INTERNATIONAL ATOMIC ENERGY AGENCY

Report of the

Final Project Co-ordinators' Meeting

RAS/8/087

on

RADIATION PROCESSING APPLICATION FOR AGROWASTE

SUBPROJECT: RADIATION DEGRADATION OF CELLULOSE PULP FOR VISCOSE RAYON PRODUCTION

OAEP, Bangkok, Thailand

20 - 22 March 2002

BACKGROUND

The conversion of cellulose from wood pulp and cotton linters into products such as fiber, cord, film etc. involves a series of treatment steps before being spinned or cast into required forms. The conventional process of converting wood pulp into a viscose liquid consists of the following steps: Alkalization; Aging; Xanthation; Ripening; and Spinning.

The product leaving the spinning step is used in the manufacture of various end-products. In the above process scheme, it is inevitable to consume large quantities of chemicals, release notorious compounds to the environment and use energy intensely. Because of the toxic nature of most effluents, the paper and pulp industry all over the world is experiencing severe environmental constraints.

Through the alkalization, aging, xanthation and ripening processes it is mainly aimed to reduce the average molecular weight of cellulose chains and make cellulose more susceptible against certain chemical attacks and increase the accessibility of reagents into cellulose structure. When cellulose is irradiated with ionizing radiations, either gamma rays or accelerated electrons, ultimate effects are scissioning of the main chain, formation of carbonyl groups, elimination of small molecules like carbondioxide, water and hydrogen from the backbone. When the main chain is cleaved, the average length of the cellulose chain is reduced which is expressed as a reduction in average molecular weight. This is one of the most important changes that is brought about by radiation treatment. This effect is very similar to those produced during the ageing step in the viscose process. A decrease in molecular weight of cellulose enhances its solubility. The reduction in molecular weight can be very easily controlled by controlling the dose delivered or in other words irradiation time.

Formation of some new function groups on cellulose chain upon irradiation helps to improve the chemical reactivity of cellulose. Imperfections created within the crystalline domains again by the action of ionizing radiation make the cellulose structure more accessible to solvents and chemical reagents. These radiation induced modifications further reduce the amount of sodium hydroxide and carbon disulphide otherwise necessary in large volumes. It has been determined that about 40% reductions in CS_2 and 15-20% in alkali are possible. With subsequent positive effects on the reduced utilization of acid in the spinning step.

In addition to savings achieved in the chemicals on a cost basis, the irradiation of pulp is an environmentally friendly process. The problems related with the regeneration of CS_2, emission of H_2S and other toxic substances are significantly reduced. It has been estimated that only savings on chemical costs can be several million dollars per year for a typical plant.

The purpose of the meeting is to review the progress made in the region in using radiation processing in the degradation of cellulose pulp. The National Project Coordinators from six countries interested in the technology are expected to attend the meeting. The meeting will assess the prospect of EB irradiation of cellulose pulp for viscose rayon industry in the region and make recommendations for further actions and implementation. The participants are expected to bring their written reports to the meeting.

The final PCM on **"Radiation Degradation of Cellulose Pulp for Viscose Rayon Production",** RAS/8/087, was held at the headquarters of the Office of Atomic Energy for

Peace in Bangkok, Thailand from 20 to 22 March 2002 and co-chaired by Ms. Jindarom and Dr. O. Güven.

The meeting started with the opening and welcome speech of Deputy Secretary General of OAEP, Dr. Phatom Yamkate. Dr. Güven, the Technical Officer, of the project thanked the Thai authorities for hosting the meeting and gave background information about the project and its objectives. He continued to inform the participants on the results of a Consultants Meeting on "Technical, Economic and Environmental Advantages of Radiation Processing of Cellulose", held in Antalya, Turkey from 17 to 19 October 2001. Ms. Jindarom continued to chair the meeting and after the adoption of the Agenda, the PCM continued with the presentation of country reports and discussions.

The PCM on "Radiation Degradation of Cellulose Pulp for Viscose Rayon Production" was attended by 9 participants from China, India, Indonesia (2), Japan, Korea and Thailand (3). During the three day meeting the participants were first informed by the Technical Officer on the results of a Consultants Meeting held on "Technical, Economic and Environmental Advantages of Radiation Processing of Cellulose" and distributed copies of the report to all participants. The results and achievements on current research, development and implementation works carried out in respective countries on radiation degradation of cellulose pulp for viscose rayon production were reported by the participants. The information received from individual country presentations and the discussions and deliberations have led the meeting to conclude on the following points:

PREAMBLE:

