1. The precedents and the aims

The water, stored in he carbonate rocks support the fourth part of the human population. This is the reason why the karsts are so interested for the science beside their natural and environmental values. In the last few decades the water claims have importantly increased all over the world so the value of the usable supplies have also increased. But because of the over-using of karstic waters they were the most attractable examples of deceasing of the usable water supplies booth by the point of quality and quantity.

These days are the clear and determined aim of the human societies the sustainable development of the drinking water supplies. In the case of the karstic water system it means the knowledge of the exact balance of the input and the output.

The „deep karst" of the Transdanubian range reserves the most important water supply in Central Europe and the 70% of Hungary' one. Nowadays it give the drinking water support of 1,5 Million people but the capacity of the system is more because the input is at least 10 m^3/minute. However it is already now over used by a point of view. Firstly the effects of the water extraction of mines have been being yet. Secondly the springs thought existing by few decades will feed high polluted streams and lakes so their water quantity will necessary for the decreasing of the waste water concentration. The distribution of the water supply is a real conflict in this region because of the density of the population and the structure of the economy.

The aims of the dissertation were:

- to determine the main features of the precipitation (the distribution of it by days, by categories of the intensity and by the macrosynoptical types)
- to find the best method of the calculation of the infiltration to this region
- to show the territorial system of the infiltration and its parameters
- the investigation of the changing of the infiltration and its parameters (with their territorial aspect) mainly in the last 50 years but in cases even in the historical times
- to determine the tendencies of the changing
- the investigation of the orographical differences of the precipitation the temperature and some other climatic and non-climatic parameters
- by the results of the orographical changing to determine the exact values of the infiltration on the karstic plateaus
- to prove this method with hydrogeological facts

2. The methods used by the dissertation

2.1. The investigation of the precipitation by one station

I have started the work with the investigation of the precipitation because it is the most important parameter of the infiltration. I used the data of one station, Bakonybél-Somhegypuszta (350 m elevation asl.), between 1991 and 1995. This is a representative measure point for the all infiltration area of the Transdanubian Range. The chosen period contents booth the finish of the dry period of the 1970-1980-ies and the years with more precipitation from the second third of 1990-ies. These means that the results of the investigation stretchable booth in space and time. This hypothesis have confirmed by the stability of the results. (For example the number of the days with precipitation)

I have showed the portion of the precipitation in time and also by macrosynoptical types. Some of it I had to put into other categories because of the Péczely-method is sometimes unsuitable to describe the real meteorological situation in the Carpathian basin. Finally I have determined the difference of the dry and wet years by portion and intensity of the precipitation and by macrosynoptic types.

2.2. The changing of the infiltration and its parameters in space and time

2.2.1. Method of the calculation of infiltration

By the examinations done earlier it was clear that in this case the most suitable method is the „climate-connected" one developed by László Maucha. But by the data, the special literature and my examinations I have modified two steps of it:

- in the case of the *correction of the winter precipitation* the basis data was the mean of the winter precipitation of Aggtelek instead of the actual station so the more winter precipitation of the Transdanubian Range appeared in the calculation
- in the case of the *correction of the reservation* I have calculated instead of the yearly precipitation by the yearly infiltration because it means that amount of water which run into the karstic system

2.2.2. The data necessary to the calculation of the infiltration

Besides the calculation method there were necessaries ***precipitation data*** and the knowledge of the stretching of the ***infiltration areas***.

- The basic data of the calculation of the infiltration were the *yearly precipitation ones of 23 meteorological stations for 50 years*. The period of certain experiments were different, this fact I have signed in the dissertation. I have chosen such stations which climate is *the most similar to the infiltration areas*.
- To determine of the territory of the infiltration areas I have used the map of *ALUTERV-FKI developed in the 1980-ies.* The connecting of the infiltration areas (total sum is 370 with 1492 km^2 stretching) and the meteorological stations was my own work by the knowledge of the local and medium climate of the territory.

2.2.3. The temporal changing of the infiltration and its parameters

The yearly precipitation and the winter half year precipitation of the infiltration areas and the total infiltration of the karst system was calculated by the Excel program. The results were illustrated in graphs, diagrams and maps.

2.2.4. The temporal changing of the territorial system of the infiltration

The idea of this examination was given by the results of the preview one: it was clear that there were changing in the last 50 years in the territorial distribution booth of the precipitation and of the infiltration.

