

Does climate change affect the incidence of skin and allergic diseases in Germany?

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Summary

Background: Skin diseases have great socio-economic importance in Germany due to their high and in some cases still-increasing prevalence. Little attention has yet been paid to the influence of the change in climate on these diseases. **Objective:** Clarify the evidence of the effects of climate change on the prevalence of skin diseases and allergies in Germany.

Methods: First, a theoretical model of the possible mechanisms and influence factors of climate and weather was created for different disease groups (skin malignancies, allergies, skin infections). Then, a systematic online and manual literature search was made for model-derived key words. The relevant publications were selected and evaluated according to a priori criteria.

Results: From a total of $n = 31,221$ hits, $n = 320$ publications remained for evaluation. Changes in the following parameters can be regarded as essential climatologic factors influencing the prevalence of skin and allergic diseases: temperature, UV radiation, precipitation/humidity, cloudiness, and general weather conditions. There were only a few original articles addressed to this topic. Most of them address recurring phenomena (especially levels of airborne pollen), UV radiation or ozone (and the ozone hole). Quantitative statements, prognosis models and climate scenarios have not yet been published for Germany with respect to skin diseases.

Conclusion: Only few scientific articles on the relationship between climate changes and the prevalence of skin diseases have been published. They do not allow a reliable statement on future developments. The outlook for changes in prevalence requires further clarification using published climate models.

Introduction

Climate has an important effect on the health and well-being of man. Therefore, every change in climate can potentially also influence human health [1]. Even if climate is not changing uniformly on a worldwide basis, current climate models make significant changes even in the

Central European region in the next decades probable [2]. These changes are especially observable in the form of melting/evaporation of the glaciers, which is why such processes are termed “fingerprints” of climate change. Factors potentially increased by climate change such as UV radiation (indirectly) and

temperature have already proven to be predictors of an increased incidence of skin disease in other regions of the earth. This is true for skin cancer [3] as well as for seasonal allergic rhinitis induced by certain inhaled allergens [4]. Today it is evident that the change in UV radiation is primarily dependent on

the ozone concentration in the stratosphere and not on climate change due to the greenhouse effect. Climate change does have an indirect effect on UV radiation, for example due to changes in cloud cover (e. g. more frequent sunny periods) or due to a possible delayed regeneration of the ozone layer. In Germany in addition to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit), the Federal Environment Agency (Umweltbundesamt) [5] and the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung) [6] are the responsible institutions for the study of ecologic and climate change and the resulting consequences for health. On an international level these functions are performed by, among others, the World Health Organization (WHO) but also by the Intergovernmental Panel on Climate Change (IPCC) [7–9].

In order to analyze scientific knowledge on effects of climate changes on skin diseases in Germany, in the following paper a systematic literature search based on a causal model of potential climatic effects on skin diseases was performed and evaluated. Even though the analysis is focused on future developments in Germany, the literature search was not limited to the German sphere. Also of interest were papers which covered other European or non-European regions and contained especially exemplary scientific information.

The following questions were to be resolved by the research:

1. Which skin diseases and allergies are affected by climate and are likely to be impacted by climate change?
2. How does the prevalence of common skin diseases and allergies alter due to the effects of climate change?
3. Do prognostic studies on the effects of climate change on skin diseases and allergies exist?

Methods

As to possible effects of climate change on prevalence, a theoretical model of influential factors was first constructed (Figure 1). This model integrates current knowledge on effects of weather and climate on the human organism as well as on pathogenetically relevant changes of

