DESIGN AND PERFORMANCE OF INMAS WHOLE-BODY COUNTER

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(*Received* 28 *February* 1973 ; *revised* 25 *September* 1973)

A whole-body counter has been commissioned at INMAS for radiation protection and clinical applications including body potassium estimations. It uses 4-crystal stretcher bed geometry inside a shielded enclosure. The background index of the system (counts) per minute per cc of detector volume in the energy band 0·1–2 meV) is about 0·6, comparing favourably with other whole-body monitors in the world. The sensitivity is 0·5 cpm per gram of *K*. Body potassium can be estimated correct to 10 g for one hour counting. The variation in detector response to a point source on the mid-line of the bed is $\pm$ 10% of the mean over a length of 170 cm. The usefulness of the large dimensions of the enclosure chosen is discussed.

In view of the utility of whole-body counting as a sensitive and versatile tool in the fields of radiation protection and nuclear medicine, it was decided to install a whole-body counter at the Institute of Nuclear Medicine and Allied Sciences (INMAS) at Delhi.

Since INMAS uses a total of around 3 curies per year of a variety of unsealed radiation sources for diagnosis, therapy and research, the hazards of internal contamination of workers is ever present and the whole-body counter is accepted to be the most suitable monitoring device for internal contamination. Secondly, the whole body counter has defence applications for monitoring of the personnel who might be subjected to internal radioactive contamination in the event of fallout from a nuclear weapon burst. Thirdly, the potentialities of whole-body counting in clinical diagnosis and biomedical research have been increasingly realised over the last decade. In fact around 70% of the existing whole-body counters of the world are using them wholly or partly for clinical work with administered radiotracers[1]. In view of its high sensitivity, very low levels of tracers are required for carrying out the studies; the radiation dose to the patient is significantly lower and long-term studies can be carried out; further, excreta collection and assay can often be dispensed with.

FACTORS INFLUENCING DESIGN OF SYSTEM

Several choices are available for the design of the total system consisting of the detectors, electronic accessories, shielding and geometry of counting. If only diagnostic work with administered radiotracers in the microcurie range were the aim, a very high degree of sensitivity or background reduction would not be necessary and minimal shielding would suffice. A multi-channel analyser may not be required since only one specific isotope will be administered in the majority of cases; for the same reason plastic scintillator could be used in place of costlier *NaI* detector. The main objective here is to have a detector response fairly independent of source position in the body, since there is substantial redistribution of many tracers within the first few hours after administration. A shadow shield counter or a multicrystal stretcher bed geometry with a shielding of around 5 cm steel would be adequate for this requirement[2]. The Marinelli chair geometry[3] has limited utility for clinical work as the response in this geometry is rather dependent on source position. If monitoring for accidental contamination (either from occupational exposure or from fallout) is the objective, the requirement becomes the identification of the unknown contaminant and its quantitative assay at levels of the order of tenths of microcuries or less, which will be far below those encountered in diagnostic work. This would necessitate massive shielding and *NaI* detector with multi-channel analyser. The type of geometry would not be critical. If only body potassium estimates were to be made (based on measurement of about 0·1 μCi ^{40}K in the adult) sensitive detectors and massive shielding would be required but the detector could be a plastic scintillator and a single channel analyser in the absence of any other nuclide in the body[3]. Table 1 summarises the design and functional characteristics for some whole-body counters of other countries. For comparison, characteristics of the INMAS whole-body counter are also given.

