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EXPOSURE TO RADON AT UNDERGROUND WORKPLACES
IZPOSTAVLJENOST RADONU NA PODZEMNIH DELOVNIH MESTIH

Janja Vaupotič[1], *Ivan Kobal*[1]

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Abstract

Aim: *The main aim of this contribution is to review the radon (^{222}Rn) surveys carried out over the last two decades at underground workplaces in Slovenia in coal mines, karstic caves, water supply plants, wineries and hospitals.*
Methods: *Alpha scintillation cells, etched track detectors, an AlphaGuard PQ2000 multiparameter radon monitor and EQF 3020 and EQF 3020-2 radon and radon progeny monitor systems were used to measure concentrations of radon and radon short-lived decay products, equilibrium factor and unattached fraction of radon decay products in air.*
Conclusions: *(1) Radon levels are low in coal mines; (2) elevated radon levels can be present in karstic caves; prior to a longer stay in a karstic cave, the radon level should be checked and, if necessary, stay in the cave limited; (3) although elevated radon levels are frequently found at water supply plants, attendance times at underground workplaces are short and the effective doses low; care is necessary for longer maintenance works; (4) under normal working regimes in a winery, exposure to radon in underground facilities is low; (5) radon levels are low in the majority of basement rooms in hospitals, but precautions are necessary in old buildings where the floor may not always be a sufficient barrier to Rn entry, and indoor radon levels may be elevated.*

Key words: radon, radon short-lived decay products, underground workplaces, effective doses

Izvirni znanstveni članek
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Izvleček

Cilj: *Glavni namen je bil podati pregled preiskav radona (^{222}Rn) na podzemnih delovnih mestih v zadnjih dveh desetletjih, in sicer v premogovnikih, kraških jamah, vodnih zajetjih, vinskih kleteh in bolnišnicah.*
Metode: *Uporabljali smo komplementarno merilno opremo, s katero smo merili koncentracijo radona (Rn) in radonovih kratkoživih razpadnih produktov (RnDP), faktor radioaktivnega ravnotežja med Rn and RnDP ter delež prostih RnDP, in sicer: alfa scintilacijske celice, detektorje jedrskih sledi, radonski merilnik AlphaGuard PQ2000 ter kombinirana merilnika EQF 3020 in EQF 3020-2 za Rn in RnDP.*
Zaključki: *(1) Koncentracije Rn v zraku rudnikov so bile nizke. (2) V kraških jamah lahko naletimo na zelo visoke koncentracije Rn v zraku, zato je potrebno pred daljšim zadrževanjem ali delom v jami predhodno izmeriti radon, delo v jami načrtovati in, če je potrebno, časovno omejiti; (3) v podzemnih prostorih vodnih zajetij lahko naletimo na povišane koncentracije Rn v zraku, ker pa je tu zadrževalni čas delavcev kratek, so dobljene efektivne doze nizke; vendar je potrebno daljša vzdrževalna dela načrtovati in, če je potrebno, omejiti delovni čas; (4) pri normalnem delovnem režimu so v vinskih kleteh koncentracije Rn v zraku nizke; previdnost je potrebna samo pri izvajanju del ob izključenem prezračevanju; (5) na večini delovnih mest v kletnih prostorih bolnišnic je izpostavljenost radonu zadovoljivo nizka – previdnost je potrebna le pri starejših zgradbah, v*

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katerih morda tla niso bila kakovostno izvedena ali pa je prišlo z leti do poškodb talne plošče, s čimer se je radonu olajšal dostop v prostor.

Ključne besede: radon, radonovi kratkoživi razpadni produkti, podzemna delovna mesta, efektivne doze

1 Introduction

Recent epidemiological studies in homes indicate that in Europe (1) the radioactive noble gas radon (^{222}Rn or Rn) together with its short-lived decay products (RnDP) accounts for about 9 % of deaths due to lung cancer and about 2 % of all deaths due to cancer. It originates in rocks and soils by radioactive decay of radium (^{226}Ra) in the uranium (^{238}U) decay chain (2). Because uranium is widely distributed, though at low levels, all over the earth's crust, radon is present everywhere in the environment, the highest activity concentration being in soil gas, i. e., from several hundred kilo Bq m^{-3} to several mega Bq m^{-3} (activity of 1 Bq equals 1 disintegration per second). Radon emanates from its place of origin in a mineral grain, into soil gas or water present in the void space. Then, dissolved in either a carrier geogas or thermal-mineral water and driven by advection, it moves towards the surface and eventually reaches the atmosphere (3). There, it is rapidly diluted and its resulting concentration in the outdoor air is low, in the range of 5–50 Bq m^{-3}. On the other hand, it accumulates in closed underground places (karst caves, mines, tunnels), as well as in basements and ground floors of the living and working environment. In the indoor air of a building, its concentration depends on the geology and pedology of the site, shape, size and quality (less often building material) of the structure, and living habits of residents and the working regime (4). Because of its decay, Rn (α-decay, half-life, $t_{1/2}$ = 3.82 days) is always accompanied by its short-lived decay products (RnDP): ^{218}Po (α-decay, $t_{1/2}$ = 3.05 min), ^{214}Pb (β/γ-decay, $t_{1/2}$ = 26.8 min), ^{214}Bi (β/γ-decay, $t_{1/2}$ = 19.7 min) and ^{214}Po (α-decay, $t_{1/2}$ = 164 μs). RnDPs are present attached to aerosols or as unattached nanosize clusters. Although theoretically possible, radioactive equilibrium between Rn and RnDP is never reached in the actual environment and activity concentrations of RnDP are lower than that of Rn, as described by the equilibrium factor *F*, which has a value between 0.40 and 0.60 in indoor air.

While extensive surveys of radon in indoor air in dwellings and workplaces have been carried out in most developed countries, much less attention has been paid to underground rooms, despite the fact that elevated Rn levels are expected here. However, underground places have not been ignored in Slovenia. In a nationwide indoor radon programme, radon in air has been monitored in 730 kindergartens (5), 890 schools (6) and 1000 randomly selected homes (7) together with a large number of underground workplaces, where elevated radon levels can be expected.

In this paper, we reported radon levels in workplaces in Slovenian non-uranium underground mines, karst caves, water supply plants, wineries and hospitals. The effective doses estimated for the employees are discussed.

2 Experimental

2.1 Survey methods

Different instruments have been used to measure radon concentration in air, the choice depending on the purpose of measurement.

- To obtain instantaneous Rn concentration, different size alpha scintillation cells (8) were used. The cells were calibrated with a standard $^{226}RaCl_2$ solution (National Institute of Standards and Technology (NIST Standard Reference Material 4953D), according to the Rushing procedure (9, 10). Using the same procedure, cells were checked monthly. Cell efficiencies lie around 1.4×10^{-3} s^{-1} Bq^{-1} m^3, which gives a lower limit of detection of 10–30 Bq m^{-3} at a 1–2 min^{-1} background and 30 minutes counting time. Air was sampled directly into a cell, which was transported to the laboratory, where gross alpha radiation was counted in PRM 145 counters (AMES, Slovenia) three hours after sampling, when equilibrium between radon and its short-lived decay products was reached.
- Average radon concentration was obtained by exposing etched-track detectors provided by various manufacturers: Forschungszentrum Karlsruhe (Germany), Radonlab (Oslo, Norway), and National Institute of Radiological Sciences (Chiba, Japan). After 1 to 3 months exposure, detectors were

mailed back to the manufacturer for development and evaluation of the results. At these exposure times the lower limit of detection was 3 to 5 Bq m^{-3}. The detectors were calibrated by the manufacturers.

- An AlphaGuard PQ2000 multiparameter radon monitor (Genitron, Germany) was used to measure radon concentration, air temperature and barometric pressure continuously, with a frequency of one per hour over a period of 5–20 days in order to determine diurnal fluctuations of Rn concentration. The lower limit of detection was 50 to 100 Bq m^{-3}. The instrument was calibrated in the manufacturer's radon chamber before delivery.
- EQF 3020 and EQF 3020-2 radon and radon progeny monitor systems (Sarad, Germany) were used to measure continuously (with a frequency of once every two hours) concentrations of Rn and RnDP, equilibrium factor between Rn and RnDP and unattached fraction (f_{un}) of RnDP together with air temperature and humidity, over a period of 5 to 20 days in order to determine diurnal fluctuations of these parameters. The lower limit of detection was 30 to 80 Bq m^{-3}. The instruments were calibrated before delivery and recalibrated every two years in the manufacturer's radon chamber.

In order to comply with the quality assurance - quality control recommendations, the devices were checked regularly at the inter-comparison experiments organized annually by the Slovenian Nuclear Safety Administration (11), and at each site, radon concentration was also measured with alpha scintillation cells calibrated with a NIST standard as described above. Results obtained with the cell and the other devices agree within experimental errors.

2.2 Measurement protocol

The survey of radon at underground workplaces was designed and performed with assistance from the Radiation Protection Administration at the Ministry of Health, except for the first measurements in underground mines and karst caves. Places to be monitored were selected jointly, taking into account the elevated radon levels previously found, the radon potential based on geology and our previous experience in indoor radon levels. Prior to our survey, the management of each place was provided with general information about the radon problem at underground workplaces, and the programme of our study was explained. Underground rooms were selected jointly with the management, giving priority to those attended by larger numbers of persons for longer times. Air was sampled by alpha scintillation cells to obtain a quick and rough estimate of radon levels. Then, at the 2 or 3 points with the highest radon levels, etched track detectors were exposed for 1–3 months. In addition, at representative places, concentrations Rn (C_{Rn}) and RnDP (C_{RnDP}), as well as the equilibrium factor (F) and unattached fraction of RnDP (f_{un}), were recorded continuously for 5–20 days.

3 Results

3.1 Underground non-uranium mines

High radon levels have been found in air of uranium mines and also of other underground workings, especially metal and coal mines (12, 13). Rn concentrations in the air were measured between 1978 and 1986 in the following Slovene mines: Mežica lead-zinc mine, Idrija mercury mine and Velenje-Preloge, Trbovlje, Zagorje, Hrastnik, Laško and Senovo coal mines (14). In total, about a hundred samples were taken with alpha scintillation cells. At several sites in the Mežica and Idrija mines Rn concentrations exceeded the Slovene national limit of 1000 Bq m^{-3} (15). At the time of our survey, both mines started to be shut down and the investigation was therefore not continued. Rn concentrations in all coal mines however were low, never exceeding 500 Bq m^{-3}.

3.2 Karst caves

In 1984 and 1985, radon in air was measured with alpha scintillation cells at about five hundred sites in more than fifty Slovene caves (16), where elevated Rn levels were expected (17). Measurable Rn concentrations ranged from 2 to 6 kBq m^{-3}, although in many caves it was below the detection limit. At one site in the Postojna Cave off the tourist guided route, it was as high as 22 kBq m^{-3} (18). A further study in this cave, lasting for several years and in which various complementary measuring devices were used to obtain C_{Rn}, F, f_{un}, C_{RnDP}, as well as meteorological parameters, showed (19) that radon concentrations may reach 4–6 kBq m^{-3} in summer. The diurnal variation of the measured parameters in summer is shown in Fig. 1. Rn and RnDP levels were lower in wintertime by a factor of about 2.

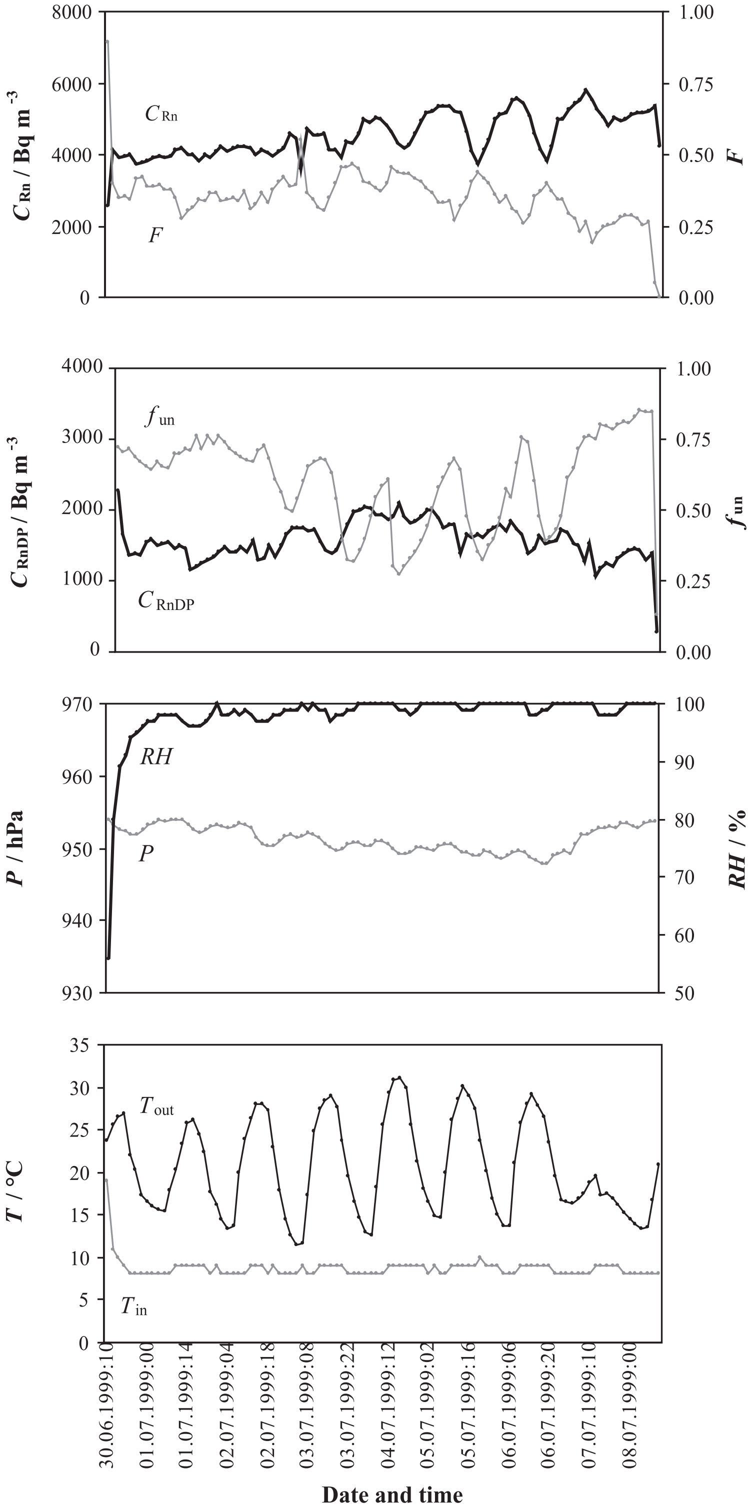

Figure 1. *Radioactivity measurements at the lowest point in Postojna Cave, June 30 – July 8, 1999. Concentrations of Rn (C_{Rn}) and equilibrium factor (F); concentrations of RnDP (C_{RnDP}) and unattached fraction of RnDP (f_{un}); relative air humidity in the cave (RH) and barometric pressure (P); air temperature outdoor (T_{out}) and in the cave (T_{in}).*

3.3 Water supply plants

Elevated Rn levels may also be found in air at workplaces in water supply plants (20). In 2001, Rn, RnDP and *F* were monitored at workplaces in 53 underground premises of water plants in Ljubljana, Grosuplje, Kočevje, Maribor, Koper, Ilirska Bistrica, Nova Gorica, Postojna, Sežana and Metlika (21). Both instantaneous and monthly average radon concentrations were found to be relatively low, exceeding 1000 Bq m^{-3} only at 4 places.

3.4 Wineries

Although wine production is an important national industry in many countries reports on radon in air at workplaces in their underground facilities are sparse (21). We focused our attention on this environment in 2002. Rn and RnDP concentrations, *F* and f_{un} were measured in 22 underground rooms of the larger wineries in the following cities/towns: Sežana, Koper, Vipava, Ptuj, Ormož, Ljutomer, Gornja Radgona and Maribor (23). While 1–2 month average Rn concentrations obtained with etched track detectors were below 150 Bq m^{-3} in all the rooms surveyed, alpha scintillation cells showed an instantaneous value above 1000 Bq m^{-3} in one room of an old winery. The reason for this disagreement is evident from Fig. 2, which shows the diurnal variation of Rn concentration. In the periods June 6–7 and 27–28, the ventilation system was shut down, resulting in high Rn levels. The air sample was taken on June 6, when Rn concentration was highest, while etched track detector showed the average, lower, value. Time runs of the parameters monitored under the normal working regime of a new winery are shown in Fig. 3.

3.5 Hospitals

In many hospitals there are laboratories, shops, kitchens and other facilities in basements where elevated Rn levels may be expected (24, 25). In 2002, a Rn survey was carried out in hospitals in the following cities/towns: Ankaran, Begunje, Brežice, Celje, Golnik, Idrija, Izola, Jesenice, Kranj, Ljubljana, Maribor, Murska Sobota, Nova Gorica, Novo mesto, Ormož, Postojna, Ptuj, Sežana, Slovenj Gradec, Šentvid pri Stični, Topolšica, Trbovlje and Vojnik (26). In each hospital, two to four etched track detectors were exposed. In total, 207 air samples were taken from 186 rooms, and 215 etched track detectors were exposed in 198 rooms. In addition, in 12 rooms of 9 hospitals, concentrations of Rn and RnDP as well as *F* and f_{un} were recorded continuously for periods of 5 to 11 days.

Monthly average Rn concentrations obtained with etched track detectors were below 100 Bq m^{-3} in more than 70 % of places (Table 1) and only in 7 rooms were they above 400 Bq m^{-3} (Table 2).

Diurnal variations of Rn and RnDP concentrations in two shops with elevated levels are presented in Fig. 4. Variations were very small in the first (Fig. 4a), fluctuating by about ±50 % around the mean value, while they were much more pronounced in the second (Fig. 4b), radon concentrations ranging from several hundred Bq m^{-3} in the morning up to several thousand Bq m^{-3} during the night. Surprisingly, both shops are on the ground floor and not in a basement. While a constantly high concentration is seen for the weekend of October 18–21 (Fig. 4b) this is not so clear for the weekend of September 27–30 (Fig. 4a). Permanent ventilation in the first shop keeps radon concentrations almost con-

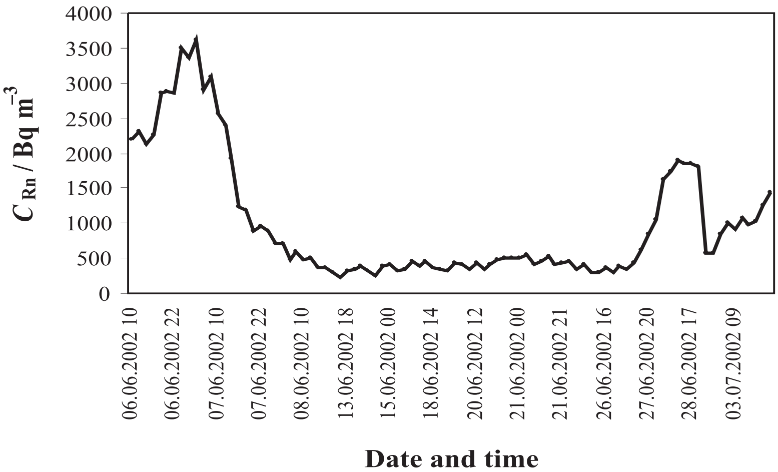

Figure 2. *Continuous measurement of concentrations of Rn (C_{Rn}) and RnDP (C_{RnDP}) in an old winery, using the Sarad EQF3020-2 instrument between June 6 and July 3, 2002.*

stant, while the second shop is only ventilated naturally by opening doors and windows, and hence a typical diurnal variation of radon concentration occurs (27).

4 Discussion

To relate concentrations of Rn or RnDP to health, the dose conversion factor (DCF) is needed, defined as the ratio of the weighted equivalent dose to the lung (expressed in mSv) to the exposure to RnDP (expressed either in WLM, if RnDP activity concentration in air is known, or Bq m^{-3} h, if Rn activity concentration in air is known). The old but still widely used unit, 1 WLM (working-level-month), is the exposure resulting from 170 hours breathing air with an activity concentration of short-lived radon decay products of 1 WL (working-level). 1 WL was originally defined as the activity concentrations of RnDP which are in radioactive equilibrium ($F = 1$) with 100 pCi L^{-1} (3700 Bq m^{-3}) of ^{222}Rn, resulting in a potential alpha energy concentration of 1.3×10^5 MeV L^{-1} (2). *DCF* values have been obtained from epidemiological studies on uranium miners. At present, the International Commission for Radiological Protection (ICRP) in Publication 65 (28) recommends 5 mSv WLM^{-1} for working and 4 mSv WLM^{-1} for living environments.

