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Trends in UV Irradiance of Tanning Devices in Norway: 1983–2005

Lill Tove N. Nilsen*[,1], Merete Hannevik[1], Tommy N. Aalerud[1], Bjørn Johnsen[1], Eva G. Friberg[1] and Marit B. Veierød[2]

[1]Norwegian Radiation Protection Authority, Østerås, Norway
[2]Department of Biostatistics, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway

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ABSTRACT

Indoor tanning increases skin cancer risk, but the importance of different parts of the UV spectrum is unclear. We assessed irradiance of tanning devices in Norway for the period 1983–2005. Since 1983, all tanning models needed approval before being sold or used. UV Type 3 limits were valid from late 1992 (<0.15 W m^{-2} for CIE-weighted, *i.e.* erythemally weighted, short and long wave irradiances). We analyzed data from 90% of the approved tanning models (n = 446 models) and two large inspection surveys in 1998/1999 and 2003 (n = 1341 tanning devices). Mean CIE-weighted short wave irradiance of approved models increased from 0.050 W m^{-2} (95% confidence interval [CI] 0.045–0.055) in 1983–1992 to 0.101 W m^{-2} (95% CI 0.098–0.105) in 1993–2005, and mean long wave from 0.091 W m^{-2} (95% CI 0.088–0.095) to 0.112 W m^{-2} (95% CI 0.109–0.115), respectively. Inspection surveys revealed short wave irradiances much higher than that approved. In 1998–1999, only 28% (293/1034) of the devices were equipped with correct sunlamps and only 1 out of 130 inspected establishments fulfilled all requirements. In 2003, corresponding numbers were 59% (180/307) of devices and 2 out of 52 establishments. Mean short and long wave irradiances of the inspected tanning devices in 2003 were 1.5 and 3.5 times, respectively, higher than the irradiance of natural summer sun in Oslo. In conclusion, the short wave irradiance has increased in indoor tanning devices in Norway over the last 20 years. Due to the high long wave irradiance throughout this period, the percentage of short wave irradiance was much lower than for natural sun.

INTRODUCTION

The first commercial tanning devices were single mercury arc lamps, often causing severe sunburn and acute eye damage. Fluorescent tube tanning beds became popular during the 1980s, and indoor tanning has become widely used in many countries during the recent two decades (1). Use may be associated with adverse health effects. Immediate effects include sunburn, phototoxic and photoallergic reactions and eye damage, while later effects include skin aging and skin cancer (1–3).

A handful of studies have described UV output and spectral characteristics from indoor tanning devices (4–11). Yet, aside from the general knowledge about the change over time from predominantly UVB (280–315 nm) to UVA (315–400 nm), little data are available about the time trends. As regards skin cancer, UVB is important for squamous cell carcinoma development, but both UVB and UVA may play a role for cutaneous malignant melanoma and basal cell carcinoma where more knowledge is needed concerning the action spectrum (1,2,12). Experimental models mimicking the induction of skin cancer are still not satisfactory (1), therefore epidemiologic studies are important. To date, these have typically investigated the effects of solar and artificial UV exposure without considering spectra. Indoor tanning has been an important source of UVA since the early 1980s and calendar year of use of tanning devices was discussed in the first prospective study relating malignant melanoma to indoor tanning (13–15) and in a recent review (1,2). Moreover, exposure to solar UVB initiates the synthesis of vitamin D in the skin, and the wavelength distribution of sunbed UV irradiance is of importance in the ongoing discussion of positive and negative effects of sunbed use (16–18).

Norway and Sweden were among the first countries to implement national regulations for indoor tanning devices (19,20). Since 1983, all models are required to have an approval from the Norwegian Radiation Protection Authority (NRPA) before being sold, used or advertised in Norway. The approval is based on UV measurements from accepted laboratories, and these data have been recorded since 1983. In addition, the regulations include requirements for user instructions and labeling (19).

The few studies that have assessed compliance with regulations suggest poor compliance, but more knowledge is required (1,9,10). In 1998–1999 and 2003, NRPA performed inspection surveys in Norway to study compliance with regulations and to assess sunbed irradiance. This study focuses on irradiance of approved and inspected tanning devices in Norway and these data provide a unique opportunity to assess UV radiation from indoor tanning devices in use from 1983 to 2005. Comparisons with irradiance of natural sun are also performed.

MATERIALS AND METHODS

The first Norwegian regulation of indoor tanning devices was implemented in 1983 (19) and UV Type 3 requirements took effect in late 1992. A UV Type 3 appliance is provided with a UV emitter

*Corresponding author email: Lill.Tove.Nilsen@nrpa.no (Lill Tove N. Nilsen)

such that the biologic effect is caused by radiation having wavelengths both shorter and longer than 320 nm (the cutoff point for UV Types 1–4) and characterized by a limited irradiance over the whole UV radiation band (< 0.15 W m^{-2} for CIE-weighted short and long wave irradiances) (21–23). A summary of the regulations is presented in Table 1 (details in Appendix 1). NRPA recorded unweighted UVA and ACGIH-weighted UVB and UVC (200–280 nm) irradiances in 1983–1992 and CIE-weighted irradiances in 1993–2005 (Table 1). All irradiances were integrated over the respective wave bands. In the results, we present CIE-weighted irradiances for both periods. Conversion factors were found from measurements on 69 different fluorescent lamp types (24). The 1983–1992 limits for unweighted UVA (200 W m^{-2}) and ACGIH-weighted UVB (0.05 W m^{-2}) correspond to approximately 0.15 and 0.19 W m^{-2} CIE-weighted long and short wave irradiances, respectively. In other words, the limit for short wave was reduced from 0.19 to 0.15 W m^{-2} in late 1992.

