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X-ray Permitted Dose and its Relevance to Equine Semen Transport: Shielded Equitainer

Some facts about X-Ray dose and permitted limits are summarized below.

- 1. X-rays are used in clinical diagnosis**, medical treatment and baggage examination at airports. The radiation is transmitted through all materials, leaving a trace of chemically reactive ions and free radicals in the path of each photon. It is these free radicals that cause the radiation poisoning associated with X-rays: the path of an X-ray photon resembles an extremely fine injection of corrosive acid, with accompanying effects on the surrounding tissues. Therefore X-ray dose is limited by law to levels at which these effects are insignificant because the dose is so low. Radiation has especially damaging effects on the cell cycle, and cells that are constantly reproducing (such as the gut) are especially vulnerable. This particularly includes embryonic cells. Permitted dose limits to pregnant women are therefore lower than for the normal population.
- 2. X-ray dose** to biological material is measured in millirem. For X-rays the millirem is equivalent to the millirad. Typical clinical X-ray doses are as follows [Webb 1990: 100 rem = 1 Gray = 1 Sievert for xrays]:

	Old Units	International Units
Breast	120 millirem	1.2 milliGray
Chest	30	0.30
Pelvis	660	6.6
Skull	440	4.4

These are doses for individual patients in diagnosis. For clinical treatment, e.g. radiation doses for tumors, the doses are much higher. However, all the above are for specific individuals. For the general population the permitted dose limits are much lower, partly in order to lessen the statistical burden for potential mutations. We will use the old-style units below.

- 3. Background Radiation.** There is a continuous burden of background radiation which varies in intensity from place to place. In some localities radon is important as a radiation source, and in others cosmic radiation is significant. Across the US typical background dose rates are 40 - 400 millirem per year [NCRP, 1987].

4. Permitted dose to population

- **The general population** is allowed to receive a limit of 100 millirem per year [NCRP, 1987].
- **Pregnant women** are allowed to receive a maximum of 50 millirem per month during pregnancy [NCRP 1987].
- **Biological Material:** No guidelines have been published on dose limits to biological material, such as equine semen or embryos. However, caution would dictate that genetic material exposure to X-rays should be no higher than that permitted to pregnant women.

5. Airport Baggage Radiation Dose.

5.1 Pre 1997 levels. The inspection of luggage used to be at the level 0.5 - 1 millirem per inspection. This dose was insignificant for unexposed film and should have little effect on biological material, since it is considerably below the permitted limits for humans.

5.2 1997 levels. The FAA has approved introduction of an X-ray explosives detector at airports. The newly introduced X-ray explosives detectors use a radiation tomography process and operate with a considerably higher dose of radiation. The explosive detector is not film-safe. According to the FAA and the detector manufacturer [Goll 1996, Rotor 1996, 7], the maximum dose will be 300 millirem of 180 kVp X-rays.

6. **Consequences for Equine Semen Transport.** In the aftermath of September 11, it must be assumed that equine semen containers, along with all other baggage, will be inspected, and may be subjected to the doses in 5.2 above. At the same time, it is reasonable to assume that the safe dose limit for equine genetic material is the same as that for pregnant women, which is a maximum of 50 millirem per month during pregnancy. Therefore the dose imposed on the semen must be reduced to below 50 millirem per inspection, by approximately a factor of 1/10 over the risk from the X-ray explosive detector.

7. **Shielded Equitainer.** The redesigned isothermalizer for the Equitainer I and Equitainer II models has built-in X-ray shielding. This has been optimized for the transport of equine semen [designed using Delgado (1999), Waggenger et al. (1999), Verhaegen et al. (1999), Hubbel and Seltzer (1997), NCRP (1998)] and attenuates the X-ray dose from 5.2 above to less than 15% of the incident dose, giving a dose level below 45 millirem per inspection.

The dose is therefore below the permitted limit for pregnant women, and may be expected to be safe for equine semen. INVISION Technologies manufacturers of the CTX5500 series of Xray baggage CAT scanners, inform us that the actual dose will be even lower than estimated above due to filtering of the bremsstrahlung emission spectrum [Francesco (2001)].

At the same time, the Equitainer can and should be opened for visual inspection of the contents within the isothermalizer. The isothermalizer may be removed, and the sample containers within it may be slipped out of the isothermalizer, for (brief) inspection.

Provided that the Equitainer is reassembled within 30 sec - 1 min, no significant effect on the cooling regime will occur.

Note on Radiation Dose Units:

The new standard international unit of biological equivalent radiation dose is the sievert. For X-rays, the conversion is 1 sievert = 100 rem, so 1 millisievert = 100 millirem. The Rem, or roentgen Equivalent for man, equals the rad for X-rays. The rad, a unit of energy deposited per gram of material, is defined as the dose depositing 100 ergs per gram. The new standard international unit of absorbed dose is the gray, defined as 1 joule deposited energy per kilogram. For X-rays, 1 sievert = 1 gray. It follows that 1 gray = 100 rad.

Note on lethal dose:

The 50% death-rate X-ray lethal dose for man is 2.5 -3.0 gray. or 250 - 300 rads, which is the same as 2.5 - 3.0 sievert, or 250 - 300 rem.

References

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