There was developed a ***calculation method*** which is sensitive to indicate of the territorial changing. The result of it is a proportion which is more than 1 if the difference is positive and less if that is negative. In this case of the *number of the stations were also 23* but the examination period was *between 1950 and 1997*.

2.2.5. The control examination of the changing of the infiltration and its parameters

2.2.5.1. The examination of the Mediterranean Index

By the last two examinations there was necessary to calculate the *„mediterranean index"* (MI) values for the region because of it is able to show exactly the supposed changing. The calculation was in three groups by the length and reliability of the data:

- 25 station between 1950 and 2002
- Budapest between 1910 and 2003
- Buda, later Budapest between 1780 and 2003

For the calculation method is necessaries monthly precipitation data so I could work with very similar data to the precipitation calculation also with *Excel*.

2.2.5.2. Looking for parallel of the proved changing to the global and regional tendencies

This step was the investigation of the special literature of the climate changing and comparing it with the results of the dissertation.

3. The orographical modifying of the infiltration and its parameters

By the special literature and the local climatologic knowledge there was developed an extrapolation method to determine the vertical modifying of the precipitation. There were necessary for it 3 things: the stretching of the examination area, the period and the best calculation method.

3.1. The examination area

It was clear that the work had to try the calculation method for only a part of the water catchment area:

- The main reason was that the *hydrogeological data of the Tata springs are the most plenty* in the whole region so the results of the extrapolation *we can check* there the most exactly.
- The catchment area of it represents the whole Transdanubian Range so if the method is working *it will be the easier to stretch it for the all region*.
- If the extrapolation is not a good method it is redundant to calculate it for the all area.

3.2. The period

It has seen that the best period is one year.

- During the examinations I have experienced that the yearly data *do not content the big and hardly differences of the daily ones* but *they have such characters* which are lacking in the more yearly means.
- The used period was confirmed by two things: in the region *the Plateaus are the most common* forms (it means that the differences are not so strong) and *the yearly unit is the same with the calculation method of the infiltration*.

3.3. The calculation method

- The calculation method was not the AURELHY, chosen at the beginning of the examination because during the detailed work have made clear that in the case of the Transdanubian Range the simple extrapolation is the best. The main reason was that the AURELHY was developed for *much more higher and complicated mountains with much more bigger territories. (Massife Central)*. If I would have used it there would have been *several times more unnecessary data* which *outshined the special local orographical features*. So I used *simple extrapolation*.
- For this really krigging method was necessary the *special group of data* because the extrapolation gives suitable connection only for *homogeneous database*.
- After it I have determined *the average of elevations of the bigger infiltration areas (in 5 group*: Gerecse, Vértes1, Vértes2, Vértes3, Bakony) and I have done the *extrapolations* for these. It meant the calculation of *yearly and winter half year precipitation and the infiltration for 100 years*.

3.4. The testing and using of the results, the stretching of the method for the whole Transdanubian Range and the checking of it

- The climatologic and infiltration data made by the extrapolation were confirmed by the hydrological budget and data of the Tata springs.
- By the infiltration data calculated on extrapolated precipitation data I managed to clear up more hydrogeological questions. By the model it is possible to make prognoses for the catchment area of the Tata springs.
- By the results of the testing of the extrapolation there were stretching the method for the whole infiltration area of the Transdanubian Range. By the infiltration data made by this way I managed to explain the output data of the special literature. So the method was confirmed also in this case.

4. Summary

The thesis has investigated the conditions of the infiltration in the Transdanubian Range with its variations booth in the time and space even with the elevation. The aim was to correct the hydrological balance of the karstic water system.

Firstly I have investigated the precipitation in daily units for 5 years in Bakonybél. This meteorological station was the most representative for the whole infiltration area. The issue have stated that:

- The infiltration areas of the Transdanubian Range – opposite the overage value (1/3) of Hungary – there is precipitation almost every second day.
- Although the number of the precipitation days is very high, the 79% of the precipitation falls only on the 1/7-1/8 part of the investigated period, so it is a very concentrated phenomenon in the area.
- The precipitation is even concentrated by the macrosynoptical types: 95% of it falls during the cyclonical types (1/3 part of the whole period), mainly the Péczely's 1st, 6th and 13th which give the 2/3 part of it.
- In my opinion the best method for the determination of the macrosynoptical situations of the investigated area is the Hess-Brezowsky's one.

