

TERA Radon Program**Radon Monitor RADIM 3AT**
Technical Specifications & Operation Manual

v.1 – 2018

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Users should be familiar with operation basis of used product. If you experience any problems with your product, please contact us at:

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1 Introduction

This document describes technical specifications of the Radon Monitor RADIM 3AT.

Product was developed and manufactured in the Czech Republic. All rights reserved TESLA. Offer or delivery of products or services related to the product does not include transfer of ownership rights.

Before using the product, please read this manual carefully and understand all operating and safety precautions. Compliance with operational and safety precaution can prevent from damage to equipment or injuries to personnel. Operating and safety instructions in the document are marked as follows:

Attention! This formatted text indicates the operating and safety instructions.

The product may only be used in the specified manner and for its intended purpose. The product may be provided to third persons along with this documentation only.

2 Use of the Instrument

The portable Radim3A instrument is developed for monitoring indoor radon concentration, temperature, humidity and pressure in resident spaces . Instrument with high sensitivity and its results are corrected over humidity and temperature. By LCD display and 3 buttons or over PC application is possible to control the instrument. due to internal accumulator is possible to use the instrument without electricity connection.

3 Scope of Delivery

The Radim3AT monitor is supplied as a complete unit consisting of the following components:

- Radon Monitor Radim3AT,
- Operation Manual,
- Power Adapter,
- Transport Box,
- CD with PC Application

4 Technical Specifications

Measured quantity:	air radon concentration
Functioning principle:	the radon diffuses into the chamber, covered by felt. The felt absorbs the air-borne radon decay products. The radon activity is determined by measuring the α -activity of ^{218}Po (RaA), collected by the electric field on the surface of the semiconductor detector.
Instrument response:	(0.5 counts/h)/(Bq/m ³)
Minimum concentration:	activity determined with a statistical error equal to $\pm 20\%$: 30 Bq/m ³ for 1- hour measurement
Maximum concentration:	150 kBq/m ³ for 1-hour measurement
Chamber capacity:	0.8 l
Sampling time:	adjustable from 10 minutes to 24 hours
Effect of humidity:	the change in the relative humidity from 50% to 90% decreases the sensitivity for -6.5% . The results are automatically corrected for the effect of humidity
Electronics:	low power, protection of data
Power:	battery powered- LiOn batteries with capacity of 2.5 Ah
Current:	0.49mA during measurement, 6 μA during stand up
Operation time:	210 days from the battery, from main: limited by the memory capacity
Memory:	a maximum of 16096 measurements i.e. results of 5060 hours-210 days of monitoring can be stored in memory when 1- hour sampling time is adjusted.
Thermometer:	precision of ± 0.5 C
Manometer:	range from 750 to 1150 hPa, reading differentiation 0.1hPa, precision $\pm 3\text{hPa}$, temperature coefficient $\leq 0.1\text{hPa}/^\circ\text{C}$
Hygrometer:	range from 10 to 99%, precision $\pm 3\%$, the computer determines the absolute humidity (g/m ³)
Display:	LCD, 2x 16-characters,
Communication:	USB standard port
Control:	3 buttons, remote control by PC
Dimensions and Weight:	230 x 230 x 230 mm, cca 1.5 kg
Climatic conditions:	temperature 5 to 40 C ^o , relative humidity 10-90%
Calibration:	carried out by manufacturer

5 Repairs

Any repairs and non basic maintenance must be performed exclusively by TESLA manufacturer.

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6 Warranty

- This product is covered by warranty of 24 months from purchase date.
- In case of warranty claim, please contact our Service Department.
- Warranty covers any defects in materials or workmanship and excludes any damage resulting from or caused by transport or handling or by any misuse.
- Warranty ceases if product has been used improperly or its seal is broken.
- In case of warranty claim, warranty period is prolonged by number of days product was undergoing warranty repairs.
- After the end of its life, product must be handled as e-waste.

7.0- Operation of the Instrument.

7.1- General Principles of Operation, Measurement and Depiction on Display.

The instrument is controlled by an efficient microcomputer. The software was designed so that the program offers a number of variants from which the operator makes a choice - i.e. the operator need not remember a set of commands or hunt through the manual. It is only necessary to have a rough idea of the types of operations carried out by the selected service - item of the Menu. The operator must also learn the manner in which measuring results are stored and displayed.

Measurement:

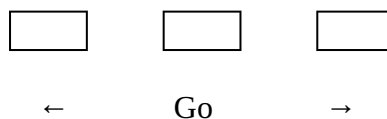
To start or stop measurement the sub- service **Start** or **Stop** in main service **Meas** should be selected- no advanced programming of experiment is needed.

The memory and manner of storing the results:

The instrument has the memory where **16096** results – recordings - can be stored. The records are numbered from 1 to 16096 from the beginning of the memory. The names of the items in the Menu, the sub-services and their description are written in English. The program offers statistical processing of the results, i.e. calculation of the mean and the standard deviation of the set of results. The set of results is stored in a **block**, whose number the program finds automatically when the measurement starts. The block is defined by the time of start and stop. The time of start, temperature, humidity and pressure is stored in the memory for each recording (record thereafter). In the memory can be stored **128 blocks - experiments**. Data can statistically processed either from all the block or from selected time interval- ROI. There is a possibility not to store results in the memory only read the last record in the display.

Concept of Operation and Depiction on the Display:

The conception of the software was based on the fact that an intelligent alphanumerical LCD display was used with 2 lines of 16 characters each and the instrument is controlled by 3 buttons. The buttons are labeled as:



In choice of items offered in the **bottom line of the display**, the operator moves to the **left** using button “ ← ” and to the **right** using button “ → ”, the selected action is confirmed using the Go button.

Numerical values entering:

The upper line of the display depicts the required information, a maximum 16 characters. The lower line is for choice, where the selected item is denoted on the display by enclosing between two arrows (in this description this will be denoted as > < and will be termed the cursor). The button Go switches the regime, denoted in the upper line.

Movement Regime:

Using the buttons ← and → the position of the cursor is moved. After pushing GO the movement regime changes to the action regime.

Action Regime:

Action depends on the symbol denoted by the cursor:

If the cursor selects the number the text changes to INC > < DEC and the buttons ← and → Increments/ decrements the number.

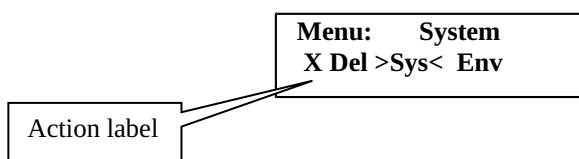
Switching ON/OFF the instrument:

The instrument has no mechanical switch ON/OFF, only electronic one. The instrument is switched **ON by synchronous pushing the buttons** ← **and** → . The instrument is switched **OFF automatically** if radon is not measured, the regime of display is adjusted to automatic switch Off (see later) and no adapter and no PC cable is connected.

Switching OFF the display:

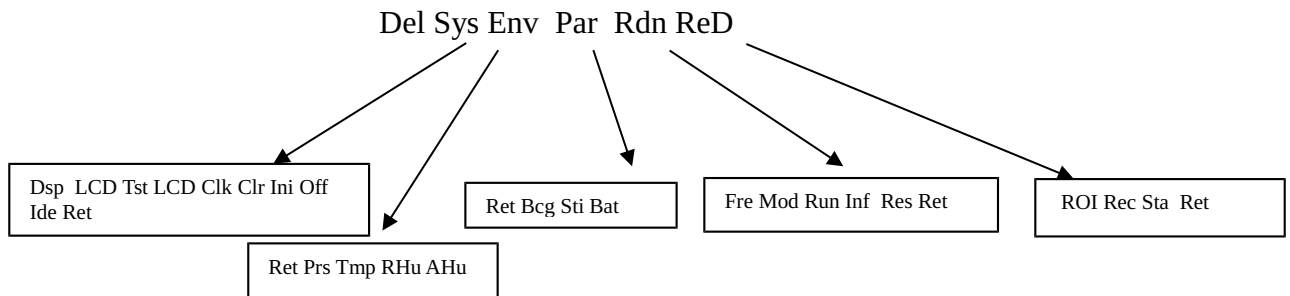
In order to reduce the power and to **protect the monitor against children a nonqualified person “playing”** the display can be adjusted to automatic switching off - see Chap.7.2. After turning the instrument on, the main **Menu** appears on the display - see picture below. The frame on the picture represents the display and the displayed text, the text which is outside the frame denotes the hidden items, which can be displayed when the cursor is moved to the right or to the left (the items can be read in a cyclic manner).

The items on the main Menu:



Main Menu:

As the description of the services can not be described as complete text on the LCD display with 16 characters, the main Menu consists of 6 items, where abbreviations denote items of Menu, indicated in the following figure, where the first steps of the services are also depicted.



When an items of the Menu are selected, the text on the upper line of the display changes, indicating the function of the item - services.

