ACCIDENTAL EXPOSURE WITH X-RAY DIFFRACTION EQUIPMENT

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1. Introduction

On account of the mechanical stop up of the shutter of one of the windows of an X-ray diffraction equipment* on the Crystalography Laboratory of the Chemistry Faculty, allowed this one to rest opened during the operation. This occur in spite of the investigator who operate the equipment moved the switch of the control's panel in order to get it closed.

The equipment was working with a tube with anode of copper at 40 kV and 20 mA, without additional filtration.

The operator was working beside the equipment, facing the window by a time of 1-2 minutes until he realize the presence of radiation because of the light emitted by a small fluorescent screen interposed by chance in the beam.

The dosimeter's film** carried by the operator was processed inmediately, evidencing that only the slow emulsion had an optical density higher than 4.5, allowing us to estimate a dose greater than of some series of ten of cGy.

We made the reconstruction of the accident in order to value the dose received by the operator and the possible consequences.

The medical observation, included the result of a thermographic examination to the affected area of the skin, didn't show signals of damage due to the radiation exposure.

We obtain information of unless two other accidents in our country with this type of equipment not well informed opportunelly, producing in one of the cases early erythema and dermal atrophy in the other. We know that in other countries were recorded some cases (Masse et al. 1990, UNSCEAR 1982).

The default of data that allow the quick evaluation of dose in these cases, motived that we realized measurements in the work conditions the most used, so that they served as reference and also evaluate the potential risk caused by the use of these equipments, as soon as the need to improve their security sistems.

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* PHILIPS PW 1010 X-RAY Diffraction Apparatus
** Kodak Monitoring Film Personal Type 2.

2. Materials and Methods

We foresee a low effective energy of radiation for the accident conditions, since the tube with anode of copper that was used had an emission K_α of 8.06 KeV and the filtration came only from the window of mica-Be of the tube which had an 82% of transmission for that energy. Therefore, besides measuring the exposure at the distance focus-skin, we determine the half value layer of aluminium in order to evaluate the power of the radiation to penetrate in the soft tissue and to know which were the tissues we had to consider irradiated. For the same reason we determine directly the attenuation of the beam, produced because of the clothes of the operator.

We make use of the same method to do the complementary measures in the most frequent conditions of work.

For the exposition measures we make use a dosemeter type farmer with a soft X-ray chamber of 0.03 c.c.*. The determination of half value layer was carried out using a kit containing absorbers of aluminium**.

The form and size of the section of the radiation beam at the same distance was measured exposing a radiographic film, and observing the image registered.

3. Results

The exposure rate determined at the distance focus-skin of 60 cm and with a height from the floor of the beam of 130 cm was of 436 Roentgen/minute.

The section of the beam has a circular form, with a diameter of 6 cm at the distance considered.

In the accident conditions, because of the thin clothes of the worker was produced an absorption of 19.7%. Therefore, correcting by this factor the exposure rate was of 350 Roentgen/minute, in surface.

The results of the realized measures are shown on the table.

4. Discussion

Owing to the low effective energy of the radiation for the work conditions in the moment of the accident the tissues involved were the skin, the thyroid and the lens of the eye.

4.1 Skin

The basal cells of the epidermis considered as the critical target (Fry 1990, Hopewell 1990) are placed at the trunk at 42 µm

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* Farmer Dosemeter type 2502/3. and 0.03 cc Soft X-Ray Chamber type 2532/3, Nuclear Enterprises ltd.

** Atomic Development Corporation, Plainview, New York.

Table of results obtained at 60 cm from the focus

Quantities	Tube of Cu* (40 kV, 20 mA)		Tube of Mo** (42 kV, 22 mA)	
	W.F.#	F.Ni‡	W.F.#	F.Zr‡‡
$\dot{X}$ (R/min)	436	159	123	13.5
1º HVL (mm Al)	0.055	0.070	0.165	0.445
(mm H_2O)	0.8	1.0	2.3	5.8
2º HVL (mm Al)	0.070	0.070	0.335	0.445
(mm H_2O)	1.0	1.0	4.3	5.8
3º HVL (mm Al)	0.071	0.070	0.375	0.445
(mm H_2O)	1.0	1.0	4.8	5.8
Ef. Energy (keV)	8.1	9.0	12.0	17.0

* Philips X-Ray Diffraction Tube type 25293/62.
** Philips X-Ray Diffraction Tube type 25295/62.
# Without additional filter.
‡ With filter of nickel.
‡‡ With filter of zirconium.

of depth; therefore there is not an appreciable reduction of the received dose in the sensible layer.

