AIR POLLUTION FEATURES OF THE VALLEY-BASED TOWNS IN HUNGARY

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ABSTRACT. - Air Pollution Features of the Valley-Based Towns in Hungary. There are 30 valley-based towns with >10,000 inhabitants in Hungary, filled by 1.023 million people i.e. 10 % of the population. Two criteria are used to define the valley-based town. They are: (i) Vertical difference between the lowest point in the town and the highest one around it should be >100 m. At the same time, (ii) the same difference on the opposite side should be >50 m. Air pollution data by the National Air Pollution Observation Network are used. Five contaminants were selected and analysed for 2007, 2010 and 2013. Due to a sharp reduction in the network, we could find data for a small part of the valley-based towns. Control towns with equal air-quality observations and similar cumulative number of inhabitants were also selected. The contaminants and the number of the settlements are: NO_2 manual (14 valley-based vs. 2x14 control), NO_2 automatic (8 vs. 8), SO_2 automatic (7 vs. 2x6), PM_{10} automatic (8 vs. 2x7) and PM_{10} deposition manual (6 vs. 8). Average values, as well as high concentration episodes (>98%thresholds) are equally analysed and evaluated. The main conclusion is that there are so big differences between the years both in absolute values and relative sequence of valley-based and control groups that the analysed there years is not enough to make any final conclusion. For step-over frequencies, however valley-based towns have some advantage, possibly due to the valley-hill wind system.

Keywords: *urban air-pollution, valley-circulation,* NO_2, SO_2, PM_{10}, *Hungary.*

1. INTRODUCTION

We can classify our towns in many ways. One of them may be whether that settlement is located in a valley (Utasi et al, 2012). As we can see below, the proportion of such settlements and their inhabitants are not at all negligible even in Hungary. Ca. 10 % of the people live in the 30 settlements over 10,000 inhabitants.

We analyse effects of this feature on the air quality, seeming two-fold, *a priori*. On one hand, the valleys may worsen the air quality since the surrounding hills form mechanical barriers to horizontal winds. On the other hand, however, the local hill-valley circulation may mix the air, which is especially important in anti-cyclonic situations, often accompanied with critical high concentrations elsewhere.

The paper is simply structured: Section 2 deals with the applied definition of the valley based towns. Section 3 introduces the investigated five air-pollution characteristics and the control-groups selected from the plain settlements with

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identical measurements and similar cumulative number of inhabitants. The results of comparison are presented by Section 4, which is followed by brief Conclusion.

2. VALLEY-BASED TOWNS IN HUNGARY

It is not easy, how to define a valley based town. In geography, the >120 deg view angle between the two sides as seen from the deepest point of the valley is an existing criterion, but it is not unequivocal if more than two hills embrace the town.

Hence, two parallel requirements will be used: (i) Vertical difference between the lowest point of the town and the highest one around should be >100 m. At the same time, (ii) the same difference on the opposing side should be >50 m.

Fulfilment of these requirements was studied in three steps: (1) Settlements over 10,000 inhabitants were selected according to the Central statistical Office for January 1, 2014. The number of such settlements (towns almost in all cases) is 143 in Hungary. (2) Topography in and around these towns in a circle of 5 km radius was investigated, centred in the lowest point of the town. The data were taken from the open source SRTM model in 3’’ (78 m) resolution. Finally, (3) the above conditions (i) and (ii) were controlled by the ArcGIS for Desktop 10.1 software.

a) b)