List of services:

Abbreviation Explanatory text

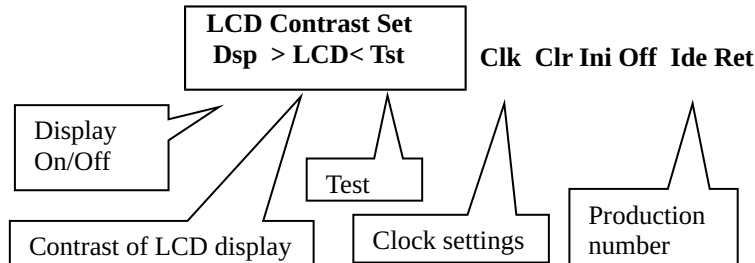
Abbreviation	Explanatory text
Sys	System
Env	Environment
Par	Parameters
Rdn	Radon Meas
ReD	ResultsRead
Del	LastMeasDel

Function:

Adjusting the contrast of the LCD display, clock, memory clearing, choice of the display control, production number
 Reading of temperature, humidity, pressure
 Background setting, adjustment of sampling interval, battery capacity
 Automatic measurement of radon, calculation of radon concentration, storing the result in the memory
 Results reading
 Deleting of the last block

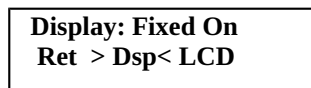
7.2-SubMenu Sys- Display On/Off, Test, LCD contrast, clock and memory clearing.

Selecting Sys- service on the bottom line of the display and pressing GO button, the following text appears on the display:

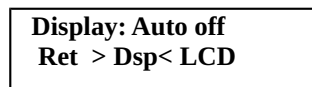


7.2.1- Display On/Off- service Dsp:

After selection of Dsp in the service Sys display depicts:



And the display is On constantly. In order to reduce the power and **protect the monitor against children a non- qualified person “playing”** push the **Go again** and the display changes to:

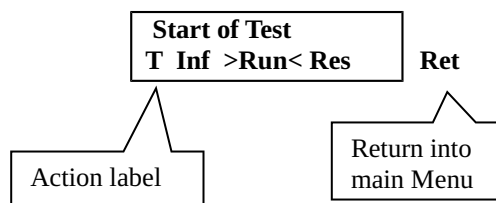


and if no button is pushed within 1 minute the display switches Off automatically. The display can be activated again by synchronous pushing the buttons ← and →.

7.2.2- Test of the monitor by internal generator- service Tst.

After beginning this operation, impulses with an exact frequency and amplitude are brought to the input of the preamplifier to test the correctness of the position of the analyzer window around the RaA peak and the functioning of the analog and digital parts of the electronics. The impulses are counted and the result is compared with the value stored in the computer memory. This operation can be begun when the background or radon are not being measured. If it is begun during these measurements, the display announces an error.

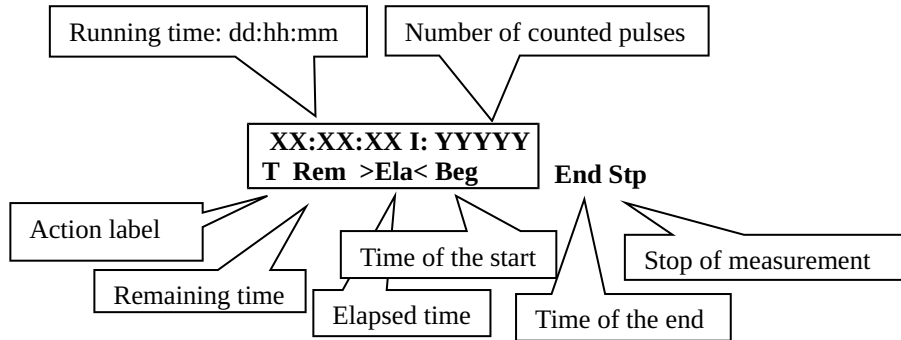
Selecting the Tst- service the display depicts:



Measurement and evaluation of the test:

The Run- item must be selected in the Test- service and the procedure starts after pressing the Go button. The “Action symbol” changes to T. When “T” appears on the display the impulses are counted and it is not suitable to select any another service- only service Info.

If you want follow the running measurement select **Info-** service and the display depicts:



The service **Info** has the identical form when radon or background is measured. The measurement can be stopped using **Stp** - service.

Note: when the operation Test (measurement of radon or background) starts the “Running time” and counter does not changes for 20s. This delay is needed as analog part of Radim3A is supplied by voltage when measurement is going only- during another operations this part is switched off and so the needed power is reduced. It takes about 15s to adjust the stable condition in the amplifier.

Depiction of the result of the test:

The result of the POSITIVE test is depicted after selection of **Res** - service as:

```

Test    OK:100%
Run    >Res< Ret
  
```

and the ratio of counted impulses to nominal number, given in %, is depicted in the upper line of the display.

If the counted number of impulse **differs** from the nominal number by **more than 5%** the notice “ **Dev. Test Failed**” appears on the upper row of the display. In this case it is strongly recommended that the producer be contacted and that **the instrument not be used**.

7.2.3-Contrast adjustment of LCD- service LCD:

When the cursor is set to the item LCD and Go- button is pushed the display depicts:

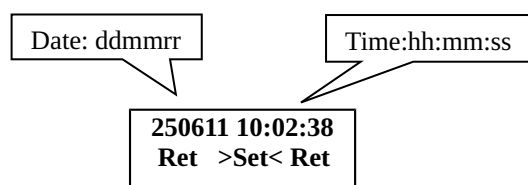
```

Contrast setting
Ret    >Inc< Dec
  
```

when the cursor is set to Inc-item it is possible to increase the LCD contrast by pressing GO. The Dec- item decreases the contrast.

7.2.4-Clock settings- service Clk

When the cursor is set to the item Clk and Go- button is pushed the display depicts (fiction date and time is shown in this text):



When the item Set is selected the display changes to:

```

250611      10:02:38
<<  MODE  >>
    
```

Using the button ← or → the desired number, which should be changed, can be chosen (here is line below the selected number). The program offers the possibility to change number by Inc or Dec and pushing of Go button. The program checks if the adjusted date and time is „sensible“. All procedure of clock setting is finished when cursor is placed on the Action symbol: „OK“.

7.2.5-Memory clearing- service Clr:

When the cursor is set to the item Clr and Go- button is pushed the display depicts

```

Are You sure ?
No >No< Yes
    
```

7.2.6- Reset-Initlize- service Ini:

Reset of computer is done in this service. Action must be confirmed after the question “Are you sure ? “

7.2.7- NoChargr- Pwr OFF- service OFF

There are a complicated computers in Radim3A and it can happen that one of the microprocessors can be latched. Only solution is to disconnect instrument from battery. It is done in this service if the instrument is not connected to external charger. **A new start is done by connection of monitor to external charger again.** Note that the parameters and real time clock **must be renovated !**

7.2.8- Reading of the production number - service Ide:

The production number of the each instrument is stored in the memory by the manufacturer (the storing procedure is available for the producer only) and the user of the instrument can read the number using Ide - service.

7.3-SubMenu Par- Background, sampling time and battery capacity.

By selecting Par- service on the bottom line of the display and pressing GO button, the following text appears on the display:

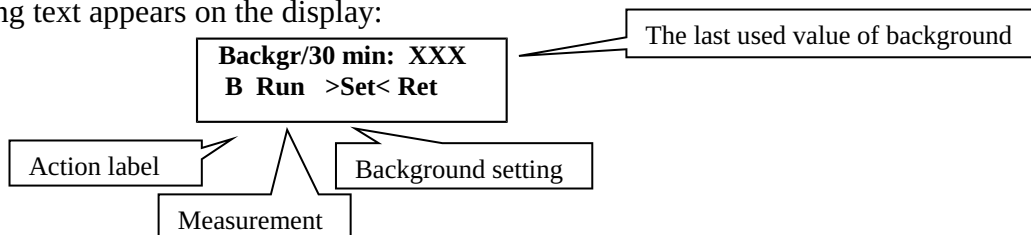
```

Background
Ret > Bcg< Sti  Bat
    
```

7.3.1- Background determination- service Bcg:

All types of radon monitors are contaminated after long- time measurement of high radon concentration- see Chapter 8.1. The service Bcg makes possible to measure background. When background is measured the HV is Off and the activity, which was deposited on the surface of semiconductor detector is determined.

By selecting Bcg- service on the bottom line of the display and pressing GO button, the following text appears on the display:



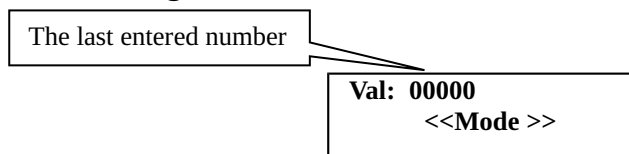
Background measurement:

Using the service Par, the 3 hours or longer sampling time should be adjusted. As the monitor is slightly sensitive to radon, it is recommended to place monitor into a space with very low radon concentration i.e. outside of house and to start background measurement at least 5 hours after last radon monitoring (one must wait for complete decay of RaC'). The measurement starts after selection of the item **Run** and confirmation by Go. After start the Action label changes to "B". If you want follow the running measurement select Info-service, see Chapter 7.2.2

Background setting:

If the results of multiple measurements of the background is known or we know a trend of background changing it is possible to set the value of the background manually. The number of background counts /30 minute can be written by the **procedure for entering of numbers.**

The "Number Writing" Routine:



There are 4 modes of writing procedure:

- << MODE >> 1: mod - selection of digit by moving the cursor to the left or right
- INC MODE DEC 2: mod - decrement (DEC) or increment (INC) of number by selected digit order of magnitude
- OK MODE ESC 3: mod - ending (valid or not valid writing)
- MAX MODE MIN 4: mod - copy of two limits of the number to current value.

