IRASM — A MULTIPURPOSE IRRADIATION FACILITY IN ROMANIA

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Abstract

A multipurpose irradiation facility is in construction at IPNE, Bucharest, under the IAEA T.C. Project: ROM/8/011. It will be the first industrial facility in Romania.This paper presents the philosophy standing behind the design, the short and long term managing plans. Some dose calculations are added in the view of use the empty spaces in the irradiation room for cultural heritage conservation. An economic study is presented aiming to provide basic estimations for further management strategy. At the start the facility will be a state enterprise. The implications, advantages and disadvantages of this situation are discussed.

1. INTRODUCTION

Irradiation can solve a lot of health and food problems. It is spread over the world, generating low costs, safe and perfectly controllable technologies. Over 40 years of research activities made the irradiation a high tech and an indisputable procedure.

In spite of the favourable perspectives, irradiation technologies penetrate the market very slowly in countries with low or medium economical level. This state of the art is time and money consuming. It is also a vicious circle hard to brake. Both objective and subjective reasons are responsible for that: among the users, practical knowledge on irradiation is confuse, the lack of legislation, the lack of pre/post irradiation control methods, the ignorance and fear of any nuclear equipment or treatment. As a consequence, in promoting irradiation technology, there is no determined pressure from the users and the routine prevails.

A number of small irradiation facilities functioning in Romania permitted a research activity covering almost all important directions validated by international practice in irradiation processing. Started thirty years ago, relevant studies accumulated sufficient experience to allow the construction of an industrial facility. Consequently, a demonstration Multipurpose Irradiation Facility is now in construction at the Institute of Physics and Nuclear Engineering-Bucharest under IAEA TC Project ROM/8/011 [1] started in 1993. It was initiated by four major institutes: Institute for Physics and Nuclear Engineering - Bucharest Magurele (IPNE), Research Institute of Chemistry and Pharmacy - Bucharest, Institute of Nuclear Research - Pitesti and Research Institute on Cereals and Technical Crops - Fundulea.

Because of its experience [3] in operation of large nuclear facilities[1] and radiation processing[2], IPNE has been chosen to set the facility at Magurele (10 km SW of Bucharest). The irradiator will be named IRASM.

IAEA supports the project by financing the main equipment, a 100 kCi Co-60 source, the operators' training and the cost of the experts' services.

[1] 3.5 MW Reactor, Isotope Separation Plant, Cyclotron and Tandem Accelerator.
[2] Pilot Plant for Polyacrilamide Production (100 t/year throughput).

The main governmental inputs are: design and construction of the building and infrastructure, a part of needed equipment and an R&D program. In 1994, IAEA chose Institute of Isotopes - Budapest, as supplier of irradiation equipment and Co 60 sources. In 1995, the internal financial support turned up, by a Decision of Romanian Government, in needed funds for design and construction. The construction started in October 1996. The commissioning of IRASM is estimated for the first part of 1998.

2. SPECIFICATIONS OF IRASM

The main characteristics of the facility are [2]:

* tote-box type irradiator (overlapping product); pneumatic action; batch or continuous irradiation
* overdose ratio: < 30% for package density = 0.2 t/cu.m.
* efficiency: > 28% for package density = 0.2 t/cu.m.
* radiation source: Co-60, C-188 type; max. load: 2 MCi; start load: 0.1 MCi
* 2000 cu.m./year at 25 kGy and package density 0.2 t/cu.m.
* storage area/volume: 500 sq.m. / 3000 cu.m.

The attribute "multipurpose" is supported by the following:

- minimum dose is 0.5 kGy; it is suitable for food treatments and permitted by a split source rack design (Fig. 1).
- complete service for users, including pre/post microbiological, chemical and physical analyses
- a room for public acceptance is previewed
- a special room is dedicated to conservation of cultural heritage

The facility layout is shown in Fig. 2.

3. DEVELOPING STEPS

On short and medium terms, the facility has a definite aim: promotion of radiation processing in the Romanian economy.

On long term, a political decision closely linked by an economically one is necessary. There is an option to take whether the facility will evolve to a Contract Irradiator or it will be the core of a National Center of excellence.

From technical point of view, IRASM is prepared for both these options.

If the first option will be chosen, the facility will have to face the economical challenge. For this reason, it has the possibility to upgrade the radiation source till 2MCi and to install a water cooling system. There is also the possibility to enlarge the store area and to add refrigerators.

The facility will have three key-moments in its life. During the intervals, its aims and resources, also its operating parameters and economical status, derive from the source load.

1. The moment of the start: $\Lambda = 0.1$ MCi - Promotion stage

Aims: licensing of some technologies; public acceptance campaign; basic research and development, associated with optimising the use of the facility and operating procedures.
Status and resources: R&D state enterprise belonging to IPNE; most necessary funds will be budgetary.

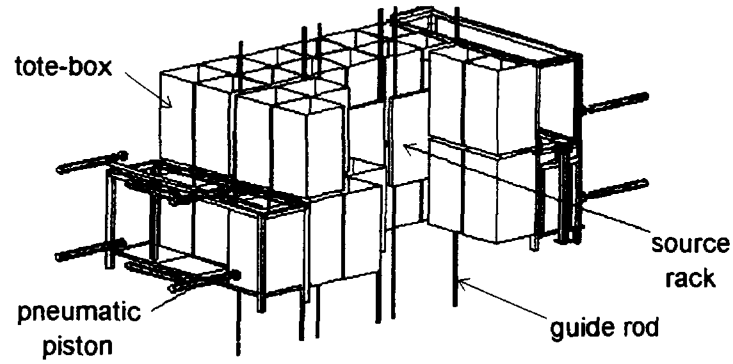

FIG. 1. IRASM tote-box irradiator. The source is splited in three identical racks.

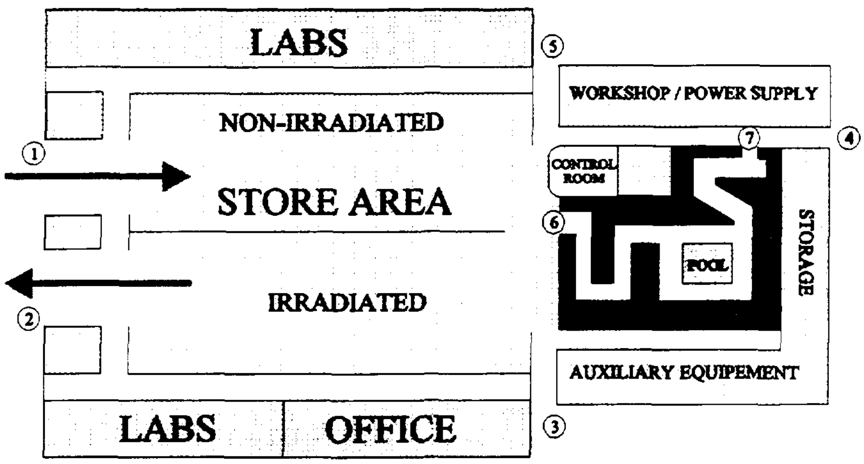

FIG. 2. IRASM facility layout.
1. Products entrance;
2. Products exit;
3. Personnel entrance;
4. Container entrance;
5. Emergency exit;
6. Goods maze;
7. Personnel maze.

Operating parameters: batch mode operation (predominantly); no cooling system; small refrigerators

2. The moment of economic independence: $\Lambda = 0.3$ Mci

Aims: economic + R&D activities.
Status and resources: commercial state enterprise belonging to IPNE; economical self-sufficiency; R&D activities supported by the users.
Operating parameters: continuos mode of operation (predominantly); cooling system in place; store arrangement appropriate with the technologies proved to be viable.

3. The moment of administrative independenee: $\Lambda = 0.5$ Mci

Aims: economic activities only; the most profitable technologies will be used.
Status and resources: independent commercial enterprise separated from IPNE similar to Canadian AECL - Nordion case.
Operating parameters: not important changing.