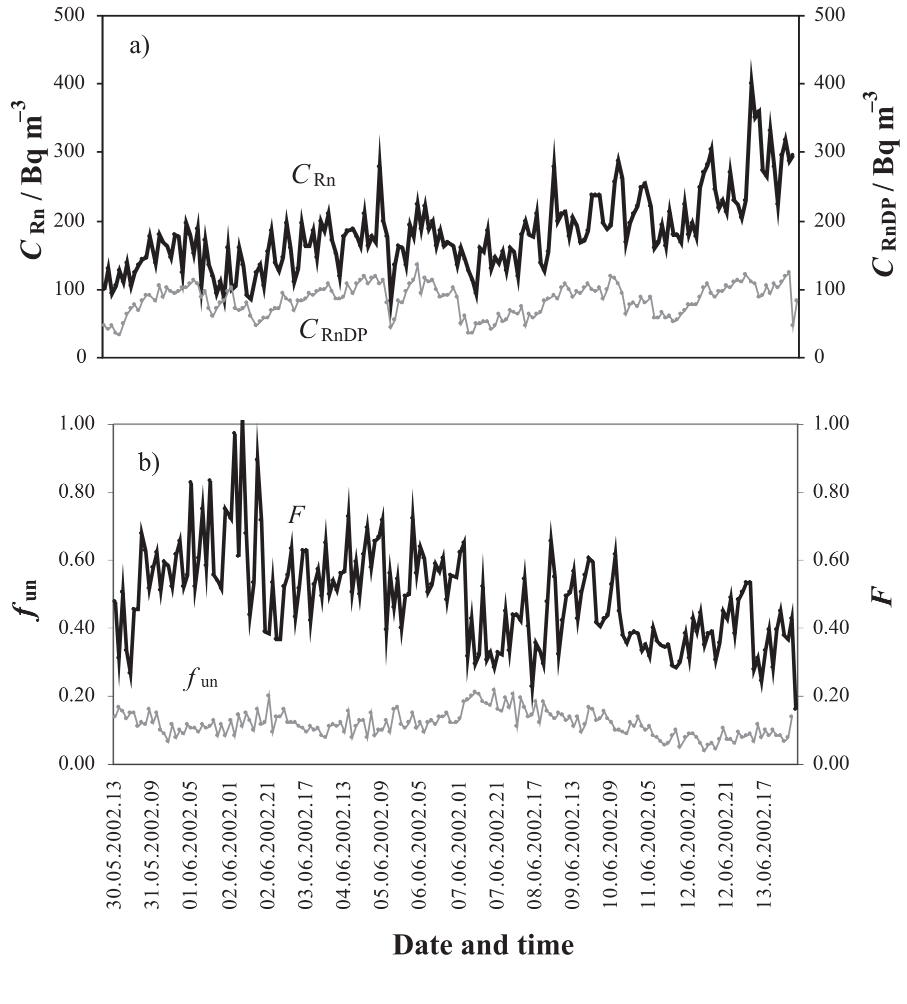

Figure 3. *Continuous measurement of concentrations of Rn (C_{Rn}) and RnDP (C_{RnDP}), equilibrium factor (F) and unattached fraction of RnDP (f_{un}) in a new winery, using the Sarad EQF3020-2 instrument in the period from May 30 to June 14, 2002.*

Table 1. *Distribution of average Rn concentrations (C_{Rn}) in Slovene hospitals as obtained by exposing etched track detectors in September and October, 2002.*

Number of rooms	Percentage of rooms %	C_{Rn} Bq m^{-3}
46	23.5	< 50
94	47.9	50 – 100
39	19.9	100 – 200
8	4.1	200 – 300
2	1.0	300 – 400
7	3.6	> 400

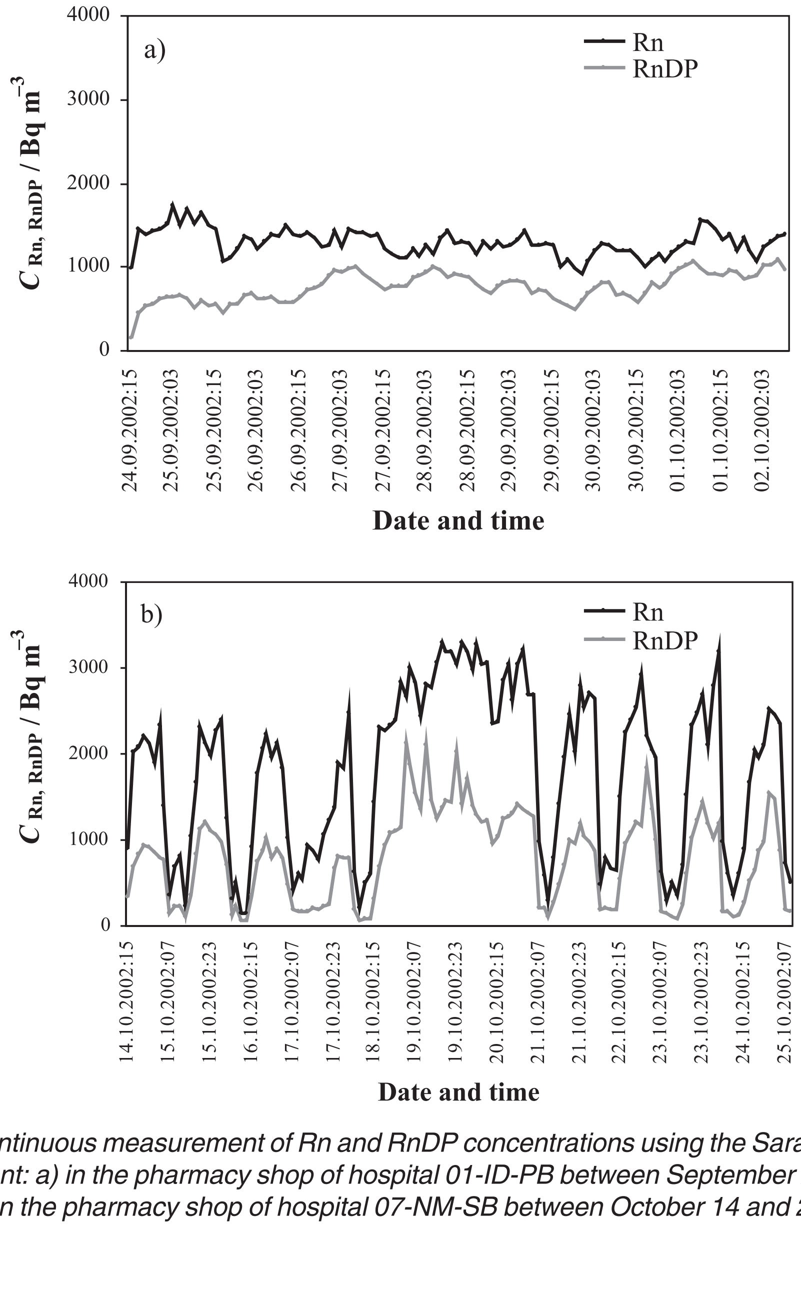

Figure 4. *Continuous measurement of Rn and RnDP concentrations using the Sarad EQF3020-2 instrument: a) in the pharmacy shop of hospital 01-ID-PB between September 24 and October 2, 2002; b) in the pharmacy shop of hospital 07-NM-SB between October 14 and 25, 2002.*

Table 2. *Hospitals (coded names) with indoor air radon concentrations higher than 400 Bq m^{-3}. Shown are: number of persons working in the rooms surveyed and their annual exposure times, monthly average radon concentrations (C_{Rn}) obtained with etched track detectors in the periods indicated (in 2002), and monthly effective doses (E) (mo stands for month), received by the personnel in the period from 23 September to 22 October.*

Hospital Code	Period of measurement	C_{Rn} Bq m^{-3}	No. persons	Exposure time h per year	E μSv mo^{-1}
01-LJ-PK	17.9. – 24.10.	600 ± 35	1	1098	191
	17.9. – 24.10.	2800 ± 140	1	816	664
01-ID-PB	16.9. – 24.10.	1400 ± 85	1	1590	646
	24.9. – 24.10.	1000 ± 50	1	1590	464
02-MB-SB	17.9. – 24.10.	565 ± 35	1	1984	327
05-SE-BS	18.9. – 22.10.	3000 ± 150	4	348	300
07-NM-SB	17.9. – 25.10.	1100 ± 55	7	1984	618

Based on radon concentrations measured at underground workplaces, effective doses (E) received by a worker at these places were calculated applying the general formula (2):

$$E = (C_{Rn} \times F) / 3700 \times (t/170) \times DCF. \quad (4)$$

Here, C_{Rn} is the radon concentration (in Bq m^{-3}) and t is the time (in hours) spent by workers at this workplace. According to ICRP-65 (28), $F = 0.40$ and DCF = 5 mSv WLM^{-1}.

4.1 Underground non-uranium mines

Rn levels in coal mines are low, as the result of the effective ventilation needed to prevent methane explosions. Therefore no precautionary measures are needed from the radiation protection point of view. Effective doses have not been published.

4.2 Karst caves

Radon concentrations in karst caves are higher in summer than in winter due to the so-called “chimney effect”. For example, air temperature in the Postojna Cave is between 8.0 and 9.0 °C and is practically constant all the year round. In winter, the air temperature in the cave is higher than outdoors and the cave works as a huge fire place in which the draught drives air from the cave rooms into the atmosphere.

Because of the high radon levels in the Postojna Cave, in 1995 regular and permanent Rn monitoring was required by the Radiation Protection Administration, and has been carried out ever since. The Cave management reports the effective doses for their workers in the cave for the first half of every year and for the whole year. If the effective dose for a worker for the first half of the year exceeds 2.0 mSv, that worker would spend a reduced time in the cave in the second half of the year. Based on the annual effective doses, the time to be spent the following year by workers in the cave is planned. The effective dose received by a tourist during one visit is negligible.

4.3 Water supply plants

The attendance time of workers in underground premises of the water plants is short and hence despite the elevated Rn levels, the resulting annual effective doses were acceptably low: they never exceeded 3 mSv (Fig. 5). Therefore under the present working regime no mitigation measures are needed. Nonetheless, the managements were recommended to prepare a time plan prior to every maintenance work underground, which should be accompanied by Rn monitoring and, if necessary, time limited for a given worker.

4.4 Wineries

Based on Rn concentrations obtained with etched track detectors, annual effective doses for the workers in underground rooms of wineries were estimated to range from 0.13 to 1.75 mSv. The latter value slightly exceeds 1.25 mSv, the effective dose a member of the general public receives from Rn and RnDP in a year on a worldwide average (29). Under the present operational regime in Slovene wineries no precautions from the radiation protection point of view are necessary for

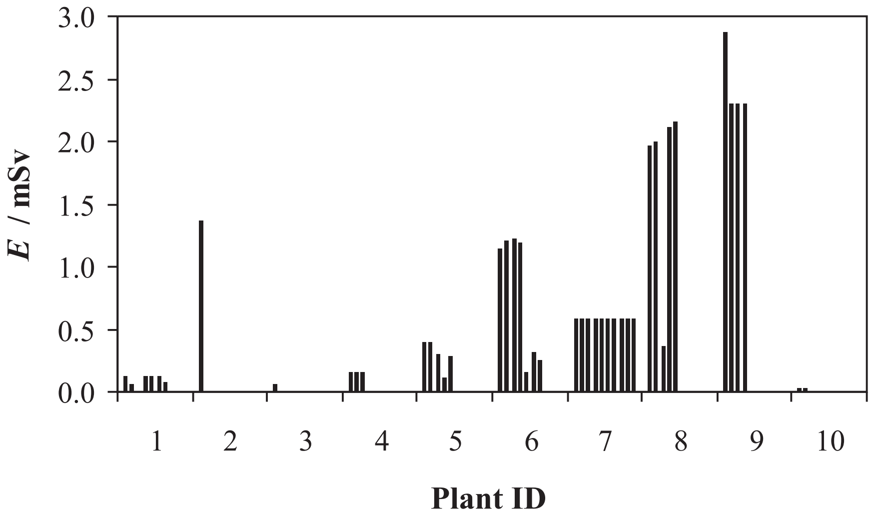

Figure 5. *Annual effective doses of workers in underground facilities in Slovene water supply plants in 2001 (PI – plant identity number).*

workers and no mitigation measures are foreseen. We have only drawn the attention of the managements to the crucial role of ventilation in keeping low Rn levels, and not to allow works, or at least to limit working times, at underground workplaces during periods when fans are shutdown.

4.5 Hospitals

The reason for elevated indoor Rn levels in hospitals was always that the floor not properly made: either the concrete slab was of bad quality, with cracks appearing with age, or wooden boards were fixed on wooden beams laid directly on a gravel ground.

Annual effective doses were calculated for 1025 persons working in the rooms surveyed. 996 persons (94.2 %) received less than 1 mSv in a year and the remaining 59, between 1.1 and 7.3 mSv. For 16 of the latter, working in rooms with radon concentration more than 400 Bq m^{-3}, the monthly effective doses are shown in Table 2. All the rooms with annual effective doses more than 2 mSv were further investigated in order to obtain reliable data on which to decide whether mitigation measures should be undertaken. Some rooms have been already successfully mitigated and the others are in the process of mitigation.

5 Conclusions

This review of the Rn survey carried out at underground workplaces in Slovenia over the last two decades, highlights the following main points: (i) because of effective ventilation, no concern is necessary for miners' exposure to radon in coal mines; (ii) prior to a longer stay in a karst cave, Rn level should be checked and, if necessary, the stay in the cave should be limited – as an example: based on the semi-annual and annual effective doses of the workers in the Postojna Cave, their stay in the cave is planned ahead and working time in the cave is limited; (iii) elevated Rn levels are frequently found in underground premises of water supply plants but the effective doses received by the workers are low because of short attendance times; however, maintenance work underground should be accompanied by Rn monitoring, and the management should plan the time needed for each worker, in order to avoid too high exposure; (iv) under normal working regime in a winery, exposure of workers to Rn in underground facilities is low; care is necessary only when work is to be carried out during ventilation shut down; (v) in the majority of basement rooms in hospitals the exposure of personnel to Rn is acceptably low, nevertheless, the occupation safety officer should pay attention to rooms in old buildings where the floor is not always a sufficient barrier to Rn entry, leading to the possibility of elevated indoor Rn levels.

While radon levels cannot be reduced in karst caves because the natural environment should be preserved, at all other places Rn problem can be successfully mitigated by undertaking appropriate technical measures.

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Contributors:
Ivan Kobal participated in field measurements and data evaluation for underground mines and karst caves, while Janja Vaupotič, as the head of the Radon Center at the Jožef Stefan Institute, designed the programme and, together with her co-workers, ran the measurements in the Postojna Cave, water supply plants, wineries and hospitals, evaluated the data obtained and prepared the paper jointly with Ivan Kobal.

Conflict of interest: none.

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List of abbreviations:

ICRP - International Commission on Radiological Protection
Rn - ^{222}Rn isotope of radon
RnDP - short-lived decay products of ^{222}Rn: ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po

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THE ROLE OF NANOSIZED AEROSOLS OF RADON DECAY PRODUCTS IN RADON DOSIMETRY

VLOGA NANO AEROSOLOV RADONOVIH RAZPADNIH PRODUKTOV V DOZIMETRIJI RADONA

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Abstract

Aim: *In order to demonstrate the difference in dose conversion factors obtained based on epidemiological studies (DCF_E) and by applying dosimetric models for mouth (DCF_{Dm}) and nasal (DCF_{Dn}) breathing the unattached fraction of nanosize radon short-lived decay products (f_{un}) was measured.*
Methods: *Portable SARAD EQF3020 and EQF3020-2 devices were used to continuously measure activity levels of radon (Rn) and radon short-lived decay products (RnDP) , equilibrium factors between Rn and RnDP, and unattached fractions of RnDP. Measurements were carried out in kindergartens, karst caves and wineries.*
Conclusion: *In kindergartens, f_{un} ranged from 0.03 to 0.24 with a geometric mean of 0.14. DCF_{Dm} and DCF_{Dn} are higher by a factor of 4.0 and 1.7, respectively, than DCF_E = 5 mSv WLM^{-1}. At the lowest point of the Postojna Cave, f_{un} values ranged from 0.54 to 0.68 in summer and from 0.12 to 0.14 in winter. DCF_{Dm} is higher than DCF_E by a factor of 11.5–14.2 in summer and 3.6–4.0 in winter, while for DCF_{Dn}, these factors are 3.1–3.5 and 1.6–1.7, respectively. In wineries, f_{un} values ranged from 0.08 to 0.20; DCF_{Dm} and DCF_{Dn} are higher than DCF_E by factors of 2.8–5.1 and 1.5–1.9, respectively.*

Key words: radon, radon short-lived decay products, unattached fraction of radon short-lived decay products, air, kindergartens, karst caves, wineries

Izvirni znanstveni članek
UDK 546.296:614.87

Izvleček

Cilj: *Meritve deleža prostih radonovih kratkoživih razpadnih produktov (f_{un}) velikosti nanometrov z namenom, da bi prispevali k razlagi razlike med doznimi pretvorbenimi faktorji (DCF), ki jih dobimo na podlagi epidemioloških izsledkov (DCF_E) oziroma izračunamo po dozimetričnem modelu za dihanje skozi usta (DCF_{Dm}) in skozi nos (DCF_{Dn}).*
Metode: *Za meritve smo uporabljali prenosna merilnika SARAD EQF3020 in EQF3020-2, s katerima smo kontinuirno merili koncentracije radona (Rn) in radonovih kratkoživih razpadnih produktov (RnDP), faktor radioaktivnega ravnotežja med Rn in RnDP (F) ter delež prostih RnDP (f_{un}). Meritve smo izvedli v otroških vrtcih, kraških jamah in vinskih kleteh.*
Zaključki: *V otroških vrtcih so bile vrednosti f_{un} med 0,03 in 0,24 z geometrično srednjo vrednostjo 0,14. DCF_{Dm} in DCF_{Dn} sta bila za faktor 4,0 oziroma 1,7 večja od DCF_E = 5 mSv WLM^{-1}. V Postojnski jami je bil f_{un} v območju 0,54–0,68 poleti in v območju 0,12–0,14 pozimi na najnižji točki v jami. DCF_{Dm} je za faktor 11,5–14,2 poleti in faktor 3,6–*

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4,0 pozimi večji od DCF_E, medtem ko sta ta faktorja 3,1–3,5 oziroma 1,6–1,7 za DCF_{Dn}. V vinskih kleteh so bile vrednosti f_{un} v območju 0,08–0,20; DCF_{Dm} je bil za faktor 2,8–5,1, DCF_{Dn} pa za faktor 1,5–1,9 večji od DCF_E.

Ključne besede: radon, radonovi kratkoživi razpadni produkti, prosti radonovi razpadni produkti, zrak, vrtci, kraške jame, vinske kleti

1 Introduction

Breathing air contaminated with radon and its short-lived decay products contributes about half the total effective dose that a member of the general public receives on worldwide average from all natural radioactive sources (1). It is the second greatest cause of lung cancer, close to cigarette smoking (2). Radon dosimetry, in which nano sized radon decay products play a crucial role, is very complex and a number of questions still remain to be resolved.

Radioactive decay of radon (^{222}Rn: α-decay, half-life, $t_{1/2}$ = 3.82 days) results in creating radon short-lived decay products (RnDP) (3): ^{218}Po (α-decay, $t_{1/2}$ = 3.10 min), ^{214}Pb (β/δ-decay, $t_{1/2}$ = 26.8 min), ^{214}Bi (β/δ-decay, $t_{1/2}$ = 19.9 min), and ^{214}Po (α-decay, $t_{1/2}$ = 164 µs). Initially, RnDPs are positive free ions which, sooner or later, depending on experimental conditions, are partly neutralised by recombination and form nanosized *clusters* or so-called *unattached* RnDPs with sizes between 0.5 and 3 nm (4). They further attach to aerosol particulates, forming *attached* decay products with an *activity median aerodynamic diameter* (AMAD) of 200 nm (5). Because of plate-out of aerosols on the walls and floor of a room, as well as air movement and entry of fresh air, radioactive equilibrium between decay products and radon is only partly achieved. It is expressed as a fraction between 0 and 1, called the *equilibrium factor*, *F* (3). Deposition of the short-lived decay products on the walls of the respiratory airways, the critical point in radon dosimetry, depends strongly on the particulate characteristics (6, 7). Therefore the *unattached fraction* (f_{un}) of decay products is an important datum.

In order to convert exposure to Rn and RnDP into dose, the so-called dose conversion factor, *DCF* is needed. In radon dosimetry, *DCF* is defined as the ratio of the weighted equivalent dose to the lung (assuming a radiation weighting factor for a particles, w_α, of 20, and a tissue weighting factor for lung, w_{lung}, of 0.12) expressed in mSv, to the exposure to radon progeny expressed either in WLM or Bq m^{-3} h. The old but still widely used unit, 1 WLM (working-level-month), is the exposure resulting from 170 hours breathing in air with an activity concentrations of short-lived radon decay products of 1 WL (working-level), which was originally defined as the activity concentration of ^{218}Po, ^{214}Bi and ^{214}Pb (^{214}Po) which are in radioactive equilibrium (*F* = 1) (3) with 100 pCi L^{-1} (3700 Bq m^{-3}) of ^{222}Rn, resulting in an alpha energy concentration of 1.3×10^5 MeV L^{-1} (3).

DCF values may be obtained either based on results of epidemiologic studies (hereafter denoted by DCF_E) or by calculation applying dosimetric models (hereafter denoted by DCF_D). For DCF_E, the ICRP Publication 65 (ICRP, 1994a) recommends 5 mSv/WLM for working, and 4 mSv/WLM for living environments.