The mode are changing by the button GO and confirmed by OK.

7.3.2 – Determination of Length of the Sampling Interval- service STi

Choice of the length of the measuring interval:

The length of the measuring interval is selected with respect to the expected level of radon concentration and required statistical error of the measurement. The following table gives the relative measuring error, expressed in percent:

Tab.4- The statistical errors, given in %, for different radon concentration and sampling time T

OAR (Bq/m ³)	20	50	100	500	1000	2000	5000	10000	50000
T=0.5h	50	33	20	10	7	5	3.2	2.2	1.6
T=1.0h	35	20	16	7	5	3.2	2.2	1.6	1.1
T= 2.0 h	25	16	7	5	3.2	2.2	1.6	1.1	0.8

From this table follows that the length of 0.5 hour seems to be optimal, with acceptable statistical error even for very low concentrations- only for concentration below 100 Bq/m³ the sampling time should be prolonged.

The length of the sampling time can be adjusted from 10 minutes to 24 hours.

Note: when sampling time is shorter than 30 minutes the seen radon concentration may be not correct, as the counting rate is not in an equilibrium with radon concentration. Therefore

the shorter sampling time should be used when a fast process is studied and relative values are important.

Sampling time setting:

When the item Sti is selected the display changes to:

```
STime : 00:30:00
X << Mode >>
```

Using the button ← or → the desired number, which should be changed, can be chosen (there is line below the selected number). The program offers the possibility to change number by Inc or Dec and pushing of Go-button. The program checks if the adjusted number is within the given limits. All procedure of setting is finished when cursor is placed on the Action symbol: „OK“ and confirmation by Yes.

7.3.3- Reading of residual capacity of the battery- service Bat

The LiON battery of 2.5Ah are used in the instrument. It is useful to know residual capacity of battery to estimate corresponding operational time. The capacity is estimated from voltage and discharging curve of the battery. Selecting Bat- service and pushing Go the display depicts for instant:

```
Bat:4.17V -OK-
- Sti >Bat< Ret
```

OK appears when voltage is higher than 3.7V

Notice To End appears when voltage is between 3.7 and 3.5 V

Notice Low appears when voltage is between 3.5 and 3.3 V

Notice Low is displayed when voltage is lower than 3.3 V, the instrument switches OFF automatically and it is not possible to start measurement.

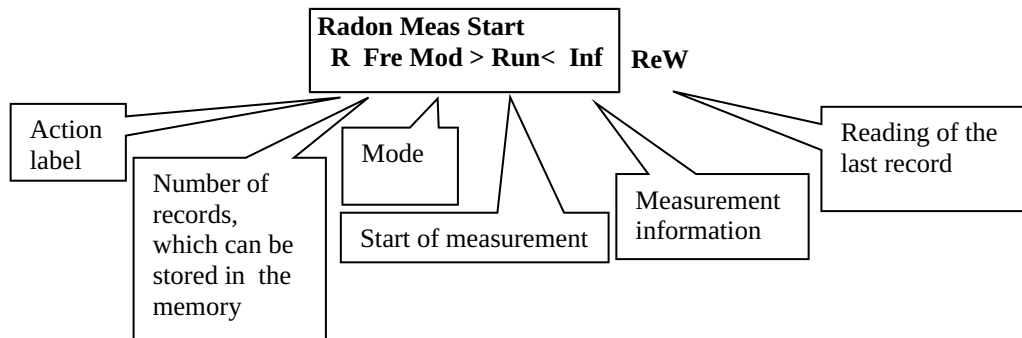
Battery charging:

Li-Ion battery has no “memory effect”, i.e. can be charged whenever the residual operation time seems to be short. Connect the adapter to the instrument and the LED, placed in rear panel, is lighting. While the battery is charging the LED is red, when charging is finished the LED is green (the orange light means some troubles with charging, e.g. low adapter voltage). The totally discharged battery will be charged in about 12 hours. The adapter can remain permanently connected to the device in order to supply in **long term measurements**.

Important ! Use the original adapter only. Using improper adapter can result in device malfunction or even damage.

7.4 - SubMenu Rdn- Automatic radon measurement and storage of the results.

By selecting Rdn - service on the bottom line of the display and pressing GO button, the following text appears on the display:



Before starting the measurement, the manufacturer recommend that the following be controlled:

- battery capacity (see Par - service),
- the length of sampling time (see Par - service),
- the background value (see Par - service),
- check the number of records, which can be stored in the memory – service Fre in Meas.

Mode: there are two versions of measurements

-Mode: DataLogging- the results are stored in memory

-Mode: MonitorOnly- the data are not stored in memory. The result of the last closed record can be read by ReW.

The measurement starts after selection of the **Run** service and confirmation by Go. After start the Action label changes to “R”. If you want to follow the running measurement select **Inf** - service, which is in detail descibed former in section **Test, 7.2.2.**

Service: Results Watching - ReW

During radon measurement the result of the last finished record can be displayed using service ReW:

38 +- 6 Bq
R Ret >Rnc< Imp Prs Tmp Rhu

Where Rnc shows radon concentration,

Imp shows number of impulses

Prs shows pressure

Tmp shows temperature

Rhu shows relative humidity

If a record is not finished no items are displayed.

7.5 - SubMenu ReD- Reading of results

Generally:

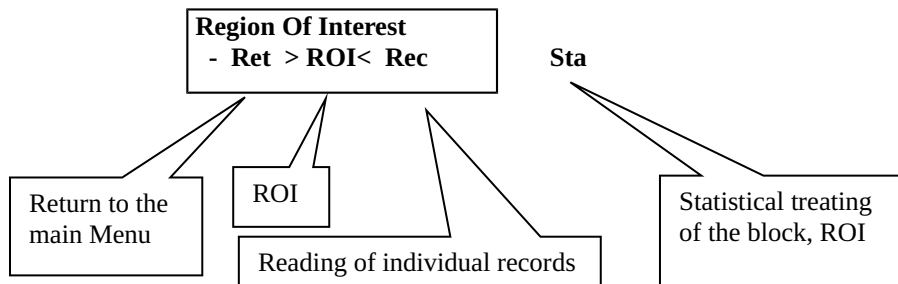
As it was noted above the results are stored in internal block as it is shown in the following figure:



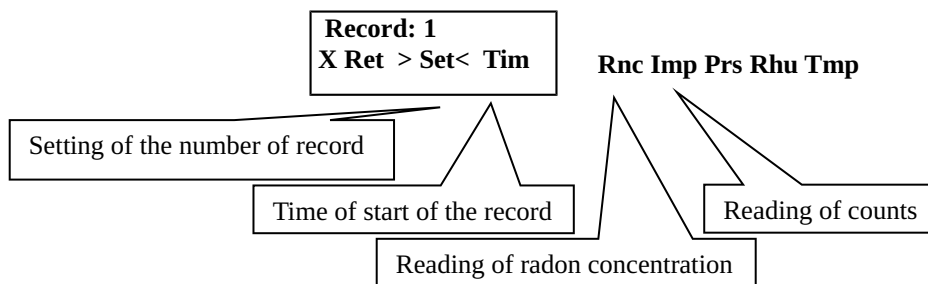
The block No.1 is defined by the start at Date 1 and by the stop at Date 2.

There is possibility to read the results of the whole block or to “cut out” a time interval in the block- ROI (Region of interest), which is processed by the same way as the whole block.

By selecting Res- service on the bottom line of the display and pressing GO button, the following text appears on the display:

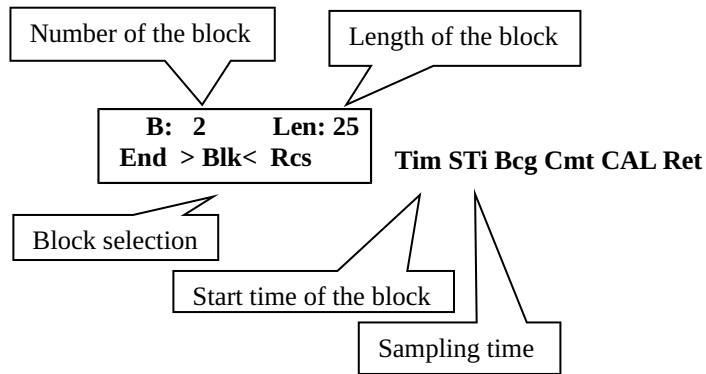


When we select the item **Rec** we can read individual results- records:



The program **starts reading from the beginning of the selected block/ROI** or from the entered number of the record. Subsequent pushing of the button Go increments the number of the record and to read another result - it is no need to return to the service Set to change the number of the record.

