16. IMPACTS ON HUMAN HEALTH

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ABSTRACT

The interactions between climate change and human health are multiple and complex. They could, however, be summarised as following: a) changes in morbidity and mortality in relation to temperature; b) effects upon health of extreme meteorological events (tornadoes, storms, hurricanes, and extreme precipitation; c) Atmospheric pollution and an increase in the associated effects on health; d) Diseases transmitted by food and water and e) Diseases transmitted by infectious vectors and by rodents (Patz *et al* 2000).
The limited size of the chapter requires us to deal with those factors that we believe are of greatest relevance in our country.

The extremely high temperatures recorded in Central Europe during the summer of 2003 and in the North and East of Spain highlighted the effects of high temperatures on morbidity and mortality. This chapter analyses the main impacts of heat waves, fundamentally, and of cold spells. The socioeconomic factors influencing this excessive mortality are considered, and the measures that ought to be taken into account in prevention plans are dealt with. The need to streamline morbidity and mortality records in Spain is emphasised, as are the policies necessary to minimise the impacts upon health of extreme temperature events.

Atmospheric pollution constitutes an environmental risk with negative consequences for health. This risk has been studied for years, and more knowledge now exists as a result of research in recent years. Emissions into the atmosphere related to climate change could exacerbate the effects of air pollution upon the health of citizens, not only directly, through the impact of meteorological phenomena, but also immediately, through the direct effects of pollutants upon health. However, for too long, efforts throughout the world have attempted to deal with both problems separately. Indeed, it has often been believed that the benefits of climate protection for health would be felt in the long term. To the contrary, what has been seen in recent years is that actions aimed at reducing emissions of pollutant gasses would produce beneficial effects in the short term due to the reduced impact of atmospheric pollutants on citizens' health. In the section dealing with atmospheric pollution, the sources and main pollutants are described, the results of epidemiological and toxicological studies carried out in Spain and abroad are reviewed, and the possible risks of the pollutants most related to climate change, such as ozone or fine particles, are presented. Taking into consideration the main uncertainties and knowledge gaps in relation to the subject at the present time, we considered the main implications for policies related to the theme in Spain, along with research needs. In this sense, both from the point of view of surveillance and research, the establishment of an epidemiological system for the observation of the effects of atmospheric pollution is believed to be necessary.

We could expect this type of diseases to be increased by climate change in Spain, due to its proximity to the African continent, and to the fact that it is a place of obligatory transit for migrating birds and people, and to its climatic conditions –close to areas in which the transmission of vector-borne diseases exists. The possible risk lies in the geographic spread of pre-established vectors or in the import and establishment of subtropical vectors adapted to survival in cooler, drier climates. Hypothetically, the vector-borne diseases susceptible to influence by climate change in Spain would be those transmitted by diptera, for example, dengue, West Nile encephalitis, Rift valley fever, malaria and leishmaniasis; the ones transmitted by ticks, such as Crimean-Congo haemorrhagic fever, tick-borne encephalitis, Lyme borreliosis, Boutonneuse fever and endemic relapsing fever; and those transmitted by rodents. But the greatest and most feasible threat would involve the establishment of the mosquito *Aedes albopictus*, which is capable of transmitting viral diseases such as West Nile or dengue. But for the establishment of authentic endemic areas, a combination of several factors is needed, such as the mass and simultaneous influx of animal or human reservoirs and the deterioration of social and health conditions and of the Public Health services.

16.1. INTRODUCTION

16.1.1. Extreme temperatures

16.1.1.1. Relationship between temperature and morbidity and mortality

Morbidity and mortality is known to present seasonal dynamics characterised by a winter maximum and a summer peak of lesser magnitude, which is, however, sometimes more intense from the point of view of its effects on health than the excess itself of winter morbidity and mortality (Mackenbach *et al* 1992, Alderson 1985). The results of numerous research projects indicate that the relationship between temperature and morbidity and mortality is usually “U” or “V”-shaped, with a minimum incidence temperature that varies from one place to another (Kunst *et al* 1993, Sáez *et al* 1995, Ballester *et al* 1997, Alberdi *et al* 1998) and which probably depends on the adaptation of the population to the temperature range to which it is exposed (Curreiro *et al* 2002, García-Herrera *et al* 2004). Wintertime excess mortality is mainly accounted for by respiratory and circulatory disorders, whereas the latter are also related to increases in summertime mortality (Alberdi and Díaz 1997). The older age groups are the ones that most contribute to this excessive morbidity and mortality (Alberdi *et al* 1998, Ballester *et al* 2003). With regard to temporal distribution, the effects of heat are short term (1-3 days), whereas the effects of cold usually occur between one and two weeks after the thermal extreme (Alberdi *et al* 1998, Braga *et al* 2001), which is coherent with the underlying biological mechanisms (Huynen *et al* 2001, Havenit 2002). An example of this is seen in the fact that the mean daily mortality due to all causes except accidents (CIE IX 1-799) registered in the Comunidad de Madrid (Madrid regional autonomy) from 1986 to 1992, in relation to maximum daily temperature, presents a “V”-shaped relationship, with a maximum daily temperature of minimum mortality of 30.8 ºC (Díaz and López 2003)

16.1.1.2. Definition of heat wave and cold spells

From the point of view of effects upon health, there is no uniform criterion for the definition of a heat wave (W.H.O 2004) or a cold spell. In the case of heat waves, some authors base their definition of extremes on an established threshold which depends on both maximum and minimum air temperature and on mean daily values, while others make use of indexes (apparent temperature, etc.) that consider relative air humidity (Nakai *et al* 1999, Smoyer 1998, Jendritzky *et al* 2000) or meteorological situations at synoptic scale (Kalkstein 1991).

Recently, different studies on the Iberian Peninsula have established the existence of a maximum daily temperature above which a sharp increase in mortality is observed. In relation to Madrid, this “triggering effect in mortality” maximum daily temperature is 36.5 ºC (Díaz *et al* 2002a), 41ºC for Seville (Díaz *et al* 2002b), 33.5 ºC for Lisbon (García-Herrera *et al* 2004) (figure 16.1) and 30,3 ºC for Barcelona. In all these places, this temperature coincides with the 95 percentile of the series of maximum daily temperatures during the summertime period (June – September) from 1991 to 2002. Given that one single day with a temperature above this threshold significantly affects mortality, it has been proposed that a heat wave be defined as the period in which maximum daily temperature exceeds the 95 percentile of the series of maximum daily temperatures in the June - September period. The duration of the heat wave will be determined by the number of consecutive days in which this threshold is surpassed.

In the case of cold waves, behaviour analogous to that of the heat wave has been observed, which is exacerbated by the fact that the effect of cold is much more intense in the long term, and it is therefore more complicated to establish a cause-effect relationship (Braga *et al* 2001). There is, however, a maximum daily temperature below which mortality rises sharply. In the case of Madrid, this maximum daily temperature, around 6ºC, coincides with the percentile 5 of the series of maximum daily temperatures during the winter period (November –March) (Díaz *et al* 2004a).

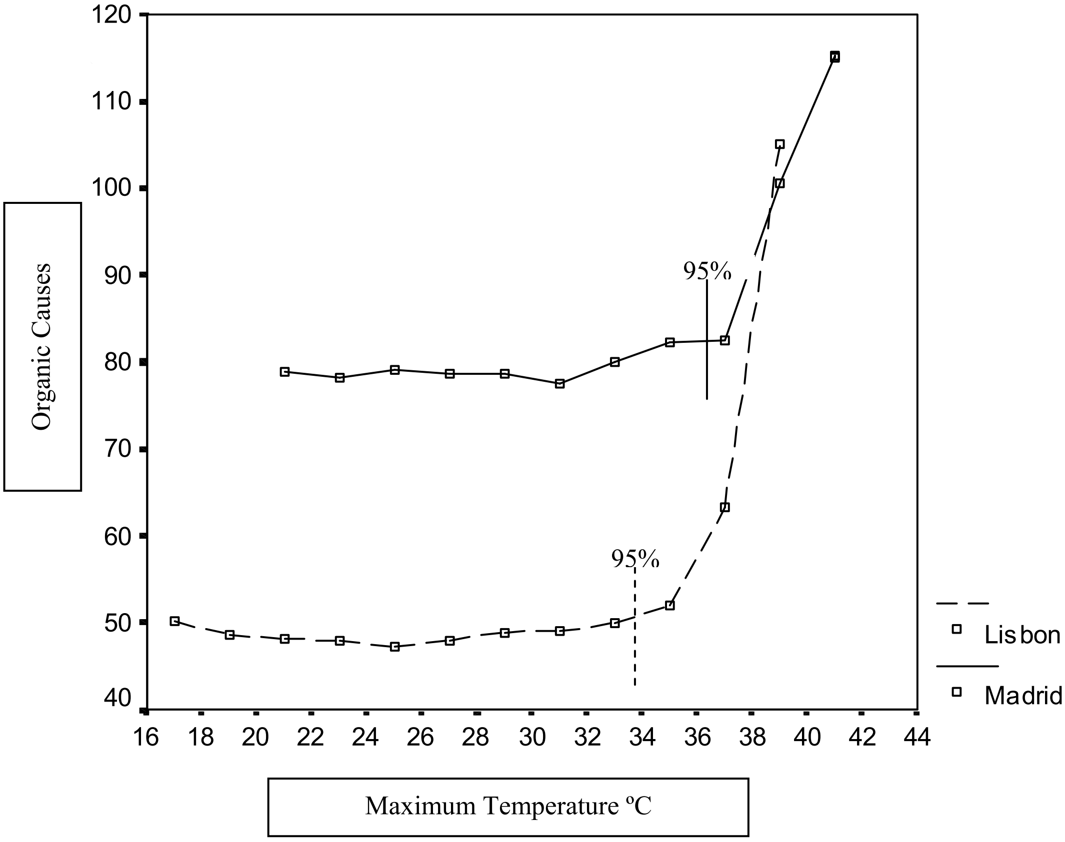


Fig. 16.1. *Mortality threshold temperature for the cities of Madrid and Lisbon. Threshold temperature is set at 95% for the series of maximum daily temperatures in the June-September period.*

Which means to say, that there is a relationship between mortality and temperature which is exacerbated in the event of thermal extremes, cold spells or heat waves. Indeed, when maximum temperature is above the 95 percentile or below the 5 percentile the magnitude of the impact becomes greater.

16.1.2. Air pollution

16.1.2.1. Air pollution and human health

Air pollution is understood to be the presence in the air of substances and forms of energy altering the quality thereof, in such a way as to pose risks or to cause harm or serious discomfort to people or property of any kind. In the field of public health, air pollution is a well-known phenomenon which has been long studied, and is of great importance in the modern world, basically due to a series of episodes that took place in the industrialised countries during the first half of the XX century.

In recent years, many studies carried out in different cities have found that even below the levels of air quality considered as safe, increased air pollution is considered to be harmful for human health. A study carried out in France, Switzerland and Austria indicates that 6% of mortality and a large number of new cases of respiratory disorders in these countries can be attributed to air pollution. Half of this impact is due to the pollution caused by motor vehicles (Künzli *et al*. 2000).

The World Health Organisation (WHO 2003) considers air pollution to be one of the most pressing world health priorities. A recent report estimated that air pollution is responsible for 1.4% of all deaths in the world (Cohen *et al* 2003). There is also growing concern about the risk of agents for which no satisfactory evaluation exists, such as Polycyclical Aromatic Hydrocarbons (PAH). In short, large sectors of the population are exposed to air pollutants, with possible negative consequences for health.

16.1.2.2. Air pollutants and their sources

Air pollutants, usually measured in the urban atmosphere, come from mobile sources (traffic) and stationary sources of combustion (industries, heating and waste disposal processes). A distinction is made between primary and secondary pollutants. The former are the ones coming directly from the sources of emission. Secondary pollutants are produced by the transformation and by the chemical and physical reactions that primary pollutants are subjected to inside the atmosphere, this involving, above all, photochemical pollution and the acidification of the environment. The characteristics of the main chemical pollutants and the sources of these are summarised in table 16.1.

Table 16.1. *Description of the main chemical air pollutants*

Pollutant	Formation	Physical state	Sources
Particles in suspension (PM): PM_{10}, Black smoke.	Primary and secondary	Solid, liquid	Vehicles Industrial processes Tobacco smoke
Sulphur dioxide (SO_2)	Primary	Gas	Industrial processes Vehicles
Nitrogen dioxide (NO_2)	Primary and secondary	Gas	Vehicles Gas heaters and cookers
Carbon monoxide (CO)	Primary	Gas	Vehicles Tobacco smoke Indoor combustions
Volatile organic compounds (VOCs)	Primary, secondary	Gas	Vehicles, industry, tobacco smoke Indoor combustions
Lead (Pb)	Primary	Solid (fine particles)	Vehicles, industry
Ozone (O_3)	Secondary	Gas	Vehicles (secondary to NO_x photo-oxidation and volatile organic compounds)

PM_{10}: particles with an aerodinamic diameter of less than 10 µm
NO_x: nitrogen oxides

16.1.2.3. Studies of the effects of air pollution on health

Interpretation of the effects of air pollution upon health is based on two types of studies, toxicological and epidemiological, which are considered to be complementary.