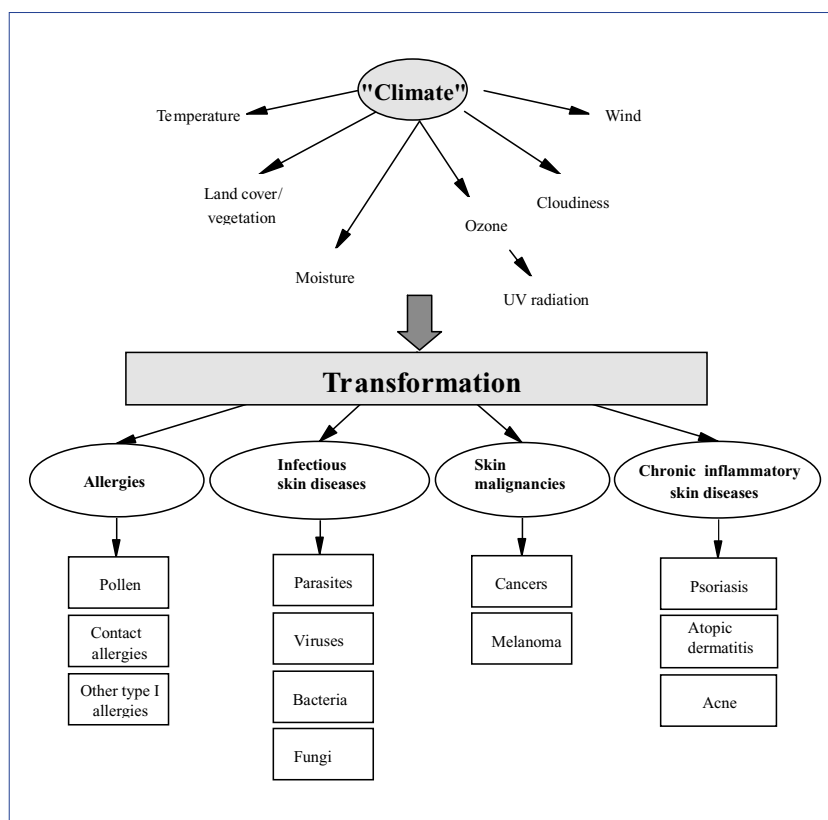


Figure 1: Model of potential effects of climate change on skin diseases as a basis for the systematic literature search.

the skin. Factors of climate change were differentiated from primarily ecological factors.

Using the effects model an expert panel consisting of two dermatologists, two climatologists and an epidemiologist formulated the criteria for the literature search in different data. The target indications: skin diseases, allergies, skin malignancies and infectious diseases had a dermatologic basis. The search terms temperature, land cover/vegetation, moisture, cloudiness, wind, ozone and UV had a climatologic foundation. The literature search was conducted between July and December 2006 in the following online data banks:

- *Medicine:* PubMed (www.pubmed.com), Medline (www.medline.de), Embase (www.embase.com)
- *Geoscientific data banks:* GEODOK (www.geodok.uni-erlangen.de), GEOLEO (<http://geoleo.sub.uni-goettingen.de/geoleo/www-docs/>), GEOMED (www.geographie.uni-muenchen.de/geomed/).

Further searches were made in the search engine Google (www.google.de) as well as in data banks of various individual institutes and research organizations.

The latter included the GSF Research Center for Ecology and Health, the WHO as well as the German National Meteorological Service (Deutscher Wetterdienst). In addition to the online search, a manual search was done in quoted secondary literature.

In the online search first the general categories skin diseases, skin cancer, allergies, climate change or meteorological factors (among others temperature, moisture, ozone) were used in combination with these general categories as well as with individual skin diseases, perhaps in various forms of writing (eczema, dermatitis, allergic rhinitis/rhinitis allergica, Lyme borreliosis, skin infections).

The hits were analyzed at the level of title and abstracts and selected according to the inclusion criteria. Publications with the following characteristics were included:

- Language (German, English)
- Time of publication between 1996–2006
- Publications older than 10 years were only considered, if their content was particularly relevant or if no more current information on a specific topic exists.

- Theme of skin diseases or allergic disease of the skin or mucous membranes
- Contents regarding the association between skin/allergic diseases and meteorological or climatologic factors
 - Meteorological terms: cloudiness, precipitation, humidity, temperature, wind, UV radiation
 - Climatologic terms: climate, climate change, atmosphere, circulation, general weather situation
- Reference to German or European region
 - Publications not dealing with the German or European region are only considered, if their content is of special importance or affects the European area (e. g. effects of the North Atlantic Oscillation on phenology in Europe)

The search in the fields climate and health using the online data bank

PubMed resulted in $n = 31,221$ hits (Figure 2) which underwent further selection as described above.

