNIVERSITY COLLEGES (GHISLIERI)

ITALIAN INSTITUTE FOR ADVANCED STUDIES

PARTNERSHIPS

THE UNIVERSITY OF PAVIA

THE UNIVERSITY OF PAVIA

ITALIAN IMPERIAL ACADEMIC INSTITUTIONS

ACADEMIC INSTITUTIONS

IAEA

RESEARCH CENTRES

INSTITUTIONS

UNIVERSITIES

• UNIVERSITY OF PAVIA
• POLYTECHNIC OF MILAN
• UNIVERSITY OF MILAN
• POLYTECHNIC OF TURIN
• UNIVERSITY OF PALERMO
• UNIVERSITY OF BOLOGNA
• UNIVERSITY OFPadova
• UNIVERSITY OF UBISRA

• INSTITUTE OF NUCLEAR CHEMISTRY AND TECHNOLOGY (University of Warsaw, Poland)
• INSTITUTE OF APPLIED RADIATION CHEMISTRY (Technical Univ. of Lodz, Poland)
• INSTITUTE OF RADIOMETOPES (Hungary)
• IFJ, OF ELECTRONICS (Bulgarian Academy of Sciences, Sofia)
• UNIVERSITY LOUIS PASTEUR (France)

NATIONAL INSTITUTIONS AND RESEARCH CENTRES

• ENEA (Research centres at Casaccia, Bologna and S. Teresa d’Leto)
• ITALIAN NATIONAL RESEARCH COUNCIL (ISOF - CNR Research Centre at Bologna, Research labs in Pisa and Pavia)
• ISTITUTO SUPERIORE DI SANITA' (ISS, Roma
• ELECTRA SYNCHROTRON (Tasini)
• FEDERAL INSTITUTE FOR FOOD RESEARCH AND NUTRITION (Katholik, Germany)
• RUTHERFORD APPLETON LAB. (Didcot, U.K.)
• NATIONAL INSTITUTE FOR NUCLEAR PHYSICS (INFN, Research Centre at Pavia, Frascati, Catania and Legnano)
• AGENCIES FOR THE ENVIRONMENTAL PROTECTION (APAT, Rome, ARPA-Lombardia, ARPA-Emilia Romagna)
• PET CENTRES (CNR-Pisa, JRC-Ispra, S. Raffaele-Milano, Humanitas-Rozzano, LENZ-Pavia, Humanitas-Rozzano, Milano)
• HEALTH PHYSICS AND RADIOPROTECTION LABS IN HOSPITALS (Milano, Pavia)
Module 1
FUNDAMENTAL THEORY

<table>
<thead>
<tr>
<th>Course Details</th>
<th>HOURS</th>
<th>CREDITS</th>
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<tbody>
<tr>
<td>Radiation physics</td>
<td>83 h</td>
<td>10 ECTS</td>
</tr>
<tr>
<td>Radiation chemistry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear chemistry and radiochemistry</td>
<td></td>
<td></td>
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<tr>
<td>Radiation biology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation dosimetry</td>
<td></td>
<td></td>
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<tr>
<td>Radiation detection</td>
<td></td>
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</tbody>
</table>
PET Centres and cyclotrone labs for Nuclear Chemistry Research in 2002

- 5 Milano, 1 Reggio Emilia, 1 Cuneo, 1 Bologna, 1 Castelfranco, 1 Firenze, 1 Pisa, 2 Napoli, 2 Palermo

**Module 3 RADIOCHEMISTRY AND RADIOISOTOPE TECHNIQUE**

**CREDITS**

- Radioisotopes manipulation and counting techniques: 10 h, 7 ECTS
- Radioisotopes manipulations and counting techniques: 31 h, 4 ECTS

**CREDITS**

- Instrumental Activation Analysis (INAA)
- Environmental radiochemistry, radiation monitoring and radioactivity control in the environment
- Radiochemical techniques in cultural heritage
- Radionuclides and Radiopharmaceuticals for Nuclear Medicine (short course)
Module 2 - INDUSTRIAL APPLICATIONS OF IONISING RADIATION

<table>
<thead>
<tr>
<th>CREDITS</th>
<th>HOURS</th>
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</thead>
<tbody>
<tr>
<td>10 ECTS</td>
<td>83 h</td>
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</tbody>
</table>

- Gamma facilities
- Electron accelerators
- Industrial X-ray irradiators
- Nuclear reactors
- Industrial radiation dosimetry
- Applications of radiation to materials science and technology
- Applications to sterilization processes in medical and pharmaceutical industry
- Applications in agriculture and food technology
- Applications to environmental problems
- Waste treatment and recycling
- The radiation techniques in Food Industry and Agriculture (short course)

- Industrial Facilities
- PET Centres
- Hospitals
- Decommissioning
## Module 4-A
### RADIOPROTECTION: PROGRAM FOR QUALIFIED EXPERTS

<table>
<thead>
<tr>
<th>CREDITS</th>
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<tr>
<td>50 h</td>
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<tr>
<td>11 ECTS</td>
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</table>