One of the most commonly used epidemiological designs used involves *time series*. These studies analyse variations in time of the exposure and population health indicators (number of deaths, hospital admissions, etc.). On analysing the population in different periods of time (generally day-to-day), many of the variables that, individually, could act as factors of confusion (smoking habit, age, sex, occupation, etc.) remain stable in the same population and lose their power for confounding (Schwartz *et al* 1996).

In recent years, different multicentre projects have been carried out, based on standardised analysis criteria for the study of the different aspects of the air pollution-health relationship. In

Europe, the APHEA project (Air Pollution and Health: a European Assessment) (Katsouyanni *et al* 1996) and in the United States the NMMAPS study (Nacional Mortality and Morbidity Air Pollution Study) (Samet *et al*. 2000a; 2000b) are among the studies that have most contributed to knowledge of the acute impact of pollution upon health. In France (Quennel *et al* 1999), and Italy (Biggeri *et al* 2001) national multicentre studies have been carried out, assessing the impacts of pollution, considering environmental, health and social characteristics. In Spain, the EMECAS project is carrying out a study of the impact of air pollution and involves 16 cities (EMECAM 1999, Sáez *et al* 2002, Ballester *et al* 2003).

Although fewer than studies of temporal series, there are several cohort studies of the impact of air pollution on health. The most important one was carried out by Pope and collaborators as a part of the Study II for Cancer Prevention. Data on factors relating to risk and air pollution were collected for a total of 500,000 adults in 151 metropolitan areas in the United States since 1982. In March 2002, the results were published of the follow-up of this cohort up to the year 1998 (Pope *et al* 2002). The fine particles (PM2.5) and sulphur oxides showed an association with mortality for all causes, for circulatory system causes and for lung cancer. Each increase by 10 $\mu g/m^3$ in atmospheric levels of fine particles was associated with an increase by approximately 4%, 6%, and 8% in the risk of death by all the causes, circulatory system causes and by lung cancer, respectively.

16.1.2.4. Effects of summer smog. Impacts of ozone upon health.

"Summer smog" type pollution refers mainly to photochemical pollution resulting from the reactions by hydrocarbons and nitrogen oxides, stimulated by intense solar light. **Ozone** is generally considered to be the most toxic component of this mixture. Ozone is formed by the action of the ultraviolet radiation of the sun upon NO_2. In the presence of volatile organic compounds, CO and methane, the formation of high concentrations of ozone is favoured.

Recent studies have described a large number of adverse effects caused by ozone. the most important being that related with respiratory diseases as a reduction in the pulmonary function (Galizia and Kinney 1999; Gauderman *et al*. 2002), exacerbation of asthma (Gauderman *et al* 2002) (McConell *et al*. 1999), increased risk of visits to the emergency ward (Tenias *et al*. 2002) and increases in hospital admissions (Anderson *et al*. 1997; Sunyer *et al*. 1997), and, probably, increased risk of death. (Burnett *et al*. 2001) (Goldberg *et al*. 2001). There is also evidence that people, especially the young, with airway hyperreactivtiy, such as asthmatics, are more sensitive to the effects of ozone.

16.1.2.5. Aeroallergens and respiratory health

Many studies have associated a high concentration of pollen and spores with epidemics of asthma and other allergic disorders, such as rhinitis or hay fever. In a recent study in Madrid (Tobías *et al* 2003) a significant association was established between increases in poceae and plantago pollen from the 95^{th} to the 99^{th} percentiles and an increase in visits to the Emergency Units of hospitals due to asthma, by 17% and 16% respectively. An association with urticaceae pollen, was also found, with an 8.5% increase in the number of visits to emergency units due to asthma. The role played by aeroallergens, however, in initiating or exacerbating asthma has not been clearly defined, and more research is therefore needed in order to establish the possible effects of climate change.

16.1.3. Infectious diseases

The emergence or re-emergence of most infections diseases is conditioned by evolutionary and environmental changes that can affect a large variety of intrinsic and extrinsic factors. Among the former is everything concerning the interaction between a pathogen and its vector, its intermediate host and its reservoir (infection, virulence, immunity and transmissibility). Among the latter are all the factors modulating the relationships between pathogen, vector and host/s, and environmental conditions (climate, meteorological conditions, habitats, ecosystems, housing development, pollution).

Climate changes can specifically affect temporal and spatial distribution, as well as the seasonal and interannual dynamics of pathogens, vectors, hosts and reservoirs. The phenomenon of the "Niño/southern oscillation" (ENSO) is the best known example of natural climatic variability and is associated with an increase in the epidemiological risk of certain diseases transmitted by mosquitoes, above all, malaria. It has been observed that, during the *El Niño* phenomenon, there was a 30% increase in malaria cases in Venezuela and Colombia, cases were multiplied by four in Sri Lanka and appeared in Northern Pakistan. More cases of dengue have been recorded in the Pacific Isles, Southeast Asia and South America. There has also been an increase in cases of Murray valley encephalitis and disease caused by Ross river virus in Australia, and cases of Rift valley fever in East Africa (Kovats 2000; Kovats *et al* 2003). The incidence of visceral leishmaniasis increased by 39% and 33% in 1989 and 1995 respectively, following the climatic oscillations of El Niño in the state of Bahía (Brasil) (Franke *et al* 2002).

A very illustrative example is what happened in California in 1984: coinciding with excessive rainfall and a warmer winter during the months of January and February, followed by drought and high temperatures (which reached 30ºC), in July there was an outbreak of San Louis encephalitis associated with a proliferation of mosquitoes of the genus *Culex* (Monath *et al* 1987) (this type of climate, with warm, rainy winters followed by hot, dry summers, are similar to the predictions of change for Spain). More recently, West Nile encephalitis was introduced into New York by migratory birds and later spread throughout the United States. This shows us how unexpected diseases can emerge.

16.2. SENSITIVITY TO THE PRESENT CLIMATE

16.2.1. Extreme temperatures

16.2.1.1. Different thresholds per province capitals for heat waves and cold spells

Having demonstrated the association between maximum daily temperature and the aforementioned excess mortality due to cold and heat, the different temperature thresholds above which excess mortality occurs can be calculated using the temperature records from the weather stations in each area. Figure 16.2 show the thresholds according to different province capitals that allow heat waves to be defined. In the case of heat, these values range from 26.2 ºC in A Coruña to 41,2 ºC maximum daily temperature for Cordoba, and for cold, from 2.7 ºC daily maximum in Ávila to 15ºC in Alicante.

These different physiological adaptation thresholds indicate that minimum mortality occurs at higher temperatures in the more temperate regions (Curriero *et al* 2002) heat having a greater impact at cold latitudes and a lesser impact at the more temperate ones (Davids *et al* 2002).

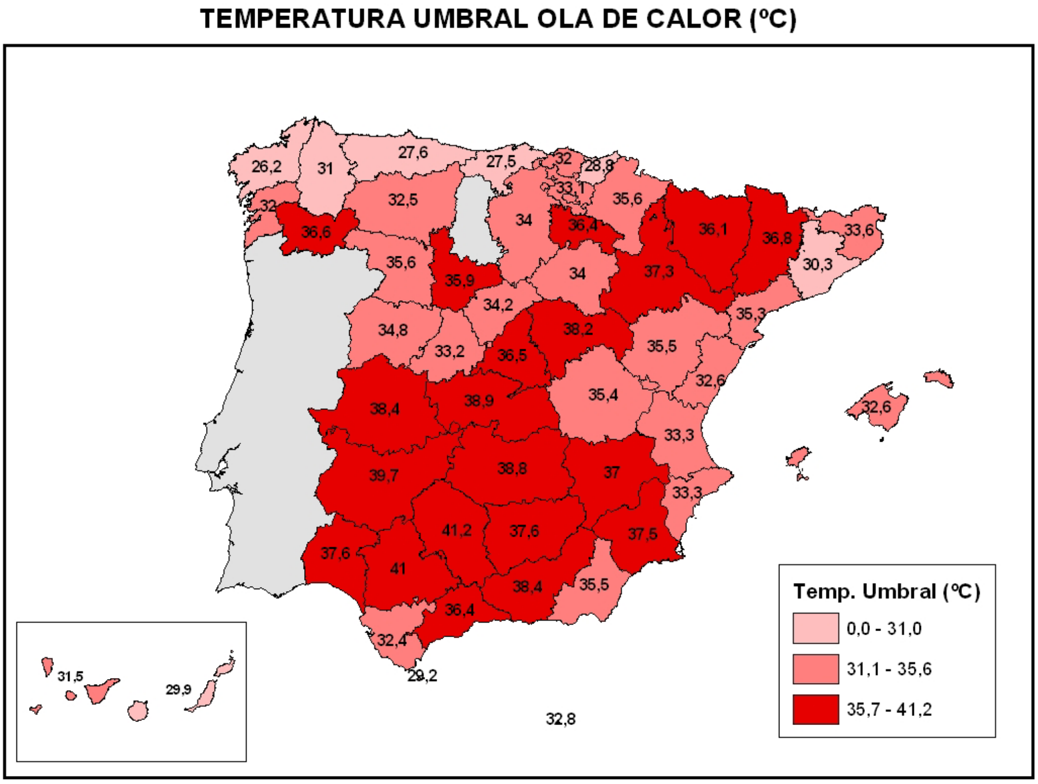


Fig 16.2. Threshold temperatures for defining a heat wave (ºC) according to the 95th percentile for the series of maximum daily temperatures in the June-September period.

16.2.1.2. Definition of an index for characterising the intensity of heat waves and cold spells

Considering the criteria that it is necessary to calculate not only excesses (defects) of maximum daily temperature in relation to the aforementioned thresholds, and even the duration of the thermal extreme, the following index can be defined to characterise the intensity of heat waves (IOC) and cold spells (IOF):

Heat:

$$IOC = \sum \left(T_{max} - T_{umbral}\right) \; si \;\; T_{max} > T_{umbral}$$

$$IOC = 0 \qquad\qquad si \;\; T_{max} < T_{umbral}$$

Cold:

$$IOF = \sum \left(T_{umbral} - T_{max}\right) \; si \;\; T_{max} < T_{umbral}$$

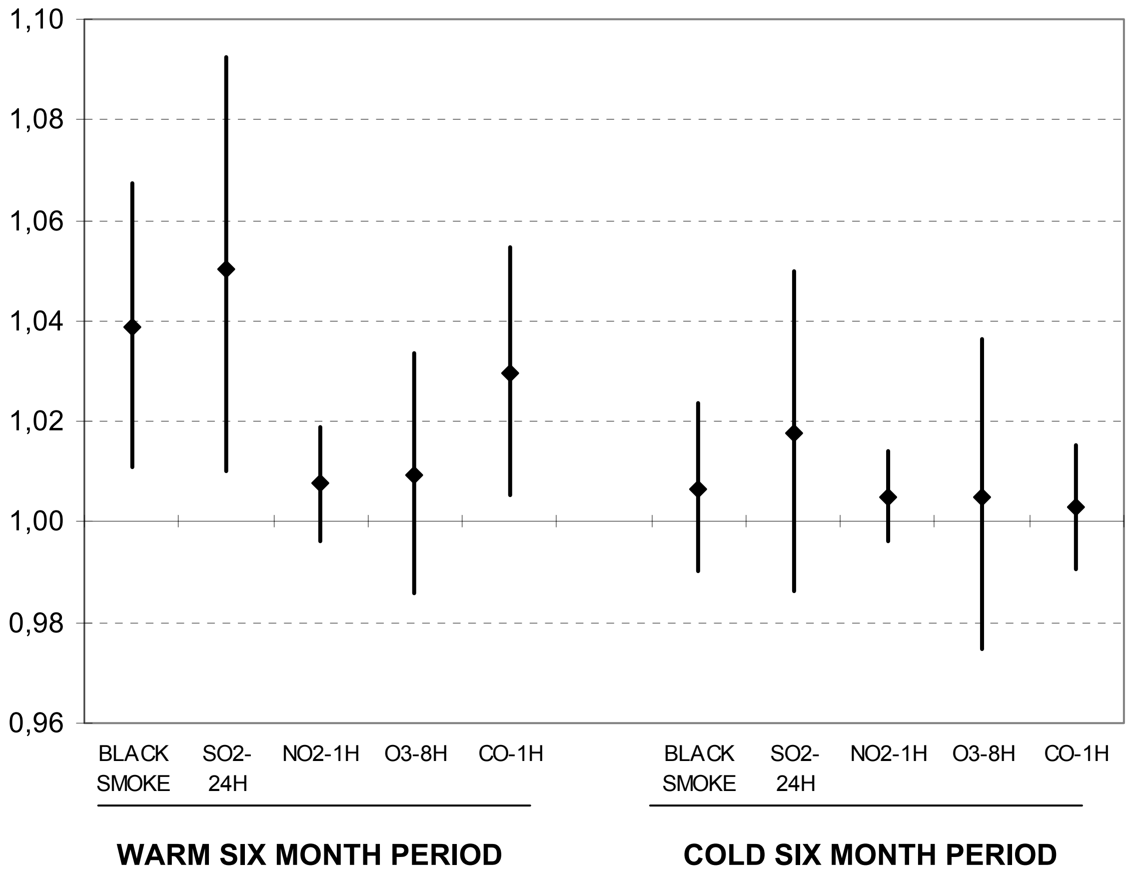
$$IOF = 0 \qquad\qquad si \;\; T_{max} > T_{umbral}$$

In the previous expressions, the sumatorio is extended to the time period to be characterised with the use of the index.

