9 Overall evaluation and recommendations

9.1 Requirements for zoning and assessment

The air quality directives oblige the EU Member States to divide their territories in zones. Zones are primarily units for air quality management. For simplicity, the Framework Directive also uses zones to specify assessment requirements. The convenience of this approach brings along the difficulty of defining a system of zones that is both suitable for air quality management and for air quality assessment. When considering possibilities to combine areas in a zone, due regard needs to be given to similarities in air quality. It is, however, important to note that zones should primarily be regarded as administrative territories for which the Directive defines requirements (for assessment, reporting and management). So, when designating zones, ensuring a good link to action is the primary concerns; this is generally served best when associating zones with administrative areas.

According to Council Directive 96/62/EC on ambient air quality assessment and management (1996) measurements as part of air quality assessment are mandatory in the following zones:

- -agglomerations with a population concentration of more than 250 000 inhabitants or where the population concentration is 250 000 or less, a population density per km^2 (usually between 750 and 100 /km^2 which for the Member States justifies the need for ambient air quality to be assessed and managed
- zones in which levels are between the limit value and the limit values plus the temporary margin of tolerance (see chapter 2)
- other zones where levels exceed the limit values

The measures provided for may be supplemented by modelling techniques to provide an adequate level of information on ambient air quality.
A combination of measurements and modelling techniques may be used to assess ambient air quality where the levels over a representative period are below a level lower than the limit value.

According to Article 8 of the Council Directive 96/62/EC (1996) Member States shall draw up a list of zones and agglomerations as follows:
1. Areas in which the levels of one or more pollutants are higher than the limit value (plus margin of tolerance if fixed).
2. Areas in which the levels of one or more pollutants are between the limit value and the limit value plus the margin of tolerance.
3. Zones and agglomerations in which the levels of pollutants are below the limit values. In such areas the Member States shall maintain the levels of pollutants in these zones and agglomerations below the limit values and shall endeavour to preserve the best ambient air quality, compatible with sustainable development.

The assessment requirements per zone are specified in the Daughter Directives. These requirements depend on how far air quality levels are below a limit value. For each pollutant two thresholds are set in the Daughter Directives: the upper assessment threshold (UAT) and the lower assessment threshold (LAT). The thresholds are lower than the limit value and are defined as percentages of the limit value. The assessment requirements in a zone depend on whether, in the preceding years, an assessment threshold is exceeded anywhere in the zone. In the first year of implementation of the Daughter Directive the assessment regime depends on the results of the Preliminary Assessment (Van Aalst, et al., 1998) which are presented in this report. If the UAT of a certain pollutant is exceeded, the most intensive assessment requirements apply for this pollutant. If LAT is exceeded, but UAT is not, slightly less intensive assessment requirements are prescribed. If the levels are everywhere below LAT the least intensive requirements apply. Thus, different regimes for the assessment measures are defined, see Figure 9.1 and Table 9.1.

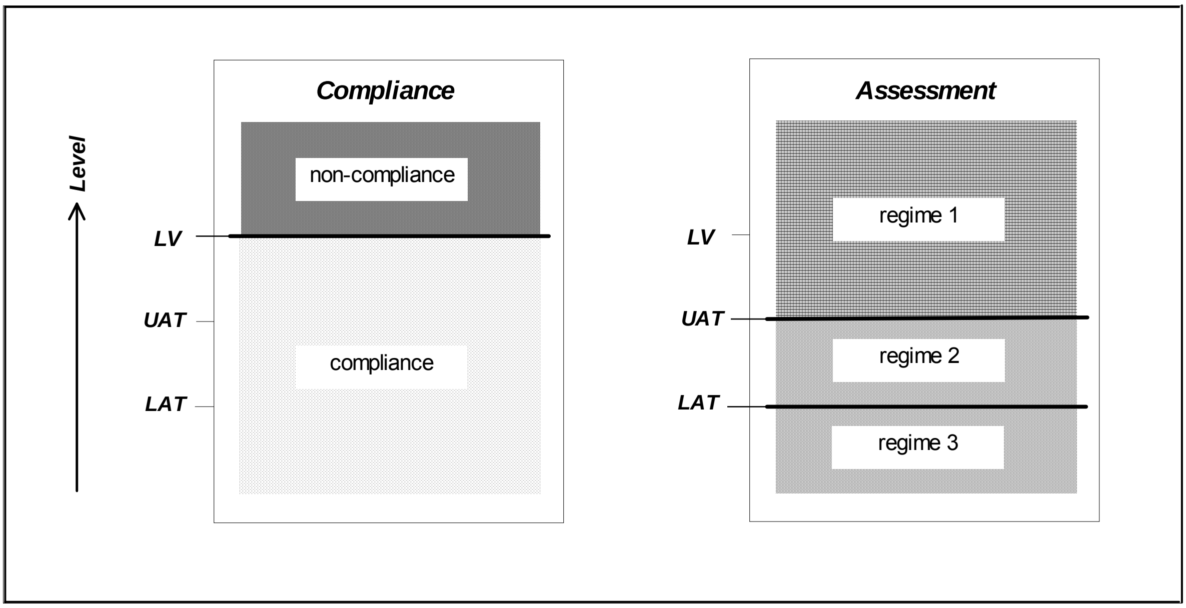

Figure 9.1. Implication of exceedance of the limit value (LV), the upper assessment threshold (UAT) and the lower assessment threshold (LAT) for compliance judgement and requirements in a zone

To differentiate the pollution situation within these regimes different concentration levels have been defined for Cyprus, see Table 9.1.

Table 9.1. Air quality assessment and pollution levels
UAT = Upper Assessment Threshold; LAT = Lower Assessment Threshold

Maximum pollution level in agglomeration or zone	Concentration Level No.	Concentration level	Assessment Requirements*
Regime 1: Greater than the upper assessment threshold (UAT)	1	Levels higher than the limit value + the margin of tolerance. For O_3: >Alert threshold	High quality measurement is mandatory. Data from measurement may be supplemented by information from other sources, including air quality modelling.
	2	Levels between limit val and the limit value + the margin of tolerance. For O_3:>Info threshold	
	3	Levels between UAT and limit value. For O_3:>120µg/m3 daily 8h average	
Regime 2: Less than UAT but greater than LAT	4	Levels between LAT and UAT	Measurement is mandatory, but fewer measurements may be needed, or less intensive methods may be used, provided that measurement data are supplemented by reliable information from other sources.
Regime 3: Less than LAT	5	Levels lower than LAT	
a. In agglomerations, only for pollutants for which an alert threshold has been set**	5a	"	At least one measuring site is required per agglomeration, combined with modelling, objective estimation, indicative measurements
b. In non-agglomeration zones for all pollutants and in all types of zone for pollutants for which no alert threshold has been set	5b	"	Modelling, objective estimation, and indicative measurements alone are sufficient.

The concentration levels 1 to 3 belong to regime 1. That means high quality measurements are mandatory there. In level 4 (regime 2) fewer and less intensive measurements are necessary, supported by other sources of knowledge. In regime 3 (concentration level 5, below LAT) in agglomerations at least one measurement site is required. The measurements there shall be combined with modelling, objective estimations and indicative measurements. In non-agglomerations of regime 3 (concentration level 5, also below LAT) modelling, objective estimation and indicative measurements alone are sufficient.

9.2 Summary of the preliminary assessment results

The presentation of the summarised results of Preliminary Assessment of Air Quality in Cyprus shall be structured as follows:

- Critical components with exceedances of threshold or limit values and locations where these high pollutant concentrations are observed and classification of the concentration levels according site categories:
  From diffusive sampling, continuous monitoring and PM sampling

- Identification of the sources of these critical components:
  From the components which show high values and the PM composition in the samples

- Meteorological conditions which influence the pollution load and critical times or seasons for high pollutant concentrations:
  From tethered balloon soundings, evaluation of meteorological data and continuous monitoring

9.2.1 Critical components, locations and classification according site categories

With results won within this submitted Preliminary Assessment of Air Quality in Cyprus the problems - critical components and affected locations - shall be indicated and suggestions for further monitoring and reduction measures shall be proposed. To identify zones where such measures shall be priorly recommended a classification of the average concentration levels in site categories (see Tables 9.3 to 9.6) and an air quality assessment according to EU limit and assessment values (summarised in Table 9.7) shall be presented.

The site categories are classified according their concentration levels (the highest at first). The interpretation and classification of the results is structured on component basis.

9.2.1.1 SO_2 and CO

Sulphur Dioxide (SO_2) is emitted from the combustion of sulphur containing fossil fuels, Carbon Monoxide (CO) from incomplete combustion in motor vehicles but also in small and low technical level furnaces) For both components no exceedances of limit or threshold values could be observed, even not in the high traffic areas.
But, the influence of the power stations could clearly be detected by increased SO_2 concentrations in their vicinity (see SO_2 maps in chapter 3). Although no SO_2 limit exceedances could be observed the stack plumes sometimes could be blown down in inhabited areas (if such areas are existing within a radius of about 5 km around the power station) and increased short term values could occur under special meteorological conditions. Though the frequency and the amount of such short term values is below the limits it should be tried to avoid such situations by emission reduction measures and a continuous SO_2 monitoring should be realised at critical sites where people are living (if it has even not been realised).
In general, the SO_2 concentration levels are higher in zones with more human activities than in zones with less activities: see Table 9.2. But all values are below any limits and assessment thresholds.

