## OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

## DISCLAIMER



## FAIR USE POLICY



## CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

23515

INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY

# FINAL REPORT

## Expert Group Meeting

**on**

## *"Cleaner technologies for green chemistry and promotion of related projects"*

Trieste, Italy

*26-27 May 2003*

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

## *1. Background*

The International Center for Science and High Technology (ICS), is an autonomous institution within the legal framework of the United Nations Industrial Development Organization (UNIDO). Its headquarters are located in Trieste, Italy. The Center's mandate relates to the transfer of know-how and technology from developed to developing countries, and is justified by the perception that a competitive industrial and technological capability cannot be built-up without adequate scientific knowledge and without participating in the development and utilization of new and advanced technologies.

ICS's target beneficiaries are identified among scientists, researchers and technologists within industrial R&D institutions, science-based industry clusters and/or industries with their own R&D facilities. Close cooperation with the industrial sector is sought either through direct interaction or through the provision of eco-services by national, regional R&D institutions. To this aim institutional strengthening and capacity building of selected national R&D institution has been adopted by ICS as a cost effective approach in order to make the required scientific, technical and managerial services available to local industries.

In the present work programme the ICS activities focus on specific sectors within the areas of chemistry, environment, new materials and high technology. In selecting the specific subprogrammes and their related activities, special consideration was given to their relevance in relation to the scientific and technological development of developing countries.

Within the area of Pure and Applied Chemistry a subprogramme on Catalysis and Sustainable Chemistry is presently carried out with the focus on clean technologies and pollution prevention. One approach, in this context, is to promote innovation by supporting the diffusion of clean technologies in small-medium enterprises and the use of renewable resources.

The growing awareness of environmental issues leads to increasing restrictions for toxic/hazardous chemicals and the disposal of wastes. In parallel, the appeal of clean technologies expands. However, hazardous compounds are still involved in a number of processes for bulk chemical production. The sector of fine chemical industry is historically not sufficiently receptive for catalysis and the large recourse to stoichiometric methods lead to massive by-product formation. In developing and in transition countries, the presence of obsolete and polluting manufacturing processes is larger, making the situation worse. Moreover, developing countries have interest in the valorization of natural products produced in their countries. These can be proposed as renewable raw materials for chemicals, with a benefit for both the environment and the economy of the country.

ICS is presently carrying a series of initiatives with the focus on clean technologies and pollution prevention, promoting innovation by supporting the diffusion of clean technologies in small-medium enterprises and the use of renewable resources. Together with the promotion of projects, other initiatives like workshops and meetings of experts have been organized by ICS in the previous years, where issues relevant to sustainable chemistry and the possibility of concerted actions were explored.

In the ICS Work programme for the year 2003, the project oriented strategy was strengthened and the Expert Group Meeting on "*Cleaner technologies for Green Chemistry and promotion of related projects*" held on 26-27 May 2003 in Trieste represents an implementation of the above mentioned strategy.

## *2. Justification*

Pollution by chemical manufacturing can result from different causes: hazardous reagents and by-products, waste production, slowly degradable materials, inefficient processes. The recourse to catalytic methods and the use of crop-derived raw materials are two effective routes to reduce the impact of chemical processing on the environment. Crop-derived feedstocks are more sustainable, in the long term, than oil-based ones. They are generally non-toxic and are biodegradable. It may be necessary, however, to reduce the transformation costs for them to become competitive with the traditional production routes. Environmental considerations, as well, might be of relevance in their use in manufacturing processes.

Catalysis is a powerful tool in promoting the reduction of pollution and sustainable chemistry, through efficient use of resources and the development of synthetic methods based on clean reagents and which avoid formation of by products. New approaches are required for clean technologies, especially in the context of their implementation in developing and in-transition countries.

During the transition step to a wider use of intrinsically safer and not polluting production technologies, the cleanup technologies will continue to play a key role to decrease the impact on environment and health of production. The control of gaseous emissions and particulate matter is a main area of application of these technologies, but water issues are becoming a key aspect dominating the transition from developing to developed countries in several geographical area. New water technologies and the application of innovative treatments is required, but in the context of adapting technologies to the specific needs of developing and in-transition countries.

The energy requirement of the world will continue to grow. New catalytic technology can lead to a better utilization of fossil fuels and biomass and to clean fuels. Hydrogen is a energy vector which in a medium-long term will be the key vector to enable a sustainable use of energy.

The EGM on "Cleaner technologies for Green Chemistry and promotion of related projects" will be particularly focused on defining suitable common initiatives and promoting joint projects. In particular, the ICS ongoing project in catalysis and sustainable chemistry is:

- *"Novel catalytic technologies for the treatment of wastewater from agro-food and industrial productions in MED countries – CAT-MED"* (approved by the European Commission within the VIth Framework Programme)

The following are project concepts/proposals which should be further promoted and developed:

- *"Technical assistance in the establishment of a cleaner catalysis research and development laboratory for the Nigerian National Petroleum Corporation (NNPC), in Nigeria"*
- *"Network on catalysis in CEE countries"*
- *"Development of new technologies for the treatment of spent catalysts" (Turkey and Brazil)*
- *"Global solutions for waste industrial effluents – GLOW"*
- *Project concept proposals on "Catalytic Technologies for Sustainable industrial processes utilizing crop-derived renewable raw materials", in South East Asian countries*
- *Project concept proposals on "Cleaner technologies for sustainable chemistry", in African countries*