16.2.2. Air pollution

16.2.2.1. Sensitivity to air pollution

We need to recognise that there is still great uncertainty regarding sensitivity (that is to say, the change rate in the outcome variability by unit of change in the exposure variable) of the association between air pollutants. It is well known, however, that the effects of exposure to air pollution are many and with different degrees of severity, the respiratory and cardiocirculatory systems being the most affected. These effects maintain a gradation of both the seriousness of the consequences and the risk population affected (Figure 16.3). Particles constituted the most extensively studied group (Table 16.2).



24, 8H 1H: average concentration of the correspondant air pollution on 24, 8, and hours, respectively

Fig. 16.3. *Association between air pollution and daily emergency hospital admissions resulting from cardiovascular diseases. Analysis per six-month periods. Valencia 1994-1996. The results are expressed as the relative risk (and the confidence interval of this up to 95%) of an increase by 10 µg/m^3 (1 mg/m^3 for CO) in the daily levels of the corresponding pollutant. Source: Ballester et al 2001*

Table 16.2. *Study of the effects described for exposure to particles. Percentage change in health indicator due to increased particles concentration.*

Effects	Acute exposure	Chronic exposure
	Increase: 10μg/m³ of PM_{10}	Increase: 5μg/m³ of $PM_{2.5}$
Increased Mortality*	*(Ecological studies, time series)	*(Cohort studies)
Causes		
- All except external ones	0.2[a] - 0.6[b,c] - 1.0	2[i] - 3
- Cardiovascular	0.7[c,d] to 1.4	3[i] - 6
- Respiratory	1.3[c] to 3.4	
- Lung cancer		4[i]
Increase in hospital admissions		
- All the respiratory ones	0.8 to 2.4[e]	
- EPOC	1.0[f] to 2.5	
- Asthma	1.1[f] to 1.9	
- Cardiovascular	0.5[g] to 1.2[h]	
Illness: bronchitis		7
Reduced pulmonary function (VEF_1)		
- Children	0.15	1
- Adults	0.08	1.5

Adapted from Pope and Dockery (1999), with the inclusion of the results of recent multicentre studies: a: Dominici et al (2002b); b: Katsouyanni et al. (2001); c: Stieb et al. (2002); d: Samet et al. (2000a); e: Biggeri et al. (2001), f: Atkinson et al (2001b), g: Le Tertre et al. (2002), h: Samet et al. (2000c), i: Pope et al (2002).

In Spain, the results of the joint analysis with available data for 13 cities in the EMECAS project indicate that an increase by 10 μg/m³ in the levels of black smoke is associated with an 0.8% increase in the number of daily deaths. A significant association has also been found between mortality and all the other pollutants. For the groups of specific causes, the magnitude of the association was greater, particularly for respiratory illnesses (Ballester *et al* 2003). With data for 3 cities, ozone only showed an association with cardiovascular mortality during the hot six-month period (Sáez *et al* 2002).

Finally, and from the public health point of view, it should be pointed out that although the impact on health is of little magnitude, a high proportion of the impact can be attributed to pollution, given that the whole population is exposed. Furthermore, together with the proved effects above, it is important to consider the potential impact of exposure to air pollution during pregnancy and first childhood, as showed in some studies. Results from a recent review on the subject (Lacasaña *et al* 2005) show an association between exposure to air pollution and low birth weight and intrauterine growth retardation, as well as an impact of early exposure on infant health including an increase in mortality. Coinciding with the Inter-ministerial Summit in Budapest, June 2004, a report has been presented evaluating the burden of some ambient exposures in Europe among infant health. Results from such report show that among European infants between 0-4 children 1.8% to 6.4% of all deaths for total causes could be due to outdoor air pollution, and 4.6% to exposure to air pollution indoors. Persistence of bad air quality situations, or its possible worsening, may represent a risk for the health of children and future generations.

16.2.2.2. Factors modifying the effects of climate change and of air pollution.

On interpreting studies that examine the relationship between air pollution and health, we must consider several factors which could confuse the study of the association with health indicators. These factors are the following: a) those determined by geophysical cycles, b) meteorological ones, and c) the sociocultural ones, such as, for instance, the life pattern conditioned to the week organisation. We would also have to consider illnesses with a seasonal behaviour, like influenza.

Furthermore, a greater influence of certain air pollutants during the hotter months of the year has been observed. Thus, a greater effect of SO_2 has been described (Ballester *et al*. 1996, Michelozzi *et al* 1998) ; or of particles (Biggeri *et al*. 2001; Ballester *et al*. 2001) on cardiovascular mortality and morbidity (Figure 16.3). In the APHEA 2 study (Katsouyanni 2001) it was found that, both mean annual temperature and the location of the city in Europe (North, South, East), that is, climate-related components, helped to modify the effects of pollution on mortality. The effect of particles on mortality was greater in the cities with warmer climates.

Different hypotheses have attempted to account for these findings. On one hand, measurement of air pollution during the hot months could be a more accurate indicator of total exposure of the population, because people spend more time in the street and windows are kept open for longer (Katsouyanni 1995). Besides, during the hotter months, individual susceptibility to pollution might increase, due to processes such as the increased effect of particles upon the plasmatic viscosity regulation system (Pekkanen *et al*. 2000). Another reason is that there could be a selective emigration of the population from the cities during summer, with more elderly people remaining in the cities (Biggeri *et al* 2001).

Different studies have described a greater effect of ozone during the days with higher temperatures (Sartor *et al* 1995) or in the hotter months (Sunyer *et al* 1996, Touloumi *et al* 1997). The EMECAS study described the influence of ozone on the number of admissions of people with diseases of the circulatory system, which is significant in the hotter months, but not during the rest of the year (EMECAS project, submitted).

16.2.3. Infectious diseases

Changes in temperature, precipitation or humidity affect the biology and ecology of vectors, and those of intermediary hosts or of natural reservoirs (Githeko *et al* 2000). Furthermore, forms of human settlement could also have an influence: dengue is basically an urban disease and would have a greater effect in very urbanised communities with a deficient waste waters and solid wastes elimination system.

Classically, one of the mathematical expressions most used, initially by malariologists, to quantify the vectorial capacity (C) of an arthropod has been defined as: Vectorial capacity: C= $\frac{ma^2p^n}{-\log_e p}$, where **m** is the density of the vector arthropod per human, **a** the daily rate of bites on a vertebrate host multiplied by the probability that that vertebrate is a human, **p** the daily survival rate of a vector and **n** the latent period of the pathogen in the vector arthropod (extrinsic incubation).

16.2.3.1. Effects of temperature

Temperature is a critical factor upon which both vectorial density and vectorial capacity depend: it increases or decreases the survival of the vector, conditions the growth rate of the vector population, changes the susceptibility of the vectors to pathogens, modifies the extrinsic incubation period of the pathogen in the vector and changes the activity and pattern of seasonal transmission.

On increasing water temperature, mosquito larvae need less time to mature and, consequently, the number of descendants increases during the transmission season. The egg-adult metamorphosis period is shortened, the size of the larvae is reduced, and adults are generated in a shorter time period, but these are smaller and females therefore have to consume blood more often in order to lay eggs, which leads to an increase in the inoculation rate. The extrinsic incubation period (the time taken by the arthropod from when it is infected until it becomes an infective agent) has a direct relationship with temperature: the higher the temperature the shorter this period is.

It is very likely that the effect of climate change on diseases transmitted by arthropods will be observed on varying the transmissibility temperature limits: 14-18ºC as the lower limit and 35-40ºC as the higher one. A minimum increase in the lower limit could lead to the transmission of diseases, whereas an increase in the upper limit could suppress this (above 34ºC the life of the mosquito is significantly shortened). At around 30-32ºC, however, vectorial capacity can be substantially modified, as small temperature increases shorten the extrinsic incubation period, and transmissibility is increased.

Climate decisively affects the phenology of many arthropods which even fall into a lethargic state (diapause) in the unfavourable season, and this behaviour is very generalised in species in the Palaeartic region. The seasonal activity period of many species can be lengthened according to the prolongation of favourable climatic conditions.

16.2.3.2. Effects of rainfall

An increase in rainfall could increase the number and quality of vector breeding places and vegetation density, which would provide ecosystems in which to alight and which would provide better shelter and food for intermediate host rodents. Flooding, however, would eliminate the habitat of vectors and vertebrates, but would force vertebrates into closer contact with humans. Droughts in humid sites would slow river flows, creating still waters which would also increase the breeding places and would cause greater dehydration of the vector, which would force it to feed more frequently, in other words, to increase the number of stings/bites.

16.2.3.3. Other factors

Housing development increases the density of susceptible human hosts, with worse hygiene conditions in poorer countries, which increases the transmissibility rate for the same number of vectors. Furthermore, urban development in the vicinity of rural or forested areas can lead to an increase in contact between man, vectors and selvatic reservoirs.

Deforestation allows humans to enter the forest, which becomes agricultural land, which increases the number of possible vector breeding places and contact between man and vectors and reservoirs.

Irrigation and water supply schemes increase the aquatic area and prevent flooding and drought, which also increases vector breeding places.

Agricultural intensification increases erosion and water areas and reduces biodiversity, thus reducing vector predators and increasing vector breeding places.

Chemical pollution by fertilisers, pesticides, herbicides and industrial waste may negatively affect the human immune system, making man more susceptible to infections.

Increased international trading could lead to the import of vectors from remote parts of the world.

Population movement resulting from tourism, work or immigration can cause the import of diseases from endemic areas.

16.3. FORESEEABLE IMPACTS OF CLIMATE CHANGE

16.3.1. Extreme temperatures

Thermal extremes associated with climate changes will clearly have a direct effect on excess mortality. In the case of heat waves, this impact will be seen in an increase in the excess mortality associated with these extreme events Díaz *et al* 2002a, Smoyer 1998). Predictions indicate and increase in the intensity and frequency of heat waves, especially during the first months of summer (Hulme *et al* 2002). An example of this is the heat wave in France, from August 1st – 20th 2003, which caused excess mortality in relation to the same period in previous years of 14,800 people. In Italy, an increase by 4,175 deaths was estimated for the over 65 age group, from July 15th to August 15th. In Portugal, from July 31st and August 12th, there was an excess mortality of 1,316 people in relation to the previous year. In Great Britain, there was an increase of 2,045 people from August 4th to August 13th (Pirard 2003). In Spain, according to unofficial data, there was an excess mortality of over 6,000 people, compared with the same period in the previous year (WHO 2004, Martínez *et al* 2004)

16.3.1.1. Models for predicting temperature-related mortality

Regardless of the data for this last summer, studies based on analyses of time series of mortality and the relationship between these and temperature in the case of different cities, enabled us to quantify the impact of thermal extremes according to each degree by which maximum daily temperature exceeded the threshold of each one of them. Thus, studies have been applied to the case of mortality associated with heat waves for the cities of Madrid (Díaz *et al* 2002a), Seville (Díaz *et al* 2002b) and Lisbon (García-Herrera *et al* 2004). By way of an example, table 16.3 shows the mortality increase in persons over 65 years of age associated with each degree by which maximum temperature exceeds the 36.3ºC threshold temperature for Madrid.

