CO-ORDINATED RESEARCH PROJECTS
(CRPs)

ANNUAL REPORT OF ACTIVITIES

and

STATISTICS FOR 2001

July 2002
Research Contracts Administration Section
Department of Nuclear Sciences and Applications
International Atomic Energy Agency

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1. Introduction

Article III of the IAEA Statute authorises the Agency to encourage and assist research on, and development and practical application of, atomic energy for peaceful purposes throughout the world and to foster the exchange of scientific and technical information, as well as the exchange of scientists in the field of peaceful uses of atomic energy.

The research supported by the Agency is within the framework of the Agency's programmes, sub-programmes and projects that are listed in the approved Programme and Budget of the Agency. The research work is normally implemented through Co-ordinated Research Projects (CRPs) that bring together research institutes in both developing and developed Member States to collaborate on the research topic of interest.

In addition, the introduction of a new type of CRP (called Thematic CRP), meant to complement traditional CRPs, is currently being tested by the Human Health programme. This new, optional type of CRP is designed to strengthen promotion of research on nuclear technologies in developing Member States through CRPs that rest on pair building between agreement holders and contract holders and includes a PhD training programme at the contract holders' institutions.

Further details of the administration of research contracts and general information on CRPs is contained in the Agency's Website at:-

http://www.iaea.org/programmes/ri/uc.html

2. CRP Support to Programmes and Subprogrammes

The CRPs reported in this document are conducted in support of the following Agency programmes / subprogrammes (Ref: GC(44)/6) August 2000.

Programme A:- Nuclear Power
Programme B:- Nuclear Fuel Cycle and Waste Management Technology

Programme C:- Comparative Assessment for Sustainable Energy Development

Programme D:- Food and Agriculture

Programme E:- Human Health

Programme F:- Marine Environment and Water Resources

Programme G:- Applications of Physical and Chemical Sciences

Programme H:- Nuclear Safety

Programme I:- Radiation Safety

Programme J:- Radioactive Waste Safety

Programme K:- Co-ordination of Safety Activities

Programme L:- Safeguards

The Sub-programmes supported by the CRPs are listed in Appendix C.

Results of research are available to all Member States, and are disseminated through national, international and Agency scientific and technical publications (TECDOCs). In certain cases the research results are directly relevant to implementation of projects in the Agency's Technical Co-operation Programme.

3. Co-ordinated Research Project Activities

In terms of number of awards and degree of funding, CRPs constitute a significant activity within the Agency's programmes.

932 contracts and agreements were awarded arising of the 1371 contract and agreement proposals received by the Agency during 2001. Annex I lists by country the number of proposals received and awards made.

In 2001, $6,199,104 were awarded from the regular budget to institutes under contractual arrangements and to fund Research Co-ordination Meetings (RCMs). Additionally, $241,901 of extra-budgetary contributions was used to fund additional contracts and RCMs. Thus, total awards amounted to $6,441,005. Table 1 summarizes all awards by Programme in 2001. The average award per contract was $5,800.

Table 1: Summary of All Awards by Programme in 2001

	Programme	Regular Budget				Extra-budgetary Funding				Total Expenses
		Contracts	CRP Purchases	RCM Expenses	**Total**	Contracts	CRP Purchases	RCM Expenses	**Total**	**Expenses**
		US $	US $	US $	**US $**	US $	US $	US $	**US $**	**US $**
A	Nuclear Power	172,500	14,500	160,600	**347,600**	0	0	23,630	**23,630**	**371,230**
B	Nuclear Fuel Cycle and Waste Management Technology	181,600	0	127,969	**309,569**	0	0	0	**0**	**309,569**
C	Comparative Assessment for Sustainable Energy Development	22,000	0	58,400	**80,400**	0	0	0	**0**	**80,400**
	Major Programme 1	**376,100**	**14,500**	**346,969**	**737,569**	**0**	**0**	**23,630**	**23,630**	**761,199**
D	Food and Agriculture	1,875,491	112,246	426,643	**2,414,380**	120,000	0	0	**120,000**	**2,534,380**
E	Human Health	1,158,792	45,469	313,842	**1,518,103**	33,748	0	0	**33,748**	**1,551,851**
F	Marine Environment and Water Resources	168,110	0	64,017	**232,127**	10,000	0	0	**10,000**	**242,127**
G	Application of Physical and Chemical Sciences	644,538	16,127	302,184	**962,849**	0	0	16,740	**16,740**	**979,589**
	Major Programme 2	**3,846,931**	**173,842**	**1,106,686**	**5,127,459**	**163,748**	**0**	**16,740**	**180,488**	**5,307,947**
H	Nuclear Safety	81,850	0	106,191	**188,041**	10,000	0	4,670	**14,670**	**202,711**
I	Radiation Safety	15,800	0	42,235	**58,035**	0	0	0	**0**	**58,035**
J	Radioactive Waste Safety	0	0	0	**0**	4,500	0	18,613	**23,113**	**23,113**
K	Co-ordination of Safety Activities	40,000	0	0	**40,000**	0	0	0	**0**	**40,000**
	Major Programme 3	**137,650**	**0**	**148,426**	**286,076**	**14,500**	**0**	**23,283**	**37,783**	**323,859**
L	Safeguards/ **Major Programme 4**	**48,000**	**0**	**0**	**48,000**	**0**	**0**	**0**	**0**	**48,000**
	Total:	**4,408,681**	**188,342**	**1,602,081**	**6,199,104**	**178,248**	**0**	**63,653**	**241,901**	**6,441,005**
	Total Contract/CRP Awards	4,775,271								
	Total RCM Expenditures	1,665,734								
	Total Expenditures	6,441,005								

Figure 1 illustrates the proportion of regular budget and extra-budgetary funding in 2001.

Figure 1: 2001 Resources

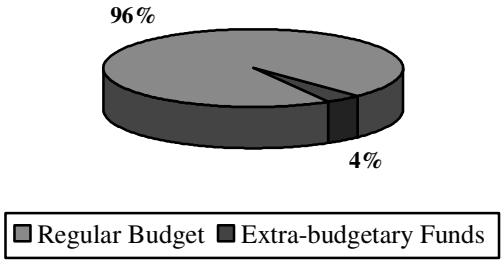
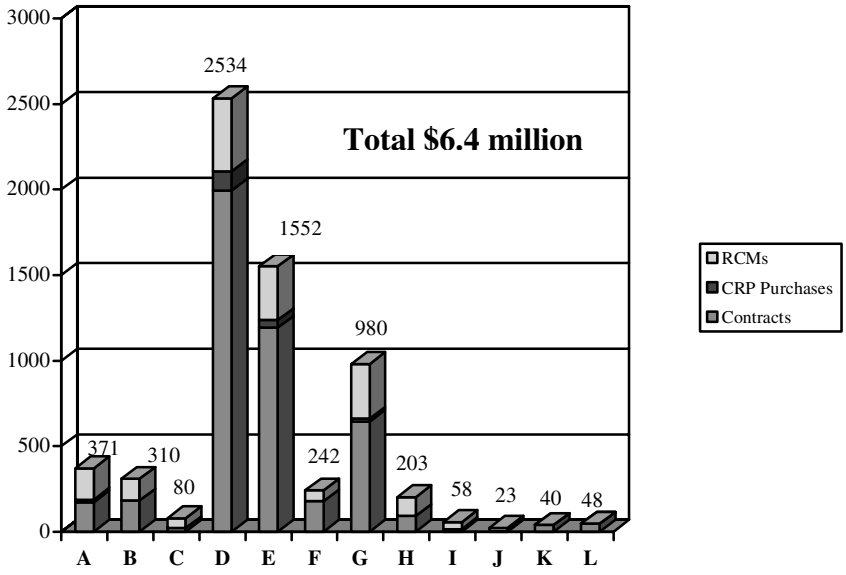


Figure 2 shows the types of awards made by programme.

Figure 2: Distribution of all 2001 Awards by Programme and Type of Activity



Details of resources for 2001 awards by programme and sub-programme and type of award are provided in Table 2. Annex II lists awards by country and programme.

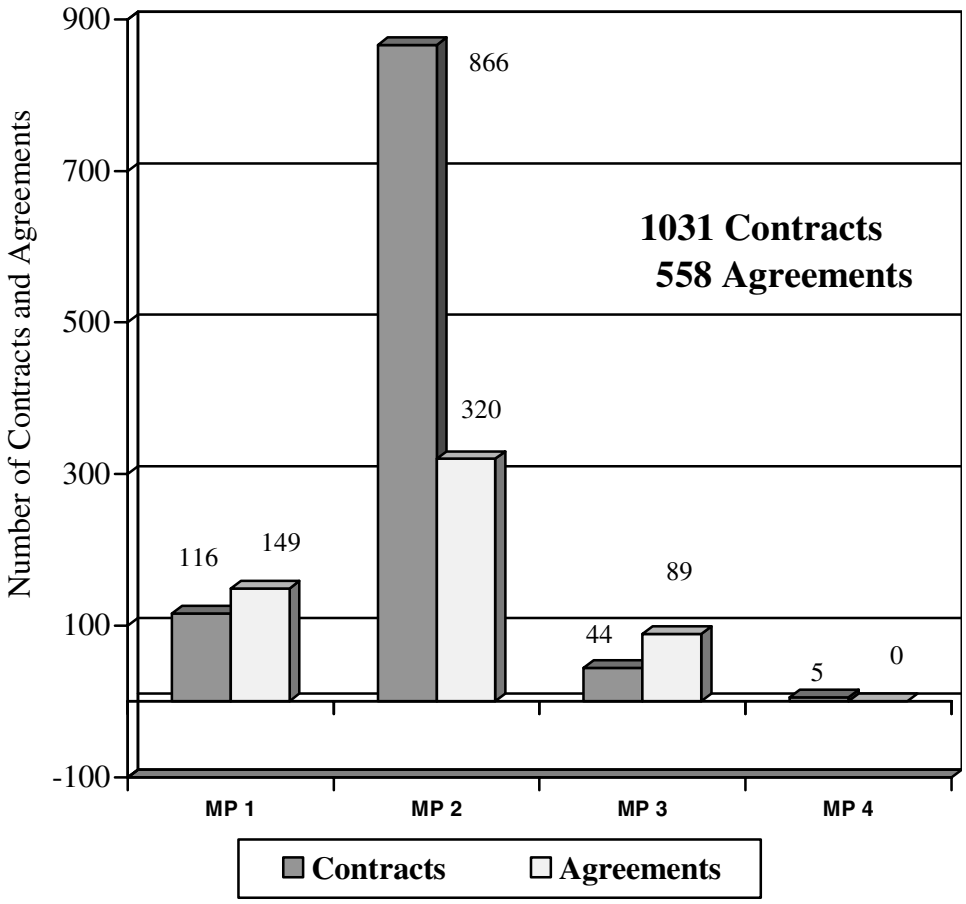
Table 2: Distribution of 2001 Total Funds by Programme

Prog.	Research Contracts		Technical Contracts		Thematic Contracts		CRP Purchases	Total	RCMs		Overall Total
	#*	US $	#	US $	#	US $	US $	US $	#	US $	US $
A1	27	108,500	0	0	0	0	14,500	123,000	5	94,300	217,300
A2	24	64,000	0	0	0	0	0	64,000	5	89,930	153,930
A	51	172,500	0	0	0	0	14,500	**187,000**	10	184,230	**371,230**
B1	19	98,000	1	18,600	0	0	0	116,600	3	53,809	170,409
B2	13	65,000	0	0	0	0	0	65,000	3	74,160	139,160
B	32	163,000	1	18,600	0	0	0	**181,600**	6	127,969	**309,569**
C1	3	18,000	0	0	0	0	0	18,000	2	31,600	49,600
C2	1	4,000	0	0	0	0	0	4,000	1	26,800	30,800
C	4	22,000	0	0	0	0	0	**22,000**	3	58,400	**80,400**
D1	39	277,000	2	16,000	0	0	110,706	403,706	4	121,863	525,569
D2	52	401,219	2	30,000	0	0	0	431,219	1	13,322	444,541
D3	63	431,750	6	45,000	0	0	0	476,750	4	85,414	562,164
D4	50	301,500	10	92,000	0	0	0	393,500	5	121,022	514,522
D5	69	356,522	4	44,500	0	0	1,540	402,562	3	85,022	487,584
D	273	1,767,991	24	227,500	0	0	112,246	**2,107,737**	17	426,643	**2,534,380**
E1	83	497,000	4	27,000	0	0	45,330	569,330	7	156,881	726,211
E2	28	113,000	8	57,000	0	0	0	170,000	2	32,437	202,437
E3	15	77,000	1	9,000	0	0	139	86,139	3	33,630	119,769
E4	46	311,290	1	1,250	8	100,000	0	412,540	4	90,894	503,434
E	172	998,290	14	94,250	8	100,000	45,469	**1,238,009**	16	313,842	**1,551,851**
F1	1	5,000	0	0	0	0	0	5,000	0	0	5,000
F3	4	20,000	0	0	0	0	0	20,000	0	0	20,000
F4	28	140,610	2	12,500	0	0	0	153,110	3	64,017	217,127
F	33	165,610	2	12,500	0	0	0	**178,110**	3	64,017	**242,127**
G1	16	68,173	4	20,000	0	0	0	88,173	5	85,178	173,351
G2	25	120,000	0	0	0	0	0	120,000	4	56,416	176,416
G4	18	90,000	1	1,000	0	0	0	91,000	1	21,077	112,077
G5	60	240,365	4	21,000	0	0	16,127	277,492	7	129,440	406,932
G6	18	84,000	0	0	0	0	0	84,000	1	26,813	110,813
G	137	602,538	9	42,000	0	0	16,127	**660,665**	18	318,924	**979,589**
H1	6	30,000	0	0	0	0	0	30,000	2	59,127	89,127
H2	8	37,250	0	0	0	0	0	37,250	1	21,710	58,960
H4	5	24,600	0	0	0	0	0	24,600	1	30,024	54,624
H	19	91,850	0	0	0	0	0	**91,850**	4	110,861	**202,711**
I1	2	3,000	2	5,800	0	0	0	8,800	1	10,241	19,041
I2	2	4,000	0	0	0	0	0	4,000	1	17,728	21,728
I3	0	0	0	0	0	0	0	0	1	14,266	14,266
I4	1	3,000	0	0	0	0	0	3,000	0	0	3,000
I	5	10,000	2	5,800	0	0	0	**15,800**	3	42,235	**58,035**
J1		4,500	0	0	0	0	0	**4,500**	1	18,613	**23,113**
K1	0	0	2	40,000	0	0	0	**40,000**	0	0	**40,000**
L2	2	38,000	1	10,000	0	0	0	**48,000**	0	0	**48,000**
	728	**4,036,279**	**55**	**450,650**	**8**	**100,000**	**188,342**	**4,775,271**	**81**	**1,665,734**	**6,441,005**

* Includes contracts with multiple fundings.

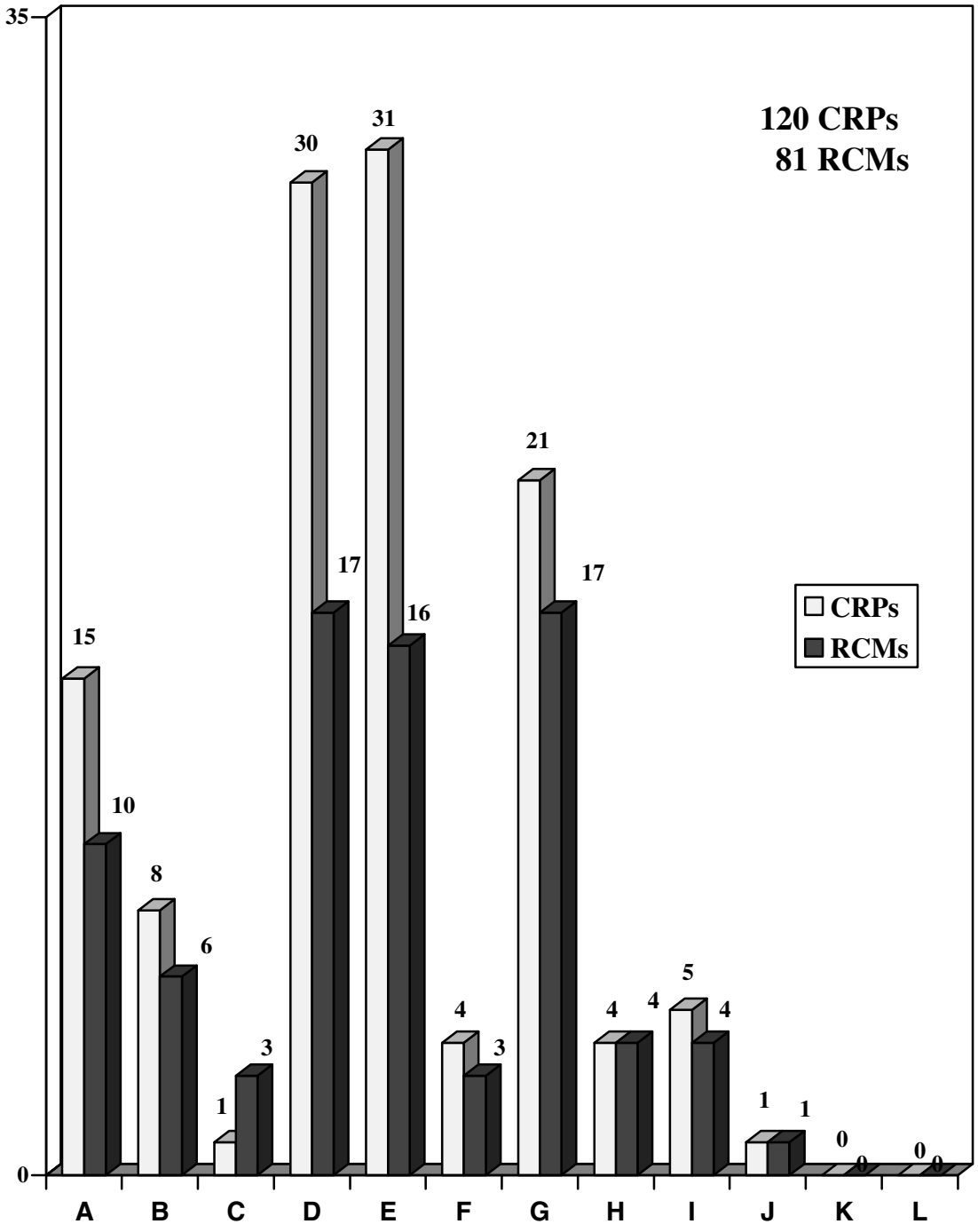
At the end of 2001, there were 1031 contracts and 558 agreements supporting 120 active CRPs (see Appendix A). 81 RCMs (see Annex III) were held in support of these CRPs and an amount of $1,665,734 was spent in support of these meetings. Figure 3 shows the distribution by Major Programme of these contracts and agreements and Figure 4 shows the distribution by programme of the CRPs and RCMs held during the year.

Figure 3: Active Contracts and Agreements by Major Programme at End 2001



MP 1: Nuclear Power; Nuclear Fuel Cycle and Waste Management Technology; Comparative Assessment for Sustainable Energy Development
MP 2: Food and Agriculture, Human Health; Marine Environment and Water Resources; Applications of Physical and Chemical Sciences
MP 3: Nuclear Safety; Radiation Safety; Radioactive Waste Safety; Co-ordination of Safety Activities
MP 4: Safeguards

Figure 4: CRPs Active at End 2001 and RCMs Held During the Year



3.1 Member State Participation

The distribution of all contract awards in 2001 is shown by country in Annex IV. 87% of the funds awarded for contracts were made to institutes in developing countries. Table 3 shows the geographical distribution of all contract awards in 2001.

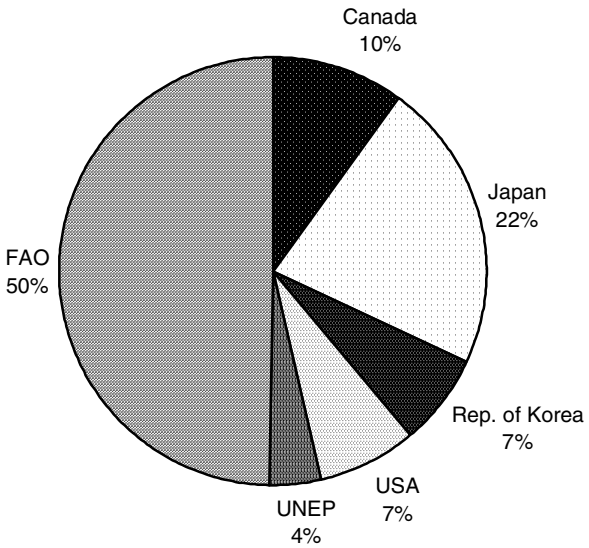
Table 3: Geographical Distribution of Research Contract Awards in 2001

	US $	%
South East Asia	1,520,496	33
Latin America	940,550	21
Eastern Europe	823,270	18
Africa	565,173	12
Western Europe	434,140	9
West Asia	174,700	4
North America	128,600	3
Total	4,586,929	100

3.2 Extra-budgetary Funding

In 2001, extra-budgetary funds amounting to $241,901 were used for financing contracts and RCMs. The funds used were from Canada, Japan, Republic of Korea, the United States of America, UNEP and FAO, as shown in Figure 5 and Table 3.

Figure 5: Extra-budgetary Funds, Approved in 2001, by Donor



Total Awards $241,901

Table 3: Summary of 2001 Extra-budgetary Funded Awards

Canada

I3.30.10	Intercomparison of techniques for pressure tube inspection and diagnostics	1 meeting 23,630

Food and Agriculture Organization of the United Nations (FAO)

D1.00.00	Food and agriculture: Soil fertility, irrigation and crop production	4 contracts 32,000
D3.20.19	Assessment of the effectiveness of vaccination strategies against Newcastle Disease and Gumboro Disease using immunoassay-based technologies for increasing farmyard poultry production in Africa	12 contracts 68,000
D3.20.20	The use of non-structural protein of foot-and-mouth disease virus (FMDV) to differentiate between vaccinated and infected animals	2 contracts 20,000

Japan

E4.30.08	Reference Asian Man Project (Phase 2): Ingestion and organ content of trace elements of importance in radiological protection (RCA)	1 contract 6,748
E4.30.10	Isotopic evaluations in infant growth monitoring - a collaboration with WHO (partly RCA)	1 contract 9,000
J7.10.09	To update and expand the IAEA reliability data for research reactor PSAs	2 contracts 10,000 1 meeting 4,670
J9.10.05	The use of selected safety indicators (concentrations; fluxes) in the assessment of radioactive waste disposal	1 contract 4,500 1 meeting 18,613

Republic of Korea

F1.10.07	Application of nuclear techniques to anti-personnel landmines identification	1 meeting 16,740

United Nations Environment Programme (UNEP)

K4.00.02	MEDPOL	2 contracts 10,000

United States of America

E4.30.10	Isotopic evaluations in infant growth monitoring - a collaboration with WHO (partly RCA)	2 contracts 18,000

Total 27 Contracts **$178,248 4** Meetings : **$63,653**

3.3 Completed CRPs in 2001

39 CRPs were completed in 2001 of which 23 of these CRPs concerned topics in Nuclear Sciences and Applications, 12 in Nuclear Power and Fuel Cycle, and 4 in Nuclear, Radiation and Waste Safety. A list of these CRPs is included in Appendix B. Evaluations of these CRPs will be completed by the end of 2002 and included in the next annual report.

4. Accomplishments of Co-ordinated Research Projects Completed in 2000

Co-ordinated Research Projects are fully evaluated about one year after their completion. During 2000, 44 CRPs were successfully completed: 35 of these related to Nuclear Sciences and Applications, 4 related to Nuclear Power and Fuel Cycle, and 5 to Nuclear, Radiation and Waste Safety.

Accomplishments of these CRPs are included in Appendix D. Publications and other outputs included 95 Agency and 405 external publications, as well as other outputs such as data bases, software packages, Web sites, presentations at conferences, etc. Detailed listings of these outputs can be seen in Appendix D.

An external review panel evaluated CRP activities in 2001 and will report its findings in 2002. Draft conclusions of the panel are that CRPs are important and a highly visible component of the Agency's activities, well conceived and worthy of expansion and refinement. A full summary of the panel's findings and recommendations will be included in the 2002 Annual Report.

Total Number of
Proposals Received and Awards Made in 2001

Country	Proposals Received			Awards*			
	Contracts	Agreements	Total	Regular	Extra-budgetary	Agreements	Total
Albania	1	0	1	1	0	0	1
Algeria	20	0	20	5	0	0	5
Argentina	44	0	44	33	0	0	33
Armenia	2	0	2	1	0	0	1
Australia	4	7	11	1	2	6	9
Austria	3	7	10	1	2	6	9
Bangladesh	14	1	15	7	0	0	7
Belarus	4	1	5	1	0	0	1
Belgium	1	5	6	1	0	4	5
Benin	3	0	3	2	0	0	2
Bolivia	4	0	4	2	0	0	2
Botswana	1	0	1	1	0	0	1
Brazil	55	1	56	39	1	1	41
Bulgaria	24	0	24	12	0	1	13
Burkina Faso	4	0	4	3	0	0	3
Cameroon	3	0	3	2	1	0	3
Canada	0	2	2	1	0	4	5
Chile	20	1	21	14	1	1	16
China	97	4	101	67	0	2	69
Colombia	12	1	13	7	0	0	7
Costa Rica	6	0	6	5	0	0	5
Cote d'Ivoire	4	0	4	3	1	0	4
Croatia	11	1	12	10	0	0	10
Cuba	25	1	26	20	0	0	20
Cyprus	3	0	3	1	0	0	1
Czech Republic	12	0	12	15	0	0	15
Democratic Rep. of the Congo	3	0	3	0	0	0	0
Denmark	1	0	1	2	0	0	2
Ecuador	4	0	4	1	0	0	1
Egypt	9	4	13	4	1	1	6
Estonia	3	0	3	1	0	0	1
Ethiopia	2	0	2	2	0	0	2
Finland	0	2	2	0	0	2	2
France	4	11	15	3	1	10	14
Georgia	1	0	1	0	0	0	0
Germany	4	7	11	2	0	10	12
Ghana	18	0	18	8	1	0	9
Greece	14	1	15	12	0	1	13
Guatemala	2	0	2	2	0	0	2
Honduras	1	0	1	1	0	0	1
Hungary	22	4	26	17	0	4	21
India	65	5	70	59	1	4	64
Indonesia	38	0	38	14	1	0	15
Iran, Islamic Republic of	25	1	26	5	0	1	6
Iraq	1	0	1	0	0	0	0

*Also includes proposals received in previous years.

Total Number of Proposals Received and Awards Made in 2001

Country	Proposals Received			Awards*			
	Contracts	Agreements	Total	Regular	Extra-budgetary	Agreements	Total
Israel	6	2	8	7	0	1	8
Italy	4	4	8	2	0	3	5
Jamaica	2	0	2	2	0	0	2
Japan	1	7	8	0	0	9	9
Jordan	6	0	6	4	0	0	4
Kazakhstan	14	0	14	8	0	0	8
Kenya	8	2	10	6	1	2	9
Korea, Republic of	37	25	62	21	0	6	27
Lao P.D.R.	1	0	1	1	0	0	1
Latvia	1	0	1	1	0	0	1
Lebanon	3	0	3	2	0	0	2
Libyan Arab Jamahiriya	1	0	1	1	0	0	1
Lithuania	2	1	3	2	0	1	3
Madagascar	1	0	1	0	0	0	0
Malawi	1	0	1	0	0	0	0
Malaysia	17	1	18	8	0	1	9
Mali	2	0	2	1	0	0	1
Malta	1	0	1	0	1	0	1
Mauritius	4	0	4	1	1	0	2
Mexico	19	0	19	12	0	0	12
Mongolia	2	0	2	1	0	0	1
Morocco	7	0	7	4	1	1	6
Myanmar	5	0	5	2	0	0	2
Namibia	2	0	2	1	0	0	1
Nepal	2	0	2	1	0	0	1
Netherlands	2	4	6	1	1	5	7
New Zealand	1	0	1	1	0	0	1
Niger	1	0	1	1	0	0	1
Nigeria	7	0	7	5	0	0	5
Norway	0	2	2	0	0	2	2
Pakistan	64	0	64	25	1	0	26
Panama	1	0	1	0	0	0	0
Paraguay	2	0	2	1	0	0	1
Peru	9	0	9	7	0	0	7
Philippines	16	1	17	11	0	1	12
Poland	21	1	22	19	0	1	20
Portugal	10	0	10	8	0	0	8
Romania	31	0	31	10	0	0	10
Russian Federation	42	2	44	39	0	2	41
Saudi Arabia	1	0	1	2	0	0	2
Senegal	2	0	2	1	0	0	1
Singapore	5	0	5	2	0	0	2
Slovakia	12	0	12	10	0	0	10
Slovenia	13	2	15	11	0	0	11
South Africa	17	3	20	13	0	2	15

*Also includes proposals received in previous years.

Total Number of
Proposals Received and Awards Made in 2001

Country	Proposals Received			Awards*			
	Contracts	Agreements	Total	Regular	Extra-budgetary	Agreements	Total
Spain	1	4	5	1	0	4	5
Sri Lanka	8	0	8	5	0	0	5
Sudan	1	0	1	1	1	0	2
Sweden	0	5	5	0	0	4	4
Syrian Arab Republic	9	0	9	4	0	0	4
Thailand	28	1	29	17	0	0	17
The Frmr.Yug.Rep. of Macedon	1	0	1	1	0	0	1
Tunisia	4	0	4	4	0	0	4
Turkey	41	1	42	18	1	1	20
Uganda	3	0	3	2	1	0	3
Ukraine	13	0	13	12	0	1	13
United Kingdom	9	11	20	8	1	10	19
United Republic of Tanzania	9	0	9	6	1	0	7
United States of America	12	23	35	10	1	26	37
Uruguay	10	1	11	8	0	1	9
Uzbekistan	7	0	7	2	0	0	2
Venezuela	3	0	3	3	0	0	3
Viet Nam	25	0	25	12	1	0	13
Yugoslavia	10	0	10	0	0	0	0
Zambia	3	0	3	3	0	0	3
Zimbabwe	4	0	4	3	1	0	4
	1201	170	1371	763	27	142	932

*Also includes proposals received in previous years.

Annex II.1

Distribution of Total
2001 Contract Awards, by Country and Programme

Country	Contracts* New	Contracts* Renewal	Total	A	B	C	MP 1	H	I+K	MP 3	D/NAFA	E/NAHU	F	G	MP 2	L/MP 4	Total
Albania	0	1	1	0	0	0	**0**	0	0	**0**	0	0	0	5,000	**5,000**	**0**	**5,000**
Algeria	4	1	5	0	0	0	**0**	0	0	**0**	0	15,000	4,000	5,000	**24,000**	**0**	**24,000**
Argentina	11	22	33	5,000	16,000	0	**21,000**	5,000	0	**5,000**	73,000	54,000	0	27,000	**154,000**	**0**	**180,000**
Armenia	0	1	1	0	0	0	**0**	0	0	**0**	10,000	0	0	0	**10,000**	**0**	**10,000**
Australia	2	1	3	0	0	0	**0**	0	0	**0**	18,000	0	0	1,000	**19,000**	**0**	**19,000**
Austria	1	2	3	0	0	0	**0**	0	0	**0**	18,000	0	0	0	**18,000**	**10,000**	**28,000**
Bangladesh	4	3	7	0	0	0	**0**	0	0	**0**	34,000	19,500	0	0	**53,500**	**0**	**53,500**
Belarus	0	1	1	0	0	0	**0**	0	0	**0**	0	0	0	4,000	**4,000**	**0**	**4,000**
Belgium	0	1	1	0	0	0	**0**	0	0	**0**	0	10,000	0	0	**10,000**	**0**	**10,000**
Benin	1	1	2	0	0	0	**0**	0	0	**0**	15,000	0	0	0	**15,000**	**0**	**15,000**
Bolivia	0	2	2	0	0	0	**0**	0	0	**0**	6,000	5,000	0	0	**11,000**	**0**	**11,000**
Botswana	0	1	1	0	0	0	**0**	0	0	**0**	4,000	0	0	0	**4,000**	**0**	**4,000**
Brazil	13	27	40	0	5,000	0	**5,000**	4,600	0	**4,600**	108,750	89,000	0	32,200	**229,950**	**0**	**239,550**
Bulgaria	2	10	12	12,000	5,000	6,000	**23,000**	3,250	0	**3,250**	25,000	5,000	0	5,000	**35,000**	**0**	**61,250**
Burkina Faso	0	3	3	0	0	0	**0**	0	0	**0**	20,000	0	0	0	**20,000**	**0**	**20,000**
Cameroon	1	2	3	0	0	0	**0**	0	0	**0**	23,000	0	0	0	**23,000**	**0**	**23,000**
Canada	0	1	1	0	0	0	**0**	0	0	**0**	10,000	0	0	0	**10,000**	**0**	**10,000**
Chile	6	9	15	0	0	0	**0**	0	0	**0**	38,500	48,000	0	0	**86,500**	**0**	**86,500**
China	17	50	67	18,000	25,500	6,000	**49,500**	0	0	**0**	153,500	98,000	14,000	64,000	**329,500**	**0**	**379,000**
Colombia	2	5	7	0	0	0	**0**	0	0	**0**	10,000	37,000	0	0	**47,000**	**0**	**47,000**
Costa Rica	0	5	5	0	0	0	**0**	0	0	**0**	31,000	0	0	0	**31,000**	**0**	**31,000**
Cote d'Ivoire	0	4	4	0	0	0	**0**	0	0	**0**	30,000	0	0	0	**30,000**	**0**	**30,000**
Croatia	4	7	11	4,000	5,000	4,000	**13,000**	0	0	**0**	5,000	9,000	5,520	14,000	**33,520**	**0**	**46,520**
Cuba	10	10	20	0	0	0	**0**	0	2,000	**2,000**	35,000	39,000	0	31,000	**105,000**	**0**	**107,000**
Cyprus	0	1	1	0	0	0	**0**	0	0	**0**	0	10,000	0	0	**10,000**	**0**	**10,000**
Czech Republic	11	4	15	17,000	10,000	0	**27,000**	10,000	0	**10,000**	0	6,000	0	22,000	**28,000**	**0**	**65,000**
Denmark	2	0	2	0	0	0	**0**	0	0	**0**	0	7,250	0	0	**7,250**	**0**	**7,250**
Ecuador	0	1	1	0	0	0	**0**	0	0	**0**	6,000	0	0	0	**6,000**	**0**	**6,000**
Egypt	1	4	5	2,000	0	0	**2,000**	0	0	**0**	10,000	0	4,000	4,000	**18,000**	**0**	**20,000**
Estonia	1	0	1	0	0	0	**0**	0	0	**0**	0	5,000	0	0	**5,000**	**0**	**5,000**
Ethiopia	0	2	2	0	0	0	**0**	0	0	**0**	11,000	0	0	0	**11,000**	**0**	**11,000**
France	0	4	4	0	0	0	**0**	0	3,050	**3,050**	8,000	5,000	0	5,000	**18,000**	**0**	**21,050**
Germany	1	1	2	0	0	0	**0**	0	0	**0**	15,000	0	9,500	0	**24,500**	**0**	**24,500**
Ghana	3	6	9	0	0	0	**0**	0	0	**0**	23,000	23,500	0	9,000	**55,500**	**0**	**55,500**
Greece	3	9	12	0	0	0	**0**	0	0	**0**	31,000	12,000	9,000	9,000	**61,000**	**0**	**61,000**

* Includes contracts with multiple fundings

Distribution of Total
2001 Contract Awards, by Country and Programme

Annex II.2

Country	Contracts* New	Contracts* Renewal	Total	A	B	C	MP 1	H	I+K	MP 3	D/NAFA	E/NAHU	F	G	MP 2	L/MP 4	Total
Guatemala	0	2	2	0	0	0	**0**	0	500	**500**	10,000	0	0	0	**10,000**	**0**	**10,500**
Honduras	0	1	1	0	0	0	**0**	0	0	**0**	5,000	0	0	0	**5,000**	**0**	**5,000**
Hungary	6	11	17	8,000	0	0	**8,000**	0	3,000	**3,000**	20,000	4,000	0	42,000	**66,000**	**0**	**77,000**
India	20	40	60	15,000	5,000	0	**20,000**	10,000	0	**10,000**	86,022	146,890	26,000	47,165	**306,078**	**0**	**336,078**
Indonesia	6	9	15	1,500	0	0	**1,500**	5,000	0	**5,000**	40,000	21,500	0	12,000	**73,500**	**0**	**80,000**
Iran, Islamic Republic of	3	2	5	0	0	0	**0**	0	0	**0**	14,000	10,000	0	8,000	**32,000**	**0**	**32,000**
Israel	2	5	7	0	0	0	**0**	0	0	**0**	21,000	0	11,000	5,000	**37,000**	**0**	**37,000**
Italy	2	0	2	0	0	0	**0**	0	2,750	**2,750**	5,000	0	0	0	**5,000**	**0**	**7,750**
Jamaica	0	2	2	0	0	0	**0**	0	0	**0**	0	13,000	0	0	**13,000**	**0**	**13,000**
Jordan	1	3	4	0	0	0	**0**	0	0	**0**	6,500	0	9,000	5,000	**20,500**	**0**	**20,500**
Kazakhstan	4	4	8	0	20,000	0	**20,000**	0	0	**0**	0	0	0	17,000	**17,000**	**0**	**37,000**
Kenya	1	6	7	0	0	0	**0**	0	0	**0**	55,000	7,000	0	0	**62,000**	**0**	**62,000**
Korea, Republic of	6	15	21	9,000	5,000	0	**14,000**	0	0	**0**	33,000	39,500	5,000	22,000	**99,500**	**0**	**113,500**
Lao P.D.R.	0	1	1	0	0	0	**0**	0	0	**0**	5,000	0	0	0	**5,000**	**0**	**5,000**
Latvia	0	1	1	0	0	0	**0**	0	0	**0**	0	0	0	0	**0**	**18,000**	**18,000**
Lebanon	1	1	2	0	0	0	**0**	0	0	**0**	6,000	0	3,000	0	**9,000**	**0**	**9,000**
Libyan Arab Jamahiriya	1	0	1	2,000	0	0	**2,000**	0	0	**0**	0	0	0	0	**0**	**0**	**2,000**
Lithuania	0	2	2	0	6,000	0	**6,000**	0	0	**0**	5,000	0	0	0	**5,000**	**0**	**11,000**
Malaysia	1	7	8	0	0	0	**0**	0	0	**0**	45,000	5,000	0	0	**50,000**	**0**	**50,000**
Mali	0	1	1	0	0	0	**0**	0	0	**0**	8,000	0	0	0	**8,000**	**0**	**8,000**
Malta	1	0	1	0	0	0	**0**	0	0	**0**	0	0	5,000	0	**5,000**	**0**	**5,000**
Mauritius	0	2	2	0	0	0	**0**	0	0	**0**	10,500	0	0	0	**10,500**	**0**	**10,500**
Mexico	3	9	12	4,000	0	0	**4,000**	0	2,000	**2,000**	54,000	6,000	0	9,000	**69,000**	**0**	**75,000**
Mongolia	1	1	2	0	0	0	**0**	0	0	**0**	0	0	0	5,000	**5,000**	**0**	**5,000**
Morocco	0	5	5	0	0	0	**0**	0	0	**0**	19,000	0	10,000	0	**29,000**	**0**	**29,000**
Myanmar	1	1	2	0	0	0	**0**	0	0	**0**	13,000	0	0	0	**13,000**	**0**	**13,000**
Namibia	0	1	1	0	0	0	**0**	0	0	**0**	4,000	0	0	0	**4,000**	**0**	**4,000**
Nepal	1	0	1	0	0	0	**0**	0	0	**0**	6,000	0	0	0	**6,000**	**0**	**6,000**
Netherlands	2	0	2	0	0	0	**0**	0	0	**0**	5,000	6,000	0	0	**11,000**	**0**	**11,000**
New Zealand	0	1	1	0	0	0	**0**	0	0	**0**	8,000	0	0	0	**8,000**	**0**	**8,000**
Niger	0	1	1	0	0	0	**0**	0	0	**0**	6,500	0	0	0	**6,500**	**0**	**6,500**
Nigeria	2	3	5	0	0	0	**0**	0	0	**0**	20,000	8,500	0	0	**28,500**	**0**	**28,500**
Pakistan	8	18	26	0	5,500	0	**5,500**	5,000	0	**5,000**	66,719	59,200	7,000	6,000	**138,919**	**0**	**149,419**
Paraguay	1	0	1	0	0	0	**0**	0	0	**0**	10,000	0	0	0	**10,000**	**0**	**10,000**
Peru	6	1	7	0	0	0	**0**	0	0	**0**	25,000	21,000	0	0	**46,000**	**0**	**46,000**