### *3. Objectives*

The main objectives of the EGM were:

- To survey the available technologies and the state of the art in the following areas:
  - use of catalysis for a green chemistry and cleaner technologies with specific reference to their implementation in developing and in-transition countries.
  - the valorization of renewable resources (with focus on cashew nuts)
  - new clean fuels production and utilization, and use of hydrogen as an energy vector.
  - control of gaseous emissions and particulate matter
  - water treatment and remediation.
- To present and discuss ICS' ongoing projects in the field of catalysis and sustainable chemistry
- To prepare and further develop ICS project concepts in this field
- To collect and evaluate new project proposals
- To update participants on recent global trends in the promotion of the concept of pollution prevention with the focus on clean technologies, sustainable chemistry and renewable resources.

## 4. *Expected Outputs*

- Survey of the state-of-the art of the international action aimed at sustainable chemistry.
- Survey of clean technologies for pollution reduction/elimination and for the promotion of renewable resources as raw materials.
- Survey of current situation in selected developing and in transition countries.
- Implementation of ICS projects
- Further development of ICS project concepts
- Collection and evaluation of project proposals
- Updated survey on the state-of-the art clean technologies for sustainable chemistry

## 5. *Profile of Participants*

- Representatives of selected developing countries and countries in transition responsible for relevant environmental issues and national experts.
- International experts in clean technologies and catalysis issues.
- Representatives from industries.

## 6. *Topics of the Programme*

Detailed agenda of the EGM is given in annex II

I. REPORTS ON THE STATE OF THE ART IN THE FIELD (INTERNATIONAL EXPERTS)

- Catalytic technologies for green chemistry
- Clean technologies and their implementation in developing and in transition countries
- Use of Renewable Resources, with focus on cashew nuts, and clean technologies based on cashew nuts
- Catalytic technologies in cleaner fuel and energy vectors
- Technologies for the control of gaseous emissions and particulate matter
- Water treatment technologies: main features and applications

II. PROJECTS IN THE FIELD OF CATALYSIS AND SUSTAINABLE CHEMISTRY

- Project CAT-MED "Novel catalytic technologies for the treatment of wastewater from agro-food and industrial productions in MED countries". State and possible follow-up projects (FP6-INCO-MPC)
- Technical assistance in the establishment of a cleaner catalysis research and development laboratory for the Nigerian Petroleum Corporation in Nigera
- Development and application of novel technologies for used oil and oil sludge treatment in Russia and new independent states - SPORE
- Global solutions for waste industrial effluents - GLOW
- Project proposals for African countries

III. PROMOTION OF PROJECTS AND COMMON INITIATIVES IN VARIOUS REGIONS

- INDIA: Project concepts/proposals on technologies from renewable resources (cashew nuts) in India
- BULGARIA: Network on catalysis in CEE countries and other project proposals in Bulgaria and CEE countries
- TURKEY: Priority needs and possible project proposals on the development of new technologies for the treatment of spent catalysts
- BRAZIL: Priority needs and project proposals on catalysis and cleaner technologies in Brazil (Development of new technologies for the treatment of spent catalysts, use of cashew nuts, water purification, etc.)
- MALAYSIA: Priority needs and project proposals on technologies from renewable resources in Malaysia
- EGYPT: Priority needs and possible project proposals on catalysis and cleaner technologies in Egypt
- GHANA: Country report and presentation of possible project concepts/proposals on clean technologies for sustainable development in Ghana

IV. WORKING GROUPS

- Working groups on actions to be undertaken for the promotion of project proposals in the various geographical regions (Mediterranean Countries, Balkan Countries, Asian countries, Brazil, Russia).

## V. RECOMMENDATIONS AND CONCLUSIONS

### *7. Detailed report*

#### Opening Session

**S. Miertus**, ICS-UNIDO Director of the Area of Pure & Applied Chemistry, opened the EGM and welcomed participants. Then he presented an overview of the mission actions undertaken by ICS-UNIDO for the benefit of developing countries, the mandate of ICS-UNIDO giving also an overview of the ICS-UNIDO activities in the Area of Pure and applied Chemistry. Finally, he presented in detail the different strategies, products, goals and activities within the ICS subprogramme on Catalysts and Sustainable Chemistry.

#### Session 1

***Clean Technologies for Sustainable Chemistry. State-of-the-Art.***

**F. Trifirò** (University of Bologna, Italy) presented an overview of catalysis for green chemistry. Catalysis is applied in different areas from refinery, fine chemicals, commodities, environment protection, solid to liquid and gas to liquid applications. In all these applications, the driving forces for new processes are ecocompatibility of the process and product, new regulation on the transport of chemicals, safety regulations and the necessity of using new raw materials. Future changes of chemical industry require new cleaner and alternative pathways (new catalysts, biocatalysis, photochemistry and biomimetic processes), use of new and alternative resources, the use of safer chemistry and new chemical products which maintain their efficacy and reduce or eliminate the toxicity

Some examples were then presented regarding new processes without coproducts, with reduction of waste, intrinsically safer, with reduction of the environmental costs, without toxic reagents, using renewable resources, using non toxic catalysts, using new raw materials (biomasses, alkanes), focused at producing more environmental benign products.