Rayon has been a popular material for nearly 100 years providing the society with a number of valuable products such as fiber, cloth, yarn, materials for making tyre cords, packaging films, personnel hygiene products and so on. It is currently manufactured mainly by Viscose-rayon process that involves dissolving the cellulose pulp in toxic chemicals such as carbon disulphide and also uses high concentrations of alkali and acids. There are about 130 viscose mills all over the world that utilize this technology. In recent years increasing concerns about the use of high concentrations of hazardous chemicals and the associated environmental pollution aspects have led to closing down of such plants in the developed countries. On the other hand, to meet the existing demands of the rayon, keeping in view its advantages such as feel good factor, silk like lustre, biodegradability and availability from renewable natural resources, the plants are now being relocated in developing countries such as China, India, Indonesia, Thailand and Vietnam. However, these plants are facing stiff regulations from the environmental agencies and the industry is looking for new technologies to reduce the pollution associated with the process.

Radiation effects on cellulosic materials have been studied for a long time and it is now well established that radiation technology can be effectively used to control the degree of polymerization of cellulose pulp as well as enhancing its reactivity towards solvents. In practice, these advantages can be utilized for reducing the concentrations of hazardous chemicals associated with the viscose-rayon process thereby lowering the pollution associated with this industry.

OBJECTIVES OF THE PROJECT

The main objectives of the projects were to introduce the technology of electron beam processing to the local rayon industry in the region, develop the necessary technology to meet their specific needs and finally demonstrate the technical, economical and environmental benefits to the industry.

ACHIEVEMENTS OF THE PROJECT

- The primary objective of the project relating to bringing the awareness of EB processing to the viscose rayon industry as end users has been successfully achieved through organization of discussion meetings, national seminars and regional workshop in many countries in the region. This has led to the establishment of strong links between the radiation technologists and viscose rayon industry in the region for further collaborative work. This has been mainly possible with the help of IAEA which provided the necessary inputs in terms of arranging experienced expert for the project.
- A detailed assessment of the major viscose-rayon industries, their scale of operation and product profile has been documented during the project. This information shall be helpful in evaluating the technical needs necessary for these industries and the techno-commercial evaluation of the process.
- Laboratory scale trials have been completed in India with one of the biggest Viscose rayon manufacturers to optimize the process parameters to achieve the viscose of desired quality.
- Pilot scale trials of 20 kg batch to obtain the end product from irradiated pulp are currently being conducted to optimize process conditions for desired end product quality.
- An economic model considering the throughput, product profile and radiation dose required for the process for different applications has been developed for Indian conditions. The model takes into consideration utilization of EB machine with different energy and power to achieve the desired output. The results of the model show that EB treatment for viscose rayon is specially beneficial for industries having very large throughput. This will help the industry in selecting proper EB machine for techno-economical operation. (Detailed information is provided in the country report of India.).
- New under-beam conveyor systems have been established to handle bulk quantities of pulp material for plant scale trial. This will pave way for demonstration of technology on a plant scale.
- The close interaction among the EB technologists and viscose rayon industry has provided “hands on” experience to the viscose industry which will help in assimilating this technology successfully.

EVALUATION

Advantages

- The effect of radiation on cellulose and the accompanying physico-chemical changes have been well studied and in depth information is already available in literature about

the scientific basis of the process which can be very helpful in understanding the process and meeting the requirements of any specific manufacturer.

- The utilization of EB processing offers benefits in terms of lower concentration of carbon disulphide, sodium hydroxide and acids resulting in lower environmental pollution
- The electron beam treatment process offers advantages in terms of energy efficiency as the duration of energy consuming aging step can be very significantly reduced. The use of lesser number of ventillators due to reduced emissions of toxic gases also results in significant energy saving.
- Unlike the conventional process where controlling each step of the process is considered an "art", use of EB processed pulp as starting material with controlled molecular weight can make the whole process easier to control in a scientific manner.
- Since the uses of viscose rayon end products are already well established, only the process parameters need to be modified using the new technology.
- The molecular weight distribution of the EB treated pulp is narrower as compared to the conventionally "aged" product that may be of advantage in obtaining a better quality product.
- The EB treatment process reduces the demands on the chemicals which can result in lower cost of production.
- The lower pollution levels associated with the process shall considerably improve the health and safety of the workers.
- Availability of reliable high power electron beam machines to meet the through put demand of the viscose industry.