* Includes contracts with multiple fundings

Annex II.3

Distribution of Total
2001 Contract Awards, by Country and Programme

Country	Contracts* New	Renewal	Total	A	B	C	MP 1	H	I+K	MP 3	D/NAFA	E/NAHU	F	G	MP 2	L/MP 4	Total
Philippines	1	10	11	0	0	0	**0**	0	0	**0**	55,000	6,000	5,000	0	**66,000**	**0**	**66,000**
Poland	7	12	19	0	0	0	**0**	0	0	**0**	31,000	27,000	0	51,000	**109,000**	**0**	**109,000**
Portugal	1	7	8	0	0	0	**0**	0	0	**0**	20,000	8,000	9,000	10,000	**47,000**	**0**	**47,000**
Romania	2	8	10	6,000	20,000	0	**26,000**	5,000	0	**5,000**	0	5,000	0	8,000	**13,000**	**0**	**44,000**
Russian Federation	14	25	39	37,000	20,000	6,000	**63,000**	30,000	2,500	**32,500**	5,000	32,000	0	42,500	**79,500**	**20,000**	**195,000**
Saudi Arabia	0	2	2	0	0	0	**0**	0	0	**0**	0	2,200	0	4,000	**6,200**	**0**	**6,200**
Senegal	0	1	1	0	0	0	**0**	0	0	**0**	6,500	0	0	0	**6,500**	**0**	**6,500**
Singapore	1	1	2	0	0	0	**0**	0	0	**0**	0	16,000	0	0	**16,000**	**0**	**16,000**
Slovakia	5	5	10	17,000	5,000	0	**22,000**	0	0	**0**	13,000	5,000	0	9,500	**27,500**	**0**	**49,500**
Slovenia	3	8	11	0	0	0	**0**	0	0	**0**	6,000	25,000	10,000	24,000	**65,000**	**0**	**65,000**
South Africa	3	10	13	0	0	0	**0**	0	0	**0**	47,000	18,000	5,000	10,000	**80,000**	**0**	**80,000**
Spain	0	1	1	0	0	0	**0**	0	0	**0**	5,000	0	0	0	**5,000**	**0**	**5,000**
Sri Lanka	2	3	5	0	0	0	**0**	0	0	**0**	21,000	17,000	0	0	**38,000**	**0**	**38,000**
Sudan	0	2	2	0	0	0	**0**	0	0	**0**	5,000	0	0	173	**5,173**	**0**	**5,173**
Syrian Arab Republic	0	4	4	0	0	0	**0**	0	0	**0**	22,000	0	0	0	**22,000**	**0**	**22,000**
Thailand	4	13	17	0	0	0	**0**	0	0	**0**	44,000	48,500	0	12,000	**104,500**	**0**	**104,500**
The Frmr.Yug.Rep. of Macedonia	1	0	1	0	0	0	**0**	0	0	**0**	0	0	0	3,000	**3,000**	**0**	**3,000**
Tunisia	2	2	4	3,000	0	0	**3,000**	0	0	**0**	16,000	0	5,000	0	**21,000**	**0**	**24,000**
Turkey	4	15	19	0	0	0	**0**	0	0	**0**	63,000	24,500	14,090	9,000	**110,590**	**0**	**110,590**
Uganda	0	3	3	0	0	0	**0**	0	0	**0**	16,000	0	0	0	**16,000**	**0**	**16,000**
Ukraine	3	9	12	12,000	10,000	0	**22,000**	9,000	0	**9,000**	5,000	5,000	0	14,000	**24,000**	**0**	**55,000**
United Kingdom	4	5	9	0	0	0	**0**	0	34,500	**34,500**	34,500	17,000	0	0	**51,500**	**0**	**86,000**
United Rep. of Tanzania	3	4	7	0	0	0	**0**	0	0	**0**	29,000	15,500	0	0	**44,500**	**0**	**44,500**
United States of America	5	6	11	0	18,600	0	**18,600**	0	10,000	**10,000**	58,000	29,000	3,000	0	**90,000**	**0**	**118,600**
Uruguay	2	6	8	0	0	0	**0**	0	0	**0**	11,000	25,000	0	12,000	**48,000**	**0**	**48,000**
Uzbekistan	1	1	2	0	0	0	**0**	0	0	**0**	0	6,000	0	5,000	**11,000**	**0**	**11,000**
Venezuela	2	1	3	0	0	0	**0**	0	0	**0**	25,000	0	0	0	**25,000**	**0**	**25,000**
Viet Nam	6	7	13	0	0	0	**0**	5,000	0	**5,000**	40,500	13,000	5,000	15,000	**73,500**	**0**	**78,500**
Zambia	0	3	3	0	0	0	**0**	0	0	**0**	17,000	0	0	0	**17,000**	**0**	**17,000**
Zimbabwe	1	3	4	0	0	0	**0**	0	0	**0**	16,000	3,000	0	0	**19,000**	**0**	**19,000**
Total	257	535	792	172,500	181,600	22,000	**376,100**	91,850	60,300	**152,150**	1,995,491	1,192,540	178,110	644,538	**4,010,679**	**48,000**	**4,586,929**

* Includes contracts with multiple fundings

Research Co-ordination Meetings Held in 2001

Nuclear Power Planning, Implementation and Performance

A1	I2.10.11	Scientific basis and engineering solutions for cost-effective assessments of software-based I&C systems
	I2.10.12	Mechanism of nickel effect in radiation embrittlement of reactor pressure vessel materials
	I2.10.13	Surveillance programmes results application to reactor pressure vessel integrity assessment
	I2.10.14	Verification of WWER steam generator tube integrity
	I2.70.01	Information management solutions for SAT applications (SAT-IM)

Nuclear Power Reactor Technology Development

A2	I3.10.12	Evaluation of high temperature gas cooled reactor performance
	I3.20.05	Updated codes and methods to reduce the calculational uncertainties of the LMFR reactivity effects
	I3.30.10	Intercomparison of techniques for pressure tube inspection and diagnostics
	I3.30.11	Establishment of a thermophysical properties data base for LWRs and HWRs
	I3.50.01	Optimization of the coupling of nuclear reactors and desalination systems

Fuel Cycle and Materials

B1	T1.20.14	Data processing technologies and diagnostics for water chemistry and corrosion control in nuclear power plants (DAWAC)
	T1.30.07	Spent fuel performance assessment and research (SPAR)
	T1.30.08	Ageing of materials in spent fuel storage facilities

Waste Management and Technology

B2	T2.10.18	Combined methods of liquid radioactive waste treatment
	T2.10.19	Long term behaviour of low and intermediate level waste packages under repository conditions
	T2.40.05	Decommissioning techniques for research reactors

Energy Modelling, Databanks and Capacity Building

C1	I1.10.01	Estimating the external costs associated with electricity generating options in developing countries using simplified methodologies
	I1.10.02	The impact of infrastructural requirements on the competitiveness of nuclear power

Research Co-ordination Meetings Held in 2001

Energy, Economy, Environment (3E) Analysis

C2	I1.40.03	The role of nuclear power and other energy options in meeting international goals on greenhouse gas emission reductions

Soil and Water Management and Crop Nutrition

D1	D1.20.06	Management of nutrients and water in rainfed arid and semi-arid areas for increasing crop production
	D1.20.07	Use of nuclear techniques for developing integrated nutrient and water management practices for agroforestry systems
	D1.40.08	The use of isotope techniques in studies on the management of organic matter and nutrient turnover for increased, sustainable agricultural production and environmental preservation
	D1.50.05	The assessment of soil erosion through the use of Cs-137 and related techniques as a basis for soil conservation, sustainable agricultural production and environmental protection (Joint CRP with F3.10.01)

Plant Breeding and Genetics

D2	D2.30.19	Cellular biology and biotechnology including mutation techniques for creation of new useful banana genotypes

Animal Production and Health

D3	D3.10.22	Use of nuclear and related techniques to develop simple tannin assays for predicting and improving the safety and efficiency of feeding ruminants on tanniniferous tree foliage
	D3.20.17	To develop and validate standardised methods for using polymerase chain reaction (PCR) and related molecular technologies for rapid and improved animal disease diagnosis
	D3.20.18	The monitoring of contagious bovine pleuropneumonia in Africa using enzyme Immunoassays
	D3.20.21	Developing, validating and standardising methodologies for the use of PCR and PCR-ELISA in the diagnosis and monitoring of control and eradication programmes for trypanosomosis

Insect and Pest Control

D4	D4.10.15	Molecular and genetic approaches to develop sexing strains for field application in fruit fly SIT
	D4.10.16	Quality assurance of mass produced and released fruit flies for SIT programmes
	D4.20.05	Genetics application to improve the SIT for tsetse control/eradication
	D4.20.06	Automation in tsetse fly mass-rearing for use in sterile insect technique programmes
	D4.30.02	Evaluating the use of nuclear techniques for the colonization and production of natural enemies of agricultural insect pests

Annex III.2

Research Co-ordination Meetings Held in 2001

Food and Environmental Protection

D5	D5.40.03	Quality control of pesticide products
	D5.50.01	The classification of soil systems on the basis of transfer factors of radionuclides from soil to reference plants
	D6.10.22	Use of irradiation to ensure hygienic quality of fresh, pre-cut fruits and vegetables and other minimally processed food of plant origin

Nuclear Medicine

E1	E1.30.20	Intravascular radionuclide therapy (IVRNT) using liquid beta-emitting radiopharmaceuticals to prevent restenosis following percutaneous transluminal coronary angioplasty
	E1.30.21	Comparative evaluation of ictal brain SPECT, magnetic resonance imaging (MRI) and X-ray computerized tomography (CT) of brain in the management of patients with refractory seizures
	E1.30.22	Harmonization of radionuclide procedures and protocols in the management of neonatal hydronephrosis
	E1.30.23	Radiopharmaceutical imaging to predict and evaluate the response of breast cancer to neoadjuvant chemotherapy
	E1.50.15	Molecular typing of mycobacteria strains in multi-drug resistant tuberculosis
	E1.50.16	Genotype/phenotype correlation in thalassemia and muscular dystrophy
	E1.50.18	The significance of viral load and virus type in Hepatitis B and C for Pathogenesis and treatment efficacy

Applied Radiation Biology and Radiotherapy

E2	E3.30.12	Clinical application of radiosensitizers in cancer radiotherapy
	E3.50.07	Comparative assessment of teletherapy modalities

Dosimetry and Medical Radiation Physics

E3	E2.10.03	Dosimetry in X-ray diagnostic radiology. An international Code of Practice
	E2.10.04	Development of techniques at SSDLs for the dissemination of absorbed dose to water standards
	E2.40.11	Electron Paramagnetic Resonance (EPR) biodosimetry

Nutritional and Health-related Environmental Studies

E4	E4.10.10	Assessment of levels and health-effects of airborne particulate matter in mining, metal refining and metal working industries using nuclear and related analytical techniques
	E4.10.12	Health impacts of mercury cycling in contaminated environments studied by nuclear techniques

Research Co-ordination Meetings Held in 2001

	E4.30.11	Application of nuclear techniques in the prevention of degenerative diseases (obesity and non-insulin dependant diabetes) in ageing
	G4.10.03	Radiochemical, chemical and physical characterization of radioactive particles in the environment

Development and Management of Water Resources

F4	F3.10.02	Isotopic composition of precipitation in the Mediterranean Basin in relation to air circulation patterns and climate
	F3.30.11	Isotope response to dynamic changes in groundwater systems due to long term exploitation
	F3.30.13	Application of isotopes to the assessment of pollutant behaviour in the unsaturated zone for groundwater protection

Nuclear and Atomic Data for Application

G1	F4.10.16	Fission product yield data required for transmutation of minor actinide nuclear waste
	F4.10.17	Nuclear model parameter testing for nuclear data evaluation (Reference input parameter library: Phase II)
	F4.10.18	Development of a database for prompt gamma-ray neutron activation analysis
	F4.30.11	Atomic and molecular data for fusion plasma diagnostics
	F4.30.12	Data for molecular processes in edge plasmas

Nuclear Instrumentation

G2	F1.10.07	Application of nuclear techniques to anti-personnel landmines identification
	F1.10.09	In-situ applications of X-ray fluorescence (XRF) techniques
	F1.10.10	Development of distance learning (DL) modules on troubleshooting of nuclear instruments

Utilization of Research Reactors and Particle Accelerators

G4	F1.20.12	Final stage of WIMS-D library update project

Radioisotopes and Radiation Technology

G5	F2.20.22	Development of agents for imaging central neural systems (CNS) receptors based on Technetium-99m
	F2.20.29	Development of radioactively labelled cancer seeking biomolecules for targeted radiotherapy
	F2.20.31	The use of radiation processing for sterilization or decontamination of pharmaceuticals and pharmaceutical raw material
	F2.20.34	Radiation synthesis of stimuli-responsive membranes, hydrogels and adsorbents for separation purposes

Annex III.4

Research Co-ordination Meetings Held in 2001

	F2.20.35	Development of radioimmunometric assays and kits for non clinical applications
	F2.30.18	Development and validation of speciation analysis using nuclear techniques
	F2.30.19	Integration of residence time distribution (RTD) tracing with computational fluid dynamics (CFD) simulation for industrial process visualization and optimization

Nuclear Fusion Research and Plasma Physics Application

G6	F1.30.08	Elements of power plant design for inertial fusion energy

Safety Assessment Developments

H1	J4.50.01	Investigation of methodologies for incident analysis
	J4.50.02	Development and application of indicators to monitor NPP operational safety performance

Nuclear Plant Engineering Safety

H2	J7.10.08	Safety of RBMK type Nuclear Power Plant in relation to external events

Research Reactor Safety

H4	J7.10.09	To update and expand the IAEA reliability data for research reactor PSAs

Radiation Protection

I1	J1.70.04	Image quality and patient dose optimisation in mammography in Eastern European Countries

Safety of Radiation Sources and Security of Radioactive Material

I2	J1.70.05	To investigate appropriate methods and procedures to apply probabilistic safety assessment (PSA) techniques of large radiation sources

Safe Transport of Radioactive Material

I3	J1.30.08	Development of radiological basis for the transport safety requirements for low specific activity materials and surface contaminated objects
	J1.30.10	Radiological aspects of package and conveyance non-fixed radioactive contamination

Safety of Disposable Radioactive Waste

J1	J9.10.05	The use of selected safety indicators (concentrations; fluxes) in the assessment of radioactive waste disposal

Annex III.5

Research Co-ordination Meetings Held in 2001

Locations:

Argentina (2)

Australia (2)

Belgium (3)

Brazil (2)

Bulgaria

China

Czech Republic (3)

Ethiopia

France

Germany

Hungary (2)

India (3)

Italy (2)

Jamaica

Japan (2)

Kenya (2)

Malaysia (2)

Mexico

Republic of Korea (2)

Russian Federation (2)

South Africa (2)

Slovenia

Slovak Republic

Spain (2)

Tunisia

Turkey

United Kingdom (2)

Headquarters (35)

Total 2001 Contract Awards, by Country

Country	Total US$
China	379,000
India	336,078
Brazil	239,550
Russian Federation	195,000
Argentina	180,000
Pakistan	149,419
United States of America	118,600
Korea, Republic of	113,500
Turkey	110,590
Poland	109,000
Cuba	107,000
Thailand	104,500
Chile	86,500
United Kingdom	86,000
South Africa	80,000
Indonesia	80,000
Viet Nam	78,500
Hungary	77,000
Mexico	75,000
Philippines	66,000
Slovenia	65,000
Czech Republic	65,000
Kenya	62,000
Bulgaria	61,250
Greece	61,000
Ghana	55,500
Ukraine	55,000
Bangladesh	53,500
Malaysia	50,000
Slovakia	49,500
Uruguay	48,000
Portugal	47,000
Colombia	47,000
Croatia	46,520
Peru	46,000
United Republic of Tanzania	44,500
Romania	44,000
Sri Lanka	38,000
Kazakhstan	37,000
Israel	37,000
Iran, Islamic Republic of	32,000
Costa Rica	31,000
Cote d'Ivoire	30,000
Morocco	29,000
Nigeria	28,500
Austria	28,000
Venezuela	25,000
Germany	24,500
Tunisia	24,000
Algeria	24,000
Cameroon	23,000

Total 2001 Contract Awards, by Country

Country	Total US$
Syrian Arab Republic	22,000
France	21,050
Jordan	20,500
Egypt	20,000
Burkina Faso	20,000
Zimbabwe	19,000
Australia	19,000
Latvia	18,000
Zambia	17,000
Uganda	16,000
Singapore	16,000
Benin	15,000
Myanmar	13,000
Jamaica	13,000
Uzbekistan	11,000
Netherlands	11,000
Lithuania	11,000
Ethiopia	11,000
Bolivia	11,000
Mauritius	10,500
Guatemala	10,500
Paraguay	10,000
Cyprus	10,000
Canada	10,000
Belgium	10,000
Armenia	10,000
Lebanon	9,000
New Zealand	8,000
Mali	8,000
Italy	7,750
Denmark	7,250
Senegal	6,500
Niger	6,500
Saudi Arabia	6,200
Nepal	6,000
Ecuador	6,000
Sudan	5,173
Spain	5,000
Mongolia	5,000
Malta	5,000
Lao P.D.R.	5,000
Honduras	5,000
Estonia	5,000
Albania	5,000
Namibia	4,000
Botswana	4,000
Belarus	4,000
The Frmr.Yug.Rep. of Macedonia	3,000
Libyan Arab Jamahiriya	2,000
Total	**4,586,929**

Active Co-ordinated Research Projects
at End 2001

A NUCLEAR POWER

Nuclear Power Planning, Implementation and Performance

I2.10.11 Scientific basis and engineering solutions for cost-effective assessments of software-based I&C systems
2 Contracts 7 Agreements 99/10/1 02/9/30
Argentina(A), China(C), Czech Republic(A), Finland(A), Germany(A), Republic of Korea (A), Norway(A), Russian Federation(C), United States of America(A)

I2.10.12 Mechanism of nickel effect in radiation embrittlement of reactor pressure vessel materials
7 Contracts 6 Agreements 99/12/1 02/11/30
Bulgaria(C), Czech Republic(C), France(A), Hungary(A), India(C), Netherlands(A), Russian Federation(C) (2), Slovakia(C), Ukraine(C), United Kingdom(A), United States of America(A) (2)

I2.10.13 Surveillance programmes results application to reactor pressure vessel integrity assessment
2 Contracts 21 Agreements 99/11/10 03/11/9
Argentina(A), Brazil(A), Bulgaria(A), Czech Republic(A) (2), Finland(A), Germany(A) (2), Hungary(A), India(A), Japan(A), Republic of Korea (A), Mexico(C), Netherlands(A), Romania(A), Russian Federation(A) (2)Russian Federation(C), Slovakia(A), Spain(A), United States of America(A) (3)

I2.10.14 Verification of WWER steam generator tube integrity
7 Contracts 5 Agreements 01/3/1 04/12/31
Croatia(C), Czech Republic(C), Finland(A), France(A), Hungary(A)Hungary(C), Russian Federation(C) (2), Slovakia(C), Spain(A), Ukraine(C), United States of America(A)

I2.10.15 National approaches to correlate nuclear power plant performance targets and O&M costs
8 Contracts 2 Agreements 99/11/15 04/10/31
Argentina(A), Brazil(C), Czech Republic(C), Hungary(C), India(C), Republic of Korea (C), Mexico(C), Slovakia(C), Ukraine(C), United States of America(A)

I2.10.16 Evaluation of radiation damage of WWER reactor pressure vessels using the IAEA database on reactor pressure vessel materials
6 Contracts 01/9/15 05/9/14
Bulgaria(C), Czech Republic(C), Hungary(C), Russian Federation(C), Slovakia(C), Ukraine(C)

I2.70.01 Information management solutions for SAT applications (SAT-IM)
3 Contracts 6 Agreements 00/6/1 04/5/31
Bulgaria(C), Hungary(A), India(C), Russian Federation(A)Russian Federation(C), Slovakia(A), Spain(A), Ukraine(A), United States of America(A)

Nuclear Power Reactor Technology Development

I3.10.12 Evaluation of high temperature gas cooled reactor performance
2 Contracts 8 Agreements 97/11/1 05/2/28
China(C), France(A), Germany(A), Indonesia(C), Japan(A), Netherlands(A), Russian Federation(A), South Africa(A), Turkey(A), United States of America(A)

I3.10.13 Conservation and application of HTGR technology: Advances in HTGR fuel technology
5 Agreements 00/11/1 05/10/31
China(A), France(A), Japan(A), Russian Federation(A), United Kingdom(A)

I3.20.04 Studies of advanced reactor technology options for effective incineration of radioactive waste
4 Contracts 10 Agreements 01/12/15 05/12/31
Belgium(A), China(C), Czech Republic(C), France(A), Germany(A), Hungary(A), India(C), Japan(A), Republic of Korea (A), Netherlands(A) (2), Poland(A), Russian Federation(C), United States of America(A)

I3.20.05 Updated codes and methods to reduce the calculational uncertainties of the LMFR reactivity effects
3 Contracts 7 Agreements 99/10/1 03/9/30
China(C), France(A), Germany(A), India(A), Japan(A), Republic of Korea (A), Russian Federation(C) (2), United Kingdom(A), United States of America(A)

I3.30.10 Intercomparison of techniques for pressure tube inspection and diagnostics
7 Contracts 1 Agreement 98/12/15 03/12/14
Argentina(C), Canada(A), China(C), India(C), Republic of Korea (C) (2), Romania(C) (2)

I3.30.11 Establishment of a thermophysical properties data base for LWRs and HWRs
7 Contracts 2 Agreements 98/10/22 02/4/21
Canada(A), China(C), Czech Republic(C), France(A), India(C), Republic of Korea (C) (2), Russian Federation(C) (2)

I3.50.01 Optimization of the coupling of nuclear reactors and desalination systems
9 Contracts 1 Agreement 98/5/15 03/5/14
Argentina(C), China(C), Egypt(C), India(C), Indonesia(C), Republic of Korea (C), Libyan Arab Jamahiriya(C), Morocco(A), Russian Federation(C), Tunisia(C)

I3.50.02 Economic research on, and assessment of, selected nuclear desalination projects and case studies
8 Contracts 2 Agreements 01/12/15 06/12/31
Algeria(C), Argentina(C), China(C), France(A), India(C), Libyan Arab Jamahiriya(C), Pakistan(C), Russian Federation(C), Syrian Arab Republic(C), United States of America(A)

B NUCLEAR FUEL CYCLE AND WASTE MANAGEMENT TECHNOLOGY

Fuel Cycle and Materials

T1.20.13 Hydrogen and hydride induced degradation of the mechanical and physical properties of zirconium based alloys
4 Contracts 6 Agreements 98/11/1 02/10/31
Argentina(A), Canada(A), China(C), India(A), Republic of Korea (A), Lithuania(C), Pakistan(C), Romania(C), Russian Federation(A), Sweden(A)

T1.20.14 Data processing technologies and diagnostics for water chemistry and corrosion control in nuclear power plants (DAWAC)
4 Contracts 14 Agreements 01/3/1 06/3/31
Bulgaria(A), Canada(A), China(A), Czech Republic(C), Finland(A), France(A), Germany(A), Hungary(A), India(A), Japan(A), Romania(C), Russian Federation(C), Slovakia(C), Sweden(A), Ukraine(A), United Kingdom(A), United States of America(A) (2)

T1.30.07 Spent fuel performance assessment and research (SPAR)
10 Agreements 97/7/1 02/6/30
Canada(A) (2), France(A), Germany(A), Japan(A), Korea, Republic Of(A), Russian Federation(A), Spain(A), United Kingdom(A), United States of America(A)

T1.30.08 Ageing of materials in spent fuel storage facilities
3 Contracts 5 Agreements 99/10/1 03/9/30
Argentina(C), Australia(A), Germany(A), Kazakhstan(C), Romania(C), Russian Federation(A), United Kingdom(A), United States Of America(A)

T1.30.09 Nuclear fuel cycle aspects of the disposition of depleted uranium (DU)
2 Contracts 3 Agreements 01/11/15 05/11/14
France(A), India(C), Japan(A), Russian Federation(C), United States of America(A)

Waste Management and Technology

T2.10.20 Anthropogenic analogues for geological disposal of high-level and long lived radioactive waste
6 Contracts 2 Agreements 99/7/15 03/7/14
Argentina(C), China(C) (2), Czech Republic(C), Egypt(C), Republic of Korea (A), Ukraine(C), United States of America(A)

Appendix A.2

T2.10.21 Chemical durability and performance assessment of spent fuel and high level waste forms under simulated repository conditions

4 Contracts 11 Agreements 98/12/15 04/2/28

Argentina(A), Australia(A), Belgium(A), China(C), Croatia(C), Czech Republic(A), France(A), India(A), Japan(A), Republic of Korea (C), Russian Federation(A)Russian Federation(C), Spain(A) (2), United Kingdom(A)

T2.30.14 Technologies and methods for long term stabilization and isolation of uranium mill tailings

4 Contracts 10 Agreements 00/2/15 04/2/14

Brazil(A), Canada(A), China(C), Czech Republic(A), France(A), Germany(A), Kazakhstan(C), Republic of Korea (A), Poland(A) (2), Russian Federation(C), Slovenia(A), Ukraine(C), United States of America(A)

C COMPARATIVE ASSESSMENT FOR SUSTAINABLE ENERGY DEVELOPMENT

Energy Modelling, Databanks and Capacity Building

I1.10.02 The impact of infrastructural requirements on the competitiveness of nuclear power

6 Contracts 1 Agreement 99/10/1 03/9/30

Bulgaria(C), China(C), India(C), Kazakhstan(C), Pakistan(C), Russian Federation(C), Turkey(A)

D FOOD AND AGRICULTURE

Soil and Water Management and Crop Nutrition

D1.20.06 Management of nutrients and water in rainfed arid and semi-arid areas for increasing crop production

11 Contracts 5 Agreements 97/12/15 02/8/31

Argentina(C), Australia(A), China(C), France(A), India(A)India(C) (2), Jordan(C), Kenya(A)Kenya(C), Morocco(C), Niger(C), Pakistan(C), Senegal(C), Syrian Arab Republic(A), Zimbabwe(C)

D1.20.07 Use of nuclear techniques for developing integrated nutrient and water management practices for agroforestry systems

9 Contracts 5 Agreements 98/12/1 05/11/30

Australia(A) (2), Benin(C), Chile(C), China(C), Costa Rica(C), France(A), Kenya(A)Kenya(C), Malaysia(C), Nigeria(A), Sri Lanka(C), Uganda(C), Zambia(C)

D1.50.06 Development of management practices for sustainable crop production systems on tropical acid soils through the use of nuclear and related techniques

9 Contracts 5 Agreements 99/10/15 04/10/14

Australia(C), Benin(C), Brazil(C) (2), Burkina Faso(C), Colombia(A), Cuba(C), Germany(A), Kenya(A), Mexico(C), Nigeria(A)Nigeria(C), United States of America(A), Venezuela(C)

D1.50.07 Integrated soil, water and nutrient management for sustainable rice-wheat cropping systems in Asia

7 Contracts 3 Agreements 01/10/1 06/9/30

Australia(A), Bangladesh(C), China(C) (2), India(A)India(C) (2), Nepal(C), Pakistan(C), Philippines(A)

Plant Breeding Genetics

D2.30.20 Genetic improvement of underutilized and neglected crops in low income food deficit countries (LIFDCs) through irradiation and related techniques

12 Contracts 4 Agreements 98/12/1 03/11/30

Bolivia(C), Costa Rica(C) (2), Ecuador(C), France(A) (2), Germany(A), Ghana(C) (2), India(C) (2), Indonesia(C), Slovakia(C), South Africa(C), Syrian Arab Republic (A), Thailand(C).

D2.30.21 Molecular characterization of mutated genes controlling important traits for seed crop improvement

13 Contracts 6 Agreements 99/7/7 04/7/6

Brazil(C) (2), Bulgaria(C), Canada(A), China(C) (3), India(A)India(C), Republic of Korea (C) (2), Philippines(C), Poland(C), Portugal(C), Turkey(C), United Kingdom(A) (2), United States of America (A)(2)

Appendix A.3

D2.30.22 Mutitional analysis of root characters in annual food plants related to plant performance

12 Contracts 4 Agreements 00/8/1 05/7/31

Argentina(C), Australia(A)(2), Belgium(A), Brazil(C)(2), China(C)(2), Cuba(C), Germany(A),India(C), Israel(A), Mexico(C), Poland(C), South Africa(C), Switzerland(A), Turkey(C), United Kingdom(A), United Republic of Tanzania(C), United States of America(A).

D2.30.23 Improvement of tropical and subtropical fruit trees through induced mutations and biotechnology

12 Contracts 4 Agreements 00/8/1 05/7/31

Australia(A), China(C), Cuba(C), India(C) (2), Indonesia(C), Islamic Republic of Iran(C), Israel(A), Malaysia(C) (2), Pakistan(C), Philippines(C), South Africa(C), Thailand(C), United Kingdom(A), United States of America(A)

Animal Production and Health

D3.10.21 Use of nuclear and colorimatric techniques for measuring microbial protein supply from local feed resources in ruminant animals

10 Contracts 6 Agreements 96/4/15 02/5/31

Australia(A), Chile(C), China(A)China(C), Indonesia(C), Italy(A)Italy(C), Malaysia(C), Morocco(C), Spain(A), Sri Lanka(A)Sri Lanka(C), Turkey(C), United Kingdom(A), Viet Nam(C), Zimbabwe(C)

D3.10.22 Use of nuclear and related techniques to develop simple tannin assays for predicting and improving the safety and efficiency of feeding ruminants on tanniniferous tree foliage

8 Contracts 3 Agreements 98/7/1 04/6/30

Australia(A), Bangladesh(C), Brazil(C), Canada(A), Germany(C), Indonesia(C), Sri Lanka(C), Tunisia(C), Turkey(C), United Kingdom(A), United States of America(C)

D3.10.23 Integrated approach for improving small scale market oriented dairy systems

11 Contracts 4 Agreements 01/11/1 06/12/31

Bangladesh(C), Cameroon(C), Malaysia(A), Pakistan(C), Paraguay(C), Peru(C) (2), South Africa(C), Sri Lanka(C), Tunisia(C), United Kingdom(A), United Republic of Tanzania(C), United States of America(A), Uruguay(A), Venezuela(C)

D3.20.17 To develop and validate standardised methods for using polymerase chain reaction (PCR) and related molecular technologies for rapid and improved animal disease diagnosis

8 Contracts 4 Agreements 97/1/1 02/12/31

Cameroon(C), Cote d'Ivoire(C), Ethiopia(C), France(A), Kenya(C), Republic of Korea (C), Mali(C), Pakistan(C), South Africa(A), Sweden(A), United Kingdom(A), United Republic of Tanzania(C)

D3.20.18 The monitoring of contagious bovine pleuropneumonia in Africa using enzyme immunoassays

12 Contracts 3 Agreements 97/11/15 03/3/31

Botswana(C), Cote d'Ivoire(C), Ethiopia(C), France(A), Ghana(C), Kenya(C), Mali(C), Namibia(C), Nigeria(C), Sweden(A), Uganda(C), United Kingdom(A)United Kingdom(C), United Republic of Tanzania(C), Zambia(C)

D3.20.19 Assessment of the effectiveness of vaccination strategies against Newcastle Disease and Gumboro Disease using immunoassay-based technologies for increasing farmyard poultry production in Africa

13 Contracts 5 Agreements 98/4/1 04/3/31

Cameroon(C), Cote D'ivoire(C), Denmark(A), Egypt(C), Ghana(C), Kenya(C), Madagascar(C), Mauritius(C), Morocco(A)Morocco(C), Netherlands(C), Nigeria(A), Sudan(C), Uganda(C), United Republic of Tanzania(A)United Republic of Tanzania(C), United States of America(A), Zimbabwe(C)

D3.20.20 The use of non-structural protein of foot-and-mouth disease virus (FMDV) to differentiate between vaccinated and infected animals

15 Contracts 5 Agreements 99/1/15 04/1/14

Argentina(C) (2), Australia(C), Austria(C), Brazil(A)Brazil(C), China(C) (2), Colombia(C), Denmark(A), Italy(A), Lao PDR(C), Malaysia(C), Myanmar(C), Peru(C), Philippines(C), South Africa(C), Thailand(C), United Kingdom(A), United States of America(A)

Appendix A.4

D3.20.21 Developing, validating and standardising methodologies for the use of PCR and PCR-ELISA in the diagnosis and monitoring of control and eradication programmes for trypanosomosis

11 Contracts 5 Agreements 00/11/15 05/11/14

Belgium(A), Bolivia(C), Brazil(C), Burkina Faso(C), Chile(C), China(C), Cote d'Ivoire(C), Germany(A), Kenya(C), Netherlands(A) (2), South Africa(C), Thailand(C), Uganda(C), United Kingdom(A), Viet Nam(C)

Insect and Pest Control

D4.10.12 Enhancement of the SIT through genetic transformation of arthropods using nuclear techniques

2 Contracts 8 Agreements 94/12/15 02/12/31

Australia(A), Greece(C), Italy(A) (3), New Zealand(C), United Kingdom(A), United States of America(A) (3)

D4.10.16 Quality assurance of mass produced and released fruit flies for SIT programmes

13 Contracts 5 Agreements 99/10/1 04/9/30

Argentina(C) (2), Australia(A), Chile(C), Costa Rica(C), France(A), Guatemala(C), Israel(C) (2), Japan(A), Lebanon(C), Mexico(C) (2), Peru(C), Philippines(C), Portugal(C), South Africa(A), United States of America(A)

D4.10.17 Development of improved attractants and their integration into fruit fly SIT management programmes

14 Contracts 4 Agreements 00/4/1 05/3/31

Argentina(C), Brazil(C) (2), Colombia(C), Costa Rica(C), France(A), Greece(C), Honduras(C), Israel(C), Mauritius(C), Mexico(C), Pakistan(C), Portugal(A), Spain(A)Spain(C), United Kingdom(A), United States of America(C) (2)

D4.20.05 Genetics application to improve the SIT for tsetse control/eradication

3 Contracts 6 Agreements 97/1/1 03/1/30

Belgium(A), Canada(A), Cote d'Ivoire(C), Greece(C), Italy(A), Kenya(C), United States of America(A)(3)

D4.20.08 Improved attractants for enhancing the efficiency of tsetse fly suppression operations and barrier systems used in tsetse control/eradication campaigns

6 Contracts 2 Agreements 94/12/15 02/3/31

Burkina Faso(C), Hungary(C), Kenya(C), Mali(C), Switzerland(A), Uganda(C), United Republic of Tanzania(C), United States of America(A)

D4.20.09 Enabling technologies for the expansion of SIT for old and new world screwworm

6 Contracts 4 Agreements 01/8/1 05/7/31

Brazil(C), Indonesia(C), Iran, Islamic Republic Of(C), Sweden(A), United Kingdom(A)United Kingdom(C), United States of America(A) (2), Uruguay(C), Venezuela(C)

D4.30.02 Evaluating the use of nuclear techniques for the colonization and production of natural enemies of agricultural insect pests

15 Contracts 3 Agreements 99/8/1 04/7/31

Argentina(C), Austria(A) (2), Bangladesh(C), Bulgaria(C), China(C), Guatemala(C), India(C), Indonesia(C), Mexico(C), Pakistan(C), Poland(C), Slovakia(C), Syrian Arab Republic(C), Turkey(C) (2), United States of America(A)United States of America(C)

Food and Environmental Protection

D5.20.34 Alternative methods to gas and high performance liquid chromatography for pesticide residue analysis in grain

10 Contracts 97/12/1 02/10/31

Argentina(C), Bangladesh(C), China(C), Croatia(C), Hungary(C), India(C), Pakistan(C), Panama(C), Philippines(C), Turkey(C)

Appendix A.5

D5.40.03 Quality control of pesticide products

15 Contracts 3 Agreements 00/12/1 05/11/30

China(C) (2), Cuba(C), Greece(A), Hungary(C) (2), India(C) (2), Republic of Korea (C), Myanmar(C), Nigeria(C), Philippines(C), Thailand(C), Turkey(C), United States of America(A) (2), Uruguay(C), Viet Nam(C)

D5.50.01 The classification of soil systems on the basis of transfer factors of radionuclides from soil to reference plants

11 Contracts 3 Agreements 98/11/1 03/12/31

Australia(A), Brazil(C), Bulgaria(C), Chile(C), China(C), Greece(C), India(C), Japan(A), Russian Federation(C), Syrian Arab Republic(C), Turkey(C), Ukraine(C), United States of America(A), Viet Nam(C)

D6.10.19 Determination of profiles of human bacterial pathogens in foods for export by introduction of quality-assured microbiological assays

10 Contracts 2 Agreements 97/12/15 02/11/30

Australia(A), Austria(A), Brazil(C), Chile(C), India(C), Indonesia(C), Republic of Korea (C), Mexico(C), Nigeria(C), Paraguay(C), Philippines(C), Thailand(C)

D6.10.20 Irradiation as a phytosanitary treatment of food and agricultural commodities

11 Contracts 4 Agreements 98/12/1 02/12/31

Australia(A), Brazil(C), Chile(C), China(C) (2), Islamic Republic of Iran(C), Japan(A), Malaysia(C), Philippines(C), Poland(C), Syrian Arab Republic(C), Thailand(C), Turkey(C), United States of America(A) (2)

D6.10.21 Evaluation of methods of analysis for determining mycotoxin contamination of food and feed

15 Contracts 4 Agreements 98/11/1 03/10/31

Argentina(C), Australia(C), Brazil(C), Canada(A)Canada(C), China(C), Cuba(C), Egypt(C), Ghana(C), India(C), Indonesia(C), Italy(A), Malaysia(C), Philippines(C), South Africa(C), United Kingdom(A)United Kingdom(C), United States of America(A), Uruguay(C)

D6.10.22 Use of irradiation to ensure hygienic quality of fresh, pre-cut fruits and vegetables and other minimally processed food of plant origin

12 Contracts 3 Agreements 01/4/1 05/3/31

Argentina(C), Brazil(C), Canada(A), Chile(C), China(C), Egypt(C), Hungary(C), India(C), Korea, Republic Of(C), Malaysia(C), Pakistan(C), Portugal(C), Turkey(C), United Kingdom(A), United States of America(A)

E HUMAN HEALTH
Nuclear Medicine

E1.10.13 Development and validation of an Internet based clinical and technical study communication system for nuclear medicine

9 Contracts 1 Agreement 98/12/15 02/12/14

Argentina(C), China(C) (2), Greece(C), India(C) (2), Thailand(C), United Kingdom(C) (2), United States of America(A)

E1.10.14 To compare clinical application software between nuclear medicine laboratories by software phantoms developed by the Agency and COST B2 project.

