Reduction of Viable Bacteria in Latex by Ultra-Violet Irradiation

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Bactericidal effects in natural rubber latex (ammoniated) resulting from ultra-violet irradiation were investigated quantitatively. Two systems of irradiation were examined; firstly a jacket tube device in which either flowing or stationary latex could be irradiated; secondly a jacket tube device in which a very thin film of latex was exposed to radiation. The first system was shown to be impracticable under the conditions studied. The second system gave a satisfactory and consistent reduction in viable bacterial population. At the intensities of u.v. radiation studied, no adverse effect on rubber properties was detected. The cost of operation of bactericidal irradiation of latex is shown to be rather high.

The importance of bactericidal effects in latex preservation and shipment overseas are well established (TAYSUM, 1957). In all cases where ammonia is present at low concentrations, bactericidal measures are of prime importance in preservation. Lower V.F.A., lower KOH number and high mechanical stability are some of the effects expected to result from sterilising the latex (GRAHAM AND TAYSUM).

It has been known for a long time that ultra-violet (u.v.) radiation can kill or at least inhibit the reproduction of micro-organisms, and investigations have established that wavelengths between about 2,500 and 2,700 Ångstrom units (Å) are the most effective (WYCKOFF, 1932). The lethal action of u.v. radiation has been found to have a temperature coefficient of approximately 1.1 (BAYNE-JONES AND VAN DER LINGEN, 1923). Ultra-violet irradiation has been successfully adopted to reduce the viable bacterial population of blood plasma (VALLET, 1957).

Ultra-violet irradiation of field and concentrated latices gave promising reductions in viable bacterial population in small scale trials using a Hanovia 9-watt spiral lamp (Model 18) and a G.E.C. 30-watt germicidal lamp to irradiate the latex. When field latex (ammoniated to 0.3%) and latex concentrate (ammoniated to 0.7%) were exposed to u.v. irradiation by immersing the u.v. lamp in latex about 2 mm deep in a beaker for 30 seconds, the following percentage reductions in viable bacteria were obtained (TAYSUM, 1956a):

Field latex	99%
Latex concentrate	90%

In view of these results further investigations which are described in this paper were initiated, the aims being: to investigate different types of irradiation systems suitable for commercial application; to see whether u.v. irradiation has an adverse effect on rubber; to estimate the cost and value of irradiation. Complete sterilisation of latex was not attempted.

EXPERIMENTAL METHODS

1. *Apparatus and Procedure for Irradiation*

(a) *Flow type apparatus.* The u.v. tube, either a Hanovia 30 watt (2537Å) straight-tube lamp with ozone reducing filter (Model 13A) or a G.E.C. 30 watt (2537Å) germicidal lamp, was fitted with an aluminium jacket, the annulus between the tube and the jacket (3 to 6 mm) being filled with field latex. The Rubber Research Institute Experiment Station

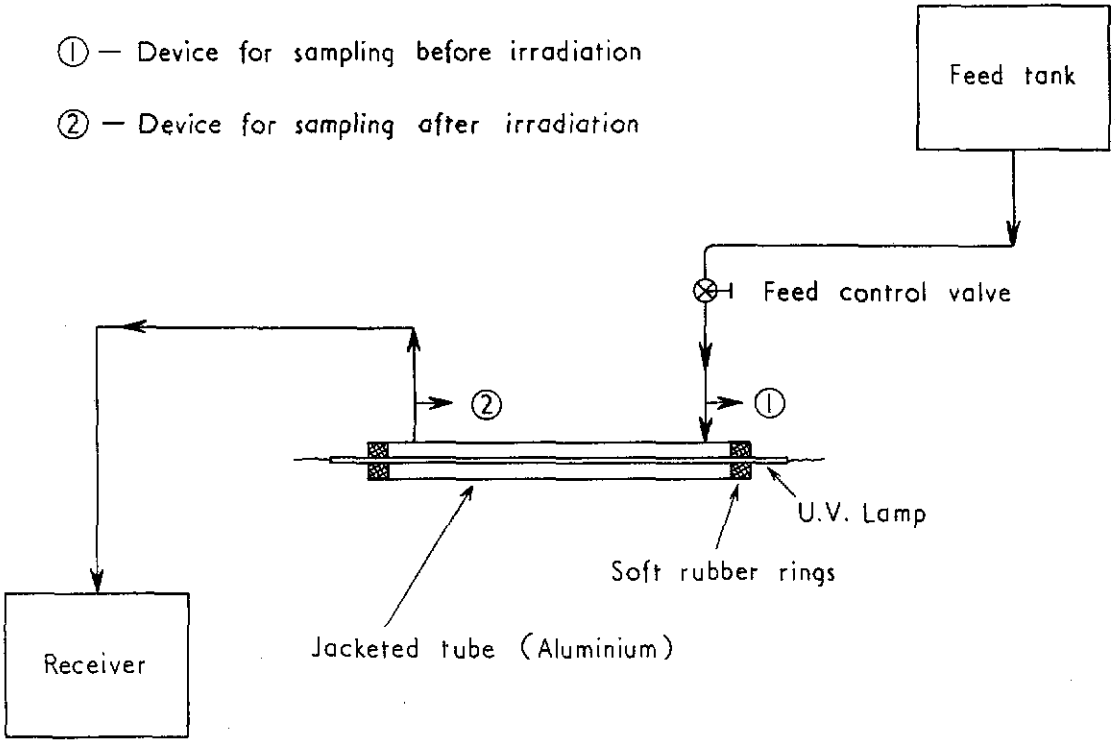

Figure 1. Jacket tube (flow type) apparatus for the irradiation of latex.

