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Software Tool for Work and Occupational Radon Health Risk Modeling

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Abstract

The occupational and work health effects of exposure to radon have been exhamined for many years. Recent advances have been made in evaluating the risk associated with radon exposure and in implementing remediation programs in dwellings. This research presents the development of a user friendly web based software package based upon current information on radon epidemiology, radon dosimetry, exhalation rates, long term measurements, demography, and countermeasure efficiency. The software has been designed to perform lung cancer risk calculations specific to populations for various exposure profiles and to evaluate, in terms of risk reduction, the efficiency of various countermeasures in dwellings. This paper presents an overview of the general structure of the software and outlines its most important modeling approaches. Radon mapping and modeling application is a web based application developed for purpose of occupational and residential health risk modeling. Its developed as web application to be available to students and scientist in Serbia. Also it have mission to collect data in unique data base. This data base will be a great resource in future research of radon. From software engineering point of view it's based on PHP – Mysql platform for managing data in data base and Ajax for user interface.

Keywords: *software, radon, health risk, modelling, building materials*

1. INTRODUCTION

Radon (^{222}Rn) and its progeny are present in all dwellings, because radium is present in building materials as well as in the soil. It is important to understand the generation and migration process of radon from building materials, which contributes to 55% of total radiation dose received by the population from the environment (UNSCEAR, 2000) [1]. A research dealing with the radiation exposure produced by radon decay products in homes has shown that the cause of increased radiation may as well be the construction material of the building [2]. When estimating an average annual radiation exposure one should also take into account life at home, because the level of radiation can be higher within homes than without, bearing in mind that walls themselves can contain and emit radionuclides. Depending on the type of the construction material and ventilation efficiency [2, 3, 4], radiation indoors can be many times higher than outdoors, and as such could represent a serious health hazard. The average annual dose in Europe from radon and its progeny in homes and workplaces is estimated to be 1,6 mSv. Radon gas is formed inside building materials by decay of the parent nuclide ^{226}Ra. However, it is not possible to determine the radon exhalation rate simply from the activity concentration of ^{226}Ra. Instead one must measure radon exhalation rates directly from the surface of the material, or measure activity concentration of radon inside premises by long term or short term measurements as shown by many studies in the literature. [3, 4].

When radon activity concentrations are calculated from exhalation rates or measured it is possible to estimate effective dose and risk of lung cancer from radon.

Based on these requirements relational database and Web technology were selected provided by its access and update. In this way, the data that is mutually correlated is optimally connected, and access and update could be provided from different locations and with more clients simultaneously. For the realization MySql database and web programming language PHP and JavaScript were used.

2. METHOD OF CALCULATION

2.1 **Radon activity concentration**

Data stored in the database are subject of further analysis and processing.

Different tasks can be applied, such as the following general tasks from the domain of low-level user activities:

- value retrieval – finding of specific attribute values for data cases (e.g. find measurements for specific date and location),
- filtering – finding data cases which satisfy the given conditions in relation to their attributes (e.g. find locations that have radon activity concentrations higher than 200 Bqm^{-3}),
- compute derived value – finding the appropriate aggregate numerical value for data cases (e.g. find the average radon activity concentration for the given location in the given time),
- find extreme values – finding data cases with extreme attribute values (e.g. find the location with highest average radon activity concentration),
- determine range – finding the range of attribute values of interest for data cases (e.g. find the span of two radon activity concentrations for a given area),
- characterize distribution – finding the distribution of the quantitative attribute of interest for data cases (e.g. find the distribution of radon activity concentrations for a given time),
- find anomalies – identification of any anomalies with respect to a given relation or expectation, i.e. statistical outliers (e.g. sudden concentration changes),
- clustering – finding clusters of similar attribute values for data cases (e.g. divide the area into two groups according to their levels of radon activity concentration),
- correlation – finding useful relations between values of two given attributes for data cases (e.g. find the correlation between sudden increase of radon activity and earthquakes).

As can be seen, the suggested starting framework for the data analysis offers a very broad spectrum of useful applications which should certainly contribute to the environmental radon monitoring.

Advanced techniques of data analysis can be relatively easily embedded into the existing general framework of the software, if there is a specific demand.

Various techniques from the domain of artificial intelligence aimed at expert systems are available, such as pattern recognition, neural networks, fuzzy logic application, etc. [6-8]].