8 Contracts 2 Agreements 99/12/15 03/12/14

Argentina(C), Austria(A), Chile(C), China(C), Cuba(C), Hungary(C), India(C), South Africa(C), Thailand(C), United Kingdom(A)

E1.20.16 Radioimmunoassay of advanced glycation end products (AGEs) in the long term management of diabetes mellitus

5 Contracts 2 Agreements 00/9/1 04/8/31

China(C), Greece(C), India(C), Mexico(C), Thailand(C), United Kingdom(A), United States of America(A)

Appendix A.6

E1.30.18 Study of the relationship between recurrent lower respiratory tract infection, gastroesophageal reflux and bronchial asthma in children

9 Contracts 1 Agreement 99/12/15 02/12/14

Chile(C), China(C), Colombia(C), India(A), Pakistan(C), Philippines(C), Poland(C), South Africa(C), Thailand(C), Turkey(C)

E1.30.19 Thematic CRP on Management of liver cancer using radionuclide methods with special emphasis on trans-arterial radioconjugate therapy and internal dosimetry

10 Contracts 8 Agreements 00/9/1 05/8/31

Australia(A), Austria(A), China(C), Colombia(C), France(A), India(A)India(C), Republic of Korea (C) (2), Mongolia(C), Philippines(C), Singapore(C), Slovenia(A), Thailand(C), United Kingdom(A), United States of America(A) (2), Viet Nam(C)

E1.30.20 Intravascular radionuclide therapy (IVRNT) using liquid beta-emitting radiopharmaceuticals to prevent restenosis following percutaneous transluminal coronary angioplasty

13 Contracts 4 Agreements 00/11/15 03/11/14

China(C), Colombia(C), Cuba(C), Cyprus(C), Germany(A), Hungary(C), India(C), Iran, Islamic Republic Of(C), Republic of Korea (A) Republic of Korea (C), Poland(C), Singapore(C), Thailand(C), Turkey(C), United States of America(A) (2), Uruguay(C)

E1.30.21 Comparative evaluation of ictal brain SPECT, magnetic resonance imaging (MRI) and X-ray computerized tomography (CT) of brain in the management of patients with refractory seizures

9 Contracts 3 Agreements 00/12/1 03/12/31

Argentina(C), Belgium(A), China(C) (2), Colombia(C), India(C), Italy(A), Republic of Korea (A) Republic of Korea (C), South Africa(C), Thailand(C), Turkey(C)

E1.30.22 Harmonization of radionuclide procedures and protocols in the management of neonatal hydronephrosis

10 Contracts 3 Agreements 01/8/1 04/7/31

Algeria(C), Chile(A)Chile(C), China(C), Colombia(C), Cuba(C), Estonia(C), India(C), Islamic Republic of Iran(A), Pakistan(C), Peru(C), Slovakia(C), Spain(A)

E1.30.23 Radiopharmaceutical imaging to predict and evaluate the response of breast cancer to neoadjuvant chemotherapy

11 Contracts 1 Agreement 01/8/1 04/7/31

Argentina(C), Chile(C), China(C), Colombia(C), Croatia(C), Cuba(C), India(C), Italy(A), Republic of Korea (C), Poland(C), Singapore(C), Thailand(C)

E1.50.15 Molecular typing of mycobacteria strains in multi-drug resistant tuberculosis

8 Contracts 1 Agreement 97/12/1 02/11/30

Brazil(C), India(C) (2), Republic of Korea (C), Malaysia(C), Morocco(C), Netherlands(A), Russian Federation(C), South Africa(C)

E1.50.16 Genotype/phenotype correlation in thalassemia and muscular dystrophy

10 Contracts 1 Agreement 98/11/1 02/11/30

Australia(A), Brazil(C), Cyprus(C), India(C), Mauritius(C), Pakistan(C), South Africa(C), Thailand(C), Tunisia(C), Turkey(C), United Kingdom(C)

E1.50.17 Development of an improved serological kit for Chagas diagnosis using radionuclide methods

10 Contracts 99/3/1 02/11/30

Argentina(C) (2), Bolivia(C), Brazil(C) (3), Honduras(C), Mexico(C), Panama(C), Venezuela(C)

E1.50.18 The significance of viral load and virus type in Hepatitis B and C for Pathogenesis and treatment efficacy

7 Contracts 1 Agreement 99/10/1 02/9/30

Argentina(C), China(C), India(C), Republic of Korea (C), Malaysia(C), Russian Federation(C), United Kingdom(A), Uruguay(C)

Appendix A.7

Applied Radiation Biology and Radiotherapy

E3.30.12 Clinical application of radiosensitizers in cancer radiotherapy
5 Contracts 2 Agreements 94/9/15 02/12/31
India(C), Japan(A) (2), Pakistan(C), Sri Lanka(C), Turkey(C), United Kingdom(C)

E3.30.13 Randomised clinical trial of radiotherapy combined with Mitomycin C in the treatment of advanced head and neck tumours
10 Contracts 2 Agreements 95/4/15 03/4/30
Bulgaria(C), Denmark(C) (2), India(C) (2), Italy(A), Malaysia(C), Pakistan(C) (2), Sri Lanka(C), Turkey(C), United States of America(A)

E3.30.17 Regional hyperthermia combined with radiotherapy for locally advanced cancers
5 Contracts 3 Agreements 97/12/15 02/12/14
China(C) (2), India(C), Japan(A) (2), Republic of Korea (C) (2), United States of America(A)

E3.30.18 Aspects of radiobiology applicable in clinical radiotherapy - Increase of the number of fractions per week
8 Contracts 2 Agreements 98/9/15 06/3/31
Chile(C), Denmark(A) (2), Estonia(C), India(C) (2), Lebanon(C), Pakistan(C) (2), Saudi Arabia(C)

E3.50.07 Comparative assessment of teletherapy modalities
11 Contracts 01/8/1 03/7/31
Brazil(C), China(C), Croatia(C), Cuba(C), Greece(C), India(C), Indonesia(C), Netherlands(C), Pakistan(C), Peru(C), South Africa(C)

Dosimetry and Medical Radiation Physics

E2.10.03 Dosimetry in X-ray diagnostic radiology. An international Code of Practice
5 Agreements 00/12/1 05/11/30
Germany(A), Malaysia(A), Sweden(A), United Kingdom(A), United States of America(A)

E2.10.04 Development of techniques at SSDLs for the dissemination of absorbed dose to water standards
4 Contracts 2 Agreements 01/4/1 04/3/31
Algeria(C), Argentina(C), France(A), India(C), Norway(A), Thailand(C)

E2.40.09 Development of a Code of Practice for dose determination in photon, electron and proton beams based on measurement standards of absorbed dose to water
3 Contracts 3 Agreements 97/9/1 02/11/30
Brazil(C), France(A), Germany(A), India(C), Slovenia(C), United States of America(A)

E2.40.12 Development of TLD-based quality audits for radiotherapy dosimetry in non-reference conditions
6 Contracts 01/12/15 06/12/31
Algeria(C), Argentina(C), Bulgaria(C), China(C), Cuba(C), Poland(C)

Nutritional and Health-related Environmental Studies

E4.10.11 Validation and application of plants as biomonitors of trace element atmospheric pollution, analyzed by nuclear and related techniques
9 Contracts 5 Agreements 97/12/15 02/12/31
Argentina(C), Brazil(A), Chile(A), China(C), Germany(A), Ghana(C), India(C), Israel(C), Jamaica(C), Netherlands(A), Norway(A), Portugal(C), Romania(C), Russian Federation(C)

E4.10.12 Health impacts of mercury cycling in contaminated environments studied by nuclear techniques
7 Contracts 4 Agreements 99/9/1 04/8/31
Brazil(C), Canada(A), China(C), Germany(A), India(C), Japan(A), Philippines(C), Slovenia(C), Sweden(A), United Republic of Tanzania(C), Venezuela(C)

Appendix A.8

E4.10.13 Use of nuclear and related analytical techniques in studying human exposure to toxic elements consumed through foodstuffs contaminated by industrial activities

11 Contracts 1 Agreement 01/12/15 06/12/31

Brazil(C), China(C), Czech Republic(C), Ghana(C), India(C), Nigeria(C), Peru(C), Russian Federation(C), Slovenia(C), South Africa(A), Uzbekistan(C), Viet Nam(C)

E4.30.10 Isotopic evaluations in infant growth monitoring - a collaboration with WHO (partly RCA)

4 Contracts 2 Agreements 99/11/1 02/10/31

Bangladesh(C), Brazil(C), Chile(C), Pakistan(C), United Kingdom(A), United States of America(A)

E4.30.11 Application of nuclear techniques in the prevention of degenerative diseases (obesity and non-insulin dependant diabetes) in ageing

8 Contracts 3 Agreements 98/12/15 02/12/31

Brazil(C), Chile(C), China(C), Cuba(C), India(C), Jamaica(C), Mexico(C), New Zealand(A), Nigeria(C), United Kingdom(A), United States of America(A)

E4.30.12 Use of isotopic techniques to examine the significance of infection and other insults in early childhood to diarrhoea morbitity, mal-assimilation and failure to thrive

12 Contracts 1 Agreement 99/12/15 03/12/14

Argentina(C), Bangladesh(C), Belgium(A), Benin(C), Chile(C), Cuba(C), India(C), Indonesia(C), Mexico(C) (2), Pakistan(C), Senegal(C), United Kingdom(C)

E4.30.13 Thematic CRP on Isotopic and complementary tools for the study of micronutrient status and interactions in developing country populations exposed to multiple nutritional deficiencies

8 Contracts 01/12/15 07/12/31

Bangladesh(C), Brazil(C), Ghana(C), India(C), Indonesia(C), Pakistan(C), Sri Lanka(C), Thailand(C)

E4.30.14 Application of isotopic and nuclear techniques in the study of nutrition-pollution interactions and their impact on the nutritional status of human subjects in developing country populations

7 Contracts 1 Agreement 01/12/15 05/3/31

Bangladesh(C), Chile(C), China(C), India(C), Kenya(C), Republic of Korea (A), Peru(C), Viet Nam(C)

G4.10.03 Radiochemical, chemical and physical characterisation of radioactive particles in the environment

4 Contracts 4 Agreements 00/12/1 05/11/30

Denmark(A), Finland(A), Hungary(C), Kazakhstan(C), Norway(A), Russian Federation(C), Ukraine(C), United States of America(A)

F MARINE ENVIRONMENT AND WATER RESOURCES

Development and Management of Water Resources

F3.10.02 Isotopic composition of precipitation in the Mediterranean Basin in relation to air circulation patterns and climate

10 Contracts 5 Agreements 00/6/15 04/6/14

Algeria(C), Austria(A), Croatia(C), Egypt(C), France(A), Greece(C), Israel(A), Italy(A), Lebanon(C), Morocco(C), Portugal(C) (2), Slovenia(C), Spain(A), Turkey(C)

F3.30.11 Isotope response to dynamic changes in groundwater systems due to long term exploitation

8 Contracts 6 Agreements 99/6/1 03/5/31

Australia(A), Denmark(A), Germany(A) (2), India(C), Israel(C), Jordan(C), Malaysia(C), Philippines(C), South Africa(C), Switzerland(A), Tunisia(C), Turkey(C), United States of America(A)

F3.30.12 Origins of salinity and impacts on fresh groundwater resources: Optimization of isotopic techniques

7 Contracts 5 Agreements 00/8/1 05/7/31

Australia(A), China(C), Israel(C), Italy(A), Jordan(C), Republic of Korea (C), Morocco(C), Pakistan(C), Sweden(A), Tunisia(C), United Kingdom(A), United States of America(A)

F3.30.13 Application of isotopes to the assessment of pollutant behaviour in the unsaturated zone for groundwater protection

7 Contracts 3 Agreements 00/12/15 03/12/14

Austria(A), China(C), Germany(C), India(C), Pakistan(C), Slovenia(C), South Africa(C), Syrian Arab Republic(C), United Kingdom(A), United States of America(A)

Appendix A.9

G APPLICATIONS OF PHYSICAL AND CHEMICAL SCIENCES

Nuclear and Atomic Data for Applications

F4.10.16 Fission product yield data required for transmutation of minor actinide nuclear waste

4 Contracts 6 Agreements 97/10/1 03/3/31

Belarus(C), China(C), Germany(A), Japan(A), Kazakhstan(C), Netherlands(A), Russian Federation(A), Ukraine(C), United Kingdom(A), United States of America(A)

F4.10.17 Nuclear model parameter testing for nuclear data evaluation (Reference input parameter library: Phase II)

5 Contracts 6 Agreements 98/7/1 02/6/30

Belgium(A), China(C), Cuba(C), France(A), Hungary(C), India(C), Japan(A), Netherlands(A), Russian Federation(A), Ukraine(C), United States of America(A)

F4.10.18 Development of a database for prompt gamma-ray neutron activation analysis

4 Contracts 3 Agreements 99/4/1 03/3/31

China(C), Hungary(C), India(C), Republic of Korea (A), United States of America(A) (2), Viet Nam(C)

F4.20.04 Update of X- and gamma-ray decay data standards for detector calibration

5 Contracts 5 Agreements 98/4/1 02/12/31

Brazil(C), France(A), Germany(A), Hungary(C), Russian Federation(C), Slovakia(C) (2), Spain(A), United Kingdom(A), United States of America(A)

F4.30.11 Atomic and molecular data for fusion plasma diagnostics

2 Contracts 9 Agreements 01/7/15 04/6/30

Austria(A), Germany(A) (2), Netherlands(A), Russian Federation(C), Spain(A), The Former Yugoslavian Republic of Macedonia(C), United Kingdom(A) (2), United States of America(A) (2)

F4.30.12 Data for molecular processes in edge plasmas

3 Contracts 8 Agreements 01/8/1 04/7/31

Austria(A), Belgium(A), Czech Republic(C), France(A), Germany(A), Italy(A), Japan(A), Russian Federation(C), Slovakia(C), Sweden(A), United States of America(A)

Nuclear Instrumentation

F1.10.07 Application of nuclear techniques to anti-personnel landmines identification

7 Contracts 8 Agreements 99/10/1 02/9/30

Australia(A), Canada(A), Croatia(C), Egypt(A), Hungary(C), Italy(A), Netherlands(A), Russian Federation(C), Slovakia(C), Slovenia(C), South Africa(C), Sweden(A), United States of America(A) (2), Viet Nam(C)

F1.10.08 Development and applications of alpha particle spectrometry

8 Contracts 6 Agreements 00/7/1 03/6/30

Algeria(C), Bulgaria(C), China(C), Cuba(C), Finland(A), India(C), Kazakhstan(C), Republic of Korea(A), Mexico(C), Norway(A), Russian Federation(A), Slovenia(C), Spain(A), Sweden(A)

F1.10.09 In-situ applications of X-ray fluorescence (XRF) techniques

9 Contracts 3 Agreements 00/7/10 04/7/9

Albania(C), Argentina(C), Belgium(A), China(C), Ghana(C), Hungary(C), Italy(A), Mongolia(C), Pakistan(C), Poland(C), Slovenia(C), United Kingdom(A)

F1.10.10 Development of distance learning (DL) modules on troubleshooting of nuclear instruments

5 Contracts 1 Agreement 01/11/1 04/12/31

Argentina(C), Brazil(C), Cuba(C), India(C), Israel(A), Viet Nam(C)

Utilization of Research Reactors and Particle Accelerators

F1.20.13 Development and practical utilization of small angle neutron scattering (SANS) applications
8 Contracts 4 Agreements 00/8/25 03/8/31
Austria(A), Brazil(C), France(A) (2), Germany(A), Greece(C), Hungary(C), India(C), Republic of Korea(C), Portugal(C), Russian Federation(C), South Africa(C)

F1.20.14 The use of ion beam techniques for analysis of light elements in thin films, including depth profiling
7 Contracts 3 Agreements 00/8/1 03/7/31
Brazil(C), China(C), Croatia(C), Finland(A), France(A), Hungary(C), Mexico(C), New Zealand(A), Portugal(C), Slovenia(C)

Radioisotopes and Radiation Technology

F2.20.32 Development of kits for Tc99m radiopharmaceuticals for infection imaging
9 Contracts 3 Agreements 00/6/15 03/6/14
Argentina(C), China(C), Hungary(A), India(C), Indonesia(C), Mexico(C), Netherlands(A), Pakistan(C), Poland(C), Thailand(C), United States of America(A), Uruguay(C)

F2.20.33 Standardized high current solid targets for cyclotron production of diagnostic and therapeutic radionuclides
7 Contracts 4 Agreements 00/10/1 03/9/30
Argentina(C), Belgium(A), China(C), Hungary(A), Indonesia(C), Islamic Republic of Iran(C), Kazakhstan(C), Romania(C), Russian Federation(A), Saudi Arabia(C), United States of America(A)

F2.20.34 Radiation synthesis of stimuli-responsive membranes, hydrogels and adsorbents for separation purposes
6 Contracts 4 Agreements 00/12/15 04/12/14
Egypt(C), France(A), Germany(A), Hungary(C), India(C), Japan(A), Kazakhstan(C), Republic of Korea(A), Poland(C), Turkey(C)

F2.20.35 Development of radioimmunometric assays and kits for non clinical applications
8 Contracts 4 Agreements 01/8/1 06/7/31
China(C), Cuba(C), Greece(C), Hungary(A), India(A), Indonesia(C), Islamic Republic of Iran(C), Poland(C), Thailand(C), United Kingdom(A), United States of America(A), Uruguay(C)

F2.30.18 Development and validation of speciation analysis using nuclear techniques
5 Contracts 2 Agreements 01/3/1 04/3/31
Argentina(C), Austria(A), Belgium(A), Brazil(C), China(C), Ghana(C), Slovenia(C)

F2.30.19 Integration of residence time distribution (RTD) tracing with computational fluid dynamics (CFD) simulation for industrial process visualization and optimization
6 Contracts 5 Agreements 01/3/1 04/3/31
Australia(A), Brazil(C), Cuba(C), Czech Republic(C), France(A), Germany(A), India(C), Republic of Korea(C), Norway(A), Poland(C), United States of America(A)

Nuclear Fusion Research and Plasma Physics Applications

F1.30.07 Comparison of compact toroid configurations
8 Contracts 10 Agreements 98/11/1 02/12/31
Argentina(C), Brazil(C), China(C), India(C), Israel(C), Italy(A), Japan(A) (5), Russian Federation(C) (2), Ukraine(C), United Kingdom(A), United States of America(A) (3)

F1.30.08 Elements of power plant design for inertial fusion energy
8 Contracts 9 Agreements 00/12/15 05/12/14
Czech Republic(C), Germany(A), Hungary(C), India(C), Japan(A) (2), Republic of Korea(C), Poland(C), Russian Federation(C) (2), Spain(A), United States of America(A) (5), Uzbekistan(C)

Appendix A.11

F1.30.09 Dense magnetized plasmas
5 Contracts 01/12/15 05/12/31
Czech Republic(C), Poland(C) (2), Russian Federation(C) (2)

H NUCLEAR SAFETY

Safety Assessment Developments

J4.50.02 Development and application of indicators to monitor NPP operational safety performance
4 Contracts 8 Agreements 99/10/1 03/9/30
China(A), Czech Republic(C), India(C), Lithuania(A), Netherlands(A), Pakistan(C), Slovakia(A) (2), Spain(A), Sweden(A), Ukraine(C), United Kingdom(A)

J4.60.01 Round-robin exercise on WWER (water-cooled and -moderated reactor pressure vessel)-440 RPV weld metal irradiation embrittlement and annealing
5 Contracts 4 Agreements 96/10/1 01/12/31
Belgium(A), Finland(A), France(A), Hungary(C), Norway(A), Russian Federation(C) (3), Slovakia(C)

Nuclear Plant Engineering Safety

J7.10.08 Safety of RBMK type Nuclear Power Plant in relation to external events
8 Contracts 5 Agreements 97/12/15 02/12/14
Bulgaria(C), Finland(A), Germany(A), Italy(A), Russian Federation(C) (6), Ukraine(C), United States of America(A) (2)

Research Reactor Safety

J7.10.09 To update and expand the IAEA reliability data for research reactor PSAs
7 Contracts 4 Agreements 01/3/15 04/3/14
Argentina(C), Australia(A), Austria(A), Brazil(C), Canada(A), Czech Republic(C), India(C), Indonesia(C), Republic of Korea (A), Romania(C), Viet Nam(C)

I RADIATION SAFETY

Radiation Protection

J1.70.04 Image quality and patient dose optimisation in mammography in Eastern European Countries
8 Contracts 3 Agreements 99/10/1 02/9/30
Czech Republic(C), France(A)France(C), Hungary(C), Italy(A)Italy(C), Poland(C), Romania(C), Slovakia(C), Spain(A)Spain(C)

Safety of Radiation Sources and Security of Radioactive Materials

J1.70.05 To investigate appropriate methods and procedures to apply probabilistic safety assessment (PSA) techniques of large radiation sources
5 Contracts 2 Agreements 00/6/27 03/6/30
Argentina(C), Canada(A), China(C), Cuba(C), Japan(C), Mexico(C), United States of America(A)

Safe Transport of Radioactive Material

J1.30.08 Development of radiological basis for the transport safety requirements for low specific activity materials and surface contaminated objects
7 Agreements 97/9/1 02/11/30
Brazil(A), Canada(A), France(A), Germany(A), South Africa(A), United Kingdom(A), United States of America(A)

J1.30.09 Accident severity during air transport of radioactive material

8 Agreements 98/6/1 02/8/31

Canada(A) (2), France(A), Germany(A), Ireland(A), Sweden(A), United Kingdom(A), United States of America(A)

J1.30.10 Radiological aspects of package and conveyance non-fixed radioactive contamination

7 Agreements 01/9/1 04/8/31

France(A), Germany(A), Japan(A), Sweden(A), United Kingdom(A) (2), United States of America(A)

J RADIOACTIVE WASTE SAFETY

Safety of Disposable Radioactive Waste

J9.10.05 The use of selected safety indicators (concentrations; fluxes) in the assessment of radioactive waste disposal

1 Contract 9 Agreements 00/2/15 05/2/14

Argentina(A), Brazil(A), China(A), Cuba(A), Czech Republic(A), Finland(A), Japan(A), Sweden(A), United Kingdom(A)United Kingdom(C)

CRPs Completed in 2001

D14008 The use of isotope techniques in studies on the management of organic matter and nutrient turnover for increased, sustainable agricultural production and environmental preservation

D15005 The assessment of soil erosion through the use of Cs-137 and related techniques as a basis for soil conservation, sustainable agricultural production and environmental protection (Joint CRP with F3.10.01)

D23019 Cellular biology and biotechnology including mutation techniques for creation of new useful banana genotypes

D32016 Rinderpest seromonitoring and surveillance in Africa using immunoassay technologies

D41015 Molecular and genetic approaches to develop sexing strains for field application in fruit fly SIT

D42006 Automation in tsetse fly mass-rearing for use in sterile insect technique programmes

D52033 Validation of thin-layer chromatographic screening methods for pesticide residue analysis

E12015 Local production and evaluation of primary reagents for the radioimmunoassay of alpha feto protein (AFP)

E13016 Study of the relationship between vesicoureteral reflux (VUR), Pyelonephritis (PN) and renal scarring in children with urinary tract infection (UTI) using nuclear medicine techniques

E24007 Development of a quality assurance programme for radiation therapy dosimetry in developing countries

E24011 Electron Paramagnetic Resonance (EPR) biodosimetry

E33020 Human Immunodeficiency Virus (HIV) markers in patients treated with radiotherapy for cervical cancer

E41010 Assessment of levels and health-effects of airborne particulate matter in mining, metal refining and metal working industries using nuclear and related analytical techniques

F12011 Application of MeV ion beams for development and characterization of semiconductor materials

F12012 Final stage of WIMS-D library update project

CRPs Completed in 2001

F22022 Development of agents for imaging central neural systems (CNS) receptors based on Technetium-99m

F22026 Development of kits for radioimmunometric assays of tumor markers

F22029 Development of radioactively labelled cancer seeking biomolecules for targeted radiotherapy

F22031 The use of radiation processing for sterilization or decontamination of pharmaceuticals and pharmaceutical raw material

F31001 Sedimentation assessment studies by environmental radionuclides and their application to soil conservation measures (Joint CRP with D1.50.05)

F32002 The use of tracers and stable isotopes in surface water pollution studies

F34008 Isotope techniques for the assessment of slow moving deep groundwater and their potential application for the assessment of waste disposal sites

F34009 Radionuclide transport dynamics in freshwater resources

I11001 Estimating the external costs associated with electricity generating options in developing countries using simplified methodologies

I14002 Case studies to assess and compare different energy sources in sustainable energy and electricity supply strategies

I14003 The role of nuclear power and other energy options in meeting international goals on greenhouse gas emission reductions

I32002 Intercomparison of analysis methods for seismically isolated nuclear structures

I33008 Potential of thorium-based fuel cycles to constrain Pu and to reduce long-term waste toxicities

I33009 Use of Thorium-based fuel cycle in accelerator driven systems (ADS) to incinerate Pu and to reduce long-term waste toxicities

J16005 Cytogenetic biodosimetry

J45001 Investigation of methodologies for incident analysis

J91002 BIOsphere Modelling and ASSessment methods (BIOMASS)

Appendix B.2

CRPs Completed in 2001

J91003 Improvement of Safety Assessment Methodologies for near surface disposal facilities for radioactive waste (ISAM)

T11005 Treatment of liquid effluent from uranium mines and mills during and after operation (post decommissioning / rehabilitation)

T12012 Modelling of transport of radioactive substances in primary circuit of water cooled reactors

T13006 Corrosion of research reactor aluminium-clad spent fuel in water

T21018 Combined methods of liquid radioactive waste treatment

T21019 Long term behaviour of low and intermediate level waste packages under repository conditions

T24005 Decommissioning techniques for research reactors

IAEA 2001 Programme /Sub-programme and CRP Codes

MP 1 MAJOR PROGRAMME 1: NUCLEAR POWER AND FUEL CYCLE

		CRP Code
Programme A:- Nuclear Power		
A1	Nuclear Power Planning, Implementation and performance	I2
A2	Nuclear Power Reactor Technology Development	I3
Programme B:- Nuclear Fuel Cycle and Waste Management Technology		
B1	Fuel Cycle and Materials	T1
B2	Waste Management and Technology	T2
Programme C:- Comparative Assessment for Sustainable Energy Development		
C1	Energy Modelling, Databanks and Capacity Building	I1
C2	Energy, Economy, Environment (3E) Analysis	I1

MP 2 MAJOR PROGRAMME 2: NUCLEAR SCIENCES AND APPLICATIONS

Programme D:- Food and Agriculture		
D1	Soil and Water Management and Crop Nutrition	D1
D2	Plant Breeding and Genetics	D2
D3	Animal Production and Health	D3
D4	Insect and Pest Control; Food and Environmental Protection	D4
D5	Food and Environmental Protection	D5, D6
Programme E:- Human Health		
E1	Nuclear Medicine	E1
E2	Applied Radiation Biology and Radiotherapy	E3
E3	Dosimetry and Medical Radiation Physics	E2
E4	Nutritional and Health-Related Environmental Studies	E4, G4
Programme F:- Marine Environment and Water Resources		
F1	Measurement and Assessment of Radionuclides in the Marine Environment	K4
F3	Monitoring and Study of Marine Pollution	K4
F4	Development and Management of Water Resources	F3
Programme G:- Applications of Physical and Chemical Sciences		
G1	Nuclear and Atomic Data for Applications	F4
G2	Nuclear Instrumentation	F1
G4	Utilization of Research Reactors and Particle Accelerators	F1, G4
G5	Radioisotopes and Radiation Technology	F2
G6	Nuclear Fusion Research and Plasma Physics Applications	F1

IAEA 2001 Programme /Sub-programme and CRP Codes

MP 3 MAJOR PROGRAMME 3: NUCLEAR, RADIATION AND WASTE SAFETY

		CRP Code
Programme H:- Nuclear Safety		
H1	Safety Assessment Developments	J4
H2	Nuclear Plant Engineering Safety	J7
H4	Research Reactor Safety	J7
Programme I:- Radiation Safety		
I1	Radiation Protection	J1
I2	Safety of Radiation Sources and Security of Radioactive Material	J1
I3	Safe Transport of Radioactive Material	J1
I4	Radiation Emergencies	J1
Programme J:- Radioactive Waste Safety		
J1	Safety of Disposable Radioactive Waste	J9
Programme K:- Co-ordination of Safety Activities		
K1	Safety Policies and Standards	J1

MP 4 MAJOR PROGRAMME 4: NUCLEAR VERIFICATION AND SECURITY OF MATERIAL

Programme L:- Safeguards		
L2	Development and Support	M2

Accomplishments of CRPs

CRP Number and Title: **D15004** **The use of irradiated sewage sludge to increase soil fertility, crop yields and to preserve the environment**

Participating Countries: Argentina(C), Austria(A), Bangladesh(C), China(C), Egypt(C), Germany(A), India(C), Indonesia(C), Japan(A), Malaysia(C), Mexico(C), Pakistan(C), Philippines(C), Portugal(C), Romania(C), Sweden, Thailand(C), United Kingdom(A), United States Of America(A)

Total Cost: **$440,193**

Duration: 1995-04-15--- 2000-01-31

CRP Overall Objectives

To assist national institutes from developing Member States to develop management practices for the efficient use of sewage sludge as an organic fertilizer for increasing and sustaining crop production in an environmentally friendly manner.

CRP Specific Objectives

1. To quantify the availability of N and P from sewage sludge to crops, using N-15 and P-32 tracer techniques.
2. To assess increases in crop yields as a result of application of sewage sludge.
3. To assess improvements in soil properties, particularly increases in organic matter content and water holding capacity.
4. To estimate the pathogenic organism content in non-irradiated and irradiated sewage sludge.
5. To assess the extent of contamination of soil by heavy metals by the use of sewage sludge.
6. To determine the beneficial effects of micronutrients in terms of increasing crop yields and soil fertility.

Research Outputs

A dose of 5 kGy gamma-irradiation eliminated pathogenic organisms and reduced total bacteria in dried sludge, thereby reducing risks to human health. The irradiated sludge is a source of plant nutrients, including nitrogen, phosphorus and micronutrients. Positive yield responses to incremental rates of sludge addition up to 400 % of the recommended fertilizer N rate were obtained, with sludge supplying up to 50 % of crop N requirements as determined by N-15 dilution. Nitrogen was more available in irradiated than non-irradiated sludge, but the yield response with the highest sludge rate was generally less than that obtained with the recommended rate of fertilizer N. Sludge should therefore be regarded as a supplementary nutrient source rather than a replacement for manufactured fertilizers. In addition to its nutritive value, sludge is also an effective soil-conditioning agent. It can play an important role in the reclamation of infertile, sandy or hard-setting soils in arid and semi-arid areas, where repeated sludge applications increased water-holding capacity and decreased bulk density through increased soil organic matter. Sludges from urban areas generally had low concentrations of heavy metals, but monitoring of heavy metal concentrations in soils and plants is recommended if sludges originating from predominantly industrial areas are applied to edible crops. The use of ornamental plants or fibre and oilseed crops is another option to avoid potential health hazards from heavy metals.

CRP Outcome (Effectiveness; Impact; Relevance)

This CRP has been effective in generating information on (i) the irradiation dose required to eliminate human pathogens from sewage sludge (ii) the agronomic effectiveness of irradiated and non-irradiated sludge in increasing crop yields at medium to high rates of application on different soils under a range of climatic conditions (iii) the effectiveness of sludge application compared with recommended rates of fertilizer application (iv) the proportional contribution of sludge to the N and P nutrition of plants (v) sludge heavy metal concentrations and accumulation in soils and crops.

This CRP provided valuable information on the treatment of an urban waste to reduce its health hazard, its efficacy as a source of nutrients to crops and pastures, its use as an ameliorant to improve the physical condition of soils and its potential hazard as a source of heavy metals in the food chain.

The nuclear components of this CRP were gamma irradiation and the use of isotopes of N and P to estimate the availability of these two major plant nutrients in sewage sludge. The NARS participants gained valuable experience in the use of indirect isotope methodologies which were further developed, evaluated and pilot tested by the Soil Science Unit (NAAL). The CRP demonstrated the value of a slow release organic waste product in better synchrony with crop nutrient demand compared with expensive

manufactured fertilizer. The results of the CRP will be widely disseminated to Member States throgh a TECDOC and complementary support through three national TC projects. The uptake of the irradiation technology by Member States will be contingent on the availability of appropriate facilities for treating large tonnages of sludge.

Nutrient mining in intensive agricultural production systems and the high cost of manufactured fertilizers require utilization of locally-available nutrient sources wherever possible. This CRP has demonstrated that irradiated sewage sludge can be safely used as a valuable nutrient source and soil conditioning agent, saving fertilizer and reducing environmental pollution and public health risks through recycling a waste product which is produced in large quantities in urban societies.

Recommended Future Action by Agency

Future Agency activities in this area should be through the TC programme. There is one such project in the 2001-02 biennium (EGY/8/014 - Irradiated sewage sludge for increased crop production).

CRP Published Results

Internal: One TECDOC in preparation

External: Journal and conference papers published by the participants

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **D23016** **Induced mutations in connection with other biotechnology for crop improvement in Latin America (related to ARCAL VII activity)**

Participating Countries: Bolivia(C), Brazil(C) (2), Chile(C) (2), Colombia(A), Colombia(C), Cuba(C), Ecuador(C), Guatemala(C) (2), Mexico(A), Uruguay(C) (2), Venezuela(A)

Total Cost: **$241,906**

Duration: 1993-12-01--- 2000-10-20

CRP Overall Objectives

To undertake research on new plant biotypes of major Andean crops and develop mutants with increased adaptability and tolerance to biotic and abiotic stresses

CRP Specific Objectives

To stimulate induced mutation activities leading to the improvement of crops productivity, yields and reliability of local cultivars
To investigate suitability of various local cultivars and methods for doubled haploid production, develop homozygous mutant lines with desired characters and initiate genetic and molecular analysis of promising mutants.
To implement protocols for in vitro induction of mutations in local cultivars of vegetatively propagated crops, evaluate stability and effectiveness of various in vitro culture methods for mutation induction and plant regeneration, evaluate frequency of selected mutants, develop true-to-type mutated clones and to initiate genetic and molecular analysis of promising mutants.
To enhance regional co-operation in the field of radiation-induced mutations and related biotechnology.

Research Outputs

The classical tools of plant genetics and breeding have recently been reinforced by the wider adoption of radiation- and chemical-induced mutation techniques and by the array of related, innovative biotechnology approaches. While the induction of desirable mutants, their selection, evaluation and dissemination to the farmers is very important in seed crops, it is perhaps even more important in vegetatively-propagated crops where only spontaneous mutants have been the source of new plant characters. This CRP covered a wide range of issues and characters in a very diverse range of plant species: some annual and some woody perennials, some sexually reproduced and others vegetatively propagated, some food plants and some ornamental. Selected molecular techniques were applied through the CRP to study induced mutants, somatic hybrids for root stocks, segregating populations and pathogens. Many approaches were refined and some procedures were improved. Characterization of rice mutants through isozyme diversity was conducted in Cuba and in Brazil. Characterization of somatic hybrids from protoplasts fusion using mandarin (Citrus limonia) and lime (Citrus reshni) was performed using RAPDs markers and isozymes. Genetic diversity of fungus Pyricularia grisea was studied in Cuba in co-operation with CIAT through molecular markers, and 4 lineages of the pathogen were identified. Low culturability of anthers was shown to be the biggest limitation of this approach. Genotypes with high anther culture response were identified as well as low responsive materials, whose anther culturability improved when stressed by chemical or physical mutagenic treatment.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP met all the objectives effectively and efficiently. Many valuable mutated germplasm populations were developed.
The regular production of doubled haploid plants through anther culture was implemented in rice, wheat and barley and has become part of the national breeding programmes in Chile, Colombia, Cuba, Guatemala, Peru and Uruguay.
The protocols for in vitro induction of mutations in local cultivars of vegetatively propagated crops has been established and mutated clones developed in banana, citrus chrysanthemum, stromantha and calathea.
The regional co-operation was enhanced in cereals through parallel developed ARCAL VII programme and through bilateral relationships in the area of vegetatively propagated crops.

All participating institutes and plant breeding stations were successful in application of induced mutation techniques for germplasm enhancement of Andean seed propagated crops and in the development of mutants of several species of vegetatively propagated fruit trees and ornamental plants.

Accomplishments of CRPs

Radiation induced mutations generated new semi-dwarf germplasm from Basmati 370 with useful agronomic characters. Ten mutant lines were selected for further evaluation in replicated yield trials (Cuba).
Promising semi-dwarf mutants with desirable grain shape were developed from traditional variety EEA-404. Methodology for DH production through anther culture was adjusted and is being applied in selected crosses. Promising doubled haploid lines were advanced to National Uniform Trials (Uruguay).
The genetic structure of blast pathogen populations was characterized in six genetic lineages and the virulence spectrum for each lineage was determined. Mutants with complementary resistance to the different genetic lineages of pathogen were identified (Colombia).
Germplasm collection of rice mutants with tolerance to blast has been established (Brazil).
The regular production of rice and wheat DH plants as a component in the varietal improvement programmes was achieved. Highly responsive anther culture genotypes were identified and are being used for increasing the efficiency of DH plant production. The enhancement of green DH frequency through gamma irradiation was demonstrated (Guatemala).
Suitable doses for quinoa and barley seed treatment with X-rays and sodium azide were determined (Bolivia).
Selection for tolerance to Fusarium wilt in irradiated banana shoot tips culture was successful. Following bud gamma-irradiation, putative citrus mutants were selected for characteristics such as plant height, yield and reduced number of seeds. Gamma irradiation of young plants of commercial chrysanthemum variety led to the identification of two flower color mutants officially released to commercial production as new varieties. Following gamma irradiation of rhizomes of the ornamental Stromantha and Calathea led to development of mutants which may be released as new varieties suitable for export (Brazil).
Promising results with in vitro propagation of avocado indicated that the protocol for a large scale multiplication can be used for mutagenioc approach (Mexico).

The CRP has been directly relevant to major objectives of the sub-programme D2. The CRP has confirmed the usefulness of radiation induced mutated germplasm in breeding programmes of Andean seed crops and vegetatively propagated tropical fruit trees and ornamentals.

Recommended Future Action by Agency

To continue regional activities especially in the field of application of molecular markers technology in mutation assisted breeding programmes.

CRP Published Results

Internal: IAEA-TECDOC -1216
Correa-Victoria, F.J. and Martinez, C., 1995. Genetic Structure and virulence diversity of Pyricularia grisea in breeding for rice resistance. In: Induced Mutations and Molecular Techniques for Crop Improvement. IAEA, Vienna pp. 133-145.

External:
Tulmann Neto, A. and R. R. Latado, 1996. 'Cristiane' and 'Ingrid': first chrysanthemum cultivars obtained by mutation induction in Brazil. MBNL. 42: 18
Moura, D. S., F. J. Zapata-Arias, A. Ando, and A. Tulmann Neto, 1997. Plant regeneration from protoplasts isolated from primary calli using mature embryos of two Brazilian rice cultivars. Euphytica. 94: 01-05.
Tulmann Neto, A., R.R. Latado. 1996. Mutation breeding in Stromantha sanguinea by gamma radiation. Brazilian J. Gen. 19: 197

Other Outputs:
Released mutant varieties, development of advanced breeding lines already used in breeding programmes.

Accomplishments of CRPs

CRP Number and Title: **D23018** **Improvement of new and traditional industrial crops by induced mutations and related biotechnologies**

Participating Countries: Bangladesh(C), Brazil(C), Canada(A), China(C) (4), Germany(A), Greece(C), Hungary(C), India(C), Nepal(C), Pakistan(C) (2), Spain(A), Turkey(C), United States Of America(A) (2)

Total Cost: **$328,870**

Duration: 1994-10-07--- 2000-04-30

CRP Overall Objectives

To undertake research on the development of improved industrial crops and domestication of new crops for industrial uses through induced mutations and related biotechnologies for sustainable agriculture and production of renewable resources and new raw materials for the chemical industry.