When the item **ROI** is selected the program offers:

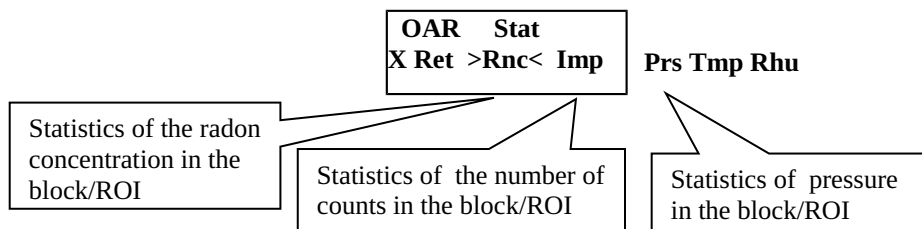


Selection of the time interval- ROI:

It is possible to cut-out a time interval from the selected block by the following procedure of the ROI definition: the item **Beg** should be chosen from the offer of the service ROI. The beginning of the ROI as number of record is selected. In the next step we find the item **End** and the end of the ROI can be determined as number of final record.

Statistical treating of the results:

We return to the beginning of the service **ReD** and after selection of the item **Sta** we can read mean value, standard deviation and maximal/minimal value in given data set.



Further items of service ReD:

Rcs- range of the records in the block, next pushing of GO selects previous block,
Tim- the beginning of the measurement, next pushing of GO selects previous block,
Sti- sampling time,
Bcg- the background, next pushing can change value of background,
Cmt- a comment in a numeric form, pushing GO one can change the value,
Cal- the calibration constant.

7.6 - SubMenu Del- deleting the last block

By selecting Del- service on the bottom line of the display and pressing GO button, the following text appears on the display and then it is possible to delete the last block:

Are you sure ?
-- No > No< Yes

8.0 – Technical notes

8.1 - Contamination of the Radim3A monitor

It has been found that **the background increases** after prolonged use of the Radim 3A monitor. This increase is caused by accumulation of ^{210}Pb on the surface of the detector (other instruments are affected by this phenomenon too). The ratio of the accumulated activity a_{pb} to the radon activity a_{Rn} can be described approximately by the relationship:

$$a_{\text{pb}} / a_{\text{Rn}} = \lambda_{\text{pb}} \quad t = 0.032 / \text{year} \quad (\text{K1})$$

Under the assumption that the efficiency of the detection of α -particles emitted by RaA and ^{210}Po is the same (practically the same energy) the following values are obtained for the background after **measuring of radon a_{Rn}** for a period of **one month**:

a_{Rn} (kBq/m ³)	5	10	50
a_{B} (imp/h)	13	27	133!!!!

This corresponds to a relatively high increase in the background. In order to assess the effect of the background on the overall precision of the measurement, it is useful to examine the statistics of the measurement in somewhat greater detail.

Effect of the background on the precision of the measurement:

During the measuring time, the number of impulses is measured, described by the symbol $N_{\text{B+S}}$, where index B indicates the background and index S is the index for the sample. The counting rate of the background is determined from the number of impulses N'_{B} , which is measured during an interval with length t_{B} :

$$N_{\text{S}} = N_{\text{B+S}} - N'_{\text{B}} t_{\text{S}} / t_{\text{B}} = N_{\text{B}} + N_{\text{S}} - N'_{\text{B}} t_{\text{S}} / t_{\text{B}} \quad (\text{K2})$$

and the dispersion σ of the thus-determined number of impulses is then described by the relationship:

$$\sigma^2 = N_{\text{S}} + N_{\text{B}} + N'_{\text{B}} \left(t_{\text{S}} / t_{\text{B}} \right)^2 \quad (\text{K3})$$

This relationship can be rearranged to the form:

$$\sigma^2 = N_{\text{S}} + N'_{\text{B}} t_{\text{S}} / t_{\text{B}} \left(1 + t_{\text{S}} / t_{\text{B}} \right) \quad (\text{K4})$$

and, after introducing the frequency of the background n_{B} , which is equal to $N'_{\text{B}} / t_{\text{B}}$, the final form is obtained:

$$\sigma^2 = N_{\text{S}} + n_{\text{B}} t_{\text{S}} \left(1 + t_{\text{S}} / t_{\text{B}} \right) \quad (\text{K5})$$

The statistical error is usually expressed as:

$$s = \frac{\sigma}{N} * 100(\%) \quad (K6)$$

for which the following modifications:

$$\frac{\sigma^2}{N_S^2} = \frac{1}{N_S} + \frac{n_B t_S}{n_S^2 t_S^2} (1 + t_S/t_B) = \frac{1}{n_S t_S} \left(1 + \frac{n_B}{n_S} (1 + t_S/t_B) \right) \quad (K7)$$

yield the relationship:

$$s = \frac{1}{N_S^{1/2}} \left(1 + \frac{n_B}{n_S} \left(1 + \frac{t_S}{t_B} \right) \right)^{1/2} \quad (K8)$$

the counting rate of impulses n_s (imp/hour) is given by the relationship:

$$n_s = a_{Rn} k$$

where a_{Rn} is the concentration of radon (Bq/m³), and

k is the response of the instrument equal to 0.8.

The selection standard deviation s (%) was calculated for various levels of concentration and background. The results are given in Tables K1 and K2.

Table K1 - The standard deviations for $t_B = 0.5$ h and $t_S = 0.5$ h.

a_{Rn} (Bq/m ³):	50	100	200	500	Background (imp/h)
s (%)	20	14.9	10.5	6.7	0
s (%)	21	15	10.6	6.7	0.5
s (%)	22	15.2	10.7	6.7	2
s (%)	25	16.5	11.1	6.8	10
s (%)	29	17.9	11.6	7	20
s (%)	49	26.8	15.3	8	100

Table K2 - The standard deviations for $t_B = 0.5$ h and $t_S = 1$ h.

a_{Rn} (Bq/m ³):	50	100	200	500	Background (imp/h)
s (%)	15	10.9	7.5	4.7	0
s (%)	15	10.6	7.5	4.7	0.5
s (%)	16	10.8	7.6	4.7	2
s (%)	19	12.1	8.0	4.8	10
s (%)	23	13.5	8.6	5	20
s (%)	41	21.8	12.1	6.1	100

Conclusions and Recommendations:

- in order to prevent contamination of the detector, it is necessary to **shorten the measuring time for high activities to a minimum**, i.e. at the beginning of the measurement it is useful to determine the activity level and, if this is greater than 20-30

kBq/m³, the measurement should be shortened to several days.

- when measuring low activity levels, i.e. concentration of less than 100 Bq/m³, it is essential to prolong the measuring time to at least 1 hour and to measure the background for several hours in an environment where the concentration of radon is known to be low. It is useful to measure the background at least 5 hours after the monitor was placed in the area with the high concentration of radon.
- when the background is higher than about 200 imp/hour, contact the manufacturer, who will replace the detector.

8. 2- Determination of the ventilation coefficient.

When the method of mitigation of a dwelling against radon risk should be proposed it is very useful to know the air exchange rate (thereafter ventilation coefficient) and rate of radon entry into a room.

When the rate of radon entry can be expected stable (there are no day- variations of radon concentration and the difference between internal/external temperature is high) there is possible to realise the following experiment:

1. The radon concentration should be measured for several days to find if it is stable within about 20%.
2. The studied room must be ventilated substantially. During the ventilation the Radim3A should be placed into the room to measure for several hours (the sampling time should be 0.5 hour) “ zero” radon concentration.
3. Then the room is closed and the growth curve is measured. It is very useful to reach equilibrium radon concentration (estimation of needed time is given below).

The rate of radon entry and ventilation coefficient can be determined from the measured growth curve.

Theory:

the change in the radon concentration **da** is given by the differential equation:

$$da = \frac{Rdt}{V} - ladt - \lambdaadt \quad (T1)$$

where

- a is the radon concentration (Bq/m³)
- R is the rate of radon entry into the room (Bq/hour)
- l is a constant characterizing the rate of air change – ventilation coefficient (h⁻¹)
- V is the volume of the room (m³)
- λ is the decay constant of radon, equal to ln 2/T_{1/2} = 0.008 h⁻¹.