The dosimetric approach was elaborated by Birchall and James (8). DCF_D is calculated based on a refined, recently proposed human respiratory tract model (9). One of the parameters that affect DCF_D most is f_{un} (10, 11). DCF_D values in the range 8-32 mSv/WLM were obtained under different conditions, with 15 mSv/WLM as the žbest estimate' for the indoor air conditions in dwellings.

In addition, Porstendörfer (12) has shown that

$$DCF_{Dm} = 101 \times f_{un} + 6.7 \times (1 - f_{un})$$
for mouth breathing, and (1)

$$DCF_{Dn} = 23 \times f_{un} + 6.2 \times (1 - f_{un})$$
for nasal breathing (2)

Which can be calculated separately based on the experimental f_{un} values.

While DCF_E values are recommended by the ICRP-65 (ICRP, 1994a) methodology for use in general radon dosimetry, DCF_D (and so DCF_{Dm}, DCF_{Dn}) are suggested to be used for research purposes only (13).

The lack of agreement between DCF_E and DCF_D values has not been fully clarified yet, and the reason for $DCF_D > DCF_E$ most probably originates from too high values being chosen for w_α (14, 15). Challenged by this problem, our group has recently been studying f_{un} in a range of various environments in order to build up an experimental basis on which the discussion may continue and lead to a better understand the disagreement and, eventually, to diminish the gap between DCF_D and DCF_E.

In this paper, results of Rn, RnDP, F and f_{un} monitoring in air, with emphasis on f_{un}, are presented in three environments in Slovenia: in kindergartens, karst caves (Postojna Cave) and wineries. The influence of air temperature and relative humidity, working regime, and ventilation on f_{un} will be shown. DCF_D values will be calculated and discussed, and compared with values of DCF_E.

2 Survey methods

Portable SARAD EQF3020 and EQF3020-2 devices (manufactured by SARAD, Dresden, Germany) have been used. Every two hours a pump sucks air over a silicon detector on which radon decay products are electro-deposited and counted. The data are stored and later transferred to a personal computer for evaluation. The instruments measure activity concentrations (hereafter simply called concentrations) of Rn and RnDP (i. e., C_{Rn} and C_{RnDP}), the equilibrium factor F between Rn and RnDP and unattached fraction f_{un} of RnDP, together with air temperature and relative air humidity, the two parameters affecting f_{un} (16). The lower limit of detection for C_{Rn} and C_{RnDP} is 50–60 Bq m^{-3} and the experimental errors 10–20 % at low concentrations and less than 10 % for C_{Rn} and C_{RnDP} higher than 200 Bq m^{-3}.

The instruments were calibrated by the manufacturer on purchase and are checked regularly at the inter-comparison experiments organized annually by the Slovene Nuclear Safety Administration (17). They are re-calibrated every two years in the manufacturer's radon chamber. In addition, at each measurement site the instruments were regularly checked by taking samples and measuring C_{Rn} with alpha scintillation cells, calibrated annually by a standard $^{226}RaCl_2$ solution (National Institute of Standards and Technology (NIST Standard Reference Material 4953D) (18).

The measurements were carried out at places where our previous survey had revealed elevated Rn levels (19). Thus, a device was operated for 10-15 days in one or more rooms of selected kindergartens (in total: 29 rooms in 13 kindergartens), at the lowest point and in the railway station in the Postojna Cave and in underground premises of four wineries.

3 Results

In Fig. 1, diurnal variations of the measured parameters are shown for the LJ-S2-01b kindergarten. Similar plots were obtained for all kindergartens and average values for each parameter for the whole period of measurement were calculated (20). The values for f_{un} are given in Table 1, and the results of C_{Rn}, C_{RnDP} and F obtained in all kindergartens surveyed are summarised in Table 2.

The results of measurements at the lowest point in the Postojna Cave (21) in summer are shown in Fig. 3. Similar plots were also obtained there in winter, and for both summer and winter at the railway station in the cave. C_{Rn} and C_{RnDP} were lower at the railway station than at the lowest point and lower in winter than in summer at both sites. In Table 3 only average values f_{un} for winter and summer time are shown for the lowest point.

From all measurements in wineries (22), the results for VK-P-02 with low f_{un} values (Fig. 5) and VK-S-05 with high f_{un} values (Fig. 6) are shown and average values are listed in Table 4.

4 Discussion

4.1 Kindergartens

Fig. 2 shows the dependence of f_{un} on F, relative air humidity (HR) and air temperature (T) in the rooms surveyed. As expected (23–28), a negative correlation between f_{un} and F was observed in all kindergartens and, for the measurement in the LJ-S2-01b kindergarten, may be approximated by a power expression (29) $f_{un} = 0.056\ F^{0.875}$ (Fig. 2a). During working hours, the plate-out of aerosols is enhanced, resulting in reduced aerosol concentration in the air (30) and thus lowering F and increasing f_{un}. Also the f_{un} – RH correlation is expected to be negative (31): increasing RH causes an increase in size of aerosol particulates, thus increasing the attachment rate of RnDPs and decreasing f_{un}. This kind of f_{un} – RH relationship was observed in some kindergartens but not in others. Thus, for example, in the LJ-S2-01b kindergarten (Fig. 2b) even a positive, though very weak, correlation was found, which cannot be explained based on the data obtained so far. The f_{un} – T relationship was neither expected (26) nor observed, as shown for the LJ-S2-01b kindergarten in Fig. 2c.

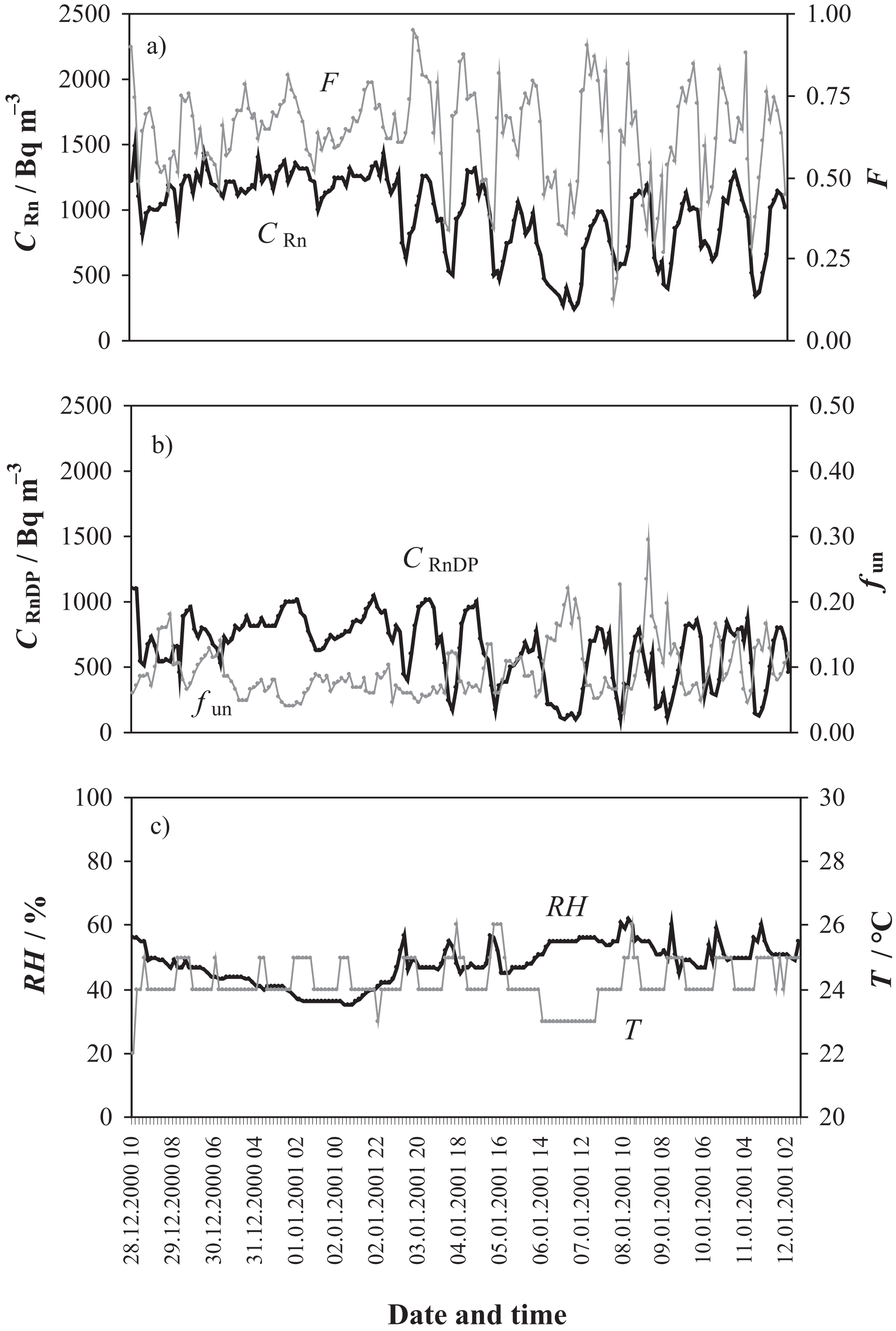

Figure 1. *Time dependence of the parameters measured in kindergarten LJ-S2-01b during the period from December 28, 2000 to January 12, 2001: a) Rn concentration (C_{Rn}) and equilibrium factor (F), b) RnDP concentration (C_{RnDP}) and unattached fraction of short-lived radon decay products (f_{un}), c) relative indoor air humidity (RH) and indoor air temperature (T).*

Table 1. *Dose conversion factors (in mSv/WLM) for mouth breathing (DCF_{Dm}) and nasal breathing (DCF_{Dn}) calculated from f_{un} values (obtained from the continuous measurements), together with DCF_m/5 and DCF_n/5, in Slovenian kindergartens (names are coded) in 1998-2002.*

kindergarten code	f_{un}	DCF_{Dm}	DCF_{Dn}	DCF_{Dm}/5	DCF_{Dn}/5
DI-S2-03	0.19	24.6	9.4	4.9	1.9
DV-S3-02	0.16	21.8	8.9	4.4	1.8
GH-S2-02	0.24	29.3	10.2	5.9	2.0
GR-S2-02	0.15	20.8	8.7	4.2	1.7
ID-S2-11a	0.10	16.1	7.9	3.2	1.6
ID-S3-11a	0.12	18.0	8.2	3.6	1.6
ID-S2-11b	0.11	17.1	8.0	3.4	1.6
ID-S3-11b	0.14	19.9	8.6	4.0	1.7
LJ-S2-01a	0.08	14.2	7.5	2.8	1.5
LJ-S3-01a	0.13	19.0	8.4	3.8	1.7
LJ-S2-01b	0.10	16.1	7.9	3.2	1.6
LJ-S3-01b	0.17	22.7	9.1	4.5	1.8
LJ-S2-01c	0.12	18.0	8.2	3.6	1.6
LJ-S3-01c	0.20	25.6	9.6	5.1	1.9
LJ-S1-01a	0.17	22.7	9.1	4.5	1.8
LJ-S1-01b	0.17	22.7	9.1	4.5	1.8
LJ-S1-02	0.17	22.7	9.1	4.5	1.8
LJ-S3-02	0.03	9.5	6.7	1.9	1.3
LS-S2-01	0.24	29.3	10.2	5.9	2.0
NM-S3-03a	0.22	27.4	9.9	5.5	2.0
NM-S2-03b	0.13	19.0	8.4	3.8	1.7
PZ-S2-11	0.18	23.7	9.2	4.7	1.8
PZ-S3-11	0.19	24.6	9.4	4.9	1.9
RI-S2-09	0.10	16.1	7.9	3.2	1.6
SZ-S2-10	0.16	21.8	8.9	4.4	1.8
ST-S2-11	0.17	22.7	9.1	4.5	1.8
VD-S2-03	0.19	24.6	9.4	4.9	1.9
VD-S2-02	0.11	17.1	8.0	3.4	1.6
VD-S3-02	0.23	28.4	10.1	5.7	2.0

Table 2. *Minimum (min.) and maximum (max.) values, geometric means (GM) and their standard deviations (GSD) of the parameters studied in Slovenian kindergartens in 1998-2002.*

parameter	min.	max.	GM	GSD
C_{Rn} / Bq m^{-3}	128	1473	458	2.09
C_{RnDP} / Bq m^{-3}	37	1118	238	2.45
F	0.20	0.81	0.50	1.40
f_{un}	0.03	0.24	0.14	1.55
RH / %	27.0	77.4	40.6	1.25
DCF_{Dm} / mSv WLM^{-1}	9.5	29.3	20.7	1.28
DCF_{Dm} / 5	1.9	5.9	4.1	1.28
DCF_{Dn} / mSv WLM^{-1}	6.7	10.2	8.8	1.10
DCF_{Dn} / 5	1.3	2.1	1.8	1.10

Table 3. *Dose conversion factors for mouth (DCF_{Dm}) and nasal (DCF_{Dn}) breathing calculated using f_{un} in Eqs. 2 and 3 for summer and winter at the lowest point in the Postojna Cave.*

season, year	f_{un}	DCF_{Dm} mSv WLM^{-1}	DCF_{Dm} / 5	DCF_{Dn} mSv WLM^{-1}	DCF_{Dn} / 5
winter, 1998	0.12	18.0	3.6	8.2	1.6
summer, 1998	0.54	57.6	11.5	15.3	3.1
winter, 1999	0.14	19.9	4.0	8.6	1.7
summer, 1999	0.61	64.2	12.8	16.5	3.3
summer, 2000	0.56	59.5	11.9	15.6	3.1
summer, 2001	0.68	70.8	14.2	17.6	3.5
summer, 2002	0.67	69.9	14.0	17.5	3.5

Table 4. *Average values of unattached fraction of radon short-lived decay products (f_{un}) in selected Slovenian wineries measured in spring of 2002, together with dose conversion factors for mouth (DCF_{Dm}) and nasal (DCF_{Dn}) breathing.*

winery	f_{un}	DCF_{Dm} mSv WLM^{-1}	DCF_{Dm} / 5	DCF_{Dn} mSv WLM^{-1}	DCF_{Dn} / 5
VK-S-05	0.20	25.6	5.1	9.6	1.9
VK-P-02	0.12	18.0	3.6	8.2	1.6
VK-L-02	0.08	14.2	2.8	7.5	1.5
VK-R-02	0.09	15.2	3.0	7.7	1.5

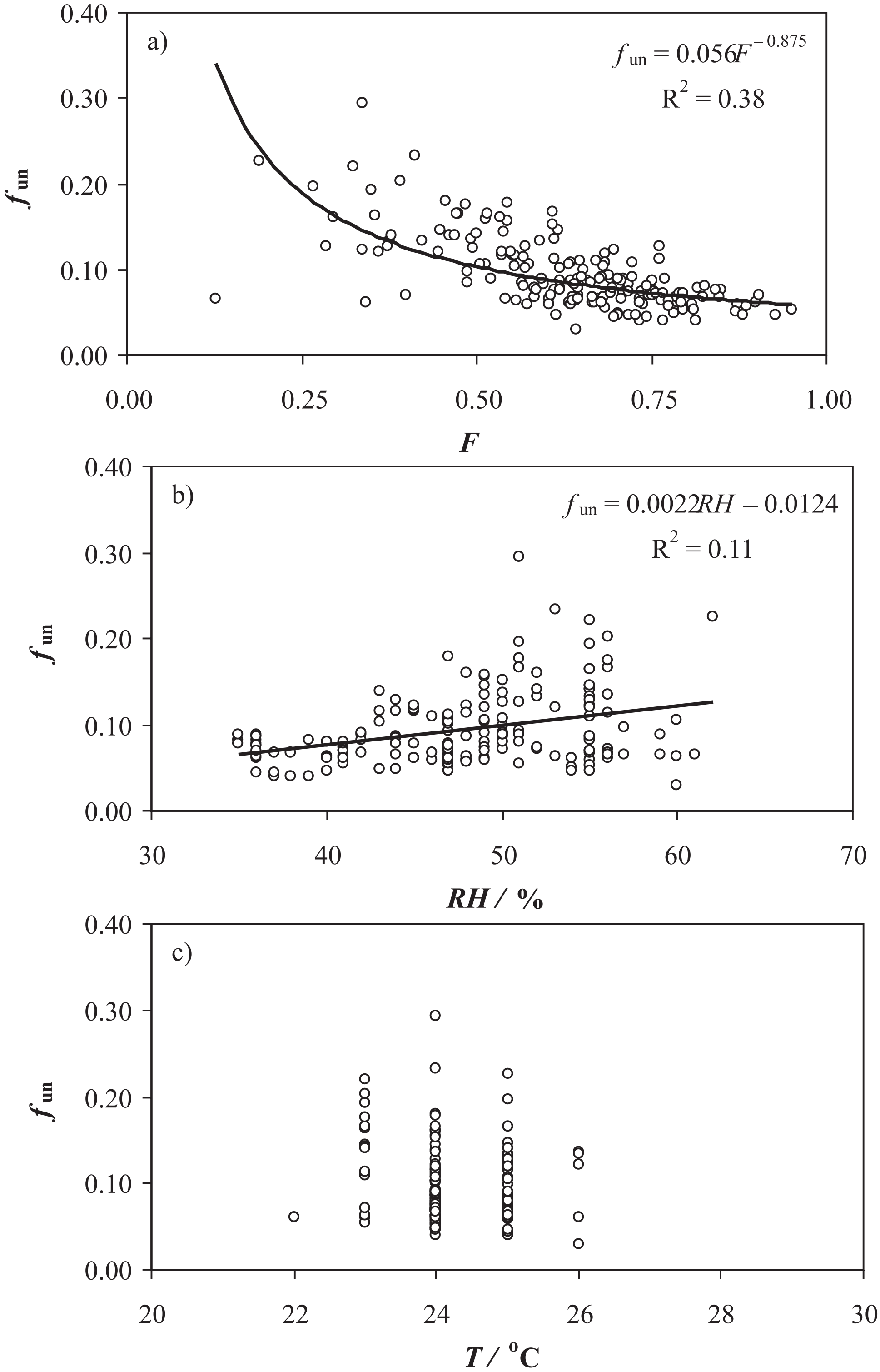

Figure 2. *Dependence of f_{un} on a) equilibrium factor (F), b) relative humidity of indoor air (RH) and c) indoor air temperature (T) in the LJ-S2-01b kindergarten.*

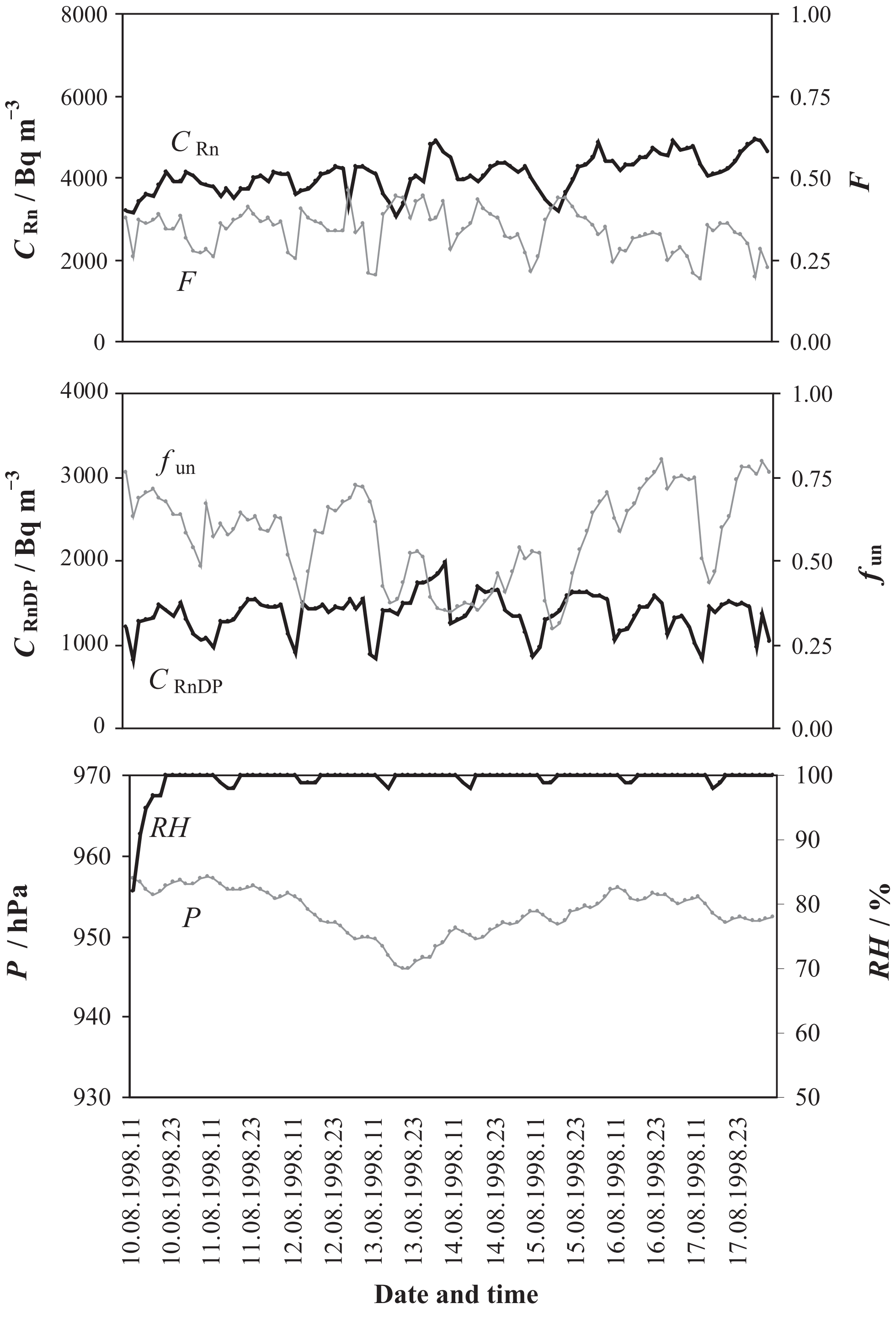

Figure 3. Rn (C_{Rn}) and RnDP (C_{RnDP}) concentrations, equilibrium factor (F), unattached fraction of RnDP (f_{un}), barometric pressure (P) and relative air humidity in the cave (RH) measured at the lowest point in Postojna Cave, August 10–18, 1998.