- The profession of 'Qualified Expert'
- Legislation of radioprotection
- Health problems related to workers exposure to radiations
- Dosemetry for radioprotection
- Natural radioactivity
- Radiological aspects for diagnosis
- Primary and secondary radioprotection shields
- Program for radiological quality assurance
- Radioactivity in radiotopes manipulation and transportation
- Elements of comparative risk assessment

## Module 4-B
### INTRODUCTION TO NUCLEAR DECOMMISSIONING

<table>
<thead>
<tr>
<th>CREDITS</th>
<th>HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26 h</td>
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<td></td>
<td>3</td>
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</tbody>
</table>

- The problems behind decommissioning
- Dealing with the regulators
- The organization and temporal action sequence in decommissioning
- The technology needed in decommissioning
- Characterization of waste plants and systems
- Dismantling and Decontamination
- Waste packaging and transport
- Waste disposals

### PROFESSIONAL SPECIALITIES

Based on the knowledge acquired in the theoretical part of the course, a definite speciality is attained by the student through the training stage:

- Industrial radiation processing
- Cyclotron operation, maintenance; production of radionuclides for nuclear medicine
- Chemical synthesis and quality control of radiopharmaceuticals
- Radioactive waste characterization (instrumental and radiochemical methods)
- Environmental radiation monitoring and radionuclides detection
- Nuclear activation analysis and its applications
- Radioprotection: the 4th module of the Master is based on the official program for the patents (1st, 2nd and 3rd levels) of "Qualified Expert".
TRAINING STAGES
The training stages have the essential purpose to focus the student’s learning on a definite speciality which will be the base for his professional activity. The duration of the training period is normally 6 months; at the end the students must write a thesis for the diploma dissertation.

The relationship between the external institution and IUSS are regulated through a formal agreement. The stage is carried out under the supervision of two Tutors nominated by the School. The Tutors are normally also lecturers in the Master course and are invited to be members of the diploma exam commission.

At the end of the stage the students are often offered job opportunities or fellowships for pursuing the training.

TRAINING STAGE
ACADEMIC YEAR 2004-2007

- IBA Molecular Italy – Milano
  - Determination of natural radionuclides in waters
  - Project of apparatus for neutron radiography at the LENA research nuclear reactor
  - Technical Organization of an Integrated system of Radioprotection

- Laboratory of Applied Nuclear Energy (LENA) – University of Pavia
  - Characterization of radionuclides sources by analytical and radiochemical methods

- Regional Agency for Environmental Protection (ARPA-Lombardia, Milano)
  - Methods and procedures for the validation and quality control of Radopharmaceuticals

- SOGIN Nuclear Power Plant at Cource-Poissanne
  - Determination of natural radionuclides in waters

Survey of 9 academic years of the Pavia’s Master course

<table>
<thead>
<tr>
<th>ACADEMIC YEAR</th>
<th>NUMBER OF MASTER GRADUATE</th>
<th>MSc PHYSICS</th>
<th>MSc ENGIN.</th>
<th>MSc CHEMISTRY</th>
<th>MSc ENVIRONMENTAL SCI.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998-1999</td>
<td>15</td>
<td>2</td>
<td>6</td>
<td>7</td>
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<tr>
<td>1999-2000</td>
<td>15</td>
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<td>2</td>
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<td>2002-2003</td>
<td>13</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
The major justification of the Master on “Nuclear and Ionizing Radiations Technologies” is that it addresses nuclear specializations which are the object of intense commercial, industrial and social activity.

A second strong point of the Master is that, taking advantage from the expertise of the partners, it has succeeded to disseminate the knowledge and organize professional training in a variety of nuclear specializations which are not yet available in current university courses.

Because of the relationships with the working world the Master has become an observatory for identifying problems, needs and novel opportunities in nuclear applications and teaching.
GENERAL REMARKS

The problem of the recruitment: after 10 years since its foundation the recruitment aimed to attain a sufficient number of selected students (minimum 10) requires hard efforts. This is because “non power” nuclear applications, although in expansion, are still a small niche in the economy of a country.

Favoring the birth and coordination of complementary initiatives in countries of adequate nuclear culture, launching projects aimed at the dissemination of non power nuclear technologies in developing countries, might be a fruitful strategy for the future. IAEA is expected to play a decisive role in this perspective.

The Master as Observatory

The Problem of Radiochemistry

Since 1987 the radiochemistry knowledge has faded progressively within Italian academic institutions and now most of the major experts are within commercial, industrial institutions and agencies and labs for radioactivity control.

The situation is not far from being satisfactory in the field of nuclear medicine due to the rapid development of PET centres where also good research is carried on.

Less satisfactory is the situation for environmental radiochemistry which is cultivated in regional and national agencies labs (ARPA, APAT).

Most severe is the deficiency of radiochemists in the field of characterization of radioactive wastes which is of crucial importance in nuclear decommissioning.

The radiochemistry Problem

As a consequence there is an increasing request of radiochemists (decommissioning, environmental controls, industrial applications) which cannot be fulfilled.

It is therefore urgent to promote the renewal of the radiochemistry cultural tradition within academic institutions with special reference to the Chemistry courses.