Table 16.3. *Percentage of increased mortality due to different causes,sex and ge groups in Madrid City by each degree by which maximum daily temperature exceeds resulting 36.5 ºC.*

Causes of mortality	Men 65-74	Women 65-74	Men >75 years	Women >75 years
Organic (%)	14,7	16,2	12,6	28,4
Circulatory (%)	9,4	11,7	6,3	34,1
Respiratory (%)	17,2	23	26,1	17,6

According to these models, the heat wave in the summer of 2003, from July 1st to 31st, caused an excess mortality in Madrid of 141 deaths, approximately 95% CI: (81 200) of which 96 % involved persons of over 65 years of age. For Seville, the excess mortality in over-65s totalled 43 deaths, 95% confidence interval: (20 - 66).

The previous definition by the intensity index of the heat wave enabled us to identify the provinces in our country in which heat had the greatest influence on mortality in the year 2003. In general terms, it was in the places in which heat is more infrequent where the highest values of this index were reached in summer. The behaviour of the index calculating the intensity of the heat wave in relation to the mortality rate in the provinces of Spain with over 750,000 inhabitants is of a logarithmic nature (Díaz *et al* 2004b) which indicate that small increases in the index have a great effect on mortality, and that, partly due to the harvester effect, there is a threshold above which the effect becomes stabilised.

Although at global level, the different patterns of expected mortality based on future scenarios of climate change (McGeehin and Mirabelli 2001) refer to an increase in mortality related to heat waves and a decrease related to cold, it is also true that studies in Europe (Eurowinter Group 1997) indicate that cold has an influence on mortality, greater in those places with more temperate winters than in areas with harsher ones. On one hand, this is due to physiological adaptation to low temperatures, and, on the other, to the infrastructures of homes, which mean that conditions referring to the fight against cold, in places accustomed to cold spells, are better than in which cold is more infrequent (Eurowinter Group 1997). By way of an example, table 16.4 shows the effects of the days in which maximum daily temperature is below the aforementioned threshold on mortality in the over-65 age group in Madrid (Díaz *et al* 2004a)

Table 16.4. *Percentage of increase in mortality in the City of Madrid, according to age groups and specific causes by each degree by which maximum daily temperature does not reach 6 ºC.*

Causes of Mortality	Age from 65 to 74 years	Over 75
Organic (%)	5,1	2,7
Circulatory (%)	6,1	2,8
Respiratory (%)	9,1	9,6

16.3.1.2. Evolution models of mortality rate for the horizon of the years 2020 and 2050

A recent study applied to the city of Lisbon (Dessai 2003) evaluated, although with a high degree of uncertainty, the possible increase in the gross mortality rate for the years 2020 and 2050. Predictions by two regional climate models were used, as well as different hypotheses referring to the acclimatisation and evolution of the population. According to this study, the increase in mortality rate associated with heat was between 5.4 and 6 for every 100,000 inhabitants in the 1980-1998 period. Between 5.8 and 15.1 for the horizon of 2020 and from 7.3 to 35.6 for 2050.

16.3.2. Air pollution

16.3.2.1. Annual tendencies and seasonal variation of air pollutants.

The SESPAS 2000 report described the descending tendency of levels of SO_2 and of black smoke, particularly of the former, in the last 20 years (Fernández-Patier and Ballester 2000). These pollutants are the ones traditionally included in air pollution monitoring and control programmes.

In Spain, information is currently available for the evaluation of the present situation, with a certain perspective, and of the tendencies of other pollutants relevant to human health (Figure 16.4).

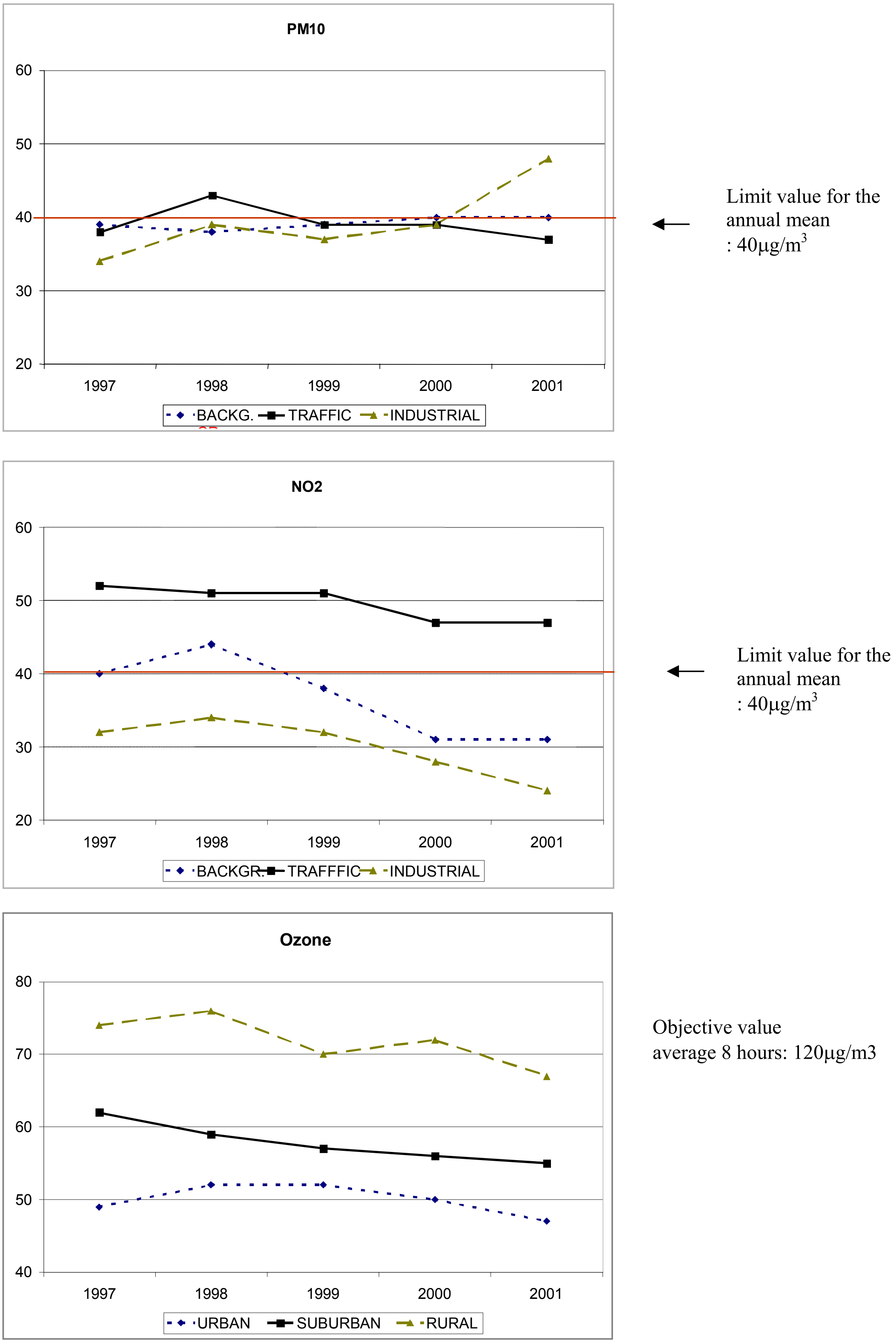


Fig. 16.4. *Average of the annual mean values of levels of PM10, NO2 and Ozone (in $\mu g/m^3$). Spain 1997-2001. Source: Air Quality Database, Ministry of the Environment 2003.*

Given that most of Spain's population lives in urban areas, the data corresponding to the PM10 and NO_2 are presented for the urban-type stations, with a distinction between those directly influenced by the traffic in a nearby street (traffic monitoring stations), and those mainly influenced by industrial factors (industrial monitoring stations) and, lastly, are not very much directly affected either by traffic or by industry (urban background monitoring stations). For these two pollutants, we can see how the values recorded oscillate around the limit value stipulated in European and Spanish regulations, which is 40 $\mu g/m^3$ as a mean annual value, set to be reached in the year 2005 or 2010, respectively (European Union Council 1999). In both cases, we must take into consideration that the values shown are the mean values of annual averages in each one of the 150 urban monitoring stations. Which means to say that in many of these cities, the annual values will be greater than the threshold value established by Spanish and European regulations.

In the case of the *PM10* the values obtained in the different types of stations present a stable tendency, with no big changes in these last 5 years. Furthermore, it can be seen that, in urban areas, particle pollution does not directly depend on the proximity of the emission sources, but rather, is distributed in quite a homogeneous manner throughout developed areas. In terms of public health, this fact is significant, because it suggests that the percentage of people exposed to average concentrations of over 40 $\mu g/m^3$ of PM10 could be high. We must consider, however, that the composition of the particles can vary substantially from one place to another, and that the toxicity of the particles appears to be related, among other things, to their composition and size. In this sense, more information would be needed in relation to the values of fine particles (PM2.5) and to the composition of these, in order to better evaluate their origin and possible impact on health.

The *NO2* values indicate a different pattern. In this case, the highest values are clearly recorded in the traffic monitoring stations indicating that this pollutant could be a good pollution indicator, due to emissions from motor vehicles. Furthermore, in the urban background and industrial monitoring stations a certain decrease was observed, and this tendency is not clearly seen in the traffic monitoring stations.

For *ozone*, as this is a secondary pollutant which usually reaches the highest values in areas distant from the emission sources, the values measured in urban background monitoring stations are represented, located in urban areas, suburban and rural ones. In the sub-urban monitoring stations, which represent exposure by a high percentage of the population, mean annual concentrations reach 60 $\mu g/m^3$. Given the high annual seasonality, with higher values in the hotter months, and the daily ozone pattern, with sharp peaks during the hours of solar radiation, it is certain that, in many days of the year the threshold values of 120 $\mu g/m^3$ will be surpassed for values of the daily maximum of 8 hours. Stability is generally observed, or a certain tendency of mean concentrations to decrease; the period considered, however, is very short to be able to identify a consistent pattern.

16.3.2.2. Seasonality and influence of meteorological conditions in relation to the emission, transport and formation of air pollutants.

Seasonality can vary from one place to another, basically depending on emissions and meteorological phenomena. There is, however, a homogeneous pattern in most Spanish cities, and primary pollutants from the combustion of fossil fuels present a pattern with higher values in winter (due to greater emission and conditions of meteorological stability) and lower values in the summer months. On the other hand, ozone presents the opposite pattern, with higher values during the months with higher temperatures, due to the interaction of ultraviolet rays with the precursory gasses (NO_2, VOC) from the exhausts of vehicles and from other sources. This pattern could be different for pollutants that are transported over long distances. In Spain, this is the case of pollution episodes caused by particles, occurring in the Canary Isles and part of the

Iberian Peninsula, as a result of dust transported from the Sahara desert (Viana *et al* 2002; Rodríguez *et al* 2001). This should be taken into account when evaluating particle levels in our country, because in certain circumstances, an important part of these involve dust from the Sahara.

Concentrations of air pollution depend on their production, and in a determinant way, on their dispersal. Climate change can affect either of the two aforementioned processes. On one hand, related to meteorology, the possible greater frequency of anticyclonic phenomena could reduce pollutant dispersal. Another meteorological phenomenon predicted as a consequence of climate change will be an increase in dry storms with dust transported from the Sahara and other places. On the other hand, and as will subsequently be described, temperature increase is very directly correlated to ozone concentrations. Lastly, and in an indirect way, a temperature increase could be associated with an increase in pollutant emissions resulting from greater energy consumption due to the use of air conditioning, cooling and refrigeration systems.

Although it would be necessary to establish the specific predictions for Spain (see other chapters of this report), given the fact that *ozone* is a secondary pollutant, we could expect climate change to be associated with increases in ozone levels.

It is difficult to predict how climate change will affect the levels of other pollutants. Pollutants more related to heating systems, such as SO_2, will possibly be less used, thus reducing emission thereof. For other pollutants, however, such as fine particles, NO_2 or CO, which are very much related to emissions from motor vehicles, it is quite difficult to predict tendencies. These will be determined to a great extent by the tendencies of fossil fuel combustion. At a local scale, there may be episodic situations of air pollution associated with meteorological phenomena involving high pressures and a lack of prolonged rainfall. Lastly, global warming could lead to an increase in the number and intensity of forest fires. The smoke produced by these fires has been related to increased respiratory disorders among the population affected.

16.3.2.3. Influence of meteorological conditions in the production and release of pollen and spores

In spite of the fact that pollen and spore concentrations depend to a great extent on the existing crop and wild species, variations in these concentrations depend very much on meteorological factors (McMichael AJ and Githeko AK 2001). Climate change could advance or lengthen the pollen period for certain species with an allergenic capacity. Besides, increased CO_2 levels could affect pollen production.