TABLE 1

CHARACTERISTICS OF SOME WHOLE-BODY COUNTERS

USED FOR CLINICAL APPLICATIONS *vis-a-vis* THAT OF INMAS

Country	Shield thickness (cm) and material	Shield dimensions (m)	Detectors number	Detectors volume (cm^3)	Background index/cm^3	Sensitivity for ^{40}K cpm/gK
USA	20 *Fe*	1·85×1·55×2·56	1	6830	0·123	—
UK	12 *Fe* (underground)	3·05×1·41×1·96	4	7070	0·146	—
USA	20 *Fe* (underground)	2·40×2·10×1·80	4	6440	0·233	—
Netherlands	10 *Pb* (underground)	2·37×1·83×1·94 (open booth)	4	6480	0·267	0·440
Fed. Rep. Germany	15 *Fe* (underground)	1·37×0·62×1·40	4	4160	0·298	0·657
Fed. Rep. Germany	10 *Pb* (underground)	2·30×1·50×2·00	4	5160	0·373	1·039
UK	15 *Fe*	2·14×1·53×1·83	4	4680	0·420	0·960
USSR	15 *Fe*	2·14×1·53×1·83	4	4520	0·650	0·731
France	5 *Pb* (underground)	3·23×1·85×1·72	1	3300	0·773	0·829
UK	10 *Pb*	Shadow shield	1	345	1·035	0·031
Poland	15 *Fe* (underground)	1·90×1·10×1·20	1	1410	1·105	0·330
USSR	15 *Fe*	1·30 diameter×1·90	8	2020	1·270	0·536
Poland	75 *Pb*	1·90×0·70×0·95	1	630	3·855	0·233
UK	Chalk (underground)	2·10×1·50×1·80	3	660	3·900	0·140
INMAS India	20 *Fe*	3·6×3·6×2·4	4	4680	0·60	0·50

DESIGN DETAILS OF INMAS SYSTEM

Since it was desired to have a single system which combined all types of uses (including body potassium estimation), the design had to be versatile with sufficient scope for further development. It was felt that the multicrystal bed geometry (with *NaI* detectors and multi-channel analyser) in a well-shielded enclosure would be a good choice for the system. After having made this basic decision, Services of military engineers were obtained for designing of the whole-body counter building and the shielded enclosure inside it. Discussions with the scientists of the whole-body counter at BARC were also beneficial in the finalisation of the building plan.

Detector System

For multicrystal systems a crystal size of 12·5 cm ×10 cm is generally accepted to be the optimum and four crystals are the usual choice[4]. The four detectors used in our system are *NaI* crystals (12·5 cm dia × 10 cm thick) with quartz window for the PM (photomultiplier) tubes and stainless steel canning; the scintillation probe has a low intrinsic background activity. The crystals were procured from Nuclear Enterprises, UK. The detectors are fed by a single stabilized HV supply through a photomultiplier balancing unit (NG 6101A) which enables the gain of the four photomultiplier tubes to be varied separately. The signals from the four detectors are summed to give a common signal output, which after passing through a non-overload amplifier is passed on to a 400-channel analyser. This analyser was procured from Electronics Corporation of India and the readout system is a Hindustan Teleprinter Unit.

Shielding Material

In view of its indigenous availability, steel was decided upon as the material for the shielded enclosure. It has been established that substantial reduction in background is achieved upto thicknesses of 15 cm shielding and beyond 20 cm further reduction in background is marginal. We, therefore, decided on a thickness of 20 cm. Care has to be exercised in the choice of steel as it may be contaminated either with fallout materials or with radiotracers like ^{60}Co deliberately added during the process of manufacture. 4 mm thick steel plates manufactured at the Rourkela Steel Plant in 1962 were available in the requisite quantity from the military engineers in Delhi. Monitoring of the steel plates showed that the intrinsic radioactivity levels were acceptably low but there were indications of some slight surface contamination. The surfaces were cleaned by a suitable method (sand-blasting or metal brushing followed by washing in detergent solution) and the activity levels after cleaning were checked to be acceptable. All plates used for the construction were similarly cleaned and samples tested at the time of construction. A thin lining of stainless steel on the inner side of the enclosure was considered desirable; the stainless steel samples were also checked to be free from radioactivity.

Shielded Room

The size of the shielded room was chosen to be reasonably large (3·6 m × 3·6 m × 2·4 m) for the following reasons : (i) there would be sufficient space to install an improved counting geometry viz, scanning bed geometry, which is increasingly coming into vogue, as well as facilities for low level sample counting work (ii) considering that patients were to be studied, the subject has less chance of a claustrophobic feeling in a