Finally, the presentation overviewed the properties of the catalysts required to address these problems.

**M.G. Clerici** (ICS-UNIDO scientific advisor) presented an overview of the clean technologies and their implementation in developing and in-transition countries. An example of clean technology is related to the alkylation of aromatics made with zeolite. A second example given was related to the increased use of $H_2O_2$, not only in fine the chemicals area, but also in bulk chemical production (propylene oxide and caprolactam synthesis). Finally the presentation overviewed the current initiatives in developing and in-transizion countries, although mainly based on a web search. The projects discussed in a more detail were a cleaner production technology project in Zimbabwe, and an African Energy Policy Research Network. The conclusion is that most frequent activities are

awareness raising, training courses and capability building, but only in few cases obsolete technologies were substituted with cleaner ones. Low cost and simpler technologies were the only applied. These observations raise the general discussion about which strategies are effective for a technology transfer. One point of the discussion is the key aspect of the training, because technologies can be successful applied only from well trained peoples.

**S. Massari** (Oltremare SpA, Italy) presented the industrial perspective in the use of cashew nuts and the different possibilities in obtaining valuable products from this renewable material. Production of cashew nuts is concentrated in India, Brazil and Vietnam, with a production of about 1 million tons cashew nuts from which during the roasting is obtained the cashew nuts liquid (around 20.000 tons). Use of this liquid and the main processes for its upgrading were discussed.

**O. Attanasi** (Univ. Urbino, Italy) overviewed the possibility of clean technologies from renewable resources, with focus on cashew nuts. After introducing the main concepts related to cashew nuts and the obtaining of the alkyl phenolic oil, the questions related to its purification and conversion to cardanol which may be then further functionalized to obtain antioxidants or additive for gasoline were discussed. India and Brazil (main consumers of cashew nuts) are interested in this possibility of obtaining added value from this byproduct.

**A. Holmen** (Univ. Trondheim, Norway) overviewed the state-of-the-art in catalytic technologies for cleaner fuels and energy production. Emphasis was given to the use and conversion of natural gas, including questions related to its conversion to liquid products and its use in natural gas vehicles, the new problematics related petroleum refining and the use of oxygen-containing additives such as MTBE, the question of lowering sulphur content of gasoline and diesel. The final part of the presentation was focused on the use of fuel cells, and the fuel processing in relation to the use of gas/liquid fuels in fuel cells. New type of microreactor and catalyst concepts are needed to address these issues and making a reality the use of $H_2$ as a clean energy vector.

During discussion, topics highlighted were the question of dimethylether as substitute for MTBE and the problem of emissions in blending oxygenated to gasoline and diesel.

**P. Fornasiero** (ICS-UNIDO consultant) presented a contribution on technologies for the control of gaseous (NOx, VOC) and particulate emissions. Urban pollution is an increasing problem in developing countries, although some initiatives to reduce urban pollution have been taken. Together with end-of-pipe solution, also a process redesign to reduce emissions at the source is needed. After a short description of the available catalytic technologies for VOC and NOx removal, discussion was focused on the issue of particulate matter removal. Particulate matter is a major class of air pollution. Combustion and non-combustion industrial processes, mining and construction activities, vehicles and incinerators are examples of potential sources of particulate emissions.

A brief survey of industrial technologies available for particulate emission control from stationary sources has been presented. Control of particulate emissions from industrial

sources is a mature technology and a variety of approaches have been developed: gravity settling chamber; mechanical collectors; particulate wet scrubbers; electrostatic precipitator and fabric filters. This technology offers valuable insight into the potential approaches which may be adapted for use in the more difficult problem of reducing particulate emissions from mobile sources.

Finally, the last part of the presentation has been dedicated to the problem of gaseous and particulate emissions from mobile sources. In particular, attention has been focused on soot formation during diesel combustion. Use of catalytic filters, able to decrease soot combustion temperature, can significantly reduce the fuel penalty, leading to economically attractive and environmentally friendly systems.

**G. Centi** (ICS-UNIDO scientific advisor) presented an overview on the state of the art in technologies for water depollution.

Water and wastewater treatment has become a major social, technological, economic, and political problem. Legislation in every country imposes environmental regulations and health quality standards that steadily become more restrictive. Sludge disposal poses additional problems.

There is an increasing need for technologies to restore the required water quality. Different uses such as for drinking water, recreation, industrial use and for agricultural uses such as irrigation and livestock watering require different water quality. The choice of water treatment technologies depends thus on both the characteristics of water source and the quality necessary for final use. However, several additional factors determine the choice of water treatment technologies: cost, manageability, impact on environment, possibility of automatic control, social acceptance.

The water treatment technologies are differentiated between water treatment technologies and water remediation technologies. Although there are several analogies between the two cases, and often similar technologies may be used, the differentiation is related to the different characteristics of the water to be treated which are in relation to the different characteristics of pollution.

Selection of a wastewater treatment process or sequence of processes depends on a number of factors. Usually, individual processes are arranged in a "treatment train" (a series of processes applied in sequence). The different water treatment technologies may also be classified according to the degree of available knowledge on the technology and its use in a variety of different situations.

Catalytic technologies are an emerging innovative way in which water treatment technologies may be improved. This lecture has reported on the use of catalytic technologies in advanced water treatments. First, some general questions on the opportunities, prospects and problems in this new field of research have been discussed, and then some specific examples have been analyzed.

