MULTI-G.M. TUBE SYSTEM FOR RADIOISOTOPE ASSAY IN BIOMEDICAL USE

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The construction, characteristics and calibration of a system useful for certain types of radioisotope assay in clinical radioisotopic work has been described. This instrument uses indigenously produced G. M. tubes and other electronics. The system consists of a ring of 8 G. M. counters and has the advantage of accepting solid or liquid samples over a wide range of volumes. Some potential clinical applications as well as the limitations of the system are also described.

In clinical investigations using radioisotopes for research, diagnosis or therapy a frequent requirement is the assay of activity in body fluids and excreta. The amount of sample available may vary from a few *ml.* in the case of blood samples to more than a litre in urine collections. The quantity of isotope (generally a gamma emitter) present in the sample may vary from a small fraction of a microcurie to several millicuries. For patients given therapeutic doses, a method for rapid (but comparatively rough) estimation of activity in excreta is desirable to decide on the safe method of excreta disposal.

CHOICE OF DETECTING SYSTEM

The main criteria governing the choice of the detecting system are : (*i*) High intrinsic sensitivity of detector system (*ii*) Favourable geometry (*iii*) Ability to accept solid or liquid samples in a wide range of volumes and (*iv*) Cost.

For gamma emitting isotopes, the G.M. counter has an intrinsic efficiency of less than I per cent. *NaI* scintillators have a much higher intrinsic efficiency (about 30%). For in-vitro counting well-type scintillation counters are normally used since they can also give excellent geometry. However, normal wells do not accept samples more than a few ml. and faecal samples will have to be homogenised before being introduced into the well counter. G. M. counters are inexpensive compared to *NaI* scintillation counters.

Veall and Vetter [1, 2] have given a design of a multiprobe G.M. counter system which is ideally suited for such requirements and has found extensive application in many clinical radioisotope laboratories all over the world. The system essentially consists of a ring of vertical G.M. counters arranged along the circumference of a cylinder. Inside the ring is placed the sample to be counted.

A similar system that has been fabricated at this Institute using indigenously available G. M. counters, electronic systems and other accessories, has been described.

CONSTRUCTIONAL DETAILS

Two designs have been fabricated, the first using a ring of 6 G.M. counters and the other one employing a ring of 8 tubes. The details of which are given below :

The G. M. counters are of the type AEETI 1,000, with the following specifications :

Halogen quenched	
Operating voltage	475 v
Overall length	15 cm
Sensitive length	8 cm
Cathode	4 mil thick stainless steel
Cathode diameter	19 mm
Background unshielded	↘100 c.p.m. (Horizontal position)
	↘50 c.p.m. (Vertical position)
Flexible fly leads	

The associated electronics used are :

AEET Type Decade Scaler	DS 321
AEET Type High Voltage Unit	HV 200
AEET Type Preset Timer	ET 450 A

The entire set up consisting of G.M. tubes, central platform for holding the samples lead shielding around and on top of the tubes, switches for choosing the desired number o, G. M. tubes is fabricated as an integral assembly fixed on a stand and moving on caster wheels. In view of the heavy weight (about 90 kg.) of the lead shielding, the construction has to be made fairly stable and sturdy.

The eight G. M. tubes are fixed vertically and at equal distances along the circumference of a cylinder of diameter 20 cm. Each tube is fitted with a male socket, fitting into a female socket. This arrangement permits a quick and easy changing of a G.M. tubes that might go bad. To reduce the background the detector sample holder assembly is surrounded by a cylindrical shell of lead (inner diameter 25 cm, height 25 cm and thickness 2·5 cm). On top there is a lead plate (30 cm × 30 cm × 2·5 cm), although practically in contact with the vertical lead shield, does not actually rest on this shield, but can be easily pushed horizontally by means of a handle provided. It moves on wheels which rests on rails of suitable length. This permits the top plate to be moved laterally whenever a sample is to be introduced and for closing it back once the sample is in position.

The sample is placed on a central circular table which is capable of vertical movement on a rack and pinion arrangement controlled by a graduated knob situated on the front panel. This enables proper position to samples of various sizes with respect to the sensitive areas of the G.M. tubes.