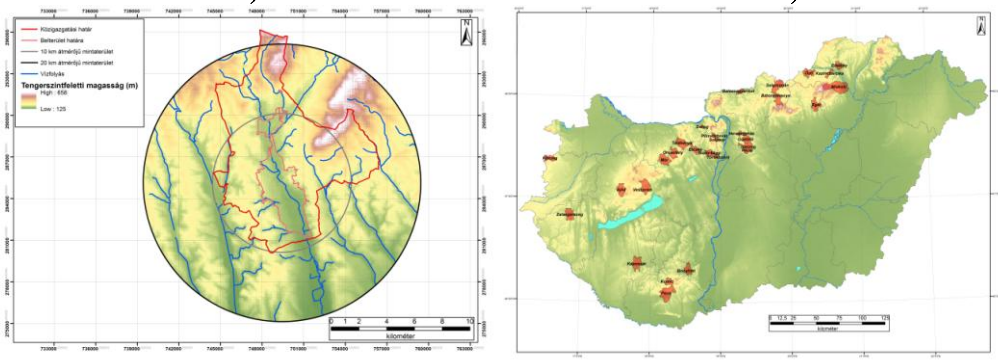

Fig. 1. ***(a) Illustration of valley-based settlement (Eger, in the example) with the 5 and 10 km radii from the lowest located point of the downtown. (b) The 30 settlements over 10,000 selected as valley based in Hungary (See also Table 1. in the next page).***

An illustration of the selection and the resulting 30 towns are presented in *Fig. 1*. Of course, they are located in the relatively hilly parts of the country with the following distribution among the geographical regions in Hungary: There are 10 valley-based towns in North-East Hungary (NE), 9 in North-Transdanubia (NT) and 4 in South-Transdanubia (ST). Besides these 23 settlements, existence and lifestyle of which is likely determined by their topography (e.g. mining, special agricultural products at larger distance, etc.), there are 7 settlements which belong to the agglomeration of Budapest (AB). Many features may be different in this group of valley-based towns, including air pollution (less industry but heavier everyday transport, rather focused both in time and space), but no air-quality station was found in these settlements. Number of inhabitants living in these 30 valley-based towns is 1,023,000 (January 1, 2014), i.e. 10 % of the population in Hungary. Not considering Budapest, there are 2 towns (Miskolc and Pécs) in the first 5 cities, which is 40 %. In the 20 most populated towns there are 7 valley based ones (35%). 26% of the first 50 towns fall into this category (13 towns), whereas in the first one hundred towns there are 21 valley-based towns. The list of 30 towns over 10 thousand finishes at the 143rd place of the whole list. Both thresholds contain 21-21% for the valley based towns. The complete list of the valley based towns is seen in *Table 1*.

Table 1. ***The 30 valley-based towns over 10,000. Abbreviations NE, NT, ST and AB stand for North-East Hungary, North-Transdanubia, South-Transdanubia and Agglomeration of Budapest, respectively.***

Town	Inhabitant	Area (ha)	Region
Miskolc	161265	23666	NE
Pécs	146581	16277	ST
Tatabánya	67043	9142	NT
Kaposvár	64872	11359	ST
Veszprém	60788	12692	NT
Zalaegerszeg	59275	10241	ST
Eger	54527	9221	NE
Salgótarján	36497	10083	NE
Ózd	33944	9165	NE
Gödöllő	32588	6192	NE
Ajka	28775	9505	NT
Kazincbarcika	27892	3664	NE
Komló	23889	4655	ST
Oroszlány	18139	7586	NT
Veresegyház	16670	2856	NE

Town	Inhabitant	Area (ha)	Region
Balassagyarmat	15857	2356	NE
Pécel	15216	4363	AB
Mór	14319	10861	NT
Pilisvörösvár	13885	2430	AB
Bonyhád	13630	7213	ST
Törökbálint	13108	2940	AB
Biatorbágy	12723	4412	AB
Bátonyterenye	12629	7892	NE
Kistarcsa	12045	1102	AB
Bicske	12009	7708	NT
Dorog	11870	1154	NT
Kőszeg	11719	5466	NT
Isaszeg	11292	5484	AB
Solymár	10049	1786	AB
Edelény	10001	5684	NE

3. AIR POLLUTION DATA

The measurement of air quality has been performed by the National Air Pollution Observation Network (OLM, 2015), which belongs to the Hungarian Meteorological Service. The evaluation was based on the three components registered in the manual measurement network: 24 hours mean nitrogen dioxide (NO_2) and monthly deposition of particulate matters (PM_{10}). Besides that, automatically registered NO_2 sulphur dioxide (SO_2) and PM_{10} concentrations were also elaborated. The concentrations are expressed in *μg/m*^{3} units, whereas the deposition is measured in gm^{-2}(30 days)$^{-1}$. Basic characteristics of these contaminants, together with their health and environmental effects are as follows, based on the EU Air Pollution Basics (*www.airqualitynow.eu/pollution_home.php*):

