INFERENCES FROM DIRECT THORAX COUNTING ON OCCUPATIONAL WORKERS OF FUEL FABRICATION PLANTS

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Introduction: Indian fuel fabrication plants produce fuel assemblies for the country's nuclear power reactors(PHWRs&BWR). Uranium Oxide(UOP), Ceramic Fuel Fabrication(CFFP), Enriched Uranium Oxide(EUOP) and Enriched Fuel Fabrication(EFFP) are the four main production plants. Nat. and enriched U of enrichments 1.6-2.66% are handled in these plants.

In most of the areas of these fuel fabrication plants, despite rigorous controls, potential internal exposures through inhalations of (U_3O_8, UO_2) class Y aerosols, remain distinctly possible. Since periodic urine assay as the sole method of controlling internal intakes may not be adequate, direct thorax counting of fuel fabricators becomes obligatory. Fulfilling this obligation, we have monitored thorax burdens in a majority of occupational workers from these four fuel fabrication plants. This paper presents methodology, results, their analysis and atttempts to draw some notable inferences therefrom.

2. **Methodology**: It is based on direct detections of 63 & 93keV γ-rays from ^{234}Th assuming it in radioactive equilibrium with ^{238}U - a valid assumption for fuel fabricators and 185 keV γ-rays from ^{235}U. Two types of detectors-a 20cm dia x 3mm thick phoswich in centrally over supine chest geometry and 12.7cm diax 1.27cm thick NaI(Tl) in one over each lung configuration, housed inside a graded lined steel room[1)] shield, facilitate the measurements of low-energy photons(LEPs). Phoswich(10-150keV) and NaI(Tl)(20-300keV) measurements together provide indications of surface contamination and uranium enrichment as well.

The calibrations of the detection systems were performed with the aid of a REMCAL phantom. Effective soft tissue thickness concept is used to derive calibration factors for each subject separately. The spectral regions of 40-105keV for phoswich and 40-120keV and 165-215keV for NaI(Tl) are employed. Averaged value is reported as the subject's thorax burden.

3. **Results**: U-Thorax burdens in 128 occupational workers from four plants have been measured-about 1/3rd showing $<$5 mg, the rest in the 5-25mg range with only three exceeding it. The plots of assessed thorax burdens Vs. cumulative % probability on log-probability graphs are given in Figs.1 & 2 displaying data from Nat.& enriched Uranium plants respectively. Burdens exceeding 15mg are shown plotted in fig.3 against the length of occupational service being an index of inhalation period of the respetive worker.

4. **Discussion**

4.1 **Log-Normal Analysis**: Log-probability plots(fig.1&2) reveal that data upto 80-90% cumulative probability appear to fall on straight lines. Hence the thorax burden data from each plant are suitably describable by log-normal distribution. The internal exposure status of an occupational group from a particular plant would,thus,be signified by the geometric mean of thorax burden distribution.Calculated geometric means (GMs) & standard geometric deviations(SGDs)corresponding to the displayed distributions along with the total number of cases measured and the maximum burdens encountered are also given in the figures.

It is evident that UOP besides showing highest GM among the four plants shows SGD much greater than 2,implying perhaps an uncommon intake by some plant workers.For other plants,SGDs are fairly close to 2.

4.2**Comparisons with Lung Model Predictions**:The observed burdens from thorax countings,in fact,represent lungs+lymph nodes contents and therefore,reflect the cumulative effects of intakes over the period of occupational service. We,now examine their magnitudes vis-a-vis lung model predictions.Since the thorax burdens show log-normal distributions,their GMs are the proper parameters to be compared with.In Fig.3,lung model predicted build-ups of lungs & lungs+lymph nodes burdens as a function of exposure time are displayed.The results are for continuous inhalations at the rate of 1ALI/365/day of 1μm AMAD class Y aerosols of Nat. & 2%enriched uranium.Apparently,for chronic exposures,burden in lungs tends to saturate with time but that in lymph nodes continues to rise. To facilitate ready comparison,the values of GMs of the thorax burdens for four plants plotted against the mean service period of the monitored group are also shown in Fig.3.It is seen that all GMs fall well below the limits delineated by the lung model predictions.It implies that the working conditions in all plants are such that a majority of occupational workers would accumulate thorax burdens much less than those expected from an intake of 1ALI for each year of service.It should be noted that Fig.3 considers AMAD of 1μm whereas the average size of aerosols in fuel fabrication plants is 6μm. Nonetheless,this does not invalidate the conclusion reached as the lung model predicts almost identical values of the saturated burdens for chronic intakes of 1ALI/365/day irrespective of the particle size if same clearance half-time is assumed.