CRP Specific Objectives

1) To develop mutagenic approaches and treatment procedures for new species and screening procedures for agricultural and industrial requirements.
2) To undertake research on known and potential new industrial crops to develop suitable genotypes adapted to new areas and for new needs - agricultural and industrial.
3) To demonstrate the value of mutation induction and related biotechnologies in the development of semi-domesticated plant species in economic crops.
4) To diversify the agricultural crop options, facilitating better crop rotations in a more sustainable pattern.
5) To assist in developing new uses for industrial crops by inducing mutations leading to new product compositions and/or qualities.
6) To assess and demonstrate the potential of induced mutations to affect critical steps in various biosynthetic pathways leading to oil quality improvements.
7) To enhance regional and interregional co-operation in the area of inducing mutations by radiation and other means, to speed up the breeding process.

Research Outputs

1) Mutagenic treatment protocols for new species have been developed (e.g. Oenothera erythrosepala). A soybean mutant was identified suitable for genetic transformation. Irradiation of donor plants combined with microspore culture of rapeseed was successful in speeding up the development of improved germplasm.
2) Conventional screening procedures for agricultural and industrial requirements adapted; molecular markers for new screening procedures developed in linseed, oilseed Brassicas, soybean, sunflower and cotton. Fluorescense in situ hybridisation and Genomic in situ hybridisation analysis techniques in rapeseed used to identify donor DNA in intergeneric hybrids.
3) Early flowering and dwarf mutants identified in Oenothera with potential for commercial production of gamma linolenic acid in China. One interspecific hybrid with high capsule density. Cultural practices for best mutant established.
4) Breeding populations and lines available with traits suitable for crop diversification and better crop rotations: earlier maturity in cotton, soybean and Oenothera; resistance to biotic stresses in soybean, cotton, rapeseed and sunflower.
5) Oilseed mutants have been developed with modified oil compositions in linseed (increased palmitic acid), and Cuphea (increased short chain fatty acids) for potential use in the oleochemical industry and for biodiesel, respectively.
6) Early maturing mutants with potential for marginal areas identified (soybean, cotton); day-neutral mutant identifed in jute; virus resistant cotton lines with potential for cultivation in virus infected areas; fatty acid mutants developed with potential for new uses: Cuphea (biodiesel from short fatty acids), linseed (new oil products with long fatty acids), high oleic acid mutation used for breeding of sunflower producing oil of frying quality.
7) Mutants developed with modified biosynthetic pathways of long fatty acids and short fatty acids, gene for short fatty acid biosynthesis cloned. Fat B gene from Cuphea transferred and expressed in linseed. OLD7, SAD7 and SAD 17 genes isolated and tranferred to rapeseed.

Accomplishments of CRPs

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objectives of the CRP were met by the participating scientists.

The CRP contributed to the overall objective through supporting and stimulating research resulting in the development of improved breeding lines of traditional industrial crops and domestication of new crops for industrials uses.

The CRP clearly demonstrated the potential benefits of using induced mutations for the generation of genetic diversity in oil and fibre crops in Bangladesh, Brazil, Canada, China, Germany, Greece, Hungary, India, Pakistan, and the USA. The combination of mutation techniques with interspecific hybridization, embryo culture, doubled haploid techniques and genetic transformation assisted by molecular techniques lead to the improvement of agronomic and quality traits of oilseed crops such as soybean, rapeseed, sunflower, linseed, Cuphea and meadowfoam and fibre plants such as cotton and jute. After official release this germplasm will contribute to stabilization and increase of production of industrial crops and will provide new industrial products.
In rapeseed it was shown that the combination of radiation and doubled-haploid techniques could speed up the development of improved rapeseed germplasm. Doubled-haploid plants developed from mutant hybrids of rapeseed indicate a potential for fixation of mutant heterosis that would be a better alternative to costly production of hybrid seed. Molecular markers for important agronomic traits such as nematode resistance in soybean were developed. Genes involved in adaptation to drought stress and in cytoplasmatic male sterility of cotton were cloned. With the help of induced mutations, genes involved in the fatty acid biosynthesis in sunflower and Cuphea could be cloned. They lead to a better understanding of the fatty acid biosynthesis.

This CRP is highly relevant to the Agency's and FAO programme. It clearly demonstrated the potential benefits of using induced mutations for the generation of genetic diversity in industrial crops.
The enhancement of variability of oil and fibre crops through various techniques adapted or developed under the CRP is in line with the base-broadening concept of the Global Plan of Action for Plant Genetic Resources for Food and Agriculture.

Recommended Future Action by Agency

In view of the many beneficial developments emanating from CRP's, as clearly demonstrated in this one, it is recommended to sustain and enhance the CRP approach. The present CRP exemplifies so well the tangible benefits of such an approach in terms of collaborative research, exchange of breeding lines and genetic stocks and sharing of information and techniques. Other benefits, especially of long-term research contacts and training opportunities, should also be recognized. Since the main beneficiaries of such CRP's are the researchers from the developing countries, the CRP approach should be enhanced.
Future CRPs in the area of industrial crops should focus on enhanced production stability (improved tolerance and/or resistance to biotic and abiotic stresses) and concentrate on related plant species or genera, respectively, in order to be able to make use of similar genes and biosynthetic pathways within respective taxonomic groups (e.g., Brassicaceae or Compositae families).

CRP Published Results

Internal: Working documents of 1st RCM, held from 4-7 April 1995 in Vienna, Austria and 2nd RCM held from 30 June to 4 July 1997 in Giessen, Germany

External: IAEA TECDOC of 3rd and final RCM held from 2 to 6 August 1999 in Corvallis, Oregon USA, in preparation for printing

Other Outputs: Publications of participants within the framework of the CRP:

ASLAM, M., ELAHI, M.T., IQBAL, N. Development of improved germplasm of cotton through radiation and DNA mediated embryo transformation technique. Pak. J. Bio. Sci. 4 (1998) 291-294.

ASLAM, M., ELAHI, M.T., IQBAL, N. Introgression of G. barbadense genes into G. hirsutum through DNA-mediated embryo transformation approach. Pak. J. Bio. Sci. 1 (1997) 11-14.

JAMBHULKAR, S.J., JOSHUA, D.C. Induction of plant injury, chimera, chlorophyll and morphological mutations in sunflower using gamma rays. Helia 22 (1999), 63-74.

KNAPP, S.J., CRANE, J.M. "The development of meadowfoam as an industrial oilseed: breeding challenges and germplasm resources", Proc. 4th National Symp. on New Crops (JANICK, J., Ed.), Wiley, New York (1999) 225-233.

LÜHS, W., WEIER, D., DETTENDORFER, J., FRIEDT, W., WOLTER, F.P., FRENTZEN, M. Biotechnological approaches in the breeding of rapeseed (Brassica napus) with trierucin in the seed oil. ISHS Symp. on Brassicas. Abs. 10th Crucifer Genetics Workshop, 23-27 Sept. 1997, Rennes, France (1997), 230.

NICHTERLEIN, K., L. VAN ZANTEN, M. MALUSZYNSKI, B. AHLOOWALIA, and E. WECK, 1996. FAO/IAEA Programmes on improvement of oil crops by induced mutations and related biotechnologies. In: Eucarpia Section Oil and Protein Crops. Symposium on Breeding of Oil and Protein Crops, 5-8 August 1996, Zaporozhye, Ukraine. Institute of Oilseed Crops of the Ukrainian Academy of Agricultural Sciences, Zaporozhye. pp.159-164

RAJGURU, S.N., STEWART, J.MCD. "Development of a transformation construct for enhanced disease resistance", Proc. 2000 Cotton Research Meeting & Summaries of Cotton Research in Progress, Special Report 198 (OOSTERHUIS, D.M., Ed.), Ark. Agric. Exp. Sta. (2000) 235-236.

SAEIDI, G., ROWLAND, G.G. The inheritance of variegated seed color and palmitic acid in flax. J. Hered. 88 (1997) 466-468.

STEWART, J.MCD. "Potential for economic production of Asiatic cotton in the Delta growing area", Proc. 1999 Cotton Research Meeting & Summaries of Cotton Research in Progress, Special Report 193 (OOSTERHUIS, D.M., Ed.), Ark. Agric. Exp. Sta. (1999) 278-280.

VOSS, A., LÜHS, W., SNOWDON, R.J., FRIEDT, W. "Development and molecular characterisation of nematode-resistant rapeseed (Brassica napus L.)", Genetics and Breeding for Crop Quality and Resistance (SCARASCIA, G.T., PORCEDDU, E., PAGNOTTA, M.A., Eds.), Kluwer, Dordrecht, The Netherlands (1999) 195-202.

WANG, L.Z., FU, Y.Q., PEI, Y.L., WANG, L., ZHAO, R.J. Genetic improvement of soybean cultivars in Heilongjiang province and Huang Huai Hai valley. Chinese J. Oil Crop Sci. 20 (1998) 20-25.

WANG, L., WANG, L.Z., LIU, Z.F. ZHAO, R.J. "Soybean transformation of foreign gene mediated Agrobacterium tumefaciens", Proc. World Soybean Res. Conf. VI, 4-7 August 1999 (KAUFFMAN, H.E., Ed.), Chicago, IL, USA (1999) 448.

Accomplishments of CRPs

CRP Number and Title: **D41014 Medfly mating behaviour studies under field cage conditions**

Participating Countries: Argentina(C), Costa Rica(C), France(C), Greece(C), Guatemala(C), Israel(C) (2), Kenia (C), Mexico(C), Poland(C), United States Of America(A)

Total Cost: **$357,883**

Duration: 1993-12-01--- 2000-08-17

CRP Overall Objectives

To improve the understanding of the medfly mating behaviour and standardise the measurement of behavioural quality of mass produced medflies

CRP Specific Objectives

1. To design an improved quality control test to assess the mating competitiveness of mass produced flies for use in medfly SIT programmes.
2. To compare the courtship behaviour of wild medfly populations originating from different geographic regions of the world, and to better understand the role of the different components of the male courtship in the female mating choice.

Research Outputs

Standardised field cage and video recording methodologies to assess the quality of mass produced medflies
The methodologies for field cage and video recordings were proposed and demonstrated in the first RCM.
Methodologies validated in laboratory and field cage tests
During the course of the CRP, participants implemented field cage tests and video recordings. The amount of data collected provided sufficient material for improvement of the effectiveness and the feasibility of the methods. The methods were then fine tuned and accepted as an international standard.
Better assessment of the competitiveness of mass reared flies and of the cross compatibility of sterile and wild flies of different genetic background or geographic origin
The standardised methods allowed more precise description of the behaviour of wild populations originating from five continents and of mass reared strains from the major rearing facilities worldwide.
Global cross compatibility of wild populations and most mass reared strains available worldwide was proven.
An extensive database documenting the detailed sexual behaviour of medfly of different geographic origin and genetic background has been assembled on CD ROM. This database represents the first and most comprehensive source of information on the variability in medfly sexual behaviour worldwide. As from now, the database is to be used by the Member States as the standard reference for assessment of the behavioural quality of mass reared strains.
The field cage test protocol is now recognised and used as a standard for mass reared strain quality assessment by most of the Member States involved in medfly SIT programmes.

CRP Outcome (Effectiveness; Impact; Relevance)

1.The biological and physical methodologies, including new indices, were prepared, standardised and validated for both the field cage test and the video recording, and all CRP participants are using them.
These outputs fulfil the first specific objective of designing an improved quality control test to assess mating competitiveness of mass produced flies for use in medfly SIT programmes. The majority of national medfly programmes are already using the improved test to assess mating competitiveness of mass reared medflies.
2.The assessment of competitiveness and cross-compatibility among wild flies of different geographic origin and genetic background was carried out, as well as between and among mass reared strains and wild populations. The findings of these cross-compatibility studies are being used as part of the operational quality control activities of the national medfly SIT control programmes.
This second output, i.e. verification of cross-compatibility, fulfils the second specific objective, which has allowed the trade-in and application worldwide of medfly strains of different genetic background; for example in SIT programmes in Argentina, California, Florida, Israel and South Africa.

The two above outputs have addressed the other aspect of the second specific objective, namely to describe, quantify and analyse the different components of the male courtship behaviour of medfly populations worldwide, and therefore to develop the tools to better understand female mate choice in medfly, which is a vital element to improve sterile male effectiveness.

The achieved outputs have substantially contributed to improve the understanding of medfly behaviour. The two standardised and validated protocols have allowed to standardise internationally the quantitative measurement of behavioural performance of mass produced medfly, which will significantly facilitate decision-taking and application of SIT technology in national and regional fruit fly programmes. These programmes have the overall objective of reducing pesticide use and fruit losses in agriculture, but also to facilitate trade of fresh fruits and vegetables across international borders.

A standardized field cage protocol has been developed, tested and incorporated into the new fruit fly QC manual
The important components of sexual behaviour, including morphometric analysis, and its impact on SIT have been documented
Wild medfly populations and mass reared insects are compatible with each other and no qualitative differences have been shown following video analysis of courtship behaviour
Mass reared medflies have been shown to be about 25% as competitive as wild flies and the high levels of radiation currently used in operational SIT programmes have been shown to be a major contributor to this reduction
The fact that nutritional status of medflies affects mating behaviour requires that this needs to be considered for flies released in SIT programmes

Mass reared and sterilized medflies can be shipped from any production facility for release in SIT programmes world-wide
There is now an increased awareness of the importance of strain replacement to maintain fly quality and an appreciation of the importance that filter rearing technology can play in achieving this goal
With the current state of knowledge it is not possible to integrate video analysis of mating behaviour into routine QC procedures
The field cage protocols developed in this CRP have now become an indispensable part of QC evaluation for mass produced medflies

Recommended Future Action by Agency

The Agency should support studies which re-examine the level of radiation that is used to sterilize medflie in operational SIT programmes, especially now that males only are being reared and released
The Agency should continue its support of quality assurance of mass produced medflies for SIT by addressing the following important components:
effect of pre-release feeding on fly quality
acoustic and morphometric correlates of mating success
the impact of filter rearing technology on fly production and quality
The Agency should maintain its key role in the co-ordination of international efforts to improve quality assessment of mass produced medflies for SIT operational programmes

CRP Published Results

Internal:

External:
1. Courtship behaviour
W. Eberhard, D. Briceno, A. Economopoulos, S. Lux, G. Calcagno, M. Hunt, J. Vilardi, J.P. Cayol
2. Lekking behaviour
T. Vera, E. Jang, P. Rendon, J. Hendrichs, P. Liedo, B. Yuval
3. Comparative approaches of sexual behaviour
D. McInnis, T. Shelly, S. Quilici, M. Mazor, C. Garcia
4. Morphometrical studies
W. Eberhard, D. Briceno, M. Mazor, J. Toledo, M. Hunt, J. Vilardi, J.P. Cayol
5. Nutritional aspects in relation to sexual behaviour
S. Quilici, B. Yuval, G. Calcagno, T. Shelly, A.S. Robinson, S. Lux, A. P. Economopoulos
6. Remating

S. Field, J. Hendrichs, P. Rendon, D. McInnis, E. Jang, T. Vera
7. Compatibility and isolation studies
A.S. Robinson, D. Briceno, S. Quilici, G. Calcagno, D. McInnis, J.P. Cayol
8. Field cage tests
J. Vilardi, M.T. Vera, M. Hunt, S. Field, M. Mazor, J. Vilardi, J. Hendrichs
9. Field evaluation
A. Economopoulos, P Rendón, B. Yuval, S. Lux, T. Brevault, E. Jang, T. Shelly

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **D52027 The use of nuclear and immuno-chemical methods for pesticide analysis**

Participating Countries: Australia(A), Bangladesh(C), Brazil(C), China(C) (2), Ecuador(C), Germany(A)Germany(C), Ghana(C), India(C) (2), Lebanon(C), Pakistan(C), Philippines(C), Syrian Arab Republic(C), Turkey(C), United Kingdom(A), United States Of America(A)

Total Cost: **$401,287**

Duration: 1993-06-17--- 2000-01-05

CRP Overall Objectives

To assist Member States establish immunochemical methods for the routine analysis of pesticides and so increase analytical capacity at modest cost. This will support the surveillance and monitoring of contaminants in foods and environmental samples assisting Member States comply with international conventions and standards.

CRP Specific Objectives

The objectives of the CRP were to:
1. evaluate the sensitivity and reproducibility of three pesticide enzyme-linked immunosorbent assays (ELISA);
2. develop extraction and clean-up methods, if necessary; and
3. validate the assays through interlaboratory studies and comparison with chromatographic procedures.

Research Outputs

Most of the participants produced acceptable standard curves, despite having little or no previous experience using ELISA. Validation data were published for three ELISA interlaboratory studies: (1) cyclodiene/dieldrin in water, sand and soil (Persistent Organic Pollutants or POPs); (2) triazine/atrazine in water and soil (one of the most frequently detected herbicide in the environment); (3) DDT and DDE/ DDT in soil (the most ubiquitous POP). The DDT validation data were the most convincing as the participant's transformed standard curves (% B/Bo) overlay one another and gave similar IC50 values (0.1-0.2 µg/l). Data on the ELISA accuracy and precision were publicized at scientific meetings, in journal articles and on the World Wide Web.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP achieved the specific objectives and established core expertise within the Agency and Member States on pesticide ELISA. The contributions of the Agrochemicals and Animal Production Units Seibersdorf and the Botany Department Weihenstephan, Germany deserve special acknowledged. Funding for the DDT interlaboratory investigation was provide, in part, by EnviroLogix. Without their support and the contributions of the Agreement Holders this CRP would not have been able to achieve its objective.

The CRP succeeded in raising awareness of the advantages and limitations of pesticide ELISA. ELISA are not a universal solution for food and environmental surveillance but they have a niche in monitoring large numbers of samples for single or closely related analytes. Cost remains a barrier to adoption in national food laboratories but may be overcome in co-operation with commercial and public antibody providers.

In the 1980s and 1990s immunoassays were tauted widely as simple and quick alternatives to conventional analytical methods. As such they would eliminate the need for complex instrumentation, time-consuming training and provide a cost-effective solution for developing countries to monitor compliance with international standards and conventions. Regrettably the results of the CRP were unable to substantiate these claims. Yet with basic training analysts were able to obtain satisfactory accuracy and precision, especially for the final DDT interlaboratory study. The participants reported good sensitivity, speed with minimal matrix interference. However, the cost of commercial ELISA and high specificity of the assays limit them to screening one analyte or, at most, several closely related analogues. While the CRP was unsuccessful in resolving the cost issue, important linkages were between analysts in developing countries and commercial/public antibody producers.

Accomplishments of CRPs

The CRP generated data on two commercial and one non-proprietary pesticide ELISA. In general the accuracy and precision obtained were comparable to those obtained by ELISA for other small molecules such as mycotoxin and antibiotics. Advances in molecular biology and biosensors could overcome some of the problems associated with ELISA and open up new possibilities for immunoassays, especially for monitoring water, blood and urine.

Recommended Future Action by Agency

(1) The CRP identified the pre-requisites for obtaining good results using pesticide ELISA. Training material should be prepared and made available over the Internet to disseminate that knowledge as widely as possible. Ideally, the work should cover mycotoxin, veterinary drug residues and use of ELISA for disease diagnosis.
(2) The consultant's report highlighted the value, and necessity, of method validation using interlaboratory studies. Such data are often not published by commercial distributors. The Agency would perform a valuable service by producing/publishing such data under its Method Validation and Reporting Service.
(3) Biosensors appear a promising development especially for matrices with little or no interferences such as water. These would have value for monitor heavy metals, anticholinesterase inhibitors and estrogenic substances. A consultants' meeting should be convened to evaluate the relevance of these advance for developing countries. The terms of reference should be sufficiently broad to encompass hybrid immunochromatographic approaches.
(4) The overall agreement between ELISA and conventional chromatographic procedure was satisfactory. However, the coefficient of variation for GC and HPLC results exceeded 50%. Such results indicates more work is required in the area of analytical quality assurance and technical backstopping to identify the sources of variability with conventional analytical approaches.
(5) The Agency should seek co-operation from FAO, UNDP or WHO national offices to expedite shipments of kits and interlaboratory samples/reference material. Ideally, this should be an agreement in principle covering the Agency's analytical programme as a whole.

CRP Published Results

Internal: Dankwardt A. 1999. Recommendations about the Use of Immunochemical Methods for the FAO/IAEA Training and Reference Centre for Food and Pesticide Control http://www.iaea.org/trc/pest-2027_review.pdf

External: Maestroni, B.M., Skerritt, J.H., Ferris, I.G. Ambrus, A. 2001. Analysis of DDT Residues in Soil by ELISA: An International Interlaboratory Study. Journal of AOAC International. 84(1): 134-142.

Other Outputs: Amin, M.R. (1998). Enzyme immunoassay for atrazine analysis in water and soil. Pesticide Science. 52 (2): 152-158.
Anon. 1998 Global cooperative studies for analysis of DDT residues. ACIAR Postharvest Newsletter 46: 5.
Dankwardt, A., Hock, B., Ferris, I. and Hance, R. (1998). Possibilities and limitations of enzyme immunoassays for pesticide analysis in developing countries - Results from an Inter-laboratory Study. In "Pesticide Use in Developing Countries: Impact on Health and Environment" San José, Costa Rica. February 23 - March 1.
B. M. Maestroni, J. H. Skerritt, I. Ferris, Application of competitive enzyme immunoassay for screening DDT and DDE in food and environmental samples: initial collaborative study, in: Seeking Agricultural Produce Free of Pesticide Residues, I. R. Kennedy, J. H. Skerritt, G. I. Johnson, E. Highley, eds., ACIAR Proceedings No. 85, Australian Centre for International Agricultural Research, Canberra, Australia, pp. 270-277.

Accomplishments of CRPs

CRP Number and Title: **D52032** **Impact of long-term pesticide usage on soil properties using radiotracer techniques**

Participating Countries: Brazil(C), Canada(A), China(C), Ecuador(C), Egypt(C), Germany(A), India(C), Indonesia(C), Pakistan(C), Philippines(C), Thailand(C), USA (A)

Total Cost: **$244,105**

Duration: 1994-09-15 --- 2000-01-05

CRP Overall Objectives

To investigate analytical methods for risk analysis related to food safety and pesticide management

CRP Specific Objectives

The main objective of the CRP was to determine if the FAO guidelines for data requirement about pesticide impact on soil microorganisms required revision for heavy, repeated applications of pesticides, i.e., as commonly used in cotton, maize and rice production.

The second objective of the CRP was to encourage interdisciplinary co-operation within the participating countries to underpin good agricultural practice and a more "holistic" approach to crop production.

Research Outputs

The CRP provided data about pesticide impact on:

(i) soil microorganisms and biochemical processes--microbial populations, respiration & biomass, nitrification, iron reduction, dehydrogenase, arginine deaminase and aryl sulfatase activity;
(ii) binding of pesticides to the soil and their release from it in terms of cumulative effects; and
(iii) degradation and mineralization of 14C-carbon-ring-labeled pesticides.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP answered a critical question. Does heavy and frequent pesticide applications have drastic long term effects on soil properties? The answer is "no" based on the soil microorganisms and biochemical processes measured in this programme. The CRP achieved a unique outcome by:

1.investigating the impact of heavy and frequent pesticide applications on soil microorganisms and biochemical processes under realistic worst case cropping scenarios such as cotton;
2. monitoring a range of microbial populations and biochemical processes;
3. using standardized protocols;
4. setting a practical assessment procedure--a change in a measured property that was no greater than the annual fluctuation in values from the control, was not considered to be biologically important even if there was a statistically significant difference between treated and control values at any particular time; and
5. focusing on pesticide sequences rather than just the impact of a single pesticide application.

The results of the CRP brought closure to key unresolved questions:

1. does frequently and heavy pesticide use affect basic soil microbial processes on which soil fertility depends; and
2. does repeated pesticide use affect the production of unextractable 14C residues ('bound residues) of another compound or the ability of a soil to mineralize another compound.

Data from this CRP indicate "no" in both case. Thus there is no clear evidence for further work in these areas.

Accomplishments of CRPs

The CRP showed that heavy and frequent rates of pesticide application used in cotton did not have drastic long-term effects on the measured soil properties (microbial populations, respiration & biomass, nitrification, iron reduction, dehydrogenase, arginine deaminase and aryl sulfatase activity). Cotton is widely regarded as the crop that receives the heaviest pesticide treatment. Hence these results are reassuring since other crops receive lower rates of application and newer pesticides are more specific and environmentally benign than those evaluated. The CRP did not provide evidence that registration requirements for data should be made more stringent. However, the lack of correlation between the various microbial activities highlights the value of not relying on the assessment of a single process.

The case for careful monitoring of pest control systems is stronger. The sequence of monocrotophos, methomyl and carbaryl used in Egypt caused quite substantial changes in several activities in the short term and lesser effects were caused by systems used in other countries.

Experiments with radiolabelled pesticides showed that repeated pesticide use did not affect the production of unextractable (bound) 14C residues of another compound or the ability of a soil to mineralize another compound. Hence there is no clear need for further work in this area.

The CRP brought closure to issues of both scientific and public concern. The hypothesis that heavy and frequent use of pesticides would drastically affect soil biota was not substantiated. Data show that pesticide effects on most soil processes are transient. Likewise, repeated pesticide use did not affect the production of unextractable 14C-residues ('bound' residues) of another compound or the ability of a soil to mineralize another compound. However, the results of the CRP suggest more research is needed to understand the factors controlling the activities of soil micro-organisms.

Recommended Future Action by Agency

(1) Current FAO guidelines for the Registration and Control of Pesticides are adequate concerning the effects of individual pesticides on soil micro-organisms.
(2) Studies with radiolabelled compounds showed that repeated pesticide use did not affect the production of unextractable 14C residues ('bound' residues) of another compound or the ability of a soil to mineralize another compound. Hence there is no clear evidence for further work in this area.
(3) Until such time as the factors controlling the activity of micro-organisms have been elucidated, the safety of a pesticide programme with regard to soil fertility can really only be assessed through measurements of crop yield.

CRP Published Results

Internal: IAEA-TecDoc-1248

External:

Other Outputs: Webpage (http://www.iaea.org/programmes/nafa/d5/public/d5_2032.html)

Accomplishments of CRPs

CRP Number and Title: **D61017 The impact of food irradiation to reduce post harvest food losses in Africa**

Participating Countries: Algeria(C), Cote D'ivoire(C), Democratic Rep. of the Congo(C), Egypt(C), France(A), Ghana(C), Morocco(C), Nigeria(C) (2), South Africa(C), Zambia(C)

Total Cost: **$207,723**

Duration: 1994-12-15--- 2000-12-19

CRP Overall Objectives

To study the impact of irradiation to prevent food losses in Africa

CRP Specific Objectives

To conduct pilot-scale research and development on irradiation of specific commodities of interest to participating countries to reduce post-harvest losses, improve hygienic quality and establish commercial potential.

A second objective of the CRP was to undertake consumer acceptance studies, market testing and feasibility to establish commercial irradiators for multi-purpose application.

Research Outputs

The CRP has demonstrated that food irradiation has a potential to reduce post-harvest losses of basic staple food crops including yams, maize, potatoes, onions, cocoa, dried and smoked fish, through pilot-scale experiments carried out in some African countries. The CRP also showed the potential application of irradiation for improving microbial safety and shelf-life of traditional ready-to- eat African foods and as a quarantine treatment for citrus fruits.

CRP Outcome (Effectiveness; Impact; Relevance)

Research and developmental work on a pilot-scale carried out under the CRP has corraborated that irradiation has a potential to be used to reduce high post-harvest losses of yams, potatoes, onions, maize, dried fish; ensure microbiological safety of ready to eat traditional African foods, and as a quarantine treatment for Moroccon citrus fruits.

Specific country-wise results included:
(i) Morocco: Demonstared the possibility for the successful application of irradiation as an alternative quarantine treatment to the classical methods for citrus fruits without affecting their technological quality.
(ii) Zambia: Irradiation inhibited sprouting in onions and potaoes stored under ambient conditions in an open shed; Irradiated labeled potatoes and onions were successfully test marketed.
(iii) Nigeria: Shelf-life and microbial safety of traditional Nigerian meat and fishery products was improved by irradiation; also eliminated insect infestation in smoked-dried fish .
(iv) Cote d' Ivoire: Irradiation inhibited sprouting of yams under local storage conditions. Market testing demonstrated favourable consumer acceptance.
(v) Ghana: Irradiation effectively inhibited sprouting in yams for 6 months under ambient conditions and controlled insect infestation in maize without affecting the quality of the starch or properties of traditional dishes prepared from it.
(vi) Senegal: An economic study for setting up a multipurpose irradiator to treat a wide range of foodstuffs destined for local consumption indicated the feasibiltiy.
(vii) The efficacy of a combination treatment of modified atmosphere and irradiation on the safety, microbilogical quality and consumer acceptability of traditional African food was studied with positive results.
(viii) Egypt: Consumer surveys and market sale of irradiated products showed positive consumer attitude towards food irradiation and acceptance of irradiated products.
(ix) Algeria: Established the techno-economic feasibility for irradiation of dates.

The results of the CRP have shown that irradiation processing can contribute to post harvest loss reduction in major staple foods and improve the hygienic quality of traditional African foods. The CRP also established public acceptance of

irradiated foods in the participating African countries.

This CRP was undertaken between 1995 and 1999 to assist institutions in Africa in conducting pilot-scale studies on food irradiation, test marketing and economic studies to determine the feasibility of food irradiation and its impact in preventing food losses in the region. Experiments were carried out either in lab-scale, pilot scale or semi-commercial scale on potatoes, onions, yam, maize, dates, beans, citrus, tomatoes, spices, traditional fish and meat, meals ready-to-eat, etc. to demonstrate technical feasibility of the process in Algeria, Cote I'Voire, Egypt, Ghana, Morocco, Nigeria, Senegal, South Africa and Zambia. Detailed economic feasibility studies for commercial irradiation facilities were carried out in Algeria and Senegal.

Significant development on harmonizing national regulations on food irradiation based on the principles of Codex General Standard for Irradiated Foods and recommendations of the International Consultative Group on Food Irradiation (ICGFI) was made in some African countries. Ghana has implemented such a harmonized regulation, whereas Egypt, Morocco, Nigeria, South Africa and Tunisia have recommended it to their national authorities but not yet implemented in their national regulations.

Research data on pilot scale irradiation of potatoes, onions, and yam for sprout inhibition, cocoa beans, dried dates, dried fish and meat, and fresh citrus for insect disinfestation, spices and meals ready-to-eat, showed the potential for irradiation to be carried out to reduce food losses of and facilitate wider trade in these commodities. However, only a few countries, i.e. Egypt, Ghana, Morocco, South Africa, Tunisia, and Zambia have irradiation facilities large enough to demonstrate the techno-economics of irradiation of food.

This CRP demonstrated that it is technologically feasible to irradiate a number of food items to reduce food losses in Africa. However, with the exception of South Africa which is one of the leading countries on commercial application of food irradiation, proper infrastructure is required in other African countries before this technology could be used to demonstrate an impact in terms of reducing food losses.

The CRP enabled the participating African countries to evaluate the efficacy and commercial potential of irradiation to reduce storage losses of staple foods under prevailing conditions and improve the hygienic quality of traditional ready-to- eat foods. Under the CRP, studies on public acceptance and market response to irradiated foods could be carried out with positive outcome.

Recommended Future Action by Agency

Infrastructure and man power development for the successful commercialization of food irradiation.

CRP Published Results

Internal: IAEA-TECDOC in print

External:

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **D61018** **Production of safe shelf-stable and ready-to-eat foods through high dose irradiation processing**

Participating Countries: Argentina(C) (2), Canada(A) (2), China(C), France(A), Ghana(C), Hungary(C) (2), India(C), Indonesia(C), Israel(A), Portugal(C), South Africa (A), Thailand(C), United Kingdom(A), United States Of America(A) (2)

Total Cost: **$235,578**

Duration: 1995-12-15--- 2000-12-31

CRP Overall Objectives

To evaluate the effect of high-dose (above 10 kGy) irradiation on microbiological safety, shelf-life, acceptability and packaging requirements of food to enable them to be kept for long term storage either under refrigeration or at ambient condition.

CRP Specific Objectives

1. Evaluate the role of irradiation above 10 kGy in combination with other processes to render food (meats, poultry, seafood, pre-cooked meals, starch) shelf-stable at ambient temperature, either as individual components or composite meals.

2. Evaluate the use of irradiation in combination with other processes to produce non-sterile shelf-stable food (e.g. intermediate moisture food).

3. Evaluate the role of irradiation on microbiological safety and shelf-life extension of prepared meals and composite foods, stored either at ambient or chilled condition.

4. Evaluate the palatability of various shelf-stable food mentioned above, especially for serving in hospitals and to individuals under medical care.

5. Evaluate the effect of irradiation, especially with dose above 10 kGy, on various packaging materials required for shelf-stable or ready-to-eat food.

Research Outputs

(i) Pathogen Control in Shelf-Stable, Ready-to-Eat Food

Irradiation was shown to be effective in controlling certain pathogens in such food. For example, L. monocytogenes in selected pre-cut, pre-packaged vegetables was controlled by irradiation dose as low as 1 kGy in combination with proper refrigeration (at or below 5 C). Staphylococcus aureau was not detected in vacuum packed intermediate moisture meat cubes subjected to 10 kGy irradiation and stored for 6 months at ambient temperature (30 C).

(ii) Improve Microbiological Safety and Quality of Chilled Prepared Meals

Irradiation of chilled prepared meals consisting of roast pork, gravy, mixed vegetables and potatoes were irradiated with a dose of 2 kGy resulted in a significant shelf-life extension at refrigeration temperature (3 C). Also, shelf-life of chilled ready-to-eat food such as ham, sausages, packaged in modified atmosphere packaging, could be extended by 2-3 times following irradiation with a dose of 4 kGy and kept at 4 C.

(iii) Development of Shelf-Stable Food (both sterile and non-sterile products)

Sterile shelf-stable products such as pre-cooked traditional fish in Indonesia, meat and poultry products inSouth Africa could be developed through the use of high-dose irradiation (45 kGy) at cryogenic temperature, vacuum packaging

and proper packaging materials. Such products could be kept at ambient temperature for about 2 years.

A number of shelf-stable non-sterile products were also developed through a combination of processes including irradiation with dose up to 10 kGy. In Ghana, a cooked marinated intermediate moisture fish could be kept at ambient temperature for several days without affecting the sensory quality. A number of intermediate moisture meat products in India were rendered shelf-stable at ambient temperature through irradiation with a dose of 10 kGy. A semi-dried and cure pork product in Thailand has a much improved microbiological quality after irradiation at 6 kGy and kept at ambient temperature.

(iv) Packaging Requirements

The performance of a number of packaging materials (HDPE, EVA, PS, PET,Nylon 6) in contact with food irradiated with doses up to 100 kGy were evaluated. In general, most of these packaging materials could withstand radiation dose up to 10 kGy. The effect of these packaging materials to doses higher than 10 kGy is being investigated.

CRP Outcome (Effectiveness; Impact; Relevance)

This CRP demonstrates that irradiation of food with a minimum dose of 45 kGy together with other processes resulted in shelf-stable food at ambient temperature with good quality. It also demonstrated that microbiological quality of chilled ready-to-eat food could be improved by irradiation with dose below 10 kGy. A number of non-sterile intermediate moisture food could be rendered shelf-stable at ambient temperature following irradiation with dose below 10 kGy.

Data generated from this CRP demonstrated that a number of shelf-stable, ready-to-eat food to be kept either at ambient or refrigeration temperature could benefit from irradiation treatment to satisfy market requirements.

This CRP was implemented to meet the increasing demand for safe, fresh or fresh-like, shelf-stable and ready-to-eat food with less chemical preservatives by evaluating the role of irradiation to produce a variety of shelf-stable foods, either sterile or non-sterile, with a view to enhance their microbiological safety, shelf-life extension and energy requirements in distribution. Data generated by this CRP demonstrated the effectiveness of irradiation of the following types of food:

1. Improving the microbiological safety and quality of chilled prepared foods. Irradiation with a dose of 2-4 kGy improved microbiological quality and safety of a number of prepared products including pre-packed, prepared vegetables, sous-vide meals, sausages and ham, and chilled prepared meals which are normally marketed under refrigeration. This dose range of radiation is also effective in improving microbiological quality of several types of food normally catered to immuno-suppressed patients/population, such as vegetable salad, fruit salad in gelatin, vanilla ice cream and fresh stuffed pasta, which no other technology could be used to achieve the same purpose.

2. Improving the quality of sterile and non-sterile shelf-stable foods. Several types of high quality sterile shelf-stable products and meals including chicken chilli, salami, sausages, mutton kabab, roast beef slices, chicken curry could be developed using a combination of high-dose irradiation (45 kGy minimum) mild heat and freezing. Such products in properly packaging could be stored at ambient temperature for at least 18 months. Some of these products have been marketed successfully in South Africa.
Irradiation with dose below 10 kGy together with reduced water activity and proper packaging resulted in safe, shelf-stable, intermediate moisture food including chicken, beef, lamb, dried fish, semi-dried pork, semi-dried shrimp, smoked sausages, ready-to-eat salt and dried fish, which could be kept at ambient conditions for at least 9 months.

3. Quality assurance guidelines for packaging materials required for food to be irradiated with doses above 10 kGy were developed.

The results generated by this CRP will not only meet the requirements of the food industry and consumers in improving the safety and quality of a variety of shelf-stable and ready-to-eat food but also broaden the horizon of food irradiation application to include shelf-stable food developed through high-dose irradiation in combination with other food processing methods. This outcome should also be valuable in meeting energy conservation in both advanced and developing countries when such food could be distributed at ambient instead of frozen or chilled conditions.

This CRP is highly relevant to the use of irradiation as a sanitary treatment of food to be kept at ambient conditions which

prevail in most developing countries. It also contributes to the convenience in having a safe, ready-to-eat food, to the consumer

Recommended Future Action by Agency

CRP Published Results

Internal: Two RCM reports

External: A TECDOC publication of the proceedings of the final RCM is foreseen.

Other Outputs: Several papers published by the participants in open literature.

Accomplishments of CRPs

CRP Number and Title: **D62006 Market development for irradiated food in Asia and the Pacific (RCA)**

Participating Countries: Bangladesh(A), China(A) (2), Korea, Republic Of(A), Malaysia(A), Pakistan(A), Philippines(A), Sri Lanka(A), Thailand(A), Viet Nam(A)

Total Cost: **$44,523**

Duration: 1994-10-07--- 2000-12-25

CRP Overall Objectives

Consumer acceptance, commercialisation and promotion of trade in irradiated foods.

CRP Specific Objectives

The main objective of the CRP was to achieve wider acceptance of irradiated foods by the public and promote domestic trade in irradiated foods.

An additional objective of the CRP was to encourage inter-country transportation of irradiated food among the participating countries in Asia and the Pacific.

Research Outputs

(i) Consumer acceptability tests carried out under the CRP showed that consumers would accept irradiated foods and that trade benefits would ensue from the application of the technology. Information dissemination was found to be a critical factor in public acceptance.