Indoor tanning devices approved for sale or use. A total of 496 models of indoor tanning devices were approved in 1983–2005, but irradiance data were not available for 50 models as approvals were based on Swedish endorsements (equal irradiance limits). The 446 models with available irradiance data include 41 models approved with several lamp types and thereby different spectral output. All approvals are based on type testing performed by European laboratories, including NRPA's laboratory from 1995. Since 1997, the approval was based on the maximum UV irradiance measured anywhere in the device (25). Previously, the mean irradiance was usually recorded, *i.e.* the mean irradiance measured over the surface of the device or at a distance stated in the instructions for use. Values for each part of the device (bench, canopy, face) are presented when available.

Inspection surveys in tanning establishments. The inspection survey in 1998–1999 included 130 establishments along the coastal road from Bergen (western Norway) *via* the southern coast to Drammen (southeast Norway). The survey in 2003 included 52 establishments in five municipalities on the east side of the lake Mjøsa (eastern Norway) and the cities Trondheim (central Norway) and Tromsø (northern Norway). All establishments that could be identified in the selected regions were inspected, including tanning salons, fitness centers, hairdressing or beauty salons, kiosks and hotels. They were identified from the regional phone catalogs in advance. A few were identified by information from rival establishments throughout the inspections. No announcements were made in advance. We included all tanning devices found in the inspected establishments, 1034 in 1998–99 and 307 in 2003. Compliance was recorded according to the following criteria: tanning models were approved, sunlamps were in accordance with the approvals, user instruction with exposure schedule followed each tanning device, poster with precaution text was present, and warning and approval labels were present on each device.

Irradiance measurements were performed according to the European Standard in a representative selection (see next paragraph) of tanning devices. Two different radiometers were used: a double monochromator scanning spectroradiometer (Macam Photometrics Ltd.) fitted with a quartz optical light guide (one sigma level 6%), and a broadband radiometer (Solar Light Co. PMA 2100, sensor head PMA 2101 for UVB and PMA 2110 for UVA). The spectroradiometer was irradiance-calibrated against 1000-W quartz tungsten halogen lamps, traceable to National Institute of Standards and Technology *via* SP Technical Research Institute of Sweden. The wavelength scale was calibrated to match known emission lines from a low pressure mercury lamp. As a routine, the wavelength and irradiance calibrations were tested before and after measurements on a tanning device, and corrections applied if necessary. The broadband radiometer was corrected according to the spectroradiometer. The spectral responsivity of the PMA 2101 UVB sensor head resembles roughly the CIE erythema action spectrum, which made it useful for field measurements. The spectral responsivity of the PMA 2110 UVA sensor head is fairly flat and was thus used to measure the UVA for some of the high-pressure lamps. Broadband measurements were converted to integrated CIE-weighted short and long wave irradiances, applying source-specific conversion factors for the UVB sensor. Conversion factors were derived from intercomparisons of broadband and spectroradiometric measurements on a selection of tanning devices during the first inspection survey and from several type tests at the NRPA laboratory in the whole period 1998–2003. The source-dependent conversion factors varied within ±20% for total UV and within ±35% for UVB and UVA. The variation is mainly due to a mismatch between the actual spectral sensitivity of the UVB sensor and the ideal CIE-action spectrum and temperature effects for the UVB sensor head. Choosing the wrong conversion factor for a specific tanning device may result in up to ±35% uncertainty in measurements of CIE irradiance, in addition to the uncertainty in the spectroradiometer calibrations (6%). The uncertainty was typically less than ±20%, as the spectral irradiance distribution of most tanning devices was known from laboratory measurements on a large set of different fluorescent tubes and tanning devices.

In the 1998–1999 survey, UV irradiance was measured in 15 tanning devices (15 different lamp combinations in six different models) with the spectroradiometer and in 82 devices (49 different lamp combinations in 30 different models) with the broadband sensor. In 2003, UV irradiance was measured in 17 devices (17 different lamp combinations in 14 different models) with the broadband sensor and none with the spectroradiometer. The remaining inspected tanning devices were either equal (model and lamps) to one of the devices already measured during the inspections or a device measured previously at NRPA's laboratory, except for 30 (10%) inspected devices in 2003 where irradiances were approximated to that of similar models.

Irradiance of natural sun. UV spectra for natural summer sun at noon were simulated for selected locations: the cities Tromsø (northern Norway) and Oslo (capital, southeast Norway), Crete in Greece, a popular holiday destination for Norwegians, and Brisbane in Australia. A radiation transfer model, FastRT, was used for the conditions cloudless sky, sand environments, sea level, local noon and midsummer (26,27). Typical seasonal ozone values were chosen, *i.e.* 350 Dobson Units (DU) for Tromsø and Oslo and 300 DU for Crete and Brisbane (28). Simulated UV spectra for Oslo were in good agreement with measured spectra (Bentham DTM 300 spectroradiometer; data not shown).

