PROCESSING COST OF RVNRL

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ABSTRACT

The main components contributing to the cost of building a pilot plant for RVNRL are highlighted. The fixed cost and operating cost of a pilot plant were determined and the production capacity andthe cost to prepare 1 kg of RVNRL were calculated. Two sets of calculations were presented. A set was based on a pilot plant installed with cobalt-60 source of 150 kCi and another set was based on a plant installed with cobalt-60 source of 1 MCi. The effect of differents power utilisation effeciencies and the effect of different vulcanisation doses on the production capacities are presented.In general, a small difference in the vulcanisation dose and powere utilisation efficiency result in a significant change in the production capacity and the cost for RVNRL preparation. Depending on the production capacity, the cost for preparing RVNRL of 50% total solid content can be as low as RM 0.242 per kilogramms.

INTRODUCTION

Though research studies on RVNRL started as early as 1960's in Europe, the potential applications are identified, and the advantages are well defined and ready for users exploitations. However, until to-day no latex irradiator capable of producing RVNRL on commercial scale is available. The effort to scale up RVNRL preparation in Indonesia and India are limited to pilot plant stage. Moreover, the production rate is very slow and hence the production capacity is very small.

In March 1996 a pilot plant cum commercial latex irradiator was commissioned in MINT. The plant is designed as 1 MCi dry source storage. It is designed to prepare at least 6 000 tons of RVNRL per annum. It is a continuous system, different from those pilot plant latex irradiators available in Indonesia and India which are batch systems.

The major component of MINT's latex irradiator besides those used for the formulation of natural rubber latex are as folows:

- feeding tank
- hydraulically operated latex pump station
- dosimeter insertion and retrieval station
- irradiation matrix
- biological shielding
- cobalt-60 source
- safety interlocking system
- computer control system.

From the results of RVNRL preparations carried out at the pilot plant scale it is proven that scale up RVNRL preparation is possible and ready for commercial production. Hence cost analysis on RVNRL processing is very important as this will another factor to determine the commercial prospect of the material.

METHOD

RVNRL processing cost analysis are done based on the MINT's latex irradiator. The processing costs are calculated based on the irradiator being installed with 150 kCi of cobalt-60 and when the irradiator is installed with 1 MCi of cobalt-60.

Estimated Cost of Asset

The estimated cost of asset is the sum of the costs for the land, building, irradiation facilities, latex formulation facilities and cobalt-60 gamma irradiation source. Details are given in Table 1. The cost of the land is not included as the plant is built on an existing premises and government's own.

Table 1: Estimated cost of asset for a latex irradiator plant

		Cobalt-60 Source	
		150 kCi	1 MCi
i)	Land		
ii)	Building - equiped with biological shielding, a research laboratory, testing laboratory, dosimetry laboratory, administrative room, a common room, wash room, store room, M & E room.	RM 1 500 000.00	RM 1 500 000.00
iii)	Irradiation facilities, equipped with latex pumping station, irradiation pipe (350 metres), computerised irradiation control panel.	RM 3 500 000.00	RM 3 500 000.00
iv)	Latex formulation facilities include receiving, mixing, storing tanks plus stirrer motors and stirrer blades, electrical fittings etc.	RM 400 000.00	RM 400 000.00
v)	Cobalt-60 source	RM 750 000.00	RM 5 000 000.00
	Total	RM 6 150 000.00	RM 10 400 000.00

Cost Calculation

The elements contributing to the cost for preparing RVNRL using the latex irradiator are categorised into two:-
i. Fixed cost, appeared in the calculation as depreciation cost, and
ii. Operating cost.

Fixed cost is contributed by the depreciation cost of building, irradiation facilities and formulation facilities. Operating cost is contributed by maintenance service and spares, cobalt-60 replanishment, wages, utilities, telecomunications and administration services, sensitiser water and stabiliser. Details are given in Table 2 and Table 3 respectively.

Table 2: Details of the elements contribute to the fixed cost.

	Facilities	Cost
i)	Building depreciation (life time of 15 years)	RM 100 000.00
ii)	Irradiation facilities depreciation (life time of 10 years)	RM 350 000.00
iii)	Formulation facilities depreciation (life time of 10 years)	RM 40 000.00
	Total	RM 490 000.00

Table 3: Operating cost of latex irradiator plant installed either with 150 kCi or 1MCi of cobalt-60.