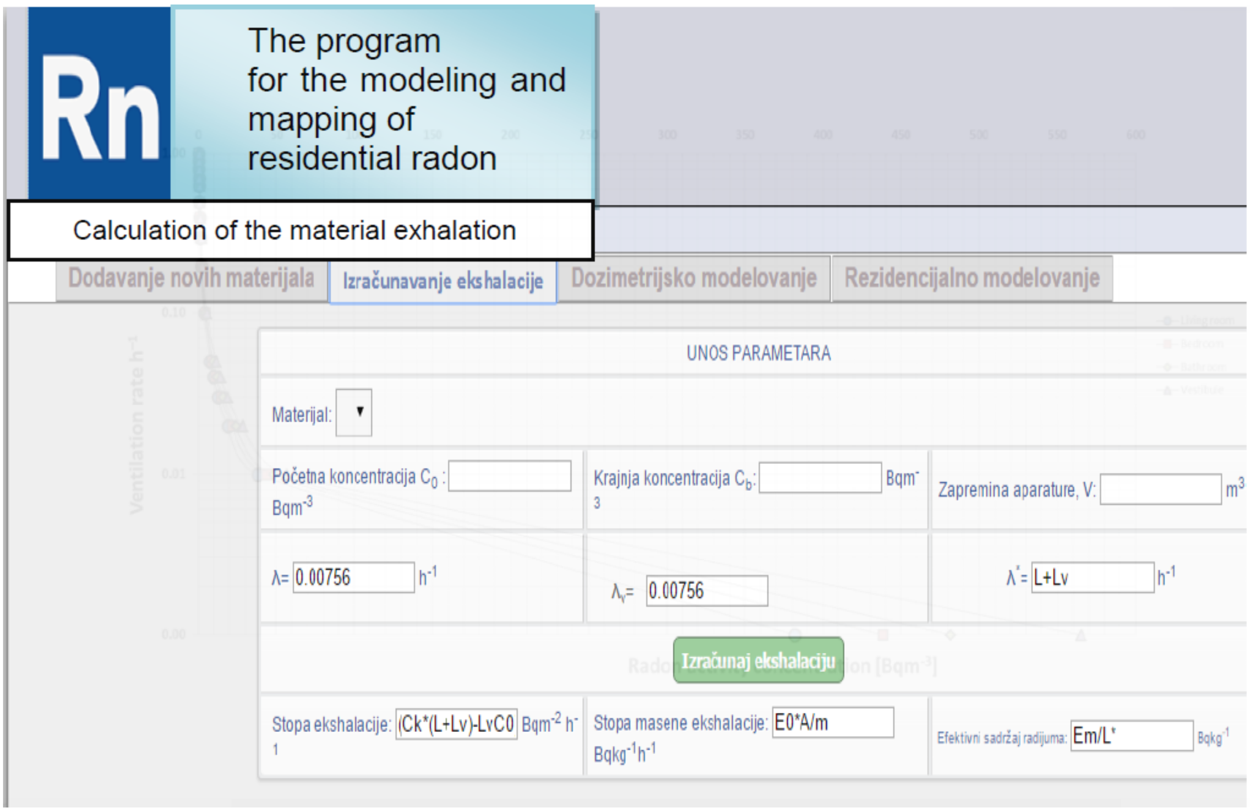

Figure 1. Appearance of the panel for exhalation rate calculation

Figure 1 shows panel for exhalation rate calculations where the radon exhalation rate E_0 is defined as the liberation quantity of radon activity from the surface area of building materials per unit time (Bq m^{-2} h^{-1}). Using this value and the area of the indoor surface, radon emanated per unit time could easily be calculated and used to estimate the radon concentration in the indoor environment.

2.2 **Dosimetric model**

The dosimetric model selected for the software is a radon specific model on the basis of the model used to describe and validate the human respiratory tract model recommended in 1994 by the International Commission on Radiological Protection (ICRP) in its publication 66 (1). This model relies on various parameters specific to the exposed individual (age, sex, activity level, nose or mouth breathing) together with parameters describing the radon progeny aerosol. It also takes into account the radiation weighting factor for alpha particles and factors describing the relative radio sensitivity of the three lung compartments.
Mathematically, the ERR (excess relative risk) in models can be represented as:

$$ERR = \beta(W_{5-14} + \theta_{15-24}W_{15-24} + \theta_{25+}W_{25+})\Phi_{age}Y_z \quad (1)$$

where: β is the exposure-response parameter (risk coefficient); the exposure windows, W_{5-14}, W_{15-24} and W_{25+} ,define the exposures incurred 5-14 y, 15-24 y and >25 y before the current age; and Θ15-24 and Θ25+ represent the relative contributions to risk from exposures 15-24 y and ≥25 y before the attained age. The parameters Φ_{age} and (z define effect-modification factors representing, respectively, multiple categories of attained age (Φ_{age}) and of either exposure rate or exposure duration (Y_z). The values for these parameters are summarized in EPA Assesment of Risk From Radon in Home.