The spectra for natural sun are compared to that from selected tanning devices with lamps most frequently observed during the inspections. For comparison, the spectrum for a common mercury arc sunlamp was also measured with a spectroradiometer (Bentham DTM 300 spectroradiometer).

Data analysis. Data for the approved devices are presented as CIE-weighted short wave and long wave irradiances, before and after 1993, in accordance with the regulations (Table 1). Mean and maximum irradiances of the tanning devices and values for each part, *i.e.* benches, canopies and facial positions, are presented as means and 95% confidence intervals (CIs). The UV index (UVI) is also presented, *i.e.* the total CIE-weighted irradiance multiplied with 40 m^2 W^{-1} (29). Pearson correlation coefficient was calculated between irradiances of approved models and calendar year. Coefficient of variation (CV) was also calculated. All statistical analyses were performed using SPSS 13.0 for Windows.

Table 1. Regulation of indoor tanning devices in Norway, 1983–2005†.

Year	UV region	Irradiance limit (W m^{-2})
1983‡–1992	Unweighted UVA (315–400 nm)	200
	ACGIH-weighted UVB (280–315 nm)§	0.05
	ACGIH-weighted UVC (200–280 nm)§	0.002
1993–2005‖	CIE-weighted long wave (320–400 nm)¶	0.15
	CIE-weighted short wave (250–320 nm)¶	0.15

†Indoor tanning models need approval from the Norwegian Radiation Protection Authority before being sold or used. The approval is valid for the tanning model with the specified sunlamps. ‡Two-year transition time, *i.e.* unapproved models could be used until 1 July 1985. §ACGIH-weighting spectrum; valid for 200–315 nm (33). ‖Only UV Type 3 tanning models are approved for cosmetic use from autumn 1992, but earlier approved models were accepted in use until 1 January 2006. ¶CIE-action spectrum; valid for 250–400 nm (34).

RESULTS

Table 2 presents approved models and inspected tanning devices. The majority of the approved models were equipped with only fluorescent body lamps in 1983–1992, and a combination of body and facial lamps in 1993–2005. There were 43 different manufacturers of the 229 models approved in 1983–1992 and 27 different manufacturers of the 217 models approved in 1993–2005, all together 53 different manufacturers of the 446 models in 1983–2005. The majority of the inspected devices were equipped with fluorescent body and facial lamps. These 1341 inspected devices constitute 89 different tanning models from 16 different manufacturers: 49 models from 12 manufacturers in 1998–1999 and 67 models from 13 manufacturers in 2003. Twenty-seven models and nine manufacturers were the same in 1998–1999 and 2003.

Indoor tanning devices approved for sale or use

The CIE-weighted short wave irradiance limit was higher in 1983–1992 than in 1993–2005 (0.19 *vs* 0.15 W m^{-2}), but the mean short wave values of many approved models were much lower in the first period (Fig. 1). Accordingly, the variation in short wave irradiances was larger in the first than in the second period; CVs were 77% and 25%, respectively. The same applies for the mean long wave irradiances; CVs were 31% and 21%, respectively. There was no clear trend in the association between irradiances and calendar year within the two periods (Fig. 1); Pearson correlation coefficient between mean CIE-weighted short wave irradiances of approved models and calendar year was 0.24 in 1983–1992 and 0.17 in 1993–2005. The corresponding correlation coefficients for long wave irradiances were 0.26 and 0.06, respectively.

Table 2. Characteristics of tanning models approved in Norway in 1983–2005 and inspected tanning devices in the 1998–1999 and 2003 surveys (*n* [%]).

	Approved models			Inspected devices		
	1983–1992 (*n* = 229)	1993–2005 (*n* = 217)	Total (*n* = 446)	1998–1999 (*n* = 1034)	2003 (*n* = 307)	Total (*n* = 1341)
Only facial high-pressure lamps	9 (3.9)	2 (0.9)	11 (2.5)	0 (0)	0 (0)	0 (0)
Fluorescent body lamps + facial high-pressure lamps	25 (10.9)	98 (45.2)	123 (27.6)	83 (8.0)	38 (12.4)	121 (9.0)
Only facial fluorescent lamps	18 (7.9)	3 (1.4)	21 (4.7)	0 (0)	0 (0)	0 (0)
Fluorescent body lamps + facial fluorescent lamps	18 (7.9)	88 (40.5)	106 (23.8)	949 (91.8)	265 (86.3)	1214 (90.5)
Only fluorescent body lamps	159 (69.4)	26 (12.0)	185 (41.5)	2 (0.2)	4 (1.3)	6 (0.5)