Necessary time for these steps is hard to be predicted, the economical context playing a very important role. Probably the 2^{nd} moment will be reached in 3-4 years.

If the decision of setting a National Irradiation Center will be taken, IRASM could be its central piece. IRASM is previewed with laboratories for diagnosis and pre/post irradiation control (chemical, physical, mechanical, microbiological, dosimetrical). A space for public acceptance is in the same time exhibition, conference and training room. A functional model of the facility will be placed here. A special room is dedicated to cultural heritage preservation.

Other parts of the presumed National Center are two small irradiators (10kCi and 20kCi, respectively) and an electron accelerator (7 MeV). These facilities already exists.

4. COST/BENEFIT ANALYSIS

There is a known algorithm for a cost/benefit analysis of industrial irradiators [4-6]. It takes into account, as a premise, a definite throughput, in other words steadies working conditions. The per unit processing cost (C) is linear dependent of capital costs (CC), operating costs (OC), time for initial investment recovery (Y), percentage of investment to be recovered (P) and annual throughput (T):

$$C = ((CC*P)/Y+OC)/T \qquad \text{(US\$/cu.m)}$$

Annual throughput (T) is given [4] as a relation between:

$$T = S*R*N/d/18.744/D \qquad \text{(cu.m/y)}$$

Where

- S = source activity (kCi)
- R = ratio of absorbed to emitted energy (%)
- N = annual operating hours (h/y)
- d = density (kg/cu.m)
- D = irradiation dose (kGy)

For main predictable applications is possible to perform a cost simulation at different installed activities (Fig. 3).

It is obviously that processing cost per unit is higher for products requiring higher irradiation doses (low throughput). A minimum activity of 300 kCi is required for an economical operational base.

This is not the case in a promotion period. It is the reason why is very difficult to calculate the costs of the promotion stage. The promotion efficiency depends on involved money, market reaction, level of specific industry maturity (GMP), bureaucracy reactivity, legislation, the ability of public acceptance campaign, etc. Trying to estimate the promotion costs, some simplifications and some hypothesis have been adopted:

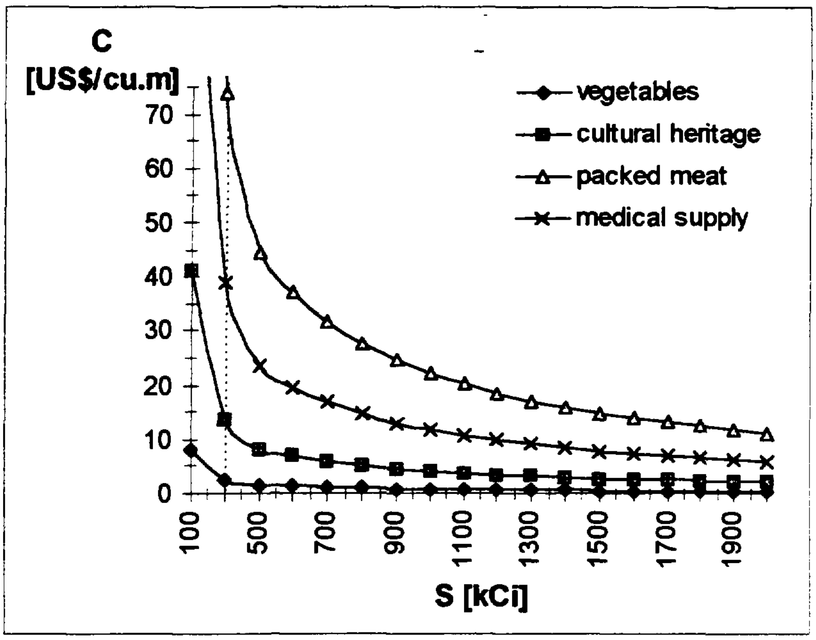

FIG. 3. Per unit processing costs simulation for IRASM.

a) The State, as owner and project initiator, will agree to postpone the influence of the capital investments onto the production costs, till the end of the promotion stage.
b) The production costs are based only on personnel costs, utilities, maintenance, operational supplies and facility insurance.
c) The promotion itself means: technological validation, licensing, legal workframe preparation and actions for public acceptance: booklets, workshops, demonstrations; all these will be supported by an R&D Project, and will not affect the processing costs.
d) Sterilisation of medical supplies is the only irradiation process took into account (packaged density: 0.2t/cu.m; absorbed dose: 25kGy +30%).