- The reason of the increasing of the precipitation between 1991 and 1995 was the increasing intensity of the cyclonical macrosynoptic types. (It gave more times considerable precipitations.) But the average sum of one precipitation event was decreased. May be this phenomenon appeared in the wet periods. It mean that this time the more precipitation was divided into smaller portions so the vegetation and the karstic system better can use it.

The next step was the investigations of the parameters of the infiltration for a long, basically 50 years long time. The aim was to determine the changing of the measured values booth in time and space. The results:

- By the data of the used meteorological stations the 50 yearly average of the yearly precipitation was 691 mm, the winter half-year precipitation 293 mm, the infiltration 195 mm (9,5 m^3/minute) was on the karstic plateaus.
- There were considerable changing in the parameters of the infiltration from the 1970-ies and this process got faster in the 1990-ies.
- The yearly precipitation after the dry period of the 1970-ies basically increased in the 1990-ies but the most characteristic phenomena was the increasing variability of it. The winter half-year precipitation clearly increased in the 1990-ies. This fact and the changing of the territorial proportion of the precipitation anomalies even the development of the yearly mean temperature suggested that the Mediterranean effect have got stronger in the area. This phenomenon is basically favourable for the infiltration.
- The increasing of the variability of the precipitation got faster in the last decade. In the 1990-ies booth in the infiltration and its parameters appeared values and fluctuations which were not earlier. Some meteorological events have resulted the extreme increasing of the fluctuations of the infiltration even in the places which had very steady values. (Mainly the plateaus) The hydrological planning has to pay attention for it.
- The variability of the winter half-year precipitation, the yearly precipitation and the infiltration is decreasing from north-east to south-west direction and to the lower elevations. So the higher values are the more permanents. It means also that the data of the valleys and basins are no usable for the determination of the infiltration of the plateaus. We have to extrapolate the data of the slopes inside the parts of the range. (These units are finding from the north-east to the south west directions.)
- The investigation of the infiltration confirmed the presumption (by the hydrological special literature) (*Böcker, T.* 2000) (*Fogarasi, S.* 2001) that the Bakony mountains is the main infiltration area of the Transdanubian Range. The water input in these plateaus is booth very large and steady.
- By the dissertation the hydrogeological border of the Móri valley is even climatologic line the difference is only that the Tési plateau is belongs to the north-eastern areas. The water infiltrating there is appeared in the springs of the Móri valley so it also confirms that this territory is connected to the Vértes.

Based on the facts mentioned in the previous paragraph there was necessary to investigate the changing of the territorial system of the infiltration for 50 years. It is the most sensible indicator of the changing of the climatic parameters. This investigation confirmed the presumption: the anomalies have considerably changed during this period. The conclusions:

- The territorial system of the infiltration is the most sensible thing for the indicating of the climate changing. The changing process of it has started already in the 1950-ies when nobody said about the climate changing. The extinction of the earlier anomaly-system was around 1970 when the long dry period started and the global climate changing became indicating. The anomaly patterns never experienced earlier appeared in the 1990-ies when the new period of the global climate changing have started. In Europe – also in the investigated

area - the oceanic air flow has become weaker and the Mediterranean belt has stretched to the northern direction. These processes were indicated in the 1990-ies in the investigated area.

- The changing of the anomaly patterns of the infiltration is very similar to the absolute infiltration values: there were not clear process in changing but the variability and instability of the values have considerably increased in the last 50 years. By the dissertation this process is getting faster and faster.
- The issue have confirmed the preconception of the special literature: the dry periods increased mainly in summer. The changing of the anomaly patterns is parallel with it.

By the results of the investigation of the infiltration I have thought that the changing showed earlier I could prove with the "Mediterranean Index" examination. The conclusions:

- The MI investigation also confirmed the opinion of the special literature: the oscillation of the precipitation is belongs to the changing of the sun-spots. There were 30 yearly periods even in the historical time. (E.g. 1780, 1960, 1990)
- There were confirmed the climatic change of the region of the Transdanubian Range also with its sections. The main features of the climate of these periods were found out even in historical time: high MI values, the yearly mean temperature is over the average, the precipitation is under the overage and the climatic elements are very variable. The consequence of these: the instability of the infiltration also increased booth in space and time.
- The Mediterranean feature got stronger in the region also by this investigation.
- The changing was indicated can modify booth the amount of the infiltration and its proportion also in time and space. It can cause the degradation of the karstic system and the changing of the dynamism of it. (E.g. the erosion get stronger, so the soil will destroy; the extinction of the pluvial life, etc.)