Nitrogen dioxide *(NO_2)*: NO_X is used to commonly describe nitric oxide (NO) and. NO is produced in much greater quantities than NO_2, but mostly oxidises to NO_2 in the atmosphere. NO_2 causes detrimental effects to the bronchial system. Together with NO, they play important role in formation of photochemical smog, as well, as in acid deposition (acid rains).

Sulphur dioxide (SO_2): Fossil fuels contain traces of sulphur compounds. SO_2 is produced when they are burnt. SO_2 is mostly emitted from power generation, whereas contribution of road transport sources is small. Exposure to SO_2 can damage health by its action on the bronchial system. Sulphuric acid generated from reactions of SO_2 is the main component of acid rain that affects all ecosystems. Acidity of lakes may lead to fish devastation. Acid rain may lead to degradation of buildings including historical monuments. Ammonium sulphate particles are the most frequent secondary particles in the air.

Particulate matter (PM_{10}): Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of <10 µm size) and $PM_{2.5}$ particles (<2.5 µm) are of major current concern, as they are small enough to penetrate deep into the lungs potentially posing significant health risks. In addition, they may carry surface-absorbed carcinogenic compounds into the lungs. The principal source of airborne PM_{10} matter is road traffic emissions, particularly from diesel vehicles. It makes monuments statues and buildings dirty and increases cleaning and maintenance costs. The limit values are still often exceeded in the cities.

All these variables are connected with heating and as their source is mostly located near the ground, the annual course of the pollutants is mostly characterised by winter maxima and summer minima (*Fig. 2*). In this behaviour a dynamical factor is not less important. This is the fact that vertical mixture of the pollutants is most limited in winter and most developed in summer.

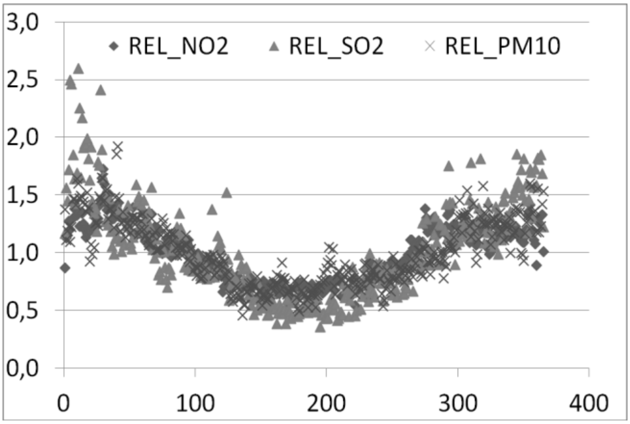

Fig. 2. ***Annual course of NO_2, SO_2 and PM_{10} expressed in proportion to the annual mean***

These variables are just a part of the operational observation program. Unfortunately, in the recent years there was a strong degradation of the network. The aim is to study possible effects of valley based nature on air pollution; hence stations with same data at the same site for 2007, 2010 and 2013 are used, only. So, effects of weather specifics in the individual years were decreased, to some extent.

Density and distribution of the air pollution network is not equal (*Fig. 3*). For NO_2 it is still acceptable, but for PM_{10} is rather rare. Good in bad, that they are mostly located in valley based towns, a part of which often suffers from smog.

There are a few larger towns (e.g. Miskolc, Pécs, Győr and Debrecen) where more than one station (of both automatic and manual kinds) existed even in the three proportionally selected years of the 2007-2013 period. In such cases the very specific transport focused station was omitted, as these extremely polluted spots are not caused by the valley, but the very local features if the given town. In general, our aim is to identify possible effect of valleys on the urban background values which are larger than the rural ones. This aim would be distorted using data observed e.g. in specific points of street canyons or urban motorways.