16.3.3. Infectious diseases

16.3.3.1. Malaria

16.3.3.1.1. Transmissibility

The natural transmission of this disease occurs through the bite of mosquitoes of the genus *Anopheles*. Of over 3,000 species of mosquitoes distributed throughout the world (particularly in warm and tropical areas), 400 are anophelines, 70 transmit malaria and only around 40 are of medical importance: *Anopheles gambiae* and *Anopheles funestus* are the main vectors in tropical Africa. These insects undergo a complete metamorphosis, passing through four clearly differentiated phases: egg, larva, pupa and adult, the first three aquatic and the last one aerial. The duration of this metamorphosis varies according to environmental temperature, from seven days at 31ºC to twenty days at 20 ºC. The males only live for a few days, and, as they do not feed on blood, they play no role in the transmission of the disease, except fertilising the females, which is done immediately after these hatch. The females are fertilised only once, and the keep the sperm in an internal reservoir for subsequent fertilisation. The first laying of eggs usually occurs on the 4th or 5th day of life of the mosquito and successive layings every 2-3 days, coinciding with the bite, as the mosquito seeks blood (which is known in entomology as "gonotrophic concordance". Once the mosquito is infected, it remains an infective agent all its life, and requires around ten days for the *Plasmodium falciparum* (extrinsic incubation period) to develop therein, and the female must therefore survive for at least four or five gonotrophic cycles in order to transmit malaria (that is, at least for 10-12 days). The longevity of the female mosquito in favourable conditions is around four weeks in Africa, although some warm climate species can survive for up to six months, on falling into winter lethargy. Most bite at night, especially from 20 to 03 hours and the most efficient ones with regard to transmission are those that have anthropophilic habits (only biting humans), endophagic and endophilic ones (which do so inside the house). There is a clear decrease in bites if relative humidity is below 52%. The optimum temperature for the development of the mosquito is 20-27ºC and 22-30ºC for the parasite (22ºC for *Plasmodium malariae* 25ºC for *Plasmodium vivax* and 30ºC for *P.falciparum*). There is no transmission at altitudes of over 3,000 metres or at constant temperatures of below 15 ºC, as the schizogony is paralysed (for *P.vivax* this is below 16ºC and for *P.falciparum* below 19ºC). There is no transmission, either, if the temperature remains constant at over 38ºC.

"Sporozoite index" is the term given to the proportion of female anophelines infected in a determined area (that is, the percentage that has sporozoites in their salivary glands), which in tropical Africa is 2-5%, whereas in other malarial areas it is 0.2-2%.

In malariology, the terms indigenous or autochthonous malaria are used when it is contracted through the bite of a mosquito infected in a country in which malaria exists. It is called introduced malaria when it is contracted in a country where malaria does not exists, through local mosquitoes that have been infected by someone infected by imported mosquitoes. Induced malaria is that transmitted by blood or organs. It is called airport malaria (or more generally, odyssean malaria) when it is caught in a country where malaria does not exist, by infected mosquitoes transported from endemic areas in baggage or aeroplanes, boats, busses, containers..., and 75 cases of this have been described for Europe in the 1997-2000 period (Mouchet 2000)

16.3.3.1.2. Malaria in Europe

In the past, malaria was transmitted throughout Europe, reaching as far north as England, Scotland, Denmark, southern Norway, southern Sweden, Finland and the Baltic provinces of Russia. At these latitudes, winters can reach -20ºC, and transmission depended upon how warm the winters were (limited to the 15ºC isotherm in July). But half-way through the XIX century, malaria disappeared from northern Europe and declined in the Centre (for example: the last outbreaks in Paris occurred in 1865, during the construction of the big boulevards) , and disappeared after the I world war. In southern Europe, it remained very prevalent (due to poverty and underdevelopment) until after the II world war, when an effective programme of vectorial control was introduced (with the revolutionary appearance of DDT), and by 1961 it had been eradicated from most countries.

In the 90s, there were outbreaks in the new states in the south of the ex - Soviet Union, with local transmission through import by troops returning from Afghanistan. At present, it is only transmitted (exclusively *P.vivax*) seasonally in very specific points of Armenia, Azerbayan, the Russian Federation, Turkmenistan, Uzbekistan and the Asian part of Turkey.

Occasionally, an autochthonous case is described in Europe, with no secondary transmission, but worrying in any case, such as in Italy, where cases of local transmission of *P.vivax* have been recorded and where anopheline density has shown spectacular growth in areas like Tuscany and Calabria (Baldari *et al* 1998).

16.3.3.1.3. Malaria in Spain

Benign tertian fevers by *P. vivax*, and to a lesser degree the malignant tertian ones by *P. falciparum* and quartan ones by *P. malariae*, were endemic in Spain until relatively recently. The last case of autochthonous malaria was recorded in May 1961 and in 1964 the official certificate of eradication was issued. Since then, all cases reported have been imported, with the exception of induced ones or those caused by exchange of syringes by drug addicts through parenteral administration or of airport malarias, although recently, a possible autochthonous case by *P. ovale* was described, in Alcalá de Henares (Madrid), but it may be a case of airport malaria caused by the proximity of the aerodrome at Torrejón de Ardoz (Cuadros *et al* 2002).

The only potential vector still present in Spain is *Anopheles atroparvus* the populations of which is still widely distributed throughout large areas. Fortunately, it is refractory to tropical strains of *P. falciparum*, which limits autochthonous transmission through cases contracted in sub-Saharan Africa (Ramsdale and Coluzzi 1975). *Anopheles labranchiae*, the other vector involved in the transmission of malaria, disappeared from the Southeast of the Peninsula in the 70s. Every year, over 400 cases of malaria are declared in our country, but to date this has not determined the re-introduction of the disease, in spite of the increase in potentially infected tourists and immigrants.

The malariogenic potential in Spain is very low, and the re-establishment of the disease is highly unlikely, unless social and economic conditions were to deteriorate drastically and rapidly. Any possible local transmission would be limited to a very small number of people and would be of a sporadic nature. Furthermore, the parasites that could most likely cause these cases would be the benign forms of malaria caused by *P. vivax / P. ovale*, as they can develop at lower temperatures and in peninsular vectors.

The most cautious predictions for the year 2050 do not indicate the Iberian Peninsula as a scenario for malarial transmission, but rather along the coast of Morocco (Rodgers and Randolph 2000). There is a possibility, however, that African vectors susceptible to tropical strains of *Plasmodium* could invade the South of the Iberian Peninsula (López-Vélez and García 1998), although exposure would be reduced with the increased use of air conditioning (Reiter 2001).

16.3.3.2. Viruses transmitted by mosquitoes

Over 520 of these viruses have been identified, of which around one hundred are pathogens for man. The most harmful ones are those that can cause haemorrhagic fevers or encephalitis. The term arbovirus (arthropod-borne-virus) is used for those transmitted by the bite of arthropods, fundamentally by mosquitoes of the genera *Aedes* and *Culex*.

Aedes aegypti, a vector of yellow fever and dengue in the tropics, appears to have disappeared from Europe and at present, it is not found above the de 35º northern latitude. To the contrary, this continent has been entered by *Aedes albopictus,* a vector of dengue (the 4 serotypes) and of yellow fever, originating in Southeast Asia and the sub-continent of India (it is also a potential vector of other viruses such as Japanese encephalitis, western equine encephalitis, Ross river fever, La Crosse, Chikungunya, Rift valley fever and West Nile fever. It is also a good vector of *Dirofilaria immitis* and *Dirofilaria repens.* In theory, it survives up to such northern latitudes as 42ºN (almost the lower two thirds of the Iberian Peninsula), but as it is capable of entering diapause when climatic conditions are unfavourable, the real limiting factor would be the -5ºC isotherm in January, which would make establishment possible as far north as southern Sweden. Furthermore, in both urban and rural environments, it feeds on the blood of mammals, birds and humans, which makes it an excellent connecting vector between wild and urban cycles and between animals and humans. Once infected by dengue, it can spread this virus vertically and through transovarial transmission to its larvae. In the 80s, it was introduced into the Americas in a cargo of used tyres from Japan. In Europe it was first detected in 1979 in Albania, apparently coming from China, it reached Italy from the USA in 1990 and after 2000 it appeared in France, Belgium, Montenegro, Switzerland and Hungary, and what was feared has happened, as it has just been detected in Spain (Aranda*, pers. comm.*).

16.3.3.2.1. Dengue

16.3.3.2.1.1. Transmissibility

The dengue virus is a flavivirus, of which there are 4 serotypes, with a wide range of clinical symptoms, from asymptomatic infections to potentially lethal haemorrhagic pattern. Every year, there are 250,000-500,000 cases of serious forms (haemorrhagic dengue- and shock dengue), producing a death rate of 1-5% which can reach 40% if untreated. There is no effective vaccine against this disease.

It is an urban environment disease, with explosive epidemics reaching up to 70-80% of the population. Transmission occurs through the bite of the mosquito *A. aegypti* and to a lesser extent by *A. albopictus* and takes place between the parallels 30ºN and 20ºS. Since the 50s, an evident re-emergence has been observed in Southeast Asia, and since the 70s, on the American continent.

The extrinsic incubation period in the mosquito is 12 days at 30ºC, but if the temperature rises to 32-35ºC this period is reduced to only 7 days. At 30ºC, a human being with dengue must infect 6 mosquitoes for a secondary case to occur, whereas at 32-35ºC only 2 mosquitoes need to be infected for this to happen, that is, the vectorial capacity of the mosquito is multiplied by 3 (Rogers and Packer 1993).

16.3.3.2.1.2. Dengue in Europe

Dengue existed in Europe in the past. The first serologically documented epidemic (in a retrospective manner) was in Greece during the years 1927-1928, with over 1 million people infected, of which over 1,000 died of haemorrhagic dengue. After the second world war, the transmission of dengue ceased in Europe, probably as a consequence of the malaria eradication campaigns with DDT.

At present, there is no documented transmission of dengue in Europe, but the worst is feared, as *A. albopictus* is well-established in Albania and Italy and, as has been previously mentioned, its presence has been detected in Belgium, France, Montenegro, Switzerland, Hungary and Spain.

16.3.3.2.1.3. Dengue in Spain

Epidemics have been described since the XVII century that might very well have been dengue, including the outbreak in Cadiz and Seville from 1784 to 1788 (Rigau 1998). In mid-June 1801 the Queen of Spain suffered symptoms of what appeared to be haemorrhagic dengue, and during the XIX century, there were epidemics in the Canary Isles, Cadiz and other parts of the Mediterranean associated with cases imported by sea.

There are no documented cases of local transmission of dengue, but there seems to be an evident risk, as Spain has the appropriate conditions for transmission: high summer temperatures and large urban nuclei, where windows are kept open and the use of air conditioning is infrequent, and there is much activity in streets and parks (ideal for contact with the vector). Although at present *A. aegypti*, one of the most important vectors of this disease, appears to have disappeared from Spain decades ago, the presence of *A. albopictus*, the second most important vector, has just been confirmed in Catalonia (Sant Cugat del Vallès) (Aranda, *pers. comm.*). The ideal climatic conditions for the development of this mosquito are: over 500 mm^3 annual rainfall, over 60 days rainfall per year, mean temperature of the cold month above 0ºC, mean temperature of the warm month over 20ºC and mean annual temperature over 11ºC. The areas believed to be most suitable for the development of this vector in Spain are Galicia, the whole Cantabrian coast, the sub-Pyrenees, Catalonia, the Ebro delta, the Tajo basin, the Guadiana basin and the mouth of the river Guadalquivir (Eritja, pers. comm.).

16.3.3.2.2. Viral encephalitis. West Nile virus

16.3.3.2.2.1. Transmissibility

Representing a wide range of viral diseases (Saint Louis encephalitis, western equine encephalitis, Venezuelan equine encephalitis, West Nile…) that are transmitted by the bites of different species of mosquito, especially of the genus *Culex* (*C. quinquefasciatus*, *C. pipiens*…) and of ticks, birds constituting the main reservoir of the disease. Transmission is impossible at isotherms of below de 20ºC in summer. These cause a pattern of meningitis or meningoencephalitis that can cause permanent neurological damage. Although it mainly circulates among birds, many species of mammals can also be infected, such as amphibians and reptiles.

Outbreaks of Saint Louis encephalitis associated with climate changes were detected in California in 1984 and of Venezuelan equine encephalitis in Venezuela and Colombia during 1995. West Nile virus is endemic in Africa, and very noteworthy was the outbreak in New York in 1999, which subsequently spread to 44 states and to 6 provinces of Canada in just five years, transmitted by mosquitoes of the genus *Culex* from infected migratory birds.