Table 9.2. SO_2 concentration levels at the different site categories – averages from one year diffusive sampling

Site category	SO_2 average in µg/m³	Number of sites Rural	Urban
Commercial (Municipality Market, Larnaca)	16,1		1
Traffic	13,2	1	16
urban background	11,4		6
Touristic beach (Governors Beach)	9,2	1	
Touristic	8,5	3	3
residential	7,5		18
village>700	6,9	13	
Industrial (Rural: Refinery near Famagusta)	6,6	1	7
Airport	5,1	1	1
village<700, incl. agriculture	4,8	12	
peripheral	4,2		7
mountainous, forests	3,2	4	
mountainous, no forests (Agia Marina, EMEP)	2,2	1	

9.2.1.2 NO_2 and NO_x

Nitrogen oxides ($NO + NO_2 = NO_x$) are emitted from combustion processes. The main sources are the automobile traffic and large furnaces like power plants. The main emitted component is Nitrogen Oxide - NO. But the limit values are established for the component NO_2 which is secondarily formed in the atmosphere by oxidation with ozone (O_3). The highest NO concentrations could be observed at high traffic roads. Due to the oxidation rate the NO_2/NO ratio increases with the distance to the road. But, at the same time the concentrations decrease due to the increasing pollutants dilution with the distance. So highest NO_2 concentrations occur also near the roads. From diffusive sampling points located in different distances to traffic roads an average NO_2 decline curve for Cyprus conditions has been calculated. It is depicted in Figure 9.2.

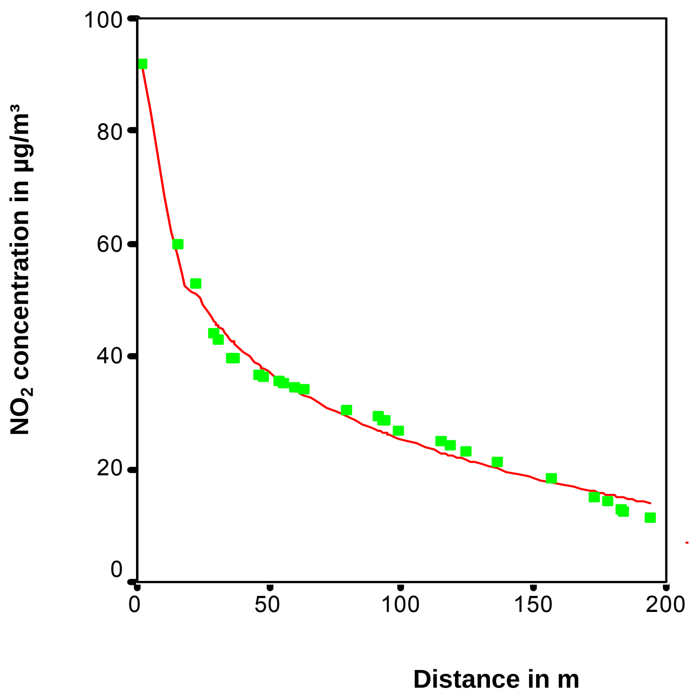

Figure 9.2. Average NO_2 decline with increasing distance to traffic roads – Results from diffusive sampling programme

The concentrations do not only depend on the emissions intensity but also on the ventilation factor at the road. Thus, the concentrations near the open highways are not as high as at the inner city roads between closed building lines. Therefore, at several high traffic roads in the cities of Nicosia, Limassol, Larnaca and Paphos exceedances of NO_2 threshold assessment values and even exceedances of annual limit values (to protect human health) have been determined by continuous monitoring at the according sites and by diffusive sampling in the site categories, see Table 9.3 and 9.9.

For the protection of the vegetation the sum of $NO + NO_2 = NO_x$ concentrations has to be considered. Thus, the high NO concentrations near the roads are determining the concentration levels and exceedances of the annual NO_x limits could be observed at the same high traffic sites where critical NO_2 values were determined, see Table 9.3.

Table 9.3. NO_2 concentration levels at the different site categories – averages from one year diffusive sampling

Site Category	NO_2 average in µg/m³	Number of sites	
		Rural	Urban
Commercial (Municipality Market, Larnaca + Armenias Street + Ezekia Papaioannou Street, Nicosia)	48,7	-	3
urban background	39,7	-	7
Traffic	38,9	1	29
recreation	32,9	-	3
residential	23,2	-	77
Industrial	22,7	1	14
touristic beaches	19,9	2	2
peripheral	16,8	-	37
Airport	15,0	1	2
village>700	14,0	20	-
Touristic	11,9	6	3
sensitive area (Akrotiri – Salt Lake)	10,7	1	-
village<700	8,1	41	-
agricultural	7,0	7	-
mountainous, forests	2,6	5	-
mountainous, no forests (Agia Marina EMEP)	2,0	1	-

9.2.1.3 Benzene – C_6H_6

Benzene is an aromatic hydrocarbon with a high toxic potential (carcinogenic). Benzene is a component in petrol fuels and is representative for the presence of other hydrocarbons (volatile organic compounds – VOC) which are emitted by petrol-driven cars generally. One part of its ambient air concentrations origins from the evaporation of petrol from vehicles and from petrol stations. But most of the benzene emissions are originating in the new formation of aromatics from aliphatic hydrocarbons during the combustion process in petrol-driven vehicle engines. The emissions load of the vehicles is high during idle, strong acceleration and during full load. Diesel-driven cars have lower benzene emissions than petrol-driven ones (on the other hand diesel cars have the problem of soot emissions!). Benzene is a direct indicator for vehicle exhaust gases. Together with the nitrogen oxides (NO_x) it causes the main air pollution problem of traffic emissions.

The highest benzene concentrations have been determined at poor ventilated high traffic roads in the cities, especially if there are stop and acceleration conditions for the vehicles. Thus, high traffic junctions with traffic lights like Makarios Avenue at Woolworth in Nicosia represent worst case conditions. In Table 9.4 it can be seen that busy sites - traffic sites, the inner cities (urban background) and commercial areas – are most affected by benzene concentrations. In industrial and residential zones going down to villages and touristic and rural sites the benzene concentrations decline down to very low concentrations.

Table 9.4. Benzene concentration levels at the different site categories – averages from one year diffusive sampling

Site category	Benzene average in µg/m³	Number of sites	
		Rural	Urban
Commercial (Ezekia Papaioannou Street, Nicosia +Municipality Market, Larnaca)	8,4		2
urban background	7,3		6
traffic	6,7	1	16
industrial	3,5	1	7
residential	2,8		22
touristic	2,2	4	3
village>700	1,7	15	
peripheral	1,7		7
agricultural	1,6	3	
airport	1,3	1	1
village<700	1,2	12	
mountainous, no forests (Agia Marina)	1,1	1	
touristic beach (Governors Beach)	1,0	1	
mountainous, forests (Troodos, Mount Olympus, Macheras, TCC north coast)	0,5	4	

9.2.1.4 Ozone – O_3

Ozone has on the one hand natural levels and is formed from nitrogen oxides and hydrocarbons under the influence of sun radiation. There is a so called photochemical balance between ozone and nitrogen oxides which is shifted by the presence of hydrocarbons. Near pollution sources the balance is on the side of the nitrogen dioxide. That means, a depletion of ozone takes places in the cities, at the highways and near industrial sources. With increasing distance to the sources the ozone formation can take place in the downwind plumes. But at the same time a dilution of the plumes and a mixing with the ozone background level occurs. If cities are not very large these latter effects are dominating and no ozone formation can be observed in their plumes. This was one important result of the German Ozone Experiment in Neckarsulm/Heilbronn 1994. Also model calculations came to such a result. This is also the fact in Cyprus. Before in the city plumes the ozone is formed which lasts around two hours the plume is diluted and mixed so that this ozone formation cannot be determined. Thus, high ozone levels in Cyprus are not determined by ozone precursors emitted in Cyprus but by the overall ozone level over the whole eastern mediterranean area. In accordance to this theory, the highest ozone levels in Cyprus could be observed at high elevated background sites: At Mount Olympus (1952 m asl) the ozone concentrations are except from few winter months permanently over the 8h target values.

In the cities the ozone levels are generally lower since the ozone depletion is dominating there. At other background sites the ozone level depends on the depletion potential. That means, if a site is influenced by NO_x sources the ozone level there is lower than the background level. Such influences could partially observed at the other background sites Stavrovouni Forest, Agia Marina, Larnacas Lapithou and Kantara. The depletion influence depends also on the elevation of the site. If a site is located above the nocturnal ground inversion layer it is decoupled from the depletion processes within these layers where the ozone concentrations are decreased over night. Whereas Mount Olympus is always above the ground inversion layers the other mentioned background sites are sometimes within such layers and are therefore exposed to lower ozone concentrations but to more measureable NO_x values. The ozone dependency on the elevation and on the presence of inversion layers could clearly be determined and demonstrated by the results of the tethered balloon soundings (see chapter 6).

Conclusion for ozone: The ozone levels in Cyprus are determined by the overall ozone occurrence. During high sun radiation and high temperature the ozone formation takes place over the whole eastern Mediterranean area and ozone is present everywhere in the background. If at several sites lower ozone concentrations than background levels are observed then this is due to the elevation of the site, to its exposure against wind advected ozone from outside or due to ozone depletion caused by local emissions of air pollutants in Cyprus. With other words the air pollutant emissions of Cyprus can only cause an ozone depletion but no measureable ozone formation. Therefore, ozone monitoring can not explain ozone formation in Cyprus, but it can be used to determine the exposure of people and to warn sensitive people of high concentrations in the free air.

In Table 9.5 the average ozone concentration levels at different sites from diffusive sampling are classified according their concentration level. These results confirm the explanation given above.

Table 9.5. Ozone concentration levels at the different site categories – averages from one year diffusive sampling

Site category	Ozone average in µg/m³	Number of sites	
		Rural	Urban
Mountainous, no forests	102,6	1	
Mountainous, forests	95,5	4	
Industrial (Larnaca close to Refinery)	92,7		1
Touristic	82,1	4	2
Village>700	81,0	8	
Village<700	78,8	8	
Peripheral (Athalassa, Meteorological Station)	78,4		1
Touristic beach (Alagadi Beach, TCC)	77,6	1	
Residential	74,4		4
Agriculture (Orange Plantages Kazivera Village TCC)	73,4	1	
Traffic + Urban Background (Nicosia General Hosp. + Kyrenia inner city)	60,9		2

9.2.2 Particulate Matter and Sources of pollutants

9.2.2.1 PM Concentrations

Particulate matter (PM) is the term for the sum of particles in the air. PM_{10} means particles with an aerodynamic diameter lower than 10 µm, $PM_{2.5}$ lower than 2.5 µm. If PM_{10} limit value exceedances are caused by natural events the first EU Daughter Directive provides a special regulation:
"Where the EU limit values for PM_{10} are exceeded owing to concentrations of PM_{10} in ambient air due to natural events which result in concentrations significantly in excess of normal background levels from natural sources, Member States shall inform the Commission providing the necessary justification to demonstrate that such exceedances are due to natural events. In such cases, Member States shall be obliged to implement action plans only where the limit values are exceeded owing to causes other than natural events" (the references to articles of the directives are not mentioned above).