## Session 2

### *Projects in the Field of Catalysis and Sustainable Chemistry*

**S. Miertus** (ICS-UNIDO) introduced this section indicating that the scopes are to define the area in which a technology survey is necessary, but especially to identify the specific and feasible routes to develop concrete projects of technology transfer. The examples discussed below are on-going initiatives or which should be further finalized, but the identification of new projects and needs is necessary.

**G. Centi** (ICS-UNIDO scientific advisor) overviewed the state of the project CAT-MED "Novel catalytic technologies for the treatment of wastewater from agro-food and industrial productions in MED countries" which has been financed from the European Union in the frame of the 5th Framework Programme. The project started on February 2003 and seen the participation of ICS-UNIDO, three Universities/Research Centres in Tunisia, one Research Centre in Egypt plus some Universities/Research Centres in Italy, France and Spain. G. Centi is the coordinator of the project and the role of ICS-UNIDO is focused on promoting the technology transfer to Mediterranean developing countries.

After a brief introduction on the aims and objectives of the project and the scientific approach (focused at identify effective technologies which may be adopted to promote the minimization of water pollution caused by olive oil milling wastewater as well as its recycle) the discussion was centred in analyzing the philosophy of the project and the state of the research.

The final part of the presentation was centred on an overview of the possibilities in follow-up projects in the area of water pollution and recycle with focus on projects possible for Mediterranean developing countries, also in relation with possibilities offered in the 6th Framework Programme of the European Community, specifically the area FP6-INCO-MPC.

During discussion question highlighted were the problem of polluted Black see streams to Mediterranean see, the problem of chromium-contaminated streams deriving from tannery, the necessity of life cycle assessment to analyze options between recovery and destruction of chemicals, and the use of advanced oxidation technologies in treating streams from municipal waste.

**M.G. Clerici** (ICS-UNIDO scientific advisor) overviewed the state of a project for the technical assistance in the establishment of a cleaner catalysis research and development laboratory for the Nigerian Petroleum Corporation in Nigeria. C. The project is focused on the use of zeolite catalysts in achieving cleaner production in the petroleum refining and petrochemical industry. An outline of existing project is given below.

UNIDO's involvement in cleaner production processes and technology dates back to the 1980's with the formation of a mutual partnership with UNEP for the promotion of cleaner production technologies in industries as a means of minimizing the continued introduction of industrial wastes and emissions with severe implications on the environment and health of the world population. A number of National Cleaner Production Centres (NCPCs) were established in selected countries for the promotion and

introduction of cleaner technologies to facilitate waste minimization at the entry process (source) level in contrast to the predominant, costly and unsustainable end of pipe approach to waste management in operation in many industrial facilities.

Cleaner production concepts have consequences for the whole life cycle of a product and can foster improvement in product design, selection of raw materials, efficiency in production and/or energy use, safety during manufacture and consumer use, reparability, and recyclability. UNIDO's network of NCPCs have recorded significant success in facilitating energy savings and in reducing waste and emission in many industries covering different sectors such as textile, pulp and paper, chemical, cement and food and beverage, pharmaceutical and petroleum refining and petrochemicals. UNIDO continuously reviews and assesses its cleaner production methodology, selects environmental sound technologies and best environmental practices (EST/BEP) in operation in industries with a view to adopting the most cost-effective approach to industrial waste management.

The unique properties and selectivity of zeolite catalysts can provide effective solutions for environmental pollution by minimizing the production of pollutants and by secondary treatment of the effluents produced. Application of cleaner catalysts in minimizing waste and emission generation in the petroleum refining and petrochemical sector is one of the approaches being adopted by UNIDO for waste containment and for improving the efficiency and competitiveness of industrial operations. The catalyst of interest to this UNIDO project is zeolite catalyst. Variations in silica-to-alumina ratios, unit cell sizes, pore sizes, surface area, cations, and incorporated metals produce a wide spectrum of adsorbent and catalytic properties in zeolites that are useful in many new application areas. The need for new step-out materials and processes that will help solve the environmental problems of the future have expanded the research that is being done on zeolites, and they are increasingly becoming the material of choice for many application areas that are being investigated in order to assure that green chemistry becomes the standard for production especially in petroleum and petrochemical industry in the coming years. Zeolites are being extensively studied as heterogeneous catalysts that can be recovered and recycled with greater ease and lower expense, leading to less waste and fewer byproducts. The use of zeolite catalysts provides such process advantages as improved selectivity, high activity, and reduced corrosion. Some processes can gain efficiency and economy by using zeolites to combine several catalytic steps. Applications using aluminosilicate and other composition zeolites are undergoing intensive development and commercialization due to their process and environmental advantages. Zeolite catalysts have been extensively used, in catalysis reactions due to their highly active sites and shape selectivity, in the petroleum and petrochemical industries as cost-effective solutions for environmental pollution by minimizing production of pollutants and by secondary treatment of effluents produced. Studies have been conducted on the use of zeolites in air cleanup such as: stationary and mobile sources of deNOx, deVOx and deSOx, automotive cold start; in land and wastewater cleanup; in fine chemical process improvements such as: waste minimization, higher efficiency, and cheaper feedstocks. This project will better position the NNPC in developing the necessary capacity in this highly technical field of research and make it a major player in petroleum refining and petrochemical industry in the West African sub-region.