16.3.3.2.2.2. Viral encephalitis in Europe

Epidemic outbreaks of West Nile were detected in the eastern Mediterranean, the Camargue in the 60s and in the surroundings if Bucharest (Rumania) in 1996. During the months of August-September 2003, a small outbreak was detected in the Var region in France (where there had been an outbreak of equine encephalomyelitis in 2000) which affected two humans (who, in fact, had spent their holidays on the East coast of Spain) and three horses. During this outbreak, in Spain around 80 samples of cerebrospinal fluid from patients with meningitis, and over 900 pooles of mosquitoes were studied, none of which were found to be positive. Other outbreaks have also been described in Italy, the Czech Republic, southern Russia and Georgia. In summer 2004, there was another small outbreak in the Algarve (Portugal), which seems to have affected two Irish tourists, although this outbreak is still to be confirmed.

16.3.3.2.2.3. Viral encephalitis in Spain

The Mediterranean basin and the South of the Iberian Peninsula in particular, which receive migratory birds from Africa, constitute high-risk areas for transmission. Seroprevalence studies carried out in Spain from 1960 to 1980 showed the presence of antibodies in the blood of inhabitants of Valencia, Galicia, Coto de Doñana wetlands and the Ebro delta, which means that the virus circulated throughout our country at that time (Lozano and Felipe 1998). The current impact this virus could have on the health of the Spanish is unknown, as it is not routinely researched in cases of viral meningitis. The association with climate change has not been established, but a temperature increase can be expected to cause an increase in vectors, and therefore, greater risk of transmission, which would lead to outbreaks of viral meningitis and encephalitis in populations in risk areas in Spain.

16.3.3.2.3. Yellow fever

16.3.3.2.3.1. Transmissibility

This disease in included within the haemorrhagic viral fevers and has a death rate of >40%. Fortunately, there is an effective vaccine for prevention. It is endemic on the continent of Africa and in the Amazon, and transmitted by the bite of the mosquito *A. aegypti*.

16.3.3.2.3.2. Yellow fever in Europe and in Spain

Spain, with its overseas colonies, was particularly vulnerable to this disease, and epidemic outbreaks associated with cases imported by sea were recorded: in 1856 there were over 50,000 deaths in Barcelona, Cadiz, Cartagena and Jerez (that same year 18,000 people died in Lisbon and there were many other cases in port cities in northern Italy and southern France) (Eager 1902). *Aedes aegypti* disappeared from the Mediterranean after the II world war, very likely as an indirect consequence of the programmes for the eradication of malaria, and since then, no risk of this disease has existed.

16.3.3.2.4. Leishmaniasis

Leishmaniasis re-emerged in Europe in the 60s, once the control programmes for the eradication of malaria had ended. A parasitic disease caused by *Leishmania infantum* in Spain, it is endemic in our country and from dogs to humans by diptera of the genus *Phlebotomus* (*P. perniciosus* and *P. ariasi*). It causes cutaneous leishmaniasis and severe visceral leishmaniasis.

Temperature increases could shorten parasitic maturation in the vector (increasing the risk of transmission), reduce the vectors' period of wintertime lethargy, with the consequent increase in the number of annual generations, and cause a change in geographic distribution, the more dangerous species being displaced towards the North of the Peninsula, at present free of the disease.

It is highly likely that the distribution of leishmaniasis on the European continent will spread northwards, as a consequence of global climate warming, from the present distribution limits of the disease. There is also a high risk that anthroponotic cutaneous leishmaniasis caused by *Leishmania tropica*, currently existing only in North Africa and the Middle East, will emerge at any moment in southern Europe.

16.3.3.3. Tick-transmitted diseases

16.3.3.3.1. Transmissibility

Ticks undergo a metamorphosis from the egg phase which includes three stages of development involving blood-sucking (larvae., nymphs and adults). It is the nymphs, however, that most contribute to the transmission of diseases to humans from animal reservoirs. The diseases are many and of varying seriousness: borreliosis (endemic relapsing fever, Lyme borreliosis), rickettsiosis (boutonneuse fever, spotted fevers), babesiosis, anaplasmosis, ehrlichiosis, tularemia and viral diseases (encephalitis caused by tick bite or Centro-European encephalitis, Crimean-Congo haemorrhagic fever, Kyasanur forest disease...).

In Spain, the most serious diseases are boutonneuse fever and Lyme borreliosis and the most widespread ticks are *Rhipicephalus sanguineus*, the "common dog tick" involved in the transmission of Mediterranean spotted fever and *Ixodes ricinus,* involved in the transmission of Lyme borreliosis.

The average life of a tick can exceed 3 years, depending on climatic conditions. The three stages of the vector can be infected, and what is most dangerous, it can transmit the infection to its young through transovarial transmission.

They can survive temperatures as low as -7ºC, recovering vital activity at 4-5ºC. They are very sensitive to minimum temperature changes, as can be seen in the fact that an isotherm of just 2ºC conditions transmission in southern and eastern Africa. Decreased humidity causes a notable reduction of viability of the eggs. A slight climate change could cause an increase in the tick population, lengthen the seasonal transmission period and displace distribution further North (Randolph 2001). Fortunately, for certain diseases, such as tick-transmitted encephalitis, the projected climate change will keep the focuses of this disease in Spain even further away.

Ixodes ricinus (on the Cantabrian coast, the Cameros mountains in the La Rioja region and in some isolated populations in the Guadarrama mountains and northern Cáceres) is very sensitive to climate warming, and the models project that this species would surely disappear from the country, although relictic populations could remain in the colder areas in Asturias and Cantabria. *Rhipicephalus sanguineus* does not depend directly on climate, but rather on the existence of housing development and types of periurban-rural construction that favour their development and colonisation. It is feared that African ticks (*Hyalomma marginatum*, *Hyalomma anatolicum*) might invade Spain, and these could be involved in the transmission of Crimean-Congo haemorrhagic fever.

16.3.3.3.2. Encephalitis. Lyme borreliosis. Rickettsiosis

The incidence of tick-borne encephalitis in Sweden has substantially increased since the mid-80s, and the distribution limits of the ticks *I. ricinus* have spread further North, due to temperature increase (Lindaren and Gustafson 2001).

Temperature increase could cause imported ticks to adapt to the new climate and to transmit diseases. Since the 90s, ticks of the species *R. sanguineus* have become established in southern Switzerland, and it has been demonstrated that these are infected rickettsia that causes Mediterranean spotted fever and Q fever (Bernasconi *et al* 2002).

16.3.3.4. Diseases transmitted by rodents

16.3.3.4.1. Transmissibility

Rodents can shelter other vectors such as ticks and fleas (*Xenopsylla cheopis*, *Ctenocephalides felis ....*) that transmit the plague and murine typhus. Furthermore, they can act as intermediary hosts or reservoirs of several diseases such as leptospirosis, haemorraghic viral fevers (Junin, Machupo, Guaranito, Sabia, Lassa), hantavirus, hymenolepis infection….

Both the population of wild rodents and the possibility of contact between rodent and human in urban areas is very much influenced by environmental changes. After years of drought, which could reduce the number of natural predators on rodents, there would be rainfall that would increase available food (seeds, nuts, insects), which would lead to an increase in the rodent population.

16.3.3.4.2. Hantavirus

In the South of the United States, there was an outbreak of a very serious epidemic of human hantavirus at the beginning of the 90s, associated with an unusual increase (up to 10 times) in the natural hantavirus reservoir rodent population (*Peromyscus* sp). The cause was the aforementioned climate change (Wenzel 2004).

In Spain, hantavirus has been detected in foxes and rodents and in human sera.

16.4. MOST VULNERABLE AREAS

16.4.1. Extreme temperatures

The areas most vulnerable to the thermal extremes expected ought to be identified with the use of different parameters. On one hand, we should consider the areas in which, according to different scenarios, greater frequency and intensity of thermal extremes are expected (see chapter 1). Furthermore, it is known that the biggest impact is on the older age groups (WHO 2004), and the greatest impact will therefore be in the places with a higher population of persons over 65 years of age, and this proportion is usually lower in the big cities. An example of this is the province of Soria, where 26.9 % of the population is over 65, whereas in Madrid, this figure only reaches 14.2%. Finally, we must consider adaptation to heat, as well as the different socioeconomic patterns and infrastructures available in each area (García-Herrera *et al* 2004)

16.4.2. Air pollution

Different studies have shown that the elderly, people with delicate health, suffering from chronic bronchitis, asthma, cardiovascular diseases, diabetes (Bateson and Schwartz 2004) and children, are among the most vulnerable groups (Tamburlini *et al* 2002). With regard to air pollution by ozone, the risk group would be made up of children, young people and adults, because these spend more time in the open air. If, besides, these people are doing intensive exercise (sports, work, play), the frequency and intensity of respiratory disorders increase, and consequently, the degree of risk. Children constitute a special risk group, because their respiratory systems are not fully developed, because they spend more time outdoors and because they breathe in more air per unit of weight than adults.

Furthermore, socioeconomic level has been related to the degree of impact of air pollution on health. Thus, a higher number of deaths due to respiratory causes has recently been described in Sao Paolo, Brazil (Martins *et al* 2004), and in Hamilton, Canada (Jerret *et al* 2004) among people with lower socioeconomical conditions . These differences could be due to different exposures (people from higher social classes live in less polluted places), to differences in the state of health (poverty is associated with illness, chronic bronchitis, for example), and to the fact that people with less financial resources could be more susceptible or vulnerable (poorer diet, worse housing conditions). The previous results, however, have been more related to primary pollutants such as CO and SO_2. As ozone is a secondary pollutant, the more exposed areas may be far from the emission points (Lipfert 2004).

16.4.3. Infectious diseases

Due to the proximity of the African continent, which is a place of obligatory transit for migratory birds and people, and to climate conditions, similar to those in areas with transmission of vector-borne diseases, Spain is a country in which these diseases could be boosted by climate change. But for the establishment of real areas of endemicity, a combination of factors would be needed, such as the mass and simultaneous arrival of animal or human reservoirs or the deterioration of socio-health conditions and of the Public Health services.

The vector-borne diseases that can hypothetically be influenced by climate change and emerge or re-emerge in Spain are shown in table 16.5:

Table 16.5. *Vectors-borne diseases that could be potentially ingluenced of climate change*

Disease	Agent	Vector	Clinical pattern
Dengue	Flavivirus	mosquito	Haemorrhagic viral fever
West Nile	*Flavivirus*	mosquito	Encephalitis
Crimean-Congo fever	*Nairovirus*	tick	Haemorrhagic viral fever
Tick-borne encephalitis	*Flavivirus*	tick	Encephalitis
Rift valley fever	*Phlebovirus*	Mosquito	Haemorrhagic viral fever
Boutonneuse fever	*Rickettsia conorii*	tick	Spotted fever
Murine typhus	*Rickettsia typhi*	flea	Typhoid fever
Lyme borreliosis	*Borrelia burgdorferi*	tick	Arthritis, meningitis, carditis
Endemic relapsing fever	*Borrelia hispanica*	tick	Fiebre recurrente
Malaria	*Plasmodium sp.*	mosquito	fiebres palúdicas
Leishmaniosis	*Leishmania sp*	flebotomo	kala-azar

Europe has warmed by around 0.8ºC in the last 100 years, but not in a uniform fashion, as the biggest increase has taken place in the North of the continent. If this tendency continues, it is likely that the high death rate of vectors in winter will decrease. It is harder to make predictions about rainfall, although winters will probably be more humid and summers drier. If the South were to become drier, wetlands would diminish, leading to a reduction of mosquito breeding places; other breeding grounds would appear, however, with the greater amount of stagnant waters produced as bodies of water, or rainwater deposits used by farmers dry out.

Predictions of change in Spain indicate rainier and warmer winters followed by hot, dry summers, which are favourable conditions for the establishment and proliferation of vectors. There would be a possible risk of the import and establishment of tropical and subtropical vectors adapted to survival in cooler and drier climates (for example, *A. albopictus*).

16.5. MAIN ADAPTIVE OPTIONS

16.5.1. Extreme temperatures

Numerous factors can have an influence on the impact of thermal extremes on the population and therefore, on adaptation to extreme events. Firstly, meteorological factors at local scale affect the occurrence of determined thermal extremes. Thus, for instance, the synoptic conditions that caused the heat wave in Madrid and Lisbon during the summer of 2003 were different in both places (García-Herrera *et al* 2004).

As the group most affected by thermal extremes appears to be the over 65s, any adaptation measures will need to be based on the population of each place. Factors associated with economic and cultural development can also condition the impact of thermal extremes. For example, heating systems have clearly mitigated the effects of cold spells, in spite of the associated increase in emissions of greenhouse gasses (Wilkinson *et al* 2001) and air conditioning systems have had the same effect during heat waves (Curriero *et al* 2002).

Although the ageing population is undoubtedly the most affected group, other groups, comprising people with different pathologies can also be negatively affected, and their pathologies exacerbated. The experience of 2003 showed us that apparently healthy people have died as a result of heat when carrying out activities such as sports in the open air at the hottest times of the day.