From the continuous intake model(Fig.3) & plant-wise estimated GMs of assessed U-thorax burdens,we deduced the projected average air concentrations as 8.8 & 7.6μg/m^3 Nat.U & 4.1 and 4.7μg/m^{3}enriched U in UOP,CFFP,EUOP & EFFP plants respectively. These estimates appear to be generally less than the five yearly averages of experimental measurements.Inevitable inference,thus,is that by and large generally satisfactory working conditions have prevailed in these fuel fabrication plants.

It is clear from Figs.1&2 that burden values lying above estimated GMs would need individual scrutiny too.Incidentally, more significant of these are data points lying beyond 80-84 cumulative % to which the assessed thorax burdens$\geq$15mg correspond.These are shown plotted in Fig.3.It is observed that except 3 data points from UOP,5 from EUOP/EFFP and 2 from CFFP appear to marginally exceed the delineated limits. However,due to in-built conservatisms in ALI and lung model,uncertainties inherent in the direct detection methods(max.±20%) and likelihood of lower effective U-enrichment invivo,the points marginally exceeding the limits cannot be adjudged as over-exposures.Usually such subjects are referred for repeat monitoring after a certain interval .By any reckoning,3 data points from UOP,indeed indicate over-exposure.But it is plain from the foregoing discussion,that over-exposures are not expected from the working conditions and are necessarily attributable to poor working habits and possibly improper use of respirators.

4.3**Follow-up Measurements**: 3 follow-up measurements over a year have been made on one over-exposure case.The shape of pulse-height spectrum recorded from a NaI(Tl)detector positioned over right lung of this subject A is compared with the observed spectral shapes from a Nat.U source embedded inside Mix.D absorbers,identifying the internal contaminant as Nat.U beyond doubt(Fig.4).Worthnoting are the changes in LEP spectrum shapes occuring with different thicknesses of tissues over a Nat.U source.Invariably,such supplementary measurements aid spectral interpretations from contaminated subjects.

Extrapolating from the limited measurements on subject A,an usually long clearance half-life from thorax of about 970days was obtained. At least a few similar cases,have been reported from Canadian fuel fabrication plants[2].In addition,the phoswich response pattern over the frontal chest gave evidence of translocation of some Nat.U from lungs to lymph nodes-indicating a relatively old intake[1].Localised measurements with NaI(Tl)over skull and kidney sites of the subject with chest covered with 3mm Pb sheet,indicated no detectable Nat.U in these organs.These observations are subtly supportive of ICRP metabolic model of inhaled Y-Class uranium.

4.4**Detection Equipment Capabilities**:Accumulated thorax burdens of about 7.5 & 5.5mg Nat.U are expected from chronic (Fig.3) and acute intakes of 1ALI respectively at the end of one year. These are much above the currently achieveable MDAs (2-3mg marked in Fig.3) of the detection equipment employed.Therefore,the direct thorax counting techniques are capable of detecting intakes of atleast 1/2 ALI/yr in a yearly monitoring frequency.

5.**Conclusions**:Direct thorax counting conducted on a majority of occupational workers of fuel fabrication plants lead to these inferences: 1.About 2/3rd of the subjects showed measurable thorax burdens in 5-25mg range. 2. The assessed thorax burdens in each of the the four plants are log-normally distributed and their estimated GMs correspond to air activity concentrations of about 1/3 DACs-testifying satisfactory working conditions. 3. Comparisons with lung model predictions have identified 3 probable over-exposures. 4. Follow-up measurements on one case revealed unusually long clearance half-life,detectable translocations to lymph nodes but not to skull and kidneys. 5. With the available detection equipments, intakes of U at 1/2ALI level are measurable.

References

1.Sharma R.C. et al 'Measurements on IAEA Realistic Phantom: Preliminary Evaluation'.Report submitted to IAEA-Research Contract 3843(1985).
2.Pomroy,C. and Noel.L.Health Physics 41(1981) 393.