(ii) Participants made commendable progress in the marketing of irradiated food as demonstrated in the marketing of close to 179,000 tons of different foods and related products through normal trading channels.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP demonstrated the wide acceptance of irradiated foods by consumers in most of the participating countries of the Asia-Pacific region. Specific information pertaining to the participating countries were:

(i) Bangladesh: Consumers had no adverse views on irradiated foods as evidenced by consumer acceptability tests. A joint venture company of government and private industry irradiated and marketed 1300 tons of different food products.
(ii) China: More than 30 consumer acceptance tests covering 20 different irradiated products in a number of cities showed favourable consumer acceptance. During 1995-1998 more than 166,000 tons of irradiated foods including rice, garlic, spices, dehydrated vegetables and health foods were marketed through normal trade channels.
(iii) South Korea: More thn 6000 tons of irradiated foods and products such as spices, dried meat and sea food, soybean paste and hot pepper paste were marketed successfully.
(iv) Pakistan: 8 tons of irradiated potatoes and onions were successfully test marketed through normal trade channels.
(v) Philippines: Marketing of 86 tons of onions and 14 tons of shallots were carried out. Willingness of consumers to purchase irradiated foods increased when prior information on the technology was provided.
(vi) Thailand: About 5114 tons of food items including spices, herbs, fermented pork sausages or 'nham' were irradiated and marketed. Market testing and consumer acceptance study of irradiated rice showed that a majority of consumers bought irradiated rice because of its high quality based on visual inspection.
(vii) Viet Nam: 45 tons of rice, 0.5 tons of litchi and 0.4 tons of mushrooms were irradiated and successfully test marketed.

The results of the CRP have answered positively questions regarding public acceptance of irradiated foods in most of the participating countries and facilitated in irradiated foods entering trade in domestic markets through normal trading channels.

This CRP was in operation between 1995 and 1999 with the aim of facilitating wide acceptance of irradiated food by the

public and promoting domestic and inter-country trade in irradiated products among countries in Asia which are members of the Regional Co-operative Agreement on Research, Development and Training related to Nuclear Science and Technology (RCA). The impact of this CRP may be summarized in the following areas:

1. Harmonization of National Regulations. Several RCA member countries made serious attempt to harmonized their national regulations through a regional workshop held in Seoul in 1998. Several countries especially those from ASEAN, Bangladesh, China and Pakistan had either implemented the harmonized regulation as adopted in Seoul or in the process of doing so.

2. Irradiation Facilities. Several more irradiation facilities were built and started operation during this time. This bring the total number of facilities in Bangladesh (2), China (50), India (1), Indonesia (1), Korea (2), Malaysia (1), Pakistan (1), Thailand (3) and Vietnam (1) which are available for processing food on commercial scale.

3. Public acceptance. A number of consumer acceptance studies of irradiated food were carried out through marketing trials in Bangladesh (irradiated potatoes, onions, dried fish and pulses), China (numerous irradiated food products from spices to fresh meat to garlic, etc.), Pakistan (potatoes and onions), Philippines (onions and garlic), Sri Lanka (spices), Thailand (fermented pork sausages, rice) and Vietnam (rice, litchi, mushrooms). In addition, consumer attitude surveys and public seminars were carried out in several countries to disseminate the information about food irradiation. All market trials were successful and the level of acceptance of irradiated food increased with proper information and better understanding of the safety and benefit of the technology.

4. Trade Development. Although trade in irradiated food in most Asian countries is restricted to domestic market so far, the volume of irradiated food produced and entered commercial channels in this region reached a total of 178,801 tones between 1995 and 1998. This volume is expected to increase further with additional facilities in operation and more market demand in the future.

The CRP enabled the participating countries to bring food irradiation technology to the marketplace to address food security, public health and trade needs. This covered the establishment of quality assurance procedures, the determination of irradiation doses for traditional as well as non-traditional foods, the conduct of techno-economic feasibility, and the identification of industry and consumer needs. In the majority of cases, R&D activities were undertaken in partnership with the industry. Public acceptance for irradiated foods was established through actual consumer acceptance and test marketing of irradiated foods.

Recommended Future Action by Agency

(i) Technical and legal assistance for the harmonization of regulations in the RCA countries to facilitate trade in irradiated foods.
(ii) Develop infrastructure in countries lacking irradiation facilties.

CRP Published Results

Internal: IAEA-TECDOC-1219

External:

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **E12014** **The standardization of I-131 treatment for hyperthyroidism with an intent to optimize radiation dose and treatment response (RCA)**

Participating Countries: Australia(A) (2), Bangladesh(C), China(C), India(C), Indonesia(C), Japan(C), Malaysia(C), Philippines(C), Singapore(C), Thailand(C)

Total Cost: **$203,866**

Duration: 1995-01-15--- 2000-08-31

CRP Overall Objectives

To establish effective use of appropriate in vivo therapeutic nuclear medicine procedures in the developing member states through Agency support.

CRP Specific Objectives

1. To evaluate the strengths and weaknesses of high and low dose radioiodine therapy, using the absorbed dose concept , in a diverse range of patients and to compare and contrast the similarities and differences based on ethnicity and geographical variations. In addition, this study aims to contribute to the standardization of therapy by describing multi-center International experience.
2. To determine the role of pharmacologic intervention with Lithium on the management of patients with hyperthyroidism.

Research Outputs

The study followed a randomized approach to treatment where patients were followed prospectively. Patients were enrolled from ten different countries during the period from January, 1995 - October, 1998. A total number of 572 patients with a minimum follow-up of 1.5 years (Mean = 3.5 yrs.) following treatment were included in the study for final evaluation. All patients included in the study were hyperthyroid with diffuse goiter, without any serious organic disease and past history of radioiodine therapy. Each patient underwent a thorough pre-treatment clinical evaluation. Patients were randomly assigned into three groups according to estimated absorbed doses. Group A consisted of 181 patients assigned for low dose therapy (less than 60 Gy), Group B consisted of 126 patients assigned for 60-80 Gy and Group C consisted of 265 patients for high dose therapy (more than 80 Gy). Two countries participating in the study (Singapore and China) assigned patients into low or high dose groups based on patient preferences. Due to cultural influences, patients in China preferred low doses, while in Singapore the preferred dose for therapy was high. Patients from India and Malaysia were further grouped into subsets (with and without pre-treatment with Lithium). The calculation of I-131 treatment dose was made on the basis of the following formula :

$$\text{Dose of I-131} = \frac{W \times D \times .37}{17 \times EHL \times TUR}$$

Where: W = weight of thyroid
D = anticipated absorbed dose (Gy)
EHL = effective half life of I-131 tracer dose (days)
TUR = 24 hrs thyroidal uptake of I-131 (%)

After radioiodine therapy all patients were followed up at 1, 3 and 6 months and at every six months there after. All patients were evaluated clinically and biochemically at all follow-up visits for thyroid function, except for the first visit (which was clinical evaluation only). Adverse effects, if any were also recorded. Patients were deemed to be non-responders if after six months, they were still hyperthyroid based on clinical and biochemical parameters (including subclinical hyperthyroidism). These patients were retreated with further doses of I-131 or antithyroid drugs. Patients retreated with radioiodine were excluded from further analyses.

Statistical analyses of data were done using appropriate statistical methods. Analyses of proportion was done using relative deviate test and Chi-square analyses. Response to therapy was assessed by Kaplan-Meyer method . Parametric data

were analyzed using the multivariate analyses.

In the immediate post-iodine period (within 6 months), persistent hyperthyroidism, euthyroidism or hypothyroidism was seen in 30%, 52% and 18% respectively in patients treated with low (Group-A) or moderate (Group-B) doses of I-131; while it was 31%, 47% and 22% in patients treated with large doses (Group-C) of I-131. Practically there were no difference in response to treatment with various doses of I-131.

Use of Lithium as an adjunct to radioiodine in the treatment of thyrotoxicosis was also evaluated in 121 patients. Use of Lithium bicarbonate resulted in prolongation of Effective half life of I-131 in the thyroid gland approaching almost the physical half life of I-131. As a result the required administered dose of I-131 to achieve the desired absorbed dose of radiation was significantly reduced in all cases treated with Lithium.

Based on the experience of the CSIs at various research sites, the final RCM noted the following observations and recommendations:

a. In the treatment of thyrotoxicosis, the absorbed dose concept should be used for the calculation of the administered dose of I-131.
b. Follow-up of patients on a medium term basis revealed best results in patients treated with a medium level of radiation dose. Hence an absorbed dose of 60-80 Gy. was recommended for the treatment of patients with hyperthyroidism.
c. Use of Lithium before I-131 therapy was found to be useful and significantly reduced the dose of I-131 to achieve same biological effectiveness as compared to those patients who receive I-131 without Lithium.
d. Patients treated with Lithium bicarbonate did not show any side effects.

The long-term follow-up data are now being evaluated by the Japanese Technical Contract Holders and will soon be published in a peer reviewed journal.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objectives of the CRP were to evaluate the strengths and weaknesses of high and low dose radioiodine therapy, using the absorbed dose concept , in a diverse range of patients and to compare and contrast the similarities and differences based on ethnicity and geographical variations. In addition, this study also aimed to contribute to the standardization of therapy by describing multi-center International experience. The CRP effectively addressed the above objectives and it has been possible to come out with specific recommendations with respect to administered dose calculations based on absorbed dose concept. The other concerns like the influence of geographic and ethnic factors influencing the response to treatment are being evaluated through a multivariate analyses of data collected by the participating centers.
The role of pharmacologic intervention with Lithium has also been addressed adequately. The recommendations to this effect are clear and unambiguous.

Radioiodine treatment is the most effective treatment for thyrotoxicosis. In fact it is the most definitive and cost-effective treatment available to-day for this disease. I-131 is a standard radiopharmaceutical, easily available in most developing countries and is reasonably cheap. Promotion of this treatment modality is consistent with the overall objectives of the project in the nuclear medicine section, i.e., "to establish effective use of appropriate in vivo therapeutic nuclear medicine procedures in the developing member states through Agency support".

Graves Disease remains an enigmatic autoimmune disorder with a high prevalence within the Asia & Pacific Region. The use of antithyroid medication is pivotal in the initial management of Graves Disease. However, between 62-80% of patients will relapse following medical therapy over a 6-18 month period. The management of such relapsed patients increasingly has involved the use of radio iodine following evidence supporting its efficacy and safety. Due to diversity of resources available world-wide a standardised approach to therapy with radio iodine has not yet been achieved. This CRP was instituted as an Extra-budgetary CRP with support from the Government of Japan in an effort to achieve standardization of treatment of patients within the Asia & Pacific Region. For the first time a therapeutic approach based on absorbed dose concept was applied in a multi-center study. The results of the study will have significant impact on the practice of radioiodine therapy in patients with thyrotoxicosis and will lead to a more scientific management rather than based on empirical calculations.

Accomplishments of CRPs

High incidence of goiter and hyperthyroidism in Asia is a well-known clinical fact. Hyperthyroidism is a functional derangement of thyroid, which, without therapy can cause severe emaciation and decompensation of heart. A variety of tests for the diagnosis of thyroid morphology and function are normally available involving radioisotopic as well as non-radioisotopic techniques. For therapy of hyperthyroidism, there are three main methods, medical, surgical and I-131 therapy. One of them, I-131 therapy is the most effective and continues to be widely employed. Its efficacy and safety have been repeatedly shown in the long-term studies. It is available and affordable to most people in developing countries of Asia. However, despite the great number of thyroid cases in this region, choice of methods of treatment using I-131 and evaluation of results have not been standardized. Different investigators in Asia have reported individual observations in their own series of patients. Most notable among them are (1) smaller doses of radioiodine for control of hyperthyroidism, and (2) low incidence of post-therapy hypothyroidism. Prior to the start of this CRP there has been no systemic study to evaluate the efficacy and incidence of post-therapy hypothyroidism using the smaller dose approach

Recommended Future Action by Agency

Promote application of this therapeutic procedure through national and regional TC projects in IAEA Member States.

CRP Published Results

Internal:

External:

1. Afroz S, Buachum V, Chou C, Kanaya S, Kusakabe K, Kusakabe M, Mohamed M, Nursal A, Sin AE, Tateno Y, Padhy AK, Torres JF, Yamasaki T. The standardization of I-131 treatment for hyperthyroidism with an intent to optimize radiation dose and treatment response. Proceedings of the International Symposium on Radioiodine, 24-27 August, 1996, Mayo Clinic, Rochester, Minnesota, USA
2. K. Kusakabe. The standardization of I-131 treatment for hyperthyroidism with an intent to optimize radiation dose and treatment response: An intermediate Report of the IAEA CRP. 6th Asia & Oceania Congress of Nuclear Medicine & Biology, Kyoto, Japan, October, 1996.
3. IAEA Study Group on Graves' Disease. Standardisation of I-131 treatment for hyperthyroidism with intent to optimise radiation dose and treatment response. Presented at "12th International Thyroid Conference" held on 22-27 October 2000 at Kyoto, Japan.
4. IAEA Study Group on Graves' Disease.Comparison of radioiodine and radioiodine plus lithiumin treatment of Graves's disease. Presented at "12th International Thyroid Conference" held on 22-27 October 2000 at Kyoto, Japan.
5. IAEA Study Group on Graves' Disease. Influence of lithium on effective half-life of radioiodine in patients of graves disease. Presented at the "7th Joint World Congress of Nuclear Medicine and Biology " held on August 30-4 September,1998 at Berlin, GERMANY.
6. Kumar R, AK Pandey, AK Padhy, GS Pant, AK Gupta, AC Amini. Factors effecting radioiodine induced hypothyroidism in Graves's disease. Endocrine Journal 47: 143, 2000.
7. Kumar R, AK Pandey, AK Padhy, GS Pant, AK Gupta, AC Amini. Standardisation of I-131 treatment for hyperthyroidism with intent to optimise radiation dose and treatment response. Endocrine Journal 47: 144, 2000.

8. Kumar R, AK Pandey, AK Padhy, GS Pant, AK Gupta, AC Amini. Comparison of radioiodine and radioiodine plus lithium in treatment of Graves's disease. Endocrine Journal 47: 148, 2000.

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **E13013** **Efficacy and toxicity of 153-Samarium radiopharmaceuticals in the treatment of painful skeletal metastases**

Participating Countries: Argentina(C), Austria (A), Brazil(C), Chile(C), China(C) (2), Thailand(C)

Total Cost: **$148,947**

Duration: 1996-04-15--- 2000-10-19

CRP Overall Objectives

To establish effective use of appropriate in vivo therapeutic nuclear medicine procedures in the developing member states through Agency support.

CRP Specific Objectives

To determine the ability of a single intravenous dose of Samarium-153 EDTMP to alleviate the pain associated with metastatic bone disease and to determine the occurrence of myelo-toxicity following treatment.

Research Outputs

1. Standardization of the preparation of Sm-153 EDTMP and its quality control for intravenous use on human subjects.
2. Standardization of the protocol for Sm-153 EDTMP therapy in the palliation of metastatic bone pain
3. Determination of the efficacy of Sm-153 EDTMP in the palliative treatment of metastatic bone pain
4. Determination of the systemic as well as haematological toxicity of Sm-153 EDTMP therapy for bone pain palliation.
5. Dissemination of the results of the study through scientific publications, presentations at international congresses etc.

CRP Outcome (Effectiveness; Impact; Relevance)

The aim of this multicenter study was to assess the efficacy and toxicity of Sm-153 EDTMP in the palliative treatment of painful skeletal metastases. Four hundred seventeen (251 males and 166 females) histologically documented cancer patients with painful bone metastases, stable hematologic profile, no signs and symptoms of spinal cord compression, and a life expectancy of greater than 16 weeks were treated with Sm-153 EDTMP. The patients were randomized into three groups; group I (n=118), group II (n=196) and group III (n=103) receiving 18.5, 37 and 55 MBq/kg of body weight. Pain relief was assessed for 16 weeks following treatment. Effective pain palliation was noted in 73% of patients. In 82% of these patients (responders) post-therapy analgesic intake was reduced substantially or completely. In 50% of responders effective palliation was observed for 4-8 weeks, while in the rest effective palliation was observed for more than 8 weeks. Further, the response to treatment was found to be independent of the administered doses of Sm-153 EDTMP. In the present study no life-threatening toxicity was noticed after single doses of Sm-153 EDTMP. However, a temporal, recoverable, but obvious mild to moderate myelotoxicity was encountered in about a third of our patients. There appeared to be a linear correlation between administered dose and hematological toxicity. This study, conducted on a large patient population at multiple centers globally, provides additional efficacy data with respect to Sm-153 EDTMP to those already available in literature.

Intravenous injection of 153Sm-EDTMP is an effective palliative therapy for patients of painful bone metastases. The response rate is 72.7% in the current CRP. There is no life-threatening toxicity noticed after single doses of 153Sm-EDTMP. However, a temporal, recoverable, but obvious myelotoxicity is encountered in 33-61% (WBC), and 22-67% (platelets) of our patients.
Sm-153 is reactor produced and is available in several developing Member States of IAEA. On the other hand Sr-89, the most widely used radiopharmaceutical in the developed countries is expensive and is not available in any of the developing member States of IAEA. In view of the similar efficacy and toxicity (in comparison with Sr-89) but favorable features in availability and price, Sm-153 EDTMP seems more cost-effective than other palliative therapies used clinically at the current time, especially in the developing country setting.

The results of the CRP has created a big impact on the practice of therapeutic nuclear medicine in several developing countries of the world. Sm-153 is easily available, less expensive and equally effective as compared to the standard of

treatment (Sr-89). As a result more and more centers in the developing countries like India, Argentina, China, Thailand and Chile are using this radiopharmaceutical in the palliative treatment of metastatic bone pain.

Skeletal metastases responsible for severe pain occur in many cancer types in up to 80% of patients during the course of the disease. The pain syndrome in patients with metastatic bone disease frequently produces considerable deterioration in quality of life even while the general physical conditions are still quite good. Therefore several therapeutic strategies to control pain in patients with disseminated bone metastases have been proposed. Local radiotherapy is successful and highly effective in the management of painful solitary bone metastasis. Systemic oncological therapy with hormones, cytostatic drugs and cytokines can improve the situation, and analgesics - from NSAR to highly potent morphine-alkaloids - can be used. Moreover it has been shown that bisphosphonates can reduce pain in such conditions. As local radiotherapy has only a limited therapeutic potential in disseminated skeletal metastases and the other therapeutic options have a variety of side effects , radionuclide therapy for pain control was introduced a long time ago, but became important only in the last 10-15 years . Sm-153 ethylene-diamino-tetramethylene-phosphonate (EDTMP) appears to be a radiopharmaceutical suitable for bone pain therapy as reports on efficacy of this therapeutic possibility were promising. However, conventional dose proposals for Sm-153 EDTMP in terms of MBq/kg body weight (18.5, 37, 55 MBq/kg body weight) have shown controversial results not only concerning therapeutic efficacy but also concerning myelotoxicity. Although myelotoxicity was shown to be usually transient, and occurred only in mild degrees using these amounts of activity, estimates of radiation dose delivered to lesions and the bone marrow are scarce. This study was therefore performed on a large number of patients, to determine the efficacy and toxicity of Sm-153 EDTMP for relief of metastatic bone pain using conventional dose proposals but at the same time, to obtain data useful for dosimetric studies. The kinetics of Sm-153 EDTMP, especially in comparison with Tc-99m phosphonates were assessed, and dosimetric studies were done in which intensity of regional uptake, functional tumor volume (SPECT) and residence time were evaluated. The results were expected to generate insights for optimal Sm-153 EDTMP therapy, with a high efficacy and an acceptable low levels of toxicity, for controlling pain in patients with disseminated skeletal metastases.

Recommended Future Action by Agency

Promote application of this therapeutic procedure through national and regional TC projects in IAEA Member States.

CRP Published Results

Internal:
1. Olea E, Quintana JC, Nagel J et al. Efficacy and toxicity of Samarium-153 EDTMP locally produced in the treatment of painful skeletal metastases. Therapeutic Applications of radiopharmaceuticals: IAEA TECDOC-1228, Vienna, IAEA, 2001, pp225-229
2. Pan Z, Zhu S. Random comparison study of the clinical response to Sm-153 EDTMP; 1.mCi/kg and 1.5 mCi/kg of body weight. Therapeutic Applications of radiopharmaceuticals: IAEA TECDOC-1228, Vienna, IAEA, 2001, pp230-235

External:
1. Olea E, Riccabona G, Tian JH, Pusuwan P, Parma EP, Pan Z, Obaldo J, Padhy AK. Efficacy and toxicity of Sm-153 EDTMP in the palliative treatment of painful skeletal metastases. World J Nucl Med (Accepted for publication)
2. Olea E, Riccabona G, Tian JH, Pusuwan P, Parma EP, Pan Z, Obaldo J, Padhy AK. Efficacy and toxicity of Sm-153 EDTMP in the palliative treatment of painful skeletal metastases: Results of an IAEA International Multi-centre study. J Nucl Med 2000; 41 (Suppl.) 146 P

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **E13015** **Diagnosis and management of patients with "unexplained" back pain using bone SPECT**

Participating Countries: China(C), Cyprus(C), Hungary(C), India (A), India(C) (2), Slovenia(C), South Africa (C), Turkey(C), United Kingdom (A), United Kingdom (C), Viet Nam (C)

Total Cost: **$136,419**

Duration: 1997-07-15--- 2000-07-14

CRP Overall Objectives

The overall objective of this CRP was to bring about a rationalized, cost-effective management strategy to deal with patients with low back pain syndrome. Such an effective management strategy would prevent high societal costs and economic loss related to work absence, considering that low back pain is one of the commonest causes of absenteeism among the adult work force in all parts of the world.

CRP Specific Objectives

1. To determine the sensitivity and specificity of bone SPECT in dealing with patients with unexplained low back pain.
2. To compare the role of bone SPECT with X-Ray CT in such patients.
3. To suggest an algorithm (flow chart) of the management strategy in dealing with such patients.

Research Outputs

This prospective study was performed in patients with low back pain and normal radiology or radiology which did not explain the patients back pain. This study was performed under the direction of an International Atomic Energy Agency (IAEA) co-ordinated research group. A total of 174 patients were studied in 8 centres in 7 countries covering 3 continents.

Patients were included in the study if they had back pain for more than 4 weeks, with either a normal spinal x-ray or an x-ray which though abnormal did not explain the patients pain. This assessment being made by the patient's physician. Patients were excluded if they had explainable back pain, was not willing to have SPECT and CT examinations, or were lactating at the time of the SPECT scan and in whom pregnancy could not be excluded.

The mean age of the 174 patients studied was 42 (range 15-80) there were 94 female patients. The professional status of the patients were as follows, Manual worker 40, clerical or professional 72 patients, retired 20 patients and homemakers 42. The economic status as defined by national criteria were as follows, middle class 142, rich 16 and poor 16 patients. In 23 patients there was a previous history of trauma either directly to the spine or to the back. In a further 8 patients there was a history of malignancy but this was thought not to be the cause of the patient's pain. There were 13 patients who had undergone previous spinal surgery. The man duration of pain suffered by the group imaged was 3 months and the greatest 240 months (20 years). There were a total of 107/174 patients complaining of lumbar pain, 55 had dorsal pain and the remaining 12 patients had pain in the sacrum. In 55 patients pain radiated down into the legs and in 125 patients the pain occurred at rest.
At the time of scanning 72 patients were taking analgesia, 51 had analgesia and physical therapy. 18 had physical therapy alone and 9 had had injection treatment. Miscellaneous treatments including yoga was used in 13 patients.
In 44 patients the spinal x-rays were abnormal but it was decided that the abnormalities seen did not explain the patient's symptoms, in the remaining 91 patients the radiology was considered normal for the patient's age. The definition of normality made by a radiologist or orthopaedic surgeon in each study centre.

Planar x-rays were performed in all patients, an anterior-posterior projection and lateral view forming the base data set. CT was performed from T12 to S1 using local institutional protocols and displayed with bone and soft tissue windows. All films were reviewed by a panel of 9 reviewers and any disagreement settled by a majority vote of these reviewers. Planar radionuclide images of the spine to include T12 to S1 were performed 2.5-3.5 hours after administration of 550-750MBq of Tc-99m diphosphonates. A minimum matrix of 128x128 was used and a minimum of 1 million counts collected. All images were stored on film for consensus reporting
SPECT imaging was performed on machines with a minimum quality control set including assessment of uniformity, linearity

and centre of rotation. Each centre performed the SPECT study to its own criteria but the minimum requirement was a high resolution collimation, 64x64 word matrix, 60 frames, with 30 second frames for a single headed gamma camera, and equivalent times for multi-head cameras. Images were reconstructed using a machine optimised back-projection filter and displayed as transverse, saggital and coronal data sets of film for review.

All films and the patient's histories were reviewed in a meeting of 9 specialists in nuclear medicine, radiology and orthopaedics. In each case the eligibility of that patient for the trial was approved and a consensus report on each of the images produced. The report produced not only had to identify the site of any pathology on the scan being reviewed but also to characterise the cause of that abnormality. This was then correlated with the final diagnosis for each patient was confirmed by a the patient's clinician using all clinical, pathological and imaging evidence available to them. Therefore review of each patients case notes was performed to determine final diagnosis and the results of any treatment given after the SPECT scan result.

Two specialists in statistics verified each of the data sets and correlated the results of each scan with the clinical diagnosis and outcome of each patient

There were a total of 87 patients in which the CT scan showed abnormalities, in 67 of these there was a degree of discordance in the results between the two imaging modalities. The most common discordance was that the CT showed some disc degeneration but the SPECT scan showed in addition facet joint uptake at the same level. In the remaining 51 patients the CT was normal but the SPECT was abnormal in 40 of these patients. Therefore SPECT was able to provide additional information in 29% of patients. In a further 48% of cases the SPECT study was able to show abnormalities not seen with x-ray and radiology.
In looking at the results by the final diagnosis it is possible to identify where bone SPECT is able to identify the presence of disease (Table 1)

Final diagnosis N x-ray CT SPECT
Infection 6 1 4 3
Degenerative+ 104 20 66 65
*Osteophyte formation only 17 11 14 15
*Disc only+ 30 4 28 10
*Facet only+ 28 5 13 27
*Mixed components+ 29 0 11 13
Spondylisthesis+ 2 1 1 0
Tumour+ 7 1 3 7
Sacroilitis+ 12 0 2 10

Non-skeletal+ 43 31 25 34

Table 1 results of the number of studies abnormal in relation to final diagnosis of back pain *subgroups of the degenerative group

It is clear that SPECT is most useful in patients with facet joint disease, planar \X-ray was not able to identify any of these patients and CT only 2 however all could be seen with SPECT. In addition in those 29 patients with degenerative disease that involved both anterior and posterior elements of the vertebrae, SPECT identified posterior element disease in 13 (45%).of these patients. In addition SPECT was able to identify tumour in 4 patients, where all were missed on x-ray and 3 on CT. In sacroilitis there was 7/9 patients positive on SPECT but only 2 were seen on CT and one on planar x-ray.

In the post-operative group SPECT proved to be most insensitive, with only one patient positive this may be because pain after surgery on the spine can be complex and SPECT was only picking up the patient with a metabolically active lesion.

In the group in which it was decided that the pain was non-metabolic, 12 had an abnormal CT but it was decided that these were not responsible for the pain. In 5 SPECT scans there was abnormal activity of the tracer, however in 2 of these patients the uptake was in the renal tract and may have explained the non-skeletal nature of the pain. This would suggest therefore that in those with non-skeletal cause for the back pain there were 12 false positive CTs (specificity 65%) and there were 3 false positive (specificity 92%).

There was a final total of 147 patients in whom a minimum of 6 months clinical follow-up was available. It is interesting to

note that the majority of the patients studied had a good or partial response .

Disease group Patients Imaged (n) Patientswith followup (n) ResponseGood ResponsePartial No Response
Infection 6 6 3 1 2
Degenerative(total) 104 83 52 8 23
OsteophyteFormation* 17 14 8 0 6
Facet joint* 28 20 10 2 8
Disc disease* 30 28 20 4 4
Mixed disease* 29 21 14 2 5
Sacroilitis 12 11 6 1 4
Spondylthesis 2 2 1 0 1
Tumour 7 5 2 2 1
TOTAL BONECAUSES 131 107 64 12 31
Non skeletal 43 40 34 0 6

Table 2 Clinical response in patients imaged with SPECT * denoted sub-group of those with degenerative disease.

It is interesting to note that a normal SPECT and a final diagnosis of non-skeletal cause carries a good prognosis with 85% having a good clinical response. This compares with 60% of those with a positive diagnosis of skeletal disease have a final good response and an additional 11% will have a partial response. Therefore in total 71% even with evidence on imaging of skeletal disease will have some response. The diagnosis did not appear to make much difference except that in those with pure fact joint disease only 50% had a good clinical response.

The results of this study clearly show that SPECT is able to identify abnormalities in the spines of patients in up to 77% of patients which was not available on x-ray and CT alone. This confirms the results of previous studies previously performed [6,8,12]. This is important as backache is an extremely common entity. In many cases the exact cause remains unknown. It is essential to have a correct diagnosis for a rational management of the case. This is because there is no definite radiographic evidence other than the age-related changes. In many other cases although the radiographic changes may be present but they are not sufficient to explain the cause of back pain.

Even computed tomography (CT) may not be significance in diagnosis in majority of cases. Minimal interventrebral disc bulge seen so often to be reported on CT but this may not significant enough to justify it as the cause of the patient's back pain. Spondylolysis and facet joint arthropathy may also be picked up by CT.

In recent years, SPECT with modern gamma cameras has become more reliable and both resolution and contrast have improved. Therefore older studies expressing scepticism about the use of bone SPECT must be considered with caution. SPECT by providing a three-dimensional image overcomes the inherent problem of superimposition of tissues seen on planar imaging and improves the contrast between pathology and normal as well as providing better localisation.
It appears that the SPECT is most useful in instances where there is greatest likelihood of stress on the articular facets. Though planar scintigraphy can pick up nearly the same number of lesions compared to SPECT it is unable to differentiate between anterior and posterior element involvement, which is crucial to the differentiation of various disease patterns. The recommendation therefore is that bone SPECT should be used as a specialised investigation in the diagnosis of the causes of low back pain particularly when the posterior elements are concerned. This has been borne out in the results of this study where facet joint disease or facet joint involvement was seen in SPET more clearly than seen with CT. The ability to localise scintigraphic abnormalities is essential in being able to clarify the final diagnosis.

Bone SPECT may pick up hidden lesions not clearly seen on plain X-Ray as in such as the extent of tuberculosis or the presence of tumour in our group only 1 site of tumour was seen on CT but all four patients were seen on SPECT. Sacroilitis is another problem in which anatomical imaging was insensitive, 7/9 cases being found on SPECT and only 2 on CT.

This study also shows that it is possible to perform high quality SPECT in a number of centres throughout the world and consistently produce new diagnostic information not available from planar x-ray and CT alone. It should therefore become more widely available and be more widely used.

In those patients with no skeletal disease, old anatomical changes can appear on x-ray or CT but the SPECT scan shows that these are metabolically inactive and therefore not the probable cause of pain, this explains the higher specificity

of SPECT compared with CT.

However what is interesting is that the process of imaging may not make a big difference on the final outcome, however those with a negative imaging and final diagnosis of non-skeletal pain, do have a slightly better prognosis than those with skeletal disease (83% good response vs 60% good response and 12% partial response). This would suggest the primary role of imaging may be to rule out the presence of skeletal disease and therefore enable those with non-skeletal causes to be reassured and not need to undergo any further (and often expensive) treatment.

The surprising figures however were in the group with facet joint disease where 50% remain with pain. However within this protocol no facet joint injection was used. It is therefore known that if the joint is not injected only 50% of patients will get better on their own this compares with a report of 83% having improvement at 12 months if the SPECT scan is used to direct treatment.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objectives of the CRP were to determine the sensitivity and specificity of bone SPECT in dealing with patients with unexplained low back pain, to compare the role of bone SPECT with X-Ray CT in such patients and suggest an algorithm (flow chart) of the management strategy in dealing with such patients. The CRP has realized all the three above objectives fully .

This study showed that it is possible to perform high quality SPECT in a number of centres throughout the world and consistently produce new diagnostic information not available from planar x-ray and CT alone. It should therefore become more widely available and be more widely used. The overall objective of the CRP, which was to bring about a rationalized, cost-effective management strategy to deal with patients with low back pain syndrome, has been achieved. The scientific paper based on the results of the CRP has been accepted for publication in one of the leading Nuclear Medicine Journals. This would help in disseminating the results of the CRP and the management strategy. Such an effective management strategy, if applied properly, would prevent high societal costs and economic loss related to work absence, considering that low back pain is one of the commonest causes of absenteeism among the adult work force in all parts of the world.

Although referrals for bone scan in unexplained back pain are a common part of nuclear medicine practice. So far no effort has been made to systematically compile data to determine the sensitivity and specificity or the clinical impact of SPECT bone scintigraphy in the management of such patients. The need to evaluate the clinical efficacy of bone SPECT in low back pain through a large-scale study was identified by Littenberg B et al 1995. Successful completion of the CRP has fulfilled this long-standing need and will have significant impact on the clinical practice in dealing with patients of unexplained back pain.

The awareness that SPECT can improve management of patients with low back pain is recent. Only few studies are available in the published literature. The sensitivity of lesion detection is increased with the use of SPECT. There has also been dearth of correlative and comparative studies between all the available imaging modalities such as CT. MRI and SPECT in patients suffering from low back pain syndrome. Although CT is a valuable diagnostic tool, about 34-40% of symptomatic cases would have abnormal findings when reviewed blindly. If the decision to proceed with surgery is based on CT alone, there is a 30-40% chance that many patients would undergo unnecessary and unsuccessful surgery. It has also been shown that a clinical false positive rate of 40% prevails when using MRI with asymptomatic patients.

From all the above information, it is evident that bone SPECT has been underutilized in the investigation of patients with low back pain and its actual role vis a vis other imaging modalities is not clearly understood.

Hence, this IAEA CRP had focused on the issue of the use of bone SPECT in the management of back pain. The CRP has produced a large volume of information and their analysis has yielded meaningful data which would improve the quality of patient care in the IAEA Member States with regard to chronic unexplained back pain.

Recommended Future Action by Agency

Promote application of this diagnostic procedure through national and regional TC projects in IAEA Member States.

Accomplishments of CRPs

CRP Published Results

1. IAEA Study Group on Back Pain. Bone SPECT in low back pain: A multi-centric coordinated research project of the IAEA. Accepted for publication in the Journal of Nuclear Medicine
2. IAEA Study Group on Back Pain. Investigation of unexplained back pain: Final report of an IAEA Coordinated Research Project. J Nucl Med 2001; 42 (Suppl.) 546

Accomplishments of CRPs

CRP Number and Title: **E13017** **Evaluation of Tc-99m based radiopharmaceuticals in the diagnosis and management of breast cancer patients**

Participating Countries: Chile(C), China(C), Colombia(C), Cuba(C), Germany(A), Greece(C), India(C), (2), Indonesia(C), Korea, Republic Of(C), Pakistan(C), Peru(C), Singapore(C), Thailand(C) (2), Turkey(C), United Kingdom(A), United Republic Of Tanzania(C), Uruguay(C) (2), Viet Nam(C)

Total Cost: **$226,690**

Duration: 1997-07-15--- 2000-07-14

CRP Overall Objectives

The overall objective of this CRP was to examine the suitability of scintimammography to serve as a first line non-invasive test for breast cancer diagnosis. Introduction of a suitable non-invasive test will improve early detection of patients with breast cancer leading the way for enhanced quality and reduced cost of health care while dealing with one of the commonest causes of morbidity and mortality in women during the most productive phase of their lives.

CRP Specific Objectives

1. To determine the sensitivity and specificity of scintimammography using readily available Tc-99m labeled radiopharmaceuticals in the diagnosis of breast cancer
2. To compare the role of scintimammography with x-ray mammography in the detection of cancerous lesion in breast
3. To make recommendation as to which tracer should be used in which circumstances and with what type of expectations while dealing with breast cancer diagnosis

Research Outputs

In total, 238 patients from 10 countries with palpable breast masses (n = 245) were included in this prospective multi-center study. All patients had a scintimammography, an x-ray mammography and a final diagnosis based on histopathology. Prone scintimammography was performed 10 min and 60--90 min post-injection using an isotime acquisition of 10 min. Mammography was assessed by radiologist according to BI-RADS categories for malignancy and breast density. The scintimammograms and mammograms, which were read blind, were compared with the histopathology results obtained during excisional biopsy. The diagnostic value for the detection of breast cancer was calculated on a per- lesion basis. Histopathology revealed 189 cancers and 56 benign lesions. The sensitivity and specificity of scintimammography were 0.83 and 0.77, respectively. The diagnostic value of scintimammography was not dependent on the incidence of breast cancer in country of origin or on imaging timing (i.e. early vs delayed scans). Mammography yielded a sensitivity and specificity of 0.85 and 0.66, respectively, with 27 mammograms classified as BI-RADS category 1, 33 as category 2, five as category 3, 56 as category 4 and 124 as category 5. Thirty-seven lesions were considered to have increased radiological density. There was no significant difference in the diagnostic value of scintimammography among the different BI-RADS categories or between the low and high breast density groups. A sensitivity of 96% was calculated when scintimammography and mammography results were combined, with 75% of all false-negative mammograms classified as true-positive by scintimammography. The CRP concluded that scintimammography can complement mammography in patients with a negative mammogram (BI-RADS categories 1--3). The CRP also proposed a diagnostic protocol whereby scintimammography could be used to assess patients with palpable breast lumps in community-based centers in developing countries with a low incidence of breast cancer.

CRP Outcome (Effectiveness; Impact; Relevance)

The sensitivity, specificity, positive and negative likelihood ratios of Tc-99m Sestamibi Scintimammography were determined and found to be 0.83, 0.77, 3.6 and 0.22 as compared to 0.85, 0.66, 2.5 and 0.22 respectively for x-ray mammography. Tc-99m sestamibi scintimammography provides clinically valuable information in the assessment of patients with palpable breast lesions. The sensitivity of the technique is neither dependent on the epidemiological or ethnic characteristics of the population, nor on the radiological density of breasts. Scintimammography has a complementary role to mammography in patients with a negative mammogram (BI-RADS categories 1--3). The technique has the potential to be used in the assessment of palpable lumps in community-based centres of countries with a low incidence of breast cancer. The CRP also carried out a comparative evaluation of various Tc-99m labeled radiopharmaceuticals like Tc-99m MDP, Tc-99m Sestamibi, Tc-99m

Glucoheptonate and Tc-99m DMSA-V. Tc-99m Sestamibi was found to be the best and most reliable radiopharmaceutical for scintimammography.

Breast cancer is by far the most common malignancy among women throughout the world, with 41% of all new cases being diagnosed in developing countries . In these countries, 323,000 cases were detected in 1990, leading to 140,000 deaths . Furthermore, as the population of the developing world increases and ages, the number of new cases is expected to increase dramatically. Mammography is the only validated imaging technique for breast cancer screening. Several randomized controlled trials have reported a reduction in mortality of about 30% in women over the age of 50 using this procedure. However, the technique is less reliable for detecting lesions in women younger than 50 years in whom dense, glandular breasts are a common radiographic finding, yielding a false-negative rate of 25--45%. The frequent delays in the diagnosis of breast cancer in this group are associated with significantly shorter survival . Furthermore, the positive predictive value of mammography is reported to be less than 40%, resulting in a high number of unnecessary biopsies. Since the encouraging results of Tc-99m sestamibi scintimammography published by Khalkhali et al., several authors have reported on the clinical value of the technique and its possible complementary role to mammography for the evaluation of primary breast cancer . One of the proposed clinical indications for Tc-99m sestamibi breast imaging is a palpable mass not clearly seen or classified as indeterminate or benign by mammography . Therefore, this multi-centre study was set up to: (1) evaluate in developing countries from different geographical regions the diagnostic value of Tc-99m -sestamibi scintimammography in palpable breast lesions; (2) compare the diagnostic accuracy of Tc-99m -sestamibi scanning with that of mammography; and (3) confirm the clinical usefulness and cost-effectiveness of an imaging protocol based on the joint use of mammography and scintimammography. The overall aim of this study was consistent with the objectives of one of the sub-programmme's projects, entitled, Enhancing cost-effectiveness of health care using in vivo nuclear medicine techniques.