Assuming that the rate R and ventilation do not change during the test period, the differential equation has a solution in the form:

$$a = \frac{R}{V(l+\lambda)} [1 - \exp(-(l+\lambda)t)] \quad (T2)$$

This equation contains two unknowns: rate R and the ventilation coefficient l. These quantities are determined from the radon concentrations activities **a_i**, measured at times t by using the method of regression analysis to fit a curve to the measured values, where this curve has the form:

$$a_i = a_0 [1 - \exp(-nt_i)] \quad (T3)$$

and constants a₀ and n are determined, which can be used to determine the required rate R and ventilation coefficient l. The latter usually has a value between 0.1 and 0.5 h⁻¹. The

following table gives times T at which the term $1 - \exp(-nT)$ attains value P at various ventilation coefficients l:

Tab. 1: Time T (h) required to attain the required values of $1 - \exp(-nT)$

($1 - \exp(-nT)$):	0.1	0.63	0.9	0.95
$l=0.1 \text{ h}^{-1}$	0.98	9.3	21	28
$l=0.3 \text{ h}^{-1}$	0.3	3.2	7.5	9.7
$l=0.5 \text{ h}^{-1}$	0.2	2	4.5	5.9

The success of the experiment depends on whether it is possible to obtain a sufficient number of results with small statistical errors, from which both the equilibrium activity a and the initial increase can be determined. The numerical analysis can be greatly simplified if the value of a_0 can be determined in the first step. This requires the determination of several experimental values of a_i in an area where the activity no longer changes greatly. Except for very low ventilation coefficients around 0.1 h^{-1} , it is sufficient to select an overall measuring time of about 12 hours to determine these points on the growth curve (see Tab. 1). It is then important in the estimation of the shape of the beginning of the growth curve that the period of the cycle be as short as possible. As mentioned above, this requirement is contradictory to the requirement of attainment of a sufficiently low statistical error. An interval of 30 minutes seems a reasonable compromise.

9.0- PC program for reading, evaluation of data and remote control of Radim3A

The program is intended for collection and storing of data from the Radim3A monitor. It works in the Windows 95/98/T environment.

The **minimum PC configuration** must comply with the following requirements:

- operating system for Windows 95 and higher
- 486 and higher processor
- 16 MB RAM
- VGA graphic card
- 1 x RS232
- 1 x LPT.

**The operation of the system retains the rules of operation of the MS-Windows system.
It can be controlled using the menu, mouse or functional keys.
The functions and a description are given in the following text.**

9.1 Introduction

9.1.1. Installation

As this is an application for Windows 95 and higher, the applications should be installed in the standard manner used for these systems.

The program should be installed in the following manner:

The CD disc contains the SETUP.EXE program. After turning on the program, it is necessary to follow the installation program. After entering the place of installation, the program begins to install itself automatically and the program announces the end of installation.

9.1.2. Description of the program

The program works in two basic modes, OFF LINE and ON LINE. If the instrument is not connected to the PC, the text OFF LINE appears in the bottom line on the left of the Main Panel- see later. In the OFF-LINE mode, the operator can view stored data and store data in files. In the ON-LINE mode, in addition to the above functions, communication with the instrument function can be set, the data is read from the memory and the monitor Radim3A can be controlled by PC.

When the PC program is started the small window with the Main Panel appears in your computer- see Fig.5. Before connection of Radim3A with PC use the service **Set** to set the number of communication port, i.e. COM1 or COM2.

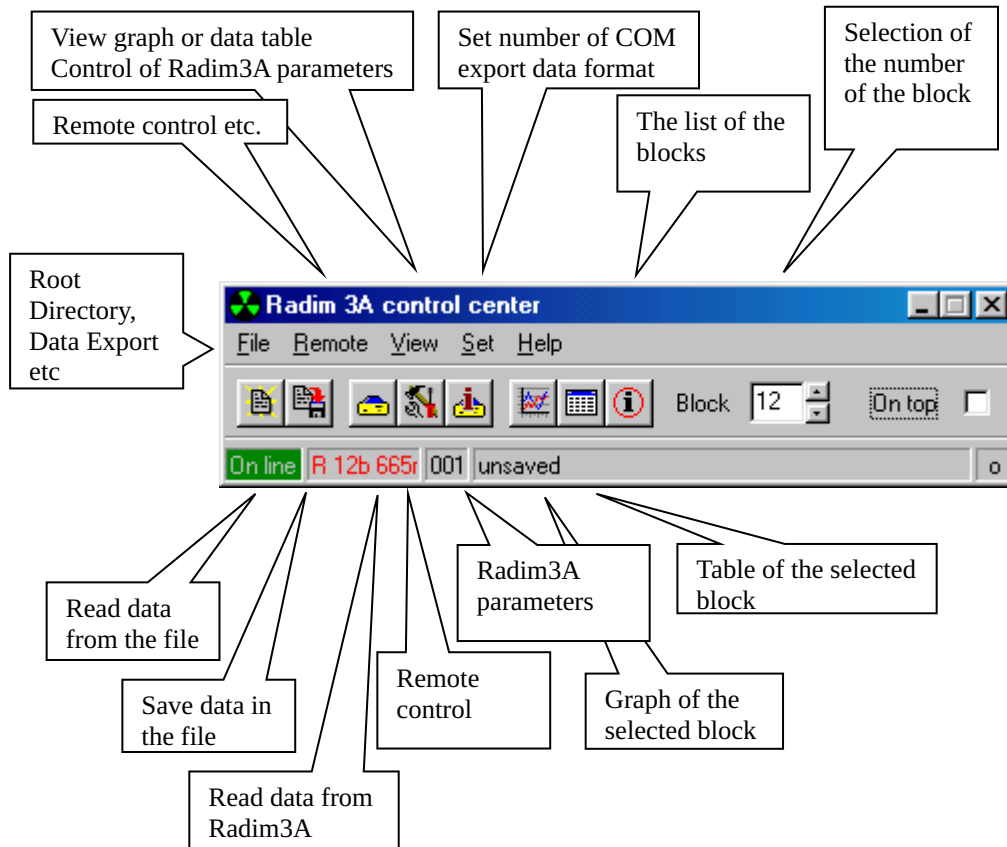
After connection of the PC with the Radim3A the small icon, placed the lower corner of the main panel, denotes connection of the PC.

The following operation can be selected in the main panel:

- load data from the file,
- save data to the file,
- read data from Radim3A,
- show graph of the whole active block,
- show data table of the active block,

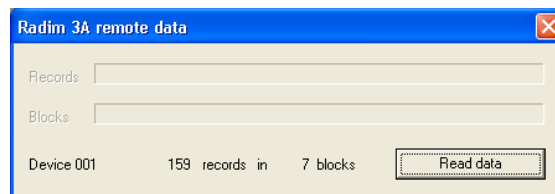
- show data overview (the list of the blocks)
- File- operation with the files,
- Remote- information about Radim3A parameters, data read from Radim3A, remote control,
- Set- selection of the number of the communication port and exported data format

Fig.5- The main control panel

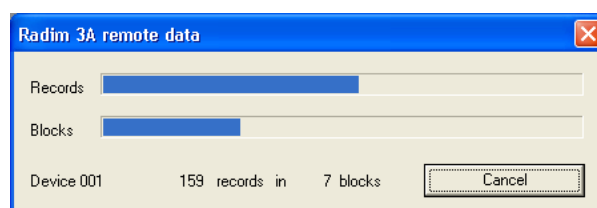


9.1.3- Reading data from Radim3A:

Use the service Remote and then Data or to click to the icon “Radim3A” to read all memory. Starting this service and the small window is depicted:



and after selection “ Read data” appears the window:



9.1.4-Information about the blocks:

When icon “i” is used the list of the blocks is depicted. The start and end of the block, number of records etc. can be found in the list.

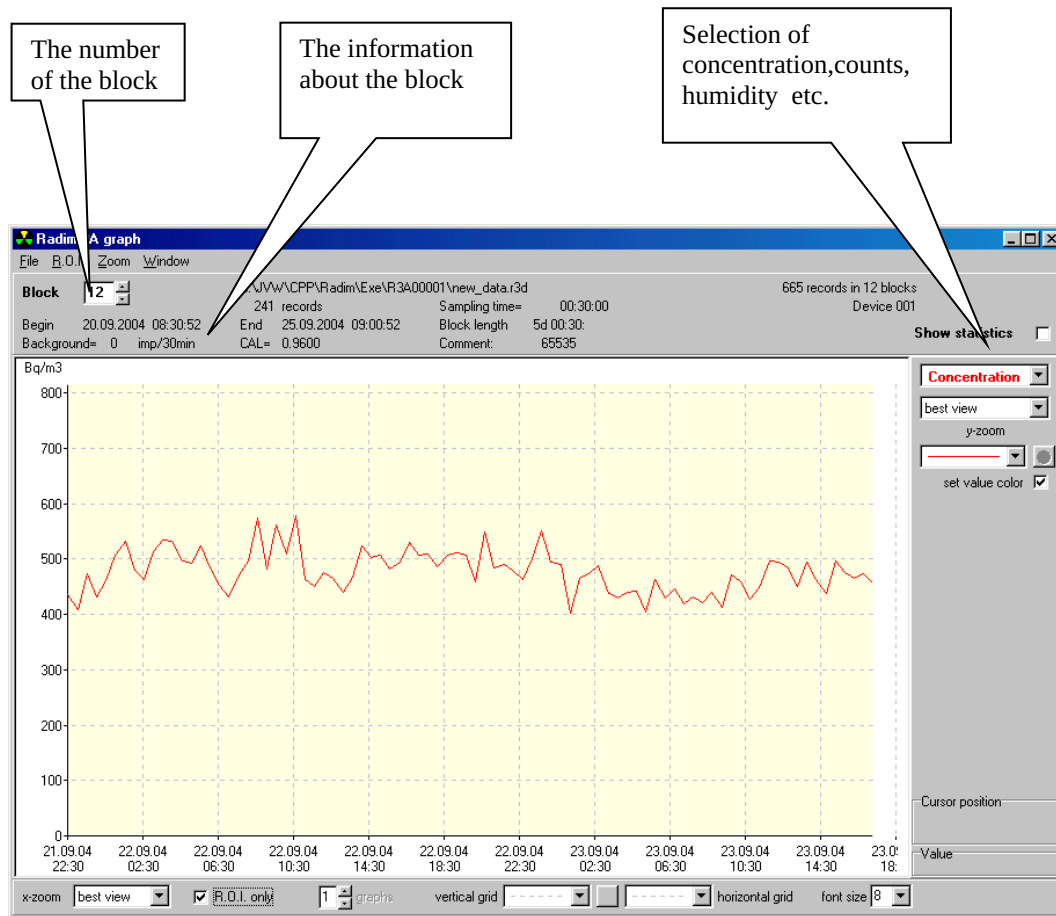
9.1.5-Selection of the block:

The number of the block can be selected in the Main Panel (see above) or in the list of the blocks (icon “i”) where it is possible to mark the needed block.