To this must be added the need to inform the population of the basic measures to be followed during thermal extremes, and to correctly train and adapt the health services in relation to possible increases in the pathologies associated with heat waves and cold spells. There is a need for *in situ* warning systems for possible thermal extremes. Each city needs to develop different systems based on their specific meteorological conditions, on the response by their own demographic distribution, infrastructure, social composition and hospital resources.

Unlike cities in the United States, European cities are unprepared for heat waves. In some European cities, the warning plan consists of weather forecasts, and only provides passive information to the general public and to the local safety institutions. Only Lisbon and Rome have implemented effective adaptive measures (Pirard 2003; WHO 2004). These systems are based on the fact that weather forecasts have a high degree of reliability – 24 – 48 hours before the thermal extreme, which means that there is enough time to mobilise a previously organised network. Thus, for example, in Philadelphia a warning is given through the media and a “hotline” is set up, the involvement of the neighbours and of the social services is brought to bear, and measures are implemented aimed at reinforcing emergency medical services and facilitating access for the elderly to places with air conditioning. These systems have proven to be efficient in the short term and could constitute a suitable long-term adaptation strategy for the population (Keatinge 2003).

Along these lines, an important adaptation strategy involves appropriate town planning aimed at mitigating urban heat island effects, along with the construction of bioclimatic buildings that guarantee the comfort of the inhabitants through minimum energy consumption.

16.5.2. Air pollution

As indicated by the United Nations Economy Commission for Europe (UNECE 2003), scientists and politicians should stop treating air pollution and climate change as different problems, because both are very closely related and are due to a great extent to the increased use of fossil fuels.

One of the first measures to be implemented should be the setting up of an air quality monitoring system (including information on meteorology, pollen and spores) and a public warning system for situations of increased levels. Legislative measures should also be implemented in order to establish certain air quality standards and emission restrictions aimed at protecting citizens’ health. The European framework facilitates the implementation of both these measures in our country, but effective policies are required in order to attain an integral systems comprising the different sectors involved: environment, public health, transport, industry, etc...

The most important measure involves reducing emissions of pollutant gasses. This in turn involves implementing strategies in the transport, town planning and industrial sectors based on the efficient use of energy and the progressive use of renewable energy sources.
Another measure could be the implementation of programmes aimed at reducing the risks of forest fires and exposure to allergenic pollen (Casimiro and Calheiros).

The previous measures ought to be complemented (McMichael AJ and Githeko AK 2001) with actions for health education and the promotion of healthy habits, including efficient and responsible energy use and information for public safety (for instance, informing of days with high levels of ozone).

One last aspect that ought to be highlighted is the need for citizen involvement in order to solve many of these problems. Environmental and health awareness should be promoted among the public, and common active participation in determining and problems and needs should be ensured, along with planning and action processes. Environmental health problems are related to the pattern of development in our country, as in other European countries (like, for example, the uncontrolled use of electric energy, drinking water, housing development, the use of private cars as the mains means of transport, etc). Consequently, the solution of these problems depends on big changes in lifestyles which affect large sectors of the population.

In short, future changes should be based on the contribution by all the sectors, that is to say, decisions by politicians, legislative changes, actions by the experts, education and information, decisions by the consumer, etc., aimed at promoting clean technologies, reduced use of fossil fuels, and the use of products that cause less pollution.

16.5.3. Infectious diseases

Recognition of the risk at official level is fundamental. We must be vigilant and not underrate the risk, and climatic data and statistics on infectious diseases should be collected in order for the early implementation, in cases of alert, of appropriate Public Health campaigns aimed at reducing the vulnerability of the population to infectious diseases, through strategies based on vaccination, vector control and water treatment (McCarthy 2001; Hunter 2003).

16.6. REPERCUSSIONS FOR OTHER SECTORS

16.6.1. Extreme temperatures

The aforementioned adaptive options clearly involved different sectors. In the first place, the meteorological information must be sufficiently reliable at local scale in order for the intervention plans to be effective, both in the detection of heat waves and cold spells and in determining their intensity and duration.

The insurance sector, in relation to both health and deaths, will be affected by an increase in the number of hospital admissions and by the costs associated with increased deaths.

The demand for energy, fundamental in air conditioning systems, will be affected by an increase in the needs of the population and of health centres, as has been described in the pertinent chapter.

In spite of the economic cost of the plans of action described, in the strict cost-benefit sense, and following the example of the Philadelphia Plan, these are highly profitable, because an annual cost of 250,000 dollars is related to profits in avoided mortality of 117 million dollars per year (Kalkstein 2002).

16.6.2. Air pollution

The adaptation measures described in the previous point will have an impact on different sectors.

16.6.2.1. Climate sector

Reduced emissions of pollutant gasses, as these are of the same origin as greenhouse gasses, would positively affect emissions of CO_2 and of other gasses into the atmosphere. This would lead to a deceleration of global warming.

16.6.2.2. Sector energía

More efficient energy use and the introduction of clean energy will reduce the use of fossil fuels, and consequently, will reduce emissions of SO_2, CO and NO_2.

16.6.2.3. Agriculture sector

The introduction of species with a high allergenic capacity in agriculture should be assessed, along with the treatment of these, particularly in crop fields close to human settlements. We should take into consideration the possible use of pesticides aimed at eliminating species with allergenic capacity, and possible repercussions upon human health, due to direct application, environmental exposure or exposure through foodstuffs.

The hypothesis that the consumption of antioxidant foods, with vitamin C, vitamin E and beta-carotene, like citrus fruits, carrots or nuts, and in general, all fruits and vegetables, protects against the effects of photochemical pollution (in particular ozone) may lead to increased consumption thereof being recommended. This would affect agricultural policies.

16.6.2.4. Forestry sector

Evidence of health risks caused by the emission of particles and gasses resulting from combustion should lead to increased protection of forests aimed at preventing forest fires.

16.B.6.5. Tourism sector

Measures aimed at attaining cleaner air and a healthier environment, together with models of good environmental practice, may also help to establish a system of ecologically sustainable quality tourism.

16.6.2.6. Health sector

An important question involves the beneficial secondary effects of mitigation policies. Actions aimed at reducing emissions of greenhouse gasses will probably lead to improvements in the health of the population (McMichael and Githeko 2001).

In an article in the review Lancet during the debate on the contents of the Kyoto Protocol, (Working Group on Public Health and Fossil-Fuel Combustion 1997) an evaluation was made of the possible short-term impact on human health of emission control, that is, without waiting to see the consequences in relation to the mitigation of climate change. This study compared what would happen, with regard to the effects of exposure to particles in suspension, if world energy policies were to continue in the same way as up to 1997, or if they changed to a scenario of emission control policies aimed at avoiding global warming. From the year 2000 to 2020, the different rates of exposure to particles could mean a difference of 700,000 deaths per year. Only in the United States, the number of avoidable deaths would be equivalent in magnitude to all the AIDS-related deaths or all those caused by hepatic diseases.

In another study, an estimate of the benefits of reduced air pollution in four north or south American cities (Santiago de Chile, Sao Paulo, Mexico and New York) indicated that if the available technologies were adopted for reducing air pollution and global warming, there would be 65,000 deaths less and a reduction of the associated cases of bronchitis and restricted activity (Cifuentes *et al* 2001).

These results illustrate the benefits, at local scale and at a closer scale in time, of policies for the reduction of emissions of the gasses that cause global warming. These figures, however, should be evaluated with care, and only taken as indicators, given the existing assumptions and doubts involved in the estimates. It has been demonstrated, however, that the use of renewable energy sources can help to reduce emissions, while at the same time, constituting an accessible source of energy for a large sector of the population that has current access to clean energy sources (McMichael and Githeko 2001).

Strategies by the transport, environment and health sectors, involving the use of the bicycle and walking as means of transport, will lead to increased moderate physical exercise in a large segment of the population that at present has sedentary habits, and this will have favourable consequences for public health (Haines *et al* 2000).

16.6.3. Infectious diseases

The biggest repercussion of the reintroduction or dissemination of vector-transmitted diseases would be seen in the Tourism sector. An increase in these disease in tourist areas would dissuade the tourist from choosing these destinations, with the resulting consequences.

The Agriculture and Forestry sectors are intimately correlated with the habitats and ecosystems in which vectors breed.

16.7. MAIN UNCERTAINTIES AND KNOWLEDGE GAPS

16.7.1. Extreme temperatures

Perhaps it is this aspect related to effects upon health, and in particular to thermal extremes, the one that presents the highest degree of uncertainty.
Firstly, there are the aspects related to the climate models themselves, which are described in the corresponding chapter. To this we must add the clearly local nature of the behaviour of extreme temperatures on the Peninsula, as has been seen in recent studies (Prieto *et al* 2004). Another key factor involves the determination of possible demographic scenarios, above all related to demographic distribution in the over 65 age group, a target group for the effects of heat waves and cold spells (WHO 2004). Furthermore, the possible impacts dealt with here depend on social, economic, technological, cultural, political and biophysical factors, the evolution of which is unknown. The implementation of prevention plans such as the one previously described, the resources involved and the effectiveness of these, will be decisive in determining the direct effects upon the health of the population.

The health sector also presents an added disadvantage, basically related to the lack of data on the effects of thermal extremes on morbidity and mortality. Current data registers do not allow for measures to be taken in real time and several months (even years) must elapse before these data become available to researchers. Without a flexible and reliable database system, any research becomes particularly complicated and any dose-response model based on this information will be biased as a result of this.

The uncertainties expounded in this section should not be used by the actors involved as an excuse for shortcomings in the adoption of measures aimed at minimising the effects of temperature extremes. The logical uncertainty relating to future climate scenarios and the effects of these on health does not mean that these effects will not occur, and an example of the effects of temperature on the excess mortality recorded in Europe during the summer of 2003, which was briefly dealt with in section 3 of this chapter.

16.7.2. Air pollution

There is a series of general uncertainties regarding the process of *climate change* and associated predictions that has been commented upon elsewhere. With regard to the effects of air pollution upon health and the relationship between these and climate change, there exists a series of specific uncertainties. Two elements that could determine this impact in the future are:

Future emission scenarios. These could be based on estimate of economic or population growth, but also upon restrictions established through legislation or accords. In both cases, it is very difficult to make estimates, due to the reality of the situation, in relation to the evolution of greenhouse gas emissions in Spain, and because the levels agreed upon by the Spanish Government in relation to compliance with the Kyoto Protocol have been well surpassed.

The sensitivity and vulnerability of populations. There is a tendency in our country towards ageing of the population, which would lead to a bigger impact, due to the greater susceptibility of the elderly and their delicate state of health. Furthermore, there is still much uncertainty regarding the quantitative calculation of the risk associated with most pollutants. For particles, a linear concentration-response relationship has been defined, but less knowledge exists of the form of the relationship with other pollutants. There will be a particular need for evidence of the impact of ozone on health, given the unpredictable increase, at least in the episodic sense, of this pollutant resulting from climate change.

16.7.3. Infectious diseases

Apart from the observations associated with periodic natural oscillations, there has been no irrefutable proof that the slight climate change in the last few decades has increased the global risk of transmission of diseases transmitted by arthropods, but there is sufficient scientific evidence to suspect so.

Mathematical predictions indicate increased risk provided that the climate change continues to occur, which seems evident to practically everyone. Some experts, however, are sceptical with regard to these predictions, because the natural history of diseases transmitted by arthropods is complex, and other factors besides climate interfere, which means that we should avoid simplistic analyses.

Apart from climate change, many other factors can influence the epidemiology of vector-borne diseases: atmospheric composition, housing development, economic and social development, international trade, human migration, industrial development, land use-irrigation-agricultural development (Suthers 2004). The recent re-emergence of many of these diseases in the world could more likely be attributed to political and economic changes, and to changes in human activity, rather than to climate change.

Climate alone would not constitute a sufficient basis for the establishment of endemic foci in Spain. A sufficient number of simultaneously infected individuals would be needed to constitute an infection reservoir. Semi-immune immigrants can serve as hosts to parasite for many months with almost no symptoms, and can act as effective reservoirs of diseases. Although increased tourism and immigration from endemic areas can import cases, these would not be sufficient in number to start an epidemic, and could, at worst, originate very local foci of self-limited transmission and cases of airport infections (Hunter 2003).

16.8. DETECTING CHANGE

16.8.1. Extreme temperatures

It is vital to avail of morbidity and mortality evolution models based on sufficiently long time series in order to detect in advance possible changes in patterns and behaviour. The anomalous evolution of a time series cannot be detected if the expected behaviour of this is unknown, and, what is more important, if these expected data are not compared with real data. There is a noteworthy need to streamline and increase the degree of reliability of morbidity and mortality records, not only as an indicator of extremes, but also as the basis of any subsequent research. Thus, these records could be used to assess the effectiveness of any intervention in relation to predicted heat waves or cold spells.