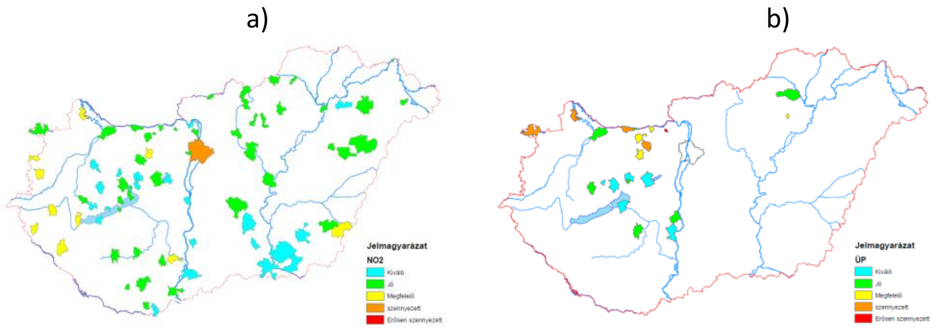

Fig. 3. ***Network of air pollution stations for (a) NO_2 and (b) PM_{10} in 2013. (The evaluation of individual towns is not interesting for our aims.)***

Having established these limitations of the stations, the numbers of valley based and control towns became rather limited (*Tab. 2*).

Table 2. ***The five kinds samples used for further analysis in the valley based towns, the controls and the second or lowland (plain) control***

Station/1000 inhabitants	NO_2 manual	NO_2 automatic	SO_2 automatic	PM_{10} automatic	PM_{10} deposition
Valley based	14 st: 540	8 st: 583	7 st: 547	8 st: 583	6 st:348
Control1	14 st: 549	8 st:574	6 st: 470*	7 st: 577**	8 st: 171***
Control 2	14 st: 540		6 st: 537*	7 st: 611**	
24 h limit[4*]	85 $\mu g/m^3$	85 $\mu g/m^3$	125 $\mu g/m^3$	50 $\mu g/m^3$	10 $g/m^2 30d$

*7/6 of the total population is considered, **8/7 of the total population, ***6/8 of the total population
4* According to the recent 4/2011. (I. 14.) VM rendelet = order of Ministry for Rural Development

Where it was possible, we tried to select control towns from the same regions where the valley based town was located. This was possible only for the manual NO_2 measurements. In this case a second control group, selected from the Hungarian Great Plain was also analysed. In the other cases, spatial location was not considered. In one or two control groups the only aim was to compile a group with similar total population to the valley based group. Altogether 16 valley based towns and 37 control ones are included.

4. RESULTS

The analyses are limited to three years of the investigations, 2007, 2010 and 2013. As Figs 4-6 indicate, there are considerable differences between the years both in the average values and in relative order of the valley based town and the different control ones. Hence, no averaging over the three years is performed and presented.