**A. Lodolo** (ICS Scientific Officer) reported on the state of development and application of novel technologies for used oil and oil sludge treatment in Russia and new independent states (SPORE - Global solutions for waste industrial effluents) with a brief presentation at the end also of the project GLOW (Global Solution for Waste Industrial Effluents) which is expected to be presented at the end 2003 during the 2nd call of EU 6th Framework Programme. The project seen the participation of several research centers and companies in the area, including several in CEE countries such as Slovenia and Hungary. The role of ICS-UNIDO in the project is in promoting technology transfer. The SPORE project is focused at the cooperation between Russia, NIS and EU countries for the development and introduction of suitable methodologies/tools for the management of used oils and oil sludges and the introduction of novel and economically viable technologies for the used oil regeneration and oil sludge treatment. The problem is very relevant. Only in Russia there is a consumption of about 7.7 million tons oil of which only 3.3% is reprocessed after use. The project involves ICS-UNIDO, Russian University and Foundation, the Municipality of Moscow and Industries and Companies in Russia.

During discussion, the problem of used oil disposal in Brazil was addressed. The solution adopted is by cofeeding it in FCC, although the question of the possible damage of FCC catalyst due to the heavy metals contained in used oil and sludges was unsolved. The possibility is a pretreatment with spent FCC catalysts.

**P. Fornasiero** (ICS-UNIDO consultant) overviewed the project proposals for African countries which derived from discussion during the ICS-UNIDO Workshop "Cleaner Technologies for Sustainable Chemistry" held in Cape Town, South Africa, on 9-11 December 2002. The creation of a cleaner production centre in Africa as the place to facilitate communication and interchange of information was highlighted. Main issues evidenced during the workshop were the use of the byproducts of sugar and the necessity of new/improved technologies for photocatalytic wastewater purification, especially from textile industries.

At the end of Fornasiero's report, M.G. Clerici illustrated a project proposal for a survey on environmental issues related with the status of chemical industry in Sub Saharan African countries. An inquiry form has been prepared and submitted to limited number of chemical industry in Zimbabwe, to test the feasibility of the project, in collaboration with Mr. W. Mutatu of the Midlands State University (Gweru, Zimbabwe).

## Session 3

### *Promotion of projects and common initiatives in various regions*

INDIA. **I. Singh** (Satya Cashew Chem., India) presented the use of cashew nuts oil as a renewable resource. India is the main producer of cashew nuts from which derive around 75.000 tons/year cashew nut shell liquid (CNSL) and 4,900,000 tons/year of shell which are used normally to produce heating. The oil derives from the method (hot oil) used to eliminate the shell. The oil can be used to produce cardanol which then can be converted to polymers, resins and other products. The project concept is based on the development of the technologies necessary for transforming CNSL to green resins and fibers.

BULGARIA. **L. Petrov** (Bulgarian Academy of Sciences, Bulgaria) presented on overview of the present situation and perspectives on catalysis and sustainable chemistry in Bulgaria and CEE Countries and the state of a project for the establishment of a CEE Network in the field of catalysis. The estimated amount of industrial solid waste generated in 1997 in Bulgaria was 25.8 million tons of which 97.7 % was disposed to dumps and landfills mostly without any treatment. About 94 % from waste came from ore processing and ore-dressing plants and only 4 % was chemical waste. Thermal Power Stations (TPS) in Maritza East Coal field are the largest source of solid wastes producing annually about 3 million tons.

Finally, the presentation was focused on the update situation about the state of the proposal for establishing ICS-UNIDO, Trieste, Network in the field of catalysis and sustainable chemistry.

TURKEY. **Nilgun Akin** (Kocaeli Univ., Turkey) presented an overview on the priority needs and cleaner technologies in Turkey and Follow up of the ICS-UNIDO Workshop 2001 held in Istanbul, with particular reference to two projects on the development of new technologies for the treatment of spent catalysts and of technologies for clean energy-$H_2$ production for combined heat and power systems.

Although Turkey has made great progress over the last fifteen years in creating mechanisms to solve its environmental problems, air and water pollution abatement problems still exist due to small scale enterprises generally using old technologies in sub-sectors including highly polluting activities such as textiles/clothing/leather, metal products/ machinery/equipment, food/beverages/tobacco, forest products/furniture.

Because of the lack of regulatory enforcement in the environmental protection field, extensive use of catalytic technologies is not widespread in Turkish industry. Most of the industrial process equipments are utilizing end-of-pipe solutions for environmental protection issues at the plant level.

The presentation focused on the discussion of the background reasons for proposing the two cited projects on $H_2$ production and spent catalyst safe disposal or regeneration. The first project was centred in designing a small-scale combined heat and power system and the construction of a prototype for a small-scale industrial plant. The second project on the treating of spent catalyst deriving from petrochemical and petroleoum industries in Turkey. As an example, the TUPRAS refineries in Turkey produce about 5 tons each of hydrocracker and desulphurizer catalysts, about 10 ton of hydrotreater catalysts and about 20 tons of FCC catalyst, plus other spent catalysts. New technologies for the treatment of the spent catalysts are required. Spent catalyst wastes present an opportunity for a new business to rejuvenate, recycle and convert the spent catalyst to an environmentally acceptable safe material.