The Pavia’s Master has taken the initiative in this direction
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- TRIGA Research Nuclear reactor 3.25 Mev
- 18 MeV IBA Cyclotrons
- 2 60-Co gamma cells (initially 4 kCi), X-ray generator (250 KEV)
- Facilities for high energy physics experiments partnership with CERN

THE NATIONAL CENTRE FOR ADROTHERAPY CNAO

Pavia is the location for the national centre for adrotherapy using adrons (protons, carbon and oxygen ions). A synchrotron for the production of the ion beams has already been installed and it will become operative within 2009. The synchrotron will also be a reference apparatus for research in radiobiology, material science, and medical physics

INDUSTRIES

- BIOSTER: e-beam irradiation centre (Sarzana, BI)
- GAMMARAD: 60-Co irradiation centre (Bologna)
- GAMMATOM: 60-Co irradiation centre (Gianutre, Co)
- NOVICO: Medical items production and sterilization (Ascoli Piceno)
- METALLURGICA BRESCIANA: e-beam curing of electric cables (Brescia)
- ST MICROELECTRONICS (Canara)
- THALES ALENIA SPACE: Space Industry (Milano, Firenze, Torino)
- TECNOTESSILE: Industrial research Centre on e-beam treatment (Prato)
- REGAR: e-beam curing of electric cables (Mignano Montelungo, Caserta)
- IBA: Ion Beam Applications (Louvain-La Neuve, Belgium)
- IBA MOLECULAR ITALY (cyclotrones, organization and management of PET centres Roma, Milano, Bologna)
- ENI AGIP-RADI (Milano)

- So.G.I.N (Nuclear Decommissioning, Roma)
- NUCLECO (Management of radioactive wastes, Roma)
- PIRELLI Labs (Advanced Research Centre, Milano)
- PIRELLI TYRES (Research Centre, Milano)
- IBA MOLECULAR ITALY (cyclotrones, organization and management of PET centres Roma, Milano, Bologna)
- ENI AGIP-RADI (Milano)
### TRAINING STAGE
#### ACADEMIC YEAR 2004-2007

<table>
<thead>
<tr>
<th>Institution</th>
<th>Project Topic</th>
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<tbody>
<tr>
<td>Socin Nuclear Power Plant at Latina</td>
<td>Evaluation of the novel methodologies for setting up the Dosimetry Laboratory at the Nuclear Power Plant of Latina</td>
</tr>
<tr>
<td>ARPA – Emilia Romagna (Piacenza)</td>
<td>Determination of Radionuclides in the environment by liquid scintillation counting</td>
</tr>
<tr>
<td>Uni Sistemi Medical S.p.A. (Milano)</td>
<td>Quality and dose assessment in digital radiology</td>
</tr>
<tr>
<td>Socin (Roma)</td>
<td>Characterization of radioactive waste from nuclear flush plants</td>
</tr>
<tr>
<td>Thales Alenia Space (Turin) and LENA – University of Pavia</td>
<td>Development of detector technology to meet the needs of the LET and WDM instruments at ISIS</td>
</tr>
<tr>
<td>University of Pavia</td>
<td>Radiation Induced Bystander Effect - The Role of TGFβ in Signal Transduction</td>
</tr>
<tr>
<td>Rutherford Appleton Laboratory Didcot (U.K.)</td>
<td>The radiotrace heating units for the COMAR mission: radiation field characterization and dose calculation by means of Monte Carlo codes and implications at spacecraft system level</td>
</tr>
</tbody>
</table>
### TRAINING STAGE
ACADEMIC YEAR 2004-2007

<table>
<thead>
<tr>
<th>Institution/Project</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Institute Superior de Sanità (IRCCS, Roma)</td>
<td>Emergency decision making including computerized experimental investigations by luminometry methods.</td>
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<tr>
<td>Hospital S. Maugeri (Pavia)</td>
<td>Radioprotection of epithelial tissues; investigation of procedures and instrumentation.</td>
</tr>
<tr>
<td>European Joint Research Centre (Ispra, Varese)</td>
<td>Labeling of nanoparticles for radiopharmaceuticals in nuclear medicine.</td>
</tr>
<tr>
<td>University of Pavia</td>
<td>Synthesis and quality control of radiopharmaceuticals for PET.</td>
</tr>
<tr>
<td>S.Raffaele Hospital Radiopharmacy Lab and PET Centre (Milano)</td>
<td>Regulatory control of radiation sources in medicine.</td>
</tr>
<tr>
<td>AstraZeneca SpA (Milano)</td>
<td>Drug discovery and synthesis of radiopharmaceuticals for PET.</td>
</tr>
<tr>
<td>LENA-University of Pavia</td>
<td>Synthesis and quality control of radiopharmaceuticals for PET.</td>
</tr>
<tr>
<td>S.Raffaele Hospital Radiopharmacy Lab and PET Centre (Milano)</td>
<td>The use of a clinical and pharmacological system for the generation of 18-F and 18-F labeled radiopharmaceuticals. Quality control by HPLC.</td>
</tr>
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