4.1. First scenario

Basic hypothesis:

- The promotion is directed to a large spectrum of endusers.
- The radiation source will not be replenished. The facility will use the initial sources
- The promotion stage will last 3 years.

In this hypothesis the promotion costs are estimated in Table I, where:

I = income, calculated at a medium market price for medical supply sterilisation of 50US$/cu.m

P = operational cost, constituted (US$/year) from:

- personnel (1 shift: 8,000; 2 shifts: 11,500; 4 shifts: 18,500)
- maintenance : 7,000
- utilities and communications : 7,000
- operational supplies : 7,000
- insurance : 17,000

R&D = R&D cost, estimated on the basis of a detailed project (its presentation as a function of operation costs illustrates a management decision).

Total cost = P + R&D - I.

TABLE I. PROMOTION STAGE COSTS (1st SCENARIO)

Promotion period	1st year	2nd year	3rd year
Installed source activity (kCi)	100	87.5	76.5
Potential throughput (cu.m/year)[a)]	2000	1,750	1,530
Estimated throughput	500[b)]	875[c)]	1530[d)]
I (US$/year)	25,000	43,750	76,500
P (US$/year)	46,000	49,500	56,500
R&D promotion cost (US$/year)	230,000 (5 x P)	148,500 (3 x P)	56,500 (1 x P)
Total cost	251,000	154,500	36,500

[a)] For 6000 operating hours/year.
[b)] One shift/day.
[c)] Two shifts/day.
[d)] Four shifts/day.

That means for the promotion period of 3 years a total cost of 441,750 US$.

To work on economical basis, the facility must be upgraded till 300kCi, as could be seen from Fig. 3. At the end of promotion period, the cost for this operation will be (estimated): 223,500Ci x 1.85$/Ci = 413,475 US$

4.2. Second scenario

Basic hypothesis:

- Promotion activity is concentrated to a few major endusers (it started before the commissioning; the legislation is in an advanced stage of preparation).
- The potential throughput of the facility will be fully covered in the second year of the promotion stage.
- The income will be spent for source upgrade. Source activity will be increased in between the promotion stage.

In this hypothesis the promotion cost is estimated in Table II (same notations as in Table I). In this case the operational cost (**P**), is constituted (US$/year) from:

- personnel (4 shifts) : 18,500
- maintenance : 7,000
- utilities and communications : 7,000
- operational supplies : 7,000
- insurance : 17,000
- source replenishment : 15,000

TABLE II. PROMOTION STAGE COSTS. (2nd SCENARIO)

Promotion period	1st year	2nd year	3rd year	4th year
Installed source activity (kCi)	100	87.5	200	300
Potential throughput (cu.m/year)[a]	2000	1,750	4000	6000
Estimated throughput	1600[b]	1700[b]	3600[b]	5600[b]
I (US$/year)	80,000	85,000	180,000	280,000
P (US$/year)	71,500	71,500	86,500	101,500
R&D promotion cost (US$/year)	214,500 (3 x P)	143,500 (2 x P)	0 (0 x P)	0 (0 x P)
Total cost[c]	286,000	214,500	-86,500	-178,500

[a] For 6000 operating hours/year.
[b] Four shifts/day.
[c] In the 3rd and 4th years: I > P.

That means for a promotional period of 4 years a total cost of 408,500 US$.

Source replenishment will be done in two moments: a) at the beginning of the 3rd year and b) at the beginning of the 4th year, when cumulated income will be sufficient.

In this scenario, at the end of the 4 years' promotion period the facility will reach the installed activity of 300kCi, in other words it could function on economical basis.