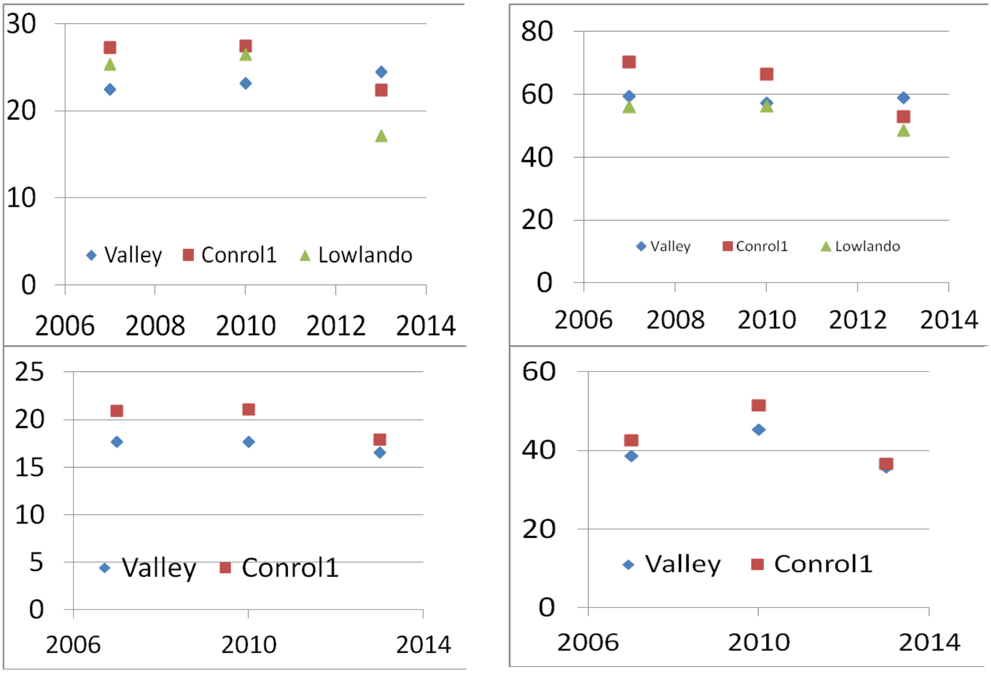

Fig. 4. ***Annual mean values (left panels) and 98% thresholds (right panels) of NO_2, according to the manual (upper panels) and automatic measurements (lower panels) in 2007, 2010 and 2013. Means for the valley based and control towns are seen in µg/m^3.***

Going into the details, year 2013 behaved rather differently from the other two years as the valley based towns showed the highest average concentrations of NO_2, together with the same highest peak in the 98 % threshold values, as well. In the two other years, 2007 and 2010 the valley based towns were less polluted than the similarly located and the lowland control groups. Here, all subgroups counted 14-14 member settlements. This means, that according to the manual observations no clear difference has yet been established.

One could think that the automatic observations of NO_2 should provide the same results. However, for this group of observations valley based towns are less polluted every year and according to both types (average and extreme) of indicators. This is especially interesting as one could think that emission of pollution by traffic could even be higher in the possibly denser population due to the topographic limits in and around the settlement in valley.

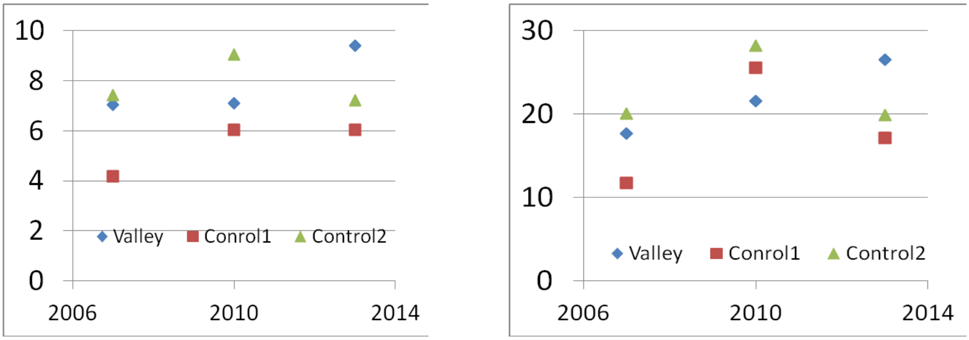

Fig. 5. ***Annual mean values (left panels) and 98% thresholds (right panels) of SO_2, according to the automatic measurements in 2007, 2010 and 2013. Averages for the valley-based towns and control ones are seen in μg/m^3.***