Annual effective dose is being calculated as:

$$\dot{H}i = C_i F_i O \times DCF \quad (2)$$

Where: $\dot{H}i$ - annual effective dose, C_i- radon activity concentration, F_i- radon equilibrium factor, O-occupancy factor, DCF-dose conversion factor for radon.

2.3 **Software architecture**

From software engineering point of view it's based on PHP – Mysql platform for managing data in data base and Ajax for user interface. All of this are open source software and platforms. The benefits of using an open-source technology are numerous. Paramount among the advantages is reliability. Open-source coding has been checked and doubled checked by thousands or even millions of people around the world. And also allow to another students and scientist to contribute in this project of Radon modeling. On this way is possible for contributors to make or do some modification on project. Also the data base have a hi level of security. All the calculation are managed to be calculate on user machine not on web server. The usage of Java script and Ajax improve user friendly interface.

2.4 **Radon exposure model**

The collective exposure of the occupants of a dwelling is determined by an exposure model that uses information on the age and sex of the occupants and also the number and type of rooms (kitchen, living room, and bedroom) in the dwelling. The room type is used to determine the equilibrium factor and the aerosol characteristics. Additionally, for each room, the average concentration of radon-gas is required (this is adjusted using an ad-hoc factor in case of a measurement of a below one-year duration), and the rooms occupancy (also the time spent in each activity level in case of the use of the dosimetric approach). Figure 2. shows application for dosimetric modeling. In order to calculate annual effective dose certain residential or working s scenario must be made and it is explained in this paper.

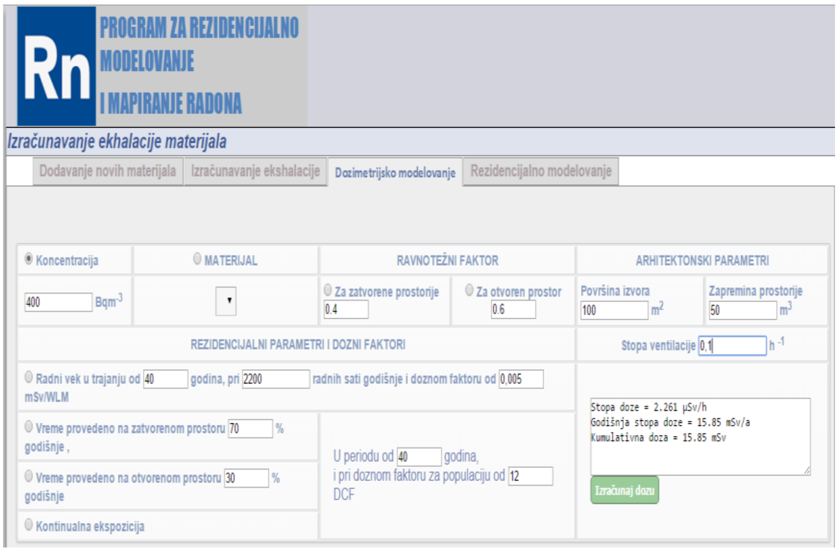

Figure 2. Application for dosimetric modeling

This paper presents a simplified model of a home with basis of 48 m^2, whose walls are built of siporex blocks 0.25 m thick and 0.6 g/ cm^3 dense while floors and ceilings are made of a 2.3 g/ cm^3 dense concrete.

The assumption is that the home consists of four rooms: bedroom, livingroom, vestibule, and bathroom and the height of the apartment is 2.2 m. In the center of each room there is a recipient (tenant) who spends some required time in it. Table 1 shows exact room dimensions as well as total walls surface and volumes of rooms. Table 1 also shows architecture parameters necesery for the calculations while Figure 3 shows floor plans of the apartment model with dimensions of residential premisses in spaces.

Table 1. Dimensions of the rooms

Room type	Room dimensions [m]	Total windows and doors surface [m^2]	Total walls surface made of siporex [m^2]	Total floor and ceilings surface made of concrete [m^2]	Room volume [m^3]
Living room	4x5	4.39	35.21	40	44
Bedroom	4x3	4.92	25.88	24	26.4
Vestibule	2x5	5.54	25.26	20	22
Bathroom	2x3	2.37	19.63	12	13.2

Contribution to total radon activity concentration of floors and ceilings made out from concrete for each room are taken into the consideration and they are calculated in the same manner and added to final radon concentration activity assasment, which is visable through all tables and figures, selected from the research and presented here.

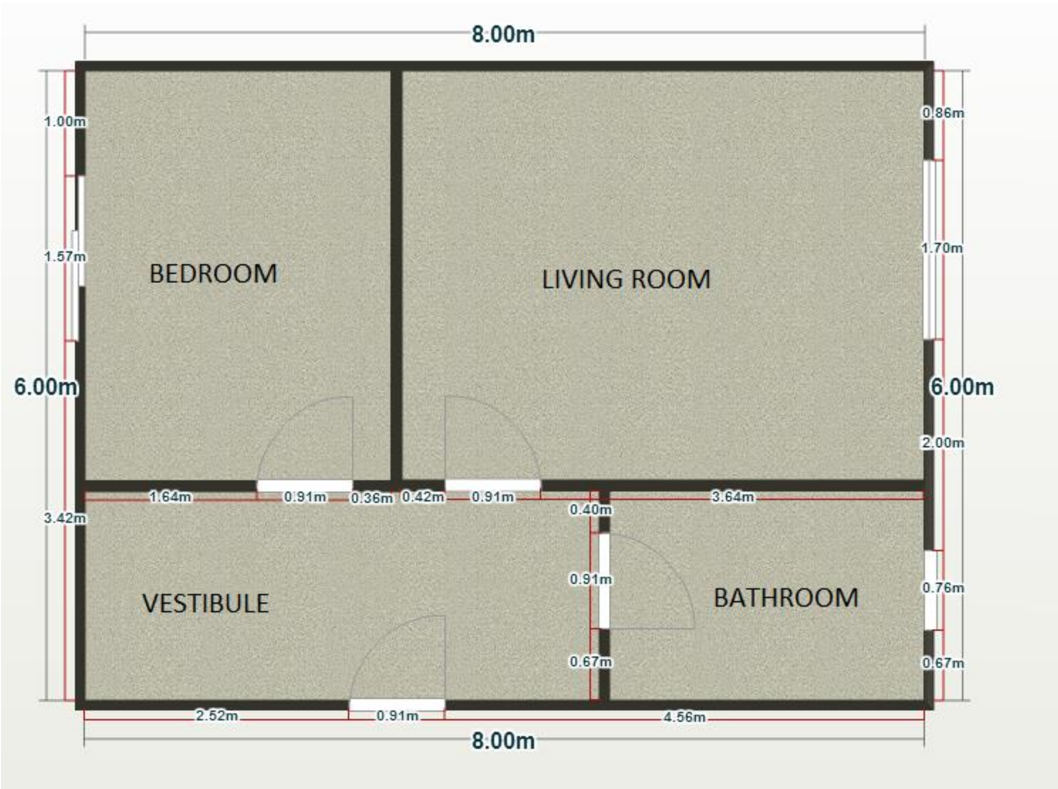

Figure 3. Floor plans with dimensions of residential premisses

Radon activity concentration can be either calculated through exhalation rate or entered as value into related textbox.

2.5 Ventilation rate

Radon mitigation is any process used to reduce radon gas concentrations in the breathing zones of occupied buildings or radon from water supplies.

If modelling shows that average annual doses are higher than recommended one could easily calculate ventilation rate needed for acceptable health risk. Software uses following equation to calculate impact of ventilation rate on annual radon dose.

$$\lambda_v = \frac{E_a AFO \times DCF}{\dot{H} i V} \tag{3}$$

Where: λ_v- ventilation rate, E_a–exhalation rate of radon, A-total surface of the radiation source, F-equilibrium factor for radon,O- occupancy factor, DCF-dose conversion factor, $\dot{H}i$ – annual effective dose, V-volume of the premisses.

3. THE RESULTS

All the data (input data and results) may be viewed and edited as tables via the built-in spreadsheet system. Data may also be presented graphically, using a builtin system (see Figure 4).
Data may be exported in standard tabular or graphical formats. Multidimensional data may be presented under any user-defined order of dimensions.Figure 4. shows ventilation in the function of radon activity concentration in above mentioned scenario.