All the eight G.M. tubes are carefully selected and matched for their characteristics so that they can be operated with the same E.H.T. applied to all of them. The tubes are connected in parallel. Provision is made by means of a gang switch to utilize at a time only one G.M. tube, or a pair of tubes situated diagonally opposite, four alternate tubes, or all the eight tubes. This would permit samples of a wide range of activity to be measured conveniently without introducing many errors. A system is also incorporated for testing individually the performance of each tube in position. The controls (one switch for testing the performance of each tube, one switch for choosing 1, 2, 4 or 8 tubes for counting) are located in the front bakelite panel. Two amphenol sockets are given in this control panel, one for connecting the E.H.T. supply to the tubes and the other for taking the output

of the tubes. In order to conserve the life of the tubes, it is arranged that only those tubes out of the eight that are actually to be used for counting get the E. H. T. The associated electronics consisting of high voltage supply, scaler and timer are kept on a nearby table and connected to the detectors by two shielded cables. Fig. 1 (a) and (b) are photographs from different angles of the system. The total cost of the 8-tube set up comes to about Rs. 1,800·00 This does not include the cost of the associated electronics (H.V. supply, scaler, timer) which alone comes to about Rs. 4,200·00.

CALIBRATION STUDIES

The 2·5 cm shielding all around cuts the background by a factor of 2. The variation in sensitivity of the different tubes was less than 10 per cent. Since the dead time of these tubes was found to be of the order of 100 μs, the deadtime correction is less than 5 per cent even at 500 cps counting rate and need not be applied in practice.

Calibration studies were made by changing various parameters, one at a time. These studies established that

(i)   the count rate was linear with activity ;

(ii) the sensitivity (cpm/μc) was the same over a wide range of volumes from 5 ml to 1 litre (Fig. 2);

(iii) the positioning of the sample on the table was not at all critical (the sensitivity for a point source was constant at all points over a 5 cm circle radius around the centre);

(iv) for simulating counting of faecal samples, cotton pads soaked in isotope solution and kept inside a glass beaker were used. The sensitivity was independent
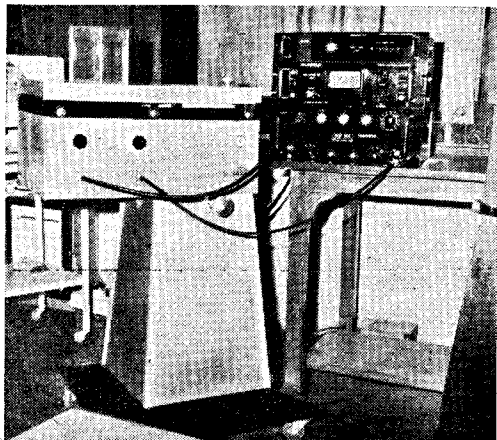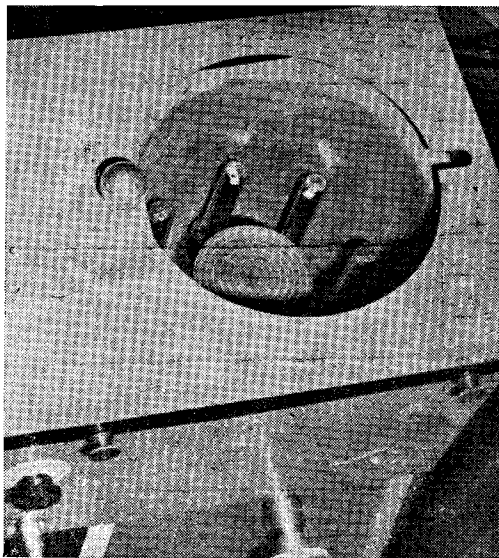
(a)   (b)

Fig. 1—G.M. tube system (a) Side view (b) Upper view

TABLE 1

CALIBRATION CHART FOR ISOTOPES

Number of tubes	Average net cpm/ c.				Background cpm	Net cpm/ c $c_p{}^{32}$
	Cs^{137}	I^{131}	Fe^{59}	Cr^{51}		
1	85	56·5	15·0	4·0	21	0·30
2	177	116·0	30·8	9·0	43	0·64
4	348	215·6	59·8	17·2	80	1·26
8	683	415·8	118·5	34·1	152	2·61

of whether the activity was distributed homogeneously or heterogeneously in the cotton pads. Further the sensitivity was the same whether the activity was contained in an aqueous solution or in the form of soaked cotton pads indicating that self-absorption effects can be neglected.

In addition to gamma emitting isotopes the set-up can also be used for estimation of isotopes which emit beta rays of sufficiently high energy, by means of bremsstra-hlung effects. As an example a P^{32} sample (maximum beta energy 1·7 Mev) in a glass vial was placed inside a lead pot one mm. thick. This thickness is sufficient to cut out all the beta rays. The X-rays produced as a result of interaction of the beta rays with lead produce an effect in the detector system.