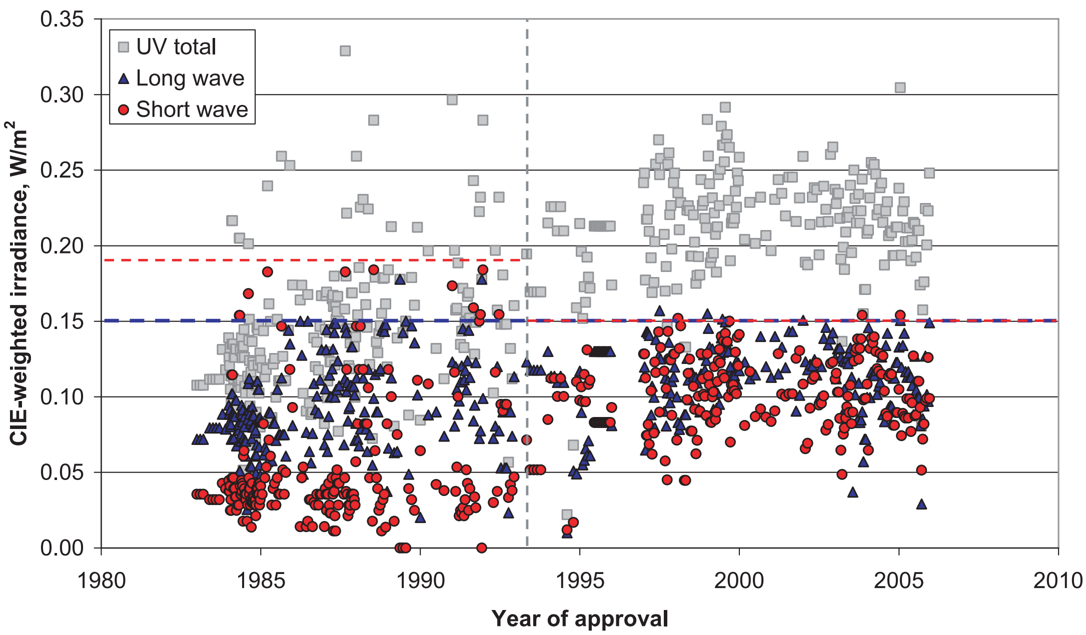

Figure 1. Mean CIE-weighted short wave, long wave and total UV irradiances for tanning models approved for cosmetic use in Norway in 1983–2005. The horizontal lines show the irradiance limits and the vertical line when new limits were introduced (see Table 1). Yearly number of approved models; models where data is missing (*i.e.* measured in Sweden, see text) in parentheses: 1983: 10 (1), 1984: 78 (4), 1985: 23 (2), 1986: 20 (5), 1987: 46 (7), 1988: 24 (2), 1989: 11 (0), 1990: 4 (0), 1991: 27 (5), 1992: 17 (5), 1993: 9 (4), 1994: 10 (1), 1995: 22 (2), 1996: 2 (1), 1997: 34 (8), 1998: 25 (3), 1999: 32 (0), 2000: 6 (0), 2001: 9 (0), 2002: 14 (0), 2003: 27 (0), 2004: 22 (0) and 2005: 24 (0).

Two high-pressure lamps with UVA irradiances below the 200 W m^{-2} limit valid in 1983–1992 have CIE-weighted long wave irradiances above 0.15 W m^{-2} (Fig. 1). Values slightly above the limits in 1993–2005 were accepted because of rounding.

The mean of the approved model's mean and maximum short wave irradiances were doubled in 1993–2005 compared to 1983–1992 (Table 3). Moreover, the percentage of short wave irradiance increased by more than 30% and the UV index by more than 50%. Similar results were found for canopy and bench, but not for the facial position (Table 3) or for devices with fluorescent lamps in both body and facial positions (data not shown). Note that there were only six facial units measured in 1983–1992.

Inspection surveys in tanning establishments

In 1998–1999, only one out of the 130 inspected establishments fulfilled all requirements and 293 (28%) of the 1034 tanning devices were equipped with correct sunlamps, *i.e.* the same type of sunlamps as approved. In 2003, the corresponding numbers were two out of 52 establishments and 180 (59%) out of the 307 devices. One hundred (77%) establishments were of the unattended type in 1998–1999 and 42 (81%) in 2003.

Mean and percentage of short wave irradiances and UV indexes were higher in 1998–1999 than in 2003, except the mean short wave irradiance for the benches (Table 4). Another exception is the irradiance measured at the facial position of devices with high-pressure lamps where the percentages of short wave were 59.0% and 38.5% in 1998–1999 and 2003, respectively (data not shown). Long wave irradiances were slightly lower in 1998–1999 than in 2003, except for the facial position (Table 4).

Mean and percentage of short wave irradiances and UV indexes were markedly higher in the inspected tanning devices than the approved models (Tables 3 and 4). This is also seen when limiting the approval data to the models that were observed during the inspections. Approval data for the 49 different models found during the 1998–1999 inspection survey were 0.096 W m^{-2}, 49.5% and 7.8 for the mean and percentage of short wave irradiances and UV index, respectively, *i.e.* markedly lower than that found in the 1998–1999 inspection (Table 4). The corresponding approval data for the 67 different models observed during the 2003 inspection survey were 0.100 W m^{-2}, 48.1% and 8.3, respectively, *i.e.* markedly lower than that found in the 2003 inspection (Table 4). Long wave irradiances differed less between inspected and approved devices (Tables 3 and 4). Here too, the conclusion does not change when limiting the approval data to the models that were observed during the inspections. Mean long wave irradiances for the approved models found during inspections were 0.098 W m^{-2} in 1998–1999 and 0.108 W m^{-2} in 2003, *i.e.* very close to the observed values in the 1998–1999 and 2003 inspections (Table 4).