Results

Quantitative analysis of the literature research

A total of $n = 65$ studies to general aspects of skin diseases and allergies in terms of climate without regional specification were found (Figure 3). On the intersection of allergy and climate $n = 63$ publications were found, especially publications on allergic rhinitis. Insect-associated or parasitic diseases were the third largest group of publications with $n = 51$ hits. Among these leishmaniasis is especially prominent. Among bacterial diseases ($n = 50$) mainly studies on *Borrelia* and borreliosis were published. The $n = 43$ hits on viral diseases and climate

related to Central European encephalitis.

Cutaneous malignancies (skin cancer) were found mainly in the context of UV radiation or the ozone layer. The number of hits was relatively low with $n = 15$. Atopic dermatitis was rarely a subject with $n = 4$ publications. Studies from the intersection of climate factors and skin/allergies could be classified most frequently in the categories climate ($n = 154$), climate change ($n = 110$) and environment ($n = 85$) (Figure 4). It is clear that a large number of publications exist on climate and health, but that the subject is usually treated in review. Further publications deal with the temporal development ($n = 78$) of a disease with the active meteorological factors ($n = 59$) and with the geographic distribution ($n = 54$).

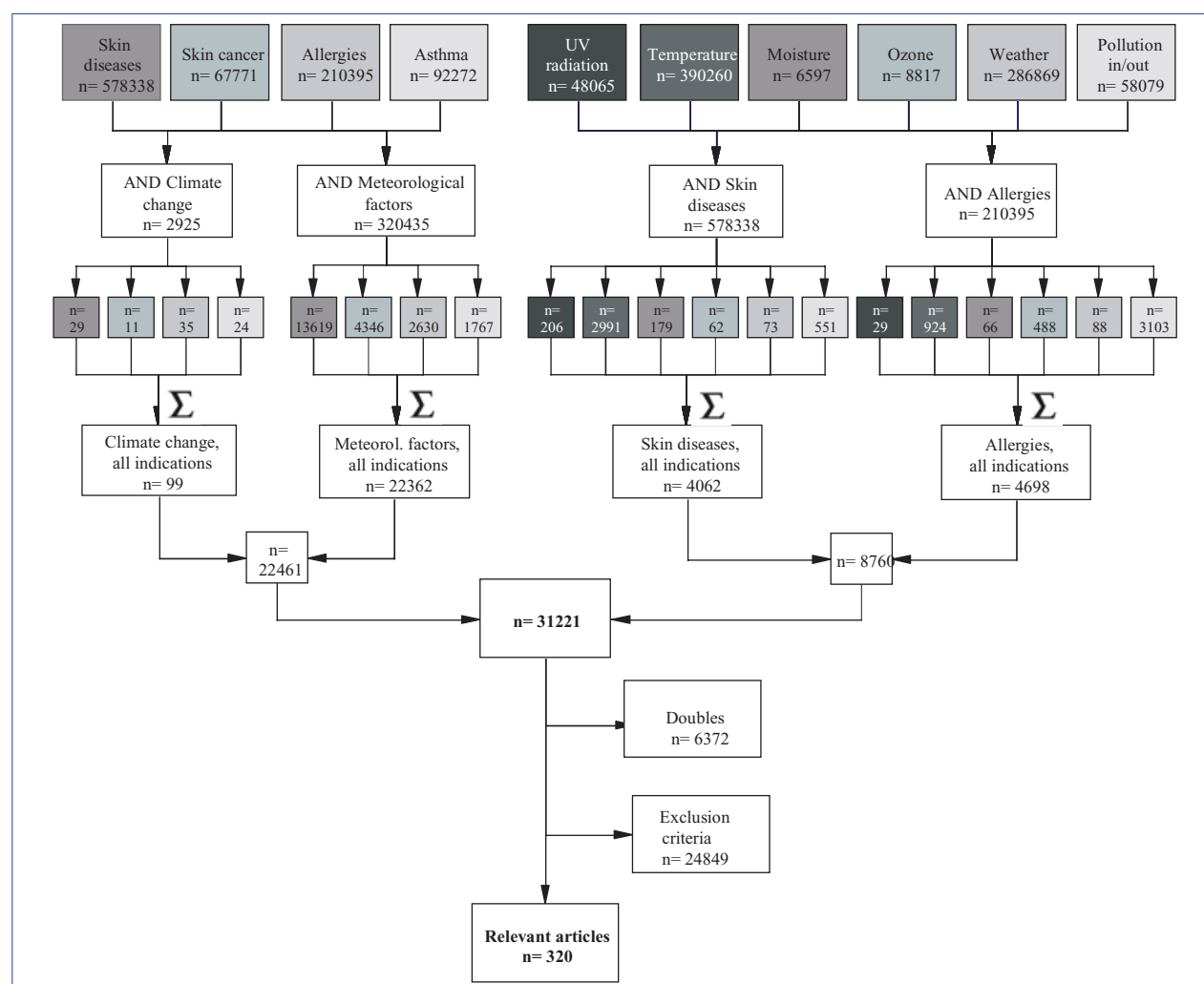


Figure 2: Course of search to the themes “skin diseases” and “climate factors” with number of hits in PubMed. The terms in row 1 were connected with those in row 2 with “AND” and the respective intersections (row 3) were determined. The gray scales in the fields of row 3 correspond to the search terms in row 1. The rows 4–6 contain the sums of the respective hits followed by the depiction of the exclusion of double and irrelevant papers. In the end $n = 320$ relevant publications were found.

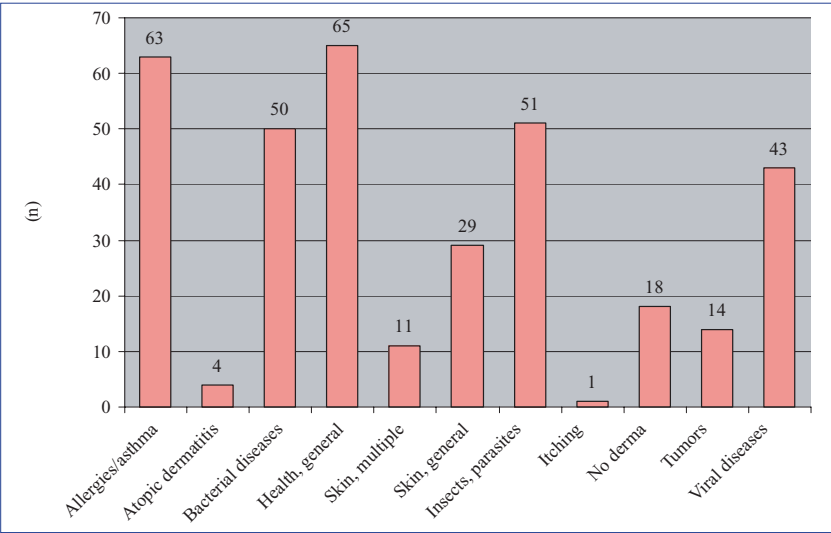


Figure 3: Number of hits (intersection) to the search terms “skin diseases/ allergies” and “climate factors” (n = 320) in PubMed.

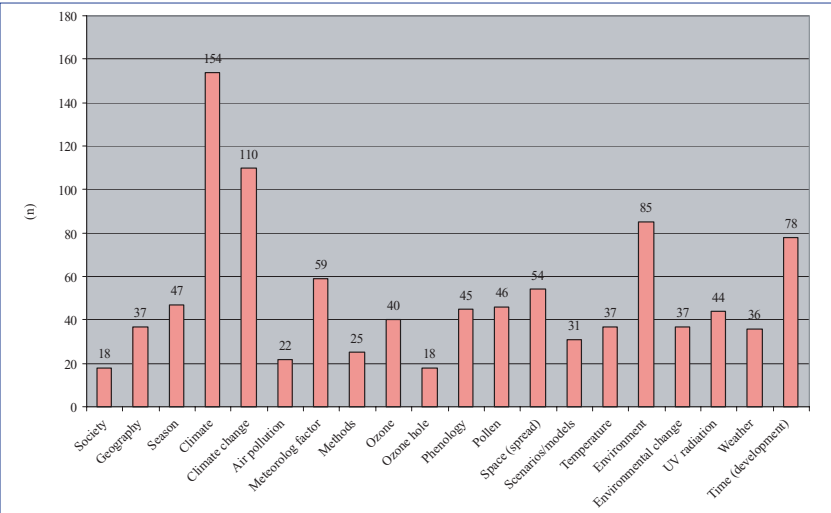


Figure 4: Number of hits (intersection) to the search terms “skin diseases/ allergies” and individual climatologic/ meteorological and geographic terms (n = 320) in PubMed.