4.3. Comments of the two scenarios

These scenarios try to estimate the costs for the promotion period. It is considered finished when the facility attends an economic independence, having: installed source of 300KCi, market and a permissive legislation.Being cheaper, the second scenario is recommended, than the first one.

The first scenario could be followed in the case of developing a National Irradiation Center, where various technologies can be studied or licensed and a legal workframe is established. Second scenario must be considered when an economical initiative is desired.

5. DOSE MAPPING FOR STATIC IRRADIATION

During the promotional stage, most probably IRASM will not work at full capacity. In this case there are important periods of time when the source activity decays useless.

On the other hand, one of the "multipurpose" conceptual targets is the irradiation for cultural heritage preservation. Unfortunately not all artefacts to be treated could be packed in an appropriate shape for a tote-box processing (wood artefacts or books, for example).

It remains only the possibility to set a static irradiation, when the respective items are stacked in a free area near the walls, parallel with the source. The source is raised without starting the conveyor. Even the use of these "dead times" of tote-box processing does not bring an important income (taking into account that the museums do not have important funds for preservation treatments, in spite of its necessity), we will take this as a very good advertising.

With the observation that about 80% of the irradiation room volume are free, we try to identify some suitable areas, free of interference with any moving parts of the irradiator.

One important area was identified near the wall parallel with the source, between the personnel and the product entrance (hatched area in Fig. 4). In this area was considered a parallelipipedal volume (target) with 240 cm length (on Y axis), 260 cm height (on Z axis) and 50 cm depth (on X axis). The parallelepiped is parallel and centred with the plane source. Taking the source center as the origin of the reference system, the center of the target is at 295 cm on the X axis.

In this volume, a rapid method for absorbed dose estimation is to assume that the plane source is made by a large number (100) of ideal line sources and to calculate the absorbed dose in air. The line sources are disposed vertically, uniformly distributed on the plane source frame (290 cm x 100 cm). The backscattered radiation and the self absorption are neglected. The activity is uniformly distributed on a line source.

The absorbed dose rate was computed by summing the individual contribution of each line source. For one line source, the problem is analytically solved. ($\Gamma_{Co\text{-}60}$ = 0.0856 $fGy \cdot m^2/(s \cdot Bq)$, air kerma rate constant)

The air absorbed dose-rate (normalised at the maximum value) are shown in Fig. 5 as dose rate maps for the Z = 0 cm and Y = 0 cm plane, respectively. The overdose ratio for not very large objects placed in this area could be easy estimated from such maps.

If the target volume is fully filled (many small objects or only a large object) this estimation could not be used. The attenuation in the material, the radiation build-up and even the backscattered radiation from the irradiation room walls must be considered. A Monte-Carlo simulation would be more suitable in this case. Such calculation will be added in the preparation of this static irradiation case.

