Health, Social and Economic Impact of Some Tritium Watches in Italy: Regulations, Derogations and Proposed Scenarios for Dose Assessment

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INTRODUCTION

The present Italian Radiation Protection regulations ban the trading, production, import, handling and keeping of "products for personal use containing deliberately added radioactive material". Tritium watches belong to such a category of consumer products. A derogation to this ban may be asked to the Italian authorities, according to a Decree of the Ministry of Health, provided that a Qualified Expert in ionising radiation performs a dose assessment for all the possible scenarios involving users, non-users, workers and general population for the use, distribution, repair and disposal of tritium watches in normal and accidental conditions.

We have been asked by some Italian watch wholesalers to carry out a dose assessment for imported valuable and high priced ***metallic wrist watches containing tritium paint***. On the basis of the results of tests, performed on the watches by specialised laboratories in compliance with the International Organisation for Standardisation (ISO) requirements, we have estimated the health hazard of tritium watches in the Italian society. In this context various scenarios were defined and cases already reported in the scientific literature were applied. The economic and social impact that the ban would have on the Italian market has also been considered, together with the pertinent legislation of some European countries.

THE ITALIAN LEGISLATIVE SITUATION

The former Italian legislation on nuclear matters (1) contained an explicit ban "to import, use or anyway keep […] signs, dials, tools, paints, general luminescent objects […] emitting ionising radiation. According to a following Decree (2), such a ban was not applied to:

- "ordinary luminescent watches, containing tritium […] for which the adhesion of the luminescent compound is such that the it cannot be detached, even partially, in normal conditions of use and for which the total activity is equal or less than […] 10 mCi (*370 MBq*) […]";
- "special luminescent watches, containing tritium […] for which a symbol related to the content of radioactivity appears on the dial, for which the adhesion of the luminescent compound is such that the it cannot be detached, even partially, in normal conditions of use and for which the total activity is equal or less than […] 25 mCi (*925 MBq*) […]";

This law was valid until 31/12/1995 and so it was possible to import and trade radioluminescent watches containing tritium (or Pm-147 or Ra-226) with concentrations and characteristics as just exposed.

The present regulations, valid since the beginning of 1996, contain the mentioned bans for trade purposes which are applied in a non explicit way also to watches (3). The only possibility for watch sellers to continue their business (and for the Italian population to keep using such watches) is to ask for a derogation to the ban according to the Decree of the Ministry of Health dated 6/3/1998 (4).

The request for a derogation must contain a Qualified Expert's evaluation, structured as follows:

a) description of the used materials with regard to the type and amount of the radioactive emission;
b) assessment of the exposure to radiation, as a consequence of the normal conditions of trade, use and disposal of the watches, for users, non-users, for those who may manipulate the watches for various reasons outside the manufacturing process and for the population;
c) analysis of the cost of detriment following the exposure of point b);
d) assessment of the risks connected to possible accidents or consequences of an inappropriate use of watches and description of their safety characteristics taken to prevent accidents or exposure to unforeseen risks, also from inappropriate uses;
e) ways and contents of the information given to the users an to those who for any reason may manipulate the watches beyond the manufacturing process.

THE EUROPEAN LEGISLATIVE SITUATION

In this context we have also compared the Italian legislation with the present one of some European countries, just a few months before the deadline for the compulsory implementation by the European Union member states of the 1996 EURATOM Directive, laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation (13). The pertinent legislation of the United States of America (USA) has been also considered.

The legislation of Italy, Germany, Spain, The Netherlands, Belgium, France, Great Britain, Switzerland has been analysed and we conclude that in all these countries, but Italy, tritium watches that comply with certain conditions can be commercialised, and their import and trade is regulated. In most cases such conditions refer to ISO requirements, e.g. tritium activity and resistance ageing (5, 6). In conclusion, in Italy this practice is prohibited and it is therefore necessary to ask the competent authorities for a derogation.

MATERIALS AND METHODS

From now on the term “watch” will refer to a ***metallic wrist watch containing tritium paint***.

We have been asked by the ANGrO (Associazione Nazionale Grossisti Orologiai, National Association of Watch Wholesalers), which represents some of the main wholesalers of watches in Italy, to prepare the technical annex to the request of derogation.

To consider the exposure to the risks from tritium watches, we have defined thirteen appropriate scenarios, summarised in **table 1**. Such scenarios represent a compromise between the situations already evaluated in some scientific papers (7, 8) and the context in which the watch wholesalers operate in Italy.

Once settled the ways and conditions of exposure, we have asked the companies to fill in a questionnaire with general and technical information on the watches for which they intended to apply for the derogation. It has to be mentioned that the single companies have encountered difficulties to obtain the necessary information, especially for those watches produced outside Europe. The data requested and finally obtained are listed here.