Disadvantages

- The main disadvantage of the technology is that cellulose being a natural product, its characteristics vary from source to source and batch to batch. The initial product needs to be characterized before deciding the radiation dose to be delivered to control the molecular weight.
- The economics of the process is very strongly dependent on the throughput of the plant. The process does not seem cost effective at low throughputs if the EB machine has to be installed at the viscose plant.
- The individual steps involved in the conventional viscose plant have to be optimized for each industry and for each application when EB technology has to be used.
- Although the reliable high power EB machines capable of meeting the requirements of high throughputs are now available, the associated under beam conveyor systems to match these throughputs and their integration with the EB process is yet to be established.
- The viscose industry, in general, is not fully informed about the benefits of radiation technology.
- Unavailability of an operational facility for demonstration of the process.

Opportunities

- The adoption of the new technology can enhance the sustainability of the viscous rayon industry by meeting the stiffer demands of environmental regulations and help in conservation of environment.

- The process can be of economic benefit to the pulp producers as they can supply better quality pulp to the viscose producer
- The EB degradation process may enhance bio-energy (ethanol) production from cellulose.
- The EB technology can also be used to decontaminate cellulosic agro-waste for animal feed.

Trends

Besides the use of radiation technology in the viscose-rayon industry, a number of other applications related to utilizing radiation technology are presently being explored which are expected to add value to the cellulosic products and may benefit this industry. These are:

- Modification or surface curing of wood-plastic composites using EB technology to improve the surface characteristics of the substrate
- Possibility of crosslinking carboxy methyl cellulose by radiation technology has opened new avenues for utilization of this product commercially
- Grafting of hydrophilic polymers on carboxy methyl cellulose by radiation technology yield super-absorbing polymers that can be used as soil-conditioners to improve the water retaining characteristics of sandy soils or can also be used in personal health care products.

RECOMMENDATIONS

- The RCA Member States should continue further work on this project as a part of the national program and should also involve the environmental regulatory agencies to inform them about potential benefits the electron beam technology can offer to this industry.
- The Member States can gain from the Indian experience gained during the project for introduction of EB technology to rayon industry.
- Though the project is complete now, the Member States can utilize avenues under Human Resources Development Programme of their countries to approach the Agency for arranging specific training programs.
- The Agency should continue support to this important program in future also by providing expert services for the industrial implementation as needed.
- The scientists and technologists in the Member States must recognize the necessity and importance of characterizing the initial raw materials being used by the industry in their respective country.

ANNEX 1

LIST OF PARTICIPANTS

International Atomic Energy Agency

Project Coordinator's Meeting
on

"Radiation Degradation of Cellulose Pulp for Viscose Rayon Production"

Bangkok, Thailand

20 - 22 March 2002

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ANNEX 2

AGENDA

International Atomic Energy Agency

Project Co-ordinator's Meeting
on

"Radiation Degradation of Cellulose Pulp for Viscose Rayon Production"

RAS/8/087

Bangkok, Thailand

20 – 22 March 2002

Wednesday, 20 March 2002

09:30 – 09:45	Opening ceremony; Introduction of participants; Announcements
09:45 – 10:30	*Background information on the sub-project on Cellulose Pulp Irradiation* ***(O. Güven)***
10:30 – 11:00	Coffee / Tea Break
11:00 – 12:30	*Briefing on the report of Consultants Meeting on "Technical, Economic and Environmental Advantages of Radiation Processing of Cellulose"*
12:30 – 14:00	Lunch Break
14:00 – 15:30	*Country Report* ***(India)***
15:30 – 16:00	Coffee / Tea Break
16:00 – 16:45	*Country Report* ***(Thailand)***
16:45 – 17:30	*Country Report* ***(China)***

Thursday, 21 March 2002

09:00 – 09:45	*Country Report **(Indonesia)***
09:45 – 10:30	*Country Report **(Korea)***
10:30 – 11:00	Coffee / Tea Break
11:00 – 11:45	*Country Report **(Viet Nam)***
11:45 – 12:30	*An overview by lead Country **(Japan)***
12:30 – 14:00	Lunch Break
14:00 – 15:30	*Discussion of the technical advantages/disadvantages, opportunities of radiation processing of Cellulose Pulp.*
15:30 – 16:00	Coffee / Tea Break
16:00 – 17:30	*Discussion on the economic aspects and environmental benefits of radiation processing of cellulose pulp.*

Friday, 22 March 2002

09:00 – 10:30	Discussion on the prospect of introducing radiation processing into viscose rayon industry, SWOT analysis.
10:30 – 11:00	Coffee / Tea Break
11:00 – 12:30	*Concluding remarks, recommendations.*
12:30 – 14:00	Lunch Break
14:00 – 15:30	*Preparation of Meeting Report*
15:30 - 16:00	Coffee / Tea Break
16:00 – 16:30	*Finalization of Meeting Report; Adjournment*