Comparison with natural sun

In Table 5 irradiance data for three tanning devices are compared to that of natural summer sun at selected locations. Tromsø is located north of the Arctic Circle and the irradiances and UVI are lower than for Oslo. The selected tanning devices were equipped with the lamp types most frequently observed during the inspections. These fluorescent lamps had high either short or long wave irradiance. For comparison, a mercury arc sunlamp is included.

There are some distinct differences between natural sun and the selected sunlamps. Wolff Life Sun S 100W is spectrally most similar to natural sun, with irradiances and UV index 1.5–1.8 times higher than for summer sun in Oslo. The UV index is twofold for Philips Performance 100W-R, where UVA

Table 3. CIE-weighted UV irradiances (W m^{-2}) of the approved models of tanning devices in Norway in 1983–2005.

		Approved in 1983–1992				Approved in 1993–2005			
		Short wave†	Long wave†	% short wave	UVI	Short wave†	Long wave†	% short wave	UVI
Mean‡ irradiance									
Whole device	*n*	227	229	35.5	5.6	217	217	47.4	8.5
	Mean	0.050	0.091			0.101	0.112		
	(95% CI)	(0.045, 0.055)	(0.088, 0.095)			(0.098, 0.105)	(0.109, 0.115)		
Maximum§ irradiance									
Whole device	*n*	227	229	36.1	5.9	217	217	49.6	9.4
	Mean	0.053	0.095			0.117	0.120		
	(95% CI)	(0.048, 0.058)	(0.091, 0.099)			(0.113, 0.120)	(0.116, 0.123)		
Irradiance of each part of the tanning device‖									
Canopy	*n*	91	92	33.1	6.0	203	203	48.1	8.6
	Mean	0.050	0.102			0.104	0.112		
	(95% CI)	(0.041, 0.058)	(0.097, 0.107)			(0.100, 0.108)	(0.108, 0.115)		
Face	*n*	6	6	46.7	7.4	119	119	42.8	8.0
	Mean	0.086	0.099			0.086	0.115		
	(95% CI)	(0.048, 0.123)	(0.060, 0.138)			(0.078, 0.095)	(0.109, 0.120)		
Bench	*n*	89	90	34.8	6.2	191	191	48.4	8.9
	Mean	0.054	0.101			0.108	0.115		
	(95% CI)	(0.045, 0.062)	(0.096, 0.106)			(0.104, 0.112)	(0.112, 0.118)		

UVI = UV index. †CIE-weighted short wave UV: 280–320 nm; long wave UV: 320–400 nm. ‡Mean irradiance of the tanning device. §Maximum irradiance measured anywhere in the tanning device. ‖Measurements for each part of the tanning device were only available for a few devices approved in 1983–1992.

Table 4. CIE-weighted UV irradiances (W m^{-2}) of the inspected sunbeds in Norway in 1998–1999 and 2003.

		1998–1999				2003			
		Short wave†	Long wave†	% short wave	UVI	Short wave†	Long wave†	% short wave	UVI
Mean‡ irradiance									
Whole device	*n*	1034	1034	65.3	11.4	307	307	58.0	10.6
	Mean	0.186	0.099			0.153	0.111		
	(95% CI)	(0.183, 0.189)	(0.098, 0.100)			(0.147, 0.158)	(0.109, 0.114)		
Maximum§ irradiance									
Whole device	*n*	1034	1034	67.1	14.2	307	307	59.2	12.2
	Mean	0.239	0.120			0.180	0.127		
	(95% CI)	(0.234, 0.243)	(0.119, 0.122)			(0.173, 0.187)	(0.124, 0.130)		
Irradiance of each part of the tanning device									
Canopy	*n*	1033	1033	64.4	10.4	305	305	57.4	10.0
	Mean	0.168	0.093			0.143	0.106		
	(95% CI)	(0.165, 0.171)	(0.091, 0.094)			(0.137, 0.149)	(0.103, 0.109)		
Face	*n*	946	946	67.3	14.4	289	289	57.9	11.2
	Mean	0.243	0.118			0.162	0.117		
	(95% CI)	(0.238, 0.248)	(0.116, 0.120)			(0.155, 0.170)	(0.114, 0.120)		
Bench	*n*	1034	1034	63.6	9.7	307	307	58.5	10.6
	Mean	0.154	0.088			0.155	0.110		
	(95% CI)	(0.152, 0.157)	(0.086, 0.090)			(0.148, 0.161)	(0.107, 0.114)		

UVI = UV index. †CIE-weighted short wave UV: 280–320 nm; long wave UV: 320–400 nm. ‡Mean irradiance of the tanning device. §Maximum irradiance measured anywhere in the sunbed.

Table 5. UV irradiance of natural summer sun at noon at selected locations and of tanning devices.