Technical characteristics (precise data for each watch)

1. detailed description, origin and use (normal or special, according to the definition (9) of the International Atomic Energy Agency (IAEA);
2. ways and contents of the information given to the users an to those who for any reason can manipulate the watches outside the manufacturing process (certificates, written warnings, symbols, media spots and others);
3. certificates of the manufactures showing that the watches are fabricated following the ISO requirements;
4. total amount of radioactivity (minimum, maximum and average);
5. rate of release of tritium vapour (test of insolubility);
6. rate of equivalent dose due to irradiation from the external surfaces.

Watches’ market (estimated numbers for each type)

1. watches disposed each year since 1996;
2. age of watches;
3. watches stored in a depository by wholesalers and retailers;
4. watches under repair every year since 1996.

Company’s information (estimates for all tritium watches)

1. number of tritium watches Vs non radioluminescent watches (turnover) since 1996;
2. number of internal employees;
3. number of repairmen working for the company;
4. number of external employees (drivers, retailers, clerks, else) who anyhow benefit from the company’s activities;
5. turnover of the activities connected to the production of accessories and components.

The purpose of the selected scenarios is to calculate the quantity of tritium expelled from watches and then incorporated by exposed individuals. The dose is then calculated using the conversion factors present in literature (10). The dose estimates have been made exclusively on the basis of documents supplied by the watch companies (written declarations, laboratory certificates, statements of compliance with international standards and others) and not on direct measurements on single watches. The evaluations regard annual individual and collective doses, due to both external irradiation (when applicable) and internal contamination, for normal and special watches (e.g. for divers).

Skin and eye irradiation have been considered to describe the external irradiation, while the internal contamination has been assumed to be caused by inhalation and skin absorption of tritium and ingestion of

tritium leachate or tritiated paint. **Tables 2** to **7** show how the information gathered from the watch companies is used in the various scenarios to assess the doses for normal and accidental circumstances. We have to remark that for the dose assessment we have proposed the most conservative hypotheses, which are surely much more severe than reality. To give an idea, the following are common to most of the scenarios:

- the tritium released is always in the form of tritiated water vapour - HTO;
- the time of stay in a house or room for an individual, wearing a watch or in contact with someone wearing a watch, is longer than usual, the size of the house or room and the air change rate are smaller than usual;
- the watches are always considered as brand new, so the release rate of tritium is always the same, despite the age of the watches and the conditions and ways by which they are used ;
- the exposed persons are, where applicable, always babies or kids (this is not the case for the repairmen, office colleagues, ..); kids are considered to be 7.5 years old.
- the skin absorption and inhalation rates of tritium are equal (11);
- the watches are disposed of with conventional waste (in reality such watches are valuable and their value increases with their age, so the disposal is a very rare event);
- the collective dose is calculated from the highest individual dose.

SCENARIOS	EXPOSED PERSONS	SITUATION	CONSEQUENCE
1	direct users	wearing a watch	skin and eye irradiation
2	direct users	wearing a watch	inhalation and skin absorption of tritium
3	members of the public	fire in a tip where watches are discarded	ditto
4	members of the public	water leaching from a tip where watches are discarded	ingestion of tritium leachate
5	members of the public	incineration of waste containing watches	inhalation and skin absorption of tritium
6	members of a user's family	living in a house where someone wears or keeps a watch	ditto
7	office colleagues	working in an office where someone wears a watch	ditto
8	repairmen	manipulation of watches for repair purposes	ditto
9	retailers and clerks	working in a shop where watches are sold	ditto
10	babies	playing with a broken watch	ingestion of tritiated paint
11	members of a user's family	fire in a house where someone wears or keeps a watch	inhalation and skin absorption of tritium
12	wholesalers and retailers	fire in a deposit where watches are stored	ditto
13	repairmen	manipulation of watches for repair purposes	ingestion of tritiated paint

Table 1. The various scenarios of exposure to the risks from tritium watches. Scenarios from 1 to 9 are referred to normal situations, 10 to 13 to accidents.

Hypotheses of the scenario	Necessary information for the scenario	Necessary data from the watch company
Bremmstrahlung radiation is absorbed completely by the superficial tissue (skin)	Time in which the watch is worn	Rate of equivalent dose due to irradiation from the external surfaces
The inverse square law is applicable to the bremmstrahlung radiation	Time in which the dial is in full contact with the skin	Number of users
The exposed person is a user	Time in which the watch is seen from the user	Number of watches for each type
	Eye-dial distance	

Table 2. Dose assessment for direct users after skin and eye irradiation, normal scenario.