9.1.6-The graph of the selected block:

The graph can be depicted using the icon in the Main Panel or using service View- see Main panel. After selection of the service the following appears in the window:

Fig.6- The graph of selected block



The value of concentration (counts etc), number of the record, date appears in this windows when the “cross” is moved in graph.

9.1.7-The data table of the selected block:

The data table can be depicted using the icon in the Main Panel or using service View- see Main panel. After selection of the service the following appears in the window:

Fig.7- The table of the selected block

The screenshot shows a window titled "Radim 3A data table" with a menu bar (File, R.O.I., Window). The window displays metadata for Block 8, including file path, record count (47), sample time (00:30:00), device (001), and start/end times. Below this is a table with 10 columns: Record, Date & time, Block time, N [cnt], Conc. [Bq/m3], P [hPa], T [°C], Rh [%], and Ah [g/m3]. Records 7 through 12 are highlighted in blue. A context menu is open over record 7, listing options: Select all (Ctrl+A), Set as R.O.I., Set as R.O.I. begin, Set as R.O.I. end, Deselect R.O.I., Refresh last R.O.I., and Data Export (Ctrl+E).

Record	Date & time	Block time	N [cnt]	Conc. [Bq/m3]	P [hPa]	T [°C]	Rh [%]	Ah [g/m3]
1	16.08.2004 09:53:31	00:00:	1158 ± 34	2377 ± 69	995.8	21.8	54.7	10.6
2	16.08.2004 10:23:31	00:30:	13250 ±115	27324 ± 236	995.7	21.8	58.3	11.3
3	16.08.2004 10:53:31	01:00:	9536 ± 98	19719 ± 201	994.7	21.9	60.1	11.7
4	16.08.2004 11:23:31	01:30:	3845 ± 62	7947 ± 127	994.7	22.0	59.4	11.7
5	16.08.2004 11:53:31	02:00:	1983 ± 45	4102 ± 91	994.4	21.9	60.3	11.8
6	16.08.2004 12:23:31	02:30:	1769 ± 42	3665 ± 86	994.0	21.7	62.3	12.0
7	16.08.2004 12:53:31	03:00:	1799 ± 42	3729 ± 87	993.3	21.6	63.1	12.1
8	16.08.2004 13:23:31	03:30:	1898 ± 44	3953 ± 90	991.4	21.4	67.5	12.8
9	16.08.2004 13:53:31	04:00:	1946 ± 44	4055 ± 91	991.4	21.4	68.1	12.9
10	16.08.2004 14:23:31	04:30:	1985 ± 45	4137 ± 92	991.3	21.3	68.6	12.9
11	16.08.2004 14:53:31	05:00:						
12	16.08.2004 15:23:31	05:30:						
13	16.08.2004 15:53:31	06:00:						
14	16.08.2004 16:23:31	06:30:						
15	16.08.2004 16:53:31	07:00:						
16	16.08.2004 17:23:31	07:30:						

It is possible to mark time interval using the left button of the mouse. Striking the right button of the mouse one can determine the R.O.I. (see later).

9.1.8- Determination of the R.O.I.:

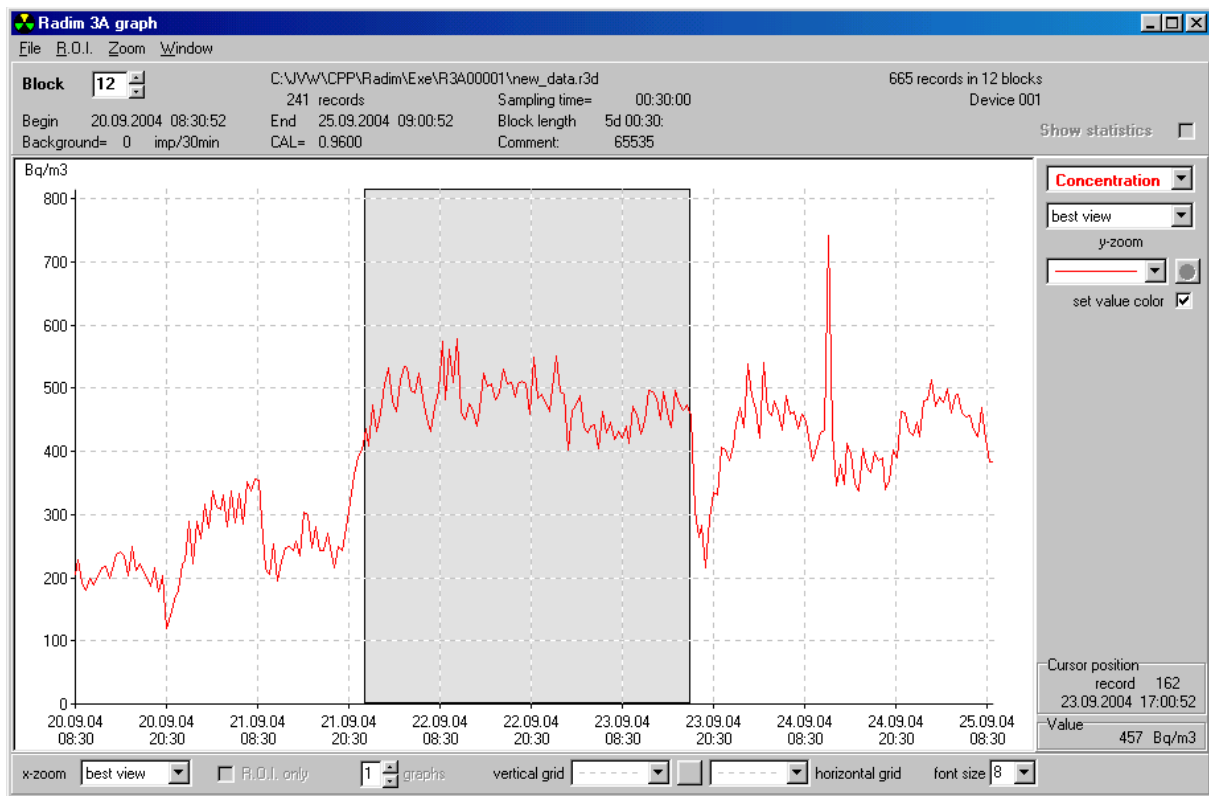
Very often it is useful to evaluate the results from limited time interval, i.e. in Region Of Interest (R.O.I.- system). It can be done in the graph or in the data table.

Determination R.O.I. in the graph:

1. place the cross in the beginning of the needed time interval
2. pushing the left button of the mouse and keeping the button move to the end of the time interval
3. push the right button of the mouse and program offers the following possibilities:
 - Set as R.O.I,
 - Refresh last R.O.I.
 - Select all , i.e. all data from the block.

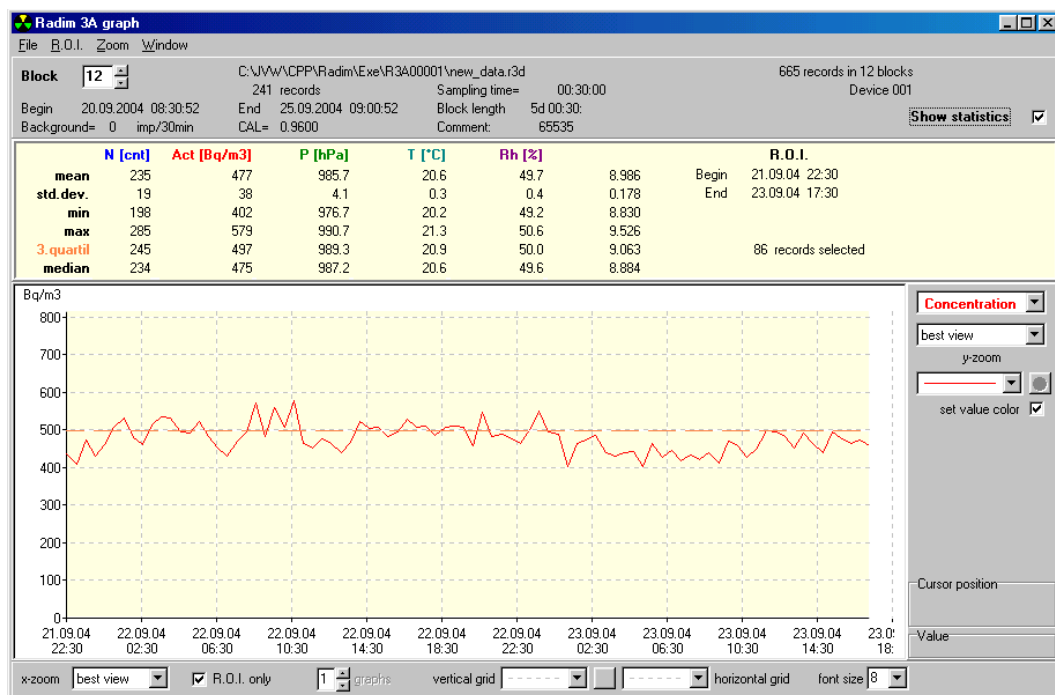
The window changes to:

Fig.8- The graph of selected block with the R.O.I.