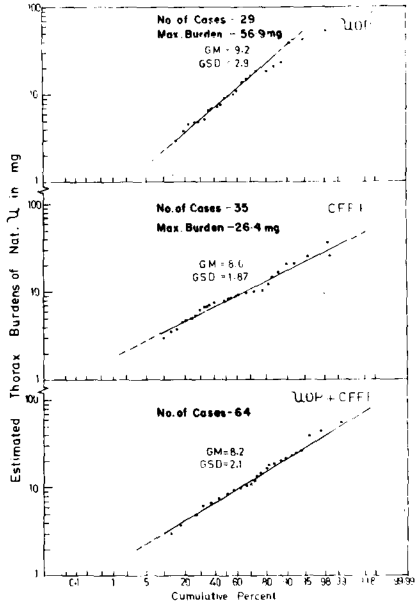

FIG. 1,- LOG-NORMAL DISTRIBUTIONS OF U-THORAX BURDENS FOR OCCUPATIONAL WORKERS FROM UOP, CFFP & BOTH PLANTS TAKEN TOGETHER.

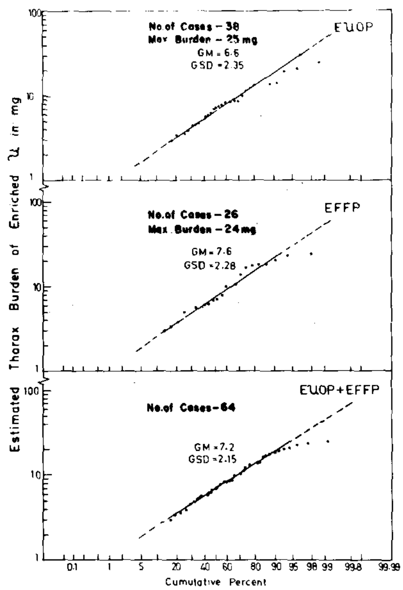

FIG. 2,- LOG-NORMAL DISTRIBUTIONS OF U-THORAX BURDENS FOR OCCUPATIONAL WORKERS FROM EUOP, EFFP AND BOTH PLANTS TAKEN TOGETHER.

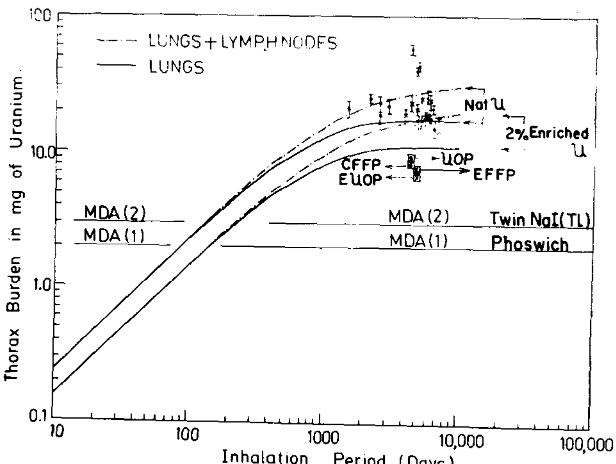

Fig.3, Lung Model predicted buildups of lung and (lung + lymph node) burdens as functions of exposure time compared with observed thorax burdens from occupational workers. Model results are for continuous inhalation at the rate of 1 ALI/365/day of 1μm AMAD class Y aerosols of Nat. and 2% Enriched uranium. Observed thorax burdens ≥ 15 mg for individual subjects are only displayed as two populations x — Enriched U; • — Nat. U together with the observed GMs from log normal analysis. ALI 1500 Bq.

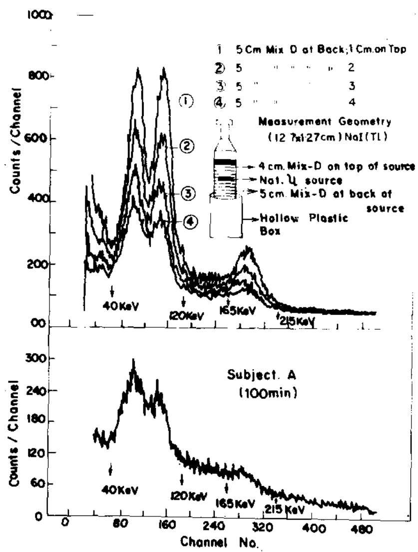

Fig. 4,- The shape of pulse-height spectrum recorded from a 12·7 cm. x 1·27 cm. NaI (TL) positioned over Right Lung of subject. A compared with the observed spectral shapes from a Nat. U source embedded inside Mix D absorbers.