Hypotheses of the scenario	Necessary information for the scenario	Necessary data from the watch company
Time in which the watch is worn by the user or stored in a house/room where non-users are present	Dimensions of the house/room where the user/non-user stays and air change rate	Tritium release rate from the watch
Tritium released is in the form of vapour	Time in which the user/non-user stays in the house/room	Number of users/non-users
The exposed user is a kid or an adult (office colleague, repairman, or retailer)	User/non-user breath rate	Number of watches for each type
The committed dose per unit intake is doubled to take in account the skin absorption	Committed dose per unit intake	

Table 3. Dose assessment for direct users and non-users after inhalation and skin absorption of tritium, normal scenario.

Hypotheses of the scenario	Necessary information for the scenario	Necessary data from the watch company
Number of tips or incinerators	Fire or incineration time duration	Tritium release rate or activity for each watch
Tritium released is in the form of vapour	Ground concentration of tritium in air at 200 m distance from the tip, with Pasquill D conditions	Number of members of the public
The exposed user is a kid	User or member of the public's breath rate	Number of discarded watches for each type
The committed dose per unit intake is doubled to take in account the skin absorption	Committed dose per unit intake	

Table 4. Dose assessment for users (or members of the public) after inhalation and skin absorption of tritium due to a fire in a tip where watches are discarded (or due to incineration of waste containing watches), normal scenario.

Hypotheses of the scenario	Necessary information for the scenario	Necessary data from the watch company
Maximum individual committed dose after ingestion of water contaminated with tritium	Number of people living around a tip	Tritium release rate from the watch
The exposed user is an adult	Tritium activity in a tip	Number of discarded watches for each type
Number of tips		

Table 5. Dose assessment for members of the public after ingestion of tritium leachate from a tip where watches are discarded, normal scenario.

Hypotheses of the scenario	Necessary information for the scenario	Necessary data from the watch company
Number of watches involved in such accident	Committed dose per unit intake	Activity of each type of watch
% of tritium removed and ingested from the watch		

Table 6. Dose assessment for a baby (or repairman) after ingestion of tritiated paint removed by a broken watch, accidental scenario.

Hypotheses of the scenario	Necessary information for the scenario	Necessary data from the watch company
Number of watches involved in such accident	Dimensions of the site where the exposed persons live or work and air change rate	Activity of each type of watch
The site involved in the accident is a house or a watch deposit	Fire time duration	Number of watches involved in such accident
The exposed persons are members of a family (kids) or wholesalers or retailers	Exposed person's breath rate	Number of exposed persons
The committed dose per unit intake is doubled to take in account the skin absorption	Committed dose per unit intake	
	Number of exposed persons	

Table 7. Dose assessment for members of a family (or wholesalers or retailers) after inhalation and skin absorption of tritium due to a fire at home (or in the watch deposit), accidental scenario.

RESULTS AND DISCUSSION

The characteristics and related data of more than 100 watch models were analysed. A final number of 50 different models (whose only 4 are declared as "special") from three different companies were provided with the necessary information in order to prepare the technical annex to the request of derogation already mentioned. **Table 8** reports the maximum, minimum and average values of equivalent dose rate on the watches' surface (for 35 types out of 50), concentration of tritium content and daily release rate in water (these values refer to both the dials and hands, either solely to the hands or to the dials). **Table 9** reports the maximum and average individual and collective doses for the thirteen scenarios applied to the considered 50 types of watches. **Table 10** gives an estimate of the turnover related to the sale of these watches in Italy by the three companies, generally indicated as A, B and C.

	Tritium concentration (MBq)	Daily release (kBq)	Dose rate (μSv/h)
MAX	300.0	99.3	//
MIN	1.9	0.2	//
AVE.	23.4	24.5	< 0.1

Table 8. Significant values of tritium content, release rate and dose rate for the considered watches.

SCENARIO	INDIVIDUAL ANNUAL DOSE			COLLECTIVE ANNUAL DOSE		
	MAX	AVE	(unit)	MAX	AVE.	(unit)
1	< 0.9 < 0.1	< 0.5 < 0.05	mSv/y (skin) nSv/y (eye)	n.a.	n.a.	n.a.
2	40.7	10.0	μSv/y	1.5	0.6	man Sv/y
3	6.6	0.5	pSv/y	0.3	0.1	man mSv/y
4	0.5	0.2	pSv/y	42.1	18.1	man μSv/y
5	4.1	2.8	pSv/y	0.2	0.1	man mSv/y
6	7.1	1.0	μSv/y	0.6	0.1	man Sv/y
7	19.7	4.9	μSv/y	0.3	0.05	man Sv/y
8	9.3	5.9	μSv/y	3.7	1.5	man mSv/y
9	56.9	15.6	μSv/y	75.1	24.2	man mSv/y
10	50.1	8.3	μSv	n.a.	n.a.	n.a.
11	3.6	0.6	μSv	14.5	2.4	man μSv/y
12	3.5	0.8	mSv	0.5	0.1	man Sv/y
13	1.0	0.2	mSv	n.a.	n.a.	n.a.