If the service “Set as R.O.I” is chosen it is possible to get **the statistical results of the R.O.I.** clicking the icon “Show statistics” (the upper right corner of the window) and selecting the version “R.O.I. only” (see the icon in the left side, lower line) Then the following window is depicted:

Fig.9- The graph of the R.O.I.



Determination of the R.O.I. in the data table of the selected block:

Click on the icon “data table of the block” placed in the Main panel, using the left button of the mouse, mark the time interval- records of the future R.O.I. and then push the right button of the mouse. When you choose “Set as R.O.I.” the statistical treatment of the R.O.I. appears in the lower part of the window:

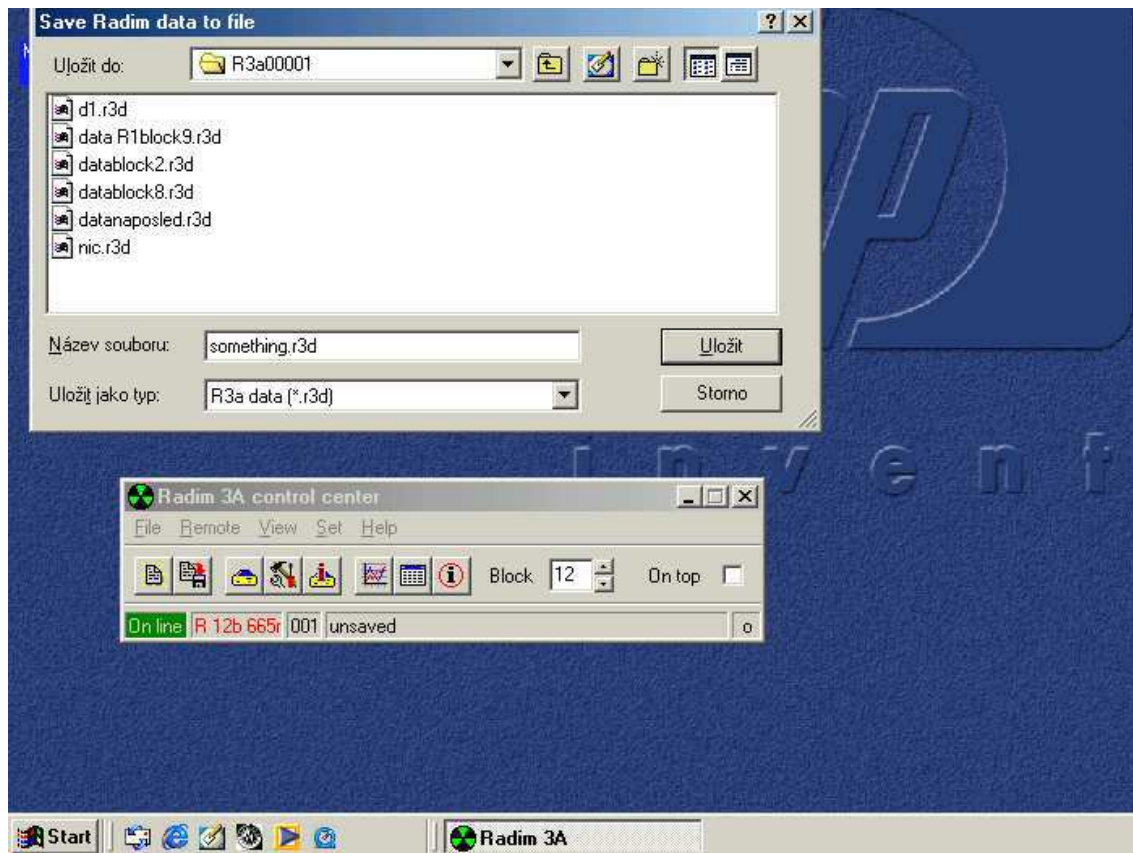
Fig.10- The data table with the R.O.I.

Radim 3A data table									
File R.O.I. Window									
Block 8		C:\Vw\ACPP\Radim\Exe\R3A00001\new_data.r3d				665 records in 12 blocks			
Begin 16.08.2004 09:53:31		End 17.08.2004 09:23:31		Sample time= 00:30:00		Device 001			
Background= 0 cnt/30min		CAL= 0.9600		Block length= 23:30:		Comment: 65535			
Record	Date & time	Block time	N [cnt]	Conc. [Bq/m3]	P [hPa]	T [°C]	Rh [%]	Ah [g/m3]	
1	16.08.2004 09:53:31	00:00:	1158 ± 34	2377 ± 69	995.8	21.8	54.7	10.6	
2	16.08.2004 10:23:31	00:30:	13250 ± 115	27324 ± 236	995.7	21.8	58.3	11.3	
3	16.08.2004 10:53:31	01:00:	9536 ± 98	19719 ± 201	994.7	21.9	60.1	11.7	
4	16.08.2004 11:23:31	01:30:	3845 ± 62	7947 ± 127	994.7	22.0	59.4	11.7	
5	16.08.2004 11:53:31	02:00:	1983 ± 45	4102 ± 91	994.4	21.9	60.3	11.8	
6	16.08.2004 12:23:31	02:30:	1769 ± 42	3665 ± 86	994.0	21.7	62.3	12.0	
7	16.08.2004 12:53:31	03:00:	1799 ± 42	3729 ± 87	993.3	21.6	63.1	12.1	
8	16.08.2004 13:23:31	03:30:	1752 ± 42	3636 ± 86	992.9	21.6	64.0	12.3	
9	16.08.2004 13:53:31	04:00:	1802 ± 42	3742 ± 87	992.6	21.5	64.9	12.4	
10	16.08.2004 14:23:31	04:30:	1787 ± 42	3714 ± 87	992.5	21.5	65.6	12.5	
11	16.08.2004 14:53:31	05:00:	1884 ± 43	3917 ± 89	992.5	21.4	66.2	12.5	
12	16.08.2004 15:23:31	05:30:	1843 ± 43	3834 ± 88	992.1	21.4	66.7	12.6	
13	16.08.2004 15:53:31	06:00:	1872 ± 43	3898 ± 89	991.9	21.4	67.5	12.8	
R.O.I. statistics: 6 records selected Begin 16.08.2004 12:53:31 End 16.08.2004 15:53:31 Length 03:00:									
mean			1811	3762	992.7	21.5	65.1	12.4	
std. dev.			46	99	0.4	0.1	1.4	0.2	
min			1752	3636	992.1	21.4	63.1	12.1	
max			1884	3917	993.3	21.6	66.7	12.6	
3. quartil.			1802	3742	992.6	21.5	65.6	12.5	
median			1799	3729	992.5	21.5	64.9	12.4	

9.2.1- Saving the results in PC:

In the first step is useful to determine the directory, in which the data will be saved. Use the service “ File” – see Main Panel and select “Data Root Directory”- the small window shows the path where data will be saved, for instant the path can be: C:\Vlach\Data. In the following window you can see two sub-directory “R3A0001” and R3A0002”. Explanation: each produced monitor has production number which is kept in the memory for instant R3A0001. Results of measurement of the used monitor are then automatically stored in the corresponding directory.