	Unweighted UV† (W m^{-2})				CIE-weighted UV‡ (W m^{-2})			
	UVC	UVB	UVA	% UVB	Short wave	Long wave	% short wave	UVI
Natural summer sun								
Brisbane, Australia (28°S, 153°E)	–§	2.2	67.2	3.2	0.253	0.046	84.6	12
Crete, Greece (35°N, 25°E)	–§	2.0	61.2	3.2	0.224	0.042	84.2	11
Oslo, Norway (60°N, 10°E)‖	–§	1.1	46.6	2.2	0.100	0.031	76.3	5
Tromsø, Norway (69°N, 19°E)	–§	0.7	37.5	1.9	0.062	0.025	71.3	4
Fluorescent lamps in tanning device¶								
Wolff Life Sun S 100W in bench of Miami Sun Suveren 31 IG††	–‡‡	1.6	69.1	2.3	0.159	0.056	74.0	9
Philips Performance 100W-R in bench of Hapro Lumina 3211	–‡‡	1.3	204.7	0.6	0.102	0.149	40.6	10
High-pressure lamp in tanning device¶								
Philips HPA 400W/30S in facial position of Hapro Lumina E40 Sli	–‡‡	0.27	210	0.1	0.018	0.098	15.5	5
Mercury arc sunlamp§§								
Osram Ultra Vitalux 300W	0.019	5.5	15	27	1.29	0.009	99.3	52

UVI = UV index. †Unweighted UVC: 100–280 nm; UVB: 280–315 nm; UVA: 315–400 nm. ‡CIE-weighted short wave UV: 280–320 nm; long wave UV: 320–400 nm. §Measurements at NRPA of natural sun have shown UVC to be less than 1×10^{-6} W m^{-2}. ‖The corresponding ACGIH-weighted UVB for Oslo is 0.02 W m^{-2}. ¶The most frequently observed sunlamp types during the inspection surveys. ††Miami Sun Suveren 31 IG is not approved with the sunlamp Wolff Life Sun S 100W. ‡‡UVC was not measured; NRPA laboratory measurements have shown UVC in sunbeds to be less than 3×10^{-4} W m^{-2}. §§A previously used mercury arc sunlamp in Norway.

and CIE-weighted long wave irradiances are markedly higher than for summer sun in Oslo. The UV index for the high-pressure lamp is equal to summer sun, but UVA is much higher and UVB irradiances much lower. For the mercury arc sunlamp the situation is opposite. The percentage of short wave irradiance is as high as 99.3% and the UV index is 10 times higher than for summer sun in Oslo. Mean short and long wave irradiances of the inspected tanning devices in 2003 (Table 4) were 1.5 and 3.5 times, respectively, higher than the irradiance of natural summer sun in Oslo.

Figure 2 shows how the spectra for three of the devices/lamps resemble the spectrum for natural sun, but with some distinct differences such as the irradiance peaks, *i.e.* mercury lines at 297, 313 and 365 nm. Furthermore, the CIE-weighted irradiance of the high-pressure lamp is lower than that of natural sun for wavelengths below 335 nm and higher for longer wavelengths.

DISCUSSION

Implementation of the first Norwegian regulations in 1983 had important implications for the use and sale of tanning devices. The UVC- and UVB-rich mercury arc sunlamps were replaced by tanning devices with UVA-rich fluorescent lamps. The

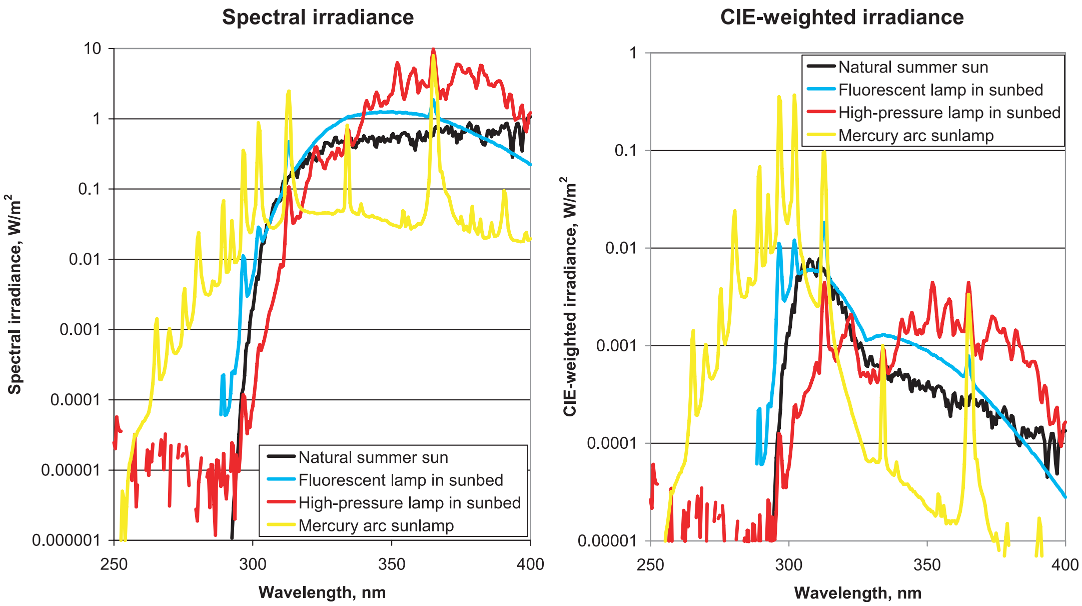

Figure 2. Unweighted and CIE-weighted irradiance for typical summer sun in Oslo compared to the most frequently observed sunlamp in the inspected tanning devices, the fluorescent lamp Wolff Life Sun S 100W in bench of Miami Sun Suveren 31 IG (data available from 290 nm), the most common high-pressure lamp, Philips HPA 400W/30S in facial position of Hapro Lumina E40 Sli, and a mercury arc sunlamp commonly used up to about 1980 in Norway, Osram Ultra Vitalux 300W.