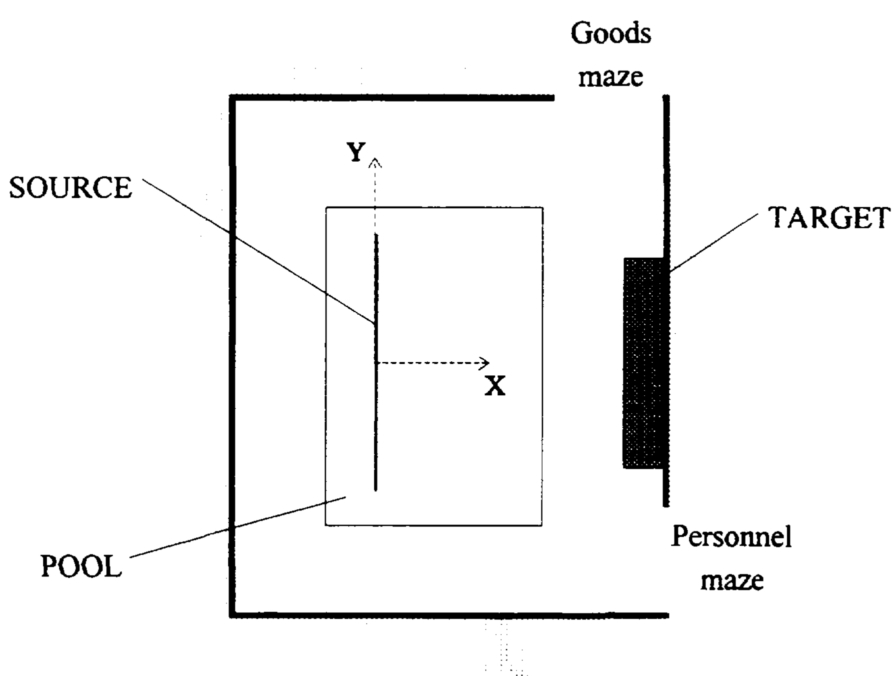

FIG. 4. Static irradiation geometry. Z axis perpendicularly on the drawing plan.

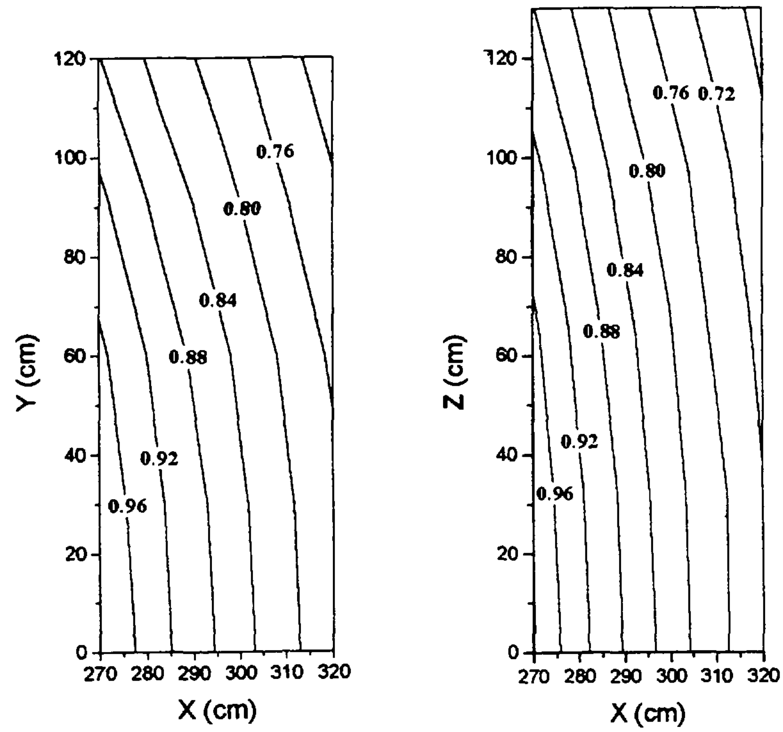

FIG. 5. Air absorbed dose rate maps for static irradiation.

6. CONCLUSIONS

This paper presents the philosophy standing behind the design, the short and long term managing plans for the Multipurpose Irradiation Facility IRASM.

The facility is designed for optionally batch or continuous mode of operation. The initial source of 100 kCi could be upgraded till 2 MCi - Co 60. The facility includes a number of laboratories for microbiology, dosimetry and chemical, physical-mechanical analyses. A public acceptance room is also previewed. Another room is dedicated to conservation of cultural heritage. By a split source rack design, the minimum dose is lowered in food irradiation range.

Some dose calculations are added in the view of use the empty spaces in the irradiation room for cultural heritage conservation. It was identified a useful space of ~ 3 cu.m. where the overdose ratio probably will not exceed 10, in 0.5 m depth, for items of 0.5 t/cu.m. density. In wood disinsectization, 500 Gy is commonly taken as useful dose for eradication. The wood structure is not affected by ten times more dose.

An economical study is presented aiming to provide basic estimations for further management strategy. It was considered the promotion stage (the most unpredictable), having in mind two possible ways of evolution of the facility. If it will remain a demonstration facility, first proposed scenario could be followed. The second scenario, being cheaper, is more proper in case the facility will have the status of a contract irradiator.

The design philosophy and management plans have both very important roles in a strategy aimed to minimize the promotion costs.

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