Fig.11- Saving the results in a file

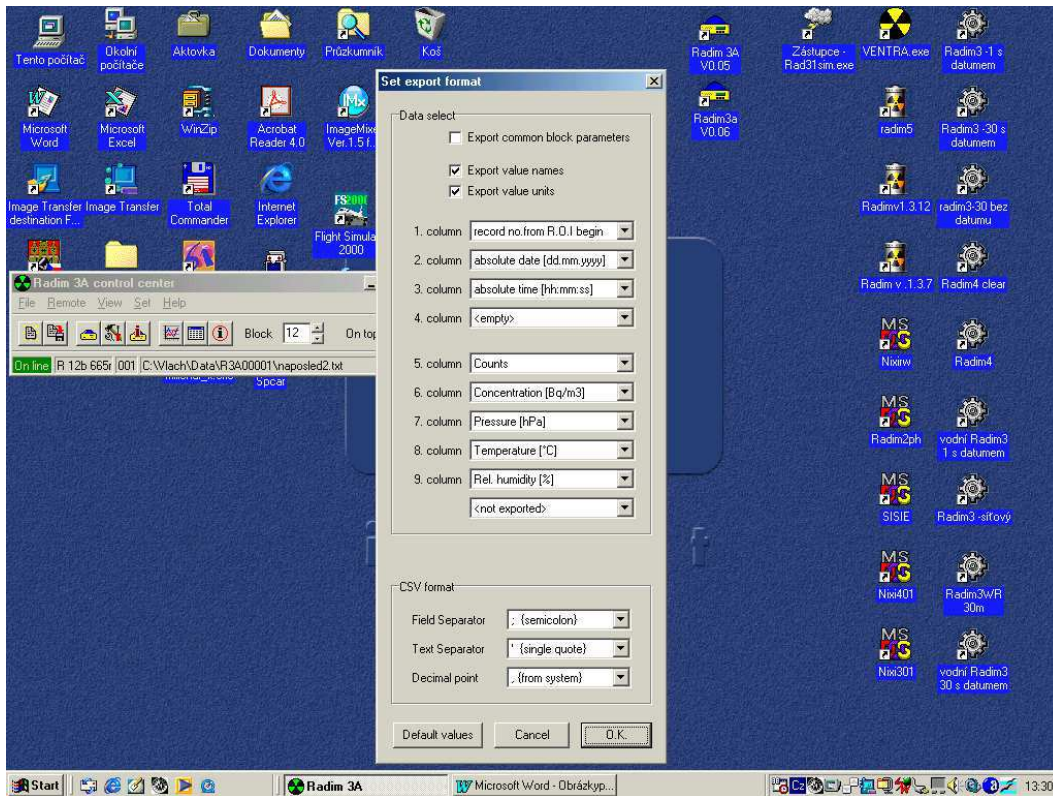


9.2.2- Export data to Excel (Word or similar)

The recommended procedure:

1. In the data table of the selected block mark the R.O.I.
2. Find the "Set" service in the Main Menu and then select service "Export format". The window is depicted in Fig.12.
3. Now it is possible to select what we want to export (concentration, counts, etc) and to adjust the format.
4. In the Main Menu the service "File" must be found and then the service "Data Export".
5. The similar window, as it is given in Fig.11, appears and then it is possible to write the name of the file but with extension ".csv".
6. To open the file in Excel or Word one must follow the proper path, for instant in our case: C:\Vlach\ Data\R3A0001 and to find saved file with the name and extension csv in the sub-directory R3A0001 (or similar).

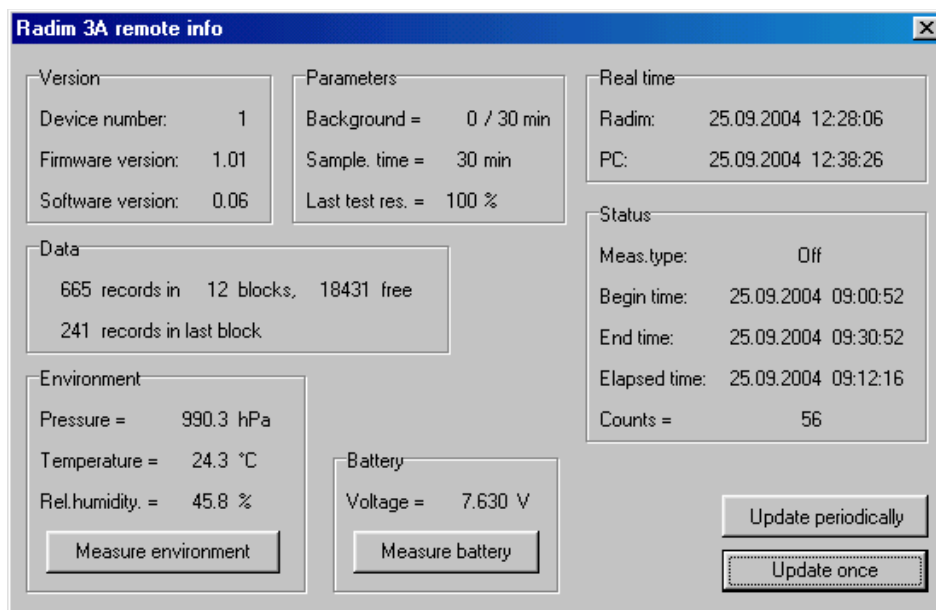
Fig.12- Set the export format



9.3.0- Information about the monitor parameters.

In the Main Panel select the icon of “Radim” with “i” and the following window is depicted:

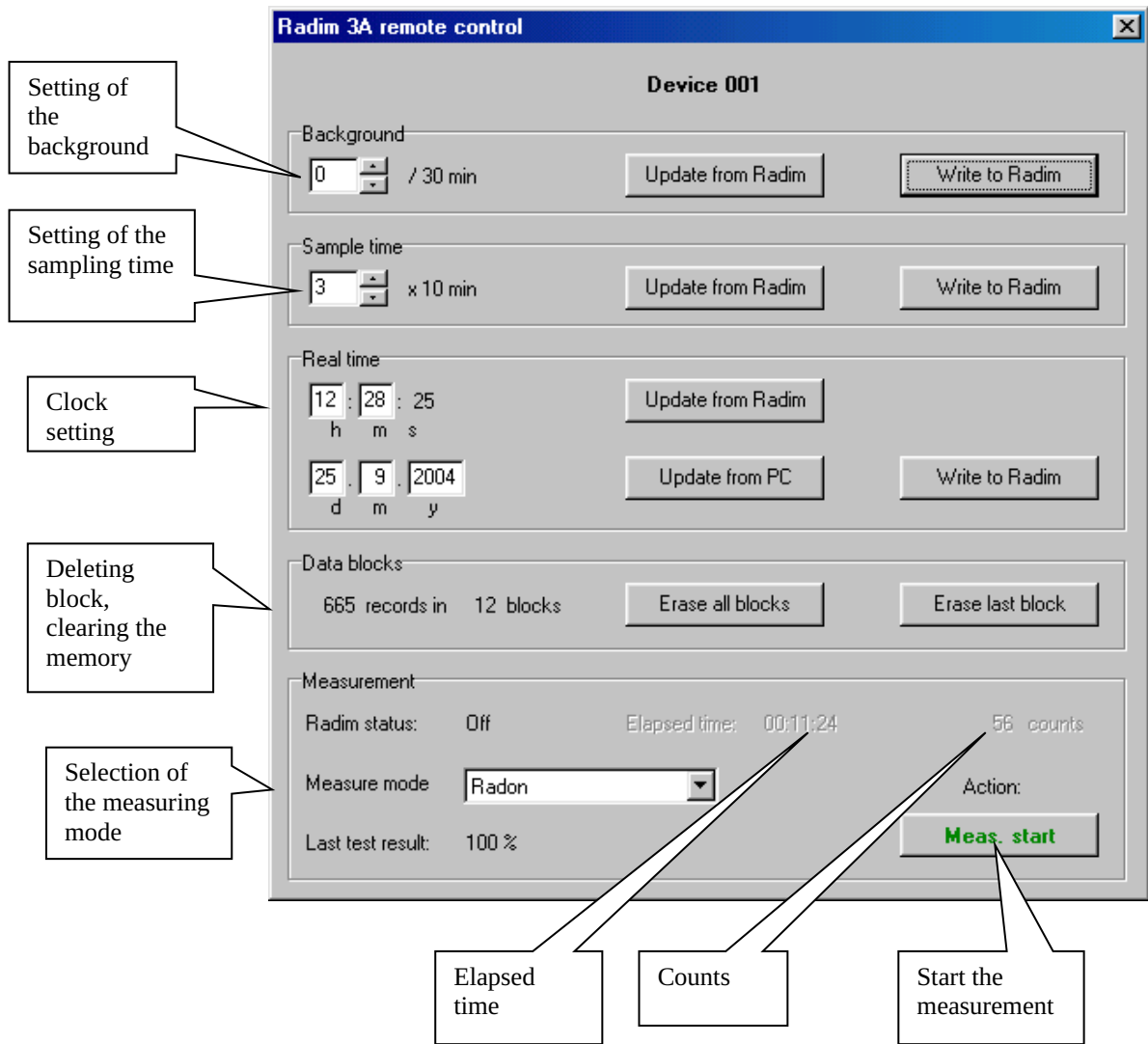
Fig.13- The monitor parameters



9.4.0- Remote control

In the Main Panel select the service Remote and Control and the following window is depicted:

Fog.13- Remote control of the Radim3A monitor



From the Fig. 13 it is clear what the service “Remote Control” offers. When we want to start “Test”, for instant, the mode Test must be selected and then clicking to small window “Meas. start” starts the measurement. The course of the measurement can be observed reading the elapsed time (time from the start of the measurement) and number of counts. Note: read the note in the Chapter 7.2.2- Test.