The modifying of the climatic parameters in the Transdanubian Range is parallel with the global and European (regional) climate changing events:

- The development of certain phenomenon is similar. (E.g. the modifying of the macrocirculation, the increasing of the instability of the climatic elements etc)
- The sections of the changing were also similar to each other: the start (1950-ies), the proved being (1970-ies), and the considerable accelerating (1990-ies) of it.

A large portion of the water input have missed after the calculation of the infiltration although the work have done it based on data of stations whose climate are the most similar to the plateaus. This fact caused the investigations of the Chapter 5: I have tried to exact the precipitation and the infiltration of the plateaus with mathematical methods.

This investigation is at the end of the work because of the extrapolated data used by the calculations: it proved only by the dissertation. The results:

- In the Transdanubian Range there are special reasons which cause the strong changing of the climatic parameters with the elevation. It also caused that the warm-wet-flow of the cyclones often pass the region at right angles which is the best situation for heavy precipitations on the plateaus.
- The importance of the topic is that the variability of the climatic parameters with the elevation also modifying the infiltration values. There is exponential connection between the growing of the precipitation and the infiltration.
- In the case of the Transdanubian Range the best method for the calculation of the climate of the plateaus is not the AURELHY but the simple extrapolation based on data of homogeneous stations which are on the slopes.
- The time unit of the calculations the year was based on earlier investigations.

- There were calculated extrapolated precipitation data for the 3 region of the Range: Bakony, Vértes (there were 3 different areas) and Dunazug Mountains. There were stated the infiltration data for the plateaus for 100 years.

- The orographical modifying of the precipitation is difference like Péczely have experienced it: basically twice more, and the values are higher in summer in the Southern areas and on the Northern slopes. The reason of the difference likely that Péczely have used partly in his investigations stations seat in valleys.

- The increasing of the precipitation starts on the slopes at 200 m overage elevation and on the opposite side fast decreases. So the orographical gradients of the lee-sides are higher.

- By this work the maximum precipitation amount is usually at the peaks and the plateaus it is rarely on the upper areas of the luv or the lee side. This portion is similar to the other regions of the Carpathian Basin. The exception is the Péczely's mCc situation.

- The portion of the precipitation on the plateaus and on the same direction slopes is very homogeneous. On the luv sides in the Transdanubian Range is very rare the decreasing of the precipitation with the increasing elevation.

- By the dissertation the earlier point of view that in the region the North-Western sides get the more precipitation is true but the plus of these slopes are much more less. The reason of this phenomenon may be the fundamentally Western air flow in this area.

- The values of the modifying of the precipitation with the elevation have changed in the last decades: it decreased (mainly in the summer half year), and the higher values have changed in the North-Western slopes. It is poor for the infiltration and prove that the important of the Mediterranean air masses have increased.

- I have proved the right of the extrapolated precipitation data with the water budget of the Tata Springs: there were successfully exact the hydrological elements and also the infiltration area of it which were not clear in the special literature:

- The water input of the Tata Springs in the natural condition were 103, 5 m^3/minute on average which arrived 1/2 part from the Bakony, 1/3 part from the Vértes and 1/6 part from the Gerecse. 78 m^3/ minute was the water mass of the springs and 25 m^3/ minute flew toward under the surface.

- The infiltration area of the springs in opinion of this work is 193,5 km^2. It is content the region of Oroszlány but does not content the area of the Dunaalmás Springs and Esztergom-Sárisáp Springs.

- After the confirmation of the extrapolation method I have tried to forecast the water level in the region. By my side it will increasing for the 139 m asl. to 2020-25 and the springs will give about 70% of their natural water mass.

After it I have investigated the orographical modifying of the snow and the other climate elements:

- The snow is very important in the infiltration because after its melting almost the whole portion of it get under the surface. The increasing of the snow precipitation is more with the elevation like in the case of the rain. The reasons are special and cause that the Transdanubaian Range is the area of Hungary with the most amount of snow.

- There was developed a three dimensional precipitation model.

- The modifying of the temperature with the elevation also very high in the investigated area especially in winter when the values may be the highest in the Carpathian Basin.

- The decreasing of the evapotranspiration with the elevation is more than the special literatures have thought because in the daily hours the gradient is much more than the average.