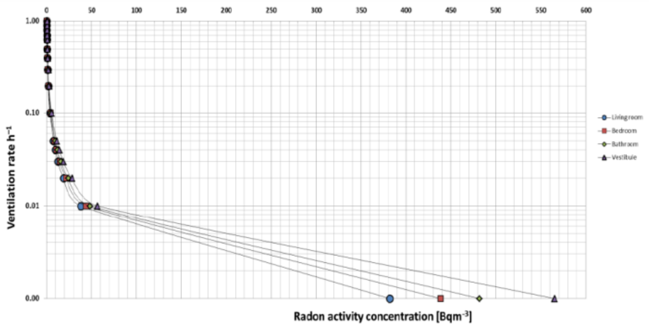

Fig 4. Dependence of radon activity concentration on ventilation rate

For each room the results are obtained by changing air ventilation mode, wherein for each changing of ventilation mode three different times spent by tenants in specific room were also varied (Table 2).

Table 2. Time (in hours) that tenants spend in a particular apartment room within 24 hours

Rooms			
Living room	Vestibule	Bedroom	Bathroom
2	0.5	8	1
7	1	10	2
10	2	12	3

The annual radiation dose is calculated for the two residence times in rooms (2 h and 10 h) and for the maximum ventilation or no ventilation mode (Table 3). By comparing the values of equivalent doses, we can conclude that at maximum ventilation and 2 hours residence time the tenant residing in the vestibule receives the lowest dose of radiation (0.04 mSvy^{-1}), while the tenant who spends the same time in the bathroom will receive the highest dose (0.001 mSvy^{-1}). In the absence of ventilation, the highest dose will also receive a tenant who is in the bathroom, a slight lower dose tenant who is in the hallway, then the tenants residing in the living room.
From the results for 10 hours residence time we can see that the annual radiation doses in the living room and bedroom are very similar for both modes of ventilation.

Table 3. Annual radiation dose (in mSvy^{-1}) for tenants which spends 2 hours or 10 hours in different rooms

Room		Living room	Vestibule	Bedroom	Bathroom
Time 2h	Mode 1	0.55	0.99	/	1.78
	Mode 9	0.0005	0.0009	/	0.001
Time 10h	Mode 0	2.78	/	3.34	/
	Mode 9	0.0027	/	0.0033	/

Four scenarios for different types of tenants, assuming that each of them spends an appropriate period of time in every room of the apartment and a part of the day outside of home are presented in Table 4. On this basis, the maximum and minimum annual doses received by the tenants are calculated that correspond to the maximum and minimum air exchange rates.

Table 4. Potential scenario or different tenants in apartment

Tenant		Old person	Student	Housewife	Employed person
Living room		10h	2h	10h	2h
Vestibule		1h	1h	2h	1h
Bathroom		1h	2h	3h	2h
Bedroom		8h	9h	1h	11h
Period outside		4h	10h	8h	8h
Dose mSvy-1	Min	0.07	0.06	0.06	0.06
	Max	6.68	7.85	7.01	6.18

Table 4 shows that the highest dose will be received by who spends student 14 hours in the apartment, followed by a housewife who spends only 8 hours outside the apartment. The lowest annual equivalent dose in both modes of ventilation will receive an employed person, in agreement with the biggest number of hours spent outside home. The results of various calculations may be compared in a single tabular or graphical output in order to facilitate the identification of the most cost-effective countermeasure as well as the analysis of the impact on the results of the simultaneous variation of one or several input parameters.

4. CONCLUSION

Software tool for radon mapping and dosimetric modeling for the evaluation of risks associated with radon exposure in dwellings, is user friendly and was developed on the basis of the most recent data on radon epidemiology, radon dosimetry, demography, and countermeasure efficiency. This software could play a role in general training, the provision of information to the public and in investigating the effect on risk of different dose reduction strategies. Finally, its sensitivity analysis capabilities and its database system together with its user friendly configuration capabilities should make it an easy to use tool for the risk evaluation experts of various countries to perform useful calculations, appropriate to their situations with regard to local radon problems.

However, decisions about whether to implement countermeasures to reduce radon exposures may benefit from an enhanced capability to evaluate and understand the associated health risk.