BRAZIL. **E. Falabella** (Petrobras, Brazil) presented an overview of the priority needs and project proposal on catalysis and cleaner technologies in Brazil. Biofuel is a main issue addressed in Brazil along two main options: hydrated ethanol and via vegetable oils. Biogasoline is obtained via direct cracking of vegetable oils. Problem is the presence of aldehydes, which favour oligomerisation (gum yield is still rather high). The main

advantage is that soya bean oil may be blended with gasoil and used in the existing FCC Unit, with no modifications. Biodiesel is obtained via transesterification of vegetable oils such as: soya, dende and babassu, peanut, castor oil. Problems are the higher $NO_x$ emissions, elastomers solvent, less stability, more corrosion (higher water solubility). Main advantages: renewable, no sulphur, high cetane number, high lubricity, no motor modification for 5% blending, and generation of jobs.

Another main issue is related to natural gas reserves which are located either in remote regions or offshore. There is high costs of transportation (pipelines, LNG) and therefore converting natural gas to liquid fuels (GTL Technology) is a primary objective for Brizil and Latino-American countries.

Producing green additives for fuel and lubricating based on cardanol (CNSL) is another aspect addressed by E. Falabella. A new technological platform has been proposed to the Brazilian Ministry of Science and Technology on this topic.

In line with these indications it may be cited that the results and follow up of the previously organized ICS-UNIDO workshop in Argentina (Buenos Aires, workshop on "Catalytic Technology for sustainable Industrial Processes", 28-30 Nov. 2001) pointed out the following issues for Latino-American countries:

- The use of bioethanol as raw material for petrochemical catalytic routes (alcochemistry) such as production of acetaldehyde, acetic acid and ethylbenzene, is technically feasible and may help the economic development of rural areas in the region.
- Studies on catalytic technologies for treating residues originated in the fermentation must be intensified, since ethanol production involves the generation of very pollutant residue.
- Use of carbohydrates as raw materials for production of pharmaceuticals, fragrances and other fine chemicals appears of particular regional interest.
- Catalytic routes in sucrochemistry are well established and work very well.
- Use of carbohydrates as raw materials for fuels is limited for the same problems concerning bioethanol or biodisel.
- Production of Natural gas is rapidly expanding in several Latin-American countries.
- There is a need of new catalytic technologies for obtaining valuable chemicals from natural gas.

MALAYSIA. **K.Y. Cheah** (Malaysian Palm Oil, Malaysia) reported on the priorities and project proposal from renewable resources in Malaysia, focused on palm oil and coconut. Malaysia and Indonesia account of over 90% of the world oil palm plantation with a production of over 20 million tons of palm oil. Coconut plantation are concentrated in Indonesia and Philippines, but a significant contribution is also given by Malaysia. Different type of oleochemicals can be produced both from palm oil and coconut. A possible project was proposed for the catalytic conversion, to valuable fine chemicals, of tryglicerides and fatty acids of palm oil, palm kernel oil and coconut oil. In this context, the substitution of toxic Nickel as hydrogenation catalyst and the development of processes working under super critical conditions (as extraction and reaction medium) were also proposed. Other Areas of great interest are the use of palm oil to produce biodiesel (presently produced from rapeseed and sunflower) and the use of glycerol as

building block (for example to polyglycerol and polyglicerol esters or to propandiol). The last point discussed was the use of biomass in the production of biomass, ethanol and fine chemicals. Therefore, the are multiple areas of interest for using palm and coconut oil (or related biomasses) as source of new higher value chemicals.

EGYPT. **F. El-Gohary** (NRC, Egypt) overviewed the priorities and possible project proposals on catalysis and cleaner technologies in Egypt. Water issues were the main aspects evidenced. The problems of water shortage in the Mediterranean region are well documented. Most countries in the Mediterranean area are arid or semi-arid. They have low rainfall, mostly seasonal and with erratic distribution. Moreover, due to the rapid development, which accorded the agricultural sector top priority, conventional water resources have been seriously depleted. This is particularly acute in Southern Mediterranean countries where irrigation accounts for 50% (Algeria) to 90% (Egypt, Lybia) of water use. Furthermore, agriculture has a seasonal demand pattern which is often conflicting with other uses such as tourism. UN projections (UN Population Division, 1994) show that four Mediterranean countries already have less than the minimum required water availability to sustain their own food production (750 $m^3$/per capita/yr). By 2025, eight countries will be in virtually the same situation.

To the scarcity factor must be added that of fragility. Water quality is increasingly endangered by pollution. Consequently, over exploitation of water resources; lowering of groundwater tables; depletion of surface water bodies; pollution of rivers, lakes & aquifers and natural eco-system degradation are the main impacts of the way that water resources have been managed so far. Consequently, water of a good quality and without risk for public health is nowadays considered to be a major asset and a pre-requisite for the sustainable development of any country.