factory bulk from daily collection was used in all cases. For the study of short periods of irradiation (1 to 70 seconds) latex flowed through the apparatus continuously from a feed (head) tank (*Figure 1*). The procedure of the experiment was briefly as follows. The floor and the plant were washed with 5% chlorinated tri-sodium phosphate to ensure initial sterilisation. The u.v. lamp and the jacket tube were fixed in position using soft rubber rings. The latex was then poured into the feed tank and the flow rate of latex through the annulus was adjusted to give a pre-determined time of contact. Samples were taken before and after u.v. irradiation for bacterial counts.

For longer periods of irradiation (10 to 75 minutes) the latex was treated in batches, the latex being poured in to fill the annulus and allowed to remain stationary during irradiation.

(b) *Film type apparatus.* The second apparatus enabled a very thin film about (0.1 mm) to be exposed to radiation. It consisted of a jacket tube (either glass or aluminium) 2.5 in. in diameter with soft annular rubber rings (external diameter 2.5 in., internal diameter 1.625 in.) attached at the ends. The u.v. lamp (either Hanovia or G.E.C.) was placed in the middle, leaving a considerable gap between the lamp and the rubber rings.

The experimental procedure was as follows. The jacket tube was initially sterilised by the u.v. lamp for about 15 minutes. Twenty-five c.c. of the latex were then pipetted in. The jacket tube was then rotated fairly rapidly (about 20 r.p.m.) by hand, so that a thin film of latex was formed around the inner surface of the jacket tube. The thin film was then exposed to u.v. radiation for one minute. Samples of latex were taken immediately

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TABLE 1. REDUCTION IN VIABLE BACTERIAL POPULATION OBTAINED WITH ROTATING TUBE SYSTEM

(Time of exposure to irradiation one minute)

Hanovia (30 Watt) straight tube lamp

Expt No.	Total number of viable bacteria per ml		Percentage reduction in viable bacteria
	Before irradiation	After irradiation	
1	3.3×10^4	1.3×10^4	60.6
2	2.9×10^4	3.5×10^3	88.0
3	1.6×10^5	4.2×10^3	97.5
4	2.6×10^5	6.0×10^4	77.0
5	2.9×10^5	1.1×10^4	99.7
6	1.2×10^6	1.0×10^5	91.7
7	1.4×10^6	5.7×10^5	59.3
8	2.0×10^6	1.5×10^5	92.5
9	9.2×10^6	7.6×10^5	91.7
10	1.6×10^7	1.1×10^6	93.1
11	2.8×10^7	6.3×10^6	77.5
12	7.1×10^5	3.3×10^4	95.5
13	1.0×10^7	1.0×10^6	90.0
14	1.0×10^5	4.0×10^3	96.0
15	9.1×10^5	1.2×10^4	98.7
16	7.0×10^4	2.2×10^3	96.9
17	1.4×10^5	9.2×10^3	93.5
18	5.6×10^5	2.9×10^4	94.8

G.E.C. (30 Watt) germicidal lamp

1	1.8×10^3	nil	100.0
2	2.1×10^4	6.8×10^3	67.6
3	2.0×10^5	8.6×10^4	57.0
4	2.9×10^5	3.1×10^4	89.3
5	5.0×10^5	1.1×10^5	78.0
6	5.6×10^5	2.4×10^4	95.7
7	4.7×10^5	9.0×10^3	98.1
8	4.2×10^4	9.5×10^3	77.4

before and after irradiation for bacterial counts.

In all the above experiments, sterile glass test tubes capped with a sterile non-absorbent plug of cotton wool and containing a trace of sterile isotonic saline (0.85% w/w NaCl) were used for sampling purposes. A modified Kligler's iron agar medium was used for estimating the viable bacterial population of latex samples (TAYSUM, 1956b).

2. *Estimation of the Effect of u.v. Irradiation on the Ageing Properties of Rubber*

Total solids (T.S.) films and coagulated rubber samples were prepared from untreated and irradiated latices and the 'D_{10} plasticity' values measured before and after 72 hours oven ageing at 100°C. The irradiated latices were obtained from rotating tube (film type) irradiation experiments.

RESULTS AND CONCLUSIONS

Flow Type Apparatus

Out of 28 samples irradiated with a Hanovia straight tube lamp, using an exposure time of 1 to 2 seconds and an annulus width of 3 mm,

7 gave no reduction in viable bacteria,
8 gave 10 to 50% reduction,
3 gave 50 to 70% reduction,
3 gave 70 to 90% reduction,
7 gave 90 to 97% reduction.