In Table 9.6 it can be seen that at nearly all **urban traffic sites** the 24h PM_{10} limit values are exceeded (that means, more than 9.6% (35 values per year) of all values are higher than 50 µg/m3). Also the annual limits of 40 µg/m3 (valid from 1 January 2005) are exceeded at all urban traffic sites where samplings have been carried out.

At **industrial influenced sites** it depends on the dust forming activities whether PM_{10} limits are exceeded or not. Whereas at the Larnaca refinery site the PM_{10} limits were not exceeded, in Zygi the 24h and the annual limits are distinctly exceeded.

In some of the **urban residential areas** the 24h PM_{10} limit values are exceeded and at a few sites also the annual limits. But, there are also residential areas in different cities without any exceedances.

At **rural background sites** neither 24h nor annual PM_{10} limit values have been exceeded, even though several Sahara dust events occurred during the sampling periods. But, the frequency of such events was lower than 9.6%. That means, the 24h limit values are less than 35 times per year exceeded (which is the limit).

Table 9.6. Average PM_{10} levels at different site categories and number of days exceeding the EU PM_{10} 24h limit values for 2005 (Air Quality Directive 1999/30/EC)

Sample Location	Average value without Sahara dust µg/m³	Average value including Sahara dust µg/m³	98^{th} percentile µg/m³	No of samples	No. of Exceed. (> 50 µg/m³) without Sahara	% of exceed. without Sahara	No. of exceed. caused by Sahara events	No of Exceed. (> 50 µg/m³) with Sahara	% of exceed. with Sahara	% of exceed. caused by Sahara
Traffic										
Pafos Traffic	63.3	67.8	270.0	56	33	59	2	35	63	6
Larnaka Traffic	60.0	60.0*	91.5	84	55	66	0	55*	66*	0
NicosiaTraffic TCC	42.5	49.9	105.8	83	21	25	3	24	29	13
Limassol Traffiic	41.0	42.9	82.7	84	25	30	1	26	31	4
General Hospital	40.1	44.8	142.6	255	66	26	7	73	29	10
Industry										
Zygi	38.7	46.1	237.2	79	18	23	2	20	25	10
Larnaka Refinery	33.5	39.0	89.3	83	3	4	3	6	7	50
Residential										
Kyrenia	45.5	52.2	147.3	50	12	24	3	15	30	20
Larnaka Residential	41.7	46.5	195.4	80	18	23	3	21	26	14
Nicosia Residential TCC	38.7	38.7*	69.7	55	13	24	0	13*	24*	0
Limassol Residential	31.5	33.9	61.9	83	4	5	1	5	6	20
Famagusta	29.9	35.5	146.6	56	3	5	3	6	11	50
Latsia	28.9	30.9	95.8	84	2	2	2	4	5	50
Morphu	27.0	32.1	119.4	56	1	2	3	4	7	75
Pafos Residential	21.7	25.0	204.9	56	0	0	1	1	2	100
Urban background										
Limassol Urban Background	38.0	38.0*	67.1	81	8	10	0	8*	10*	0
Archangelos	33.5	47.6	186.1	56	4	7	3	7	13	43
Trahoni	28.6	28.6*	54.3	28	4	14	0	4*	14*	0
Kornos	25.2	25.2*	54.9	42	2	5	0	2*	5*	0
Athalassa	20.1	30.4	122.3	41	2	5	4	6	15	67
Rural background										
Sfalangiotissas	32.2	36.4	139.5	55	10	18	1	11	20	9
Sotira	26.7	35.3	173.1	56	3	5	4	7	13	57
Kofinou	21.7	21.7*	47.2	42	0	0	0	0	0	0
Suni	21.1	21.1*	62.2	53	2	4	0	2*	4*	0
Lefka	19.2	19.2*	41.3	56	1	2	0	1*	2*	0
Kidasi	18.0	18.0*	50.9	55	2	4	0	2*	4*	0
Akaki	16.1	27.4	152.4	70	1	1	5	6	9	83
AgiaMarina	15.8	20.0	83.2	241	7	3	5	12	5	42
Macheras	15.8	15.8*	40.7	57	2	4	0	2*	4*	0
Tsakistra	11.9	20.7	134.3	56	1	2	5	6	11	83
Drousia	11.2	18.2	109.8	56	0	0	5	5	9	100
					∑320		∑66**	∑386		17%

*) no Sahara dust events during the sampling periods; **) 66 events from 386 exceedances: 17% exceedances are caused by Sahara dust events

9.2.2.2 Sources of Particulate Matter

By analysing the PM composition in the ambient air and comparing this with the composition of PM emissions the main PM pollutant sources can be estimated.

The **main sources for PM in the air** are:

1. Anthropogenic sources:

- Automobile traffic
  - Exhaust gas emissions, main component soot from diesel engines, but also lead
  - Resuspended PM from road (mineral dust), brake and tire abrasion
- Aircraft emissions
- Fossil fuel combustion in
  - Industrial boilers (furnaces)
  - Hotel heatings
  - Domestic heating
- Waste combustion
- Industrial processes
  - Quarries, cement factories and other special industries
- Unpaved roads
- Agriculture, works and uncontrolled field burning
- Controlled and uncontrolled waste burning
- Fire accidents and forest fires

2. Natural Sources

- Resuspended soil: important because of the dryness in Cyprus; there are various soil compositions due to the complex Geology in Cyprus
- Sea-salt aerosols
- Sahara dust intrusions

To find out how many of the exceedances are resp. how much of the collected PM_{10} is due to natural events resp. due to natural sources analyses of the PM composition have been carried out for several sampling sites. For the three sites Nicosia General Hospital (traffic), Famagusta (residential) and Agia Marina (rural background) the contribution of natural sources and anthropogenic sources to the PM_{10} load have been calculated statistically with the method of Factor Analysis.
Which elements are typical for several sources has been found out on the one hand from the literature and on the other hand from numerous analyses of Cyprus soils at different sites. The results are summarized in the following Tables 9.7 and 9.8.

As a result of factor analyses it can be stated that at the investigated **traffic site** which is representative also for other urban traffic sites (but not for very high load) about 60% of the **annual average PM_{10} load is caused by dust by traffic. At least 20% are coming from natural sources**. A part of the traffic induced dust is of natural origin but resuspended from the roads by the traffic and therefore allocated to traffic PM_{10}.

Apart from this permanent load there are remote transport events, mainly **Sahara dust events**, which cause **exceedances of the 24h limits of around 17% per year**. This could be found at different sites - urban and rural - in Cyprus because such events are affecting more or less the whole island.

Table 9.7. Source apportionment of PM_{10} at the sites Nicosia General Hospital, Famagusta and Agia Marina

Nicosia General Hospital Traffic			**Famagusta Residential**			**Agia Marina Rural Background**		
Factor	Sources	Contri-bution	Factor	Sources	Contri-bution	Factor	Sources	Contri-bution
1	Local mineral dust, resuspension by traffic	23%	1	Local mineral dust	29%	1	Local soil dust	28%
2	Sea-salt with natural dust	19%	2	Sea-salt with soil dust	29%	2	Soil from surroundings	23%
3	Combustion and traffic (diesel vehicles)	17%	3	Traffic (gasoline) and local resuspended dust	11%	3	Sea-salt with mineral dust	20%
4	Traffic (Diffusive): Tire and brake abrasion	12%	4	Local soil dust, resuspension by traffic	11%	4	Combustion	9%
5	Traffic (Exhaust): Gasoline vehicles	10%						
	Total explained contribution	81%		Total explained contribution	80%		Total explained contribution	80%
	Not allocated	19%		Not allocated	20%		Not allocated	20%
	Total traffic induced dust Inclusive resuspension from roads	**60%**		**Total traffic induced dust Inclusive resuspension from roads**	**22%**		**Total traffic induced dust resuspension from roads**	Not allocated
	Average concentration without Sahara dust	40,1 µg/m³		Average concentration without Sahara dust	29,9 µg/m³		Average concentration without Sahara dust	15,8 µg/m³
	Average concentration with Sahara dust	**44,8 µg/m³**		**Average concentration with Sahara dust**	**35,5 µg/m³**		**Average concentration with Sahara dust**	**20,0 µg/m³**
	Sahara dust contribution	**4,7 µg/m³**		**Sahara dust contribution**	**5,6 µg/m³**		**Sahara dust contribution**	**4,2 µg/m³**

At the **rural and the residential sites** – Agia Marina and Famagusta as example – around **70%** of the annual average load is caused by soil particles from the surrounding and by sea-salt particles. The soil resuspensions are caused by the dry climate in Cyprus. They can only a little be influenced, e.g. by pavements of roads and to carry out field works not under extremely dry conditions. But, most of this natural dust load can not be influenced.

Table 9.8. EU PM_{10} 24h limit value exceedances at three different characteristic sites in Cyprus

Location	No. of exceedances (>50 µh/m³) without Sahara dust	% of exceedances without Sahara dust events	No. of exceedances caused by Sahara dust	No. of exceedances (>50 µh/m³) with Sahara dust	% of exceedances with Sahara dust events	% of exceedances caused by Sahara dust events
General Hospital	66	26	7	73	29	10
Famagusta	3	5	3	6	11	50
Agia Marina	7	3	5	12	5	42

9.2.3 Meteorological conditions which influence the pollution load and critical times or seasons for high pollutant concentrations

9.2.3.1 Winter season

If no stormy weather situation is dominant caused by the position and intensity of high and low pressure areas the winds in Cyprus at ground level are mainly dominated by local wind systems. In **Nicosia** the local wind system is generated by mountain- valley up and down-winds. During night-time, the winds come from the cool mountains located in south west. Stable boundary layers exist as a surface inversion during the whole night. The wind speed is quite low during the whole night. This leads to the formation of a stable boundary layer during the whole night. Within this stable layer, in the cities (Nicosia) concentrations of pollutants like NO_x , Particulate Matter (PM), Benzene, accumulate and reach to threshold limits. On the other hand, ozone is depleted within this stable layer. Above the stable boundary layer, concentrations of pollutants are quite low while ozone is present above the layer in a so called ozone reservoir. So the top of the mountains rise above the stable boundary layer and the air is quite fresh and clean at the top of mountains. If high-rise buildings would be built across the flow lines then this mountain breeze would be obstructed and the transport of this fresh air from the cool mountains to the valley would be hindered.

During daytime, the winds are coming from the valley (plane) located north east of Nicosia. The observed wind speeds were quite high during the day and the stable layers were no longer existing. So the pollutants concentrations are decreased at ground level because of the vertical and horizontal mixing of the pollutants in the so called “Mixing layer”. Some hundred meters above the ground the concentrations are reduced to almost zero. Sometimes a low level jet is present 100 m above the ground, which can support the cleaning effect at that height.

In general, it could be observed that in the winter season the pollutant concentrations in the cities (apart from particulate matter) are higher than in the summer season when more ventilation is induced by the summer heat and the duration of inversions is shorter because of the shorter nights.

In **Limassol** and also in the other **coastal cities like Paphos, Larnaca, Kyrenia and Famagusta** the winds during night are coming from the land respectively from the mountains: They are land or mountain breezes. The observed wind speeds are low during night.

Inversion layers exist at the ground level during the night. So the accumulation of pollutants at the ground level occurs within these stable layers. In Limassol during daytime the winds are coming as a sea breeze from south with relatively high speed. The inversion layer has dissolved and thus this sea breeze has a cleaning effect within the city. On the other hand, sources of high pollution like power plants and factories located on the shore site blow their emissions along with the sea breeze and are touching sometimes the cities.

9.2.3.2 Summer season

During summer the local wind systems are covered up by the overall weather situation and the winds in the upper atmosphere. In **Nicosia** during night-time, the winds are coming from west direction along the channel which is located between the two mountain ranges as the plane around Nicosia. Inversions are formed during night-time at ground level or some hundred meters above the ground. Because of these stable conditions during night increased pollutant concentrations (compared to day time) could be observed. During the daytime the inversion layers are dissolved and a mixed layer is formed with an extended mixing height compared to winter conditions. The winds during day time are dominated by gusty winds coming from the warmed plane in NW to NE direction.

In **Limassol** during night-time the winds are coming from the north west direction as a mountain breeze and from north east direction as a land breeze with low wind speeds. The mountain breeze was not so clearly developed as in the winter season.

Also in the coastal city inversions develop during night-time on the ground level and thus, higher pollutant concentrations occurred consequently.

During daytime, the winds come from the sea as a sea breeze with high wind speed. The sea breeze phenomenon was further enhanced in summer by the longer daytime duration and more heating of the land compared to winter season. Inversion layers can occur during the daytime at some hundred meters above ground level where the overall wind is blowing over the sea breeze. Where both winds with different temperatures are touching the elevated inversion layer is formed.

High rise buildings and building walls should be avoided at the coastal line not to block the ventilation by the land-sea breezes.

9.3 Proposal for zoning

9.3.1 Concentration levels at different selected sites in Cyprus

In Table 9.9 the concentration levels and the exceedances of limit or target values or assessment thresholds as most important results of continuous monitoring, PM and diffusive sampling are summarised for different selected sites in Cyprus. The concentrations of the different pollutants are classified into a fine structure of concentration levels according Table 9.1. As shown in Table 9.1 these concentration levels are the base for further requirements for monitoring stations, simplified measurements or estimation and modelling of pollutant loads.

9.3.2 Proposal for zoning

The EU directives do not pose formal limitations to zone definitions, so the geographical definition is up to the EU Member States and shall be proposed in the following based on administrational areas. Cyprus is divided in six districts which are shown in the map of Figure 9.3. Since these districts are administrative units it is proposed to define them as zones according to the EU air quality directives. From the administrative view it would not make sense to use concentration levels as base for zones since the different levels are overlapping the districts and thus shared responsibilities for zones would be difficult to manage. So, the districts shall be defined as zones; the data of the districts are listed in Table 9.10. This division means that in each zone different urban and rural categories with different regimes of air pollution concentration levels are existing.

Table 9.9. Most important results of continuous monitoring, PM and diffusive sampling:

Monitoring or Sampling Site	**NO_2** Limit 2003: 54µg/m3 2010: 40µg/m3 UAT: 32µg/m3 LAT: 26µg/m3	1) Con cent le-vel No.	**NO_x(vege -tation)** Limit:30 UAT:24 LAT:19.5 All in µg/m3	**Benzene** Limit up to 2005: 10µg/m3 2010: 5µg/m3 UAT: 3.5µg/m3 LAT: 2 µg/m3	1) Con cent le-vel No	**PM_{10}** Limits for 2005 24h limit: 35 x 50 µg/m3 = 9.6% UAT:7x30µg/m3=1.9% LAT:7x20µg/m3=1.9% annual limit:40µg/m3 UAT:28; LAT20µg/m3	1) Con cent le-vel No	**Ozone O_3** 8h target value: 25 x 120µg/m3 Info threshold: 180µg/m3 Alert threshold: 240µg/m3	1) Con cent le-vel No
Urban Sites - Traffic									
Nicosia General Hospital	45 µg/m3 UAT exceeded	2		6.5 µg/m3	2	24h limit:29% exceedan ann. limit: 7% exceeded	1 1	No exceedances	5
Nicosia Makarios Ave Woolworth	58.7 µg/m3 Annual limit value exceeded	1		18.6 µg/m3	1	no sampling point		no sampling point	5
Nicosia TCC Busstop Old City	23.8 µg/m3 30.8 µg/m3	5 4		2.1 µg/m3	4	24h limit:27% exceedan ann. limit:39% exceed	1 1		
Larnaca Urban Backg	48.5 µg/m3 35 µg/m3	1 2		8.8 µg/m3 4.1 µg/m3	2 3	24h limit:66% exceedan ann. limit:50% exceed	1 1	no sampling point	5
Limassol Urban Backg	51.7 µg/m3 Annual limit excd 40.7 µg/m3	1	Ann. limit exceeded	8.0 µg/m3 5.5 µg/m3	2 2	24h limit:29% exceedan ann. limit: 3% exceeded	1 1	no exceedance	5
Paphos	30 µg/m3 LAT exceeded	4	Annual limit value exceeded	7.0 µg/m3	2	24h limit:63% exceedan ann. limit:70% exceed	1 1	no exceedance	5
Morphou	22 µg/m3	5		2.5 µg/m3	4	24h limit not exceeded ann. limit: not exceeded	3 3		
Urban Sites - Residential									
Nicosia TCC	< 20 µg/m3 no exceedance	5		1.8 µg/m3	5	24h limit:29% exceedan ann. limit: near limit	1 3		
Famagusta	< 20 µg/m3 no exceedance	5	no exc.	1.6 µg/m3	5	24h limit: near limit; ann. limit: not exceeded	1 3	no exceedance	5
Kyrenia	< 20 – 24 µg/m3 no exceedance	5	no exc.	1.2 - 2.9 µg/m3	5 – 4	24h limit:39% exceedan ann. limit:34% exceed	1 1	no exceedance	5
Larnaca	27 – 31 µg/m3	4		2.0 - 3.9 µg/m3	4	24h limit:29% exceedan ann. limit: 7% exceeded	1 1	No sampling point	5
Limassol	27 – 39 µg/m3	4 - 3		2.0 - 5.8 µg/m3	4 - 3	24h limit: not exceeded ann. limit: not exceeded	3 3	no exceedance	5
Paphos	< 20 µg/m3 no excceedance	5		1.9 µg/m3	5	24h limit: not exceeded; ann. limit: not exceeded	3 4	no exceedance	5
Urban Sites -- Peripheral									
Nicosia Athalassa Meteo. Station	< 20 µg/m3 no excceedance	5		1.6 µg/m3	5	24h limit: 12% exceedances ann. limit: not exceeded	1 3		
Industrial Influenced Sites									
Larnaca Refinery	< 20 µg/m3 no excceedance	5		2.2 µg/m3	4	24h limit: not exceeded; ann. limit: near limit	3 3		
Zygi	< 20 µg/m3 no excceedance	5		No sampling point		24h limit:25% exceed; ann. limit:15% exceed	1 1		
Rural Sites - Background									
Mount Olympus 1952 m asl	< 2 µg/m3 no exceedances	5	no exc.	0.3 µg/m3	5	No sampling point		8 h target val. March to Oct. permanently exceeded, 63 % per year	2
Stavrovourni Forest	3 µg/m3 no exceedances	5	no exc.	0.2 - 0.5 µg/m3	5	No sampling point		8 h target val. in summer mostly exceeded, 31 % per year	3
Agia Marina EMEP station	< 2 µg/m3 no exceedances	5	no exc.	1.1 µg/m3	5	24h limit: not exceeded; ann. limit: not exceeded	3 4	8 h target val. in summer mostly exceeded	3
Larnakas Lapithou	< 2 µg/m3 no exceedance	5	no exc.	1.2 µg/m3	5	No sampling point		8 h target val. in summer several times exceeded, 13 % per year	3
Kantara	< 2 µg/m3 no exceedances	5	no exc.	No sampling point		No sampling point		8 h target val. in summer sev. times exceeded	3

Exceedances of limit or target values or assessment thresholds **1): The concentration level classification is according Table 9.1**

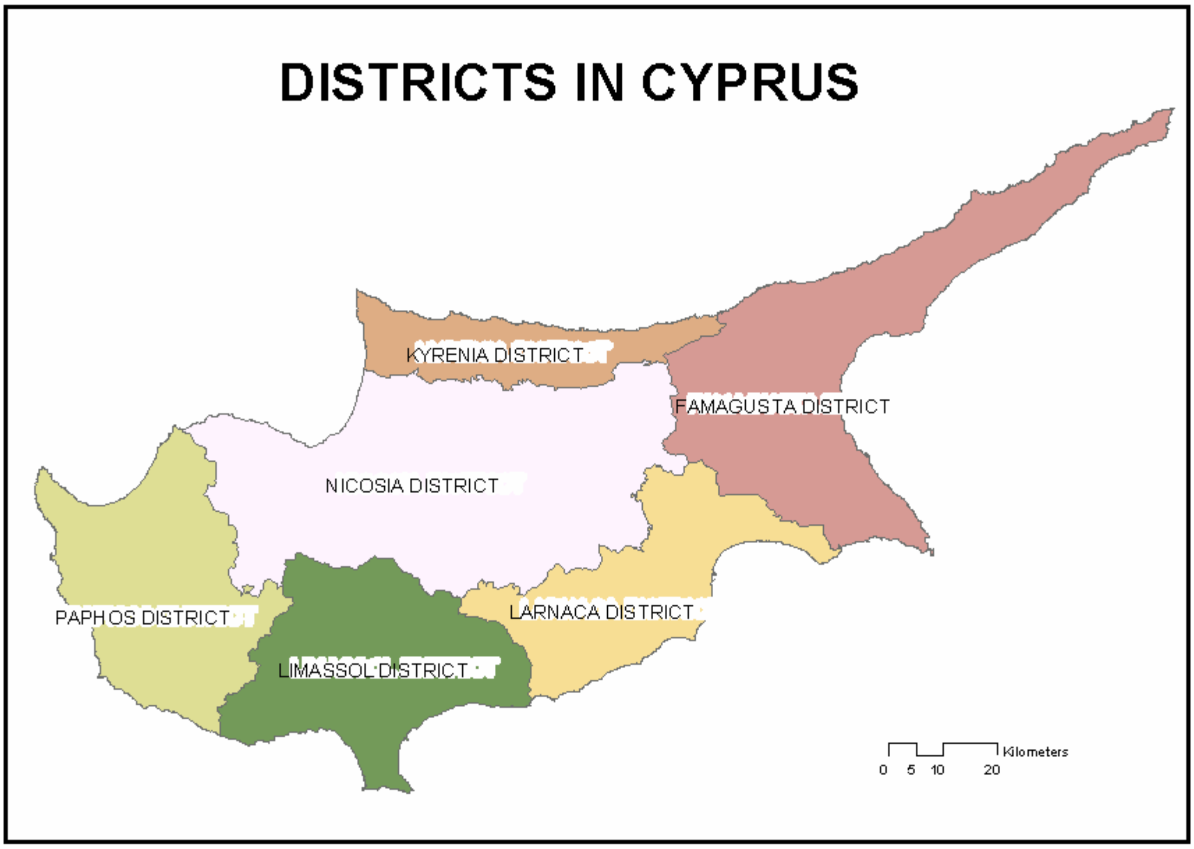

Figure 9.3. Administrative districts in Cyprus. Data Source: Geographical Service of Cyprus 2003

Table 9.10. Districts characterisation

District/Zone Number	District Name	Population	Area in km^2
1	Nicosia	208 770	2 708
2	Larnaca	60 225	1 118
3	Limassol	107 267	1 388
4	Paphos	60 320	1 391
5	Kyrenia	37 275	641
6	Famagusta	120 393	1 983

9.3.3 Proposal for monitoring stations in the zones

According to the concentration levels classification of Table 9.9 a proposal for the allocation of monitoring stations within the zones (districts) defined in Figure 9.3 and Table 9.10 has been worked out. It shall be presented in Table 9.11, separated for GCC and TCC sites.

Table 9.11. Proposal for automatic continuously operating monitoring stations within the zones

Zone number and name	Area	Category	Concentration Level Number Results of Preliminary Assessment				Monitoring site proposed	Type of moni-toring station	No. of sta-tions
			NO_2	Ben-zene	PM_{10}	O_3			
GCC Greek Cypriot Community									
1 Nicosia District GCC	**Urban Nicosia** (Agglo-meration)	Urban **Traffic:** General Hosp.	2	2	1	5	General Hospital, for observation of long term development	Multi com-ponent	1
		High traffic with population exposure	1	1	-	-	Makarios Avenue (Inner city)	Mini traffic station	1
		Urban **Residential**	4-5	5	1	4	e.g. school area in Strovolos	Multi com-ponent	1
	Rural	Cyprus Background/ EMEP	5	5	3-4	3	Agia Marina	Multi compon background	1
2 Larnaca District	**Urban Larnaca**	Urban Traffic/Background	2	3	1	-	Inner City	Mini urban station	1
		Urban Traffic/Residential	4	4	1	4	Not fixed	Mobile Multi Comp.	1
	Rural, industrial influenced	Village			1		Zygi	Multi Component	1
	Rural	Background South-East	5	5	-	3	Stavrovouni Monastery	Mini Backgr.: O_3, NO_x,Mete	1
3 Limassol District	**Urban Limassol**	Urban **Traffic**	1	2	1	4	Traffic	Multi Comp.	1
		High traffic with population exposure	1	1	-	-	Inner city	Mini traffic station	1
		Urban Residential	4 - 3	4 - 3	3	4	Not fixed	Multi Comp.	1
	Rural	Elevated Background **Transboundary Pollutant Transport**	5	5		2	Mount Olympus 1952 m asl	Mini Backgr.: O_3, NO_x, Meteo	1
4 Paphos District	**Urban Paphos**	Urban City with traffic	4	2	1	4	City with traffic	Multi Component	1
	Rural **Sensitive Area**	Agriculture, **Effects on ecosystems**					Akamas	Mini Backgr.: O_3, NO_x, Meteo	1
6 Famagusta District	Rural	Agriculture, Toutristic	5	5	1-3		Agriculture Near Agia Napa	Mini Backgr.: O_3, NO_x, Meteo	1
Independent		All categories					For changing residential, urban background or special studies	Mobile Multi Component	2
Total GCC							**Multi Component** **Mini Backgr.** **Mini Urban/Traffic** **Mobile Multi Component**		**7** **4** **3** **3**
TCC Turkish Cypriot Community									
1 Nicosia District TCC	**Urban Nicosia**	**Urban City with Traffic**	5 -4	4	1	4	Edge of Old Nicosia City	Multi Component	1
5 Kyrenia District	**Urban Kyrenia**	Urban City With traffic	5	5 - 4	1	4	City with traffic	Mini urban station	1
	Rural	Background elevated	5	5		4	Five Finger Mountains	Mini backgr: O_3, NO_x, Meteo	1
6 Famagusta District	**Urban Fama-gusta**	Urban Residential	5	5	1-3	4	For changing resi-dential, urban back-ground or traffic sites	Mobile Multi Component	1
Total TCC							**Multi Comp.** **Mini Backgr.** **Mini Urban/Traffic** **Mobile Multi Component**		**1** **1** **1** **1**

1)Concentration levels:

1	Levels higher than the limit value + the margin of tolerance.	4	Levels between the LAT and UAT
2	Levels between the limit value and the limit value + the margin of tolerance.	5	Levels lower than LAT
3	Levels between the UAT and the limit value	(6)	(Levels lower than the lower assessment threshold for vegetation)

The monitoring stations should be connected with **one network control centre** from where regular function controls, plausibility controls and quality control measures are carried out.
The area in which the monitoring stations should be placed (e.g. at high polluted sites where people are staying) shall be determined by means of the concentration maps won by modelling.

9.4 Reference Laboratory

According to the daughter directives for each air pollutant component reference methods have to be provided. The calibrations carried out in the monitoring stations have to be referable to these reference methods. The reference methods should be installed in a permanent well air conditioned so called "Reference Laboratory". Even if the monitoring stations are operated by a subcontractor the operation of the reference laboratory should be operated by the authority.
The reference laboratory in Cyprus should include reference methods for the following components, see Table 9.12.

Table 9.12. Components and recommended resp. available reference methods

Pollutant Component	Recommended Reference Method	Calibration standards
NO/NO_x	ISO 7996 (1985): Chemiluminescence method	
SO_2	ISO/FDIS 10498: UV Fluorescence method	
CO	CEN Non-Dispersive Infrared Spectrometric Method	
O_3	ISO FDIS 13964 UV photometric method	ISO FDIS 13964, VDI 2468, Bl.6: Reference UV photometer
PM_{10}, $PM_{2.5}$	EN 12341: Collection of PM10 fraction on a filter and gravimetric mass determination	
Benzene	Current CEN standardisation: Pumped sampling method on a sorbent cartridge followed by GC analysis	

The reference methods for the continuous monitoring should be provided and carried out in the authorities lab.
The sampling and gravimetric analysis of PM_{10} (and $PM_{2.5}$) and the sampling for benzene including quality assurance should be carried out in the authorities lab too.
But, the analyses of elements in the PM_{10} samples and the hydrocarbon determination by gas chromatographic analysis should be carried out by external specified labs.

9.5 Need of Personnel

9.5.1 Personnel in GCC

The personnel needed in GCC for the air quality assessment tasks is listed in Table 9.13.

Table 9.13. Personnel needed for air quality assessment tasks in GCC

Task	No of personnel	Qualification
• Air quality assessment, monitoring, etc. managing • Development of plans/programmes for air pollution abatement measures and air quality assessment and management strategies	1 1	Scientific manager Scientist
17 Monitoring stations: • regular tests • maintenance • taking of samples • calibration	1 5	Scientist Technicians
Control centre: • Daily data plausibility control • Consideration of emissions conditions • Consideration of meteorological conditions • data quality control • preparation of daily diagrams • preparation of informing the public • reporting to EU, WHO, WMO, EMEP and other international organisations	2	Scientist
Reference Laboratory: • Maintaining the reference instruments, • certification of calibration gases, • checking of instruments performance, • carrying out of comparison measurements, • participation in internat. ring tests • visit to European reference labs: comparison of national standards to international ones • evaluation of calibration experiments, statistical calculations • documentation	1 1	Scientist Technician
Particulate Matter • Maintaining the weighing room, • weighing filters • preparing sampling units • documentation • Quality assurance for gravimetric determinations • Logistics of filter exposure • Evaluation of PM measurements and depicting of results • Assessment of results	1 1	Scientist Technician
Benzene and VOC: • sampling and pre-preparation of tube magazines • Maintaining of automatic samplers • Data evaluation and depicting	1	Technician
Quality Assurance and Quality Control	1	Scientist

• Preparation of SOPs • Uncertainty assessment • Checking the whole chain from data generation in monitoring stations up to evaluation and reporting		
Mathematical Modelling • Modelling of stack plume dispersion • Operating the model for spatial distribution • Prediction of pollutants situation • Graphical depiction • Combination of measurement and modelling • Air quality modelling • Forecast modelling	1	Scientist
Emissions Inventory Permanent care of the emissions data base/update	1	Scientist
Total	**10** **8**	**Scientists** **Technicians**

9.5.2 Personnel in TCC

The personnel needed in TCC for the air quality assessment tasks is listed in Table 9.14.

Table 9.14. Personnel needed for air quality assessment tasks in TCC

Task	No of pers	Qualification
• Air quality assessment, monitoring, etc. managing • Development of plans/programmes for air pollution abatement measures and air quality assessment and management strategies	1	Scientific manager
4 Monitoring stations: • regular tests • maintenance • taking of samples • calibration Quality Assurance and Quality Control • Checking the whole chain from data generation in monitoring stations up to evaluation Reporting	1 2	Scientist Technicians
Particulate Matter • Maintaining the weighing room, • weighing filters • preparing sampling units • documentation • Quality assurance for gravimetric determinations • Logistics of filter exposure • Evaluation of PM measurements and depicting of results **Benzene and VOC:** • sampling and pre-preparation of tube magazines • Maintaining of automatic samplers • Data evaluation and depicting	1	Technician
Mathematical Modelling • Modelling of stack plume dispersion • Emissions Inventory: Permanent care of the emissions data base/update	1	Scientist
Total	**3** **3**	**Scientists** **Technicians**

9.6 Recommendations for Air Quality Improvement Measures in Cyprus

9.6.1 General

As result of all the measurements carried out in the project it can be stated that the most affected sites in Cyprus are:

- High traffic zones in the cities
- Bad ventilated city areas with traffic influence
- Residential areas influenced by close traffic zones
- Surrounding areas of power plants and cement factories and some special industries
- Neighbourhood of quarries
- Sites affected by uncontrolled burning: surrounding areas of wild waste burning and of field or bush fires

Due to the possibility of implementation different time scales have to be considered for the air quality improvement strategies:

1. Short term measures
2. Medium term measures
3. Long term measures

In general it has to be distinguished between

- Technical measures to reduce the emissions at the sources
- Administrative, planning and management measures
- Educational measures

First the possible measures shall be described, technically and administratively structured. After this, the classification in time horizons shall be given.

9.6.2 Reduction of traffic caused air pollution

The traffic causes air pollution in different ways:

- Exhaust gas emissions, distinguished between
    - Gasoline engine vehicles: passenger cars: NO_x, CO, Benzene and Hydrocarbons in general, Pb
    - Diesel engine vehicles: passenger cars, vans and trucks: Soot (black smoke), NO_x, SO_2 and sulphates, Hydrocarbons, CO
- Dust from tire, brake and road abrasion, resuspended during driving, especially under dry conditions like in Cyprus
- Transfer of soil to the roads and resuspension by the vehicles.

9.6.2.1 Reduction of exhaust gas emissions

EU regulations for new vehicles

Since Cyprus became EU member on 1st of May 2004 the EU exhaust gas limits have to be met for newly imported passenger cars and light duty vehicles as well as for trucks and busses regulated in EC directive 98/69/EG.

- That means in the moment (from **1st January 2000**) the EU limits **Euro3** are valid

- From **2005/2006** the stricter **Euro4** regulation has to be met for all vehicle categories which are sold in the EU
- From **2008/2009** the once more stricter **Euro 5** regulation will be valid.

Gasoline engine driven cars can meet these limits only with the **three-way-catalyst** technique and with a closed tank system with charcoal filter to remove fuel evaporations (which mean hydrocarbon emissions). The **precondition** for the operation of cars with catalysts is the usage of **unleaded gasoline**. Otherwise the catalysts will be destroyed. Unleaded gasoline is available in Cyprus.

Vehicles with modern **Diesel engines** meet Euro3 and Euro4 regarding particulate emissions. But Euro5 can only be met by diesel vehicles with particle filters which are available now.
The precondition to meet the low PM emissions with diesel engines is the usage of low sulphur diesel fuel which is also available in Cyprus.

Existing vehicles
If all vehicles in Cyprus would meet these new EU regulations right now the air quality would improve distinctly. But there are many older vehicles in operation which do not fulfil these limits. Since the vehicle emissions are causing the most serious air quality problems measures have to be arranged to reduce the emissions from the existing vehicle fleet. There are two possibilities:

1. **Regular official emission checks for all existing vehicles**, e.g. every two years. During these checks the exhaust gas emissions and the adjustments of the engines according the manufacturers specifications have to be tested and certified. Vehicles with incorrect adjustments can be improved or sorted out by this way. Also the function of the catalyst and of the lambda control system has to be checked with this method. Since one bad vehicles can cause a pollution like ten others this measure is very important. But, it will not improve the situation drastically.

2. This can only reached by an early **exchange of the old vehicle fleet** (which is non conforming with Euro 3 or Euro 4) against new vehicles. To accelerate this process a **tax reduction or tax remission** for Euro 4 and Euro 5 vehicles is recommended. This tax reduction should last until the regulation becomes valid, 2005 (Euro4) and 2008/2009 (Euro 5). This measure was effective in other European countries to promote the newest low emission vehicle technology and thus to improve the air quality in these countries.

9.6.2.2 Reduction of traffic

The relatively small cities of Cyprus (compared to the dimensions of other European metropolitans), especially Nicosia and Limassol suffer under a lot of traffic and traffic jams (not only with respect to air pollution but also regarding the mobility and safety). Therefore, a public transport system with regular routes and frequent servicing is most important within the cities and to connect the villages and the cities.

Public transport systems
To avoid individual traffic a well structured and organised bus system with high frequent servicing will be the solution (using Euro 5 or at least Euro 4 busses of course). This should be established in all major cities of Cyprus and (very important) between the cities. In the cities the buses must have priority (set up of special lanes and traffic lines for them!).

School busses

For transporting pupils to the schools and bring them back a special bus system logistics should be worked out by the municipalities together with the schools and the parents, e.g. establishing mini bus systems which picks up pupils from limited areas from their flats.

Inner city transport

For the city of Nicosia a **trolley bus system** is recommended for servicing the main roads. These buses operate without any exhaust gas emissions because of their electrical engines. For the inner city of Nicosia this emissions free transport system is very important to improve the air quality there (together with the next recommended measure, see below). The most modern trolley buses can change their drive to diesel engine when they leave the city boarders. Thus, a flexible transport system can be installed. It is assumed that this bus system is operating for GCC and TCC Nicosia as well in the future.

Extending pedestrian areas

There are three reasons for extending pedestrian areas in the cities:

1. Where no vehicles are driving no pollutants are emitted, especially if the roads are used by people for intensive shopping, open street restaurants etc.. These people would breathe less pollution load.
2. If roads are closed for individual traffic public transport systems have more chances to be accepted.
3. The living standard in the inner cities increases in general with less traffic by establishing pedestrian areas (also less noise and saver moving for pedestrians). The experience with the pedestrian area, established ten years ago in inner Nicosia proves this fact.

Promotion of cycle ways

In Cyprus bicycle riding is developing. This can be observed by the growing number of bicycle shops within the last years. This cycling is helping to avoid traffic exhaust gases if it would be used e.g. for the regular way to work. To make biking saver in Nicosia the construction of cycle ways has started. These cycle ways should be extended to a network, especially with connection to the city centres. This is recommended for all the cities of Cyprus.

Studies for the design of integrated traffic systems in each major city of Cyprus

All the mentioned traffic measures

- Public transport, busses, trolley busses
- Pupils transport
- Pedestrian areas
- Cycle ways
- combined with the recreation areas, parks etc.
- and combined with shopping and servicing requirements

should be brought together and linked which each other. To achieve this, **special integrated traffic system studies** should be established for the main cities of Cyprus and for whole Cyprus (with linkages of GCC and TCC of course). In such studies the possibilities of all mentioned systems should be considered with the target to avoid individual traffic, for better life quality and for drastical reduction of air pollution. Such studies require own projects considering the individual situations in the cities based on traffic numbers and working out the usage of each road of the city, the public transport lines, pedestrian areas, cycle ways etc. in detail.

For the guidance of the individual traffic,

- modern traffic management systems should be included in such studies.

A pilot project could be started for the city of Nicosia.

Such studies should be worked out by traffic management experts. Since such experts are usually focused on one part of traffic management (mainly on the individual road traffic) a commission has to be established in which ecologists respectively air quality specialists, meteorologists (for climatic aspects), public transport and logistic experts are represented.

9.6.2.3 Planning and constructive measures to reduce traffic induced pollution

Pavement of roads
According to the dry weather conditions in Cyprus dust on the roads becomes always resuspended by moving vehicles. To reduce this resuspension the amount of soil brought onto the roads should be minimised. That means a complete pavement of roads which are open for and used by automobile traffic. This concerns also the pedestrian ways beside the roads. In the cities this pavement becomes more and more realised. It should be consequently promoted. In the villages and in the rural areas very often great dust plumes can be observed caused by vehicles resuspending the dust of unpaved or even from paved roads. So, in this field there are possibilities for improvement.

Bushes and hedgerows at the edges of fieldS
Very often dust is transported from open fields to the roads and resuspended there. To reduce this dust movement from the fields, bushes or hedgerows should be planted at the edges of the fields. Such hedgerows still exist at many sites but they should be consequently extended in the rural areas with especial respect of improving the air quality.