16.8.2. Air pollution

Detecting climate change and attributing the effects of this on health require a monitoring system aimed at the early detection of effects (Kovats *et al* 2000). This system should provide quality data on meteorology, environment, health and demography. The health-related data eligible to form part of these systems should satisfy the following prerequisites (McMichael 2003):

- Evidence of sensitivity to climate changes
- Relevance for public health due to the health statistics they represent
- Feasibility of the information gathering system

In our country, there is no *epidemiological surveillance system of the effects of air pollution.* Different air quality monitoring programmes currently exist, managed by the central government, and in the regional autonomies, by the departments of the environment. These systems are generally not integrated into the warning systems or public health services. This should be a priority for the near future in our country, and not only in relation to the detection of effects associated with climate change. This surveillance system should include daily information on the levels of air pollution, on meteorological variables and on health variables such as deaths (total and due to specific causes), on the number of hospital admissions due to cardiovascular and respiratory causes, and if possible, information on emergency hospital admissions. If the latter information were not available, a series of emergency services could be chosen as an indicator. The corresponding information should also be obtained in relation to demographic structure, socioeconomic level and quality of habitat and of health services.

In order to reach the objectives of a surveillance system, this should generate and keep records, and, very particularly, it should produce pertinent and representative information for use in the planning, development and evaluation of public health measures.

A complementary alternative to the previous one consists of *periodic evaluations of the impact on health* of air pollution and the possible relationship between this and climate change (WHO 2000). In Europe, the programme APHEIS (2001 2002) evaluated the impact of air pollution on health in 26 cities in 12 European countries. The total population covered by this impact evaluation is around 39 million European inhabitants. As a whole, for the 19 cities with available data on PM10, a 5µg/m3 reduction of PM10 levels would cause a decrease in long-term mortality by 5,000 deaths yearly, of which 800 would be short-term deaths. This evaluation provides a quantitative calculation of the potential benefits of a reduction of pollutant levels.

16.8.3. Infectious diseases

As has been mentioned, there is no irrefutable evidence that the climate change that has occurred to date has substantially modified the epidemiology of vector-transmitted infectious diseases.

The collection of survey data and timely research in the “climate - vectors - man” triangle of interaction would have the advantage of providing an extremely useful database. These systems should also include variables such as demographic, economic and environmental ones, because changes in the epidemiology of infectious diseases are more likely to be the result of these than of climate change itself.

There should be studies of the prevalence of certain diseases, such as flaviviriasis, using seroprevalence studies in risk populations. Furthermore, vector populations should be studied for the early detection of new species and to determine the geographic dispersion of the populations of recently detected foreign species (as is the case of A. albopictus).

These studies should be sufficiently effective and accurate in order to detect minimum changes in health. Unfortunately, current vector monitoring systems do not fulfil to these requirements.

Essentially, the detection of change involves the detection of pathogenic micro-organisms: - in the vectors (dengue or West Nile encephalitis viruses in mosquitoes); - in the natural reservoirs (rodents, birds or horses); and in humans (both the asymptomatic inhabitants of risk areas and patients admitted for treatment with compatible pathologies, through blood analysis, sera, cerebrospinal fluid…etc.).

16.9. IMPLICATIONS FOR POLICIES

16.9.1. Extreme temperatures

Although we have insisted throughout his chapter upon the local nature of prevention or action plans, these should be governed by general policies that serve as a framework for the development of these activities.
Following the WHO stance on climate change (WHO 2003), the medium-term development of the following measures is considered to be necessary:

1. Facilitating the organisation of interdisciplinary forums between politicians and experts aimed at identifying needs and courses of action.
2. Facilitating the creation of multidisciplinary teams for informing the public of potential health risks related to thermal extremes and the implementation of measures aimed at mitigating the effects of these.

3. Facilitating the design of mechanisms for the early evaluation of plans of action in order to increase efficiency.

In the short term in Spain, there is a need for public health plans of action based on early warning systems allowing risk situations to be identified before these occur. In this sense, meteorological information is fundamental. It is a question of predicting excessive morbidity and mortality within a time period that allows for rapid response. Morbidity and mortality records, as one of the first elements in a chain of actions, should be flexible and reliable. No warning plan can be based on real increases in morbidity and mortality if access can only be gained to these data weeks or even months after these excesses have occurred. Furthermore, the implementation of hospital management actions aimed at adjusting the health services to determined situations has been seen to be a vital part of action policies. Lastly, total co-ordination with the social services is required, fundamentally with those working with the less favoured social classes, in order to articulate the aforementioned plans of action.

In this sense, the Comunidad de Madrid (regional autonomy) intends to set up a “heat wave warning and prevention plan” for the summer of 2004. This plan would include a meteorological warning and surveillance system intended to provide a warning several days before the event takes place, which would allow for early warning for the population and for the social and health services. The actions include assistance for the population subjected to particular risk, and special surveillance for the elderly in order to guarantee accessibility to health services and a social support plan dealing with needs related to food, healthcare, mobility and climatic comfort.

16.9.2. Air pollution

1. Application and follow-up of European Directives on Air Quality, including the implementation of procedures and techniques for the correct measurement and continuous recording of pollutant levels.
2. Co-ordination between the different Departments involved (Environment, Heath, Transport, Town Planning, Public Works, Agriculture).
3. Inter-territorial integration and co-ordination between central Government and Regional Autonomies.
4. Establishment of integrated policies for surveillance and protection of public health, including information on environmental risks.
5. Actions aimed at reducing emissions related to fossil fuels.
6. Implementation of activities aimed at increasing public awareness and participation in aspects related to climate change, involving a communication strategy for ensuring information and presenting this in an understandable way and guidelines on how it should be used (McMichael 2003).
7. Lastly, it is necessary to invest in studies and research in order to reduce the uncertainties involved in decision-taking (McMichael 2003).

16.9.3. Infectious diseases

In Spain, there is no specific legislation adapted to the current needs of vector control. Apart from mosquito control programmes in Spain, there are also regulations involving the inspection, certification and quarantine applied to the products from endemic areas that could transport vectors, such as used tyres or exotic plants like the luck bamboo tree.

Very concisely, we could summarise the implications for policies as: promoting and developing Surveillance and Control Programmes for vector-transmitted diseases, through sufficient and stable funding. –These programmes should, in turn, be co-ordinated with other surveillance programmes at national level. Uniting research among the different research groups working in different fields and belonging to different areas, such as veterinary, epidemiology, entomology, zoology and medicine. Providing appropriate facilities for reference laboratories and for hospital laboratories for accurate diagnosis of vector-borne diseases. – Disseminating existing knowledge through specific training courses in Spanish universities.

16.10. MAIN RESEARCH NEEDS

16.10.1. Extreme temperatures

The main research needs should be basically aimed at eliminating, to the greatest possible extent, the aforementioned uncertainties. It will therefore be necessary to analyse atmospheric conditions at lesser meteorological scale in order to establish with sufficient warning the production, intensity and duration of an extreme thermal event, at least in each province.
There should be more in-depth study of the mechanisms of physiological adaptation and of the role played by socioeconomic variables in adaptation processes. Studies of the temporal evolution, according to different time periods, of the behaviour of morbidity and mortality in recent years, according to thermal extremes are considered to be appropriate with regard to establishing this type of tendencies.

There is also a pressing need for research at local scale into the behaviour of morbidity and mortality associated with extreme temperatures, with particular emphasis on the influence of these extremes on hospital admissions according to specific causes and age groups, in order to establish, to the greatest possible extent, the behaviour of each population group in relation to temperature. Finally, we ought to evaluate the effectiveness and functioning of the action plans for thermal extremes wherever these have been established, and use these experiences for implementing new ones. All these initiatives should be set within a European framework, in order for their objectives, quality and effectiveness to be compared with determined common references for all the neighbouring countries.

16.10.2. Air pollution

It is generally agreed that research into impacts upon health should have an international perspective and be based on an international network of scientists. On one hand, we are dealing with situations on a worldwide scale which have no borders, and we should therefore provide a maximum guarantee of information exchange, in order to assess differences in environmental, socio-demographic and health situations between the different geographic locations and populations. It is generally a question of assessing the possible impacts on health associated with each one of the phenomena constituting climate change. In the specific field of the possible effects of *air pollution* related to climate change, the fundamental needs are:

- Establishing surveillance and monitoring systems including appropriate information on meteorology, environment, health and socio-demography, for the early detection of changes and in order to obtain data for further study.

- Carrying out epidemiological studies aimed at evaluating the impact of ozone, fine particles and other pollutants related to climate change and the influence of these upon health. These studies should provide proof of the effects of these pollutants, including the dose-response relationship and factors that could modify its effects (greater susceptibility of certain groups of people, and protection factors, such as, for example, increased antioxidant capacity through diet).

- It will also be necessary to carry out epidemiological studies aimed at assessing the possible benefits of actions for mitigating climate change.

- Developing models for predicting the possible effects on health of the expected changes in climate and air quality. These models should include predictions of the future tendencies of air pollution, changes in population characteristics and variations in meteorological and climatic phenomena. These predictions ought to be validated in a continuous manner, by means of comparison with data from the surveillance system.

16.10.3. Infectious diseases

The main lines of research should focus on: -the design of models that correlate climatic parameters with the incidence of infectious diseases (rather than models based on risk areas and populations). –The design of validation models between present and past climatic data and the frequency of infectious diseases transmitted by vectors.- Sampling of populations, vectors and reservoirs. –Studies of changes in the distribution or changes in the frequency of transmission of the diseases most likely to be influenced: dengue and other flavivirus, malaria, leishmaniasis, rickettsiosis….-Development of new rapid diagnosis tests.

In relation to this, an initial European initiative is starting to take its first steps. The Sixth Framework Programme, under the auspices of the European Union, includes among its priority research themes emerging diseases and in particular the relationships between these and "Global Change and Ecosystems". Following the appeal made by the European Research Commission in this respect, requesting an expression of interest in the subject, in 2004 a proposal on Emerging Diseases in a Changing European Environment was accepted (EDEN network). This international network comprises a consortium of European researchers belonging to 33 countries, including Spain, whose objective is to anticipate the effects that environmental changes could have on public health in Europe, and to co-ordinate the pertinent research in a common scientific framework divided into these five main areas: Landscapes; Biotopes and Habitats; Bionomics of Vectors and Parasites and Competition; Public Health and Human Activities; Animal Reservoirs; Integration and Management of Databases. For the next five years, this network will be dedicated to identifying, evaluating and classifying the European ecosystems and environmental conditions associated with global change that could affect the spatial and temporal distribution and the dynamics of pathogenic agents. To this end, predictive models of emergence and dispersal will be developed, including global and regional prevention, early warning systems, surveillance, monitoring of tools and description of scenarios. The diseases selected for this research are West Nile encephalitis, Lyme borreliosis, encephalitis transmitted by ticks, Rift valley fever, Dengue, Malaria and leishmaniasis.

16.10.4. Conclusion

The authors of this chapter insist upon the implementation of an *evaluation of the possible impact of climate change on health in Spain*, as has been done in other countries like the United States (Bernard *et al* 2001) the United Kingdom (Anderson *et al* 2001) or Portugal (Casimiro and Calheiros 2002). This evaluation should include a quantitative estimate of impacts upon health, taking into consideration the different scenarios of climate change and predictions of the demographic structure of our country. In this sense, the World Health Organisation has developed a methodology for the assessment of the vulnerability of human health and the adaptation of human health to climate change (Kovats *et al* 2003).
This evaluation would fulfil the following *requirements:*

- To establish an explicit mandate of the decision takers in public health and/or environmental policies. Indeed, the national governments have the responsibility of implementing these, according to agreements by the United Nations at the Climate Change Summit (UNO 1992)
- Multidisciplinary perspective, with the use of new analysis and interpretation techniques. This should include not only the disciplines directly related to the theme (environmental health,

epidemiology, climatology, clinical medicine, toxicology), but should also consider other disciplines such as sociology, psychology and economy.

- Priority should be given to specific problems in the different regions of Spain, and particular attention ought to be paid to specific local problems (for example, temperature increases in certain parts of the Peninsula, dust storms from the Sahara in the Canary Isles, etc.).
- The purpose of the evaluation of the impact upon health should be aimed at the prevention of the disease and at the evaluation of the consequences of the measures taken, including public health actions.

The evaluation should identify the areas with the highest levels of uncertainty, consider research needs and be linked to the surveillance and monitoring systems to be created (McMichael 2003).

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