Abstract
The metabolic reactions in human organism as well as the need for specific essential nutrients change with age. Water, as an essential nutrient, consists of numerous elements which are less or more desirable for human survival. In our study daily water intake for different age groups was assessed according to the Water Institute data and the average body weight from Family Practise Notebook website. The contribution of drinking water radioactivity to the total exposure is very small, at about 5% of all naturally radioactive sources, but it is very important quality factor due to its hazardous effects on human health. $^{226}\text{Ra}$ is naturally present in water and contributes significantly to the ingestion dose by water consumption. Radium is calcium homologue so its deposition occurs mostly in the period of intensive growth. In all samples, both tap and bottled waters (spring and table) the specific activity of $^{226}\text{Ra}$ was determined by alpha spectrometric measurement after radiochemical separation.

The research results range from 0.53 mBq/L to 50.04 mBq/L which does not exceed the $^{226}\text{Ra}$ maximum activity concentration recommended by the World Health Organisation. The annual effective doses for different male age groups were assessed and range from 0.11 µSv to 85.84 µSv. The most exposed male age groups are infants and children from the age of 13 to 17. Infants and young adolescents have very high amount of determined sexual hormones (testosterone) that might account for high body sensitivity of these age groups to the radioactive bone-seeking $^{226}\text{Ra}$.

Introduction
Today water consumption is one of the most popular topics connected to the health and the optimal body weight maintaining. Therefore water quality needs special attention and it should be restricted by water safety regulations [1]. Croatian natural resources include clean underground waters which nowadays become more popular as bottled waters. Quality of Croatian bottled water was proved on Aqua Expo 2003 (Paris) where Croatian natural mineral bottled water 'Jamnica' was awarded Eauscar as the best foreign natural mineral water [2]. Bottled and tap waters in Croatia are regulated by government regulations and recommendations of World Health Organization (WHO). According to the existing water regulations in the Republic of Croatia there are three types of bottled waters: mineral, spring and table waters [3]. Mineral and spring waters originate from underground water-beds protected from any kind of pollution. They come from one or more natural or drilled springs. Mineral water can contain minerals in concentration even above 1500 mg/L while the concentration of carbon-dioxide varies. In contrast to mineral water, spring water contains less than 250 mg/L of minerals. Water labelled as table water is water produced from drinking water with addition of one or more compounds (NaCl, CaCl$_2$, Na$_2$CO$_3$, MgCO$_3$, NaHCO$_3$, Na$_2$SO$_4$, NaF, CO$_2$) added for improvement of organoleptic property [3,4]. Contrary to many minerals which act positively on human organism radiotoxic effect of $^{226}\text{Ra}$ is well-known. $^{226}\text{Ra}$ is naturally present in mineral and spring waters. Following metabolism of Ca, $^{226}\text{Ra}$ could be deposited in bone where in critical concentration could cause bone cancer [5]. Since radioactive substances affect water quality the aim of this study was to estimate the effective dose from consumption of $^{226}\text{Ra}$ in tap and bottled waters (spring and table) produced in Croatia and to determine the possible difference in $^{226}\text{Ra}$ content. Special attention was given to the age of consumers in order to determine life periods when the organism is more susceptible to the presence of $^{226}\text{Ra}$ in water.

Material and methods
Samples of several randomly selected brands of bottled spring and table waters produced in Croatia available in supermarkets in Zagreb and samples of tap water from five Croatian towns (Zagreb, Osijek, Zadar, Rijeka and Split) were analysed.
The radiochemical analysis of $^{226}$Ra separation was carried out in all samples. $^{226}$Ra in precipitated Ba(Ra)SO$_4$ was determined by alpha-spectrometric measurement using Si detector during 80 000 seconds [6].

**Results and discussion**

In this paper the results of specific concentration of $^{226}$Ra (FIG.1.) were compared with maximal concentration of $^{226}$Ra recommended by WHO. According to WHO recommendations drinking water with $^{226}$Ra content below 1000 mBq/L is acceptable for life-long consumption [7]. The average $^{226}$Ra specific activity in bottled spring waters was 24.12±8.53 mBq/L, in bottled table waters 11.16±9.06 mBq/L and in tap waters 19.00±7.33 mBq/L. Since all samples showed $^{226}$Ra specific activity below 1000 mBq/L, these waters are acceptable for drinking.

![FIG.1. Specific activity of $^{226}$Ra in spring, table and tap waters](image)

There is evidence from both human and animal studies that radiation exposure at low to moderate doses may increase the long-term incidence of cancer. The reference level of dose from one year consumption of drinking water is 0.1 mSv and represents less than 5% of the average effective dose attributable annually to natural background radiation [7].

Dose from radioactivity in drinking water depends on intake and metabolic bodily reactions. Therefore, in this paper the effective dose was assessed for different male age groups. The effective dose was calculated as:

$$D_{^{226}Ra}(g) = C_{^{226}Ra}(i) \times WI(g) \times DCF_{^{226}Ra}(g)$$  \hspace{1cm} (1)

where

- $D_{^{226}Ra}(g)$: effective dose for g-year-old male individual from ingestion of $^{226}$Ra in sample $i$ [Sv/year];
- $C_{^{226}Ra}(i)$: $^{226}$Ra specific activity in sample $i$ [Bq/L];
- $WI(g)$: water intake [L/year];
- $DCF_{^{226}Ra}(g)$: dose conversion factor for $^{226}$Ra and g-year-old individual [Sv/Bq];
The results were obtained by dose conversion factor for individual age groups [8] and by water intake data calculated on Water Institute data [9] and the average body weight from Family Practise Notebook website [10].

The values of annual effective doses range between 0.11 and 85.84 mSv. Mean values of annual 226Ra effective doses from consumption of spring and table bottled waters and tap waters are presented in FIG.2. Considerable low values of effective doses are related to the consumption of table water which is to be expected due to the fact that table water is drinking water (purified) with artificially regulated composition. The most exposure groups to 226Ra in drinking water are infants and boys between 13 and 17. These are life periods of intensive production of sexual hormone, testosterone, which helps Ca deposition into the bone [11, 12]. For that reason, rapid growth accompanied with impact of testosterone could intensify 226Ra deposition into the bone instead of Ca.

**Conclusion**

Although there is an increasing tendency of bottled water consumption, tap water is still main source of drinking water in Croatia. 226Ra specific activity in samples of bottled (spring and table) and tap waters showed acceptable values in range from 0.53 to 50.04 mBq/L. The effective doses from ingestion of 226Ra in drinking water are age-dependent and they are considerable high in infants and children between 13 and 17. These are life periods of intensive production of testosterone accompanied with rapid growth that could amplify deposition of 226Ra (as Ca homologue) into the bone.

Water consumption and water quality are necessary for health maintaining. Since exposure to low doses may increase the long-term incident of cancer, constant monitoring of 226Ra presence in drinking water is required.
Literature: