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EDITOR'S NOTE

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- 1 Within the framework of the MONITRAF project, the environmental strains with regard to air and noise were investigated in the following six regions situated at the Fréjus, Mont-Blanc, Gotthard, and Brenner Alpine crossings: Piemonte (Susa Valley); Aosta Valley; Central Switzerland (Urner Reuss Valley); Ticino (Leventina, Riviera, Sottoceneri); Tyrol (Unterinn and Wipp Valleys); South Tyrol (Eisack and Etsch Valleys).
- 2 In all valleys, the situations in the central part of the valley and in the upper part close to the Alpine crossing were differentiated; as the internal, import and export traffic as well as the transit traffic may differ in importance regarding the effects on the environment depending on the location in the valley. The only exception was made for the Urner Reuss Valley since this valley is quite short compared to the others and is generally situated «close to the Alpine crossing».
- 3 The data used were provided by the relevant regional and national authorities.
- 4 The following components were investigated: traffic volume of light vehicles (particularly passenger cars) and heavy goods vehicles, nitrogen-oxide and particle emission, air concentration of nitrogen oxide and fine-particles (PM₁₀: particles with an equivalent diameter of up to 10 µm), climatic conditions regarding wind and inversions. It was also possible to gather a number of information about the noise situation.

Selected Measuring and Monitoring Points

- 5 The following table (tab.1) lists all the available air pollution, traffic, and temperature profile monitoring points (except for noise measurements).

Table 1. Selected air pollution, traffic, and temperature-profile monitoring points.

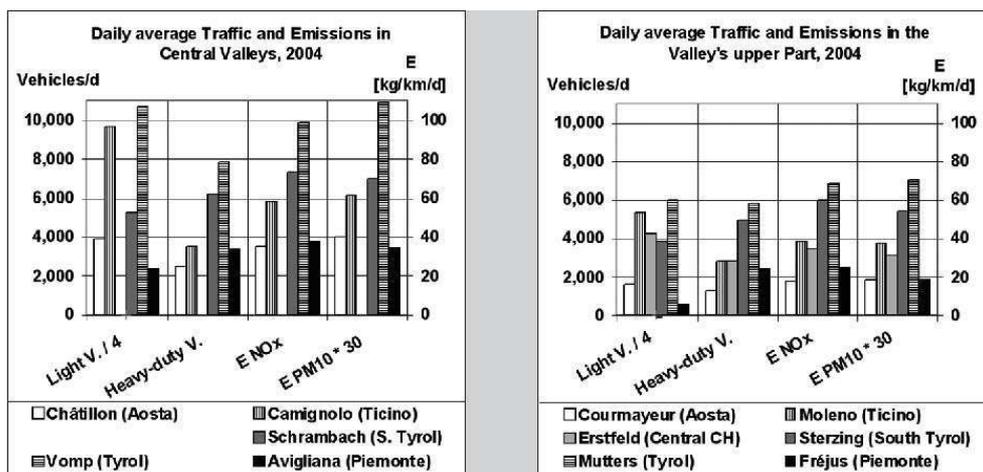
Alpine crssing	Region	Central region	Upper region	Temperature profile
Fréjus	Piemonte	Avigliana	Fréjus	Bardonecchia
Mont-Blanc	Aosta Valley	Châtillon	Courmayeur (Capoluogo)	Aosta
Gotthard	Central Switzerland		Erstfeld	Erstfeld
Gottardo	Ticino	Camignolo	Moleno	Moleno
Brenner	Tyrol	Vomp	Mutters	Schwaz
Brennero	South Tyrol	Schrambach	Sterzing	Bozen