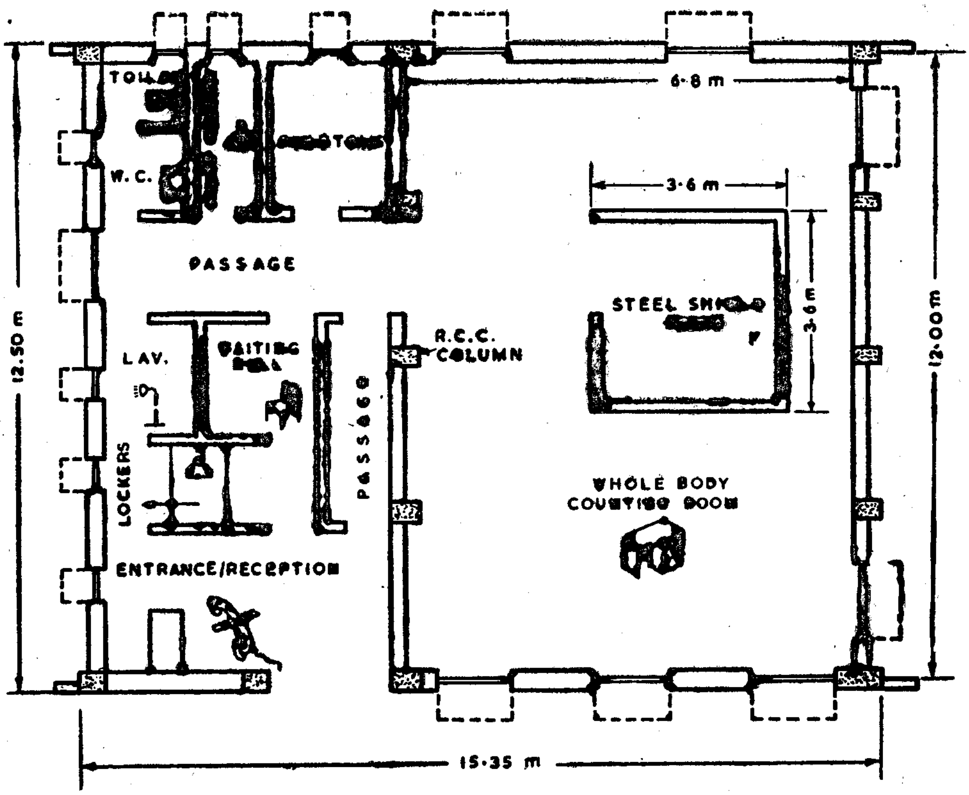

Fig. 1—Plan of whole-body counter building—INMAS.

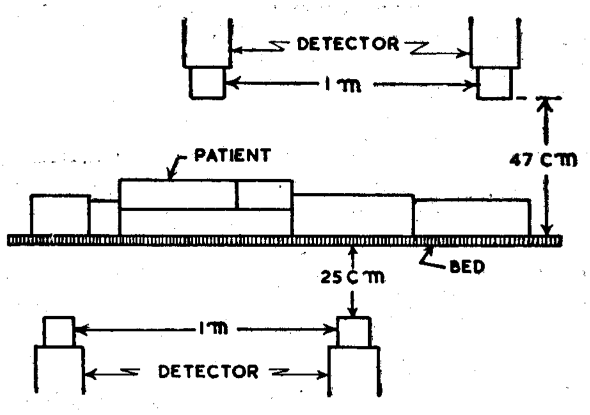

Fig. 2— Subject—detector geometry.

larger sized room. The enclosure is provided with a manually operated hinged door with the same 20 cm thick steel shielding. The location of the detector relative to the door is such that for clinical applications with radiotracers the door could be kept half open without significant increase in background, to give the subjects a greater sense of freedom. A 15 cm × 15 cm peephole fitted with a 10 cm thick lead glass window is provided for viewing the subject from outside. It is proposed to provide two-way telephonic intercom and soft music facilities inside the enclosure.

OVERALL BUILDING DESIGN

Fig. 1 gives the plan of the main building with its parts. The building is in 2 parts. Reception, change room, wash room and phantom room comprise the first part. The other part, which is air conditioned consists of the shielded enclosure and the instrumentation room. The air of this part is filtered through a coarse filter and is changed once in half an hour. The temperature is kept at 23±5°C and relative humidity around 50%. The detectors are mounted on a readily adjustable mounting framework, permitting them to be arranged conveniently over or under the patient's couch or clustered together to provide effectively a single detector over a particular body site. Fig. 2 shows the normal arrangement of detectors i.e., two over and two below the patient's bed. For control of contamination hazards, the floor is lined with PVC tiles, as this material was found to be superior to linoleum which had higher intrinsic radioactivity.