Out of 40 samples irradiated with a G.E.C. germicidal lamp, using 20 to 70 seconds exposure time and an annulus width of 6mm,

8 gave no reduction in viable bacteria and
32 gave 0.6 to 32% reduction in viable bacteria.

Thus the results obtained with flow conditions are inconsistent and no definite conclusion can be derived. However, it can be generally stated that in the majority of the cases the percentage reductions in bacterial population obtained are low.

Flow Type Apparatus. Latex Stationary

Of the 3 samples irradiated with a Hanovia straight tube lamp, using an annulus width of 3 mm,

1 gave 94% reduction in viable bacteria with 10 minutes exposure time,
1 gave 95% reduction in viable bacteria with 30 minutes exposure time,
1 gave 99.5% reduction in viable bacteria with 75 minutes exposure time.

In all the above cases a film of rubber was formed on the surface of the u.v. tube. This is considered to be undesirable.

Film Type Apparatus (Rotating Tube)

Out of 18 samples irradiated with a Hanovia straight tube lamp, and exposed for 1 minute,

2 gave 50 to 70% reduction in viable bacteria,
3 gave 70 to 90% reduction,
13 gave 90 to 98.5% reduction.

Out of 8 samples irradiated with G.E.C. germicidal lamp, and exposed for 1 minute,

2 gave 50 to 70% reduction in viable bacteria,
3 gave 70 to 90% reduction,
3 gave 90 to 100% reduction.

As the percentage reductions in bacterial population obtained are high and consistent, it is concluded that the rotating tube type of irradiation is more satisfactory than the others.

Detailed results of both Hanovia and G.E.C. lamp experiments are given in *Table 1*.

The results are given in terms of a numerical bacterial count without error estimate but their application for the purpose of this paper is only to show the trend in the reduction of bacterial population and its consistency.

TABLE 2. AGEING OF RUBBER FROM LATICES OBTAINED BEFORE AND AFTER IRRADIATION,* USING A ROTATING TUBE APPARATUS

Expt No	Designation	Williams Plasticity				Remarks
		Normal		Oven : 72 hrs T = 100°c		
		D_{10}	Recovery	D_{10}	Recovery	
1	before irradiation	2.76	3.35	2.98	4.67	Total solids film
	after irradiation	2.91	3.62	2.82	4.84	
	before irradiation	2.91	3.65	1.41	1.79	Coagulated rubber
	after irradiation	2.65	3.40	1.38	1.64	
2	before irradiation	3.30	4.92	3.15	5.24	Total solids film
	after irradiation	3.12	4.69	2.95	4.93	
	before irradiation	2.58	5.41	2.08	2.57	Coagulated rubber
	after irradiation	3.38	5.21	2.48	3.29	
3	before irradiation	2.75	3.50	2.72	4.13	Total solids film
	after irradiation	2.97	3.91	2.84	4.80	
	before irradiation	2.90	3.81	2.25	2.99	Coagulated rubber
	after irradiation	3.25	4.36	2.67	3.98	

*Reduction in bacterial population after irradiation was approx. 95%

Ageing

The results obtained for ageing of rubber from untreated and irradiated latices are given in *Table 2*. There is no significant difference in ageing properties between the two rubbers.

COST ESTIMATION

The cost estimation is based on the rotating tube irradiation system in which the latex was exposed to u.v. radiation in a form of thin film, as it gave a satisfactory and consistent reduction in viable bacterial population.

Taking 25 c.c. per minute of 36% d.r.c. field latex (or 9 gm of rubber per minute) as the throughput per tube, the power required for a 30 watt lamp is 0.025 kWh per pound of rubber. Assuming the cost of power as 7 cents (Malayan) per kWh, the cost of power required to operate the unit is 0.175 cents per pound of rubber. Assuming that a lamp has a normal life of 3,000 hours (HANOVIA LTD, 1957) and an initial cost of $30, the depreciation charge is 0.84 cent per pound of rubber. Thus the total cost including power and depreciation for lamps, but excluding the cost of labour and the capital depreciation for the plant, is 1.0 cent per pound of rubber.

A plant with 100 gallons per hour throughput would require 303 u.v. lamp units and the capital cost of lamps would be approximately $9,000 (Malayan).

DISCUSSION

Inconsistent reductions in viable bacteria were obtained using the jacket tube apparatus to give a short time of contact under flow conditions. Longer times of exposure with the latex remaining stationary gave a good bacterial kill, but unfortunately under these conditions a film of rubber formed on the surface of the tube, probably due to heating of the latex.

The exposure of the latex in the form of a very thin film, e.g. 0.1 mm thickness, overcame this difficulty and good reductions were obtained with an exposure of one minute. No differences in ageing properties were observed between the rubber samples from untreated and irradiated latex.

The economics of the process are, however, less encouraging. The total cost of power, and the depreciation charge for the lamps is 1.0 cent (Malayan) per pound of rubber. Although the degree of bacterial kill obtained would be valuable as a means of improving preservation, the cost as estimated is excessive.

The project thus appears uneconomic at present, unless a cheaper source of u.v. radiation can be obtained. An alternative method, which might prove more economic and could be considered for further investigation, is to employ higher intensity u.v. sources permitting the use of thicker films.

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