Traffic Volume and Emission

- 6 The traffic volume recorded in the six MONITRAF regions was divided into 2-7 different vehicle categories. Thus, the traffic volume in all of the regions can only be divided into two categories in order to present a comparative illustration:
- Light vehicles, mainly passenger cars, motorcycles, and partly trucks, with the passenger cars dominating this category in all regions.
 - Heavy goods vehicles, i.e. trucks, trucks with trailers, and semi-trailer trucks. In the Italian regions, these vehicles could not be clearly identified from the traffic counts presented. Thus, the share of heavy goods vehicles in the category «pesanti» was estimated on the basis of traffic counts at the Brenner (A) and in Sterzing (I). In 2004, it accounted for 78% each month with only slight variations and for only 63% solely in August.
- 7 In principle, the emissions were determined by multiplying the number of vehicles with the emission factor of the respective component. With regard to the Swiss regions, the emissions of nitrogen oxides (NO_x) and particles were determined by multiplying the number of vehicles recorded in seven different categories with the emission factor applying to the respective vehicle category as per HBEFA 2.1 (Version CH). Most of the passenger cars from foreign countries, i.e. diesel-powered vehicles, moving on the transit axis were also included into the comparison with the national average. In the Austrian region, the number of vehicles recorded in four categories was also multiplied with the emission factor applying to the respective vehicle category as per HBEFA 2.1 (Version A). In the Italian regions, it was assumed that the fleets of heavy goods vehicles in the central and/or the upper part of the valleys were composed in the same manner as in Austria. There, emissions were estimated by means of these average emission factors. The distinction between the central and the upper part of the valley had to be made since the fleets are composed on average of heavier vehicles, the closer they are to the Alpine crossings.

- 8 The emission results showed a clear ranking: Brenner – Gotthard – Fréjus and Mont-Blanc, the last two forming together a result which is between those obtained for Gotthard and Brenner. The highest emissions are generally measured in summer, the lowest around the turn of the year.

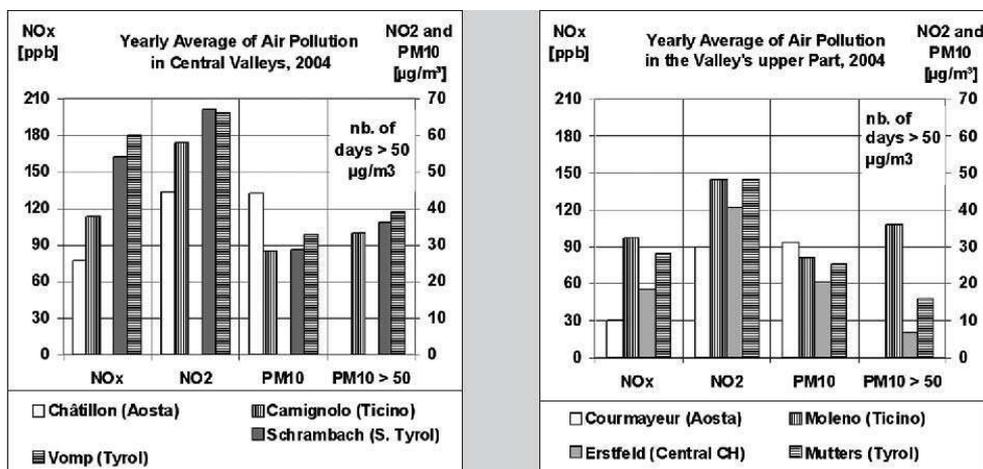
Figure 1. Annual average of daily traffic and daily NOx and particle emissions in the central part of the valleys, 2004. Please note: 1/4 of the light vehicles and 30 times the total particle emission is indicated.



Air Pollutants

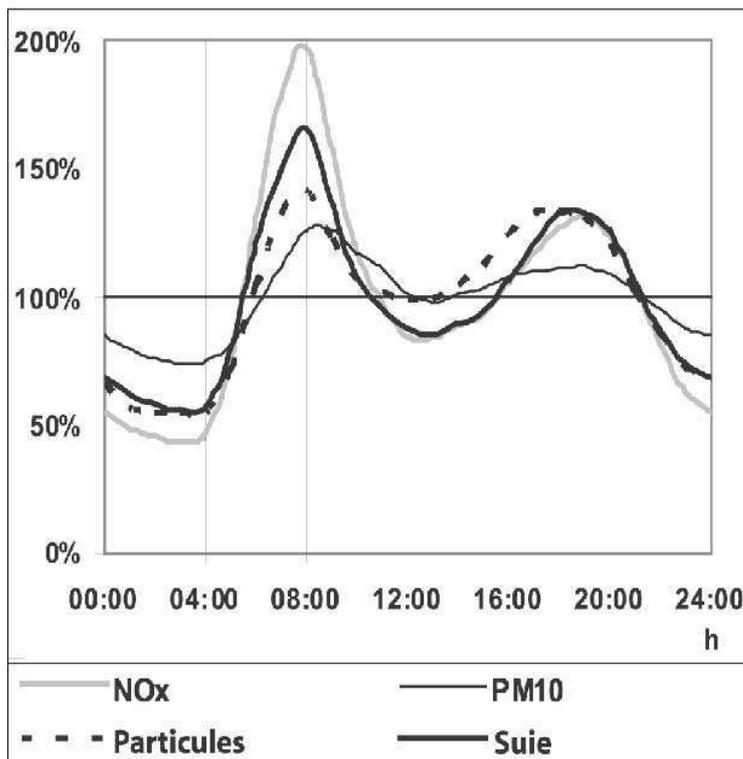
- 9 Fundamental data for air concentration of nitrogen oxide (all nitrogen oxides NO_x and nitrogen dioxide NO₂) and fine particles (PM₁₀; particles with an equivalent diameter of up to 10 μm) are available for comparison to all regions. These components are presented below. In the figure below (Fig. 2), only the monitoring points close to the road are presented: They are all located at a distance of 5 to 6 m from the road and therefore form a good basis for comparisons.

Figure 2. Annual mean of NOx, NO2, and PM10 and number of mean daily values above 50μg/m³ in the central and upper parts of the valleys, 2004.



- 10 In some instances, air pollution thresholds have been exceeded. The distribution of air concentration of NO_x only partially reflects the NO_x emissions. Since other sources of pollution apart from the roads play an insignificant part with regard to nitrogen oxides at all locations under investigation, the differences in distribution of emissions and air concentration can only originate from different propagation conditions. With regard to the particles (PM_{10}), other sources play a bigger role. As tests at the neighbouring monitoring point in Roveredo (Grisons) have shown, PM_{10} in Moleno (Ticino) also originates from a considerable amount of wood-fired furnaces; this may as well be the case in the Aosta Valley (Châtillon and Courmayeur).
- 11 Although emissions are highest in summer, air pollutions are higher in winter than in summer, the reason being that propagation conditions are worse in winter. NO_2 follows NO_x variations, albeit at a lower intensity, the reason being that the share of NO_2 in the entire NO_x declines if the NO_x concentration increases.
- 12 Since 2003, soot and particle concentrations are also measured in the Swiss regions. The particle concentration is dominated by very fine particles with a diameter of up to $1\mu\text{m}$, which do not contribute much to the total mass of PM_{10} . Soot (e.g. from diesel engines) is mostly included in the category of very fine particles.
- 13 The following illustration (Fig. 3) shows the relative daily variation of the four components NO_x , PM_{10} , particle concentration, and soot at the Erstfeld monitoring point in 2004.

Figure 3. Mean relative daily variation of NO_x , PM_{10} , particle concentration, and soot near Erstfeld (Central Switzerland) in 2004. 100 % corresponds to the annual mean value of the respective component.

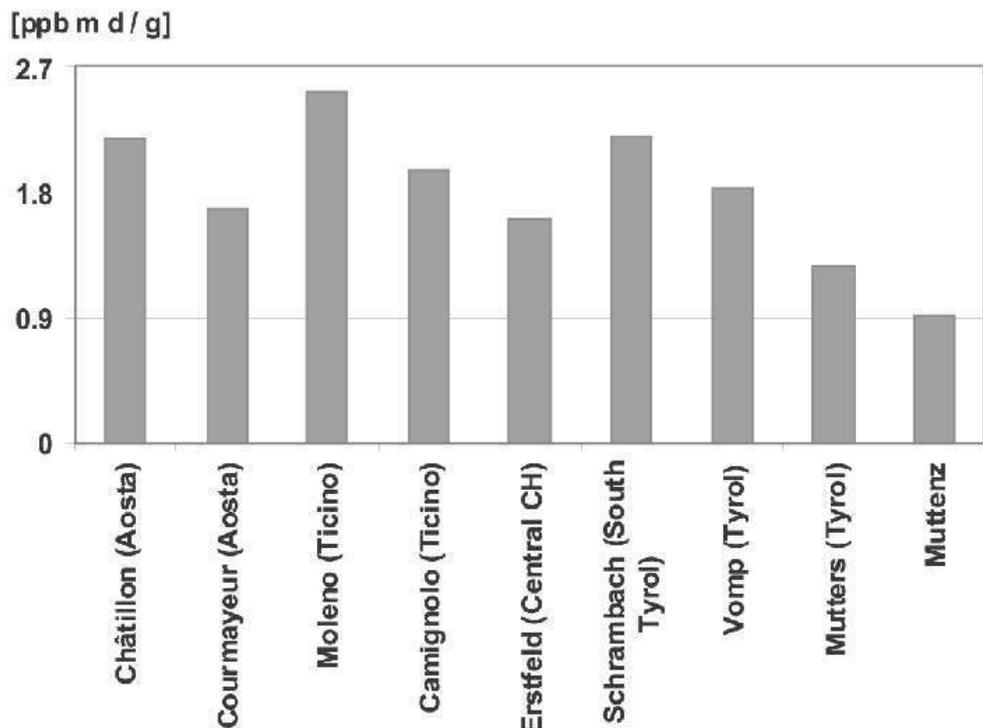


- 14 Soot and particle concentration, i.e. the very fine particles, show a daily variation similar to NO_x ; they are mainly produced by road transport. PM_{10} is also linked to other sources with a different daily variation.

Empirical Propagation Conditions: The Proportion between Air Pollution and Emissions

- 15 The proportion between the air pollution and the emission caused by a specific source (in this case road transport) is an empirical factor for the prevailing propagation conditions, which develop in a completely different manner in Alpine valleys than in the open country. A truck with a constant emission rate increases the air pollution to many different extents, depending on in what region and under which meteorological conditions it is moving.
- 16 Empirical models, already applied to a multitude of different regions by *Oekoscience*, are developed on the basis of such proportions (e.g. Thudium, 2005). Within the framework of this project, such models could not be developed. Nevertheless, we can use the annual proportion between air concentration and emission as a factor to determine the average propagation conditions at the stations close to the roads and at which NO_x concentrations are dominated by the roads, and thus compare the sensitivity of various Alpine valleys with each other and as well as to the open country.

Figure 4. Proportion between air concentration and emission of NO_x (annual mean) at the monitoring points close to the roads in the MONITRAF regions and the Muttenz monitoring point (near Basle) in the open-country part of Switzerland.



- 17 One emission unit causes approximately 2 to 3 times as much air pollution in the Alpine valleys of the MONITRAF project as in the open-country part near Basle (Fig. 4). What should be mentioned in this context is that compared with other European regions the

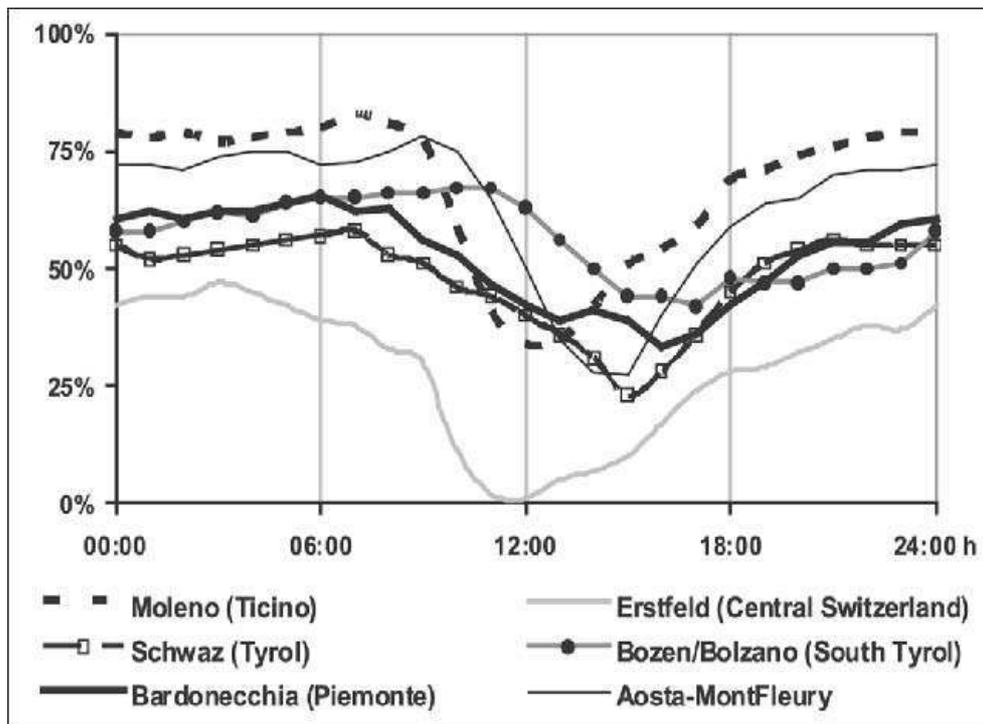
Basle region is not at all «a plain» and that quite significant air pollution originates from other sources near Muttenz, causing the height of the column. Concerning their air hygiene, the Alpine valleys can thus be considered as sensitive regions.

- 18 The foehn near Erstfeld and Courmayeur could be responsible for a decline in the mean proportion between air pollution and emission. Mutters (Tyrol) is a special case: The measuring point is situated on a mountain spur above the Sillgraben, a ditch that was dug so deep that the masses of air do not stagnate very often. Therefore, the air concentration/emission rate is very low there. Apart from that, the values range between the minimum near Erstfeld (Central Switzerland) and the maximum near Moleno (Ticino).

Climatic Aspects

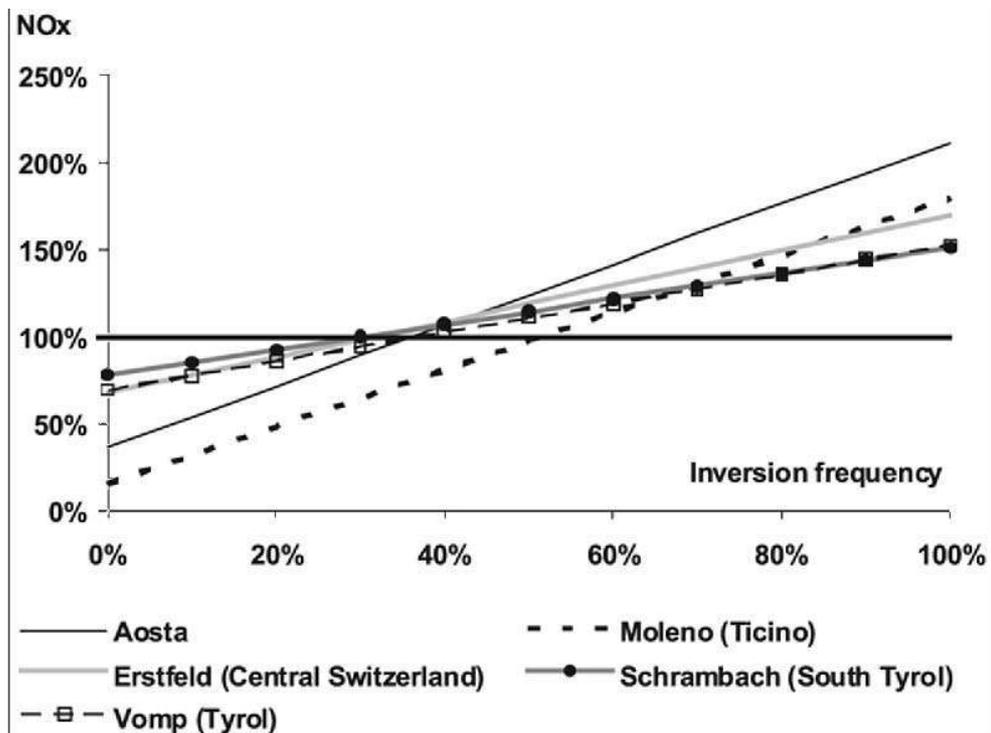
- 19 The most essential climatic aspects influencing the propagation of air pollutants are the thermal stratification and the behaviour of the wind. The thermal stratification will be discussed in detail below.
- 20 In the three regions, Erstfeld (Central Switzerland), Moleno (Ticino), and Vomp (Tyrol), specific temperature profile measurements with several sensors set up at a distance in height of 20 to 70 m are taken. In the other three regions, provisional temperature-monitoring points were used, which were situated at different heights (a few hundred meters in height apart) and at a greater spatial distance from each other. Thus, only estimates of the inversion volume in these three regions may be presented. By means of these temperature profiles, the near-ground inversions in the whole year of 2004 could be identified at intervals of 15 or 60 minutes depending on the respective time resolution. From that, it was possible to determine frequency distributions of near-ground inversions depending on the time of year and the time of day. Therefore, a comparable rate of the inversion volume is available for each region. The following figure (Fig. 5) illustrates this frequency distribution for the winter of 2004.

Figure 5. Frequency distribution of near-ground inversions in the six MONITRAF regions in winter of 2004.



- 21 In winter, the inversion frequency had its minimum near Erstfeld (Central Switzerland) and its maximum near Moleno (Ticino), analogous to the average air concentration/emission relations. In summer, Moleno (Ticino) similarly stands out with clearly the most frequent inversions. Inversions generally occur more frequently in winter than in summer but the regional differences are considerable at each season of the year.
- 22 In each region, there is a quantitative connection between inversion frequency and air concentration of NO_x . If the daily mean of NO_x is compared against the daily inversion frequency in each region, a cloud of dots appears that increases parallel with the inversion frequency. The regression line describes this dependency of the air concentration of NO_x on the inversion frequency.
- 23 The annual inversion frequency is exactly where the regression lines intersect the 100% line of NO_x (Fig. 6). The gradient of the straight line corresponds to the sensitivity of the air concentration of NO_x towards inversions: a higher gradient signifies an increase of NO_x per % of increase of the inversion frequency. Moleno (Ticino) and Aosta possess a greater sensitivity than the other three monitoring points. In general, the reaction of the air concentration of NO_x to inversions is considerable; a 100% inversion leads to an average air concentration rate of NO_x that is several times higher than that at 0% inversion, even though all other conditions remain unchanged.

Figure 6. Sensitivity of NOx air pollution in five MONITRAF regions compared to inversions, 2004.



Noise Pollution

- 24 Only the two Swiss regions possess a total of three monitoring points close to the road that continuously measure the noise pollution.
- 25 Near Moleno (Ticino) and Tenniken (Northwest Switzerland), noise-reducing road surfaces were subjected to tests. It was found that they reduce noise by approximately 4dB compared to standard road surfaces (Tami, Bozzolo *et al.*, 2005). To achieve the same noise reduction, the entire traffic volume would have to be reduced to a mere 38%; what deserves mentioning in this context is that the reduction should mainly be applied to high frequencies.
- 26 Measurements in the Susa Valley (Piemonte) demonstrated that railway noise is basically on the same scale as noise on the roads and partly even greater at night than at day. Important international railway lines cross through all MONITRAF regions except for the Aosta Valley, causing noise effects that should not be neglected. The Swiss Federal Transport Office, among others, is currently executing a large-scale programme to reduce railway noise based on the respective law.
- 27 The mean values do not adequately reflect the noise pollution. Like those of air concentration of pollutants, 30-minute noise levels fluctuate considerably around the annual mean. Within each 30-minute period, the noise values similarly show great variations, which is mostly not the case with regard to air concentration of pollutants, thus receiving a great deal of significance in connection with the noise pollution perceived by the residents, especially at night.

- 28 In general, the Alpine region can also be considered as particularly sensitive with regard to noise. According to Lercher (2005), this situation can be summarised as follows:
- Direct propagation of noise towards the slopes (no damping through soil or topology) «amphitheatre effect»;
 - Winds and inversions increase the propagation;
 - Greater differences between low general levels and local-impact levels;
 - Less adequate opportunities for protection (no really «quiet» side due to single houses and the noise reflected by the slopes);
 - Limited use of open-air areas in residences with large gardens.

Executive Summary

- 29 Within the framework of the MONITRAF project, the environmental effects of road transport were investigated with regard to air and noise in the transit valleys of Fréjus, Mont-Blanc, Gotthard, and Brenner for the year 2004. In addition to the transit traffic, the import, export and internal traffic plays in the central parts of these valleys a more important role than in the upper parts. The following components were investigated in the six valleys: traffic volume of “light vehicles” (mainly passenger cars) and heavy goods vehicles, nitrogen oxide and particle emissions, air concentration of nitrogen oxide and PM₁₀ fine-particles, and climatic conditions regarding wind and inversions. It was also possible to gather a number of information about the noise situation.
- 30 The following statements can be made with regard to all valleys under investigation:
- 31 The air pollution produced per emission unit is two to three times higher than in the open country.
- 32 - The reasons for that are the topography (obstruction of the lateral propagation of pollutants and wind channelling) and the climate (frequent occurrence of inversions), although the valleys differ considerably with regard to their respective topography (differently-aligned valley axes, different topographic structures).
- 33 - The share of transport crossing through the Alps in the overall transport differs considerably within as well as between the valleys.
- 34 - Road transport dominates the air concentration of nitrogen oxide, soot, and very fine particles; the PM₁₀ values do not present such a clear picture.
- 35 - At numerous monitoring points, the air pollution thresholds were exceeded.
- 36 - Regional wind fields with thermal updrafts at daytime (particularly in summer) and downwashes following gravity in winter are predominant.
- 37 - The frequency of near-ground inversions accounts for 30-40 %, in one case for 50 %, throughout the whole year, and can thus be rated as considerable.
- 38 - With regard to noise, the valleys are affected equally bad: The «amphitheatre effect» carries the noise to the higher reaches that would not be exposed to so much acoustic irradiation if the source of noise was situated at the same distance in the open country.
- 39 In aggregate, all transit valleys under investigation have turned out to be sensitive towards air and noise pollution.

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ABSTRACTS

The environmental consequences of road transport with regard to air and noise in the transit valleys of Fréjus, Mont-Blanc, Gotthard, and Brenner have been analysed and compared with each other for the year 2004. In respect of the share of transport passing through the Alps in transport as a whole, there are in part considerable differences between the valleys under investigation as well as within the individual valleys. The air pollution produced per emission unit of road transport is two to three times higher than in the open country, mainly because of the topography and the climate. At numerous monitoring points, the thresholds for the air pollution were exceeded. With regard to noise, the valleys are affected equally bad: The “amphitheatre effect” carries the noise to the higher reaches that would not be exposed to so much acoustic irradiation if the source of noise was situated at the same distance in the open country; furthermore, protection from the noise reflected by the slope is difficult. In aggregate, all transit valleys under investigation can be considered as sensitive regions.

Les conséquences du trafic routier, en termes de nuisances sonores et de qualité de l'air, ont été analysées et comparées pour quatre vallées de transit alpin (Fréjus, Mont Blanc, Gotthard et Brenner) durant l'année 2004. Au regard du trafic alpin dans son ensemble, des disparités considérables apparaissent entre les vallées étudiées, mais également à l'intérieur de ces mêmes vallées. Les immissions (concentration de polluants) produites par unité d'émission du trafic routier sont deux à trois fois plus élevées dans ces vallées alpines qu'en plaine. Ceci s'explique principalement par la topographie et le climat particuliers de ces vallées. À de nombreux points d'observation, les seuils d'immission ont été dépassés. Les vallées sont également affectées durement par la pollution sonore. « L'effet amphithéâtre » transporte le bruit à des altitudes supérieures, qui n'auraient pas été exposées à autant d'irradiation acoustique si la source de nuisances était située à égale distance, mais dans un « paysage ouvert ». De plus, la protection contre le bruit qui se réfléchit sur les pentes est malaisée. En résumé, toutes les vallées de transit étudiées peuvent être considérées comme des régions sensibles.

INDEX

Mots-clés: émissions de nuisances sonores, qualité de l'air, transit alpin, vallée de transit

Keywords: air hygiene, air pollution, alpine transit valleys, noise pollution

Geographical index: Aoste, Brenner, Fréjus, Gotthard, Gotthard, Mont-Blanc, Piémont, Suisse, Tessin, Tyrol

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