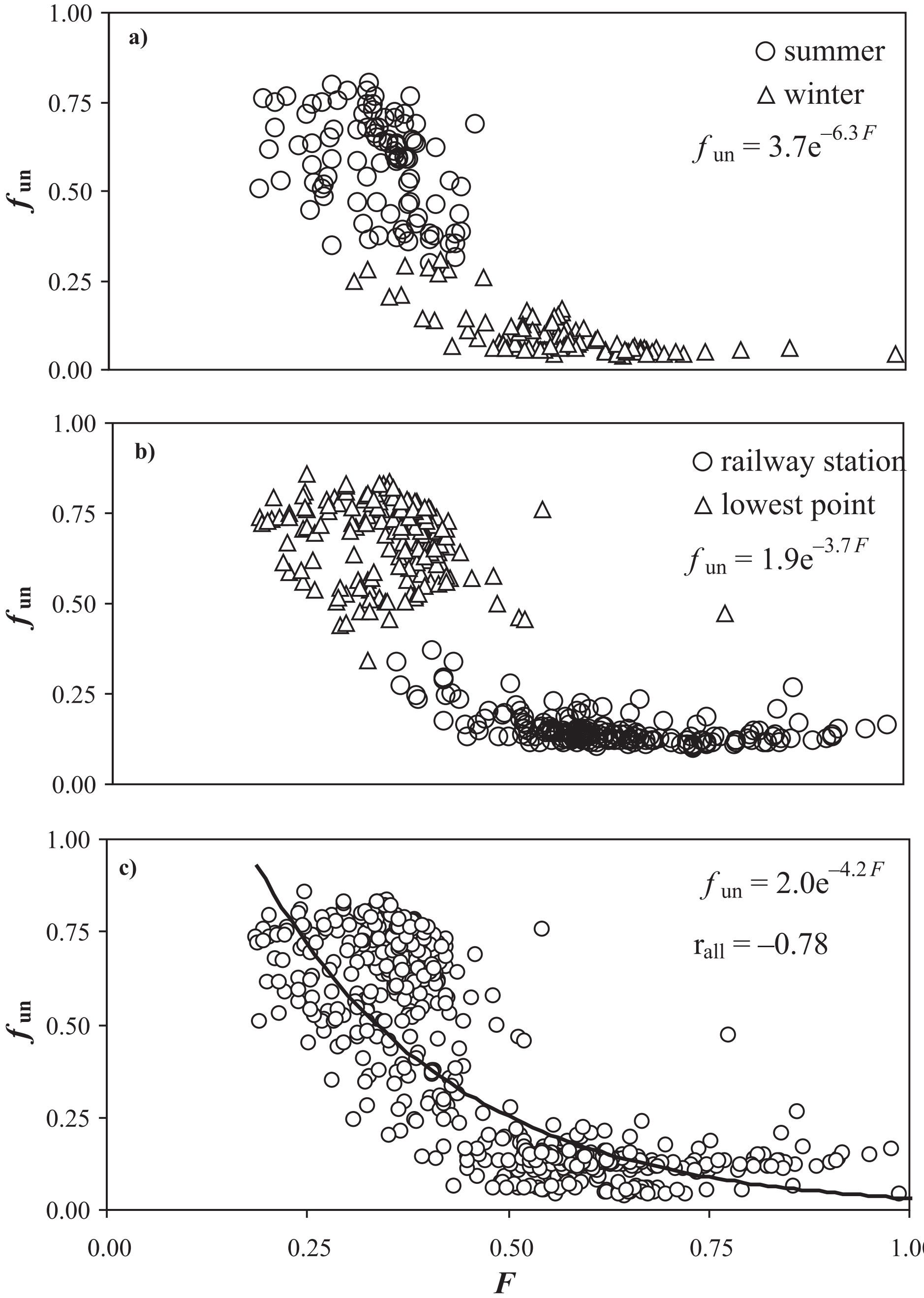

Figure 4. *The relationship between the unattached fraction of RnDP (f_{un}) and the equilibrium factor (F): a) at the lowest point in Postojna Cave, in summer (August 10–17) and in winter (December 14–22, 1998), b) in summer, at the lowest point (July 17 – August 2, 2001) and railway station (July 17–18, 2001), c) general exponential correlation for all points from plots a and b above.*

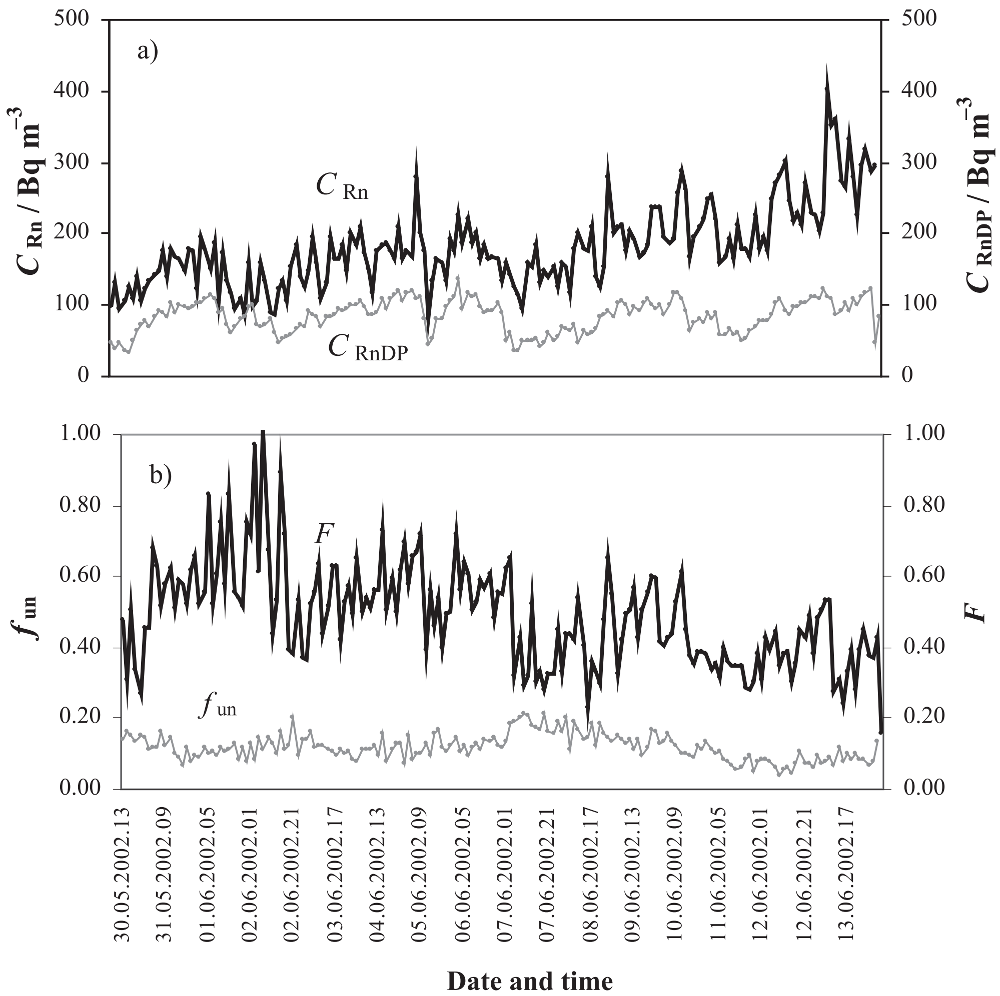

Figure 5. *Continuous measurement of concentrations of Rn (C_{Rn}) and RnDP (C_{RnDP}), equilibrium factor (F), and unattached fraction of RnDP (f_{un}) in the winery at VK-P-02, using the Sarad EQF3020-2 instrument in the period from May 30 to June 14, 2002.*

Based on f_{un} values in Table 1 and using equations 1 and 2, DCF_{Dm} and DCF_{Dn} were calculated together with their values divided by 5 (Table 1). Table 2 summarises the results obtained in all kindergartens surveyed and shows that, on average, DCF_{Dm} is higher than DCF_E by a factor of 4.0 and DCF_{Dn} by a factor of 1.7. According to ICRP criteria (9), all persons in kindergartens, both personnel and children, are considered as nasal breathers.

4.2 Postojna Cave

As expected, higher F values are accompanied by lower f_{un} values (24, 28). While Fig. 4a shows the f_{un} – F relationship for summer and winter at the *lowest point* (together described as $f_{un} = 3.7e^{-6.3F}$) and this relationship is compared at the *railway station* and *lowest point* (together described as $f_{un} = 1.9e^{-3.7F}$) (Fig. 4b), Fig. 4c shows the best fit of all the points from Figs. 2a and 2b, approximated by $f_{un} = 2.0e^{-4.2F}$. Due to the *chimney effect* the air draught from the cave to the outdoor atmosphere is stronger in winter than in summer, thus we would expect the cave air to be more stagnant, and thus f_{un} lower, in summer than in winter. Nonetheless, the opposite was observed, with much higher f_{un} values in summer ($f_{un} = 0.58$) in the period August 10–18, 1998 than in winter ($f_{un} = 0.10$) in the period December 14–22, 1998. The *chimney effect* appears to be dominated by the air mixing produced by the visitors moving through narrow corridors. A low f_{un} value in a stagnant air (32) during the night was rapidly increased at the start of the visits in the morning, and started to decrease in the afternoon. Fluctuations of f_{un} are much more pronounced in summer than in winter, most probably because of much larger number of visitors in summer.

Dose conversion factors are summarized in Table 3 which shows that average f_{un} values are much higher than in kindergartens. The resulting DCF_{Dm} is higher by factors of 11.5–14.2 in summer and 3.6–4.0 in winter than DCF_E (= 5 mSv WLM^{-1}), and similarly, DCF_{Dn} is higher by factors of 3.1–3.5 and 1.6–1.7, respectively . According to the ICRP criteria (9), only maintenance workers carrying out heavy physical work in the cave may be considered as mouth breathers, while all the others are nasal breathers.

4.3 Wineries

At VK-P-02, the cellar system is more than 200 years old and is very complex, composed of hundreds of metres of underground tunnels vaulted with stone and clay brick. The C_{Rn} run (Fig. 5a) does not show the typical diurnal variations, with maxima during nights and minima during days, as observed at other workplaces (33). Neither are the values constantly higher during weekends (June 1–2 and June 8–9). Similarly, at VK-S-05, neither typical diurnal C_{Rn} fluctuations nor elevated values during non-working days (First May holiday: May 1–5 and weekend: May 11–12) were observed (Fig. 6a). This winery is composed of several large underground halls, vaulted with stone. It is located in the karst region where the majority of elevated indoor Rn levels have been observed within the national radon programme (34), due to underground cracks, fissures and faults which enable Rn to travel long distances and accumulate in closed rooms (35). Elevated Rn levels in this winery were therefore expected but not observed, because of effective ventilation. Similar C_{Rn} runs have also been observed in other wineries, not presented here. In the VK-P-02 winery, the C_{Rn} – F relationship can be approximated by $C_{Rn} = 302e^{-1.14F}$, though with a low correlation coefficient (Fig. 7a). Although expected (29) no dependence of f_{un} on F could be seen (Fig. 7b). In contrast, in the VK-S-05 winery no dependence of C_{Rn} on F was observed (Fig. 8a) while the f_{un} – F relationship was described, though with low correlation coefficient, by $f_{un} = 0.13F^{0.25}$ (Fig. 8b). In the majority of wineries the situation resembles that of the VK-S-05 winery.

Average f_{un} values and dose conversion factors are summarized in Table 4. Both are similar to those in kindergartens, although workplaces surveyed were underground and therefore values similar to those in the Postojna Cave were expected. Clearly, the concentration of aerosols in the cave air is much lower than in a winery (26). The resulting DCF_{Dm} is higher than DCF_E = 5 mSv WLM^{-1} by a factor of 2.8–5.1 and DCF_{Dn} by a factor of 1.5–1.9. According to the ICRP criteria (9), all workers in the wineries may be considered as nasal breathers.

5 Conclusions

The measurements of f_{un} in the three environments have shown the following situation. In kindergartens, f_{un} ranged from 0.03 to 0.24 with a geometric mean of 0.14. The resulting dose conversion factors for mouth (DCF_{Dm}) and nasal breathing (DCF_{Dn}) are higher than DCF_E (= 5 mSv WLM^{-1}) by factors of 4.0 and 1.7, respectively. f_{un} values in the Postojna Cave were much higher than in kindergartens, ranging from 0.54 to 0.68 in summer and from 0.12 to 0.14 in winter at the lowest point. The resulting DCF_{Dm} is higher than DCF_E by fac-

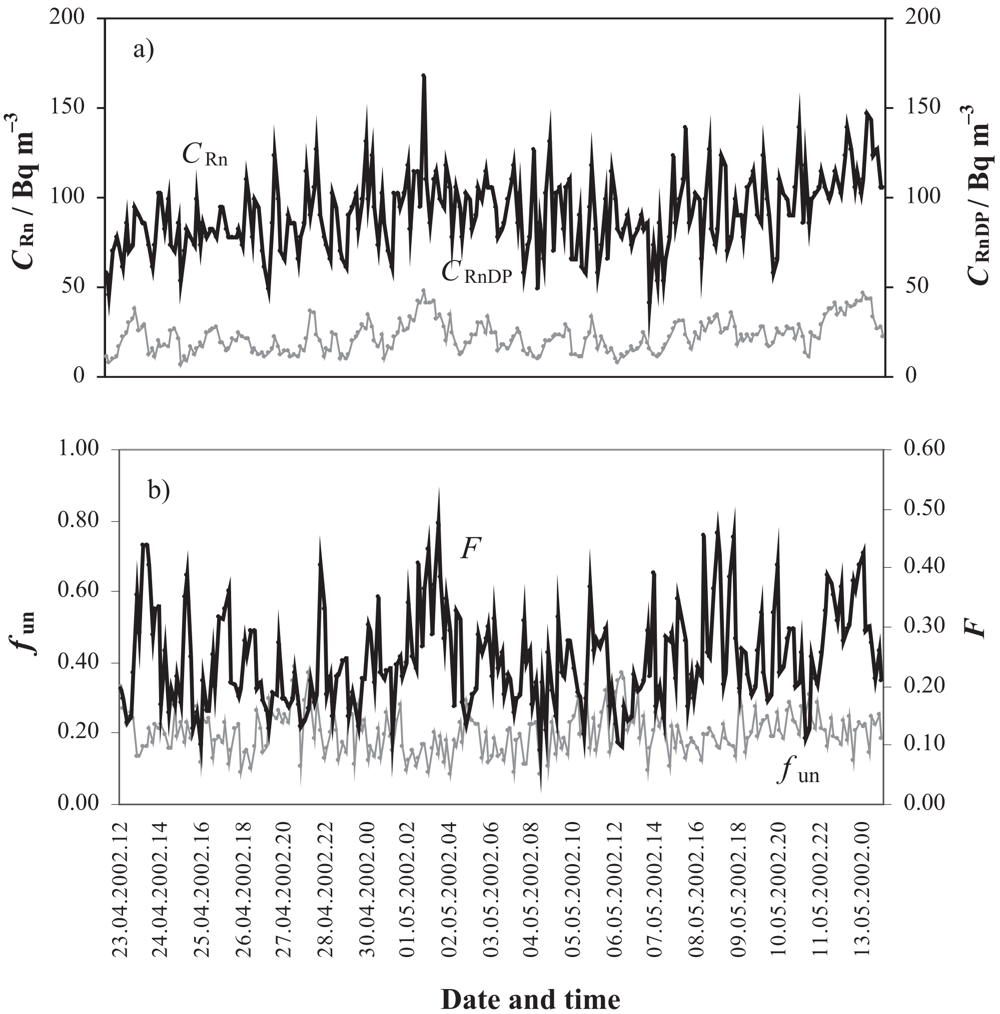

Figure 6. *Continuous measurement of concentrations of Rn (C_{Rn}) and RnDP (C_{RnDP}), equilibrium factor (F), and unattached fraction of RnDP (f_{un}) in the winery at VK-S-05, using the Sarad EQF3020-2 instrument in the period from April 23 to May 13, 2002.*

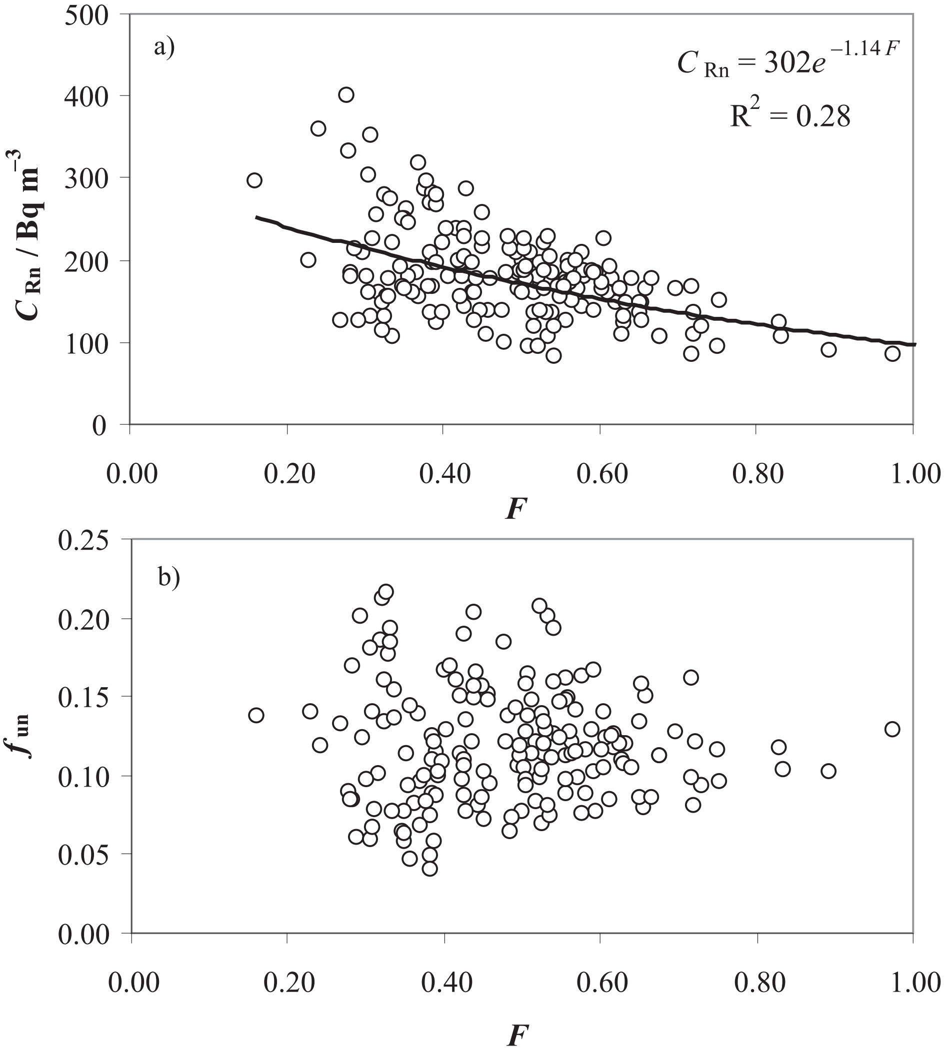

Figure 7. *Dependence of: a) Rn concentrations (C_{Rn}) on equilibrium factor (F), and b) unattached fraction of RnDP (f_{un}) on equilibrium factor (F), in the winery at VK-P-02, using the Sarad EQF3020-2 instrument in the period from May 30 to June 14, 2002.*