		Cobalt-60 Source	
		150 kCi	1 MCi
i)	Maintenance service and spares for formulation facilities	RM 6 000.00	RM 6 000.00
ii)	Irradiation source replanishment, taken as 12 % of the initial cost annually	RM 42 000.00	RM 560 000.00
iii)	Wages a) 1 Plat Manager b) 2 QC Managers c) Plant Operator 1 Senior Technician 4 Technicians d) 8 Latex Formulators e) 1 Latex/RVNRL Handlers	RM 233 000.00	RM 233 000.00
iv)	Utilities	RM 20 000.00	RM 20 000.00
v)	Telecomunications and administration services	RM 15 000.00	RM 15 000.00
vi)	Sensitiser	Will be determined by the amount of latex used	
vii)	Stabiliser		
viii)	Water		
	Total	RM 316 000.00	RM 834 000.00

Estimation of RVNRL Production Capacity

If cobalt-60 source strength is 100 kCi :-

$$100 \text{ kCi} \xrightarrow[\text{power}]{\text{emitted}} 1.48 \text{ kW}$$

Assumed the irradiation dose require for RVNRL preparation is between 10 to 15 kGy i.e 1 to 1.5 Mrad.
1 Mrad may be defined as:

$$1 \text{ Mrad} = 10 \text{ kGy} = 10 \text{ kJ per kg}$$

$$1 \text{ Gy} = 1\text{J per kg}$$

$$100 \text{ rad} = 1 \text{ Gy}$$

$$10 \text{ kJ/kg} = 10 \text{ kJ per s} \times \text{s per kg}$$

$$= 10 \text{ kWs per kg}$$

$$1 \text{ Watt} = 1 \text{ J per s}$$

$$1 \text{ Mrad} = 10 \text{ kGy} = 10 \text{ kWs per kg}$$

$$= \frac{10}{3600} \text{ kWhr per kg}$$

$$= \frac{1}{360} \text{ kWhr per kg}$$

Production rate, M may be calculated using the following formula:-

$$M = 360 \cdot f \cdot \frac{P}{D} \text{ kg per hr}$$

where f = Power utilisation efficiency i.e the efficiency of using the power from the radiation source cobalt-60

D = Vulcanisation dose, Mrad

P = Power emitted, kW.

The efficiency of power utilisation may vary, say from 20% to 50% depending on the irradiation system and the irradiation field.

Assuming a pilot plant is installed with 150 kCi of cobalt-60 source, power utilisation efficiency of 25% and vulcanisation dose of 1.2 Mrad (12 kGy), the rate of RVNRL production:-

$$M = 360 \times 0.25 \times \frac{2.22}{1.2} \text{ kg per hr.}$$

$$= 166.5 \text{ kg per hr.}$$

If the plant is operated 24 hours per day, daily production:-

166.5 kg x 24 = 3 996 kg per day

Monthly production:-

3 996 kg x 28 = 111 888 kg per month

Yearly production:-

111 888 kg x 12 = 1 342 656 kg per year

Irradiation cost:-

Cost to irradiate 1 kg of latex (50% t.s.c):-

$$\frac{\text{Fixed cost + Operating cost}}{\text{Production capacity}} = \text{Irradiation cost}$$

$$\frac{\text{RM 806 000.00}}{\text{1 342 656}} = \text{RM 0.60 per kg.}$$

Latex as it is may be vulcanised by radiation. However, the irradiation dose required is extremely high, 40 Mrad or above. Therefore in an effort to reduce the vulcanisation dose and make the process more economical and attractive to the users, prior to irradiation stage latex must first be formulated. The materials used and their cost to formulate latex to prepare a required amount of RVNRL is presented below.

To prepare 1 342 656 kg of RVNRL the amount and cost of materials required are as follows:-

Latex (62% t.s.c)	= 1 121 342 kg (will depend on market price)		
Sensitiser (5 pphr)	= 33 570 kg	@ RM 3.60	= RM 120 852.00
Stabiliser (0.02 pphr)	= 137 kg	@ RM 35.00	= RM 4 795.00
Water	= 187 850 kg	@ RM 0.003	= RM 563.00
			RM 126 210.00