mean UVA and long wave irradiances of the new devices were much higher than that of tropical sun. Despite the possibility in the regulations for UVB irradiances higher than that of Norwegian summer sun, these were instead much lower. The mean UV index was therefore almost the same as for summer sun in Oslo. As harmonized European limits were implemented in the Norwegian regulations in late 1992, the mean short wave irradiance of the approved models increased to the same level as summer sun in Oslo. Long wave irradiance was still much higher than for natural sun. No time trends were seen within the two periods 1983–1992 and 1993–2005. Inspections revealed devices used in the tanning establishments with much more UVB-rich sunlamps than approved for.

The approved models had lower total UV and lower percentage of short wave irradiance in 1983–1992 than in 1993–2005. This was in agreement with the general European opinion, *i.e.* lower UVB to UVA ratio compared to that of natural sun was considered less hazardous, and such lamps dominated the European market in the mid-1980s (30,31). In 1993–2005, the majority of approved models had fluorescent body lamps combined with either high-pressure or fluorescent lamps in the facial position. Particularly the short wave irradiances were higher, even though the limit became stricter in late 1992. The CIE action spectrum has low weighting of the longer UVA wavelengths and lamps with high UVA irradiance may therefore be approved, *e.g.* high-pressure lamps (Table 5). The regulation in late 1992 most likely led to production of new and more UVB-rich sunlamps resulting in an increase in total UV.

An important strength of the study is that we have data from 90% of all tanning models approved for the Norwegian market since indoor tanning regulations were implemented in 1983 (10% approved on the basis of Swedish endorsement). Moreover, the authors from NRPA (L.T.N.N., M.H., T.N.A., B.J. and E.G.F.) have performed all approvals since 1983. Converting the 1983–1992 approval data to CIE-weighted irradiances may have given slightly too high long wave irradiances, as the most UVA-rich lamps differ spectrally from the majority of the fluorescent lamps that the conversion factors were based on (24). The ACGIH and CIE-weighting functions are spectrally more equal for UVB wavelengths. Moreover, the output variation within the same lamp type can be large. NRPA has found a 20% variation for some lamp types (data not shown).

The number and type of approved models do not necessarily map those being used most frequently, as demonstrated by our inspection surveys. By the end of 2002, 392 models had been approved (Fig. 1). The 1341 inspected tanning devices in the two surveys represent only 89 different models. Furthermore, the irradiances of the approved devices did not map that available to the public. Especially in the first inspection survey, the mean short wave irradiance was much higher than for the approved models. The range of short and long wave irradiances was similar to that found in other European studies (4,5,7,11), but with lower total UV irradiance. However, a Scottish study in 1997 (9,10) showed even lower total UV irradiance and an American study showed mean UVB irradiance almost twice as high (8). This demonstrates a strong influence from other European countries on the Norwegian market. These studies also showed large variation in UV output between different tanning devices and across the device surface (4,5,7,9,11).

The main reason for too high short wave irradiances in the inspected devices in 1998–1999 was use of sunlamps other than that specified in the approvals. Only 28% of the devices had correct lamps and thereby complied with the UV Type 3 irradiance requirements. It is easy to replace the lamps in a tanning device, and the authorities can usually only reveal use of incorrect lamps by inspection.

The short wave and total UV irradiance decreased from the first to the second survey in Norway, whereas two studies from

Scotland in 1997 and 2004–2005 showed the opposite trend (9,11). There are no national regulations regarding the use of tanning devices in Scotland. In Scotland the mean erythemal UV increased from less than 0.15 W m^{-2} in regular sunbeds and 0.34 W m^{-2} in stand-up units in 1997 up to 0.41 W m^{-2} for all tanning units in 2004–2005. In Norway, the mean erythemal UV irradiances were 0.29 W m^{-2} in 1998–1999 and 0.26 W m^{-2} in 2003 (Table 4). The number of tanning devices complying with UV Type 3 requirements increased from 28% to 59% in Norway and was only 17% in Scotland in 2004–2005 (11). Much publicity after the first survey may have shifted attention to the existence of regulations and motivated for better compliance in Norway. This demonstrates the importance of inspections. In France, the proportion compliant with technical requirements increased from 51% when the controls started in 1999 to 72% in 2003 (1).

The high number of inspected establishments and tanning devices is a strength of this paper. Furthermore, all measurements were performed by the authors (E.G.F. and B.J. in 1998–1999; T.N.A. and L.T.N.N. in 2003). Prior to the first survey, there had been no systematic inspections, but some sporadic inspections by local authorities. Due to practical reasons, the surveys included all tanning establishments that could be identified in selected areas. A register for tanning establishments did not exist (established in 2004). Possibly, a few manufacturers dominated in some districts, but the largest ones sell their products throughout the whole country.