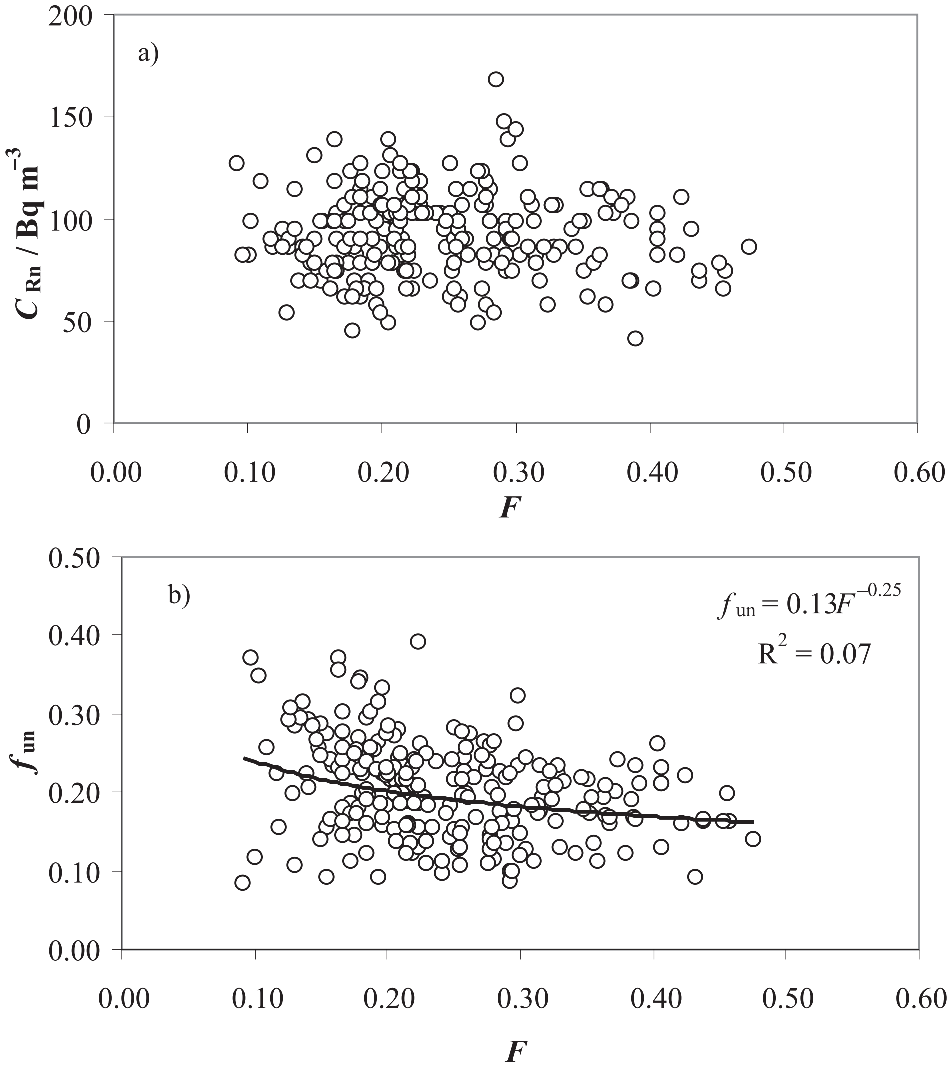

Figure 8. *Dependence of: a) Rn concentrations (C_{Rn}) on equilibrium factor (F), and b) unattached fraction of RnDP (f_{un}) on equilibrium factor (F), in the winery at VK-S-05, using the Sarad EQF3020-2 instrument in the period from April 23 to May 13, 2002.*

tors of 11.5–14.2 in summer and 3.6–4.0 in winter, while these factors are 3.1–3.5 and 1.6–1.7 respectively for DCF_{Dn}. f_{un} values in wineries are similar to those in kindergartens, ranging from 0.08 to 0.20. The resulting DCF_{Dm} and DCF_{Dn} are higher than DCF_{E} by factors of 2.8–5.1 and 1.5–1.9, respectively. These results provide experimental evidence for the disagreement between dose conversion factors (and hence effective doses) suggested by the epidemiologic studies and those calculated applying the dosimetric approach for the above environments, and as such provide a good basis for continuing the discussion as to how to tackle this problem and eventually solve it.

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Contributors:
Janja Vaupotič, as the head of the Radon Center at the Jožef Stefan Institute, designed the programme and, together with her co-workers, ran the measurements, evaluated the data obtained and prepared the paper. Ivan Kobal contributed to data evaluation and writing the paper.

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List of abbreviations:

DCF	- dose conversion factor (in mSv WLM^{-1})
ICRP	- International Commission on Radio logical Protection
Rn	- ^{222}Rn isotope of radon
RnDP	- short-lived decay products of ^{222}Rn: ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po
UNSCEAR	- United nations Scientific Committee on Effects of atomic Radiation

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UPORABA BIOMARKERJEV ZA DOLOČANJE VPLIVOV NANODELCEV

THE USE OF BIOMARKERS FOR ASSESSING EFFECTS OF NANOPARTICLES

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Pregledni znanstveni članek
UDK 577.1:615

Izvleček

V zadnjem desetletju smo priča izrednemu napredku nanotehnologij, ki so nam in nam bodo v prihodnosti prinesle celo vrsto pridobitev za vsakdanje življenje. Poleg tega pa se moramo zavedati dejstva, da se bodo v našem okolju v velikih količinah pojavljali novi nanomateriali (velikost vsaj 1-100 nm v eni dimenziji), ki imajo zaradi majhnosti drugačne fizikalno-kemijske in toksikološke lastnosti kot njihove večje oblike. O vplivih teh materialov na ljudi in okolje vemo zelo malo, zato je potrebno raziskati njihove morebitne vplive na različnih ravneh biološke organizacije. V prispevku smo predstavili testni sistem z mokrico Porcellio scaber za proučevanje vplivov nanomaterialov na organizme. Pri živalih, izpostavljenih 15 nm nanodelcem titanovega dioksida (TiO_2), smo opazovali biokemijske biomarkerje, tj. aktivnosti encimov glutation S-transferaze in katalaze, ter fiziološke biomarkerje (stopnja prehranjevanja, iztrebljanje, asimilacijska učinkovitost, sprememba mase živali). Opazili smo manjše vplive TiO_2 na stopnjo prehranjevanja mokric in signifikantne spremembe aktivnosti obeh encimov. Menimo, da je predstavljeni pristop testiranja hiter in ponovljiv ter nudi veliko informacij o mehanizmih delovanja nekega nanomateriala. Priporočamo nadaljnje nano(eko)toksikološke študije, ki nam bodo omogočile uporabo nanomaterialov s čim manjšimi posledicami za človeka in naše okolje.

Ključne besede: nanomateriali, titanov dioksid, biokemijski biomarkerji, prehranjevanje, kopenski rak Porcellio scaber

Review article
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Abstract

During the last decade, an enormous development of nanotechnologies has resulted in numerous improvements for our everyday lives. Nanomaterials (size at least 1-100 nm in one dimension) are new chemical forms of common chemical elements and exhibit unique physico-chemical and toxicological properties that may differ greatly from those of larger particles of the same materials. Until now, not many studies have focused on the effects of nanomaterials on humans and environment, so it is important to investigate their effects at several levels of organization. This paper presents our test system using terrestrial isopod Porcellio scaber as a model organism for the evaluation of the nanomaterials' effects on organisms. Animals were exposed to 15 nm titanium dioxide (TiO_2) nanoparticles, and afterwards biochemical biomarkers, e.g. the activities of glutathione S-transferase and catalase, and physiological end-points (feeding rate, faeces production, food assimilation efficiency and animal mass change) were evaluated. An insignificant effect of TiO_2 on feeding and significant effects on the activities of both enyzmes were noticed. The test system presented in this work proved to be quick, reliable and

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very informative. Further nano(eco)toxicological studies are recommended to enable the safe use of new nanomaterials.

Key words: nanomaterials, titanium dioxide, biochemical biomarkers, feeding, terrestrial isopod Porcellio scaber

1 Uvod

Smo v obdobju izredno razvijajočega se področja nanotehnologije, t.j. tehnološkega razvoja v nanometrskem merilu, ali po eni izmed prvih definicij: »*the design, characterisation, production and application of structures, devices, and systems by controlling shape and size at nanometre scale*« (»načrtovanje, določanje lastnosti, produkcija in uporaba struktur, sredstev in sistemov s kontrolo oblike in velikosti v nanometrskem merilu«) (1). Po mnogih napovedih bo imela izreden vpliv na industrijo, zdravstvo, proizvodnjo hrane in kozmetike, medicino, transport, energijo ter informacijske in komunikacijske tehnologije (2). Nekateri njen potencial primerjajo z industrijsko revolucijo in z odkritjem elektrike in komunikacijskih tehnologij (3).
Produkti nanotehnologije so nanomateriali (tj. materiali, ki imajo vsaj eno dimenzijo v območju 1-100 nm) in so različnih oblik, npr. nanodelci, cevke, filmi in površine. Zaradi izredne majhnosti imajo popolnoma drugačne fizikalno-kemijske lastnosti kot njihove večje oblike, zato jih v mnogih ozirih lahko obravnavamo kot nove kemikalije. Slednje pomeni, da imajo tudi drugačne toksikološke lastnosti od znanih kemikalij, zato njihov morebitni vpliv na ljudi in okolje v veliki meri ni znan. Veliko nanomaterialov se že danes uporablja v vsakdanjem življenju (npr. v sončnih kremah, kozmetičnih proizvodih, materialih s samočistilno sposobnostjo, barvah, senzorjih za detekcijo onesnaževal, čiščenju onesnaženja vod in tal, ...), zato so študije o njihovih toksikoloških vplivih nujno potrebne (1). Kot predlagajo mnogi avtorji, mora toksikologija usmerjati pot nanotehnologiji (4).
V prispevku predstavljamo naš pristop k študiju mehanizma toksičnega delovanja nanomaterialov. Kot modelni organizem proučujemo kopenskega enakonožnega raka mokrico (*Porcellio scaber*). Le-ta ima pomembno vlogo v talni favni, in sicer so začetni dekompozitorji organskega materiala, pri čemer mehansko razgradijo material in ga pripravijo za nadaljno mikrobno razgradnjo. Naseljujejo se v bližini človeških bivališč in so primeren indikatorski organizem za onesnaženje tal (5). Prednost študij z mokrico je v tem, da zaradi večletnih izkušenj dela z njim zelo dobro poznamo njegove odzive na različne fiziološke in kemijske stresne dejavnike. To nam omogoča t.i. »primerjalni pristop« k ovrednotenju delovanja neke neznane kemikalije/nanomateriala s primerjanjem delovanja znane kemikalije.
Zaradi velike kompleksnosti naravnega sistema je za najbolj stvarno oceno potrebno proučiti spremembe na več različnih ravneh biološke organizacije. Pri tem se ocenjujejo t.i. biomarkerji, ki so merilo biološkega odziva na izpostavljenost in/ali učinek okoljskemu stresorju na suborganizemski (molekularni, biokemijski) stopnji in na ravni organizma (6). Biokemijski biomarkerji so velikokrat bolj občutljivi in specifični kazalci izpostavljenosti in učinka kemikalij kot odzivi na višjih ravneh biološke organizacije, npr. smrtnost. V našem laboratoriju smo kot dodatek standardnim testom optimizirali metode za merjenje dveh biokemijskih biomarkerjev, glutation S-transferaze (GST) in katalaze (CAT). Omenjena encima sta del skupine antioksidativnih encimov, ki v celici sodelujejo pri uravnavanju ravnovesja med oksidanti in antioksidanti. To se namreč lahko poruši, če v celico vstopijo kovine ali ksenobiotiki (7). Katalaza odstranjuje presežke nastalega vodikovega peroksida, GST pa odstranjuje produkte poškodovanih lipidov in veže ksenobiotike, ki so vstopili v celico. Poleg GST in CAT pri uravnavanju ravnovesja reaktivnih kisikovih zvrsti (ROS) sodelujejo tudi drugi encimi, vendar pa smo se za omenjena dva odločili zato, ker sta zelo razširjena, tako med prokarionti kot evkarionti. Poleg tega se je na osnovi naših predhodnih izkušenj izkazalo, da je njuno merjenje enostavnejše kot določanje drugih biokemijskih biomarkerjev, npr. glutationa in glutation peroksidaze.
Izbrana biokemijska biomarkerja sta primerna za proučevanje vplivov nanomaterialov, ker naj bi le ti zaradi izredne površinske reaktivnosti pozročali nastanek ROS (8,9). Predlaganih je bilo več mehanizmov nastanka ROS na površini nanomaterialov, med njimi npr. ob indukciji z UV, poškodbi nanomaterialov in reakcijami ovojev delcev z okolico (10). Vodikov peroksid je eden izmed ROS, ki nastane kot rezultat nastanka drugih kisikovih radikalov, ki primarno nastanejo zaradi TiO_2, npr. superoksidnega radikala in hidroksilnega radikala. Na ravni organizma

smo spremljali prehranjevanje, in sicer stopnjo hranjenja, stopnjo iztrebljanja, asimilacijsko učinkovitost ter spremembo mase živali.

Proučevali smo vplive nanodelcev titanovega dioksida (TiO_2, 15 nm). Titanov dioksid se že nekaj desetletij uporablja v pigmentih in kozmetiki, vendar so bile prve toksikološke študije o vplivih različnih velikosti teh delcev na pljučno tkivo objavljene šele leta 1990 (11). Te študije so med prvimi pokazale, da je poleg vrste kemikalije pri strupenosti pomembna tudi velikost delcev. O strupenih vplivih nanodelcev TiO_2 je bilo objavljenih kar nekaj študij, vendar pa je bila velika večina opravljenih na celičnih kulturah pljučnih tkiv glodalcev, večinoma podgan (11, 12). Znano je, da nanodelci TiO_2 povzročajo nastanek ROS, vendar pa mehanizem nastanka v teh študijah ni bil raziskan. Ob stiku nanodelcev TiO_2 z UV je nastanek ROS večji, vendar pa le ti nastanejo tudi brez prisotnosti UV (13). Nanodelci naj bi bili v telo sposobni prehajati tudi preko prebavne cevi (14), zato je prehranjevalni poskus z izopodnim kopenskim rakom primeren testni sistem za toksikološke študije nanodelcev. Poleg tega pa je potrebno omeniti, da s stališča varovanja okolja vemo zelo malo o vplivih nanodelcev na kopenske in vodne organizme. Pred kratkim je bilo objavljenih le nekaj raziskav o vplivih na vodne organizme (15, 16).

2 Metode

2.1 Priprava testne suspenzije TiO_2

Uporabili smo komericalno dostopni TiO_2 z velikostjo delcev 15 nm, tipa anataza in s povprečno površino delca 200–220 m^2/g (kataloška številka sigma 637254). Nanodelce smo zatehtali in dodali v destilirano vodo. Suspenzije nismo sonicirali, kot je to priporočeno za nanodelce v vodni suspenziji, ker smo v preliminarni študiji ugotovili, da s tem procesom še dodatno pospešimo agregacijo delcev.

2.2 Prehranjevalna študija

V poskusih smo uporabili odrasle živali obeh spolov, ki smo jih nabrali na neonesnaženem kraju v Lukovici pri Domžalah in gojili v laboratoriju do začetka poskusov. V poskusih smo izbrali kontrolno in testno populacijo, ki sta bili primerljivi po spolu, masi in levitvi organizmov. Poleg tega smo na osnovi naših predhodnih raziskav prepričani, da te lastnosti živali ne vplivajo na aktivnost testiranih encimov.

Predhodno smo herbarizirali liste leske (*Corylis avellana*), jih stehtali in navlažili zaradi lažje aplikacije nanodelcev. Suspenzijo TiO_2 smo nanesli na liste po standardnem postopku, ki ga uporabljamo v našem laboratoriju (17). Suspenzijo smo odpipetirali na spodnjo stran lista in jo s čopičem enakomerno porazdelili po celotni površini. Na ta način smo zagotovili homogenost nanosa testne snovi na liste. Tak način aplikacije je v preteklosti pokazal, da so dejanske izmerjene koncentracije nanešene kemikalije (npr. kovine) enake tistim, ki smo jih prvotno želeli nanesti. Po nanosu TiO_2 smo liste sušili en dan in suhe ponudili živalim

Pripravili smo kontrolo in 3 različne koncentracije TiO_2 (1000, 2000 in 3000 µg TiO_2/g lista). Te koncentracije smo izbrali na osnovi preliminarnih študij, kjer se je izkazalo, da imajo nižje koncentracije (1000 µg TiO_2/g lista) po 14 dneh izpostavljanja že učinek na iste encime v izopodnem raku. Zato smo v 3 dnevnih poskusih testirali višje koncentracije. Za vsako koncentracijo smo izpostavili 10 živali, in celoten poskus trikrat ločeno ponovili. Ves čas poskusa smo vzdrževali primerno vlažnost v testnem sistemu.

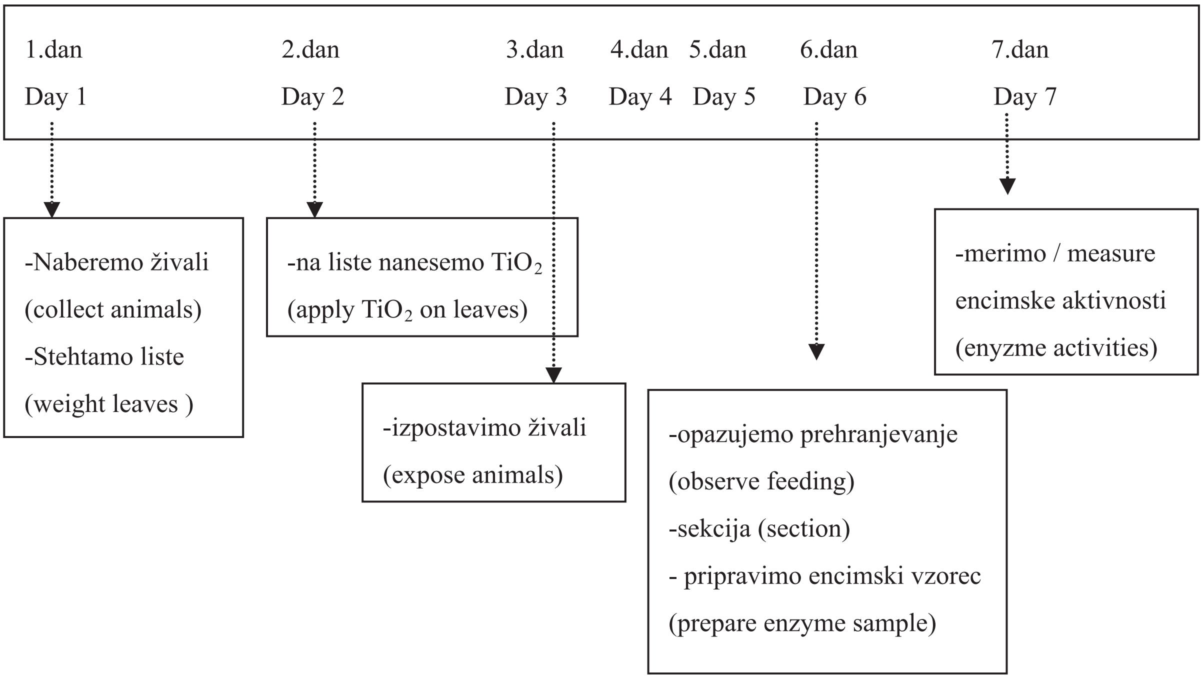
Po 3 dneh smo prešteli število iztrebkov in jih po 3-dnevnem sušenju v eksikatorju stehtali. Stehtali smo maso listov in živali. Iz dobljenih podatkov smo izračunali maso zaužitega lista, maso iztrebljene hrane in iz razlike teh dveh parametrov določili asimilacijsko učinkovitost, tj. koliko hrane je žival asimilirala. Živali smo secirali in izolirali prebavno žlezo, iz katere smo pripravili vzorec za encimske analize (Slika 1).

Kot referenca za dobro opravljen poskus in ustrezno populacijo testiranih živali so nam služile kontrolne vrednosti biomarkerjev po koncu poskusa, ki smo jih primerjali z že znanimi vrednostmi, ki smo jih v preteklosti dobili za zdravo populacijo živali. Tako smo zagotovili, da je bila testirana populacija primerna za uporabo v testu, in da je bil poskus izveden korektno.

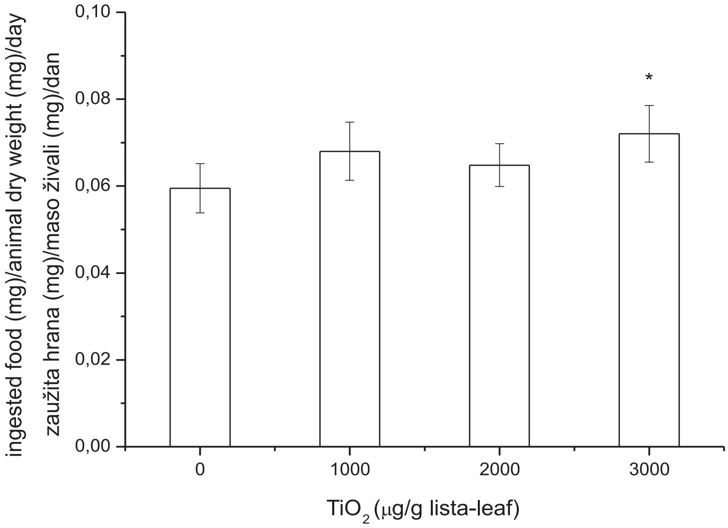
2.3 Merjenje encimskih aktivnosti

Prebavno žlezo smo s steklenim Elvehjem-Potterjevim homogenizerjem 3 minute homogenizirali v 0,8 mL 50 mM kalijevega fosfatnega pufra pH 7.0. Vzorce smo centrifugirali 25 min pri obratih 15000 g in temperaturi 4 °C. Aktivnosti encimov smo merili v sveže pripravljenih vzorcih.