The results of this CRP clearly bring out the role of scintimammography in the management of patients with breast cancer. Scintimammography has a very clear cut role in breast cancer management. It is simple, safe, inexpensive, can be carried out in any standard nuclear medicine facility. The results of this study will have significant impact on the management of patients with breast cancer in the developing countries.

The role of Tc-99m based radiopharmaceuticals for cancer diagnosis is being increasingly recognized. These radiopharmaceuticals are easily available. Any nuclear medicine service with a gamma camera and trained personnel can undertake this study. As an international organization charged with the mandate of promoting application of nuclear technology in health care system, the IAEA is very well placed to organize such multicenter studies.

Recommended Future Action by Agency

Promote application of this diagnostic procedure through national and regional TC projects in IAEA Member States.

CRP Published Results

1. Alonso O, Massardo T, Delgado LB, Horvath J, Kabasakal L, Llamas-Olier A, Maunda KK, Morales R, Padhy AK, Shankar UR. Is (99m)Tc-sestamibi scintimammography complementary to conventional mammography for detecting breast cancer in patients with palpable masses? J Nucl Med 2001 Nov;42(11):1614-21
2. Papantoniou V, Sotiropoulou M, Stipsaneli E et al.; Scintimammographic findings of in situ Ductal Carcinoma in a double-phase study with Tc-99m(V) DMSA and Tc-99m MIBI . Value of Tc-99m(V) DMSA. Clinical Nuclear Medicine 2000; 25: 434-439
3. Massardo T, Alonso O, Zhu Q, Gonzalez P, Quiroz M, Lopera J, Pardo M, Nunez M, Touya E, Lin X, Padhy AK; Comparative diagnostic value of Tc-99m pentavalent DMSA and Sistamibi in the assessment of palpable breast lesions. J Nucl Med 2000; 41:27P
4. Alonso O, Massardo T, Zhu H, Quiroz M, Lin X, Pardo M, Nunez M, Gonzalez P, Touya E, Garces N, Andruskevicius P, Padhy AK. Quantitative evaluation of Tc-99m Sestamibi uptake in malignant breast tumours: Double or one phase protocol ? Eur J Nucl Med 2000; 27:112
5. IAEA Study Group on Breast Cancer. Diagnostic value of 99mTc-Methilendiphosphonate and 99mTc-Pentavalent Dimercaptosuccinic Acid compared to 99mTc-Sestamibi in palpable breast lesions (Accepted for publication in the JNM)
6. IAEA Study Group on Breast Cancer. Axillary lymph node assessment in patients with primary breast cancer using Tc999m -sestamibi scanning : Results of a prospective multi-centre trial by the International Atomic Energy Agency

Accomplishments of CRPs

CRP Number and Title: **E24008** **Dose determination with plane-parallel ionization chambers in therapeutic electron and photon beams**

Participating Countries: Argentina(C), Belgium(A), Belgium(C), Cuba(C), Germany(A), Germany(C), Spain(A), Spain(C) Sweden(A), (2) Sweden(C)

Total Cost: **$80,731**

Duration: 1996-07-15--- 2000-11-30

CRP Overall Objectives

An International Code of Practice " The use of plane parallel ionization chambers in high energy electron and photon beams" (TRS 381) was published by IAEA in 1997. To investigate the accuracy of the data and the procedures included in the TRS 381 the CRP "Dose determination with parallel plate ionization chambers in therapeutic electron and photon beams" was designed and implemented.

CRP Specific Objectives

- to compare absorbed dose to water determinations under reference conditions with different detectors
- to compare absorbed dose to water determinations by using different plastic phantom materials
- to compare TRS-381 with currently used dosimetry protocols

Research Outputs

As an output of the CRP the following results were obtained:
- Frike dosimetry is the only way to resolve discepancies between TRS 381 and AAPM TG-39 for measurements in plastic phantoms,
- Plastic measurements should be scaled to water using special procedure,
- Methods for determination of ND,air using TRS 381 were analysed and the recommendations to the hospital users were given,
- Recommended fluence perturbation factors for cylindrical chambers were confirmed.

CRP Outcome (Effectiveness; Impact; Relevance)

The IAEA Code of Practice for plane parallel ionization chambers (TRS 381) meets the highest scientific standards and yields the most accurate results, based on air kerma calibration available today.

The use of TRS 381 will improve practical dosimerty in high-energy electron and photon beams used for the radiotherapy in Member States

The results obtained within the CRP will provide users in Member States with improved dosimetry practice.

The recommendations produced by the participants of the CRP will complete the IAEA Codes of Practice (TRS 277, TRS 381) with analysis, regarding the differences with existing dosimetry protocols and possible impact in patient dosimetry

Recommended Future Action by Agency

The report is published and no future actions are needed.

CRP Published Results

The final report of the CRP was published as IAEA- TECDOC-1173 in 2000:
"Review of data and methods recommended in the international code of practice for dosimetry
IAEA Technical Report Series No.381, The use of Plane Parallel Ionization Chambers in High Energy Electron and Photon Beams." IAEA,October 2000

Accomplishments of CRPs

CRP Number and Title: **E33016 The use of radiotherapy in advanced cancer**

Participating Countries: Austria(C), Brazil(C) (2), Cameroon(C), China(C), India(C), Nigeria(C), Pakistan(C), (2), Peru(C) (2), Poland(C), (3) South Africa(C) 3), Spain(A), Thailand(C), United States Of America(A) (2), United States Of America(C)

Total Cost: **$381,188**

Duration: 1995-12-15--- 2000-08-31

CRP Overall Objectives

To investigate (3) resource-sparing protocols of cancer management by radiotherapy.

CRP Specific Objectives

Three distinct clinical protocols:
i. advanced oesophageal cancer with brachytherapy alone;
ii. disseminated bone metastases with hemibody radiation;
iii. advanced cervical cancer with reduced number of pelvic radiation fractions.

Research Outputs

i. Oesophagus
- ESTRO prize for most innovative protocol 1998.
- Keynote presentation at the American Brachytherapy Society (ABS) Congress 1999.
- Cited on NIH webpage as standard of care for advanced oesophageal cancer.
- Cited in the latest 2001 Edition of de Vita Textbook.

Invited presentations scheduled:
- Am.Soc.Ther.Radiation Oncologists (ASTRO); USA, Oct. 2001 (Dr. R. Sur, South Africa)
- World brachytherapy Congress: , Brazil, Sept. 2001 (Dr. V. Sharma, India)
- Final peer review article is in preparation.
(Contract holders: 10197/IND-Dr. V. Sharma; 8952/SAF - Dr. R. Sur; 8953/SAF -Dr. S. Nag)

ii. Hemibody irradiation
- Peer review publication of final results accepted by Int.J.Rad.Onc.Biol.Phys. (General article)
-Subset of breast patients submitted to ECCO conference (Lisbon)
- Subset of prostate patients: awaiting finalization for 'Urology"
- Positive clinical outcome incorporated into participants regular practice.
(Contract holders: 10196/BRA-Dr. N.Motta; 10279/USA-Dr. O. Salazar; 8940/CMR-Dr. A. Moulle Sone; 8943/SPA-Dr. E. Lanzos; 8953/USA-Dr. S. Nag)

iii. Cervix
- Equivocal clinical outcome: protocol subjected to modification and accepted into participants regular practice.
- Revised protocol submitted for new CRP
- Presentation to ABS Congress 1999.
(Contract holders: 10016/SAF-Dr. E.Retter; 10198/PER-Dr. J. Moscol; 8939/BRA-Dr. N. Motta; 8942/PER-Dr. M. Zaharia; 8946/NIR-Dr. F. Durosinmi-Etti; 8947/POL-Dr. K. Urbanski; 8949/AUS-Dr. B. Pokrajac; 8953/USA-Dr. S. Nag)

CRP Outcome (Effectiveness; Impact; Relevance)

All three protocols have come up with clinically valid results.
New techniques have been introduced and in one case (oesophagus) a significant medical advance made.
Research methodology has been transferred.

Accomplishments of CRPs

This project has demonstrated that cost-effective (nuclear technology) radiation protocols can be developed, which achieve clinical results equal or superior to less cost-conscious protocols.

Widespread presentations have significantly contributed to the image of Agency activities in cancer and radiation oncology. Oesophagus protocol has made a significant contribution to the accepted management of this cancer.

These three protocols mentioned above highlight management decisions in the most common cancers of developing countries. These countries have the least research opportunities and the cancers, seen are generally less investigated in the advanced countries.

Recommended Future Action by Agency

Further protocols focusing on resource-sparing treatment of cancers predominantly seen in developing countries, should be solicited and the best selected for future CRP support (E3-AG-1122, 22-24 August 2001, Vienna).

CRP Published Results

External: Presentations were done. At least 3 peer review articles are in preparation or being adjudicated by appropriate journals.

Other Outputs:
The widespread use of the oesophagus protocol in India will result in a more rapid incorporation of this protocol in routine practice - this is the objective of publication.

Accomplishments of CRPs

CRP Number and Title: **E43006 Comparative international studies of osteoporosis using isotope techniques**

Participating Countries: Brazil(C), Canada(A), Canada(C), Chile(C), China(C) (2), Croatia(C), Germany(C), Hungary(C), Philippines(C), Russian Federation(C), Singapore(C), South Africa(C), Turkey(C), United Kingdom(C) United States Of America(A), United States Of America(C)

Total Cost: **$399,280**

Duration: 1994-10-07--- 2000-04-30

CRP Overall Objectives

To undertake pilot studies of bone density in selected developing country populations for the purposes of: (i) determining the age of peak bone mass (PBM) in each study group, and (ii) quantifying differences in bone density as functions of the age and sex of persons in the study group, as well as quantifying differences between the study groups in different countries.

CRP Specific Objectives

1. To harmonize the techniques of measuring bone mineral density (BMD) within the participating countries and to obtain data that can be compared between the different study groups (countries)
2. To determine whether early adult PBM varies between populations over the age range from 15 to 50 years. In other words, to determine the age of PBM in selected populations from developing countries.
3. To explore environmental and nutritional contributions to any identified differences.

Research Outputs

In summary, the main results that came out of this study are as follows:
i. Significant differences were found in the mean ages of the subjects between the study centers (countries).
ii. There were significant differences between the center's subjects in terms of height and weight with the lowest values observed in the South East Asian Centers.
iii. At all centers, the standardized bone densities for the femoral neck (sfn BMD) showed small or occasionally significant correlations with height and weight.
iv. Equipment brands (Lunar and different Hologic equipment) seemed to have a significant effect on mean bone density at the femoral neck in both sexes. However, following adjustment of Lunar and Hologic equipment, as has been done by the Ankara center, no significant difference between mean bone density measured by both dosimeters were detected.
v. There were highly significant differences in mean bone density between centers. The highest values were observed at the Russian center and the lowest at Shanghai's. Adjusting for age, height and weight had very little impact on these differences.
vi. Femoral neck BMD appears constant between the age of 25-45 years, but this will require confirmation by further statistical analysis.
vii. Low femoral neck BMD is accompanied by low spinal BMD
viii. The impact of family history, environmental factors and nutrition will be explored in subsequent analyses.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP has been very effective in leading to improve measurement techniques for bone density using nuclear and related techniques and to obtain data which are comparable from one study group to another by using appropriate quality assurance programme.

This is the first project of its kind, where harmonized data under extensive analytical quality control has been generated in a group of countries.

The CRP has generated important information concerning designing studies to address the problem of BMD determination in people from different countries. In addition, the extent to which age, sex, body size, ethnicity and geographical region contribute to variations in BMD has been investigated through this CRP. Such information will be used to address the reasons for global differences in fracture rate and to predict future trends in fracture incidence. Research group working on BMD evaluation from

participating countries have set up a harmonized protocol regarding BMD evaluation by nuclear and related technique and collection of nutritional and other data on lifestyle according to WHO questionnaire. Nuclear and analytical techniques and measurements used for bone assessments data has been properly standardized to ensure quality insurance of the scientific outcomes. A meaningful database on bone mass density and trace element composition has been compiled. The effect of age, sex, height, weight and ethnic differences has also been added to this database. Most of the participants of the CRP are now much aware of quality assurance throughout the measurement process. Most of the participants improved in data interpretation. On the basis of the results provided, several participating countries will implement technical measures aimed at improving bone assessment.

The participants now have the experience to carry out appropriate studies regarding bone measurements and are capable of transferring this knowledge to other institutes in their countries. Initial step has been taken in order to establish co-operation with WHO in this kind of research, by collaborating with a WHO-recognized Centre for Osteoporosis.

Recommended Future Action by Agency

The Agency should continue supporting research on bone issues using nuclear and related analytical techniques.

CRP Published Results

Internal:

1. Parr, R.M., Crawley, H., Abdulla, M., Iyengar, G.V., Kumpulainen, J., Human dietary intakes of trace elements: A global literature survey mainly for hte period 1970-1991:I. Data listings and sources of of information, IAEA Vienna (NAHRES-12).

2. Report on the first research co-ordination meeting for the CRP on "Comparative international studies of osteoporosis using isotope techniques", 12-15 December, 1994, Vienna, Austria (NAHRES-31)

3. Iyengar, G.V., Tandon, L., Minor and trace elements in human bones and teeth, IAEA, Vienna, June 1999 (NAHRES-39).

4. Report on the second research co-ordination meeting for the CRP on "Comparative international studies of osteoporosis using isotope techniques", 7-10 October 1996, San Diego, USA (NAHRES-40)

5. Report on the third research co-ordination meeting for the CRP on "Comparative international studies of osteoporosis using isotope techniques", 24-27 August 1998, Sao Paulo, Brazil (NAHRES-51)

6. Report on the fourth research co-ordination meeting for the CRP on "Comparative international studies of osteoporosis using isotope techniques", 28 Feb-3 Mar, 2000, Sheffield, UK (NAHRES 67)

External:

1. Parr, RM., Dey, A., McCloskey, EV., Aras, N., Balogh, A., Borelli, A., Krishnan, S., Lobo, G., Qin, LL., Zhang, Y., Cvijetic, S., Zaichick, V., Lim-Abrahan, M., Bose, K., Wynchank, S., Iyengar, G.V., Contributions of calcium and other dietary components to global variations in bone mineral density in young adults, Accepted for publication in Food and Nutrition Bulletin, 2002.

2. Parr, R.M., Iyengar, G.V., The role of minerals and trace elements in osteoporosis. In: Abdulla, M., Bost, M., Gamon, S., Arnaud, P., Chazot, G., eds. New aspects of trace element research. London: Smith Gordon, 1999: 248-252.

Other Outputs:

1. A Dey, R Parr, N Aras, A Balogh, J Bostock, A Borelli, S Krishnan, G Lobo, Q Lin Lin, Y Zhang, S Cvijectic, V Zaichick, M Lim-Abrahan, K Bose, S Wynchank, EV McCloskey, Young adult bone mineral density across diverse geographical and racial populations, Presented at the ASBMR Symposium, 22-26 September 2000, Toronto, Canada.

Accomplishments of CRPs

CRP Number and Title: **E43008** **Reference Asian Man Project (Phase 2): Ingestion and organ content of trace elements of importance in radiological protection (RCA)**

Participating Countries: Bangladesh(C), China(C), India(C), Indonesia(C), Japan(A), Korea, Republic Of(C), Malaysia(C), Pakistan(C), Philippines(C), Viet Nam(C)

Total Cost: **$226,050**

Duration: 1995-12-15--- 2000-08-24

CRP Overall Objectives

To establish representative "reference" values for Asian populations pertaining to the ingestion and organ content of selected trace elements that are relevant in radiological protection.

This CRP was started in Dec. 1995 and was completed in August 2000. 1st, 2nd and 3rd RCMs were held in Manila, PHI, Taiyuan, CPR and Hanoi, VIE, respectively. This is a follow-up of Phase 1 which contributed to the development of physiological parameters of Reference Asian Man.

CRP Specific Objectives

To collect national representative samples of diets, staple food stuffs and autopsy specimens (in some countries); to develop validated analytical methods for the elements of interest; to analyse the samples and thereby obtain national representative data for the specimen sand elements of interest and to develop a Reference Asian Man to strengthen the regional capability in responding to radiological safety issues.

Research Outputs

Most participants have made good progress towards the objective of measuring trace elements of radiological significance, such as Cs, I, Sr, Th and U (known as priority one elements) as well as nutritionally important elements such as Ca, K, Mg, Na (essential minor elements) and Cu, Fe, Mn, Se and Zn (essential trace elements), and toxic ones such as Cd, Hg and Pb (together known as priority two elements) in total diets and staple foods, and in some countries, also in tissues such as thyroid, bone liver and muscle. Some of the participants have also collected and analysed a number of individual food samples as specified in the protocols for the CRP. One of the most important tasks within the CRP was to "normalise" the data from different study centers so as to allow a meaningful comparison of the analytical measurements between countries and dietary practices. To achieve this objective, the central reference laboratory (CRL) from Japan provided continuous co-ordination and monitoring of the laboratory part of the work for the entire project. In addition, support activities were provided by the CRL to all the countries by assisting with QC problems and analyzing 10% of the real samples for methodological comparison (external QC). A number of certified reference materials were circulated among the participating centers (internal QC) who have reported their results for evaluation along with their results for real samples (tissues, foods and total diets). The CRL's role has been very useful and effective in coordinating the laboratory work from participant countries, and streamlining both internal and external quality control (QC) that was critical for the overall success of the CRP. Importantly, it has contributed to the development of a "Reference Asian Man' combining the result of both Phase 1 and Phase 2 to strengthen the Asian region's ability in the context of radiological safety issues.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP has effectively contributed to strengthen ability in a group of Asian countries for applying sensitive and robust analytical techniques (including sampling and sample preparation methods) for carrying out reliable analytical measurements for Cs, I, Sr, Th and U, which are trace elements of radiological significance.

The most significant outcome of this CRP is the generation of reliable data sets for dietary intake by each of the participating countries (and in tissues by some) that will enhance their ability in resolving national problems of radiological protection, as well as facilitating the development of the characteristics of a Reference Asian Man, the primary goal of this region.

Accomplishments of CRPs

The AQC profile in the Asian participating countries has been strengthened in acquiring analytical ability to carry out reliable measurements for a group of trace elements of great radiological significance, namely Cs, I, Sr, Th and U. As a result, improved reference values have been derived for a number of elements and matrices of interest, and that this work has been described in several publications.
In addition, a Japanese Total Diet Reference Material was developed during the course of this project as a supplemental activity as a collaborative effort that has been certified for a number of elements of nutritional and radiological importance. In addition, China, India and Japan have developed their own national reference man and Korea and Vietnam are also on the way to achieving the same objective to meet their national radiological safety goals.

This CRP has demonstrated that many Asian countries benefit by combining data generated within the region. Such an effort should result in the evaluation of the characteristics of a Reference Asian Man, enhancing the effectiveness of addressing specific national radiological safety problems.

Recommended Future Action by Agency

Although the RAM project provided the needed platform to generate the required data by other countries in the Asian region, some countries were faced with logistical problems (e.g. traditional barriers against autopsy sampling, technical capability and other resources to handle large numbers of samples for analyses, etc.) that prevented them from generating all the data required to characterize a reference man specific to their country. For this reason, the impact of this RCA (while facilitating efforts to develop national models in some cases) is highly significant since many Asian countries benefit by combining data generated within the region. Such an effort should result in the evaluation of the characteristics of a Reference Asian Man, enhancing the effectiveness of addressing specific national radiological safety problems. This is particularly applicable to those countries who cannot generate their own data for autopsy samples for various reasons.

Therefore, this CRP mechanism should continue to be available under the RCA initiatives to address regional problems that include research component.

Moreover, there is a need for covering the remaining parameters such as physiological (e.g. respiratory dynamics, water balance) and metabolic aspects (GI absorption/excretion) to complete the requirements of the Reference Asian Man, and also for investigating the metabolic parameters of 3-Hydrogen, 137-Cesium, 131-Iodine, as these can be studied in accidental or nuclear medicine subjects, and analysis of excreta (urine/faeces) for Sr, Cs, U, (Th) to help complete the development of a metabolic model.

CRP Published Results

Internal:

1. NAHRES-38: Report on the First Research Co-ordination Meeting, Manila, Philippines, 1-4 July 1996.

2. NAHRES-54: Report on the Second Research Co-ordination Meeting, Taiyuan, China, 15-19 June 1998.

External:

1. H Kawamura, RM Par, GV Iyengar, HS Dang, Analysis of food and tissue samples for IAEA's Reference Asian Man Project (Phase 2): Quality assurance aspects, Journal of Radioanalytical and Nuclear Chemistry, 249 (2001): 5-10.

2. H Kawamura, RM Parr, HS Dang, W Tian, RM Barnes, GV Iyengar, Analytical quality assurance procedures developed for the IAEA's Reference Asian Man Project (Phase 2), Journal of Radioanalytical and Nuclear Chemistry, Vol. 245, No.1 (2000) 123-126.

Other Outputs:

1. GV Iyengar, H Kawamura, RM Parr, R Griffith, The IAEA/RCA Co-ordinated Research Programme on Reference Asian Man, Invited lecture presented at the 8th International Conference on "Low Level Measurements of Actinides and Long-Lived Radionuclides in Biological and Environmental Samples, Oarai, Ibaraki, Japan, 16-20 October 2000.

2. GV Iyengar, H Kawamura, RM Parr, FK Miah, J Wang, HS Dang, H Djojosubroto, SY Cho, P Akhter, ES Natera, MS Nguyen, Dietary intake of essential minor and trace elements from Asian Diets, Short oral communication at the

International Congress of Nutrition (August 2002, Vienna, Austria) during the IAEA Symposium on Tracer Techniques for Evaluating Nutritional Interventions.

3. H Kawamura, GV Iyengar, RM Parr, FK Miah, J Wang, HS Dang, H Djojosubroto, SY Cho, P Akhter, ES Natera, MS Nguyen, Ingestion of cesium, iodine, strontium, thorium and uranium from diets, Poster: International Congress of Nutrition (August 2002, Vienna, Austria).

4. J Kucera, GV Iyengar, Z Randa, RM Parr, Determination of iodine in Asian diets by epithermal and radiochemical neutron activation analysis, Paper to be presented at the 7th International Conference on Nuclear Analytical Methods in the Life Sciences (NAMLS-7), Antalya, Turkey, 16-21 June 2002.

5. CS Sastri, GV Iyengar, S Demirel-Guelen, M Heck, P Hoffmann, HM Ortner, G Blondiaux, Y Tessier, T Sauvage, H Petri, Determination of boron, fluorine and some medium Z elements in diet samples, Paper to be presented at the 7th International Conference on Nuclear Analytical Methods in the Life Sciences (NAMLS-7), Antalya, Turkey, 16-21 June 2002.

Accomplishments of CRPs

CRP Number and Title: **F11005 Specialized software utilities for gamma-ray spectrometry**

Participating Countries: Belarus(C), Bulgaria(C), Cuba(C), Denmark(A), Finland(A), Germany(A), Hungary(C), India(C), Latvia(C) (2), Slovenia(C)

Total Cost: **$134,546**

Duration: 1996-12-15--- 2000-09-30

CRP Overall Objectives

To assess nuclear spectrometry techniques, to develop improved software, to enhance Member States' utilization of nuclear spectrometry.

CRP Specific Objectives

To identify and evaluate some specialized utilities in the field of gamma-ray spectrometry . To prepare a set of new gamma-ray spectrometry algorithms, routines, complete programs, documentation, development reports and specialized nuclear data libraries.

Research Outputs

In the CRP several basic applications of nuclear data handling were assayed that also dealt with the development of new PC computer codes for various spectrometric purposes, such as for calculating true coincidence corrections and efficiency calculations for extended (large) sources or nuclide activities estimation from low intensity scintillation gamma-ray spectra. The CRP addressed problems of the analysis of naturally occurring radioactive soil material gamma ray spectra, questions of Quality Assurance and Quality Control (QA/QC) in Gamma-Ray Spectrometry, and verification of the expert system SHAMAN for the analysis of air filter spectra. Validation procedures for reporting uncertainties in peak areas have been completed. Deviations from Poisson statistics were studied for spectra measured under Compton suppression. A procedure to correct lack of statistical control in Radiochemical Neutron Activation Analysis has been given for selected cases where propagation of uncertainties caused problems.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP developed eight computer programs covering various aspects of analysis of gamma ray spectra, assessed and evaluated three issues related to gamma-ray spectrometry. Within its limited resources the CRP effectively covered a good number of identified and suggested issues.

The CRP was a part of the project D2.02. Nuclear Spectrometry. It contributed to the objective of this Agency project by: (i) assessing and evaluating several selected problems related to gamma-ray spectrometry and, (ii) by development of a number of specialized utilities for gamma-spectrometry spectra.

This CRP was recommended by the AGM on Nuclear Spectroscopy Software held in December 1994. In the resulting TECDOC a number of specific problems was identified, important and not included seriously at that time in available software packages for analysis of gamma spectrometry software, including commercial ones (before starting the CRP an extensive intercomparison of available gamma ray analysis software packages was performed in 1995). Commercial companies are starting to include these issues in their software packages (for example, efficiency determination for extended sources with associated true coincidence corrections were included in the Canberra and Ortec software just very recently - at the begining of 2002).

This CRP has been important part of a wider process of assessing nuclear spectrometry techniques and development of improved nuclear spectrometry software.

Accomplishments of CRPs

Recommended Future Action by Agency

To monitor the status of software, libraries, algorithms and documents produced under the CRP and their utilization by wider scientific community.
To support further development of selected software packages if they are used by wider scientific community.
To monitor development of nuclear spectrometry software by wider scientific community (including commercial ones).

CRP Published Results

1. Specialized software utilities for gamma ray spectrometry, Final report of a co-ordinated research project, IAEA TECDOC-1275, March 2002.

2. V. S. Kondrashov, S. J. Rothenberg and I. Petersone, Librarian driven analysis with graphic user interface for nuclides quantification by gamma spectra, Nucl. Instr. and Meth. A 470, (2001) 583-589.

3. V. S. Kondrashov, S. J. Rothenberg and I. Petersone, Database driven analysis for nuclide quantification by gamma spectra, Radiation Physics and Chemistry, 61 (2001) 475-476.

4. V. A. Muravsky, S. A. Tolstov and A. L. Kholmetskii, Comparison of the least squares and the maximum likelihood estimators for gamma-spectrometry, Nucl. Instr. and Meth. B145 (1998) 573-577.

5. V. A. Muravsky, S. A. Tolstov, Algorithms of nuclides activities estimation by the maximum likelihood method, 5th Int. Conference on Applications of Semiconductor Detectors in Nuclear Physics, Riga, Latvia, May 18-22 1998, p.102.

6. V. A. Muravsky, S. A. Tolstov, Statistical criterion for choosing optimal model of ionizing radiation spectra, 5th Int. Conference on Applications of Semiconductor Detectors in Nuclear Physics, Riga, Latvia, May 18-22 1998, p.103.

7. K. Heydorn, Radiochemical neutron activation analysis, in Encyclopedia of Analytical Chemistry, ed. by R.A. Meyers, Wiley (2000), 12762-12782.

8. P.A. Aarnio, J.J. Ala-Heikkila, T.T. Hakulinen, M.T. Nikkinen, The nuclide identification system SHAMAN in the verification of the CTBT, MARC V Conference, Kailua-Kona, Havaii, April 9-14 2000.

Accomplishments of CRPs

CRP Number and Title: **F11006 Bulk hydrogen analysis, using neutrons**

Participating Countries: Australia(A), Canada(A), Cuba(C), Hungary(C) (2), India(C), Japan(A), New Zealand(A), Nigeria(C), Poland(C), Romania(C), Russian Federation(C), South Africa(C), Thailand(C), Turkey(C), United States Of America(A)

Total Cost: **$271,266**

Duration: 1997-05-01--- 2000-10-31

CRP Overall Objectives

To increase the utilisation of accelerators (neutron generators) and research reactors in IAEA Member States. Four research fields were identified were techniques utilising neutrons produced by neutron generators and research reactors could be further developed. 1) Fast n/gamma transmission. 2) Digital neutron imaging. 3) Hydrogen detection by epithermal neutrons. 4) Microscopic behaviour of Hydrogen in bulk materials.

CRP Specific Objectives

To utilse the abovementioned techniques for developing instruments for use by the industry and/or research laboratories.

Research Outputs

39 publications in international journals and 7 PhD theses.

CRP Outcome (Effectiveness; Impact; Relevance)

The participating groups have produced neutron based instruments for different applications such as: measurement of fat content in meat, ripeness of fruits, elemental composition of coal and quality of nuclear fuel elements.

The CRP has increased the utilisation of research reactors and accelerators in IAEA Member states and enhanced the knowledge of neutron based techniques among students and scientists in developing Member States.

The original impetus and focus of the Co-operative Research Programme is "Bulk Hydrogen Analysis, Using neutrons". As the programme progressed, there was a clear consensus of the participants that the programme had met the goals and in addition, that techniques and applications were evolved such that broader application and extensions of the methods could be envisioned. As a results of discussion at the final meeting, three overlapping application areas which are of major importance to society have emerged: Energy and Quality Control, Nuclear Energy Materials and Security and non-proliferation. We emphasise here the importance of the co-ordinated nature of this research, which enabled us to extend the methodologies to other significant problems. To cite one example, new approaches to the problem of humanitarian demining have also emerged from the original goals of the Co-operative Research Programme.

As can be seen from the number of publications (46 including 7 PhD theses) the scientific relevance of the CRP is high.

Recommended Future Action by Agency

To promote the use of neutron based methods for applications in areas such as 1) Energy and quality control, 2) Nuclear energy materials 3) Security and non-proliferation.

CRP Published Results

[1] IAEA/PS/RCM97-1, Bulk Hydrogen Analysis using Neutrons, Report of the Second Research Coordination Meeting, IAEA HQ, Vienna, November 1998.

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[8] M. Balasko, E. Svab, P. Meier, A. Vida, I. Cserhati, D. Ozsvari, Dynamic neutron-, and gamma radiography for optimization of absorption-type refrigerators, In: Budapest Neutron Centre PROGRESS REPORT (Eds. J. Gado et al), 1998 p l15
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[11] Zs. Szalay, M. Balasko, Investigation of microporosity in die-cast AlSil2(Cu) alloys by neutron- and X-ray radiography, as complementary radiographic methods, Proc. International Conference Nuclear Energy in Central Europe'99, September 1999, Portoroz, Slovenia, pp. 703-708
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Accomplishments of CRPs

CRP Number and Title: **F12010 Analysis of research reactor transients**

Participating Countries: Algeria(C) (2), Argentina(C) (2), Bangladesh(C), Brazil(A), Czech Republic(C), Germany(A), Ghana(C), Hungary(C), India(C), Korea, Republic Of(A), Pakistan(C), Thailand(C)

Total Cost: **$230,948**

Duration: 1995-12-15--- 2000-12-19

CRP Overall Objectives

To enhance research reactor utilization in member states for many practical applications, such as isotope production, radiography, neutron beam research and material composition analysis.

CRP Specific Objectives

To develop models for transient analyses for specific cases and validate the calculations by simulating the conditions. The aim was to characterize safety related processes and parameters, update existing models and codes, co-ordinate and optimize model development and standardize the method of transient analysis.

Research Outputs

During the course of the CRP each member country presented its results of the transient calculation for their operating reactor.
Following transient processes were considered for the analysis:
(1) Reactivity transients due to the movement of absorber rods
(2) Heat removal transients due to loss of heat sink
(3) Loss of flow transients
(4) Reactivity insertion due to heavy water ingress into the reactor core.
For the simulation of transients, kinetic and thermohydraulic models are applied. The models used for the pool type reactors where heat removal is by natural convection are quite different from the ones used for those with close primary circuit and forced flow. Following reactor types were chosen for simulation:
(1) MTR with plate type fuel
(2) MTR with tubular type fuel element
(3) VVR
(4) MNSR
(5) LVR-15 with IRT-M fuel assemblies.
During transients the safety behavior of a research reactor is influenced by the design characteristic, operating conditions and event sequence. The most important parameters in transient analysis are (a) power distribution and power peaking factor (b) the temperature coefficients of reactivity and (c) the power density in the hot spot. The kinetic parameters such as neutron generation time, delayed neutron fraction and time constants are coupled with heat transfer characteristic thermal material properties of the coolant and fuel to allow for the interaction of thermohydraulic and neutronic processes.
The power peaking factors were evaluated for 3 MW TRIGA-II reactor in Bangladesh, TRR1/M1 reactor in Thailand and modified APSARA reactor in India. For TRIGA-II hot rod power peaking, radial and axial peaking factors were calculated for different core configurations using the lattice code WIMS and diffusion code CITATION. Peaking and hot spots were found to be strongly dependent on the core configuration. The gradient peaking factor was found to be sensitive to the type of reflector interface with the fuel. For TRR/M1 with mixed core, the peaking limits the maximum reactivity insertion. For modified APSARA reactor power distribution and peaking factors are calculated using FINFOR-SQR code.
Some kinetic parameters and temperature coefficients were calculated for the 30 kW Ghana MNSR and 3 MW TRIGA reactors using WIMS and CITATION codes. For MNSR the transient analysis was found to be very sensitive to the temperature coefficients. For TRIGA reactor the temperature coefficients obtained from CITATION significantly improved the predicted power and temperatures from those obtained from WIMS code. The agreement between calculations and experimental results was better using CITATION.
Some of the examples used for validation of the models are as follows:

Accomplishments of CRPs

The clean core reactivity of 4 mK was released by withdrawing the central control rod out of the core of the MNSR reactor at Ghana. The predicted values of the power and outlet temperature using the TEMFED code compared well with the data. The model could be satisfactorily validated for reactivity transients.
The SORTRAN code was verified at the FRJ-2 reactor in Germany where the loss of heat sink was simulated by closing the valve of the secondary circuit. The temperature variation was measured at 30 points on the primary circuit. The agreement between the calculations and the observations gives the confidence in the code developed.
Experiments for validating the codes LVR15-D, KIKO3D, FLOW CIRNAT were also carried out.
The results of the CRP will be published as a TECDOC.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objectives of the CRP are fulfilled. The validation process has shown the success as well as the limitation of the codes developed.

The analysis of transients in research reactors is important in safe operation of the reactor which influences the availability of the reactor for utilization.

The CRP has contributed in understanding the transient behavior of research reactors. The new codes developed have added to the tools to analyze transients and to understand the processes. The agreement between calculations and the experiment carried out during the process gave a confidence in the codes developed. The outcome of the CRP will increase the capability of the reactor operating staff in the application of systematic calculations.

The knowledge of the effect of the transients on the safety parameters is essential in the safe operation of a research reactor. The work done during this CRP has relevance in that field. The process should be extended to the conditions not considered during the present CRP.

Recommended Future Action by Agency

CRP Published Results

Received comments from the publication committee on the TECDOC.

Accomplishments of CRPs

CRP Number and Title: **F22024** **The use of radiation processing to prepare biomaterials for applications in medicine**

Participating Countries: Argentina(C), China(C), Egypt(C), Hungary(C), Indonesia(C), Japan(A), Kazakhstan(C), Netherlands(A), Poland(C), Turkey(C), United States Of America(A)

Total Cost: **$174,221**

Duration: 1995-12-15--- 2000-01-10

CRP Overall Objectives

To coordinate the research and development programmes carried out in different countries on the radiation synthesis and modification of biomaterials to ensure that different programmes complement each other and duplications are eliminated. To assist in transfer of technology through cooperation in scientific research and help to establish cooperation between radiation research scientists and end-users in medicine.

CRP Specific Objectives

The CRP had the specific objectives of:
- radiation formation of hydrogels for biomedical applications;
- synthesis of environmentally responsive biomaterials;
- modification of surfaces to achieve biocompatibility;
- synthesis of functional microspheres and membranes for medical applications.

Research Outputs

Hydrogels with controlled physical and chemical properties; pore size, swelling-shrinking kinetics, water content, etc., have been synthesized from synthetic and natural polymers. The synthesis conditions; absorbed dose, dose rate, monomer types, their concentrations, irradiation temperature affecting the final properties of gels were optimized, the mechanisms of polymerization and crosslinking were explained. Homogeneous hydrogels with acid monomers were prepared for topical delivery of antifungal drugs. Biodegradable and affinity-based hydrogels were also prepared. The potential applications of these systems as biosensors, affinity separation supports, enzyme immobilization, cell encapsulation and drug delivery devices have been evaluated. Microgels injectable as intervertebral discs were developed. Mono disperse functional microspheres were prepared for use in separation, protein purification and diagnostics. Radiation was used to modify polymer surfaces for preparation of non-fouling, protein-repellant surfaces for potential use as implants, sensors and diagnostic aids. Grafting of suitable monomers by gamma and electron beam initiated polymerization was employed for biocompatable surface preparation, hemodialysis membranes and implant applications.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP was very effective in reaching specific objectives set at its inception. Almost all of the scientific and technical objectives are met and at the end of the CRP the research gaps identified were mostly closed.

A very efficient cooperation was established among the participants of the CRP. Close contacts and partnerships established during the course of the CRP have brought synergy to their research programmes.

A better understanding and control of the effects of ionizing radiation on the polymerization, crosslinking and grafting reactions taking place during the synthesis and modification of polymers for biomedical applications. A significant portion of the scientific information generated during the course of the CRP was transferred to industry and hydrogels were started to be produced commercially as wound dressings in Poland and Japan. Several participating institutes submitted TC proposals to the IAEA with the anticipation of establishing technical lines in their countries for the radiation production of hydrogels (KAZ, INS, TUR).

The scope of the CRP, using radiation for the preparation of biomaterials was quite relevant and its inception timely. It helped to fill the most of the research gaps in this field, generating enough data and information for the commercialization

of the process in the Member States.

Recommended Future Action by Agency

The IAEA should pursue the subject of radiation synthesis and modification of biomaterials and developments in this field by organizing Consultants Meetings. A new CRP can be considered to elaborate the incorporation of molecular recognition into hydrogel structures.

CRP Published Results

External:
The CRP was very productive in generating new research results, almost all of which were published as scientific papers in highly acclaimed technical scientific journals. 67 Scientific papers were published by the participants of the CRP in referred journals during the course of the CRP.

Accomplishments of CRPs

CRP Number and Title: **F22027** **Improvement of physical properties of radiation vulcanized natural rubber latex (RVNRL) - (RCA)**

Participating Countries: Bangladesh(C), China(C), India(C), Indonesia(C), Japan(A), Philippines(C), Sri Lanka(C), Thailand(C), Viet Nam(C)

Total Cost: **$104,080**

Duration: 1997-12-15--- 2000-12-14

CRP Overall Objectives

To create awareness in the use of radiation for the vulcanization of rubber latex by transferring the experience and information gathered around the CRP and to augment the replacement of sulphur vulcanization by radiation vulcanization in Natural Rubber Latex Industry.

CRP Specific Objectives

To improve the mechanical properties of Radiation Vulcanized Natural Rubber Latex (RVNRL). In order to achieve this goal the research studies were planned to be concentrated on:
i) Raw materials; green strength, gel content and maturation of NRL.
ii) Fillers; inorganic, organic and reactive fillers.
iii) Natural antioxidants to improve aging properties.

Research Outputs

Studies conducted by several research groups revealed the importance of maturation of latex, before irradiation for getting RVNRL of good physical properties. The relation between gel content and green strength of latex stored for different maturity periods has also been established. It has been found that RVNRL of good physical properties can be produced by using:
- High ammonia preserved Latex of minimum maturity period of three weeks;
- The volatile fatty acid of the Latex must be below 0.03;
- The magnesium content of Latex must be below 15ppm;

Water soluble polymers, carboxy methyl cellulose, fumed silica and hydroxy apatite were found to be useful additives to improve physical properties of RVNRL. The Indian research group has standardized the procedures of RVNRL having physical properties that meet the requirements of examination glove manufacturers. Due to inferior aging properties of NRL, it cannot be used as such in manufacture of products like surgical gloves, condoms, nipples and catheters. Some additives acting as antioxidants are needed to improve the aging properties to a reasonable level. The extracts from certain indigenous materials, some amino acids, keratin were found to show antioxidant action comparable to commercially available synthetic antioxidants.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objective of improving mechanical properties of RVNRL has been reached and radiation vulcanizates with tensile strength and tear resistance properties better than or at least equal to sulphur vulcanizates have been obtained. As a result of systematic research activities carried out under this CRP, RVNRL films with minimum residual protein were synthesized which helped reducing the problems associated with protein allergy.