Cost to formulate 1 kg of latex:-

$$\frac{\text{Cost of sensitiser + Cost of stabiliser + Cost of water}}{\text{Quantity of RVNRL}} = \text{Cost of Formulation}$$

$$\frac{\text{RM 126 210.00}}{\text{1 342 656}} = \text{RM 0.094 per kg}$$

Hence, the cost to prepare 1 kg of RVNRL:-

Cost to formulate latex + Cost to irradiate latex = Cost of RVNRL

RM 0.094 + RM 0.600 = RM 0.694 per kg of RVNRL

If plant is installed with 1 MCi of cobalt-60 source, assume power utilisation efficiency is 25% and vulcanisation dose is 1.2 Mrad (12 kGy) the rate of RVNRL production:-

$$M = 360 \times 0.25 \times \frac{14.8}{1.2} = 1\,110 \text{ kg per hour}$$

If the plant is operated 24 hours per day, daily production:-

111 0 kg x 24 = 26 640 kg per day

Monthly production:-

Say the plant is operated 28 days in a month:-

26 640 kg x 28 = 745 920 kg per month

Yearly production:-

745 920 kg x 12 = 8 951 040 kg per year

Irradiation cost:-

Cost to irradiate 1 kg of latex (50% t.s.c):-

$$\frac{\text{RM } 1\,324\,000}{8\,951\,040} = \text{RM } 0.148 \text{ per kg.}$$

Formulation cost:-

Latex	= 7 474 947 kg (will depend on market price)	
Sensitiser (5 phr)	= 223 774 kg @ RM 3.60	= RM 805 600.00
Stabiliser (0.02 phr)	= 912 kg @ RM 35.00	= RM 31 905.00
Water (to dilute to 50% t.s.c)	= 1 252 327 kg @ RM 0.03	= RM 3 757.00
		= RM 841 262.00

Cost to formulate 1 kg of latex:

$$\frac{\text{RM } 841\,262}{8\,951\,040} = \text{RM } 0.094 \text{ per kg}$$

Hence cost to prepare 1 kg of RVNRL:

RM 0.094 + RM 0.148 = RM 0.242 per kg RVNR

Please note that the price of materials used in this calculations are based on spot purchased using government local order. The price of cobalt-60 is RM 5.00 per Curie, the price of the sensitiser and stabiliser is RM 3.60 per kg and RM 35.00 per kg respectively and water cost RM 0.03 per kg.

Table 4: Cost distribution in RVNRL production

	Cost	Percentage of Total Cost, %
Building and facilities depreciation	RM 490 000.00	23
Cobalt-60 source replanishment	RM 560 000.00	26
Wages	RM 233 000.00	11
Sensitiser, stabiliser and water	RM 839 890.00	39
Utilities, administration, maintenance and spares	RM 41 000.00	2
Total cost	RM 2 163 890.00	per year

It is shown in the Table 4 that in RVNRL production the cost of purchasing the required amonut of sensitiser, stabiliser and water accounted for the highest percentage of the total cost. Any possibilty of reducing the amount of these materials use in the process will definitely help to make the cost of RVNRL more atttractive to the users.

Effect of Power Utilisation Efficiency on The Production Capacity

At a fixed cobalt-60 source of 1 MCi and latex vulcanisation dose of 12.0 kGy the effect of power utilisation efficiency on the rate of RVNRL production is given in Table 5.

Table 5: Effect of plant efficiency on the production capacity of RVNRL

Efficiency, %	Production Capacity, kg			
	Hourly	Daily	Monthly	Yearly
20	888	21 312	596 736	7 160 832
25	1 110	26 640	745 920	8 951 040
30	1 332	31 968	895 104	10 741 248
35	1 554	37 296	1 044 288	12 531 456
40	1 776	42 624	1 193 472	14 321 669
45	1 998	47 952	1 342 656	16 111 872
50	2 220	53 288	1 491 840	17 902 080

From Table 5, it seems that the production capacity increases as the irradiator efficiency increases. More significant increased in the production capacity is observed when efficiency improvement is made to an irradiator of a low efficiency compared to when efficiency improvement is made to a plant of already sufficiently high in efficiency. Furthermore, no proper correlation is observed between the efficiency improvement and the increment in production capacity. The results is presented graphically in Figure 1.