Ventilation of high traffic roads
There are two factors which influence the air quality in the cities and at high traffic roads especially:

- the emissions
- the ventilation which distributes the emissions by dilution and transporting them away.

Many investigations have shown that for the local air quality situation the ventilation is as efficient as reducing the emissions. This knowledge concerns

- high traffic roads where people are moving or living and
- cities or city areas as a whole.

Generally, TCC Nicosia is better ventilated because of the lower building density compared to GCC Nicosia. This is one of the reasons that the air pollution situation there is not as bad as in inner GCC Nicosia. Of course, the traffic load in GCC Nicosia is also distinctly higher but the ventilation effect is dominating.
For improving the air quality in the cities the consequences of this knowledge are the following:

- Reducing the emissions at the roads as shown above
- Taking care of maintaining a good ventilation at the roads and of the cities in general.

The latter understanding is very important for the city planning! That means:

- No closed building lines at high traffic roads!

Negative examples: Makarios Avenue and Limassol Avenue are too poor ventilated according to their traffic load.

The recommendations for the improvement are:

- For existing bad ventilated roads the emissions have drastically to be reduced (see measures above!)

- For new developments a good ventilation has to be considered. That means providing of enough and large building gaps considering the wind directions in this area.

9.6.3 Ventilation of cities – planning recommendations

The ventilation is not only an important property for the pollutants reduction on high traffic roads, but also for the improvement of the air quality of whole cities. In the following the ventilation situation shall be considered for the larger cities of Cyprus.

- No closed building lines with high buildings along cities or parts of cities which could block the positive ventilation effect of general wind systems, especially the sea-land breezes or the mountain-valley winds.
  Negative example: The hotel line at the beach side in Larnaca. The inner city behind this line is decoupled from the sea-land breezes and therefore very bad ventilated.

The recommendations for improvement are the same as for the high traffic roads but in a larger scale:

- For existing bad ventilated city areas the emissions have drastically to be reduced (see measures above!)
- For new developments a good ventilation has to be considered. That means, providing of open strips for the wind flows of the local wind systems, individually designed for each city. Most important is to consider the nocturnal wind direction since the nocturnal winds are slowing down and mostly weaker than the winds during the day and during night time stable meteorological conditions prevail and thus the dilution of the pollutants is inhibited. But the winds during the day shall also not to be obstructed or blocked as well. Based on the results of the project examples for some cities of Cyprus shall be given:

  Nicosia (GCC and TCC)
  The local winds are induced by the mountains in south-west direction and the plain in east north-east direction, increased by overall winds.
  The nocturnal winds are coming from west/south-west: On the south-west and west edge of the city open strips have to be maintained!
  The morning and daytime winds are coming from east: The eastern edge shall not be blocked for the winds as well!
  Also open wind strips must be available within the city, especially in west/south-west to east/north-east direction.

  Limassol
  In winter the land-sea breeze could be clearly observed. During night the land wind intensified by mountain winds is blowing from north-westerly to northerly direction into the city of Limassol. These winds have a great nocturnal cleaning effect. So, open wind strips from north to south (from land to the sea) and from opposite from south to

north (for the sea breeze during the day) should be maintained. That means, no closed hotel lines at the beach side!
But, open wind strips should also be maintained from west to east and opposite since these are summerly wind directions.

Larnaca
In Larnaca the two wind directions west/north-west (land breeze) and east/south-east (sea breeze) are prevailing. The overall winds have also mostly these directions. The hotel line along the beach is strongly blocking these winds with their cleaning effect. Thus, the inner city of Larnaca is very bad ventilated.
New city developments have to consider the climatic conditions in Larnaca and open wind strips should be planned so that the land- sea breeze can develop its positive ventilation effect.

Kyrenia
In Kyrenia the winds are channelled by the Kyrenia mountains and therefore they are mostly coming along the beach from west and sometimes from east. During night when these winds along the beach slow down the mountain wind (cold air flow) from the Kyrenia Mountains (south of Kyrenia) is blowing. Since this wind is not very strong but important for the nocturnal cleaning of the city open wind strips at the feet of the mountains resp. at the southern edge of the city have to be maintained – no high buildings at this side which would block this nocturnal mountain wind. Of course, at the west and east edge also open wind strips should be kept for the cleaning effect of the regular winds during day time. But, this is not as critical since during daytime the turbulence and thus the vertical distribution and dilution of the air pollutants is higher.
The general rule from Larnaca and Limassol is also valid for Kyrenia: No closed building lines around or in the city!

Famagusta
The winds in Famagusta are dominated by the sea-land breezes which have the same direction like the overall winds: east-west and west-east. In the moment the ventilation in Famagusta is not bad since the building density is not very high. For further development this ventilation situation should be maintained. That means, no construction of closed building lines and high buildings along the beach side and at the west edge. Also in the city no closed building lines should be constructed perpendicular to these wind directions.

General
There are other urban climate influencing factors which should be considered, e.g. maintaining zones as “Green Lungs” in the cities which are almost existing there. Such parks or other green areas are important for the absorption of pollutants and as areas without pollution sources. Especially the existence of green plants is important there which requires irrigation there.

In general, urban climatic aspects should be part of city planning and should be considered in each development plan.

9.6.4 Reduction of industrial air pollution

Each industry has it's own air pollution problem. In the following some general recommendations shall be submitted for the most important industries, especially PM emitting emission sources in Cyprus:

- **Power plants**
  The power plants in Cyprus are operated with heavy fuel oil. The emissions of its combustion are particulate matter, SO_2 and NO_x. Although no limit values are exceeded the ambient air in the neighbourhood is sometimes affected by the plumes.
  There are two ways to reduce the emissions:
  1. Using oil of higher quality with less sulphur and ash content (light oil): less SO_2 and PM emissions!
  2. Installation of a dry or semidry flue gas absorption with fabric filter: less SO_2 and PM emissions.
  3. For NO_x reduction low NO_x burners are recommended.

- **Cement industries**
  Apart from the legal requirements, the following measures are necessary to reduce uncontrolled PM emissions: A consequent housing of all dust producing processes like milling etc. and dust removal of the exhaust gases of these housings.

  Consequent pavement and regular cleaning of all roads in the cement factories to avoid dust resuspension.
- **Quarries**
  Consequent housing of all dust producing processes, like stones breaking etc. and dust removal of the exhaust gases of these housings.

  Consequent pavement and regular cleaning of all roads in the quarries areas to avoid dust resuspension.

- **Filling stations**
  If not even realised: Installation of a gas pendulum resp. gas suction and recycling systems for filling the gasoline stations tanks and for filling up individual vehicles at each gasoline pump

9.6.5 Domestic heating, warm water preparation and other individual firings

- In Cyprus a great number of solar collectors for warm water preparation is installed. These systems have consequently to be extended to all buildings, also to all **hotels**. Thus, emissions of oil combustion including the greenhouse gas CO_2 can be furthermore avoided.
- For cases where the combustion of oil cannot be avoided low sulphur light oil should be required and provided in general for whole Cyprus
- Official regular check of combustion quality in small no permission required firings (regular once per year) CO and soot measurements e.g. carried out by the chimney sweeps or other authorised persons).

9.6.6 Avoidance of wild and diffusive emissions including waste deposits and agriculture

- There are **wild and official waste deposits**. Both are burning regularly. The smoke of these fires contains a lot of unburned toxic substances and odours and is moving over the neighbourhood and causes nuisances and toxic exposures there. Especially during night under stable inversion conditions the dilution of this smoke is limited and the negative effects are high. Since a self ignition of waste deposits cannot be avoided the waste problem should be solved in general:

- Installation of a **waste incineration plant** of high technical standard with best available flue gas cleaning and with electrical power generation, one plant **for whole Cyprus!** But compostable waste should be collected separately at the households and should go to special compost sites!
- **Complete avoidance of straw and agriculture residues burning on the fields**. This burning was used in other European countries in the past (e.g. Denmark was regularly under smoke in August) but it became forbidden by law there and the air quality became much better.
- The danger of **bushfires** which can develop from field burning is lower if there is a general prohibition of field burning.
- To avoid soil dust resuspension from the fields the **ploughing** should take place **not under hot and totally dry weather conditions** if agricultural cultivation conditions would allow this.
- To reduce dust movement from the fields into the air or on sites where it can be resuspended **bushes or hedgerows should be planted at the edges of the fields.** Such hedgerows still exist at many sites but they should be consequently extended in the rural areas with special respect of improving the air quality. (This measure has even been mentioned to reduce traffic induced pollutants.)

Keep air clean in sensitive areas
No industries and big hotels in sensitive areas, e.g. Troodos, Akakamas and Karpacia!

9.6.7 Information and education of the public

There are three main reasons that the population should be informed about the air quality:

1. People should know and have the right to know the quality of the air they breathe. They have to be informed about bad and contaminated air quality conditions and health risks.
2. Air quality improvement measures are sometimes inconvenient or costly. So, they have to be justified for the acceptance by the population and thus to become efficient.
3. Many measures concern directly the behaviour of people, e.g. the usage behaviour of vehicles. For example: If people are used to take their car for any little way and for any shopping it will not be easy to convince them to disclaim on the vehicle and to use public transports.

So, the information of the population is necessary on the following subjects:

- Health and ecological effects of air pollutants: short, medium and long term effects
- Actual air quality in the cities and tourist areas: pollutant concentrations with comparison with limit values
- Long term development of air quality
- Reasons and sources of air pollutants
- Possibilities and contributions of individuals to avoid or reduce air pollution (influencing the individual behaviour)
- International and national air quality regulations
- Demonstration that a good air quality is a precondition for a sustainable environment and for health and life standard. It should become conscious for people that the preservation of the environment is the base for their health and for their living standard.

Regular publication of air quality parameters (air pollutant concentrations) in:
- Newspapers
- Radio
- Television including Videotext
  Internet: Homepage of the Government
- On large panels installed in the inner cities and on-line connected to the measurement network centre.