The overall objective of establishing a network among research groups working on radiation vulcanization of natural rubber latex in the Member States of South East Asia and the Pacific and creation of awareness in the use of radiation for the vulcanization of natural rubber latex, both have been well achieved. The practical results have been transferred to relevant industries and India, Thailand and Malaysia have started manufacturing products made of RVNRL.

The CRP helped with the establishment of procedures related to collecting, handling, storing natural rubber latex for radiation crosslinking as well as optimizing radiation vulcanization conditions to produce RVNRL of consistent and good

physical properties. The facility established at Rubber Research Institute of India is capable of producing two tonnes of RVNRL of 50% DRC (Dry Rubber Content) every day. Thailand and Malaysia are the two other countries benefited from transferring this technology to their rubber industries. Dipped products made of RVNRL are being commercially produced in these two countries.

For rubber growing countries the crosslinking of natural rubber latex to make a variety of products such as surgical gloves and condoms is most important. Most of the countries in the south East Asia and the Pacific region are producers of natural rubber latex. It was therefore highly relevant to initiate this CRP as a regional CRP to bring together the expertise and experience gained in the region to solve problems associated with conventional sulfur vulcanization.

Recommended Future Action by Agency

To provide technical and financial support to the Member States of the region planning to establish facilities to vulcanize natural rubber latex by radiation.

CRP Published Results

External:
Papers published by the participants in the Proceedings of the Regional and International Meetings organized on relevant subjects.

Other Outputs:
N/A

Accomplishments of CRPs

CRP Number and Title: **F22028 Radiation processing of indigenous natural polymers (RCA)**

Participating Countries: Bangladesh(C), China(C) (2), India(C), Indonesia(C), Japan(A), Korea, Republic Of(C), Malaysia(C), Philippines(C), Thailand(C), Viet Nam(C)

Total Cost: **$132,515**

Duration: 1997-12-15--- 2000-12-07

CRP Overall Objectives

To better use and evaluate indigenous natural polymers through their modification by radiation processing.

CRP Specific Objectives

The main objective of this project was to identify the most promising indigenous natural polymers with the anticipation of converting them into more useful industrial products by radiation processing. Depending on the specific application purpose, bulk and/or surface properties of these natural polymers (cellulose, polysaccharides, and protein based) would be modified by irradiation. For the synthesis of hydrogels to be used in health-care and pharmaceutical industries, biocompatibility of products would be the key research issue, while for other applications (agriculture, environment, textile, etc.) degradation under environmental conditions would be considered.

Research Outputs

The Member States of the region of South East Asia and the Pacific are very rich in natural polymers such as chitin/chitosan, carrageenans, alginates, cassava and sago starch etc. During the short duration of the CRP a majority of participants have developed new products from these natural resources and some of them have reached a stage of technology transfer/scale-up.
Plant growth promoting effect of low molecular weight chitosan and alginates have been shown and optimum conditions of degrading these natural polymers by irradiation have been established. Field tests for irradiated alginates as plant promoters for various plants such as tomato, tea, carrot, cabbage and grapes have been completed. The results show that 20-30% enhancement in yields can be achieved by using radiation processed polysaccharides. Radiation processed chitosan and alginates have been established as wholesome specific plant growth promoters with no side effects. Irradiated polysaccharides have been found to possess excellent properties for use as fruit coatings to increase their shelf life and reduce spoilage. Preliminary tests showed that after 10 days while 90% of mangoes coated with unirradiated chitosan were spoiled, only 25% spoilage was observed in the mangoes coated with irradiated chitosan. Conditions for achieving crosslinking of carboxymethyl cellulose and starch have been standardized to form their hydrogels. These hydrogels have been shown to possess biodegradability and can be used to prepare environment friendly packaging films.
In health-care applications, formulation of radiation processed carrageenan-PVP hydrogels for use as wound/burn dressing has been successfully developed and clinical studies have been carried out. Water soluble chitosan and carboxymethyl chitosan containing PVA hydrogels have been successfully produced and tested on mice samples showing excellent healing characteristics.

CRP Outcome (Effectiveness; Impact; Relevance)

The Member States of RCA region are especially rich in respect to wide variety of indigenous natural polymers. Although there are a variety of those polymers of hydrocarbon (rubber, gutta percha), cellulosic (cotton, jute, pulp, wood), polysaccharide (starch, agar, carrageenans, alginates, mannans, chitin, pectin hyaluronan) and protein (leather, collagen, silk, wool, keratin, casein) origin, those with greater industrial importance and suitability for radiation processing were selected. These are identified to be chitin/chitosan, alginates, carrageenans and sago starch. Irradiation techniques and methodologies have been developed to use ionizing radiation as a tool to degrade, crosslink or sensitize the polysaccharides mentioned above for health-care and agricultural applications.

The CRP was effective in reaching its overall objective of introducing the concept of radiation processing of indigenous natural polymers to upgrade them to more useful and valuable end-products. The momentum gained through the

Accomplishments of CRPs

CRP has already been reflected in the establishment of new regional projects on the same subject, "Upgrading Natural Polymers and Environment by Radiation Processing", RAS/8/090.

The major impact of this CRP is to show to the countries of the RCA Region the unique properties of ionizing radiation in inducing controlled changes on the properties of locally available natural polymers. The abundant natural resources such as chitin, carrageenans and alginates can be converted into value-added products to be used in health-care, pharmaceutics and agricultural and agro-chemical applications. In addition to economic benefits that will arise from using locally available cheap materials, development of biodegradable products brings additional advantages from environmental point of view.

Chitin is the second most abundant natural polymer after cellulose, carrageenans and alginates are exclusively produced in the RCA region. The upgrading of those indigenous materials by using ionizing radiation is a subject of great relevance and importance for the region.

Recommended Future Action by Agency

Although the CRP was terminated prematurely seeing the importance of the subject, the Member States of the region continued to include this subject under the regional TC project. The IAEA should continue to support the activities in the region though organization of training courses, workshops, seminars and expert missions.

CRP Published Results

External:
Papers published by the participants in the proceedings of the Regional and International Meetings organized on relevant subjects.

Other outputs:
N/A

Accomplishments of CRPs

CRP Number and Title: **F22030** **Radiotracer technology for engineering unit operation studies and unit processes optimization**

Participating Countries: Argentina(C), Chile(C), China(C), Cuba(C), Czech Republic(C), Denmark(A), Finland(A), France(A), India(C), Pakistan(C), Poland(A), Poland(C)

Total Cost: **$191,995**

Duration: 1997-12-15--- 2000-12-14

CRP Overall Objectives

To further develop and refine radiotracer methodology through validation of hardware and software for experimental design, data treatment and interpretation with special reference to complex industrial processes from petroleum industry, mineral ore processing and waste water purification plants.

CRP Specific Objectives

The specific objective was to validate demonstrative and didactic tracer experiments in terms of experimental design and execution, data processing and interpretation, modelling and problem solving. In particular, the objective was establishment of the residence time distribution (RTD) method as the main universal tool for tracer investigations of industrial processes.

Research Outputs

The major outputs are:
- Development and validation of software for residence time distribution (RTD) data modeling;
- Preparation and validation of protocols for investigation of major industrial processes, including fluidized catalyst cracking (FCC) unit, sugar crystallizer, trickle bed reactor, cement rotary kiln, flotation cells, grinding mills, incinerators, waste water treatment unit and interwell communications in oil fields.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP was very effective in reaching specific objectives. Active network cooperation was established for validating two RTD software and obtaining the proper model of major processing units with common interest.

The CRP has shown the importance of radiotracer technology in:
- Troubleshooting. Radiotracers are very competitive in diagnosing specific causes of inefficiency in plant or process operation.
- Process Optimisation. The radiotracers provide information that facilitates improvements either in the throughput or the product quality.

The case studies clearly demonstrated the beneficial value of industrial radiotracer applications. An average benefit to cost ratio of 20:1 - 50:1 was found reasonably representative. There are few short-term investments, which will give a return of this magnitude. The cost effectiveness of radiotracer applications should be widely promulgated to encourage industrialists to take full advantage of the technology.

The CRP have shown considerable progress in the area of radiotracer methodology, such as:
- Improvement and increased adaptability of existing software for data modeling
- Validation of the methodology and software for RTD modeling for various cases including chemical reaction units, incinerators and waste water treatment unit
- Highlighting the potential of tracers for oil field reservoir studies
- Underlining the importance of tracers for multi phase flow measurements.
- Preparation of technical documents to assist transfer of technology from developed to developing countries and accreditation of radiotracer techniques in developing countries.
- Generating better quality TC projects.

Accomplishments of CRPs

CRP participant groups guided case studies to validate the radiotracer methodology in investigation of major industrial processes. The results achieved pointed out that tracer technology offers an invaluable tool for research and industrial maintenance work.
This was the first CRP in the field of radiotracer methodology, which has consolidated this technology opening the way for larger and better use of radiotracer techniques in routine service to end users.

Recommended Future Action by Agency

The prospect of tracer technology depends on the degree to which benefits for the end-user can be properly demonstrated and disseminated.
An increasing demand for extraction of still more complex, precise and reliable information from tracer studies, however leads to current improvements in the technology. This in turn depends on a current progress in research and development within the tracer area.
The estabishement of a new CRP devoted to the relations between RTD and the emerging technology of computer fluid dynamics (CFD) complies very well with the outcome of this CRP.
Further research and development projects can be undertaken for:
- oil field reservoir studies
- multiphase flow measurements
- software and models for complex processes

CRP Published Results

TECDOC-1262
Radiotracer technology as applied to industry,
IAEA, December 2001
Technical Report Series (draft completed):
Radiotracer Applications in Industrial Processing, Oil & Geothermal Reservoirs

Accomplishments of CRPs

CRP Number and Title: **F23013 Irradiation treatment of water, waste-water and sludges**

Participating Countries: Argentina(C), Austria(A) (2), Brazil(C), Canada(A), China(C), Egypt(C), Ghana(C) (2), Guatemala(C), India(C), Indonesia(C), Italy(A), Korea, Republic Of(A), Russian Federation(A), United States Of America(A) (2)

Total Cost: **$206,874**

Duration: 1995-12-01--- 2000-05-12

CRP Overall Objectives

To integrate the effects of ionizing radiation on refractory organic pollutants and of its effects on pathogenic mircroorganisms and protozoan parasites in the treatment of water, wastewater and sewage sludge, so as to reduce or eliminate chemical as well as micro-biological contaminants.

CRP Specific Objectives

- To establish optimal combination treatments utilizing radiation and other agents (oxygen, ozone, heat, etc.) for decontamination of polluted water from ground and surface reservoirs, and of wastewater and sewage sludge.
- To establish the effects of dose rate on the decontamination efficiency.
- To establish technological and economic parameters.

Research Outputs

The research and development works carried out in participating institutes were concentrated in three main subjects namely, groundwater remediation, decontamination of industrial and municipal wastewater, and sewage sludge hygienization. Scientific, technological economic parameters were established for the purification of groundwater contaminated with perchloroethylene, trichloroethylene and some genotoxic compounds. The combination of ozone and electron beam irradiation was shown to mineralize trace amounts of chloroethylenes in groundwater in a single process without formation of any by-products to be disposed of. Fundamental studies were conducted on radiation degradation of several halogenated methanes, thioanissole and methyl tert-ethylbutyl ether, a common contaminant arising from gasoline tank leaks to ground water in the USA. Experimental and pilot scale studies for degrading organic pollutants in municipal and industrial wastewaters as well as decolorizing of textile industry wastewater revealed technical and economic information for further scale-up. Radiation induced destruction of deeply colored reactive and direct dyes currently used by the textile industries was examined and synergistic effect of addition of reagents (hydrogen peroxide, ferrous ammonium sulphate) on the decontamination of actual wastewater was established. Technical and economic data were collected for the hygienization of raw sewage sludge by irradiation.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP was very successful in reaching specific objectives. Technological and economic parameters were established for ground water remediation in Austria and for treatment of textile dyeing factory waste water in Korea. The effects of dose rate, additives and combination of irradiation with conventional techniques were understood and operational parameters were optimized.

The research efforts of different groups were coordinated to have an integral approach on using ionizing radiation to destroy both organic chemical pollutants as well as pathogenic micro-organisms and protozoan parasites in the treatment of water, wastewater and sewage sludge.

The CRP has generated new information that will enhance the application of radiation for decontamination of water, wastewater and sludge. Its impact has already been obvious from the increasing number of TC project proposals submitted to the IAEA on the same subject. Even during the course of the CRP pilot facilities were erected in Russia, Korea and India to irradiate municipal wastewater, industrial wastewater and sewage sludge respectively. The results of the CRP also demonstrate that there is a significant progress in understanding radiation degradation of refractory pollutants.

Accomplishments of CRPs

There is an increasing interest in using ionizing radiation for environmental clean-up and this is in great part due to very promising results recently achieved by researches worldwide and participants of this CRP involving radiation technology.

Recommended Future Action by Agency

IAEA should organize Consultants Meetings for the preparation of guidelines for feasibility analysis of radiation treatment of wastewaters. A CRP to consider the detoxification of wastewater with emphasis on water handling and process control will complement this one.

CRP Published Results

TECDOC (#1225) is published.

External:
The research results of CRP participants were presented in various international symposia and they are published in prestigious journals such as: Environmental Sciences and Technology; Radiation Physics and Chemistry; Journal of Advanced Oxidation Technologies; Water Science and Technology.
A book titled "Environmental Applications of Ionizing Radiation" is published by John-Wiley & Sons, New York, 1998 edited by W. Cooper, one of the participants of the CRP.

Other Outputs:
Construction and operation of pilot irradiation facilities in Russia, Korea and India. Involvement of big international companies (Samsung, Siemens) in radiation treatment of water.

Accomplishments of CRPs

CRP Number and Title: **F23015 Nuclear analytical techniques in archaeological investigations**

Participating Countries: Argentina(C), Brazil(C) (2), Chile(C), Cuba(C), Mexico(C), Peru(C), United States Of America(A)

Total Cost: **$175,135**

Duration: 1996-12-01--- 2000-09-30

CRP Overall Objectives

a) To promote interdisciplinary research between analytical chemists using nuclear analytical techniques and archaeologists in the Latin American region

CRP Specific Objectives

b) To establish competent working groups that could act as a multiplier for similar applications in their respective countries.
c) To strengthen of the role of nuclear analytical techniques in the region by demonstration of it's reliability in the field of archaeological investigations

Research Outputs

ARGENTINA: Investigated provenience studies of ceramic raw material and artefacts using INAA: pre-Hispanic social relationships between Puna and mesothermal valleys (Chaschuil, Catamarca, Argentina).
BRAZIL: Analysed 149 ceramic fragments from three different archaeological sites using INAA. Statistical analysis of the results confirmed that the ceramics of each site were produced from a distinctly different raw material source.
BRAZIL: Investigated socio-economic relationships of different tribal societies in Central Amazon, Minas Gerais, and found surprisingly large compositional differences pointing to distinctly different raw material sources and low developed commercial exchange.
CHILE: Focused on the pre-Hispanic ceramic production and distribution system of the Majpo region in Central Chile by determining the concentration of elements in pottery of the Aconcagua Culture (900-1450 AD). The differences in chemical composition were interpreted as indicators of resource and ceramic production location as well as imprint of the geological background.
CUBA: Studied aborigine ceramic production and distribution in the Central Region of Cuba and more recent majolica pottery from colonial Havana using INAA. Principle component analysis of results could resolve several distinct groups being closely linked to the archaeological context where the samples have been produced.
MEXICO: Ceramic samples from the Templo Major excavation in Mexico City were investigated by INAA and PIXE to find elemental differences between different styles and glazes. It was found that Spanish style ceramics were copied in Mexico during the early Colonial period.
PERU: Analysed 250 ceramic samples from the Cuzco Middle Horizon styles to determine their source of production and patterns of distribution. Identification of various resources for similar pottery styles suggest that production occurred in different parts of the region and was exchanged between centres for local distribution.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP demonstrated the synergistic effects emerging from a close collaboration between analytical chemistry and archaeology. Both sides profited through mutual recognition of their specific needs and requirements displayed within well defined archaeological problems. The collaborative effort opened new perspective for future scientific investigations using the available nuclear analytical facilities for problem solving approaches. In the Latin American region archaeology is one of the major focuses for research and NATs have been strongly linked to this important field through this CRP.

The introduction of statistical treatment of large data sets (cluster analysis, analysis of variance, principle component analysis) helped a lot to enhance the understanding of inter-element correlation and for the interpretation of analytical results from archaeological artefacts. Data reduction and graphical representation of results is important in the process of publishing in international journals.

Accomplishments of CRPs

The validated application of nuclear analytical techniques in the Latin American Region to provenience studies of pottery has strongly enhanced the analysts' confidence in their own capabilities and has put NATs further in the focus of potential users of analytical data for problem solving in non-nuclear research fields.

Recommended Future Action by Agency

The demonstrated potential of the nuclear analytical laboratories in the region should be used for similar applications, e.g. in a guided approach to solve a common problem in the region such as "Socio-economic relations within the Inca Empire" or "Provenience and trade of Obsidian artefacts in South America". This proposition would not only consolidate the interdisciplinarity of the research groups but foster collaboration between countries and laboratories in the region as well. Future CRPs should involve a geologist and a statistician at the same time as specialized knowledge of the geological situation of clay beds and excavation sites cannot be provided by either chemists or archaeologists. Statistical data treatment of large data sets needs expert knowledge as well, and should be included in the project design.

CRP Published Results

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Accomplishments of CRPs

CRP Number and Title: **F23017** **Validation of protocols for corrosion and deposit evaluation in pipes by radiography**

Participating Countries: Algeria(C), China(C), Colombia(C), Costa Rica(C), France(A), India(A), Korea, Republic Of(A), Malaysia(A), Sri Lanka(C), Syrian Arab Republic(C), Tunisia(C), Turkey(C)

Total Cost: **$157,363**

Duration: 1997-06-01--- 2000-11-30

CRP Overall Objectives

To promote evaluation of corrosion and deposit in pipes by using advance NDT technologies.

CRP Specific Objectives

To validate protocols for corrosion and deposits determination in small diameter pipes by radiography (CORDEP)".

Research Outputs

Each participating laboratory produced 3 test specimens of straight and bent pipes containing natural as well as simulated corrosion defects. Typical diameters of these pipes were up to 168 mm (6 inches). Some of the test specimens or their parts were naked while others were insulated. The details of defects in all the specimens were properly recorded. The designs and simulated defects had been agreed between the participating laboratories during the first Co-ordination Meeting.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP addressed the specific needs of end users in terms of developing reliable and appropriate NDT measurement protocols which should refer to general requirements of international standards, with full implementation of recognised quality assurance methodologies.

X- ray and Gamma ray radiography using films were chosen. Rapid, instant and real time- radioscopy testing (e.g. for preliminary searching corrosion attack) were not included in to the programme due to limited availability of these specialised equipment and materials in the participating laboratories. In principle, " Tangential Radiography" only was the main subject of the CRP.

The complementary NDT methods like Ultrasonic, as well as destructive tests and metallography when required, were applied for verification of the RT results (validation).

Future industrial application based on the following:
Tangential radiography and density measurement techniques are complementary methods. However for insulated pipes only tangential radiography is recommended, since the density measurement method requires complicated simulations
Low speed films are recommended especially for density measurement techniques.
The accuracy of the technique is also depending on measurement conditions. Using the film density as high as possible is advisable for better definition measurement

Lack of reliable and well verified testing protocols discourages NDT laboratories from proposing services to potential customer/end-users in the industry; this in spite of well identified needs in such areas as determination of deposits and under-deposit corrosion in sea water desalination pipelines, corrosion./erosion attack in bends, corrosion in insulated as well as non-insulated hot pipes in oil refineries, fossil plants, etc.
The Co-ordinated Research programme (CRP) aimed at developing radiographic protocols and instructions for identification and measurement of the corrosion attack and deposits in pipes (across insulation) in industrial installations during operation (on - line and in maintenance).
The CRP addressed the needs of end users in terms of developing reliable and appropriate NDT measurement protocols

which should refer to general requirements of international standards, with full implementation of recognized quality assurance methodologies.
X- ray and Gamma ray radiography using films was chosen by the participants. Rapid, instant and real time- radioscopy testing (e.g. for preliminary searching corrosion attack) were not included in to the programme due to limited availability of these specialised equipment and materials in the participating laboratories. In principle, " Tangential Radiography" only was the main subject of the CRP.

The complementary NDT methods like Ultrasonic, as well as destructive tests and metallography when required, were applied for verification of the RT results (validation).

Recommended Future Action by Agency

CRP Published Results

Accomplishments of CRPs

CRP Number and Title: **F33008** **Isotope-based assessment of groundwater renewal and related anthropogenic effects in water scarce areas**

Participating Countries: Austria(A), Bolivia(C), China(C), Egypt(C), India(C), Jordan(C), Mexico(C), Nigeria(C), Saudi Arabia(C), Senegal(C), South Africa(C), Syrian Arab Republic(C), Tunisia(C), United Kingdom(A), United Kingdom(C)

Total Cost: **$313,330**

Duration: 1995-12-01--- 2000-05-10

CRP Overall Objectives

To use isotope techniques to investigate moisture and pollutant transport hydrodynamics in the unsaturated zone of selected major aquifers in the arid and semi-arid regions.

CRP Specific Objectives

To conduct applied field research to provide characteristic isotope concentration profiles along the depth of the unsaturated zone
To provide recharge rate estimates to selected aquifers
To delineate relevant dynamic parameters for pollutant transport in the unsaturated zone

Research Outputs

Profiles on water infiltration or water losses from groundwater
Pollutant profiles and information on transport dynamics
Geochemical parameters characterizing pollution sources
Information on self-purification capacity of the unsaturated zone

CRP Outcome (Effectiveness; Impact; Relevance)

A total of 44 sites from 14 countries were involved in the project on which detailed information on physiography, lithology, rainfall, unsaturated zone moisture content and a variety of chemical and isotopic determinants have been compiled.

Interpretation of the data gathered has provided reliable recharge estimates in many areas speciallly in predominantly sandy sediments, producing values ranging from fractions of a millimeter to tens of millimeters. These results are of paramount importance for the management of the concerned aquifers.

The CRP was initiated on the basis that the isotopic compostion and chemical constituents of water infiltrating through the soil zone (unstaurated zone) into groundwater can be employed to determine the water infiltration rate and characterize the behavior of contaminants. The impressive body of data which had been accumulated by this project forms the most extensive survey of the unsaturated zone in arid and semi-arid regions. A major feature which emerged from the project is that isotopic data highlight the complexities of the processes involved and which had previously only imperfeclty been appreciated and in certain instances been glossed over.

The CRP has provided a positive input on the complex physical nature of the movement of water and conservative solutes through the unsaturated zone (e.g., Cl-). Applied field research carried out at selected sites, has focused on the use of tritium, and the stable isotopes of water (D and 180) for the study of transport in different regions of the world and under different climatic conditions, particularly in arid and semi-arid regions. A follow-up research work to elucidate quantitatively the processes related to pollutant transport in the unsaturated zone is being carried out under the new CRP on "Isotopes in the study of pollutant behavior in the unsaturated zone" (F3.30.13).

Recommended Future Action by Agency

Compilation of all data available from the sites into a database using the ISOHIS database developed by the Agency. Each

participant institue is expected to provide detailed data from their sites using the "Data Entry Module of the ISOHIS".

CRP Published Results

Internal: Research Progress reports and final reports and IAEA-TECDOC 1246

External: Publication by Edmunds and Verhagen
"Isotope based assessment of groundwater renewal - An international study of the unsaturated zone". In Proceedings XXX IAH Congress on Groundwater- Past achievements and future challenges, Sililo and al., eds; Cap Town, 2000 pp487- 492

Other Outputs :

Accomplishments of CRPs

CRP Number and Title: **F33009 The use of isotope techniques in investigating acidic fluids in geothermal exploitation**

Participating Countries: China(C) (2),Iceland(A), Indonesia(C), Italy(A), Japan(A), Mexico(C), Philippines(C), Russian Federation(C), Turkey(C), United States Of America(A)

Total Cost: **$125,985**

Duration: 1997-07-15--- 2000-07-14

CRP Overall Objectives

To develop methodologies in the application of S-34 and O-18 in SO4, together with O-18 and H-2 in H2O for field investigations in geothermal energy development.

CRP Specific Objectives

To investigate the origin of acidic geothermal fluids in both ow and high enthalpy systems by the use of isotope techniques integrated with traditional hydrogeochemical tools.
To understand the genesis of acidity in geothermal systems by the use of S-34 and -18 in SO4.
To apply the SO4-H2O geothermometer pair for estimating temperatures and detecting various reservoir processes due to exploitation.

Research Outputs

The CRP has generated new and important information and understanding on the following aspects: 1) the major types of acidity found in geothermal fields worldwide; 2) the origin of chemical components that constitue the major species in terms of acidity in geothermal fluids, such as S and Cl; 3) charateristics of acidic fluids in terms of chemical composition as well as pH; 4) isotopic signatures indicating most probable origin of the geothermal water especially regarding the magmatic inputs to the geothermal fluids. 5) improved understanding of 10 geothermal fields where acidic fluid is enountered, and 10 other geothermal fields regarding the origin of geothermal fluids as well as its salinity.
The CRP has promoted the application of the following isotope tecniques in geothermal investigations: 1) O-18, H-2 and Tritium in water; 2) S-34 in H2S, S and in sulphuric minerals found in geothermal fields, S-34 and O-18 in aqueous SO4; 3) the SO4-H2O pair used for geothermometry.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP has been effective in reaching the specific objectives as outlined above.

Based on the findings in the CRP, geothermal acidity is closely related to mamatic inputs, therfore, geothermal resources managers will be able to locate future production wells further from volcanic centers near the geothermal field, thus reducing the chances of encountering acidic fluids.
Based on the demonstrated effectiveness in applying isotope techniques to investigate and improve the understanding of the origin of acidic fluids, geothemal managers will be able to initiate investigations on the origin and occurrence of acidity in a specific case so mitigation measurements can be taken, e.g. Miravalles geothermal field in Costa Rica, where acidic fluid is encounterd and mitigation measures have been impleemnted successfully, enlighted by the improved understanding of the occurrence.

The outputs of the CRP are expected to be useful for the other countries and regions where geothermal acidity is also encountered in geothermal development and where Agency technical assistance is being provided through the technical coperation programme.

Recommended Future Action by Agency

CRP Published Results

Agency TECODC including 10 papers.

Accomplishments of CRPs

CRP Number and Title: **F33010** **The application of isotope techniques to the assessment of aquifer systems in major urban areas**

Participating Countries: Australia(A), China(C), Germany(A), India(C), New Zealand(A), Pakistan(C), Senegal(C), South Africa(C) Thailand(C), United Kingdom(A)

Total Cost: **$105,396**

Duration: 1997-12-15--- 2000-12-14

CRP Overall Objectives

To assess the usefulness of geochemical and isotopic techniques to address the development and management issues pertaining to urban aquifers

CRP Specific Objectives

1) To assess the artificial recharge in and around the urban areas
2) To identify the processes of groundwater contamination
3) To assess the impact of groundwater exploitation for urban areas on the hydrologic cycle

Research Outputs

Design of isotope methodologies for improved groundwater resources assessment and management in urban areas.
Test and identification of isotope tracers that are particularly well-suited to specific studies in the urban environment.

CRP Outcome (Effectiveness; Impact; Relevance)

Applied field research has been carried out by participating institutes in 8 countries to provide geochemical and isotopic data on sites under a variety of hydrogeological settings in urban environments.
The CRP has identified areas where application of isotopic tracers can make a difference in urban hydrogeology and issues that need further research and development work.
A major output of the CRP is the testing and identification of isotopic tracers that are particularly well-suited to specific studies in the urban environment. The methodolgies developed will be transferred to member States through several ongoing TC project dealing with water resources assessment and management in major cities.
The CRP has provided the opportunity to test and identify a set of isotopic tracers that are particularly well-suited to specific studies in the urban environment. A variety of isotopes and chemical tracers were used to characterize the hydrological processes and changes for aquifer systems in ten major urban centers in Africa, Asia-Pacific and Europe. It has set the basis for a new CRP (F3.30.10) aimed at investigating the transport of solutes and gasses through the unsaturated zone into the water table region of phreatic aquifers. A complex process which determines the quality of groundwater.

Recommended Future Action by Agency

Consideration of future possible CRP in this field. This should gather complementary international expertise to concentrate on one or two specific developing large cities.

CRP Published Results

TECDOC

Accomplishments of CRPs

CRP Number and Title: **F43008 Atomic and plasma-wall interaction data for fusion reactor divertor modelling**

Participating Countries: Austria(A), Belgium(A), Canada(A), Denmark(A), France(A) (2) , Germany(A), Italy(A), Japan(A) (2) Russian Federation(C) (2), Spain(A), The Frmr.yug.rep. Of Macedonia(C), United States Of America(A) (2), Uzbekistan(C)

Total Cost: **$109,425**

Duration: 1995-07-01--- 2000-06-30

CRP Overall Objectives

To enhance the atomic and molecular databases for nuclear fusion energy research.

CRP Specific Objectives

The specific objective of this CRP was to establish as complete as possible database for atomic, molecular and particle-surface interaction processes taking place in a low-temperature, high neutral density divertor plasma for improvement of the predictive power of divertor modeling computer codes.

Research Outputs

This CRP has brought researchers together from 15 different institutions for collaboration on this topic. Extremely valuable collaborations were arranged and a wealth of research was carried out. This research resulted in significant new data on a variety of topics. This CRP covered a number of different physical processes including atomic collisions, particle surface interactions and data collection and assessment. For the five year duration of this CRP over 150 scientific articles were published by the CRP participants in refereed scientific journals on the subjects covered by the scope of the CRP. In addition extensive data generated by the research institutions were gathered in the electronic databases of the Atomic and Molecular (A+M) Data Unit. These data were subjected to careful evaluation and made accessible through the web-based interface to the electronic databases.

Significant contributions were made to the fields of electron impact processes of vibrationally excited hydrogen isotope molecules, electron-atom and ion collision processes, heavy particle collision processes particle surface interaction physics and the construction of a collisional-radiative model for hydrogen. These data were either absent or inadequate in previous models of the divertor region.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objective to establish as complete as possible database for atomic, molecular and particle-surface interaction processes taking place in a low-temperature, high neutral density divertor plasma for improvement of the predictive power of divertor modeling computer codes was fully achieved.

The results of this CRP have made a significant contribution to the enhancement of the atomic and molecular databases for nuclear fusion energy research.

The work of this CRP had a significant impact on the field of modeling of the divertor region. There are now large databases available for modeling where data were missing completely or were inadequate in accuracy and in completeness. This is of high importance in the modeling of the divertor region, the design of which is crucial to the performance of a nuclear fusion reactor.

The organization of this CRP was motivated by the needs of modelers of the divertor region of fusion reactors. The results of the CRP therefore had a direct relevance on these models. This is especially important with the ITER design activities and this CRP was of high relevance to that design.

Accomplishments of CRPs

Recommended Future Action by Agency

As more accurate experimental facilities become available and computational power increases, it will become possible to further advance the quantity and accuracy of the data relevant to the divertor region. As the ITER design is further refined, it will be important to identify additional areas for which current data is inadequate. Therefore, additional reviews of the status of data needs in this area should be undertaken using Advisory Group or other expert meetings.

CRP Published Results

Internal:
A significant portion of the CRP results have been published in Summary Reports and stored in the A+M Data Unit Aladdin electronic database. Significant use has been made of the online access to these data through the Internet.
Furthermore, some of the results of the work of this CRP were included in the IAEA journal series "Atomic and Plasma Material Interaction Data for Fusion" in Volume 7A.

External:
For the five year duration of this CRP over 150 scientific articles were published by the CRP participants in refereed scientific journals on the subjects covered by the scope of the CRP.

Other Outputs:
Extensive data generated by the research institutions were gathered in the electronic databases of the Atomic and Molecular (A+M) Data Unit.

Accomplishments of CRPs

CRP Number and Title: **F43009 Charge-exchange cross section data for fusion plasma studies**

Participating Countries: Austria(A), France(A), Germany(A), Hungary(C), Japan(A) (3), Netherlands(A), Norway(A), Russian Federation(C), Spain(A), The Frmr.Yug.Rep.Of Macedonia(C), United Kingdom(A), United States Of America (A) (2)

Total Cost: **$71,789**

Duration: 1997-12-15--- 2000-12-14

CRP Overall Objectives

To enhance the atomic and molecular databases for nuclear fusion energy research.

CRP Specific Objectives

The specific objective of this CRP was to generate, by both theory and experiment, new charge exchange cross section data for the collision systems of prime fusion interest in the energy ranges where such data are fragmentary or in insufficient accuracy.

Research Outputs

This CRP has brought researchers together from 14 different institutions for collaboration on this topic. Especially important was the interaction between theorist and experimentalists. Several areas of disagreement between theory and experimental cross sections have been resolved. Cross section measurements were carried out at lower energy than previously possible. Significant new data on hydrocarbons were generated. New computational techniques for cross section calculations have been developed and made available to the scientific community. The role of metastable states in measurements has been carefully examined using a new experimental technique. For the three year duration of this CRP over 100 scientific articles were published by the CRP participants in refereed scientific journals on the subjects covered by the scope of the CRP. In addition extensive data generated by the research institutions were gathered in the electronic databases of the Atomic and Molecular (A+M) Data Unit. These data were subjected to careful evaluation and made accessible through the web-based interface to the electronic databases.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objective to generate new charge exchange cross section data was fully achieved.

The results of this CRP have made a significant contribution to the enhancement of the atomic and molecular databases for nuclear fusion energy research.

The work of this CRP had a significant impact on the field of charge exchange cross sections. These cross sections are needed in areas of nuclear fusion reactors where atoms and ions of differing charge states interact, as in neutral beam injection. These cross sections are vital to the careful modeling of such interactions in the plasma. Since many of these cross sections were not known for low energy regions, this CRP has had a significant impact on the ability to model the behavior of neutral beam injection as well as interactions of the plasma with cool particles sputtered from the plasma facing components.

This CRP was strongly recommended by the A+M Subcommittee of the International Fusion Research Council. These cross sections are vital to the diagnostics of the plasma processes occurring in nuclear fusion reactors. It is especially important to generate the cross section data for state selective processes from which characteristic radiation can be used for deriving the physical conditions of the plasma.

Recommended Future Action by Agency

This CRP addressed the most pressing needs for charge exchange cross sections for the processes identified at the

beginning of the CRP. However, other physics issues cause changes in the materials proposed for construction of new fusion reactors such as ITER. Therefore it will be necessary to continue to monitor the need for high quality cross section data for any new materials proposed for next generation machines.

CRP Published Results

A significant portion of the CRP results have been published in Summary Reports and stored in the A+M Data Unit Aladdin electronic database. Significant use has been made of the online access to these data through the Internet. Furthermore, the results of the CRP will be published in the IAEA journal series "Atomic and Plasma-Material Interaction Data for Fusion" as Volume 10.

Accomplishments of CRPs

CRP Number and Title: **F43010** **Plasma-material interaction data for mixed plasma facing materials in fusion reactors**

Participating Countries: Canada(A), Germany(A) (2), Japan(A), Russian Federation(A), Russian Federation(C) (2), Spain(A), United States Of America(A) (2) Uzbekistan(C)

Total Cost: **$56,599**

Duration: 1997-12-15--- 2000-12-14

CRP Overall Objectives

To enhance the atomic and molecular databases for nuclear fusion energy research.

CRP Specific Objectives

The specific objective of this CRP was to generate new data on the erosion properties and hydrogen characteristics of mixed plasma facing fusion reactor materials, collect and critically assess all the existing information of this type and produce a recommended database for use in fusion energy research and other plasma applications.

Research Outputs

This CRP has brought researchers together from 12 different institutions for collaboration on this topic. At the start of this CRP the participants generated a chart of processes for which data were needed but not available for various plasma interactions with mixed plasma facing materials. Such mixed material areas occur in nuclear fusion reactors due to erosion of plasma facing components with subsequent redeposit of materials in other regions of the machine.
In current designs the important materials include Be, B, C, O, SI, Ti, V and W. Processes for plasma interaction include chemical erosion, sputtering and hydrogen retention. At the final RCM the participants reviewed the chart and updated it with the result that nearly all the areas exhibited significant improvement of available data. A large number of experiments were undertaken to study the plasma interactions with a large number of mixtures of the important materials. For the three year duration of this CRP over 100 scientific articles were published by the CRP participants in refereed scientific journals on the subjects covered by the scope of the CRP. In addition extensive data generated by the research institutions were gathered in the electronic databases of the Atomic and Molecular (A+M) Data Unit. These data were subjected to careful evaluation and made accessible through the web-based interface to the electronic databases.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objective to generate new data on the erosion properties and hydrogen characteristics of mixed plasma facing fusion reactor materials, collect and critically assess all the existing information of this type and produce a recommended database for use in fusion energy research and other plasma applications was fully achieved.

The results of this CRP have made a significant contribution to the enhancement of the atomic and molecular databases for nuclear fusion energy research.

The work of this CRP had a significant impact on the study of plasma interaction with mixed material. It was shown conclusively that the interaction of plasma with a mixture of elements is significantly different from the interaction of the plasma with either pure element. The interaction of plasma with the mixture is not a simple combination of the interactions with pure materials and there are often unexpected behaviors even with relatively simple materials. This discovery has a large impact on the design of next generation fusion reactors such as ITER. In particular, the retention of hydrogen isotopes will be an extremely important issue in such machines and is one process that is strongly affected by the mixing of the materials.

This CRP was strongly recommended by the A+M Subcommittee of the IFRC and was strongly supported by the ITER community. The results have been received very favorably by the fusion community and represent an important advance in the understanding of the interaction of fusion plasmas with the plasma facing materials.

Accomplishments of CRPs

Recommended Future Action by Agency

The information generated by this CRP strongly suggests that plasma interactions with mixed materials will play a strong role in any fusion reactor design. Of particular importance will be the retention and release of tritium from such materials . It is very important to continue research in this area and to reassess such data periodically with expert meetings. Such meetings will be able to recommend times when further data are needed.

CRP Published Results

Internal:
A significant portion of the CRP results have been published in Summary Reports and stored in the A+M Data Unit Aladdin electronic database. Significant use has been made of the online access to these data through the Internet.
Furthermore, some of the results of the work of this CRP were included in the IAEA journal series "Atomic and Plasma Material Interaction Data for Fusion" in Volumes 7A and 7B.

External:
Over the course of this CRP over 100 scientific articles were published by the CRP participants in refereed scientific journals on the subjects covered by the scope of the CRP.

Other:
Data generated by the research institutions were gathered in the electronic databases of the Atomic and Molecular (A+M) Data Unit.

Accomplishments of CRPs

CRP Number and Title: **G42001 Development of computer-based troubleshooting tools and instruments**

Participating Countries: Austria(A), Brazil(C), Cuba(C), Ghana(C), Hungary(C) (2), Mongolia(C), Poland(C), Romania(C), Turkey(C), Viet Nam(C)

Total Cost: **$184,222**

Duration: 1996-06-15--- 2000-12-31

CRP Overall Objectives

To upgrade maintenance skills of instrument service technicians/engineers through developing expertise in design/fabrication of selected computer-based instruments and/or troubleshooting tools.
To contribute to the improvement of the capabilities of laboratories in developing Member States to maintain, repair and service nuclear instruments.