The major challenges facing the water sector in Egypt is to close the rapidly increasing gap between the limited water resources and the escalating demand for water, which the development in various economic sectors has created, and to protect the water from pollution. In 2002, the Government of Egypt has prepared a National Water Policy including three main themes: (i) optimal, use of available water resources; (ii) development of non-conventional water resources; and (iii) protection of water quality from pollution. At present, Egypt is addressing the issue of limited water quantity by managing the demand side. The following is the set of proposed strategies to achieve this goal:

- Minimize water losses
- Irrigation improvement project
- Cost recovery

Industrial consumption of water was estimated to be 3.6 BCM/year in 2000. The consumption is expected to reach 5.5 BCM/year by the year 2017. Consequently, an increase in the volume of industrial wastewater is expected. Wastewaters produced in many industrial processes contain organic compounds which are not amenable to conventional biological oxidation. The necessity of developing new projects on wastewater treatment for managing the scarce regional water resources was stressed as a key issue for the socio-economic modernization of the southern Mediterranean Countries. Particular problems evidenced are related to textile, tannery and pulp and paper productions.

GHANA. M. Duku was not able to attend to the EGM, but a presentation of a possible project concept on clean technologies for sustainable development in Ghana was given by **P. Fornasiero** (ICS Consultant). He presented the main aspect of the Cleaner Production component of the UNIDO Integrated Programme for Ghana. Aims of this component are to raise awareness and strengthen capacities for environmentally sustainable industrial development and encourage companies (especially micro, small and medium scale enterprise which account of more than 90% of companies in Ghana) to adopt cleaner, safer and energy-efficient production methods. Serious pollution problems are present in the Accra-Tema metropolis (especially land and water pollution), in the Chemu II Lagoon and in the Odaw River due to untreated effluents. Planned projects are to establish a Ghana Cleaner production centre (with the support of World bank) and the integrated exploitation of industrial minerals.

During discussion it was evidenced that 50% of the solutions adopted by companies have a pay-back of less than one year. Therefore, strategies for project implementation should be focused on low cost solutions and training/education (known to buy better). For higher tech technologies the market are driven from the availability of raw materials.

## Session 4

### *Working groups, recommendations and conclusions*

Before the discussion, **S. Miertus** (ICS-UNIDO) introduced the working group activities mentioning that the objective is to define the practical actions which may leave to the development of projects, i.e. not only define the key project ideas, but also to identify realistic mechanisms for financing the project and all the supporting activities (workshops, networks, competence centres, awareness building, training, etc.) which are useful to realize the objective of developing projects on technology transfer. He also recall that there are various possible mechanisms of funding of projects, such as:

- General scientific and cooperation funds (such as EU projects)
- Global Environment Demonstration actions through UNIDO
- Bilateral Cooperation (also supported through the Ambassadors of Permanent Missions to the International Organizations in Vienna).

ICS-UNIDO can evaluate through its consultants the preferable funding mechanisms which should be explored for projects after the phase of project preliminary assessment.

The following working groups were created:

***Working Group 1***: O. Attanasi, K.Y. Cheah, I. Singh, S. Massari, E. Falabella

Focus: definition of key project ideas and actions for projects in Asian countries related to the use of renewable resources, with focus on cashew nuts, palm and coconut oils.

***Working Group 2***: G. Centi, F. El-Gohary, A. Nilgun Akin. With the external participation of A. Lodolo

Focus: evaluation and definition of possible joint initiatives and project proposals in the field of southern Mediterranean Countries.

***Working Group 3***: M. Clerici, L. Petrov, F. Trifirò. With the external participation of G. Centi

Focus: networking activities and creation of network on catalysis in CEE and Balkan countries.

***Working Group 4***: F. Trifirò, A. Holmen, S, Miertus.

Focus: Cooperation of ICS-UNIDO with European initiatives within the 6th Framework Programme of the European Commission

Each group discussed specific issues and proposed recommendations and conclusions of the EGM.

***Recommendations and Conclusions***

The leaders of each working group presented the results of the group discussions:

***Working Group 1*** presented a summary of the key project ideas and actions for projects in Asian countries for renewable resources, with focus on cashew nuts, palm and coconut oils

The establishment of a Centre for Clean Technologies in Malaysia focused the evaluation of upgrading routes for the use of oil derived from palm oil and coconut and the waste produced during the manufacture of these oils was suggested.

The center should evaluate and promote both the separation and transformation of chemicals presented in these oils to produce a range of fine chemicals and or biodegradable polymers, and the use of byproducts (waste, glycerin) produced during the conversion of oils and of associated waste products.

Another project idea was formulated by Professor Orazio Attanasi on "Development of novel technologies for the utilization of cardanol in the preparation of green fine chemicals"

E. Falabella observed that the following steps in projects development should be defined:

1. Definition of the theme
2. Definition of the potential players
3. Definition of the role of ICS-UNIDO in coordinating actions leading to a successful project - Identification of the necessary actions and promotion activities, with the priority given to those activities in which ICS-UNIDO can act as implementing or coordinating agency.
4. Definition of project feasibility with focus on the funding mechanism as well as technical feasibility and socio-economic-environment impact
5. Definition of the project steps and its features on the basis of an analysis of the following aspects:
    a. Is it the project a general one (platform) or is it a small branch of a larger platform?
    b. Is there technology to be transferred and who holds the patent?

***Working Group 2*** presented an evaluation and definition of possible joint initiatives and project proposals in the field of southern Mediterranean Countries. On the basis of the discussion, three possible projects were identified:

- protect the limited water resources by improved purification technologies and their optimized integration
- spent catalysts treatment and safe disposal
- $H_2$ as a clean energy vector.