Information about special subjects of air quality or air pollution (as shown above)
- In newspapers
- In magazines
- As television contributions (and radio)
- In public seminars and conferences
- Newspaper articles on special air quality subjects:
  From time to time newspaper articles should be switched which explain the events of air pollution situations or subjects of air quality and air pollution, e.g. the sources of pollutants, their effects, their behaviour in the air and the formation of new pollutants, their deposition and depletion, information on Sahara dust events, etc..

Education of people
- Education of people in schools:
  Air quality should become subject in different kinds of schools and higher schools
- In churches:
  The priests in the churches should state the preservation of humans environment as a divine order to preserve the creation of God!

9.6.8 Responsibilities for the realisation of air quality improvement measures

Several of the proposed measures need a legal base which has to be developed by the Government and the Parliament! The task of the Government is also the transfer from EU directives and Guidelines into national laws and ordinances and their application.

There are different responsibility levels which concern for the realisation of measures which should be illustrated by the following diagram, Figure 9.4.

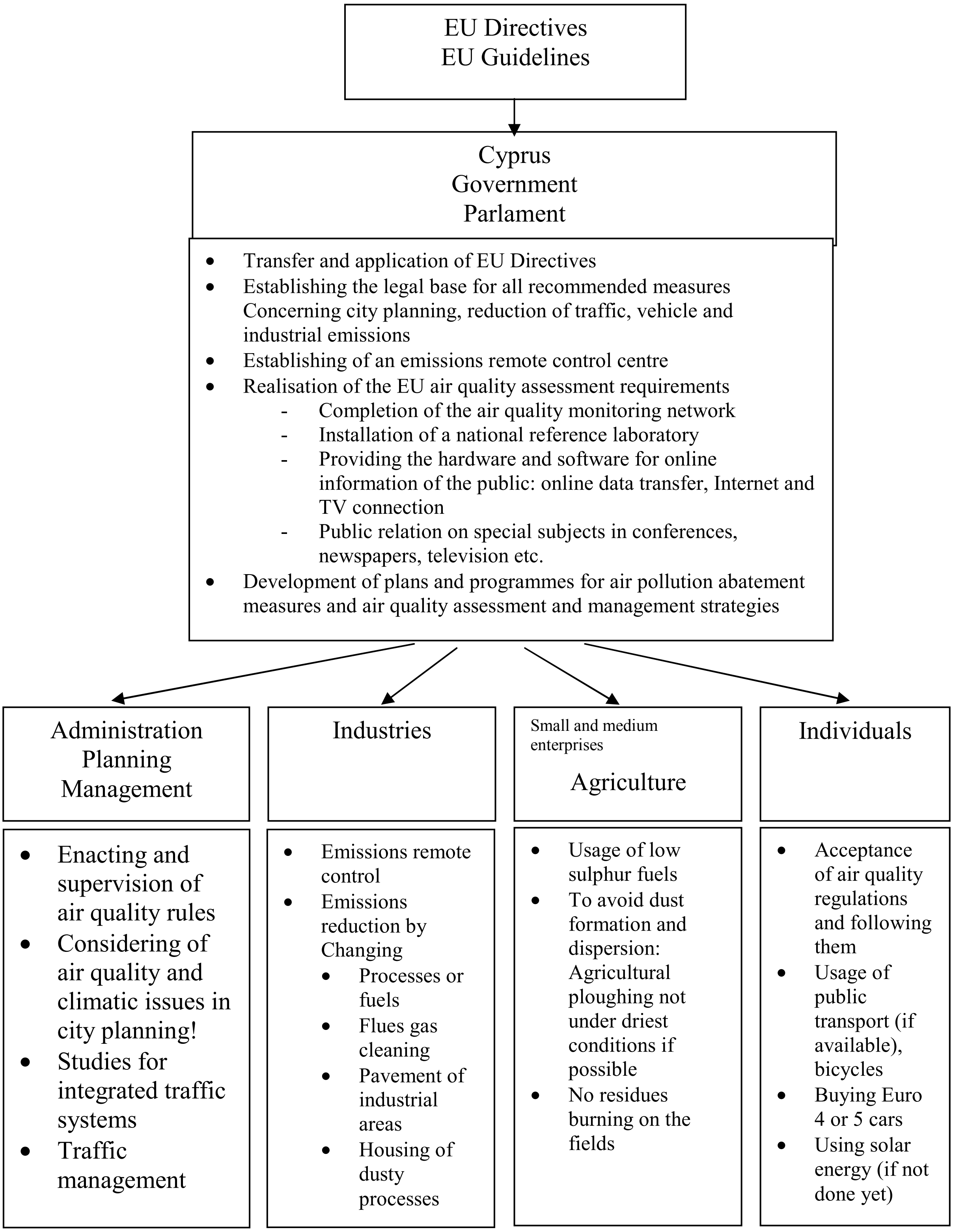

Figure 9.4. Distribution of responsibilities for air quality improvement measures

9.6.9 Priorities in air quality improvement measures

To improve the air quality different measures have been recommended. The realisation of such measures has different time scales. Not all measures can be realised immediately because of costs or other reasons. But some measures could be implemented at once. In the following the recommended air quality improvement measures are classified in short, medium and long term improvement activities, classified according the responsibilities. The three categories are based on the following time scales:

1. Short term measures: immediately up to one year
2. Medium term measures: one to five years
3. Long term measures: five to ten years

These time scales consider the realisation of the measures. Of course, the medium and long term measures have to be planned much earlier, even now beginning. Some measures are recommended as short term and as well as medium term measures for their continuation or as medium and long term measures respectively.

9.6.9.1 Short term measures

Government

- Transfer and application of EU Directives
- Establishing the legal base for all recommended measures concerning city planning, reduction of traffic, vehicle and industrial emissions
- Establishing of an emissions remote control centre
- tax reduction or tax remission for Euro 4 and Euro 5 vehicles
- Regular official emission checks for all existing vehicles
- Realisation of the EU air quality assessment requirements
  - Completion of the air quality monitoring network
  - Installation of a national reference laboratory
  - Providing the hardware and software for online information of the public: online data transfer, Internet and TV connection
  - Public relation on special subjects in conferences, newspapers, television etc.
- Regulations for:
  - Avoidance of fires and combustion on wild or controlled waste deposits
  - To avoid dust formation and dispersion: Carrying out of agricultural ploughing not under driest conditions
  - No residues burning on the fields

Administration, Planning, Management

- Introduction of air quality and urban climate aspects into the city planning of all cities in Cyprus: No development plan should be decided without an air quality and climatic experts opinion which considers the ventilation of the cities and of high traffic roads
- Studies for the design of integrated traffic systems for each major city of Cyprus including modern traffic management systems
- Initial set up of bus systems with high frequent servicing (and priority lanes and traffic lights) in the major cities and as interconnection between the cities
- Establishing of school bus systems
- Extending of pedestrian areas
- Promotion of cycle ways

- Planting of bushes and hedgerows at the edges of fields
- For existing bad ventilated roads in the cities, the traffic emissions have drastically to be reduced (by the measures mentioned above)
- Drastically emissions reduction in bad ventilated inner cities by closing them for traffic (e.g. inner cities of Larnaca, Kyrenia and Makarios Avenue in Nicosia etc.)

Small and medium enterprises, Agriculture
- Consequent extension of solar warm water systems for all buildings, also to all **hotels**
- For cases where the combustion of oil cannot be avoided (all small firings) low sulphur light oil should be required and provided in general for whole of Cyprus
- Avoidance of fires and combustion on wild or controlled waste deposits
- To avoid dust formation and dispersion: Carrying out of agricultural ploughing not under driest conditions
- No residues burning on the fields
- Planting of bushes and hedgerows at the edges of fields

Individuals
- Going by feet and bicycle for short ways
- School minibus organisation together with schools and authorities and acceptance and usage of the school bus system to avoid individual traffic
- Buying of environmental friendly Euro 4 and 5 cars
- Consequent extension of solar warm water systems for all buildings

9.6.9.2 Medium term measures

Administration, Planning, Management
- Further development of the bus systems with high frequent servicing (and priority lanes and traffic lights) in the major cities and as interconnection between the cities
- Extending of pedestrian areas
- Promotion of cycle ways
- Extending of the pavement of roads
- Extending of the planting of bushes and hedgerows at the edges of fields
- Realisation of the ventilation of cities: No closed building lines with high buildings along cities or parts of cities or along high traffic roads which could block the effect of cleaning wind systems, especially the sea-land breezes or the mountain-valley winds

Industries
Stepwise reduction of industrial pollution:
- Power plants: usage of better oil or flue gas cleaning by dry absorption
- Cement factories: Housing of all dust producing machines and processes and dust removal of the exhaust gases of these housings. Pavement and holding clean of all roads within the factory
- Quarries: Housing of all dust producing machines and processes and dust removal of the exhaust gases of these housings. Pavement and holding clean of all roads within the quarry area
- Installation of gas suction systems at filling stations.

Small and medium enterprises, Agriculture
- Further extension of solar warm water systems for all buildings, also to all **hotels**.

- Official regular check of combustion quality in small no permission required firings

9.6.9.3 Long term measures

Government ,Administration, Planning, Management

- Further realisation of the ventilation of cities: No closed building lines with high buildings along cities or parts of cities or along high traffic roads which could block the effect of cleaning wind systems, especially the sea-land breezes or the mountain-valley winds
- Installation of a trolley bus system in Nicosia
- Installation of a waste incineration plant for whole Cyprus
- Extending of the pavement of roads
- Extending of the planting of bushes and hedgerows at the edges of fields

Industries

Finalisation of reduction of industrial pollution:

- Power plants: usage of better oil or flue gas cleaning by dry absorption
- Cement factories: Housing of all dust producing machines and processes and dust removal of the exhaust gases of these housings. Pavement and holding clean of all roads within the factory
- Quarries: Housing of all dust producing machines and processes and dust removal of the exhaust gases of these housings. Pavement and holding clean of all roads within the quarry area
- Installation of gas suction systems at filling stations

Individuals and persons in responsible positions

Target:

Development of an environment conscious, acceptance of air pollution prevention measures and proposals and realisation of improvement measures!