CRP Specific Objectives

To establish/upgrade expertise and facilities for computer-based troubleshooting tools.
To assist developing Member States in research activities related to maintenance of modern nuclear electronics applied in the following important areas: human health, agriculture, industry, nuclear spectroscopy and environmental pollution monitoring.
To increase motivation of service engineers in the developing Member States.
To develop simple end-user oriented tools for troubleshooting of modern nuclear instruments.

Research Outputs

Major research outputs of the CRP include (i) development of a versatile tool, called MOICE, for troubleshooting of selected microprocessor-based systems (working prototype and documentation available), (ii) development of a universal data acquisition I/O hardware system for PC-based test and troubleshooting purposes, (iii) development of a PC-based analog signal generator to simulate the radiation detector signals and arbitrary test waveforms for troubleshooting and testing of nuclear instruments, (iv) development of an expert system (called NITEX) for troubleshooting of selected preamplifiers, amplifiers and single channel analyzer (a programme on CD ROM and user manual available), (v) development of a random pulse generator for troubleshooting and maintenance of nuclear instruments (prototype available).

For most of the developments, technical documentation including description of the modules, circuit diagrams, user manuals etc. were submitted to the Agency.

CRP Outcome (Effectiveness; Impact; Relevance)

The outputs of the CRP contributed to establishing/upgrading expertise and facilities for computer-based troubleshooting tools. Through the research activities carried out under the CRP, the participating laboratories were assisted in the development of PC-based troubleshooting tools inevitable in maintenance of modern nuclear instruments. Some results obtained under the CRP are functional prototypes which can be upgraded or expanded in the future. Participation in the development work under the CRP increased also the motivation of the electronics engineers working in the field of nuclear instrumentation.

The participants became acquainted with the development of computer-based troubleshooting tools by using dedicated and advanced software and modern design technologies. The acquired knowledge and practical skills can easily be applied in the advanced training, interfacing of PC with instruments, further development of advanced nuclear instruments etc.

The completed CRP was useful for the Agency and the target groups in the Member States. Since the emphasis in the future activities under the relevant IAEA projects is on a development of ICT-based training/learning materials and relevant training kits, the research efforts have to be focused on the different areas. However, the experience and expertise acquired under the CRP are extremely useful for the new development as well.

Accomplishments of CRPs

Recommended Future Action by Agency

No action is recommended.

CRP Published Results

Internal:

External:

Other Outputs:
Final reports were submitted to the Agency by the RC/RA holders and are available upon request from the Instrumentation Unit, NAAL.
Summary of the results obtained under the CRP will be available on the IAEA Laboratory web site and distributed via the Agency instrumentation mailing list.

Accomplishments of CRPs

CRP Number and Title: **I21010 Nuclear power plant outage coding system**

Participating Countries: Czech Republic(C), France(A), Germany(A), Hungary(A), India(C), Pakistan(C), Slovakia(C)

Total Cost: **$39,056**

Duration: 1998-11-01--- 2000-12-31

CRP Overall Objectives

To develop a general, internationally applicable system for codification of nuclear power plant outages providing worldwide nuclear utilities with a standardised tool for reporting outage information.

CRP Specific Objectives

a) Analyse existing outage coding systems and evaluate their suitability and completeness for international use
b) Propose a new outage coding or modifications in the existing systems to be used for exchange of information in operating experience of NPP internationally.

Research Outputs

Improvements of the existing outage coding system used at the IAEA were proposed and a modified outage coding system, which would be applicable to any nuclear power plant operator, was developed. Participant countries have also implemented the proposed system in their NPPs for validation and checking. Fully support from other countries were also got for implementation in the IAEA PRIS.

CRP Outcome (Effectiveness; Impact; Relevance)

The specific objectives were achieved. Various international organisations have already developed coding systems associated with events at nuclear power plants. From the existing systems, CRP participants selected three systems: WANO, IAEA-IRS and IAEA-PRIS and evaluated their suitability for the purpose of the intended outage coding system. Based on this review, the PRIS outage coding system was chosen as a basis for the project, as the code structure better corresponded with the outage description requirements. Improvements to the system were proposed and a modified outage coding system, which would be applicable to any nuclear power plant operator, was developed.

With the implementation of the results in the IAEA PRIS, the project achieved the Overall Objective, which was to provide a standardised tool for reporting outage information. This CRP was also innovative to implement collaborative work environment among the participants which has provided additional means of communications at national level and among counterparts, and has reduced the number of meetings needed to accomplished the goals.

The CRP's goal was to provide nuclear utilities with a standardised tool for reporting the outage information, so that it could be stored in a database enabling subsequent analysis of outage type and cause.
This provides an opportunity to learn from nuclear industry operating experience which is beneficial to all.

Experience feedback is probably the most important factor that can help achieve uniform excellence in operating performance of nuclear power plants in the competitive electrical power industry. To maintain smooth plant operation and avoid unnecessary production losses in operation, all incidents affecting power production should be tracked and analysed, causes of the significant events should be identified and appropriate corrective actions taken. The output of the CRP has directly contributed to achieve these goals. Nevertheless, in just part of the operating experience information. The Agency should continue looking at the issue as relevant to nuclear power plant operations.

Recommended Future Action by Agency

Strategies for analysis of operating experience of nuclear power plants could be analysed by the IAEA covering other areas such as: to assess methodologies used for operating experience including communication, human resources, information technology, etc. It could include good practices on processing operating experience deriving from outages.

Accomplishments of CRPs

CRP Published Results

The CRP proposed a Technical Document on International Outage Coding System. The final draft is with the Scientific-secretary and should be submmitted to the Publications Committee by the end of June.
The results are also being implemented in the IAEA PRIS as recommended by the PRIS liaison-officers in a meeting held in 2001.

Accomplishments of CRPs

CRP Number and Title: **I31009** **Design and evaluation of heat utilization systems for the high temperature engineering test reactor (HTTR)**

Participating Countries: China(C), Germany(A), Indonesia(C), Israel(A), Japan(A), Russian Federation(A), United States Of America(A)

Total Cost: **$98,923**

Duration: 1993-12-02--- 2000-12-06

CRP Overall Objectives

To foster, within the framework of the IWG-GCR, the exchange of scientific and technical information and international co-operation on generic research and development programmes for gas cooled reactor systems with the potential to provide electricity and/or high temperature process heat.

CRP Specific Objectives

1. To select candidate heat utilization systems which are of international interest for potential demonstration at the HTTR
2. To prepare design concepts and identify development needs for these systems
3. To evaluate these systems regarding safety and status of technology

Research Outputs

The CRP addressed the following heat utilization systems:

Steam reforming of methane for the production of hydrogen and methanol
Carbon dioxide reforming of methane for the production of hydrogen and methanol
Thermochemical water splitting for hydrogen production
Combined coal liquefaction and steam generation
High temperature electrolysis of steam for hydrogen production
In addition to the heat utilization systems indicated above, testing of advanced intermediate heat exchangers and coupling the HTTR to the gas turbine for the generation of electricity were examined.
Production of hydrogen as an energy carrier for the future through the reforming of methane was selected as the highest priority heat utilization application. Reforming of methane with steam and carbon dioxide were investigated and, although the primary goal was the production of hydrogen, both processes have the proven ability to result in the final production of methanol (or syngas) through subsequent synthesis. This chemical conversion of natural gas with the HTGR offers the added benefits of a substantial decrease in CO2 emissions and an increase in calorific value of the products with a corresponding greater fuel versatility. The next priority application was determined to be the generation of electricity through the use of the gas turbine. Application of the Brayton Cycle utilizing high temperature helium from a modular HTGR was chosen for development because of its projected benefits as an economic and efficient means for the production of electricity. Evaluation of the remaining high temperature heat utilization applications chosen for investigation by the CSIs resulted in the prioritized selection of hydrogen production through thermochemical water splitting, followed by the conversion of coal into higher quality fuels.
These processes are to be demonstrated by out-of-pile tests prior to coupling to the HTTR.

CRP Outcome (Effectiveness; Impact; Relevance)

The objectives of the CRP were effectively addressed by the cooperative contributions of the participating Member States. The results are documented in detail in the TECDOC on the CRP.

High temperature process heat is explicitly identified in the statement of the overall objective. The scope of this CRP is entirely focused on high temperature process heat applications, thus the CRP was very effective in contributing towards the overall objective

High Temperature Gas Cooled Reactors are generally recognized as having the highest temperature capability for supply of

process heat with nuclear energy. This CRP addressed possible process heat applications to be further developed through the test program conducted by the HTTR test reactor in Japan. The results of the CRP will be a primary input to the planning and conduct of the test program to be conducted, possibly as an international program, by the HTTR project in Japan.

High temperature process heat applications for nuclear energy, particularly the thermochemical production of hydrogen are of considerable current interest in many countries. This CRP directly addresses this interest as well as the overall objective as identified earlier.

Recommended Future Action by Agency

A follow-on CRP on heat utilization systems testing, to be conducted in the period 2000-2004 was identified in the IAEA 1999/2000 Programme and Budget. This CRP was not initiated at the request of Japan due to delays in the startup of HTTR and beginning of the test program. It is anticipated that the possibility of initiating a future CRP related to test operation of HTTR for high temperature process heat applications will be revisited within the frame of the Technical Working Group on Gas Cooled Reactors. The IAEA should be prepared to consider a possible follow-on CRP and ensure that the results of this CRP are effectively factored in.

CRP Published Results

Internal:

A TECDOC entitled "Design and evaluation of heat utilization systems for the High Temperature Engineering Test Reactor" was completed and approved by the Publication Committee in March 2001.

External:

Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **J12014** **Limitations of radioepidemiological assessments for stochastic radiation effects, in relation of radiation protection**

Participating Countries: Bulgaria(C), Canada(A), Russian Federation(C) (5), Ukraine(C)

Total Cost: **$98,770**

Duration: 1994-07-15--- 2000-07-30

CRP Overall Objectives

Radioepidemiological assessment of stochastic radiation effects

CRP Specific Objectives

Radioepidemiological study of the changes in health parameters of workers and population groups exposed to ionizing radiation of radioactive discharges from the Mayak Plant (Ural, SU, 1950-56) and the radioactive releases from the Chernobyl accident (1986) or in the Bulgarian uranium mines (1953-1991).

Research Outputs

BUL-10240: The average cumulative occupational exposure of the uranium workers in 38 years of operation of U-mines in SW Bulgaria was 1250 WLM. 27 lung cancer cases were developed in 1800 U-miners with latent periods of 15 to 48 years. It was observed that the higher the lung dose, the shorter the latency period.

RUS-8039 & 10716:
a) In the analysed period of 50 years (1949-99) no difference in the structure of death was found in the exposed Techa riverside residents (25,945 persons) except a less then twofold increase of Acute leukaemias.
b) The gonad doses were estimated from radioactive discharges of the Mayak Plant to Techa river between 1 to 3000 mGy to 1100 women (forming the study group). No increase in the incidence of stillbirth and early perinatal death was observed among their 1376 children (as compared to the offspring of 557 unexposed women of the control group.
c) No dependence of the infant mortality rate on the dose to the fetuses in 2000 pregnancies (in Techa river residents) was established.

RUS-8035:
a) No dose-dependent increase of all-cause, all-cancer and leukemia mortality in the population of Ozersk city, exposed to 0.35-14 mSv/yr of radioactive discharges from the Mayak Plant for 40 years was observed. All-cancer mortality in the study group - having an estimated average cumulative dose of 180 mSv - during the whole analysed period was found lower than in the comparable control group.
b) No significant increase in the rate of congenital malformation was found in 110,000 persons continuously exposed to low dose rate gaseous and aerosol releases from the Tomsk-7 Siberian Chemistry Enterprise in 1955-95. The cumulative dose from this source of radiation was found to be between 14 and 30 mSv only. It is most probably that the described insignificantly higher inmcidence of stillbirth and neonatal death can be associated with other factors, eg. exposure to lead, reportedly exceeding 5-30-times the limit of permissible concentration in the air than the 0.5 mSv/yr average radiation dose.
c) There was no increase of infant mortality, stillbirth and death rate due to immature birth detected depending on the level of contamination with 137-Cs of the area of residence around Chernobyl (according to the study covering the period of 1986-1997 in 4 Russian regions - Bryansk, Tula, Kaluga and Ryazany - affected by the Chernobyl accident).

RUS-9305: A pilot study was conducted in 10500 workers of the Inst. of Physics and Power Engineering, Obninsk: a dosimetric and medical database was created to study cancer morbidity and mortality below cumulative dose of <0.5 Gy. It was shown that the relative risk of morbidity of malignant diseases had increased depending on the dose registered.

CRP Outcome (Effectiveness; Impact; Relevance)

During the study research was skewed from the originally planned stochastic effects towards deterministic (teratogenic)

effects and also towards study of Pu-Am toxicology or establishing databases on the formerly classified Russian radiation accidents with spent sources.

The analysis over the period 1995-2001 and summarized here represents radioepidemiological projects that have added important data on the health effects of exposure of large groups of the population and workers to ionizing radiation.

The achieved/presented data are consistent with the generally accepted knowledge about the health consequences of radiation exposure and support the existing regulation and guidance for radiation protection.

Recommended Future Action by Agency

CRP Published Results

Internal: 1 draft TecDoc
External: 15 papers (mainly in Russian journals)
Other Outputs: 20 presentations at internatl. and natl. conferences

Accomplishments of CRPs

CRP Number and Title: **J13007** **Development of relevant accident data for quantifying risks associated with transport of radioactive material**

Participating Countries: Canada(A), China(A), China(C), France(A), Germany(A), India(A), Japan(A), Romania(C), Sweden(A), United Kingdom(A) United States Of America(A) (2)

Total Cost: **$85,688**

Duration: 1994-09-15--- 2000-10-17

CRP Overall Objectives

To assess and to analyze the risks associated with the transport of radioactive material.

CRP Specific Objectives

The CRP was established in 1996 as a continuation of the CRP on "The Probabilistic Safety Techniques Related to the Safe Transport of Radioactive Material". Within that CRP, a computerised package for risk assessment on transportation of radioactive material was developed. This package contained computer codes and some advisory documentation, called the INTERTRAN2 package.

During the preparation and development of the INTERTRAN2 package it was felt that some work needed to be done to advise users on how input data should be determined. Therefore, it was proposed to establish a CRP dealing with how to collect, analyse and process relevant input data and identify databases describing for example package characteristics, accident environments and package behaviour under accident load conditions. This CRP was also supposed to give advice on how to present the risk assessment results and on how to quantify the uncertainty inherent in the predicted consequences and risks.

Research Outputs

This CRP was concluded in 2001. It was supported by ten Member States (Canada, France, Germany, India, Japan, People's Republic of China, Romania, Sweden, United Kingdom and United States of America). The CRP resulted in the development of an updated computer code system, known as INTERTRAN2, and a detailed report that is currently under review prior to being published. The INTERTRAN2 computer code system is now available on the Internet. The detailed report provides insights into the application of this computer code system, for both incident-free and accident situations relating to the transport of radioactive material. It discusses (a) health effect modelling, (b) uncertainties in the modelling, (c) sources of human error and how these may affect risk assessment modelling, and (d) quality assuring the efforts in transport risk assessment. It also provides examples of accident scenarios, event trees and severity frequencies; a discussion of transport accident severity and frequency assessment methods, including illustrative examples; and a brief discussion of dose assessment techniques as they relate to both incident free transport and accident transport situations and how they can be applied in the assessment of transport risk.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP was very effective in reaching the specific objectives which were to continue a previous CRP and to update a computerised package.

The CRP was effective in providing information and tools that can be used by Member States about risk assessment.

The results of this CRP will have direct impact on the knowledge in the fields of risk assessment and about consequences of accidents in transport of radioactive material

This CRP is very relevant to the main task of the Transport Safety Unit which is to contribute to the Safe Transport of the radioactive material

Accomplishments of CRPs

Recommended Future Action by Agency

It is recommended that the Secretariat follow through and complete publication of the TECDOC summarizing the findings of the CRP

CRP Published Results

Internal: the TECDOC is under review and should be published in the following months.

External: The INTERTRAN2 computer code system is available on the Internet. An update should be done on a regular basis.

Accomplishments of CRPs

CRP Number and Title: **J16003 Regional personal dosimetry intercomparison**

Participating Countries: Argentina(A), Argentina(C) (2), Bolivia(C), Brazil(C), Chile(C), Cuba(C), Guatemala(C), Peru(C), Uruguay(C), Venezuela(C)

Total Cost: **$73,064**

Duration: 1996-06-15--- 2000-04-12

CRP Overall Objectives

To harmonize individual monitoring quantities as defined in the Agency's International Basic Safety Standards Publication 115

CRP Specific Objectives

Implementation of dose assessment performance verification through intercomparison exercises of individual monitoring services for external irradiation organized by regional Secondary Standard Laboratories, SSDL.

Research Outputs

Implementation of the ISO standard phantom, 30x30x15 cm3 PMMA/water for type testing and calibration of personal dosimeters in terms of the operational quantity, Personal dose equivalent, Hp(10) for different irradiation modes comprising; radiation quality, dose and incidence angle.

CRP Outcome (Effectiveness; Impact; Relevance)

Regional SSLDs have gained insight and experience in organizing intercomparson events which the should in the future apply to the follow up of dose assessment performance for local and neighbouring countries' services laboratories.

Harmonization in the use of Hp(10) operational quantity and in availability of an important tool for its verification as it is intercomparison procedures.

The expected impact of the CRP is the assurance of reliable personal dose assessment by regional personal dosimetry laboratories. A compromise to compliance with radiation protection regulations for occupational exposure control.

The relevance stems from the possibility that regional SSDLs may assume the task to periodically verify services laboratories performance s well as type test and calibrate personal dosimeters under request by the laboratories.

Recommended Future Action by Agency

Agency should establish a firm compromise to follow up and support the full implementation of intercomparison events in the region

CRP Published Results

Internal:
External:
Other Outputs:

Accomplishments of CRPs

CRP Number and Title: **J41004** **Development of methodologies for optimization of surveillance testing and maintenance of safety related equipment at nuclear power plants**

Participating Countries: Bulgaria(C), China(A), China(C), Germany(A), Hungary(A), Hungary(C), Mexico(C), Netherlands(A), Korea, Repulic Of(A), Pakistan(C), Romania(C), Slovakia(A), Slovenia(C), Spain(A), Sweden(A), United States Of America(A)

Total Cost: **$194,416**

Duration: 1996-10-01--- 2000-08-17

CRP Overall Objectives

To assist Member states in the development and implementation of methods and strategies for the improvement and optimization of the testing and maintenance programmes for safety related systems and equipment at nuclear power plants, including the improvement of Technical Specifications and the development of on-line maintenance programmes. To exchange experience regarding the definition of acceptance criteria, regulatory acceptance of the optimization process, and the development of guidance.

CRP Specific Objectives

The specific aims of this CRP were: 1) To promote an understanding of the applicability, usefulness and limitations of the probabilistic methods and criteria, and also of the impact of PSA assumptions for improving testing and maintenance programmes. 2) To emphasize the need for combining engineering, deterministic and probabilistic judgement in the decision making process for improving test and maintenance activities. 3) To compile good practices in conducting the evaluations to improve testing and maintenance, including ways to define criteria for such evaluations. These objectives were pursued bearing in mind that: 1)There were different plant designs among the participating organizations. 2)There were significant differences in interrelations between the nuclear institutions in the participating countries. 3) There are various possible methods and approaches to improve the testing and maintenance practices. 4) Not all NPPs have a plant specific PSA and not all plant-specific PSAs are adequate to be directly used for decision making in testing and maintenance, i.e., all along this CRP there were discussion on specific data to be included in the PSA in a way to enable the model of the plant to be representative for such applications.

Research Outputs

In the framework of the CRP six technical areas have been investigated by the participants:
1) Maintenance activities, 2) Testing intervals and strategies, 3) Allowed outage times for maintenance, 4) Configuration control during maintenance, 5) Testing and maintenance procedures, 6) Global optimization of testing and maintenance. Different research groups were formed to address these topics. Optimization strategies were analyzed for preventive maintenance and for Technical Specifications and Operational Requirements, aiming to focus testing and maintenance on components that are relevant to to plant safety and detecting incipient component degradations. At the same time a reduction of testing and maintenance frequencies without compromising plant safety is intended by the optimization strategies. Configuration control mechanisms have been developed to ensure that whatever combination of maintenance and testing activities taking place at a certain time doesn't unacceptably impact the plant safety. In the field of procedure optimization, a substantial effort has been devoted to the development of computerized systems and a process of effective feed back as a way to achieve low frequency of errors in the interpretation and execution of procedures, high quality documentation of the tasks performed, and optimal sequence of procedure steps. A final global optimization has been considered as the integration of the tasks described above to achieve minimal risks taking into account all the relevant issues concerning the decision making process, such as utility perception, regulatory perception, etc., and also conditions imposed by the optimization methods, such as scope and level of detail of the analysis, the objective function, etc.

CRP Outcome (Effectiveness; Impact; Relevance)

This CRP has been effective in providing information on good practices and guidance for conducting test and maintenance optimization using insights from Probabilistic Safety Assessment and also deterministic-engineering evaluations

Accomplishments of CRPs

The CRP has effectively contributed to the better understanding by the participants of optimization methods to increase plant safety, and minimize workers' exposure to radiation and maintenance costs.

The results of the CRP can provide guidance in the covered fields of test and maintenance optimization for a broad spectrum of managers and specialists. In particular, system designers and equipment manufacturers, safety engineers, maintenance staff, and nuclear regulators may benefit from it.
Member States can use the results of the CRP, to be widely disseminated as a TECDOC, for effective optimization of maintenance and testing activities. The optimization process combines at the same time 3 principal goals, increasing plant safety as much as possible, minimizing workers exposure to radiation, and reducing costs. Other relevant factors are considered as well. The most suitable optimization strategies remain nevertheless case specific, depending on plant design and operational features, type and scope of PSAs available, nature of the regulatory regime, etc. Therefore, complementary support to Member States, e.g. through TC programmes, would be very beneficial for case specific application of the CRP results. Member States can also benefit from the analyses performed in the CRP of on going activities in some countries in areas such us: improvement of Technical Specifications, balancing between preventive and corrective maintenance, on-line preventive maintenance, accommodation of maintenance programmes to fuel cycle extensions, configuration control, etc.

Component Maintenance in most Nuclear Power Plants in operation is based on a non-structured combination of suppliers advice, plant experience and engineering know-how. Many plants are at this moment conducting studies to determine a more balanced structure for maintenance activities. The CRP has been successful on proposing optimization techniques that allow to reduce maintenance costs while reducing plant risk and radiation exposure or keeping them under acceptable limits.

Recommended Future Action by Agency

The Agency has already initiated some actions in this area after finalisation of the CRP. Optimization of Test and Maintenance activities has been included so far as a topic in 3 Training Courses on PSA and PSA applications. In addition, a workshop is planned for December 2002 on the use of PSA for improving Technical Specifications and implementing on-line maintenance programmes at NPPs. All these activities are carried out under regional TC programmes for Europe. Further activities in this direction are recommended.

CRP Published Results

An IAEA-TECDOC is under preparation.
External: Scientific papers published in open literature by the CRP participants

Accomplishments of CRPs

CRP Number and Title: **J71005 Management of ageing of in-containment instrumentation and control cables**

Participating Countries: Canada(A), Czech Republic(C), France(A), Germany(A), India(C), Japan(A), Romania(C), Russian Federation(A)Russian Federation(C), Sweden(A) (2), Switzerland(A), United Kingdom(A), United States Of America(A)

Total Cost: **$148,864**

Duration: 1992-12-04--- 2000-10-10

CRP Overall Objectives

To develop guidelines on the evaluation and management of safety aspects of NPP ageing on the basis of information gathered from Member States and to provide training and conduct advisory missions aimed at ensuring that required safety margins are maintained over plant lifetime through timely detection and mitigation of age-related degradation.

CRP Specific Objectives

To identify the dominant ageing mechanisms and to develop an effective strategy for managing ageing effect caused by these mechanisms.

Research Outputs

A summary of the revelant ageing mechanisms; operating experience for a range of NPP types; description of cables sampling and laboratory ageing methods; a 'tool box' of practical condition monitoring methods (including their limitations and test procedures for different cable materials and applications); a database of cable CM methods.

CRP Outcome (Effectiveness; Impact; Relevance)

Transfer of technical know how among CRP participants.
Dissemination of practical guidelines to NPP operators and regulators.
Enhanced capability of NPP operators to maintain required safety margins of cables over NPP lifetime.

CRP very relevant to ensuring functional capability of cables throughout long service life (40-60 years)

Recommended Future Action by Agency

Participante in OECD/NEA Task Group on Wire System Ageing
Consider follow up CRP to develop non-intrusive CM methods for installed cable systems

CRP Published Results

Internal:
TECDOC-932 (1997) and 1188 (2000)

External:
Paper by J. Pachner and S.G. Burnay on Assessment and Management of ageing of Electrical, Instrumentation and Control Cables presented at and published in proceedings of ICONE 9, Nice, April 2001

Other Outputs:
CRP database included in EPRI Cable CM database.

Accomplishments of CRPs

CRP Number and Title: **K41006 Worldwide marine radioactivity studies**

Participating Countries: Denmark(A), Germany(A), Italy(A), Japan(A), Korea, Republic Of(C), Thailand(C), United States Of America(A) (2)

Total Cost: **$45,991**

Duration: 1998-03-20--- 2000-03-20

CRP Overall Objectives

To develop an understanding of the present open ocean distribution of radionuclides in the water column and sediment and thus predict the radiological impact to be addressed, and to encourage and support marine radioactivity studies in Member States by methodological assistance and total analytical quality management. The programme was designed with the intention of contributing to scientific knowledge of the processes which affect radionuclide distributions and the sources which have introduced radioactivity to the world's oceans.

CRP Specific Objectives

i) to examine present distributions of key radionuclides (3H, 14C, 90Sr, 137Cs and Pu isotopes) in water, biota and sediment of the world's oceans.
ii) to extrapolate the results from contemporary ocean-wide surveys such as the tracer component of the World Ocean Circulation Experiment Hydrographic Programme (WOCE) where the large sets of tritium data available could be used for the prediction of 90Sr and 137Cs concentrations in the same regions.
iii) to study the development of radionuclide concentrations in water with time using good quality historical data (e.g. from the GEOSECS programme of the mid-seventies) with new data sets collected recently (e.g. from the IAEA '97 cruise to the NW Pacific Ocean which will include new data taken from some of the GEOSECS stations).
iv) to identify the major sources of anthropogenic radionuclides in the world's oceans.
v) to input all available data on radionuclide distributions in water, biota and sediment into the Global Marine Radioactivity Database (GLOMARD) so that temporal and spatial variations of key radionuclides can be investigated.

Research Outputs

The results obtained by the CRP are described in comprehensive form in an IAEA TECDOC report, which includes:

i) quantitative identification of major sources of anthropogenic radioactivity in the waters, biota and sediment of the world's oceans.
ii) the present distribution of key radionuclides (3H, 14C, 90Sr and Pu isotopes) in waters, biota and sediment of the world's oceans.
iii) temporal and spatial variations of key radionuclides in water, biota and sediment with possible predictions in the near future.

The TECDOC provides the most comprehensive information on radionuclide levels in the world's oceans. Three anthropogenic radionuclides - 90Sr, 137Cs and 239,240Pu have been chosen as the most representative of anthropogenic radioactivity in the marine environment, comprising beta, gamma and alpha-emitters which have the highest potential contribution to radiation doses to humans via seafood consumption.

The results confirm that the dominant source of anthropogenic marine radioactivity is global fallout. The total 137Cs input from global fallout was estimated to be 311 PBq for the Pacific Ocean, 201 PBq for the Atlantic Ocean, 84 PBq for the Indian Ocean and 7.4 PBq for the Arctic Ocean. For comparison, about 42 PBq of 137Cs was released to the marine environment from Sellafield and Cap de la Hague reprocessing plants. The Chernobyl accident contributed about 17 PBq of 137Cs into seas, mainly to the Baltic and Black Seas, where the present average concentrations of 137Cs in surface water were estimated to be about 60 and 40 Bq/m3, respectively, while the worldwide average concentration due to global fallout is about 2 Bq/m3.
The world was divided into latitudinal belts for which average radionuclide concentrations were estimated. Further, where

available, time trends in radionuclide concentrations in surface waters were studied and mean residence times of radionuclides in these areas as well as in the world oceans were estimated. The results confirm similar mean residence times for 90Sr and 137Cs in surface water, 25+/- 1 year and 13+/-1 year for 239,240Pu.
Changes in radionuclide concentrations in water profiles with time in the North Atlantic and Pacific Oceans were also studied. A clear decrease of radionuclide concentrations in surface waters was observed due to transport of radionuclides to medium water depths.

CRP Outcome (Effectiveness; Impact; Relevance)

The work carried out within the CRP was very comprehensive and effective. 8 laboratories in MS (Denmark, Italy, 2 in Japan, the Republic of Korea, Germany and 2 in the USA) took part in the evaluation work and 2 laboratories (the Philippines and Malaysia) participated in the data collection from South-East Asia.

The results obtained in the framework of the WOMARS CRP provide the most complete data set available to MS on the levels of radionuclides in the marine environment. The results will be used as the international reference source on the average levels of anthropogenic radionuclides in the marine environment so that any further contributions from nuclear reprocessing plants, radioactive waste dumping sites, nuclear bomb test sites and possible nuclear accidents can be identified.

The CRP has been highly relevant to the IAEA and Member States as the obtained results represent an international reference source on radioactivity in the marine environment.

Recommended Future Action by Agency

It is recommended that future studies on the distributions of radionuclides in the open ocean, seas and coastal zones should continue and new data obtained through the collaboration of Member States laboratories should be input into the GLOMARD database.

CRP Published Results

A pre-print of the TECDOC has been issued (see separate document) and the TECDOC itself will be published by the Agency.

A special issue of the journal "Deep Sea Research" comprising 15 publications prepared in the framework of the CRP is under preparation and will be published in 2002.

Accomplishments of CRPs

CRP Number and Title: **T12010 Stress corrosion cracking (SCC) of zirconium alloys fuel cladding**

Participating Countries: Argentina(C), China(C), India(C), Korea, Republic Of(C), United Kingdom(A)

Total Cost: **$110,485**

Duration: 1994-04-01--- 2000-09-20

CRP Overall Objectives

To provide basic data on this phenomenon for a selection of different materials, using a matrix of different temperature and iodine levels, with the work conducted at five different laboratories around the world. The second overall objective was to transfer know-how at the laboratory level on the very difficult testing procedures required to measure stress corrosion cracking in iodine from the Host Laboratory to the participating laboratories.

CRP Specific Objectives

The specific purpose of the experimental programme carried out under the CRP was to investigate stress corrosion cracking (SCC) of unirradiated zirconium alloys in iodine vapour. The major variables influencing stress corrosion cracking in these alloys are metallurgical state (including composition, orientation, thermo-mechanical treatment, texture and cold work), environment (composition, concentration and temperature) and stress. It was not feasible to investigate the effects of all these variables within the scope and time-scale of the programme. The test programme was thus focused on determining the dependency of stress corrosion crack propagation rate to temperature, iodine concentration and stress within the range of available materials.

Research Outputs

Effect of creep
During the course of the experimental work, it was found that, at the beginning of a new experiment, significant changes in direct current potential drop (DCPD) could be measured without any observable crack propagation. This led to the consideration of a possible contribution of creep to the electric resistance changes of the sample, as measured by the DCPD.
Effect of temperature
The test matrix included tests at three temperatures: 300, 350 and 400°C. The results from the participants do not show a clear, consistent effect of temperature on the threshold stress intensity factor or the crack propagation rate in the Stage II region. Temperature would be expected to influence SCC due to its effect on the mechanical properties of the material and on the diffusion rate of iodine. This would be expected to produce a reduction in KI-SCC and increase in Stage II crack propagation rate as found in most of these tests.
Effect of material condition
Five materials were tested from two manufacturers. These were recrystallised Zircaloy-2 (Zr-2) and Zircaloy-4 (Zr-4) and stress-relief annealed Zr-4. By determining X-ray pole figures, each was shown to have a similar texture, so any effect on I-SCC would be expected to arise due to the effect on the mechanical properties and grain shape of the different heat treatments. The results from the host laboratory and the Korean participant were consistent with this, with both finding a higher KI-SCC for recrystallised materials compared to the stress relief annealed Zircaloy. The Argentinean and Chinese results were inconclusive in this respect.
Effect of iodine partial pressure
Iodine pressure was studied in the range 100 to 10,000 Pa I_2. Both the host laboratory and the Argentinean participant found no effect of iodine pressure on KI-SCC. The Argentinean tests on stress relieved Zr-4 and the Chinese results on recrystallised Zr-2 indicated an increase in Stage II crack growth rate with increasing iodine concentration. These results are consistent with literature observations of a threshold iodine concentration and with crack propagation being diffusion controlled, so that a higher external iodine concentration will produce more rapid diffusion of iodine to the crack tip and hence higher crack propagation rates. This latter effect has also been shown to saturate once sufficient iodine is present. The supervisory group believe that the iodine replenishment rate in the test chambers varied markedly between laboratories, so that the true iodine concentrations in each test were unlikely to be consistent between laboratories.
Effect of texture
The CRP was extended in order to capitalise on the improvements in test facilities and experimental technique of the participants, both from the advice provided to them by the supervisory group, and from their increased experience in performing the tests. All

previous tests in the CRP were performed on specimens in the TL orientation, so the additional series of tests were to generate crack growth data in the opposite, LT, orientation. From texture considerations, SCC was expected to be more difficult in the LT specimens, producing a higher KI-SCC. This was found to be the case by the host laboratory and the Argentinean participant. For the Korean participant, there remained too much experimental scatter for any firm conclusions on KI-SCC to be drawn. The Chinese found no difference between TL and LT oriented specimens.
Fractography
One important aspect of any experimental programme on iodine SCC of zirconium alloys is the fractography of the crack surfaces produced. The features to be expected are by now well known, and the extent to which they are observed can be very helpful in understanding the test results.
By the end of the CRP most laboratories were obtaining good fractographs showing the expected features.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP was reasonably effective in reaching the specific goals, but with a much lower number of samples than originally anticipated because of the unproductive destruction of many samples by all of the participants in the early, learning phase of the CRP. For the same reason, results were limited to smaller ranges of the critical parameters.

In retrospect, the choice of test method did not make it easy for the participants to reproducibly obtain good stress corrosion cracking data from the specimens supplied. This arose primarily for two reasons. Firstly, by selecting a uniaxial rather than a biaxial stressing method, even though the specimens were fatigue pre-cracked, there was a tendency to blunt the crack tip if the chemistry conditions were not ideal. This resulted in much plastic deformation of some specimens. Secondly, the use of a uniaxial system generally resulted in participants building rather large specimen chambers that made it more difficult to achieve the right chemistry conditions at the crack tip. This situation was sometimes rendered more difficult by the use of high I2/He flow rates that inhibited the development of the right chemical environment.
Thus, for some of the participants, the CRP developed into an exercise in learning how to reproducibly obtain iodine stress corrosion cracking, rather than in the gathering of data which could be compared with the other results. Most participants had solved these problems by the originally planned end of the CRP. In the process, however, many of the original batch of specimens were tested unproductively. In order to capitalise on the learning that had occurred, an extension of the CRP was approved to test a new set of specimens.
In summary, the know-how transfer was very effective but the other overall goal of collecting crack growth rates for input to specific codes was less effective.

The project consisted of out-of-pile laboratory measurements of crack propagation rates in Zircaloy sheet specimens in an iodine containing atmosphere. It was overseen by a supervisory group consisting of experts in the field. The project was carried out by a host laboratory and four laboratories from different developing countries. Besides the basic goal of obtaining stress corrosion cracking data, a secondary goal was the transfer of "know-how" at the laboratory level from the host laboratory and supervisory group to the four target institutes from developing Member States. Stress corrosion cracking experiments in iodine are notoriously difficult to carry out successfully. There were early failures in carrying out the tests in iodine and many samples were destroyed in the process. This led to a modification and reduction in the original experimental matrix and the extension of the CRP for one year. By the end of the CRP, all of the participants were making satisfactory measurements of crack growth rates at the specified temperatures and in an iodine atmosphere. Moreover, most of them were producing fractographs showing the expected characteristic features of stress corrosion cracking. The results together with a state-of-the-art review of stress corrosion cracking in Zircaloy fuel cladding have been prepared and Published as IAEA-TECDOC -1185, November 2000.

Corrosion is the single most important and costly degradation and ageing mechanism of materials used in any industry and, most particularly, in the nuclear industry. This CRP on fuel-side corrosion of fuel cladding is part of an integrated overall programme of the Agency to address corrosion problems.

Recommended Future Action by Agency

No further action in this area by the Agency should taken in the foreseeable future.

CRP Published Results

Internal: TECDOC-1185

Accomplishments of CRPs

CRP Number and Title: **T23013 Site characterization techniques used in environmental restoration activities**

Participating Countries: Australia(A), Belgium(A), Brazil(A), Canada(A), France(A), Kazakhstan(C), Netherlands(A), Romania(C), Russian Federation(A), Slovakia(A), Spain(A), Ukraine(C), United Kingdom(A), United States Of America(A)

Total Cost: **$129,954**

Duration: 1995-12-01--- 2000-12-31

CRP Overall Objectives

To promote the exchange of information on practical experience being gained by Member States in characterization of radioactive contaminated sites.

CRP Specific Objectives

The objective of this CRP was the development of methods and techniques for the optimization of radiological characterization, with the following specific targets:
- definition of a strategy for site characterization;
-sampling and measurement techniques;
-data management incl. statistical analysis and radioisotope migration modelling;and
-post-cleanup radiological surveys.

Research Outputs

From the overall range of R&D activities conducted under this project, outputs are clearly recognizable for radiological characterization of the following typical sites :
-" historical" sites;
-nuclear research centers;
- sites contaminated by nuclear accidents;
-mining sites.
R&D achievements concerned the following technical areas: identification of relevant contamination barriers; protocol development; screening surveys; determination of background levels;costs and number of measurements; QA programmes; vehicle-borne monitors; hand-held instruments; media sampling; automated survey techniques; complex geometries; and assurance of compliance with release criteria.

CRP Outcome (Effectiveness; Impact; Relevance)

The CRP was effective in addressing the specific objectives delineated above. In particular, several national projects were active in each target area and this allowed effective comparison of results.

The CRP has resulted in a speed up of applicable methodological developments by fostering the exchange of experience between participants with seemingly different contamination problems, but essentially similar characterization challenges.

It is expected that the CRP will increase the awareness of Member States of the need for timely environmental restoration planning. It is evident that radiological characterization is the first, essential step towards this awareness. In some countries, in particular those facing the most critical environmental conditions, this should lead to the formulation of detailed environmental restoration plans.
In more general terms, the CRP should have contributed to enhance the organizational capabilities of the Member States which participated. Since environmental restoration is a multi-disciplinary activity, of which radiological characterization is an essential part, the CRP will stimulate these countries to develop an integrated approach to optimize resources. Also, it should be noted that radioactive contamination is part of the overall environmental contamination, and a spin-off from the CRP is expected in non-radioactive contamination projects.

Accomplishments of CRPs

The CRP was an important step towards establishing a comprehensive data base for the IAEA's environmental restoration programme for radioactively contaminated sites. This includes activities associated with the characterization of contaminated sites, as well as others such as technologies for cleanup and remediation, factors to be considered in the formulation of a decommissioning strategy, computerised directories, and the monitoring of decommissioned sites. In parallel, guidance is being provided to Member States on remedial actions.

Recommended Future Action by Agency

The IAEA should continue to expand its environmental restoration programme in parallel with the growing awareness by Member States that their contaminated sites need remedial actions.

CRP Published Results

Internal: Interim progress reports

External: TECDOC-1148

Other Outputs: