POSSIBILITIES OF RADON REMOVAL FROM WATER ORIGINATED FROM SMALL WATER SOURCES

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Abstract

Radon, natural gas, is present in all parts of environment – in lithosphere, atmosphere as well as hydrosphere. Radon is even present in our living and working places and it causes on average the highest radiation of the population. The Czech Republic belongs according to National Radiation Protection Institute [16] to the top countries with the highest average radon concentration in the world.

The radon research focused on human health risk is divided to these areas: radon from rocks, radon from building materials and radon from water. All these areas refer to radon in buildings. This article deals with possibilities of radon water removal. It is focused on small water sources. Radon dissolved in water comes with water into buildings and then volatilizes into the indoor air (when showering 50%, when boiling and washing up to 100%) and decays the progeny there. The progeny inhalation causes human radiation. [16] The health risk is greater when the water is used in households where the radon volatilizes in one's breath zone. Radon is radioactive gas, so the most common disease is lung cancer. Drinking of the water is less significant in the case of radiation.

The rules for small water sources are less strict than for the large water sources in the Czech law. That is why the radon risk is underestimated or even ignored in context with small water sources. Project No. 2A-1TP1/044 „Radon removal from water originated from small water sources" is focused on the radon in small water sources. This project is granted by Ministry of Industry and Trade of the Czech Republic.

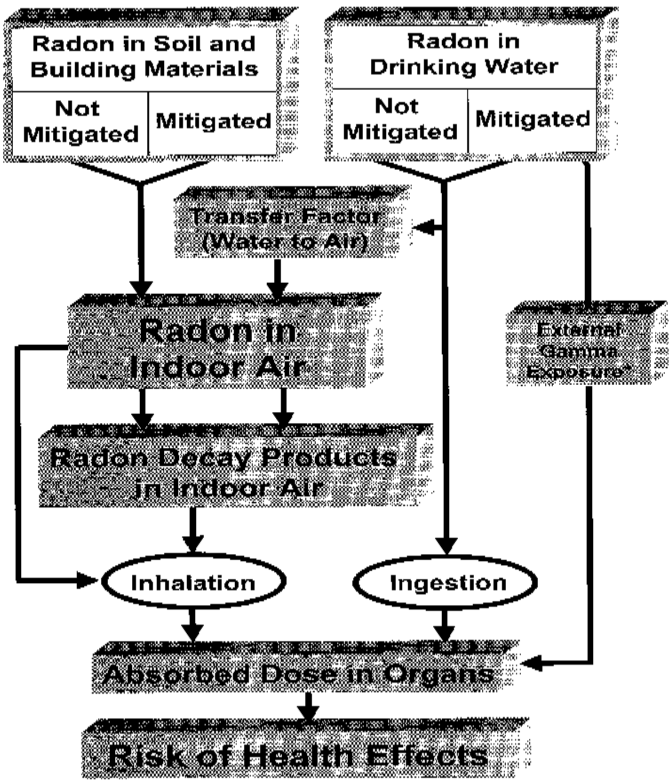
Key words

radon, removal, small water sources

Radon and the environment

Most people do not suspect that the greatest exposure to the population is caused by natural sources. Human bodies have been always exposed to natural radiation, and to a certain extent, this exposure has been unavoidable. [16] The main part of human radiation is caused by breathing radon and its progeny. Radon causes more than a half of the total human radiation. [18] Radon from indoor air has significant participation in the total radiation dose absorbed.

The health risk posed by indoor radon can be divided into two groups – ingestion and inhalation, see picture No.1. The main risk is lung cancer caused by inhalation, then stomach cancer arisen from ingestion of radon water with relatively high concentration. The source of the health risk is that the radon half-life is 3.8 days when it is transformed to other members of sequence of radioactive decay commonly known as short-term radon decay products (progeny). Radon itself is not risk to human body at all, because its large amount inhaled into lung is exhaled immediately. But the radon decay products (^{218}Po, ^{214}Pb, ^{214}Bi) are hazardous – they connect to small dust particles present in the air and create radioactive aerosol. [9], [15] They have short half-life (in minutes and less). They are, in contrast to gas radon, metals. Radon decay products pass through the respiratory airways, stay in the lung, where they decay spontaneously. So, the radon is one of the risk factors for lung cancer [17].



Picture 1. *Sources of radon and related radiation exposure pathways [15]*

Radon ^{222}Rn is a radioactive decay of the radioactive modification of uranium ^{238}U. The uranium concentration in the rock varies very much for individual rock types. The highest uranium concentration is usually in eruptive magmatic rocks like granite, syenite, granodiorit. Czech Republic's geologic background is composed from metamorphosis magmatic rocks in more than two thirds (2/3). That means radon released from geologic background should be monitored with high priority [6].

Radon released from rocks diffuses into the soil pores or may transfer to underground water. Transformation of natural radionuclide contained in rocks to water is quite difficult process, influenced by geochemical, physical and hydrological factors. Higher radon concentrations in water are in underground water because radon in the surface water releases to the air [14], [15].

Evaluation of current state in the matter of radon in water
LEGISLATION IN THE CZECH REPUBLIC

Radon in water and its health risk to citizens is known. There exist restrictions on radon concentration in water that are applied in large water tank stations or packing water factories. Small water sources stay outside the interest.

Atomic act [21] and public notice No. 307/2002 Sb. [20] place a duty on public water companies to measure radon concentration in water systematically and evaluate the results at least once a year. Public notice No. 307/2002 Sb. also contains recommended values for the radon concentration for public water tank stations and packing water factories in order to apply specific remedy.

WATER SUPPLIER DUTIES

Atomic act and public notice No. 307/2002 Sb. place a duty for public water suppliers to measure and evaluate radon concentration in water once a year. When the volume activity exceeds 300 Bq/l (limit value), the water cannot be used, thus the radon must be removed from the water or the supplier must find a different water source. If the radon volume activity is above 50 Bq/l (recommended value), the suppliers should evaluate total efficiency of radon removal (related to the costs and advantages of such procedure) [16].

INDIVIDUAL WELL WATER SOURCES

There are no rules or regulations for individual water sources. Also there are no total activity levels and one does not have to measure radon volume activity in such water source. Anyway, the recommended and emergency values are defined as well as remedies for them. If the radon volume activity is below 200 Bq/l, no remedy is needed. For the values ranging from 200 to 1000 Bq/l one shall ventilate the rooms with high water consumption (like bathrooms). If the radon volume activity exceeds 1000 Bq/l, the radon shall be removed from water or the water source needs to be replaced. Although the measurement of radon volume activity is not obligatory for private water sources, it is recommended citizens living in the places with high concentration of radon in geological background to measure radon periodically. In these places the probability of radioactivity presence in water is high; in some places we can find water having radon volume activity values in thousands Bq/l. [16] Tentative standard ČSN 75 5115 imposes the technical inspection of the wells once a year but it is hard to enforce this regulation. If the well is used for personal use only, there is no regulation for it.

Solution for small water sources

Missing regulations and the ability of reducing health risk of radon for people living in contained areas are the main focus of research. The project No. 2A-1TP1/044 “Radon removal from small water sources”, which is held from 2006 to 2009 and supported by Ministry of Industry and Trade of the Czech Republic focuses on these two topics. The goal of the project is to develop equipment that would be able to remove radon from small water sources. We are using new innovative techniques and research a solution that would be cost-inexpensive.

The Equipment development is divided into several parts. First part of the project is the research of today publications and today methods for removal of radon from water. One goal of this part is to test suitable methods; the second goal is the preparation of the fact sheet with today's radon removal equipments and technologies.

The literature research was taken on printed as well as electronic documents. From hundreds of materials found we chose 150 to analyze further. Patents belong to important sources of information. Some of the useful information was found on internet pages of companies focused on radon removal. The results of the research are written below.

WAYS OF RADON REMOVAL FROM WATER

The goal of this research is the analysis of principles that may be used for radon water removal and identification of strong and weak properties of these principles. This together contains the basement for next applied research.

The possibilities of radon removal from water are related to radon's chemical and physical properties. Radon belongs to noble gases, it is inert member. Chemical properties of radon are unfortunately bad for separation techniques because radon's valence sphere is filled completely and so it belongs to noble gases with very little reactivity. Radon is present in atomic form in nature only, thus methods using chemical processes would not work. We must use physical principles to remove radon from water. To do so, we must move radon from water to other phase (air or other gas), or we can catch the radon on the sorbents surface or consume the radon with a liquid that is not soluble with water.

Many techniques for radon separation from water already exist. Each of them has some advantages and restrictions for the concentration of separated radon, requested level of decontamination, water constitution etc. When thinking about transport of radon from water to other phase, the first idea is to move radon to the air. Radon's atom is non-polar perfect symmetric element with little polarization. Radon's affinity to non-polar materials is higher than to polar water. An example of non-polar material is gas. Some of the organic liquids and rigid materials are non-polar too; non-polarity of the surfaces is important too. In all cases one must take into account the diffusion process so the effectiveness of the method is not given by the equilibrium only, but also by the transport speed of radon inside the polluted water and the speed of transport.

The principle of radon transfer from water to air is used by one of the most common methods of radon removal called aeration. Aeration exploits multiple extension of phase interface. Many books refer to this technique as very effective, effectiveness may be around 99%. [15] See below the technical description of these methods. Another perspective method is the usage of membranes. These techniques were researched further [2], [12]. There is a possibility of membrane utilization in the project.

Talking about methods based on radon absorption in a liquid, they work on the following principle: if two liquids are insoluble and both contain radon, the equilibrium of radon concentration is established as in the case of water – air scenario. So the radon transfers from the liquid with higher chemical potential to water with lower chemical potential. Radon absorption in non-polar liquid can be used to separate radon with liquid – liquid scenario. We must take care about specific criteria such as: the liquid must be insoluble with water so much that it neither contaminate the water for home activites nor change water neuroleptic properties (taste and smell), it must be healthy, the dissolve of the liquid in the water must be high enough, etc. In the real world this scenario is not used by big water tank suppliers so often but there exist liquids that meet these requirements [1].

Another way of radon removal from water is the usage of sorption on the surface of rigid material (adsorption). The principle of this method is the usage of large surface of sorbent. Porous materials can have its inner surface so big that the outer surface can be insignificant. [4] Sorbents may be natural or synthetic. Important role of the adsorption process is granulometry. Sorbents shall have essential properties too: high sorption value, availability, easy warehousing, stability in water environment etc.

There are only few results published of the water – solid scenario [8], [13]. Most of the literature focused on adsorption talk about activated carbon. Activated carbon is natural material made from black coal or shell of coconuts activated by steam. Activated carbon is hydrophobic and oil-phile material. Granulometry is important in the process. One can divide coal into categories such as powdered coal, granuled coal and solid blocks of coal. [7], [10] The most common is granulated activated carbon form.

CURRENT TECHNOLOGIES FOR RADON WATER REMOVAL

The main information source of today's technologies is placed on internet pages of companies that either use the devices on radon removal or develop them. This part of literature research is the base for the technical background of the project.