Finally I have extended the extrapolation method for the whole infiltration area of the Transdanubian karstic system. The aim was to correct the water budget. The results:

- The average elevation of the 1492 km^2 infiltration area is 450,9 m asl., the yearly mean precipitation was 851 mm and the winter mean one was 373 mm between 1901 and 2000.
- The 100 yearly average infiltration in the Transdanubian Range was 225 mm (750 m^3/minute), the 34% portion of the yearly precipitation.
- The importance of Bakony in the infiltration of the karstic system is more than was thought.
- The hydrological elements of the Transdanubian Range calculated with extrapolated precipitation data were confirmed by the output data of the special literature and it can show the origin of the amounts of it. So the extrapolation method was confirmed also in this case.

Publications

1. *Fogarasi, S.* (1995): A Dunántúli-középhegység karsztvízrendszerének modellje; Modellek a természetföldrajzban, Acta Geographica Szegediensis Különszáma, Szerk. Mezősi Gábor, JATE, Szeged, pp. 32-37.
2. *Fogarasi, S.* (1997): A Tatai-források vízrendszere (Bányászati és Kohászati Lapok Közlésre elfogadta)
3. *Fogarasi, S.* (1998): A Dunántúli-középhegység karsztvízrendszerének modellje II.; VI. Országos Felsőoktatási Környezettudományi Diákkonferencia, Budapest, 1998. május 27-29; Program, Előadások összefoglalói pp. 128.
4. *Fogarasi, S.* (1999): Infiltration in the Transdanubian mountains, Hungary; Essays in the Ecology and Conservation of Karst; Edited by Ilona Bárány-Kevei and John Gunn; International Geographical Union, Comission Sustainable Development and Management of Karst Terrains, Szeged-Budapest-Miskolc, Hungary, pp. 212-218.
5. *Fogarasi, S.* (1999): A Dunántúli-középhegység éghajlati vizsgálata a karsztvízrendszer szempontjából; Egyetemi Meteorológiai Füzetek No. 13., Szerk: Kircsi, A.-Pongrácz, R., Meteorológus PhD hallgatók II. Országos Konferenciája, Bp., pp. 9-13.
6. *Fogarasi, S.* (1999): A karsztvíz szerepe az Által-ér vízrendszerében; „A táj és az ember geográfus szemmel"- Geográfus PhD hallgatók II. Országos Konferenciája, Szeged (CD publikáció)
7. *Unger, J. - Botttyán, Zs. - Sümegi, Z. - Gulyás, Á. - Fogarasi, S. - Sódar, I.* (1999)*:* A Model for the Maximum Urban Heat Island in Szeged, Hungary; A Szombathelyi Berzsenyi Dániel Tanárképző Főiskola Tudományos Közleményei, Természettudományi Füzetek 4., Szerk.: Veress, M. - Puskás, J. Szombathely, pp. 31-39.
8. *Fogarasi, S.* (2000): A karsztvízbeszivárgás mezőinek módosulásai a Dunántúli-középhegység területén; Karsztfejlődés V., BDF Természetföldrajzi Tanszék, Szombathely, pp. 195-211.
9. *Fogarasi, S.* (2001): Analysis of Precipitation in the Bakony mountains; Acta Climatologica Et Chronologica Tomus XXXIV-XXXV., Curat: Ilona Bárány-Kevei, Szeged (Hungary), pp. 69-81.
10. *Fogarasi, S.* (2001): A beszivárgás változásának éghajlati okai a Dunántúli-középhegységben; Karsztfejlődés VI., BDF Természetföldrajzi Tanszék, Szombathely, pp. 71-81.
11. *Fogarasi, S.* (2001): Vízellátás és vízvédelem: az Észak-Dunántúli Vízmű Részvénytársaság tevékenysége; Karsztfejlődés VI., BDF Természetföldrajzi Tanszék, Szombathely, pp. 83-102.

12. *Fogarasi, S.* (2001): Visszatérnek-e a Tatai források? II. Magyar Földrajzos Konferencia poszterelőadása, Szeged (CD-publikáció)

13. *Fogarasi, S.* (2002): A Katona-forrás feltörésével kapcsolatos kérdések; Karsztfejlődés VII., BDF Természetföldrajzi Tanszék, Szombathely, pp. 129-139.

14. *Fogarasi, S.* (2004): A Mediterrán Index változása és kapcsolata más éghajlati elemekkel a Dunántúli-középhegység karsztterületein; Karsztfejlődés IX., BDF Természetföldrajzi Tanszék, Szombathely, pp. 251-268.