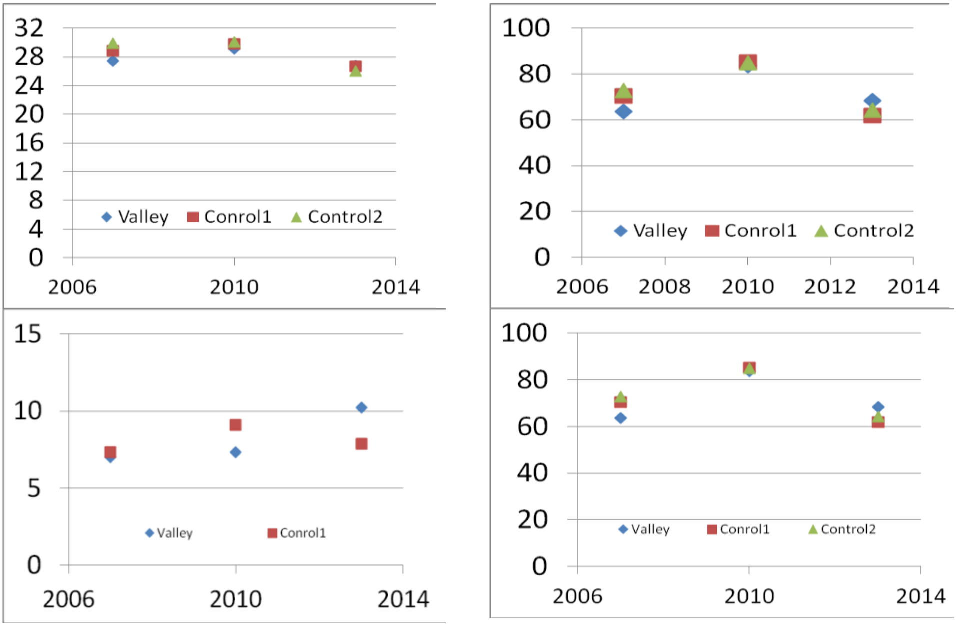

Fig. 6. ***Annual mean values (left panels) and 98% thresholds (right panels) of PM_{10}. According to the manual observations, monthly aerosol deposition is seen (upper panels). From the automatic measurements the PM_{10} concentrations are presented (lower panels), both in 2007, 2010 and 2013. Averages for the valley-based towns and control ones are seen in gm^{-2}(30 days)$^{-1}$ for the deposition and in μg/m^3 for the concentrations.***

Continuing with the low values of SO_2, there are both relative and absolute differences between the years, too. The valley based towns have different serial numbers according to both characteristics. From these numbers it is rather difficult to establish any advantage or disadvantage by the valley based type of location.

Practically the same can be told about the observed indicators of PM_{10}, too.

Let us finally analyse threshold step-over frequencies, as comprehended in *Tab. 3*. We can see four variables, only, as in case of sulphur dioxide not any step-over happened in the three investigated year. In majority of the years the valley-based towns exhibit the less frequent step-over which might be acknowledged to the slight valley-hill winds that cannot evolve in the settlements in a plain location.

Table 3. Frequency of limit (health threshold) step-over in the individual years. The thresholds are given in the last line of Tab 2. Lowest values of each year are set in italic. (No step-over happened in SO_2)

Step-over frequency	**2007**	**2010**	**2013**	**Step-over frequency**	**2007**	**2010**	**2013**
NO_2	**%**	**%**	**%**	**NO_2 aut**	**%**	**%**	**%**
Valley	*0,5*	*0,8*	*0,3*	Valley	0,0	0,0	0,0
Conrol1	1,8	0,9	0,4	Conrol1	0,1	0,0	0,0
Lowland	*0,5*	1,1	*0,3*				
PM_{10} aut	**%**	**%**	**%**	**PM10 depo**	**%**	**%**	**%**
Valley	*8,7*	*12,1*	9,4	Valley	0,0	*5,6*	0,0
Conrol1	10,7	13,9	*6,7*	Conrol1	0,0	15,5	0,0
Control2	12,7	12,9	7,5				

5. CONCLUSION

Objective definition of valley-based towns is given by the paper. Ca. 10 % of population in HU lives in such towns, representing over 20 % of the settlements inhabited by over 10 000 people. Operational air pollution stations allow selecting just 20-47 % of the valley-based towns, representing 35-60% of overall population lining in such settlements. Mean and extreme (98%) values differ too much between the investigated three years (2007, 2010 and 2013) that one cannot finally establish any difference between the valley-based towns and the control ones. The only difference between them, occurring in majority of chemical components unequivocally that frequency of step-over is less in valley-based towns, possibly due to the hill-valley winds.

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