The discussion on these three projects started from a feasibility assessment of the projects based in the identification of the financing mechanism and related aspects briefly summarized below:

- constrains of the financing mechanism (requirements, limits, objectives and priorities)
- ICS-UNIDO objectives: technology transfer, developing and in-transition countries, regional (not country only) problems
- area specificity.

While the topic on water possess these characteristics and a financing mechanism in the 6th Framework Programme (INCO-MED area) can be identified, the other two projects, although certainly valuable, suffer of the lack of area specificity, social relevance (for example, the problem of spent catalysts is seen as a problem of the companies who use the catalyst) and identification of the right funding mechanisms. Nevertheless, they are relevant problems which should be further discussed to identify the right funding and promotion mechanisms.

Water issues possess instead the characteristic of area specificity (pollution is a much more critical problem in countries having a lack of water resources) and EU social relevance (contamination of Mediterranean see is a common problem; water is defined a priority for Mediterranean partner countries in EU 6th Framework Programme). Calls for this type of projects will be probably open at the end of 2003 and therefore it is useful to organize a Workshop possibly in Oct.-Nov. this year in a country such as Egypt which can be the place to have all the actors necessary to prepare a project to be submitted to EU.

Expectation from this project are to:

- survey the state of water pollution in southern Mediterranean countries
- awareness building by direct collaboration on scientific defined subjects
- training and education
- dissemination and public awareness
- create the critical mass to solve water issues which typically require multidisciplinary competences

***Working Group 3*** summarized the needs and action plan to create a network on catalysis in CEE and Balkan countries.

The Objectives of the proposed Network are:

- Promotion of clean catalytic technologies, in the framework of sustainable industrial development.
- Development of strategies and options for sustainable improvement of environmental protection.
- Development of environmental quality management system for the region.
- Logistic support of international research projects countries.
- Development of international cooperation on the study of transboundary pollution (air and water).
- Air and water quality assessment and improvement trough collaboration among countries
- Creation of a Database, on the basis of individual country reports, containing the following information.
    - Pollution problems of the country and relevant ongoing initiatives (type of pollutant, initiatives, etc.)
    - Survey of national chemical industry (type, production, pollution, etc.)
    - University/Research Institutions operating in the field (Short outline of research activities)
    - Information from official Bodies (Governmental bodies, Industrial Associations etc.)

A specific possibility of application inside the 6th EU Framework Programme was preliminarily identified and will be further checked from Prof. Petrov that will also prepare a detail plan of actions to create the CEE network on catalysis, including the list of potential partners and the supporting actions which ICS-UNIDO can made to implement this network and make successful its application.

***Working Group 4*** evaluated the possibility for ICS-UNIDO to be involved and cooperate within the 6$^{th}$ Framework Programme of the European Commission. Professor Trifirò suggested that ICS-UNIDO be involved in an already approved project within the 6$^{th}$ Framework Programme on alternative resources for fuels production, coordinated by the University of Vaxjo (Sweden)

***Plan of Follow-up Activities***

***Working Group 1***

- **K.Y. Cheah** (Malaysia) in collaboration with O. Attanasi (Italy) and I. Singh (India) will present before November 2003 a specific plan of actions the establish a Centre for Clean Technologies in Malaysia focused on the upgrading routes for biomasses and renewable raw materials and specific focus on the use of oil derived from palm, coconut and cashew nuts.

- **O. Attanasi** (Italy) in collaboration with E. Falabella (Brazil) will present before November 2003 a specific draft project on "Development of novel technologies for the utilization of cardanol in the preparation of green fine chemicals"

*Working Group 2*

- **G. Centi** (Italy) in collaboration with A. Lodolo (Italy) and on the basis of the results of an ICS Workshop that will be held in Morocco in September 2003 will prepare a plan for a possible project to be submitted to EU 6th Framework Programme (or other financial sources, as will be defined in the cited Workshop) on the protection and remediation of water resources by advanced water treatment technologies in Mediterranean Basin Countries

- **F. El-Gohary** (Egypt) in collaboration with G. Centi (Italy) and A. Nilgun Akin (Turkey) will prepare before September 2003 a proposal for an ICS Workshop to be held in Egypt possibly before the end of 2003 and focused on cleaner technologies to protect environment and water resources in Mediterranean Basin Countries

*Working Group 3*

- **L. Petrov** (Bulgaria) in collaboration with M. Clerici (Italy) and G. Centi (Italy) will prepare before November 2003 a detailed plan of actions to establish a CEE network on catalysis, identifying in particular the actions items and deadline to submit a proposal for financial support to the 6th EU Framework Programme

*Working Group 4*

- **F. Trifirò** (Italy) in collaboration with S. Miertus (Italy) will prepare before November 2003 a detailed plan of actions to include ICS-UNIDO in on-going EU projects on sustainable chemistry and energy. Specifically will define in detail a plan to include ICS-UNIDO in a project under the phase of negotiation on alternative resources for fuel prodyction.

*Closing of the Meeting*

**S. Miertus** (ICS-UNIDO Area Director for Pure & Applied Chemistry) closed the meeting tanking all the participants for their active involvement in the discussion.

These contributions during the meeting will be available as internet contributions in the web area dedicated to the EGM at http://www.ics.trieste.it/chemistry/catalysis/egm-greenchemistry2003.htm.

The EGM was closed at 17:15 p.m. of Tuesday 27 May 2003.