Aktivnost GST smo določali z 1-kloro-2,4-dinitrobenzenom (CDNB) kot substratom (18) s



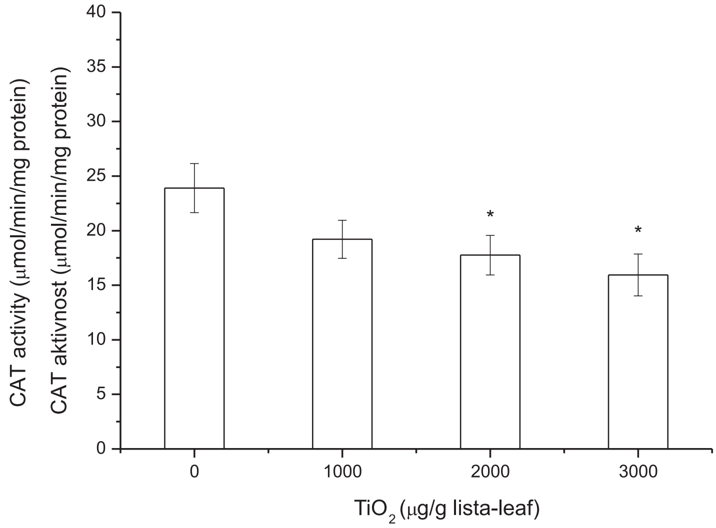
Slika 1. *Shema 3-dnevnega prehranjevalnega poskusa z mokrico.*
Figure 1. *Experimental set-up of 3-days feeding of the terrestrial isopod Porcellio scaber.*



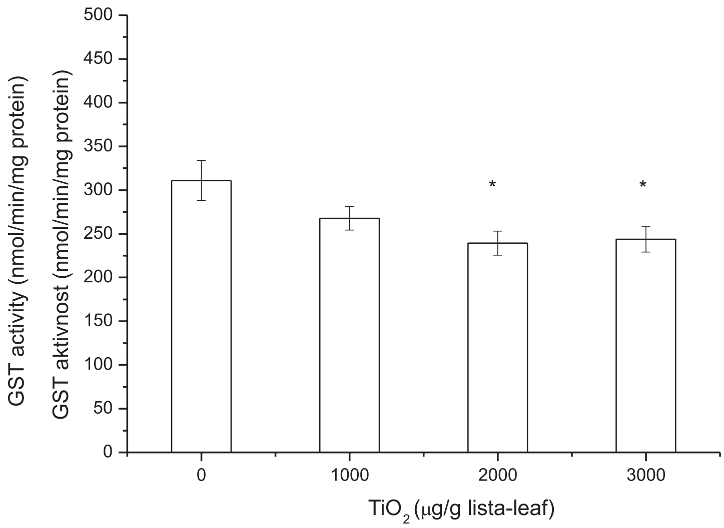
Slika 2: *Vpliv TiO_2 na dnevno stopnjo hranjenja mokric (srednja vrednost ± standardna napaka). Simbol (*) pomeni statistično signifikantno razliko glede na kontrolo (Mann Whitney test, P<0.05).*

Figure 2. *The effect of TiO_2 on the daily feeding rate of isopods. Symbols on the box plot represent maximum and minimum value (-), mean value (¦), median value (-) and significant changes compared to control (*) (Mann Whitney test, P<0.05).*

a.)



b.)



Slika 3: *Vpliv TiO_2 na aktivnosti encimov CAT (a) in GST (b) (srednja vrednost ± standardna napaka). Simbol (*) pomeni statistično signifikantno razliko glede na kontrolo (Mann Whitney test, P<0.05).*

Figure 3. *The effect of TiO_2 on catalase (a) and glutathione S-transferase (b). Symbols on the box plot represent maximum and minimum value (-), mean value (¦), median value (-) and significant changes compared to control (*) (Mann Whitney test, P<0.05).*

pomočjo čitalca mikrotitrskih plošč Bio-Tek® Instruments, USA; PowerWave™ XS. 50 µL 100 mM kalijevega fosfatnega pufra pH 6.5 smo zmešali z 50 µL 4 mM reduciranega glutationa, 50 µL 4mM CDNB in 50 µL vzorca. Reakcijo smo spremljali 3 min pri 340 nm in 25 °C.

Katalazno aktivnost smo merili na spektrofotometru (Shimadzu UV-2101PC spectrophotometer, Japan) (18). 100 µL vzorca smo dodali k 700 µL 11,5 mM raztopine H_2O_2 pripravljene v 50 mM kalijevem fosfatnem pufru pH 7.0. Reakcijo smo spremljali 2 minuti pri 240 nm in 25 °C.

Koncentracijo proteinov smo določali s komercialnim setom BCA™ Protein Assay Kit (Pierce, Rockford, IL, USA).

Encimske aktivnosti smo izrazili kot število molov nastalega produkta/razgrajenega substrata na minuto in jih podali na mg proteina.

3 Rezultati in razprava

3.1 Prehranjevanje

Po statistični obdelavi podatkov smo ugotovili, da testirane koncentracije TiO_2 nimajo očitnega vpliva na prehranjevanje mokric. Statistično značilno razliko smo opazili le pri dnevni količini zaužite hrane, ki je bila pri najvišji koncentraciji TiO_2 rahlo povečana glede na kontrolne organizme. Nesignifikantno povečanje je opaziti tudi pri koncentraciji 1000 µg TiO_2/g lista (Slika 2). Navadno pri izpostavitvi kemikaliji pričakujemo zmanjšano prehranjevanje živali, vendar pa pojav povečanja prehranjevanja tudi ni izključen. Podoben rezultat smo v preteklosti dobili pri izpostavljanju nekaterim pesticidom (Drobne et al., neobjavljeni rezultati).

3.2 Aktivnosti encimov

Pri najvišjih koncentracijah TiO_2 sta bili aktivnosti obeh encimov zmanjšani (Slika 3). Aktivnosti izbranih encimov sta lahko pod vplivom kemikalije zmanjšani ali povečani, odvisno od koncentracije. Pri nizkih koncentracijah kemikalije sta navadno aktivnosti povečani, ker se inducirajo obrambni sistemi, pri visokih koncentracijah pa kemikalija sama po sebi inhibira aktivnost encima ali pa je le ta zmanjšan posredno zaradi splošno slabega stanja celice. V našem primeru sta bili aktivnosti obeh encimov signifikantno zmanjšani, na osnovi česar zaključujemo, da imajo testirane koncentracije vpliv na celične sisteme prebavne žleze mokrice, vendar pa učinek ni bil opazen na višjih ravneh razen pri prehranjevanju.

Potrebne so nadaljne študije z višjimi koncentracijami, kjer bi študirali predvsem vpliv nanodelcev na višjih organizacijskih ravneh, ter poskusi z nižjimi koncentracijami, kjer nas zanima predvsem, če se omenjena encima inducirata zaradi nastanka ROS. Predlagamo tudi nadaljnje študije z različnimi časi izpostavljanja.

Trenutno o ekološki relevantnosti naših rezultatov težko razpravljamo, saj ni na voljo nobenih podatkov o koncentracijah nanodelcev TiO_2 v okolju. Dobljenih rezultatov tudi ne moremo primerjati z drugimi študijami, saj je ta študija ena imed redkih opravljenih na kopenskih nevretečarjih. Možna je primerjava z nekaterimi našimi neobjavljenimi rezultati, kjer smo enake učinke na aktivnost obeh encimov v enakem testnem sistemu dobili, ko smo živali izpostavili 100 µg Cd/g lista in 1000 µg Zn/g lista (naš laboratorij, neobjavljeno). Ti dve koncentraciji kovin sta glede na koncentracije v okolju zelo visoke, saj so mejne vrednosti za vnos v tla 0,5–1 µg Cd/g suhe mase in 160–200 µg Zn/g suhe mase (19). Le ena študija je na voljo o učinkih zaužitih nanodelcev TiO_2 na miši, kjer so po oralnem zaužitju 5 g teh nanodelcev/ kg telesne teže opazili histopatološke učinke na jetrih in ledvicah (20).

4 Zaključek

V prispevku smo predstavili testni sistem z mokrico *Porcellio scaber* za proučevanje vplivov nanomaterialov na organizme. Menimo, da je predstavljeni pristop testiranja hiter, ponovljiv in nudi veliko informacij o mehanizmih delovanja neke kemikalije/nanomateriala, saj nam omogoča proučevanje vplivov na več ravneh biološke organizacije. Zavedamo se, da so kakršne koli korelacije med vplivi nanomaterialov na mokrice in človekom nemogoče, vendar pa so v začetni fazi fazi proučevanja neznanih kemikalij bazične študije zelo dobrodošle. Poleg tega ne smemo pozabiti dejstva, da bo velika uporaba nanomaterialov rezultirala v njihovem pojavljanju v naravnem okolju, kar bo imelo velik vpliv na organizme, ki žive v tem okolju in posledično tudi na nas. Opozoriti želimo, da se bomo v prihodnosti srečali s posledicami izrednega razvoja nanotehnologij, med katerimi bodo mnoge za nas zelo koristne, s pospešenimi nanotoksikološkimi študijami pa moramo poskrbeti, da bo tistih negativnih čimmanj. To bo prav gotovo velik izziv javnemu zdravstvu v tretjem tisočletju.

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PREDLOG ORGANIZACIJE PREVENTIVNEGA ZDRAVSTVENEGA VARSTVA ŠPORTNIKOV V SLOVENIJI

PROPOSAL FOR THE ORGANISATION OF PREVENTIVE HEALTH CARE OF ATHLETES IN SLOVENIA

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Pregledni znanstveni članek
UDK 617.7:616-057

Izvleček

Bolezni med športniki je potrebno iskati aktivno. To je mogoče le z izvajanjem ustreznih presejalnih testov v okviru preventivnega zdravstvenega varstva. Protokoli preventivnih zdravstvenih pregledov športnikov žal po svetu niso poenoteni, obstajajo pa smernice za njihovo izvajanje. V Sloveniji preventivno zdravstveno varstvo opredeljujejo Navodila za izvajanje preventivnega zdravstvenega varstva na primarni ravni. Z novimi predlogi želimo postaviti temelje za njegovo izboljšanje ter ga tako približati evropskim smernicam.

Ključne besede: preventivno zdravstveno varstvo, športniki

Review article
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Abstract

Diseases in athletes must be searched for actively using appropriate screening tests. Prevention protocols of medical check-up for athletes vary from one country to another, yet some guidelines for these health services have been formulated in the USA and Europe. In Slovenia, a protocol of medical check-ups has been defined in the document »Guidelines for implementing prevention programmes in primary health care«. We believe that the proposed strategies will contribute considerably to improved disease prevention and health care of athletes, and bring these guidelines more into line with the well-established European norms.

Key words: preventive medical care, athletes

1 Uvod

Problematika ugotavljanja, spremljanja in vrednotenja zdravstvenega stanja športnikov je vselej aktualna. Dosedanje tovrstne obravnave so bile usmerjene predvsem v sistematično ugotavljanje in spremljanje zdravstvenega stanja vrhunskih športnikov, bistveno manj pa je bilo storjenega na področju zdravstvenega varstva športnikov kakovostnega razreda in rekreativnih športnikov. Razlogov za to je več. Večina strokovnjakov s področja športa in tudi zdravnikov – specialistov s področja medicine športa navaja velike obremenitve, ki so jim po pravilu izpostavljeni vrhunski športniki tako med treningi kot tudi na tekmovanjih. Zato je povsem logično, da je bila večina raziskav s področja medicine športa usmerjena v preučevanje vplivov zahtevnih treningov vrhunskih športnikov v različnih športnih panogah na njihovo celovito zdravstveno stanje. Športna stroka pa se je ukvarjala z iskanjem odgovorov na vprašanja pravilnega izbora in učinkovitosti treningov, ki naj bi posledično na tekmovanjih dajali visoke rezultate. Ob tem pa se

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na treningih in tudi tekmovanjih ni bilo mogoče izogniti različnim poškodbam in boleznim, ki so jim bili in so jim vrhunski in potencialno vrhunski športniki še posebej izpostavljeni. Tovrstna izpostavljenost je na področju kakovostnega in rekreativnega športa manjša. Vendar pa se v praksi kljub temu dogajajo odkloni v smislu preobremenjevanja oz. neustreznega izvajanja športnorekreativne vadbe ali treninga. V zvezi s tem je snovalec področja »športnorekreacijske medicine« (1) že pred več kot dvema desetletjema zapisal, da na področju vrhunskega športa vrhunskim športnikom vselej ne moremo jamčiti za njihovo zdravje, na področju rekreativnega športa pa smo to dolžni za vsako ceno zagotoviti. Pri tem je posebej poudaril smiselnost povezovanja strokovnjakov in raziskovalcev s področja športa in medicine. Nasploh je tesnejše povezovanje medicinske in športne stroke ter znanosti še posebej aktualno tudi danes (2). Vedno bolj je namreč očitno, da prihaja pri športnikih vseh kategorij do neustrezne intenzivnosti in pogostosti vadbe ter do napačne izbire trajanja in vrste vadbe glede na njihovo zdravstveno stanje in glede na njihov psihosomatski status. S preventivnimi zdravstvenimi pregledi lahko zmanjšamo tveganje za morebitne poškodbe ali bolezni (3), zato bi jim morali posvetiti bistveno več pozornosti ne le pri vrhunskih športnikih, temveč pri športnikih vseh kategorij.

V Sloveniji se z rekreativnim športom redno (najmanj dvakrat tedensko) ukvarja približno 30 % odraslega prebivalstva obeh spolov, prav toliko pa tudi občasno (1– do 2– krat mesečno).

2 Pregled zdravstvenega stanja športnikov

Športniki veljajo za zdravo populacijo, vendar pa raziskave kažejo, da zaradi pogostosti in intenzivnosti treningov nemalokrat trpijo zaradi različnih zdravstvenih težav (4). Pri analizi zdravstvenega stanja naših športnikov v letih 2002 in 2003 (5) smo ugotovili, da je zdravih le približno tretjina športnikov (32 %). Pri okvarah so na prvem mestu okvare kostno-mišičnega sistema (42 %), sorazmerno pogoste pa so tudi okvare dihalnega (9 %) in srčno-žilnega sistema (6 %). Naše ugotovitve se ujemajo z izsledki raziskav o zdravstvenem stanju športnikov v drugih razvitih državah (6-13). Žal v Sloveniji nimamo natančnih podatkov o nenadni srčni smrti športnikov in tudi ne o klinično nemih boleznih srčno-žilnega sistema, ki so po dosedanjih raziskavah eden glavnih vzrokov nenadne srčne smrti pri športnikih vseh kategorij (14). Nenadna srčna smrt je pri športnikih sicer redka, je pa zato toliko bolj odmevna. Podatki so znani za ZDA, v Evropi pa le za Italijo. V ZDA je incidenca nenadne srčne smrti 0,5/100.000 športnikov srednješolcev na leto in 1/3500 profesionalnih športnikov na leto (15, 16). Najpogostejši vzroki za nenadno srčno smrt pri mladih tekmovalcih v ZDA so hipertrofična kardiomiopatija in kongenitalne anomalije koronarnih arterij (17). V Italiji so med vodilnimi vzroki aritmogena displazija desnega prekata, kongenitalne anomalije koronarnih arterij in prezgodnja ateroskleroza koronarnih arterij (18). Če bi prenesli ameriške podatke na našo populacijo športnikov (v Sloveniji imamo približno 70.000 registriranih športnikov), lahko pričakujemo eno nenadno srčno smrt v treh letih med športniki vseh starosti in kategorij in skoraj eno srčno smrt na leto med športniki, ki po športnih rezultatih izpolnjujejo merila za kategorizacijo pri Olimpijskem komiteju Slovenije.

3 Namen preventivnih zdravstvenih pregledov športnikov

Preventivni zdravstveni pregled (PZP) športnika je namenjen zgodnjemu odkrivanju patoloških sprememb, ki bi lahko negativno vplivale na varno ukvarjanje s športom. To po opisu United States Preventive Services Task Force (USPSTF) pomeni, da moramo biti s pregledom sposobni ugotoviti ciljno patologijo prej, kot bi bilo to mogoče opaziti brez pregleda (testa), ob tem pa mora biti test zadovoljivo zanesljiv (ne preveliko število lažno pozitivnih in lažno negativnih rezultatov). Presejanje je seveda učinkovito le, kadar ima zgodnje odkrivanje in zgodnje zdravljenje bolezni večji uspeh kot zdravljenje pozno odkrite bolezni (19).

4 Preventivno zdravstveno varstvo športnikov v Sloveniji

V Sloveniji preventivno zdravstveno varstvo športnikov opredeljuje 43. člen Zakona o športu (Ur.l. RS 22/98) (20). Po tem členu so predhodni in obdobni zdravstveni pregledi, ki jih financira Zavod za zdravstveno zavarovanje Slovenije, obvezni za

športnike, ki nastopajo na uradnih tekmovanjih nacionalnih panožnih športnih zvez.
Natančnejši pogoji za njihovo izvajanje so navedeni v Navodilu za izvajanje preventivnega zdravstvenega varstva na primarni ravni (Ur.l. RS 19/98) (21). Le-ta določa, da se iz obveznega zdravstvenega zavarovanja financirajo pregledi športnikov, ki so razvrščeni v skupine vrhunskih in potencialno vrhunskih športnikov, športnikov panog z večjim tveganjem poškodb, perspektivnih športnikov in športnikov, vključenih v programe kakovostnega športa (republiški razred), ki jih je skupno v Sloveniji okrog 3500. Izvajalci pregledov so specialisti medicine dela, prometa in športa z usmeritvijo v medicino športa (licenca A). Obseg pregleda vključuje pregled medicinske dokumentacije z anamnezo in kliničnim statusom, antropometrijo, spirometrijo, inštrumentalni pregled vida, EKG v mirovanju, funkcionalno oceno srčno-pljučnega sistema (spiroergometrijo) in osnovne laboratorijske preiskave krvi in urina. Fakultativno se pregled razširi še na psihološki pregled, ADG in vestibulogram, Flackov test, perimetrijo in niktometrijo, testiranje razpršene pozornosti in redkih signalov, teste evrofit in stomatološki pregled. Obdobni pregledi se pri navedenih skupinah športnikov opravljajo enkrat letno. Pregledanih je le slaba polovica športnikov, in sicer zato, ker nekateri športniki o pregledih niso ustrezno obveščeni, drugi pa menijo, da pregledi niso potrebni. Nadzor nad opravljanjem pregledov, ki je v pristojnosti Inšpektorata za šport, zaenkrat še ni zadosten.
Ker sta Navodilo in Zakon glede financiranja pregledov neusklajena, sledi, da ostali športniki, ki nastopajo na uradnih tekmovanjih nacionalnih panožnih športnih zvez, niso dolžni opraviti preventivnega zdravstvenega pregleda. Med njimi so izjeme le športniki, včlanjeni v športne zveze, ki pregled za prisotnost na treningih in tekmovanjih zahtevajo, le-te pa so redke. Ti športniki opravijo preglede samoplačniško ali pa jim jih plačajo klubi ali športne zveze. Pogostnost pregleda je na eno leto, obseg pregleda pa je enak kot pri prvih štirih skupinah, razen funkcionalne ocene srčno-pljučnega sistema. Tudi vse ostale skupine športnikov, to so športniki rekreativci, invalidi, trenerji in sodniki na športnih tekmovanjih, opravijo preglede samoplačniško oziroma jim pregled plačajo društva ali organizacije. Preglede naj bi opravljali pri specialistih medicine dela, prometa in športa. Obdobni zdravstveni pregledi, katerih obseg je opredeljen v Navodilu, se za sodnike opravljajo na 12 mesecev, za rekreativne športnike na 24 do 36 mesecev, za športnike invalide na 6 do 12 mesecev, za trenerje pa na 36 mesecev.

5 Priporočila za preventivne zdravstvene preglede športnikov v drugih državah

Priporočila za preventivne zdravstvene preglede športnikov se od države do države razlikujejo. Prikazana so priporočila nekaterih vodilnih držav na tem področju, vključno z pozitivnimi učinki uvedbe obveznih preventivnih zdravstvenih pregledov športnikov.