As written above, one of the best methods for radon removal from water is aeration. Aeration was designed as the best available technology (BAT) since 1991. In this year Environmental Protection Agency U.S. established first regulation limits of radon in drinking water for USA. Thanks to widespread usage of this method we know its advantages as well as disadvantages. A big advantage of the method is its compatibility with the water treatment system. Another advantage is low maintenance. Aerator devices are usable either for big water equipments or for home aeration devices that are used for cleaning of small water sources. Disadvantages of the aeration are for example sedimentation of water minerals like hydroxides, magnesium or calcium; microbial contamination of water, corrosion, chemical pollution of technology, price. Costs related to obtain and run such devices are in hundreds thousands Czech crowns, so they are used rarely for small water sources. [15] During the background research we have found devices suitable for small water sources on the market but the purchase costs are very high for potential customers, they oscillate about 50 thousand Czech crowns. Aeration does not solve one question – what to do with the radon in air. Usually the contaminated air is mixed with free air. Thus one have to assure that the contaminated air is released in such way that it cannot be breathed by a person in any circumstances (climatic, building etc.). That means to avoid increase of human health risk.

We can use one of the following ways to achieve the large area of the interface for radon removal. The next text is focused on the techniques used for different exercises during the project:

1. free water surface contact with air – process is known as a natural action because surface water have smaller radon concentration than groundwater. The main disadvantage is slow diffusion, this method is not acceptable for project aim,
2. bubble aeration – the most common method, especially to deal with large flows of water with high radon concentration [3], [5]; instruments and energetic demands, problem with ventilation of radon-contaminated air, in project possible with another solution,
3. spray aeration – water is formed into droplets, released radon is ventilated out with the air stream; instruments and energetic demands, problem with ventilation of radon-contaminated air, microbial risk, in project possible with another solution,
4. cascade aeration – simple technology with series of slats, need of hydraulic head to operate; large space requirement – non acceptable for project.
5. Jet aeration [5] – radon is removed due to pressure changes after the water is sprayed; it can be possible for small water source as a supplement of the technology, it is necessary to verify a microbial contamination of the water.

The second frequent method for radon removal is activated carbon technology. There are many references in the literature about activated carbon, for example [5], [7], [10], [13]. The carbon filters can be installed on the way between the water source and home, or near by the tap. The main advantage of this method is its efficiency up to 95%. This method is the second best radon removal methodology after aeration. It would be an alternative of the aeration, but this method is not the best available technology for radon removal [7], [15]. It takes the water contamination on the coal one - radiation buildup, waste disposal, contact time. Another disadvantage is the reduction of efficiency in time. It is caused by the water canals in the total coal volume and the reducement of the active coal surface due to adsorption of all contaminants in water and manganese and ferrum coagulation. The coal bed has to be changed.

For the utilization of this method as a basic radon removal principle it is necessary to consult the real risk of forming radioactive waste depending on radon water concentration and the coal quantity demand. The actual price information is necessary to specify the utilization of this method.

Other possibilities are the methods that are not used so often in practice. Information about these techniques is accessible in literature as a result of experiments from many world´s laboratories. They include radon sorption in liquids, radon adsorption on solid materials (not activated carbon) or membranes utilization. The possibilities of usage of these methods for project aim will be consulted after the experimental research.

APPLIED RESEARCH

The experimental research is running these days. For the experiments it is necessary to provide radon water source. So first we had to explore areas with radon water. The Krouna village with one water source was chosen. Krouna village lies 30 km SE from Chrudim. This area is composed by volcanic rocks. Not only field experiments are running, the laboratory ones too. The planning of experiments arises from the facts of background research. The results from literature research contribute to our process of the research to be faster.

PARTIAL SPECIALIZATION OF RESEARCH

Not only current technologies but the new technologies or technologies with little information only are the possibility of the project solution. The project research is focused on:

- the place of radon removal (in the water source or on the way)
- using of aeration
- testing of membranes
- testing of liquid sorbents
- testing of solid state sorbents.

RESEARCH PERSPECTIVES

Perspective principle of the new technology will be chosen after evaluation of data from partial experiments and the requirements on the technical style of the components of the equipment will be specified. The final equipment for radon water removal for small water sources will be constructed after testing the prototype.

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