5. REFERENCES

[1] United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2000 Report to the General Assembly, VOL I,UNSCEAR secretariat Vienna International Centre

[2] Mladen Nikolić, Milena Nikolić, Anastasija Matić, A Resrad Build Programme Based Assessment of Radiation Exposure as a Serious Health Hazard in Homes Built of Siporex Blocks, International Conference of Biomedicine and Geosciences, June 2014, Belgrade, Serbia

[3] Svetlana Stevovic, Dragana Vasilski, Smart materials in architecture as a function of sustainable development, Proceeding of the Conference ”Contemporary theory and practice in building development”, Publisher: Institute for Construction Banja Luka, pp 87-97, B. Luka, 2013.

[4] Hranislav Milošević, Dragana Vasilski, Svetlana Stević, Full Length Research Paper: Sustainable technology for existing buildings renovation in the function of energy efficiency, Techniques Technologies Education Management Journal, vol 8 no 1,

[5] Cavallo, A., Gadsby, K., Reddy, T.A. (1996) Comparison of natural and forced ventilation for radon mitigation in houses. Environment International,Volume 22, Supplement 1, 1996, Pages 1073–1078,The Natural Radiation Environment VI

[6] Mladen Nikolic, Predrag Sibinovic, Nemanja Ilic, Information System in The Function of a Quality System Development Illustrated in the Example of a Serbian Academy of Applied Studies, International Conference on Quallity Assurance for Successful Business and Competitiveness, December 2014, Kopaonik, Serbia

[7] Svetlana Stević, Predrag Popović, Fuzzy methodological approach to technical and environmental quality management, 6th International Working Conference ‘Total quality management advanced and intellegent approaches’, 1st – 4th June, 2009, BelgradeKarpovich, S.E., Mejinschi, S. and Zharsky, V.V. (2004), "Precision motion systems" Reports BSUIR, Vol. 3, No. 7, pp. 50-61.

[8] Danijela Tadić, Svetlana Stević, Dragan Milanović, Improvement of Quality Tools and Methods by Applying Fuzzy Sets Theory, 6th International Working Conference ‘Total quality management advanced and intellegent approaches’, 1st – 4th June, 2009, Belgrade

[9] N.P Petropoulos, , M.J Anagnostakis, S.E Simopoulos, Building materials radon exhalation rate: ERRICCA intercomparison exercise results, Science of The Total Environment, Volume 272, Issues 1–3, 14 May 2001, Pages 109–118

[10] Samuelson C. The closed-can exhalation method for measuring radon. Journal of Research of the National Institute of Standards and Technology, 95, 167-169, 1990.

[11] Chao,C.Y.H., et al., Determination of Radon Emanation and Back Difussion Characteristics of Building Material in Small Chamber Tests, Building Environment, 32, (1997),4, pp. 355-352

[12] G Keller, B Hoffmann, T Feigenspan, Radon permeability and radon exhalation of building materials, Science of The Total Environment, Volume 272, Issues 1–3, 14 May 2001, Pages 85–89

Softverski alat za modeliranje rizika po rad i zdravlje na radu u sredini izloženoj Radonu

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Apstrakt

Efekti po zdravlje i bezbednost u uslovima izloženosti radonu izučavaju se već dugi niz godina. Nedavni napredak je načinjen u proceni rizika koji se odnosi na izlaganje radonu i u sprovođenju programa sanacije u domaćinstvima. Ovo istraživanje predstavlja razvoj korisničkog softverskog paketa baziranog na trenutnim informacijama o radonskoj epidemiologiji, radonskoj dozimetriji, brzini izdisavanja, dugotrajnim merenjima, demografiji i efikasnosti protivmera. Softver je dizajniran da izvodi izračunavanje rizika od karcinoma pluća specifičnih za populacije i različite profile izloženosti, i da u cilju smanjenja rizika proceni efikasnost različitih kontramera u domaćinstvima. Ovaj rad predstavlja pregled opštih struktura softvera i opisuje njegove najvažnije pristupe modeliranju. Radonova aplikacija za mapiranje i modeliranje je veb aplikacija razvijena u svrhu modeliranja rizika za radno i stambeno zdravlje. Mrežna aplikacija je dostupna studentima i naučnicima u Srbiji. Takođe, jedan od ciljeva je i prikupljanje podataka u jedinstvenu bazu podataka koja će postati odličan izvor podataka za buduća istraživanja radona. Sa aspekta softverskog inženjeringa zasnovana je na PHP - MySQL platformi za upravljanje podacima u bazi podataka i Ajax-a kao korisničkog interfejsa.

Ključne reči: *Softver, radon, zdravstveni rizik, modeliranje, građevinski materijali*