Priporočila za preventivne zdravstvene preglede športnikov v ZDA

Priporočila Ameriškega kardiološkega združenja (AHA) (22) so dokaj skopa. Vsebujejo 12 točk in temeljijo na osebni zdravstveni anamnezi, družinski anamnezi in kliničnem pregledu. EKG v mirovanju posnamejo le vrhunskim športnikom, obremenitveni EKG in lipidogram pa šele po 35. letu (23). Preventivne preglede opravljajo športnikom od vstopa v srednjo šolo dalje, mlajšim športnikom pa ne. Priporočena pogostost pregledov je vsaki dve leti.
Z omenjenimi priporočili se večina panožnih zvez ne strinja, zato imajo posamezne panožne zveze določen poseben obseg pregleda za svoje profesionalne športnike.
Profesionalni športnik mora pred vstopom v National Football League (NFL) opraviti pregled, ki obsega anamnezo in klinični status (upoštevajoč 7 priporočil AHA), 12–kanalni EKG, RTG pljuč in srca in laboratorijske preiskave krvi (vključno z določitvijo lipidograma in glukoze v krvi). Pregled se v enakem obsegu opravi enkrat letno, UZ srca in obremenitveno testiranje pa opravljajo po potrebi.
National Basketball Association (NBA) ima še nekoliko strožje zahteve. Športnik mora opraviti pregled, ki obsega anamnezo in klinični status (9 priporočil AHA), 12–kanalni EKG, UZ srca, RTG pljuč in srca, obremenitveno testiranje in laboratorijske preiskave krvi vključno z lipidogramom. Večjemu obsegu preventivnih

zdravstvenih pregledov je botrovala nenadna srčna smrt enega od igralcev v letu 2006.
Večina drugih profesionalnih klubov zahteva preventivni zdravstveni pregled, ki ob izčrpni anamnezi in kliničnem statusu vsebuje tudi 12–kanalni EKG po zgledu Italijanskega nacionalnega preventivnega programa za vse tekmovalne športnike. Z 12–kanalnim EKG se lahko odkrijejo srčne bolezni zaradi okvare ionskih kanalčkov, pomembno pa lahko prispeva tudi pri diagnozi aritmogene displazije desnega prekata, miokarditisa in aterosklerotične bolezni koronarnih arterij.
Ker tveganje za nenadno srčno smrt pri profesionalnih športnikih močno presega tveganje pri športnikih srednješolcih, si delujoči na področju medicine športa prizadevajo za uvedbo standardizacije preventivnih pregledov, ki bi vključevali usmerjeno anamnezo, klinični pregled, EKG v mirovanju in UZ srca pri vstopu v ligo (24). To bi omogočilo zgodnje odkrivanje klinično nemih srčnih bolezni, kot so lahko hipertrofična ali dilatativna kardiomiopatija, prolaps mitralne zaklopke ali dilatacija začetnega dela aorte, kar so na primer pred kratkim odkrili pri treh igralcih NBA. Ob tem pa še ni popolnoma jasno, kako pogosto naj bi to presejanje dalo lažno pozitivne ali lažno negativne rezultate in kako pogosto je potrebno dodatno testiranje.

Evropska priporočila za preventivne zdravstvene preglede športnikov

Evropska priporočila delovne skupine za športno kardiologijo pri evropskem kardiološkem združenju iz leta 2005 (25) temeljijo na italijanskem modelu preventivne zdravstvene oskrbe športnikov in so v primerjavi z ameriškimi nekoliko strožja, glavna razlika pa je, da ob izčrpni osebni in družinski anamnezi, kliničnem pregledu in meritvah krvnega tlaka zagovarjajo rutinsko snemanje 12–kanalnega EKG (18). Delovna skupina namreč zagovarja tezo, da je EKG za odkrivanje klinično nemih srčnih bolezni bistveno bolj občutljiv kot le anamneza in klinični pregled, saj so pri športnikih, ki so umrli zaradi nenadne srčne smrti, na osnovi anamneze in kliničnega pregleda posumili na klinično nemo srčno bolezen le v 3 % (26). V nasprotju s tem je EKG patološki pri 75 do 95 % bolnikov s hipertrofično kardiomiopatijo, pogosto pa je patološki tudi pri ostalih boleznih, pri katerih lahko pride do nenadne srčne smrti (27).
Evropska priporočila se nanašajo na športnike med dvanajstim in 35. letom, ki redno trenirajo in/ali sodelujejo na športnih tekmovanjih. Priporočena pogostost pregledov je vsaj vsaki dve leti (25).
V primeru pozitivnih rezultatov pri presejalnih testih se opravijo še preostale preiskave, kot so UZ srca, obremenitveno testiranje, monitoriranje s holterjem, magnetno-resonančno slikanje srca ali angiografija. Žal tudi evropska priporočila niso popolna, saj ne vsebujejo nobenih navodil za izvajanje preventivnih zdravstvenih pregledov za športnike, ki so starejši od 35 let. Pri teh je najpogostejši vzrok nenadne srčne smrti ateroskleroza koronarnih arterij (25).

Primer dobre prakse – Italija

Najboljšo preventivno zdravstveno oskrbo športnikov imajo v Italiji, kjer imajo že 25 let uzakonjeno sistematično pregledovanje športnikov vseh kategorij, tako rekreativnih kot tekmovalnih. Stroške tega programa krije država. Pregled vključuje izčrpno anamnezo, klinični pregled, vključno z meritvijo krvnega tlaka, in 12–kanalni EKG. Preglede opravljajo specialisti medicine športa s 4-letno specializacijo. Najboljših 500 tekmovalnih športnikov v državi mora enkrat letno opraviti še razširjeni pregled v osrednjem Inštitutu za športno medicino in znanost v Rimu (28). Za ostale športnike se dodatne preiskave opravijo ob indikaciji, nekateri športniki pa se za doplačilo odločijo za razširjeni obseg pregleda, ki tako vsebuje še oceno vida, spirometrijo in 3-minutni test step.
Po uvedbi sistematičnega pregledovanja športnikov leta 1981 se je letna incidenca nenadnih srčnih smrti športnikov v 25 letih znižala za 89 % - iz 3,6/100.000 oseb letno na 0,4/100.000 oseb letno, medtem ko se incidenca nenadnih srčnih smrti nepregledane populacije mladih, ki se ne ukvarjajo s športom, ni bistveno spremenila. V primerjavi z obdobjem pred sistematičnim pregledovanjem (1979-81) je bilo relativno tveganje (RT) za nenadno srčno smrt športnikov v zgodnjem obdobju presejanja le nakazano nižje, (RT = 0,56, 95% IZ 0,29 – 1,15; p =0,04), občutno nižje pa v poznem obdobju presejanja (RT = 0,21, 95% IZ 0,09 – 0,48; p = 0,001). Zmanjšalo se je predvsem število smrti zaradi kardiomiopatije (iz 1,5/100 000 oseb letno v obdobju pred sistematičnim pregledovanjem na 0,15/100 000 oseb letno v poznem obdobju pregledovanja; p=0,002). V 25-letnem obdobju je bilo zaradi različnih srčno-žilnih vzrokov iz tekmovanja izključenih 879 športnikov (2 %).
Po uvedbi nacionalnega sistematičnega presejanja

je tako pogostost nenadne srčne smrti pri mladih športnikih pomembno upadla, predvsem na račun zgodnjega odkrivanja kardiomiopatij ob vstopu v tekmovalni proces (29).

6 Naši predlogi za izboljšanje preventivne zdravstvene oskrbe športnikov

Naši predlogi za izboljšanje preventivne zdravstvene oskrbe športnikov temeljijo na ugotovljenem dejanskem zdravstvenem stanju športnikov v Sloveniji (5), podatkih, povzetih po tujih raziskavah, priporočilih evropskega združenja za športno kardiologijo ter na primeru dobre prakse iz Italije.

Prvi predlog za spremembo je bil podan na Ministrstvo za zdravje že leta 2004. Preventivni zdravstveni pregledi športnikov šolarjev do 19. leta in športnikov študentov bi se priključili rednim sistematičnim pregledom pri specialistih pediatrih in specialistih šolske medicine, ki bi se v ta namen dodatno izobrazili in tako pridobili licenco C iz medicine športa. Tako bi sistematičnim pregledom, ki se izvajajo vsako drugo leto, dodali le nekaj vsebin, kot so osebna anamneza o športni dejavnosti in obremenitvah, o športnih uspehih in poškodbah, klinični pregled, usmerjen v gibalni, srčno-žilni in dihalni sistem, EKG v mirovanju, pri zdravstveni vzgoji pa bi poudarili še prehrano športnika, pitje tekočin in vpliv športnih obremenitev na zdrav telesni razvoj v obdobju odraščanja. Ob ugotovitvi morebitne patologije bi športnika napotili k specialistu medicine športa (30). S predlogom je soglašala tudi ZZZS.

Priključitev preventivnih zdravstvenih pregledov športnikov šolarjev in študentov rednim sistematičnim pregledom v okviru šolske medicine se tudi danes še vedno zdi smiselna. Tako bi rešili problem preventivnih zdravstvenih pregledov velikega dela športnikov, predvsem kakovostnega razreda. Ostali športniki kakovostnega razreda, ki niso v rednem procesu šolanja, bi pregled v enakem obsegu enkrat na dve leti opravili pri specialistu medicine dela, prometa in športa z ustreznim znanjem iz medicine športa.

Športniki, ki se po uspehih uvrstijo v enega od razredov za kategorizacijo, ki jih določa Olimpijski komite Slovenije, bi preventivne zdravstvene preglede še naprej opravljali pri specialistih medicine dela, prometa in športa, usmerjenih v medicino športa, potrebno bi bilo dodati le, da se v okviru PZP ob indikaciji lahko opravi tudi UZ srca ali 24-urno snemanje EKG in merjenje krvnega tlaka. UZ srca bi moral biti tudi sestavni del PZP svetovnega, mednarodnega in perspektivnega razreda športnikov.

Dodati bi bilo potrebno tudi, da se ob indikaciji lahko v sklopu pregleda odredijo razširjene laboratorijske preiskave krvi, pri športnikih po 35. letu pa rutinsko določi lipidogram in krvni sladkor.

Dodaten predlog spremembe v Navodilih je tudi obvezni preventivni zdravstveni pregled vseh rekreativnih športnikov, ki se želijo organizirano ukvarjati s športom ali nastopati na tekmovanjih. Pregled bi obsegal anamnezo (glede na AHA priporočila), status z meritvijo krvnega tlaka in 12–kanalni EKG. Dodatne preiskave bi se opravile ob indikaciji. Priporočena pogostost pregledov je vsaki 2 leti. Preglede bi opravili specialisti medicine dela, prometa in športa z ustreznim znanjem iz medicine športa.

7 Zaključek

Z navedenimi spremembami bi lahko ustrezno uredili predvsem preventivno oskrbo tistih športnikov, pri katerih je le-ta najslabše opredeljena. Sem sodijo športniki do 19. leta starosti in rekreativni športniki. Z manjšimi spremembami bi lahko olajšali tudi izvajanje preventivnih zdravstvenih pregledov kategoriziranih športnikov.

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PREVENTIVA PRED ZDRAVSTVENIMI OKVARAMI POKLICNIH GLASBENIKOV

PREVENTION OF OCCUPATIONAL DISORDERS IN MUSICIANS

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Izvleček

Veliko poklicnih glasbenikov ima resne zdravstvene težave, zaradi česar trpi kakovost njihovega nastopa. Večina težav nastane zaradi čezmernih fizioloških in duševnih obremenitev in obremenjenosti (telesni in psihosenzorni stres) s posledično okvaro mišično-skeletnega sistema, kot so: bolečinski sindrom hrbtenice, ramenskih obročev, fokalna distonija, poklicni preobremenitveni sindrom, utesnitvene nevropatije (zapestje, komolec, torakalni izhod), okvara sluha, tenzijski glavoboli, depresija, živčni zlom ipd. Te težave so posledica specifičnih obremenitev in kariernih zahtev glasbenikov, kot sta stresno življenje in nefiziološka drža telesa ob igranju instrumenta in sedenju. Strokovnjaki glasbene medicine poskušajo razumeti specifične težave glasbenikov, jim pomagajo preventivno ter se lotevajo že nastalih poklicnih bolezni. Zelo pomembno je, da glasbeniki že med šolanjem ob začetku glasbene kariere pridobijo ustrezne optimalne in racionalne motorične modele igranja na instrument. Le ob ustreznem ravnanju s telesom so glasbeniki sposobni prepoznati tako negativne kot pozitivne napetosti, ki spremljajo njihovo igranje in nastopanje.

Ključne besede: glasbena medicina, zdravstvene okvare glasbenikov, trema, tehnike zavedanja telesa, Grindeajina tehnika

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Abstract

Many professional musicians have severe health problems. Most of these ailments are caused by excessive physiological and mental loads and strains (physical and psychosensory stress) resulting in malfunction of the musculoskeletal system, which may be manifested as pain syndrome of the spine and shoulder girdles, focal dystonia, occupational overuse syndrome, wrist, elbow and thoracic outlet entrapment neuropathies, hearing damage, tension headaches, depression, nervous breakdown and others. These problems are due to specific demands of the musician's career, and originate from stressful lifestyle and misuse of the body while playing. The goal of music medicine specialists is to identify and help prevent health problems in musicians, and to treat performance-related injuries once they occur. It is important to learn appropriate rational motor patterns of playing an instrument at the earliest stage of musical training. Only if a musician develops body awareness, is he/she able to recognize negative and positive tensions associated with musical performance.

Key words: music medicine, injuries in musicians, stage fright, body awareness techniques, Grindea Technique

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1 Uvod

Glasbena medicina je del medicine, ki se je razvil šele potem, ko so glasbeniki dolgo časa zaman iskali skupni jezik z medicinsko stroko, ki ni razumela njihovih specifičnih zdravstvenih problemov. Potem ko so si glasbeniki upali tudi javno spregovoriti o svojih težavah – ne da bi se ob tem bali, da se bodo iz njih norčevali kolegi ali bodo zaradi tega izgubili vir zaslužka, je nastal tudi večji interes za iskanje vzrokov težav in njihovo zdravljenje tako med medicinsko stroko kot med samimi glasbeniki. Prav zato so se oblikovala združenja, v katerih sodelujeta obe stroki: v začetku 70. let prejšnjega stoletja je najprej nastalo Avstralsko medicinsko združenje nastopajočih umetnikov – Australian Performing Artists Medical Society (PAMS) (1). Eden od soustanoviteljev, prof. Earl Owen, oče mikrokirurgije in tudi pianist, je takrat napisal prvi članek o poškodbah, ki jih povzroča igranje instrumenta ("Music Induced Injuries") (1). Leta 1974 se je v Nemčiji, v Hannovru, oblikovala zasnova kasnejšega Inštituta za glasbeno fiziologijo in medicino odrskih umetnosti – Institut für Musikphysiologie und Musiker-Medizin. Sledila so razna združenja v ZDA (International Arts Medicine Association v Philadelphiji, 1985, PAMA – Performing Arts Medicine Association v Chicagu, 1985), Veliki Britaniji (BPAMT – The British Performing Arts Medicine Trust, 1984, BAPAM – British Association of Performing Arts Medicine, AMABO – Association of Medical Advisers to British Orchestras), na Nizozemskem ipd. (2, 3). V Sloveniji sicer že nekaj let glasbeniki v sodelovanju z medicinsko stroko aktivno iščemo vzroke svojih težav, bolj organizirano pa od 1. decembra 2006, ko je EPTA, Društvo klavirskih pedagogov Slovenije, ustanovilo sekcijo ISSTIP – Mednarodnega društva za proučevanje napetosti med nastopom (International Society for the Study of Tension in Performance), ki je bilo ustanovljeno že leta 1981 v Londonu (3, 4, 5). Kot ISSTIP Slovenia deluje tudi pod okriljem organizacije "ISSTIP International Institute of Performing Arts Medicine" s sedežem v Londonu (direktorica: prof. Carola Grindea, svetovalec: prof. Earl Owen).

2 Namen prispevka

Vse več glasbenikov ima težave, ki so posledica specifičnih zahtev njihovega poklica. Potrebno jim je dati spodbudo, da o svojih težavah spregovorijo, in zaupanje, da njihove specifične težave razumejo strokovnjaki, jih znajo uspešno ozdraviti, obenem pa skrbijo tudi za to, da do takih težav sploh ne pride. Tako spodbudo in zaupanje vse bolj potrebujejo tudi slovenski glasbeniki. Ob opredelitvi zdravstvenih težav poklicnih glasbenikov, ponazoritvi s primeri vrhunskih glasbenikov, ki so morali zaradi težav spreminjati tok svoje kariere, ter predstavitvi tehnike zavedanja telesa, ki pomaga ne le reševati že nastale okvare, temveč deluje predvsem preventivno, želim tako vzpostaviti še bolj dejaven, predvsem pa organiziran odnos med medicinsko stroko in poklicnimi glasbeniki v Sloveniji. Cilj takega odnosa je ne le razviti prepoznavnost dejavnosti v Sloveniji in na tujem, temveč predvsem omogočiti glasbenikom, da lahko čim dlje in kakovostno izvajajo glasbo in jih obenem na ta način spodbujati pri njihovem ustvarjalnem delu.

3 Opredelitev zdravstvenih težav glasbenikov

Da imajo glasbeniki zares poklicne in nepoklicne zdravstvene težave, dokazujejo tudi podatki številnih epidemioloških in biomehanskih raziskav (6–18). Ena prvih takšnih epidemioloških raziskav je bila narejena leta 1986 v organizaciji ICSOM, International Conference of Symphony and Opera Musicians (6, 7). Na vprašalnik je odgovorilo 2212 glasbenikov iz 47 orkestrov (le eden od povabljenih orkestrov ni sodeloval). 82 % je priznalo vsaj eno zdravstveno težavo, zaradi katere trpijo med igranjem, 76 % je imelo resne zdravstvene težave, zaradi katerih je trpela kakovost nastopa, 12 % je celo moralo prenehati igrati, ker so bile težave tako resne, 21 % glasbenikov je priznalo, da zaradi čezmernega stresa in treme čezmerno pijejo alkohol, 24 % je bilo zaradi izvajalske anksioznosti nenehno v skrbeh in 27 % je tešilo težave z jemanjem beta-blokatorjev.

Izkazalo se je, da imajo zdravstvene težave tudi slovenski orkestrski glasbeniki. V raziskavi, ki jo je naredil mag. Rajko Črnivec s Kliničnega inštituta za medicino dela, prometa in športa, objavljeni leta 2004, je bilo zajetih 70 izmed 115 zaposlenih v orkestru Slovenske filharmonije (15). Vsi sodelujoči glasbeniki so priznali zdravstvene težave, od tega je imelo 47,14 % manjše, 40 % srednje in 12,86 % resne zdravstvene težave. V raziskavi je bilo tudi ugotovljeno, da je 62,86 % glasbenikov sposobnih za delo, manj sposobnih je bilo 30 %, 5,71 % je bilo nesposobnih za delo, pri 1,43 % pa ni bilo možno oceniti sposobnosti za delo.

Tabela 1. *Pogostost zdravstvenih težav med 2212 orkestrskimi glasbeniki ICSOM, 1986 (6, 7).*
Table 1. *Incidence of health problems in 2,212 orchestra musicians ICSOM 1986 (6,7).*

VRSTA TEŽAVE / *HEALTH PROBLEM*	DELEŽ PRIZADETIH / *PERCENTAGE OF AFFECTED MUSICIANS*
Vsaj ena zdravstvena težava, zaradi katere trpijo med igranjem / *At least one health problem experienced during music performance*	82 %
Resne zdravstvene težave, zaradi katerih trpi kakovost nastopa / *Serious ailments interfering with the quality of performance*	76 %
Tako resne težave, da so morali prenehati igrati / *Serious problems that made the musician quit his/her music career*	12 %
Preveč alkohola zaradi stresa in treme / *Too much alcohol because of stress and stage freight*	21 %
Zaradi izvajalske anksioznosti nenehno v skrbeh / *Constant worry and perfromance anxiety*	24 %
Jemanje blokatorjev beta / *Use of beta-blocking agents*	27 %

Resda se rezultati raziskav, narejenih med nastopajočimi, v odstotkih včasih nekoliko razlikujejo, dejstvo pa je, da velik delež glasbenikov trpi med igranjem instrumenta in nastopanjem zaradi težav, ki se lahko tako stopnjujejo, da mora glasbenik celo prenehati igrati. Težav je več vrst, od mišično-skeletnih, nevroloških do psihičnih, se pa velikokrat prepletajo (3, 6–21). Med najbolj izrazitimi mišično-skeletnimi težavami so bolečine in napetosti v predelu vratu in ramen ter v lumbalnem predelu. V raziskavi med glasbeniki ICSOM je bilo 20 % takih, ki so potrdili težave z desnim ramenskim sklepom, prav tolikšen delež težav je bil z levim, 21 % jih je imelo težave na desni strani vratu, 22 % na levi strani vratu, 22 % glasbenikov je imelo težave v desni polovici spodnjega dela hrbtenice in 22 % v levi polovici spodnjega dela hrbtenice (7). V raziskavi, narejeni med zaposlenimi v Slovenski filharmoniji, je 33 % glasbenikov potrdilo bolečine v ramenih in zgornjih udih, 30 % jih je imelo bolečine v lumbosakralnem delu, 13 % v zapestju, zlasti v desnem, in 3 % v podlakti, 27 % violinistov in violistov pa je imelo težave zaradi bolečin v predelu vratu (15). Poseben problem je tudi trema, nemir in napetost neposredno pred nastopom in med njim, z vzporednimi dejavniki, kot so mrzle, potne roke, plitvo dihanje, razbijanje srca, suho grlo ipd., kar lahko v veliki meri vpliva na kakovost nastopa.