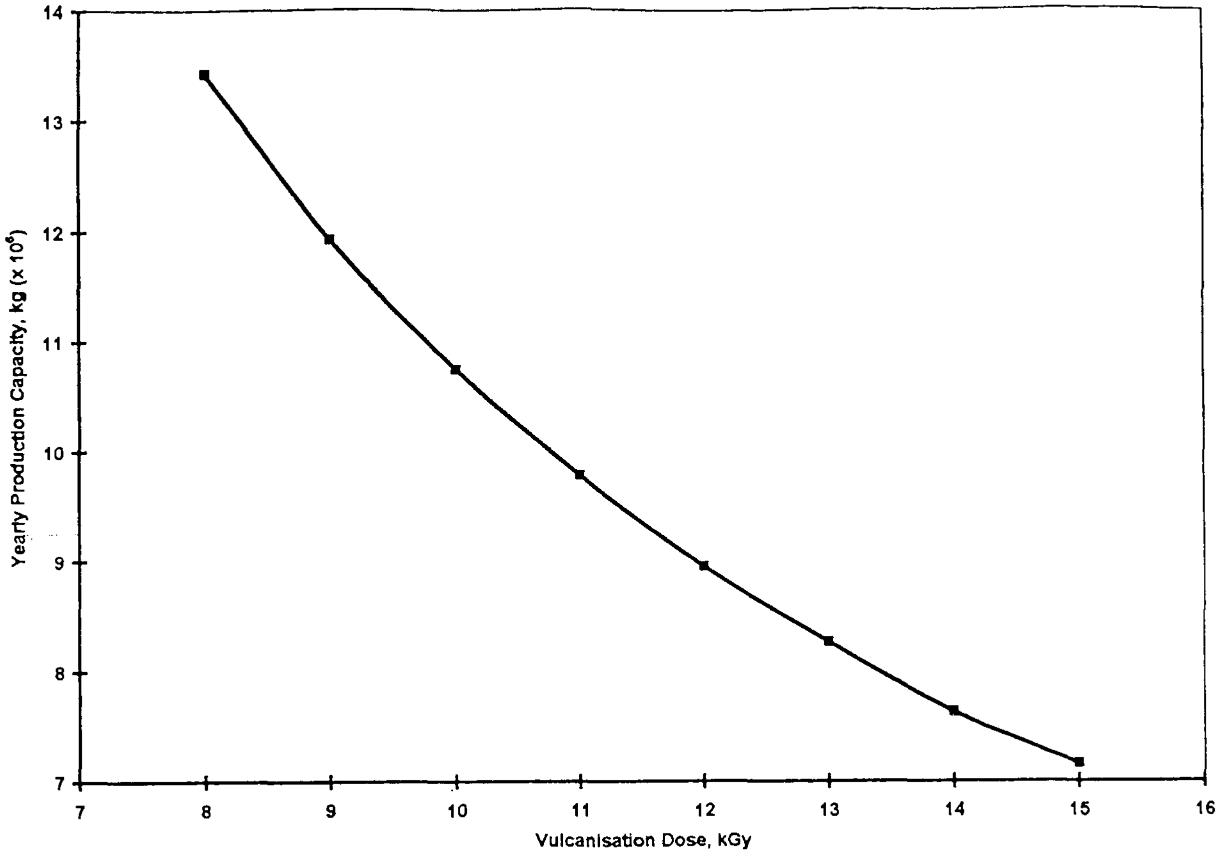

Figure 1: Effect of vulcanisation dose on a production capacity of RVNRL

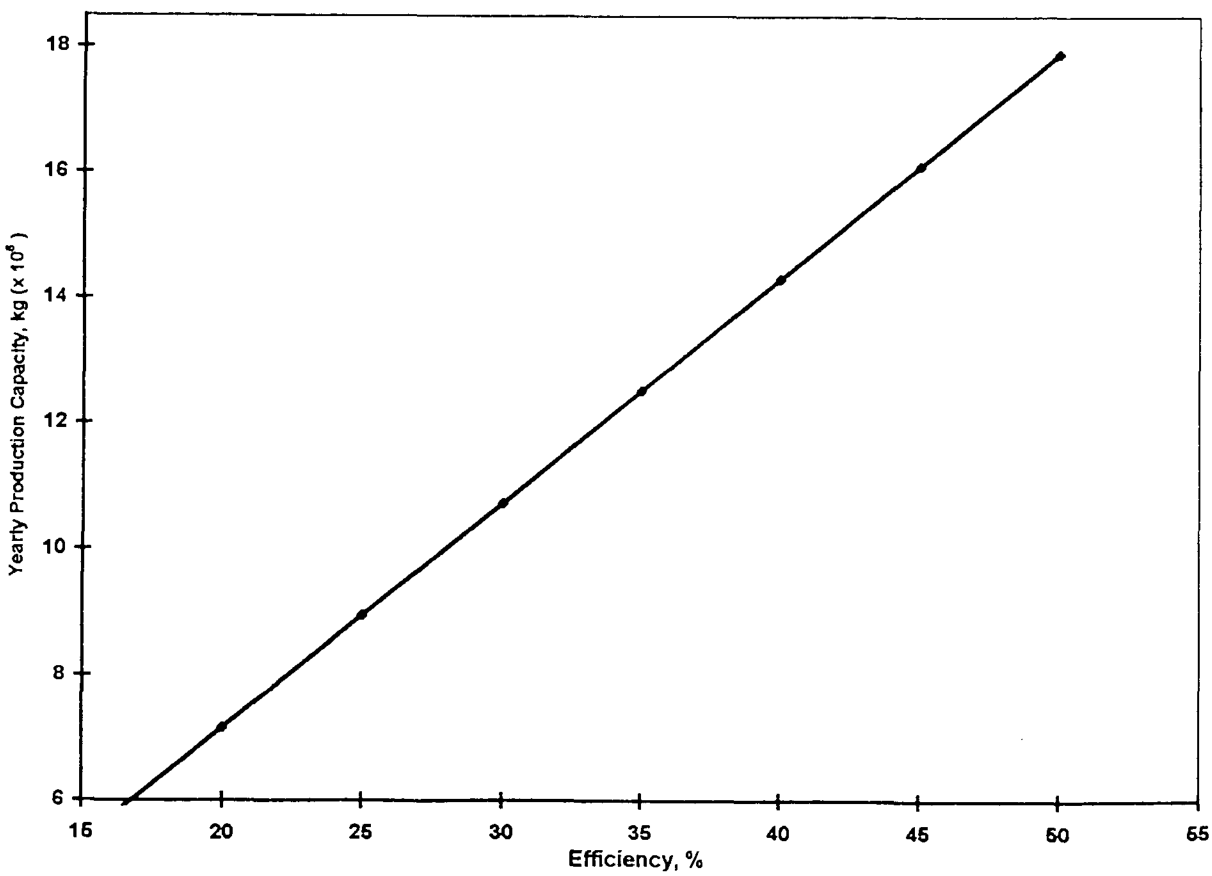

Figure 2: Effect of plant efficiency on a production capacity of RVNRL

Effect of Vulcanisation Dose on The Production Capacity

At a fixed cobalt-60 source of 1 MCi and plant power utilisation efficiency of 25%, the effect of different vulcanisation doses on the production capacity of RVNRL is given in Table 6.

Table 6: Effect of vulcanisation dose on the production capacity of RVNRL

	Production Capacity, kg			
Vulcanisation dose, kGy	Hourly	Daily	Monthly	Yearly
8	1 665	39 960	1 111 880	13 426 860
9	1 480	35 520	994 560	11 934 720
10	1 332	31 968	895 104	10 741 248
11	1 211	29 062	813 731	9 764 771
12	1 110	26 640	745 920	8 951 040
13	1 025	24 591	688 341	8 262 498
14	951	22 834	639 360	7 672 320
15	888	21 312	596 736	7 160 832

From Table 6, it shows that the production capacity decreases with the increased in the vulcanisation dose used in RVNRL preparations. Graphical representation of the results is given in Figure 2. Therefore, using latex of right maturity is important to ensure high through put of the plant and hence reduces the cost of RVNRL processing.

CONCLUSIONS

The cost to prepare RVNRL is determined by many factors, among them are the cost of sensitiser and stabiliser, the efficiency of the plant and irradiation vulcanisation dose employed in RVNRL preparation.

The price of RVNRL and the price of sulphur prevulcanised latex can be very competitive especially when RVNRL production is 8 000 tons or more.

QUESTIONS & ANSWERS, and COMMENTS

Session IV

Q1	Yaziz	How do we establish the homogeneity of the latex in the irradiator so designed?
A1	**E. Smolko**	**The latex is homogenised through the pumping action and circulation of the latex around the gamma source. The dose distribution problem could be solved using a suitable source design.**
Q2		How do we check the dosimetry?
A2	**E. Smolko**	**Use solid dosimeters.**