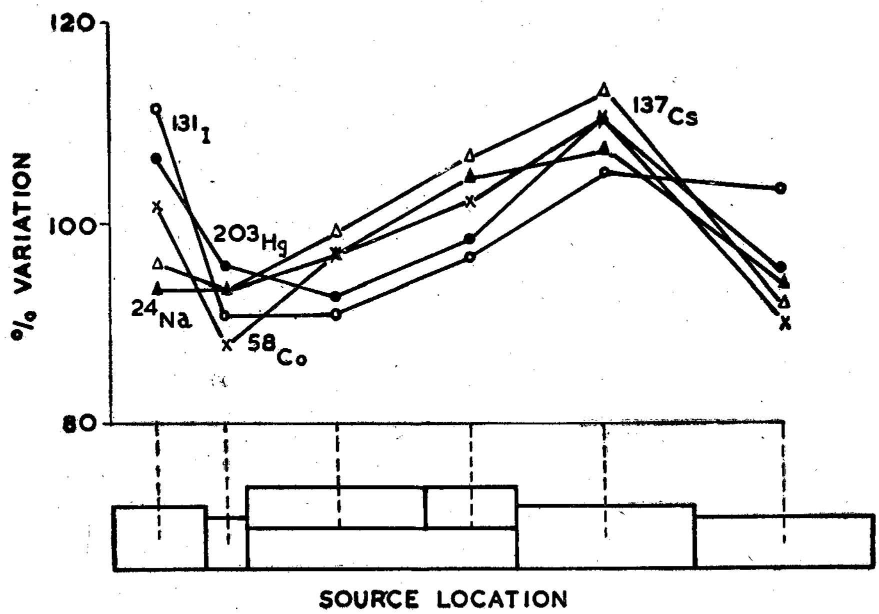

Fig. 3—Point source response in wax phantom under 4-crystal array.

CALIBRATION OF THE SYSTEM

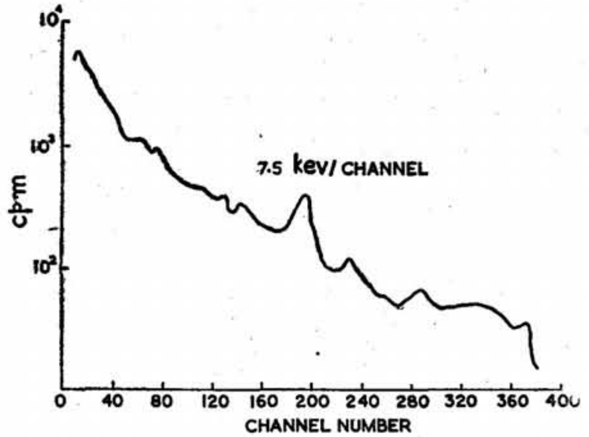

Fig. 4—Background spectrum.

Studies were carried out to find appropriate placing of the 4 detectors with respect to the patient's bed to achieve an optimum combination of high sensitivity and uniformity of spatial response. Fig. 3 gives the point source response of the final arrangement of the detector as the point source moves on the bed along the midline over a length of 170 cm. The response for any location varies within $\pm 10\%$ of the mean. Fig. 4 gives the background spectrum. The background index of the system (counts per minute in the energy range 0·1–2 meV per cc of detector volume) is around 0·6, comparing favourably with otherwhole-body monitors in the world. The system was calibrated for potassium by counting for one hour a polythene Bush phantom (procured from Grey and Martin, UK) filled with a known quantity of AR grade *KCL* dissolved in distilled water. Table 2 gives the results of calibration.

TABLE 2

CALIBRATION OF INMAS WHOLE–BODY COUNTER

Background of the system with water filled polythene Bush phantom in position. (Energy band 1·32 meV–1·60 meV)	$150 \pm 1 \cdot 5$ cpm
Polythene phantom containing 140 g of potassium	$221 \cdot 4 \pm 2 \cdot 0$ cpm
Net count rate due to 140 g of potassium	$71 \cdot 4 \pm 2 \cdot 5$ cpm
	$71 \cdot 4 \pm 3 \cdot 5\%$
	$0 \cdot 51 \pm 3 \cdot 5\%$ SD-per g of *K*

In a typical case of 100 g potassium content of the body, a variation of 10 g (3 SD) of potassium can be measured confidently.

The system has been in use since early 1971. Body potassium estimations in healthy adults have been initiated as well as clinical radiotracer work, mainly iron and Vit B_{12} absorption studies. The assembly is also being used for certain low level counting studies including estimation of natural radioactivity levels in common environmental samples like building materials.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation of the work done by technical workshop in constructing the couch and the framework for the detector system and the MES authorities for the help in constructing the building and the shielded enclosure, which has involved many technical innovations. They also take pleasure in expressing their thanks to the staff of the body building measurements section, BARC for many helpful discussions. The interest and inspiration of Colonel S. K. Mazumdar, Director, INMAS, during all aspects of this work, is gratefully acknowledged.

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