Dolgotrajna izpostavljenost psihosenzornemu in telesnemu stresu med poklicnim muziciranjem, ki pomeni zdravju škodljivo dejavnost, pomeni povečano tveganje za nastanek poklicnih mišično-skeletnih bolezni hrbtenice in sicer okvare medvretenčne ploščice hrbtenice pod zaporedno številko 62, kroničnih bolezni hrbtenice zaradi stalnih obremenitev v nefiziološkem položaju pri delu pod zaporedno številko 63, poklicnega preobremenitvenega sindroma v okviru poklicnih bolezni zaradi prevelikega obremenjevanja kit, kitnih ovojnic in mišičnih oziroma kitnih narastišč pod zaporedno številko 60, utesnitvene nevropatije medianega živca v zapestju, ulnarnega živca v komolcu in brahialnega pleteža v ramenu z možno posledično ohromitvijo pod zaporedno številko 64, poklicne okvare sluha zaradi hrupa pod zaporedno številko 35 Pravilnika o seznamu poklicnih bolezni, Ur. list RS štev. 85/03, ter fokalne distonije (22). Posledično so možne tudi z delom povezane psihosomatske, duševne, srčno-žilne in endokrine motnje z začasno ali s trajno omejeno možnostjo za delo ali celo z invalidnostjo.

4 Glasbeniki s težavami

Izvrstni kanadski pianist Glenn Gould (1932–1982) je imel vrsto (tudi izmišljenih) zdravstvenih problemov, ki si jih je zdravil tako, da je dobival recepte od več zdravnikov, ki niso vedeli drug za drugega (23). Pianist je do danes ohranil sloves zaradi izjemnih interpretacij – predvsem J. S. Bacha, zaradi genialnosti, pa tudi zaradi diverzij v obnašanju – delal je v glavnem ponoči. Ni maral koncertiranja in bil od svojega 33. leta fasciniran nad moderno tehnologijo, snemal je le še v lastnem studiu; z ljudmi je najraje komuniciral po telefonu, običajno jih je zbudil sredi noči in nadaljeval z dolgimi, a filozofsko zanimivimi monologi ... Manj znano je dejstvo, da je pianist več mesecev trpel zaradi zmanjšane kontrole nad prstom desne roke in posledično neizenačenega tona pri igranju, o čemer je vodil tudi dnevnik. Strokovnjaki, ki danes berejo ta dnevnik, sumijo, da je šlo za fokalno distonijo (21, 24). Za isto boleznijo sta mnogo bolj trpela tudi ameriška pianista Leon Fleisher in Gary Graffman, ki sta s svojo izpovedjo pravzaprav vplivala na nastanek in razvoj glasbene medicine v ZDA (20, 25, 26). Sicer pa je fokalna distonija najverjetneje najhujše zlo, ki resda prizadene le majhen odstotek glasbenikov, izraža pa se v nekontroliranem spodvijanju prstov na roki, oziroma v problemih ambažure (omrtvičenost mišic okrog ust in obraznih mišic, ki lahko sega celo do prsnih in trebušnih mišic) pri pihalcih in trobilcih (11). Zaradi tega je deloma ali povsem onemogočeno igranje, običajno pa mine tudi po več let preizkušanja raznih metod zdravljenja, preden se stanje vsaj deloma popravi.

Glenn Gould je imel to srečo, da je imel tovrstne težave le nekaj mesecev in da jih je znal nadzorovati z natančnim opazovanjem in s korigiranjem tehnike igranja klavirja. Njegova tehnika je bila zelo nevsakdanja, a je ni želel korenito spremeniti; med igranjem je visoko dvigoval prste, kar je zahtevalo dodaten napor mišic, in obenem sedel zelo nizko, kar mu je še bolj onemogočalo nadzor nad klaviaturo in povečevalo napetosti v predelu ramen in vratu, ki je že tako ali tako pereč problem večine glasbenikov. Taka tehnika mu je sicer zadostovala pri igranju predklasične glasbe in nekaterih modernih skladateljev, mu je pa onemogočala igranje romantične literature, ki zahteva veliko zvoka; najverjetneje pa je, kot je sam slutil, ta tehnika bila najmočnejši dejavnik, ki je vplival na spremenjen in nezaželen način igranja.

Težave prizadenejo vrsto glasbenikov, med njimi veliko število vrhunskih koncertantov. Znano je, da so v preteklosti imeli težave zaradi bolečin v rokah vrhunski

Slika 1. *Kanadski pianist Glenn Gould (27).*
Figure 1. *Canadian pianist Glenn Gould (27).*

pianisti: Chopin, Clara Schumann, Rahmaninov, Paderewski ... (20). Robert Schumann je moral opustiti pianistično kariero, ne toliko zaradi psihičnih težav kot zaradi poškodbe prsta na roki, današnji strokovnjaki predvidevajo celo, da je trpel zaradi fokalne distonije. Pomagal si je z opornicami za prste, a brez večjega uspeha (20, 28). Podobno je tudi Skrjabin moral preusmeriti koncertiranje na kompozicijo (20). Mnogi glasbeniki iz sveta klasične in popularne glasbe so priznali, da so se zaradi težav zatekli k Aleksandrovi tehniki: violinist Yehudi Menuhin, pop pevca Paul McCartney in Sting, kitarist Julian Bream, flavtist James Galway, dirigent Sir Adrian Boult in pianist Leif Ove Andsnes, da jih naštejem samo nekaj (29, 30). Pravzaprav so, po besedah prof. Earla Owena, "vsi glasbeniki, od dneva, ko se začnejo učiti instrument, do dneva, ko se upokojijo, v resnični nevarnosti, da bodo zaradi predanosti svoji umetnosti in karieri trpeli zaradi hudih telesnih težav zaradi instrumenta, na katerega igrajo". Prof. Earl Owen, ki se je v mladosti učil klavir pri slavnem pianistu Solomonu, je tudi sam občutil težave, ki jih povzroči igranje instrumenta. Svojo kariero je okronal kot mikrokirurg, obenem pa je – skupaj z dr. Hunterjem Fryem – vodilni specialist glasbene medicine glasbe v Avstraliji. Obravnaval je težave glasbenikov vodilnih orkestrov na svetu; v svoji ordinaciji hrani je približno 1000 kartotek glasbenikov, med njimi so tudi slavni ... (31).

5 Preventivni ukrepi

Dolgo časa (ali pa tako še vedno počnejo) so poklicni glasbeniki po svoje reševali probleme, ki nastajajo zaradi psihosenzornega in telesnega stresa (zdravju škodljiva poklicna dejavnost), kajti poleg stresogenega dela in nefiziološkega sedenja so dodatno obremenjeni z instrumentom, ki ni ergonomsko oblikovan, torej prilagojen glasbeniku, temveč je bil "narejen zato, da bo iz njega prišel lep zvok" (31). Povrh vsega so vse kretnje in misli usmerjene v note, za katere glasbenik, publika in kritiki pričakujejo, da bodo zaigrane ob pravem času, z lepim zvokom, stilno dovršeno in z občutji ugodja.

Danes vemo, da so težave glasbenikov posledica psihofizičnih okoliščin igranja instrumenta (oz. petja) ter nastopanja. Ure vaj in nastopanja v neugodni in prisilni drži telesa, ob ponavljanju istih ali podobnih kretenj ter ob slabi tehniki, ki je v veliki meri odvisna od prej naštetega, so vzrok teh problemov, ti pa se stopnjujejo tudi zaradi stresnega načina življenja, ki zahteva veliko odgovornosti zaradi pričakovanj drugih, pa tudi lastnih pričakovanj; obenem pa so vsi našteti problemi vsota še drugih dejavnikov, kot so socialni, kulturni, značajski in podobno.

5.1 Tehnike zavedanja telesa

Pristop k reševanju problemov glasbenikov je zelo kompleksen; vendar vse več zagovornikov izhaja iz razumevanja telesa kot sredstva za igranje instrumenta oziroma glasbenega izvajanja, obenem pa tudi kot zunanji pojavi fizioloških (telesnih, senzornih) in duševnih procesov, ki omogočajo naše delovanje. Ta struktura pa ima zaradi pomanjkanja zavestne kontrole poleg funkcij za vzdrževanje ravnovesja našega življenja in delovanja tudi neomejene možnosti za ustvarjanje negativnih napetosti v telesu; produkt teh napetosti so sprva blokade, ki pa se sčasoma razvijejo v že omenjena bolezenska stanja (19, 32).

Glasbeniki so v sodelovanju z medicinsko stroko ugotovili, da dejavno pozitiven odnos do telesa in njegovih funkcij ne le pomaga pozdraviti telesne in duševne okvare (preobremenjenosti), temveč je to lahko celo boljši način zdravljenja za razliko od standardnih medicinskih postopkov. Obenem pa tehnike zavedanja telesa, kot so Aleksandrova tehnika, Feldenkraisova metoda, Grindeajina tehnika ipd., pomagajo razviti optimalno in racionalno tehniko igranja instrumenta (petja) in nastopanja in tako nimajo zgolj funkcije zdravljenja, temveč je njihov učinek predvsem v preprečevanju ter obenem v spodbujanju razvijanja glasbenih potencialov (19, 33–41). Nujna podlaga vsem tem oblikam preventive pa je urejen način življenja in ustrezna telovadba.

5.1.1 Grindeajina tehnika (37, 40–45)

Ozaveščeni glasbeniki danes skrbijo za kakovost svojega instrumenta in primernost sedeža, ki ga uporabljajo med igranjem, ter se v času, ko vadijo poudarjeno posvečajo tehniki igranja instrumenta, zavedanju mišično skeletnih struktur in njihovih pozitivnih napetosti, ki omogočata gibčnost kretenj, ter prepoznavanju negativnih napetosti, ki so vzrok naštetim težavam. Številni glasbeni kolidži in akademije na zahodu imajo imenovane tehnike zavedanja telesa že vključene v svoj učni program, vse bolj pa se uveljavlja vadba Grindeajine tehnike. Temeljni cilj vseh teh tehnik je zavedanje mišično-skeletne strukture telesa ter vzpostavljanje ravnotežja v telesu tako v mirujočem stanju kot v gibanju.

Pianistka **Carola Grindea**, avtorica Grindeajine tehnike, je po rodu Romunka, ki že od leta 1939 živi v Londonu. Sprva je koncertirala in kasneje postala profesorica klavirja na Guildhall School of Music and Drama (1968-1989). Leta 1978 je ustanovila Evropsko združenje klavirskih pedagogov (EPTA), ki ima danes že okrog 40 članic; bila je tudi prva urednica revije Piano Journal, ki jo izdaja EPTA. Leta 1981 je ustanovila še ISSTIP, Mednarodno združenje za proučevanje napetosti med nastopom (International Society for the Study of Tension in Performance). Je urednica in soavtorica knjige "Tensions in the Performance of Music – a Symposium", ki je doslej izšla že šestkrat (predgovor h knjigi je napisal Yehudi Menuhin). O napetosti med igranjem instrumenta in nastopanjem je napisala že vrsto knjig in člankov ter predavala v različnih državah (Velika Britanija, ZDA, Kanada, Japonska, Avstralija, Izrael, Irska, Rusija, ipd.). Leta 1990 je osnovala Performing Arts' Clinic na London College of Music and Media (LCMM). Od leta 2002 je direktorica tečajev za terapevte glasbene medicine, v organizaciji ISSTIP in LCMM, Thames Valley University. Je urednica revije ISSTIP Journal, organizatorica ter predavateljica seminarjev ISSTIP ter mednarodnih konferenc Instituta ISSTIP za medicino odrskih umetnosti. Ves čas je prisotna v britanskih in mednarodnih radijskih in televizijskih programih. Prejela je več nagrad, leta 2001 je bila med finalistkami za "Evropsko nagrado za ženske dosežke".

Grindeajina tehnika je – za razliko od ostalih tehnik in metod – prilagojena posebej glasbenikom, z željo, da z razvijanjem zavedanja telesa in z utrjevanjem zdrave tehnike igranja instrumenta in petja ozdravijo že nastale težave, po drugi strani pa razvijajo sebe v zdrave in uspešne glasbenike. Gre za dva sklopa vaj: prvi sklop je fizična vaja, ki pomaga razbremeniti napetosti v mišicah ramenskih obročev in vratnem delu hrbtenice. Drugi sklop je prav tako fizična vaja, ki pa je ne izvajamo s fizičnim premikanjem telesa, temveč s t. i. mentalnimi direktivami. Najprej najdemo ravnotežje med glavo, vratom in ostalimi deli hrbtenice, se nato usmerimo na umirjeno, ritmično dihanje ter nazadnje najdemo ravnotežje celemu telesu ob popuščanju negativnih napetosti v predelu nog. Posledica izvajanja te vaje je ne le uravnoteženost fizičnih struktur telesa, temveč tudi večja osredotočenost in umirjenost misli in duha, ob čemer se naučimo tudi umiriti neprijetne fiziološke in psihološke procese, ki spremljajo nastop.

Grindeajina tehnika – postopki drugega sklopa vaj (40, 41):

1. korak: Stojimo sproščeno, zelo mirno, z nogami rahlo narazen in z zaprtimi očmi. Mislimo na svojo hrbtenico in ji dovolimo, da se podaljša, da se začne gibati navzgor, proti nebu (ne premikamo se, to so samo t. i. mentalne direktive). Pustimo svojemu "računalniku" v možganih, da uredi, katere mišice vratu se bodo skrčile, katere se bodo sprostile in katere bodo ostale v ravnotežju. Glava se bo nežno pomaknila navzgor in bo postavljena na prvo vratno vretence (atlas), medtem ko bo vrat popolnoma sproščen. V tem trenutku so glava, vrat in hrbet popolnoma poravnani.

2. korak: Počasi in karseda dolgo izdihujemo zrak, medtem šepetamo "haaaaaaa". Pozorni smo na svoja ramena, ki so spuščena. Dih pošljemo v notranjost svojega telesa, proti trebušni preponi, ki jo obenem sproščamo. Po izdihu telo začuti potrebo po vdihu. Pustimo, da se to zgodi, in medtem smo pozorni, kako se širi naš hrbet.

3. korak: Svojo pozornost usmerimo na kolena in gležnje in jim omogočimo, da so mehki, prožni; občutimo jih kot milnico. Doživljamo nenavadno občutje, kot da bi lebdeli, telo postane lahko in je v popolnem ravnotežju.

5.1.2 Apliciranje Grindeajine tehnike

Grindeajina tehnika je zelo kratka in enostavna, vendar je učinkovita le ob vztrajni vadbi po njenih načelih. V začetku traja nekaj minut, kasneje, ob vztrajni vsakodnevni vadbi, pa lahko njene učinke dosežemo že v nekaj trenutkih. Njene pozitivne učinke lahko preskusijo tudi neglasbeniki. Pomaga namreč prepoznati negativne napetosti v telesu, ki se postopno nabirajo v nas takrat, ko smo v situacijah, ob katerih se neugodno počutimo. Vendar tudi ko zapustimo tako situacijo, se telo že navadi nove, nepravilne drže in si jo prisvoji; žal se v vsakdanjem življenju zelo malo zavedamo nepotrebnih napetosti v telesu, še manj pa se zavedamo njihovih negativnih posledic.

Ob učenju Grindeajine tehnike zavedanja telesa glasbeniki ne prepoznavajo zgolj napetosti, ki jih ovirajo; prav tako pomembno je prepoznati in usvojiti tiste gibe, ki najbolj ekonomično in učinkovito omogočajo igranje instrumenta. Ta tehnika je tudi idealno izhodišče za prepoznavanje optimalne orientacije telesa v prostoru, za izvajanje vaj, ki krepijo fizično kondicijo (napor glasbenikov večkrat primerjajo z naporom atletov!), prav tako pomembne komponente zdravja pri glasbenikih. Glasbeniki namreč ob izvajanju glasbe uporabljajo le določene gibe in tako obremenjujejo le določene dele telesa in določene mišice. Zato se morajo nujno zavedati, kateri gibi in mišice so zapostavljeni in jih morajo za naravno vzpostavitev ravnovesja celemu telesu in za preprečevanje bolečin v predelu obremenjenih mišično skeletnih struktur uporabljati in krepiti.

Slika 2. *Prizor s srečanja slovenske sekcije ISSTIP: utrjevanje mišic, ki jih pri igranju instrumenta zanemarjamo.*
Figure 2. *Meeting of the Slovene ISSTIP section: exercises to strengthen the muscles that performing musicians tend to neglect.*

6 Zaključek

Dejavno pozitiven odnos do telesa in telesnih aplikacij, prav tak odnos v razmerju do instrumenta in publike ter utrjevanje fizioloških in mentalnih občutkov, ki ta razmerja spremljajo, so se že večkrat izkazali za učinkovite. Ob doslednem zavedanju in ustrezni uporabi telesa, v skladu z njegovimi naravnimi značilnostmi, se glasbenik tudi v mejnih stanjih kmalu zave, da je kos izjemnim obremenitvam. Na tej podlagi se vzpostavi skladno poenotenje telesa z instrumentom, kar vpliva na kakovost glasbene izvedbe. Izpiljenost vseh pogojev nastopanja zelo vpliva tudi na publiko, ki ugodno verificira izvajalsko vzdušje, to pa nadalje samodejno odpravlja nezaželene stranske učinke (tremo, negativno napetost, vznemirjenost, ipd.). Ustrezna telesna in umska osredotočenost na trenutno dogajanje in končni cilj, ki je potreben za dovršeno glasbeno izvedbo, prinašajo zadovoljstvo glasbenikom in posledično tudi njihovi publiki.

O pozitivnem vplivu ob izvajanju tehnik zavedanja telesa poročajo vsi, ki jih vadijo, tudi za reševanje težav v drugačnih okoliščinah. Poudariti pa je potrebno, da ne glede na to, katero tehniko zavedanja telesa izberemo (Aleksandrova tehnika, Feldenkraisova metoda, Grindeajina tehnika, gimnastika, joga ipd.), je ob pravilnem in rednem izvajanju ravno tako učinkovita kot ostale tehnike. Najboljše pa je preudarno kombiniranje različnih tehnik.

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Za njihovo vestno in ažurno delo se jim uredništvo iskreno zahvaljuje!

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Prispelo gradivo daje uredništvo v strokovno recenzijo in jezikovno lekturo. Po končanem uredniškem delu vrnemo prispevek avtorju, da popravke odobri in upošteva. Popravljeni čistopis vrne v uredništvo. Med redakcijskim postopkom je zagotovljena tajnost vsebine prispevka. Avtor dobi v pogled tudi prve, t. i. krtačne odtise, vendar na tej stopnji upoštevamo samo še popravke tiskovnih napak. Krtačne odtise je treba vrniti v treh dneh, sicer menimo, da avtor nima pripomb.

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The title page should carry the Slovene and English title of the article, which should be short and concise, descriptive and not affirmative (statements are not allowed in the title). Names of authors with concise academic and professional degrees and full address of the department, institution or clinic where the work has been performed should be cited. Authors be should qualified for authorship. They should contribute to the conception and design resp. analysis and interpretation of data, they should intelectualy draft resp. revise the article critically and approve the final version of the contribution. The collecting of data solely does not justify the authorship.

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Examples for literature citation:

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2. Mahy BWJ. A dictionary of virology (2nd ed.). San Diego, Academic Press, 1997.

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3. Urlep F. Razvoj osnovnega zdravstva v Sloveniji zadnjih 130 let. In: Švab I, Rotar-Pavlič D, editors. Družinska medicina, Ljubljana, Združenje zdravnikov družinske medicine, 2002: 18-27.
4. Goldberg BW. Population-based health care. In: Taylor RB, editor. Family medicine. 5th ed. New York: Springer, 1999: 32-6.

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5. Barry HC, Hickner J, Ebell MH, Ettenhofer T. A randomized controlled trial of telephone management of suspected urinary tract infections in women. J Fam Pract 2001; 50: 589-94.

example for the article in journal with no author given:

6. Anon. Early drinking said to increase alcoholism risk. Globe 1998; 2: 8-10.

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7. Women's Concerns Study Group. Raising concerns about family history of breast cancer in primary care consultations: prospective, population based study. BMJ 2001; 322: 27-8.

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8. Shen HM, Zhang QF. Risk assessment of nickel carcinogenicity and occupational lung cancer. Environ Health Perspect 1994; 102 Suppl 2: 275-82.
9. Payne DK, Sullivan MD, Massie MJ. Women's psychological reactions to breast cancer. Semin Oncol 1996; 23 (1 Suppl 2): 89-97.

example for the article from collection of scientific papers:

10. Sugden K. et al. Suicides and non-suicidal deaths in Slovenia: Molecular genetic investigation. In: 9th European Symposium on Suicide and Suicidal Behaviour. Warwick : University of Oxford, 2002: 76.

example for master theses, doctor theses and Prešeren awards:

11. Bartol T. Vrednotenje biotehniških informacij o rastlinskih drogah v dostopnih virih v Sloveniji. Doktorska disertacija. Ljubljana, Biotehniška fakulteta, 1998.

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