The risk of letal cancer of skin for exposures of the whole area of the body (1.8 m^2) and supposing a death rate of 0.2% is $2x10^{-4}$ Sv^{-1} (Fry 1990, Shore 1990).

The beam section at the distance wich was placed the worker is 0.0028 m^2. Therefore the maximun death risk of the worker is 7 Sv x $2x10^{-4}$ Sv^{-1} x (0.0028/1.8) = $2x10^{-6}$, and the probability of cancer is $2x10^{-6}$ x (100/0.2) = $1x10^{-3}$ without taking account that the area mainly exposed isn't exposed a UV radiation. Since the irradiation was mainly in a skin area not exposed at UV, considering the relative risk model (Shore 1990), the real risk would be 2 orders of magnitude smaller.

Considering a risk factor for the skin of W_T = 0.01 the Effective Dose is : 7 Gy x (0.0028/1.8) x 0.01 = $1x10^{-4}$ Sv

Since the exposition didn't reach to produce early erythema no one of the skin areas received a greater dose than 2 Gy, which is more lower than the threshold dose of 10.5 Gy for the latter deterministic damages (Hopewell 1990).

4.2 Thyroid

The area which comprise the thyroid could have received as maximun 2 Gy in the skin surface.

The depth of the thyroid is 1 cm, with sufficient approach, that is why it received a dose of 0.002 Gy estimated in accordance with the obtained results, which are showed in the table.

The risk of letal thyroid cancer is 10^{-3} Gy^{-1}, therefore the risk for the worker is $2x10^{-6}$ and the probability of cancer induction is $2x10^{-5}$ considering a 10% of death.

The Effective Dose would be in this case :
$(0.002\ Gy \times 0.03) + (7\ Gy \times 0.0028/2 \times 0.01) = 1.6x10^{-4}\ Sv$

4.3 Lens of the eye

The lens of the eye placed at a depth of 3 mm and more, and the radiation at which the accident occurred is attenuated 9 times at that depth. So, to reach the threshold dose of 2 Gy for the induction of cataract of eye (Merriam 1957), would be necessary a surface dose sufficient to damage the most external tissues that haven't occured. Therefore there is no risk of cataracts of eye induction.

4.4 Considerations for another conditions of work

We must take into account that in the moment of the accident the equipment was working with 50% of its maximun power and then the exposition rates measured could reach to double.

The exposition rates with the tube with anode of Mo is enough smaller than with the Cu (in disappointment with the expected agreed with the greater atomic number of the anode), meanwhile penetration of radiation is much higher.

In that case the risk of inmediate effects in skin is reduced regarding to the risks of latter effects in lens of eye, thyroid and, in the case in wich the operator affected will be a woman, the breast gland.

5. Conclusions

In spite of the worker received a partial and relative high dose, this one didn't reach the threshold values to produce the deterministic effects (cataracts of eye, erythema, skin latter damages), then there is no possibility of detriment on account of this causes.

The calculated effective dose is in the order of 1% for the anual limit for workers occupationaly exposed, that is why the risk produced because of the accident is very lower.

Owing to the high dose rates produced by these equipments and the repeated incidents, its security sistems might be better. It can be taken some suggestions given by Masse et al. 1990, at which we can add as complementary independent measure of the intrinsec security of the equipment, the use of an individual monitor with alarm which might respond at the presence of the scattered radiation.

It would be expected that in some accessibles places it could produce accidentally dose-rates over than 8 Gy/min at the thorax and eventually the face, and greater rates at the extremities. In that case it would be expected burns of 3rd degree and exceed the threshold for the production of cataracts (2 Gy), as well as a significative increase in thyroidal and skin cancer risk specially in areas exposed to UV radiation.

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