Table 2 gives the minimum detectable activity for each of the isotopes, calculated under the following assumptions :

(i) All the G.M. tubes are used

(ii) Counting time is 10 minutes

(iii) A sample activity equal to three times the standard deviation in background (for a counting time of 10 minutes) is just detectable.
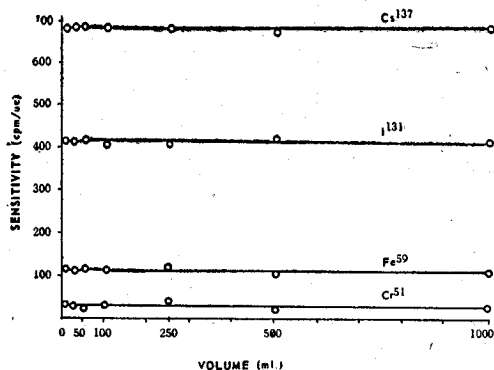

Fig. 2—Sensitivity (cpm/μc) vs sample volume.

TABLE 2

DETECTABLE ACTIVITY FOR ISOTOPES

Isotope	Minimum detectable activity in μc.
Cs^{137}	0·017
I^{131}	0·028
Fe^{59}	0·09
Cr^{51}	0·34

DISCUSSION

On the basis of the calibration studies it is seen that the system has the following advantages :

(i) The count rate varies linearly with activity and no correction would be needed for count rates up to about 30,000 cpm.

(ii) The count rate is not critically dependent on the positioning of the sample.

(iii) The count rate for a given activity is independent of volume of the sample. Volumes from 1 or 2 mil up to 1 litre can be easily measured.

(iv) The count rate is the same for homogeneous as well as heterogeneous distribution of activity and self-absorption even for faeces-like samples is not important. Faecal samples, collected in waxed cartons, can thus be counted as such without any homogenisation or other treatments.

(v) A wide range of activities, from about $0.02 \mu c$ to a few millicuries, can be immediately measured. The following choice of number of tubes is recommended for the different range of activities :

Less than 50 µc	8 (tubes)
50–150 µc	4 tubes
150–300 µc	2 tubes
More than 300 µc	1 tube

These levels have been arrived at in order not to have a counting rate exceeding about 500 cps.

For measurement of activities exceeding 1–2 millicuries, the single tube in use can be shielded by a rectangular plate of lead interposed between the source and the tube in order to cut down the flux of radiation reaching the detector to reasonable values.

LIMITATIONS

The G. M. tubes used are not particularly gamma sensitive. A G.M. tube to count gammas comparatively efficiently should have a cathode of high Z-material like lead or bismuth. Unfortunately, such tubes are not indigenously available.

Secondly the tubes are not of sufficient length, which would be helpful in two respects, viz. presenting a larger sensitive detector area and better geometry.

SOME POTENTIAL CLINICAL APPLICATIONS

Diagnostic Thyroid Studies—Estimation of activity excreted in urine after a tracer dose of I^{131} is a standard adjunct to the measurement of actual uptake by thyroid in estimation of thyroid function. Some laboratories in fact do only excretion studies for assessment of thyroid status. Urine activity can conveniently be measured by this system.

Uptake after Therapeutic Doses—A scintillation counter is somewhat too sensitive for the purpose of assessing uptake after a therapy dose of I^{131}. Measurement of urinary activity (which will be in the millicurie range) can easily be done by this system.

Assessment of activity in Excreta for Safe Disposal—The assessment of urinary or faecal activity after therapeutic doses of I^{131} or P^{32} can be quickly carried out with the system and would help in the proper choice of method of disposal.

Iron Metabolism—In iron metabolism investigations, faeces are collected for several days in succession after a tracer dose of $F_e{}^{59}$ until the activity excreted comes down to negligible values. Assay of activity in faecal samples can very conveniently be carried out by such a set up without any pretreatment or homogenisation of the samples.

Vitamin B_{12} Metabolism—In the study of anaemias Vitamin B_{12} absorption is an extremely valuable diagnostic tool. Vitamin B_{12} labelled with $Co{}^{58}$ is given as a tracer oral dose. Activity excreted in faeces is followed for several days. Another method is to give a dose of labelled vitamin, and after a short time to administer a flushing dose of non-active vitamin B_{12}. The activity that is excreted in the urine is then an index of the metabolism. The system described would be convenient for both types of studies.

Electrolyte Balance Studies—In studies of electrolyte balance using Na^{24} or K^{42}, urinary excretion pattern can be assessed by the set up and provides valuable diagnostic information.

ACKNOWLEDGEMENTS

REFERENCES

1. VEALL & VETTER, *Brit. J. Radiol.*, 25 (1932), 85.

2. VEALL & BAPTISTA, A. M., *Brit. J. Radiol.*, 27 (1954), 198