A limitation of our inspection surveys is that we did not measure all tanning devices, *i.e.* when models and lamps were equal to one of the devices already measured during the inspections or a device measured previously at NRPA's laboratory. For 10% of the inspected devices in 2003, irradiances were approximated to that of similar models. The output from UV fluorescent sunlamps declines with hours in use (5), and type testing is performed with fluorescent lamps aged 50 h (test requirement up to 1997) or 5 h (after 1997) (21,25). Acceptance of these uncertainties illustrates our priority: to map UV output for many devices with a simple instrument, rather than only a few devices with a high quality, but less mobile, spectroradiometer. Our inspection results give estimates for the Norwegian tanning market and also indicate changes with respect to UV output from 1998–1999 to 2003.

The recent expert report on exposure to artificial UV radiation and skin cancer listed regulations and recommendations of health authorities where they are available (1). The Scientific Committee on Consumer Products has suggested stringent European regulations regarding the use of tanning devices and with strict UV irradiance limits (16). Nevertheless, few countries regulate the use of indoor tanning, thus comparisons between epidemiologic studies as regards exposure from tanning devices must be performed in guarded terms.

In conclusion, UVC- and UVB-rich mercury arc sunlamps were replaced by UVA-dominated tanning beds in the early 1980s in Norway. The variation in short wave irradiance was large until the UV Type 3 requirement was implemented in the Norwegian regulations in late 1992. The mean CIE-weighted short wave irradiance of approved models then increased from half that of summer sun in Oslo to the same level as the summer sun and with less variation. CIE-weighted long wave irradiance of approved models has been about 3–3.5 times higher than for natural summer sun in Oslo in the whole period (1983–2005).

Inspections are essential. Despite strict Norwegian regulations, inspections revealed tanning devices in use with too high short wave irradiance, and being 1.5–2 times that of natural summer sun in Oslo, while long wave irradiances differed less between inspected and approved devices. The irradiances of the inspected sunbeds were similar to that of other European studies and the ongoing discussion on stricter European regulations is important. Stricter and more uniform European regulations might lead to production and distribution of more sunlamps and tanning devices complying with UV Type 3 requirements. The current study adds to the existing knowledge of UV irradiances of tanning devices, and is useful for planning and interpretation of studies on sunbed use in relation to adverse health effects (*e.g.* risk of skin cancer) and potential health benefits (*e.g.* photosynthesis of vitamin D).

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APPENDIX 1—REGULATION OF INDOOR TANNING DEVICES IN NORWAY

From 1933 to 1992 Nemko AS performed mandatory safety testing and national approval of electrical equipment to be marketed in Norway, excluding radiation safety. According to their register, mercury arc sunlamps were sold in Norway since 1937 and the first whole body tanning model appeared in 1972. Since 1982 most tanning models were equipped with fluorescent lamps (32).

1983–1992

The first Norwegian regulations were issued on 1 July 1983 with a 2-year transition time (19). As described in the Introduction, from this date all tanning models needed an approval from NRPA before being sold, used or advertised in Norway. Approval was based on UV measurements from accepted laboratories and was valid for the tanning device with specified sunlamps. Data were recorded in terms of unweighted UVA, and ACGIH-weighted UVB and UVC irradiances. All irradiances were integrated over the respective wave bands. The ACGIH-weighting function is a reference action spectrum for UV-induced acute erythema and photokeratitis in humans which is valid for the wavelength range 200–315 nm (33). The radiation limit was 200 W m^{-2} for unweighted UVA, and 0.05 and 0.002 W m^{-2} for ACGIH-weighted UVB and UVC, respectively (19).

The Norwegian and Swedish regulation authorities agreed upon these limits, being around 4 and 2–2.5 times the UVA and ACGIH-weighted UVB values, respectively, for typical clear sky summer sun irradiances at noon at 60°N (Gunnar Saxebøl, NRPA, Director Department for Radiation Protection and Nuclear Safety). Consequently, this excluded the extremely UVC- and UVB-rich sunlamps and lamps that were so intense that sunburn could easily happen in the case of a defective timer.

1993–2003

In 1989 the European Committee for Electrotechnical Standardization (CENELEC) published harmonized European regulations (21) based on an international standard (22,23).

Conflicting national regulations had to be withdrawn within a 3-year period. Tanning models were classified into UV types 1–4 according to the CIE-weighted UV irradiance. The CIE-action spectrum is a reference action spectrum for UV-induced erythema in Caucasian human skin (34) valid for the UV region 250–400 nm. Wavelength regions differ from the previously used ACGIH-weighting. CIE-weighted data are presented as short wave (250–320 nm) and long wave (320–400 nm) UV irradiances.

As in some other European countries, the European Standard was implemented in Norway in late 1992 with a restriction that only UV Type 3 tanning beds were allowed for cosmetic use. The irradiance limits were 0.15 W m^{-2} for both wave bands. Tanning models approved prior to the revision were still accepted in use.

2004

There is still a restriction to UV Type 3 tanning models, and it was stated that models approved prior to implementing UV Type 3 could not be used after 1 January 2006 (35).