Table 9. Maximum and average individual and collective doses for 50 types of watches and for 13 scenarios.
n.a. = not applicable

COMPANY	rough number of tritium watches sold since 1996	% of tritium watches sold Vs non tritium watches	% turnover from tritium watches Vs non tritium watches	number of persons who benefit from tritium watches sale
A	26200	65	40	2200
B	35800	57	53	1400
C	12400	1	1	3200

Table 10. Average estimate of the turnover related to the import, trade and sale of the considered watches in Italy.

It has to be remarked once more that the values reported in **table 9** are calculated on the basis of ridiculously severe and conservative hypotheses. In credible circumstances, the maximum committed dose to the exposed individuals, in normal conditions of use, is less than 10 μSv/y ("trivial dose", as defined later) and in many cases neither in the worst and unlikely scenarios such a value is exceeded.

In those situations in which the values slightly exceed the trivial dose, cheap and easy countermeasures can be taken: for instance, increasing the air change rate in a room decreases the tritium vapour concentration and thus the dose.

For all scenarios the individual doses are well below the annual limits set by the Italian legislation for practices involving radioactive man-made material (3). Nevertheless, these values have been compared with the constraints, reported in **table 11**, suggested by the IAEA (12) and by the latest European Union Directive (13). The doses can be considered trivial below these values.

WHO	DOSE COSTRAINTS	DOSE LIMITS
IAEA and EU DIRECTIVES	10 μSv/y (individual dose) 1 man Sv/y (collective dose)	n. p.
ITALIAN LEGISLATION	n. p.	1 mSv/y individual dose

Table 11. Dose limits and dose constraints given or recommended by Italian and International organisations. n. p. = not provided

The "cost of detriment" due to a certain practice is defined as the price that the community has to pay as a consequence of the application of that practice. If the benefits for the community are larger than this cost, then the practice may be justified. As an example, this concept can be applied to nuclear power plants: in this case the cost for the community in terms of consequences on the environment and population (for example in medical cures or site decommissioning) is lower than the advantages gained in terms of availability of electric energy. This cost is calculated by multiplying the amount of money necessary to reduce to zero one unit of collective dose (1 man Sv) times the collective dose.

The cost of detriment is not accepted by the Italian authorities in the context of tritium watches. In literature it is possible to find values for the calculation of the cost of detriment referred to the use of nuclear power plants (14, 15) as well as of consumer products containing radioactive substances (16, 17). Using these values we have calculated the maximum, minimum and average amounts for the different scenarios, as reported in **table 12**. The cost for the community would be in these cases much lower than the turnover from the import and trade of such tritium watches, with particular regard to the job places connected to these activities.

The ALARA principle is the basis of modern radiation protection. It is based on the optimisation of radiation protection and limitation and justification of doses. In particular this system states that doses should be reduced to values *As Low As Reasonably Achievable*, considering social and economic factors.

We conclude that the ALARA principle can be applied with success to the tritium watches taken in consideration in this paper, in fact:

- the dose estimates have been always carried out considering the most conservative hypotheses (optimisation of radiation protection);
- the dose values calculated can be considered as trivial, below constraints suggested by International organisations (limitation of doses);
- the cost for the community is much lower than the economic and social advantages (justification of doses)

SOURCE	DOSE RANGE mSv/y	COST OF DETRIMENT (€/man mSv/y)	MAX (€)	MIN (€)	AVE. (€)
A (14)	0-1	15	22500	0.05	2396
B (15)	<1	ca. 25	37500	0.08	3994
C (16)	<5	< 2	3000	0.01	322
D (17)	<5	1-100	1500-150000	0.003-0.3	160-15974

Table 12. Cost of detriment (€) calculated for the scenarios used for the dose assessments. A to D are the sources reported in literature, quoted 14 to 17 in the references.

CONCLUSIONS

We have traced the evolution of the Italian legislation in the matter of luminescent tritium watches in the last thirty years and have analysed the equivalent legislation in some of the main European countries. Scenarios have been proposed for the calculation of the doses absorbed by the Italian population as a consequence of the practice of importing, trading and keeping the tritium watches considered in this paper. Such a practice does not lead to any health hazard. Furthermore, the social and economic impact of this practice is higher than its cost of detriment.

The requests of derogation are still waiting for an answer from the Italian competent authorities.

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