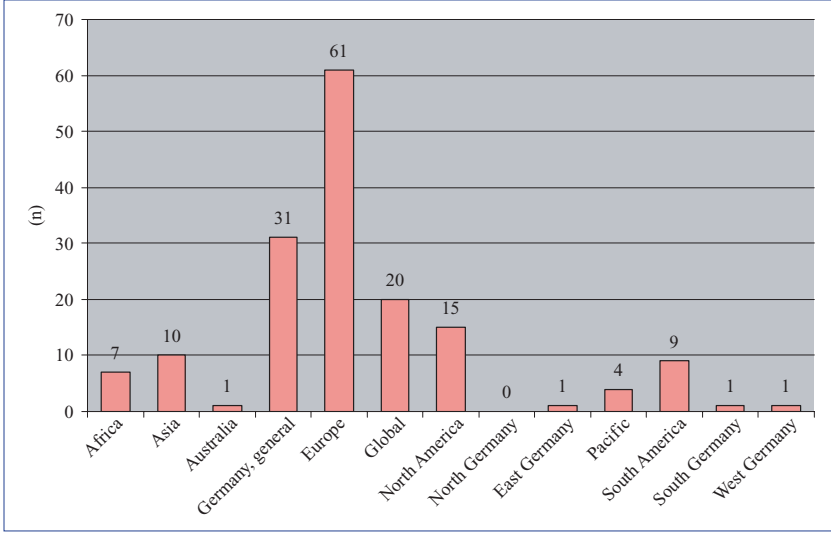


Figure 5: Regional reference of relevant publications (n = 320).

Regarding geographic distribution many studies (n = 61) dealt with the European region (Figure 5) followed by studies explicitly devoted to the whole German region (n = 31). One study each focused on East, West and South Germany.

Reviews on climatic factors of influence on skin and allergic diseases

As to the question, which skin diseases and allergies are affected by climate, the data banks and publications of the WHO provide indications, especially the publication “Health and Climate Change” [7], on the interactions of human health and the climate change. In this article the alterations of pollen release in changed climate conditions is depicted and the spread of Lyme borreliosis and Central European encephalitis to higher latitudes and altitudes is explained.

In publications on the effects of climate change on human health in Central Europe it is stressed that health risks due to climate change are no longer limited locally [10, 11]. In face of the extensive spread of climate changes and the far-reaching socio-economic technologic and infrastructural causative factors scientific evaluation of health risks due to climate changes are highly complex and uncertain [11]. Fundamentally, therefore, global research on health effects is necessary as the IPCC has described, for example. The report of the IPCC published every six years in its 2001 edition pointed to possible effects of climate change on health. On the basis of theoretical assumptions for the field of dermatology the spread of aeroallergens and of infectious diseases was prognosticated [8, 9]. McMichael et al. [3] come to similar conclusions in the publication “Climate Change and Human Health: Risks and Responses”.

The role of phenology in the prevalence and incidence of skin and allergic diseases

Only few studies have been published to date on the question of prevalence and prognosis of allergic diseases of the skin during climate change. The publications contain no statements with causal or quantitative supports. The interpretation of data on inhaled allergies is made more difficult by regional and individual differences in susceptibility to pollens [12]: “There are local differences in sensitivity to different pollens and this

makes forecasting future health impacts difficult”.

With a view to changes in pollen release the focus is on the development of phenology [13]. Phenology describes the seasonal recurrence of phenomena in nature (e. g. bloom phases). It plays a significant role with regards to climate changes [14, 15] and together with glacial dynamics and ornithological observations (bird migration) can also serve as an indicator of climate change [16–18]. In a study on the phenology of the olive tree as an indicator of warming of the Mediterranean region model results showed rising temperature and an earlier occurrence of blossoming time [16]. With an assumed temperature rise of 4.5 °C by the year 2099 an up to 30 day earlier bloom of the olive is possible. As the pollen of the olive tree belongs to the most relevant allergens of allergic rhinitis in the Mediterranean an increase in prevalence can be expected. With the input data of the climate model HadCM2Sa1 (Hadley-Centre, UK) for the time period 2000–2099 a 13 day earlier bloom of the birch tree and a 20 day earlier bloom of the elder was calculated [19].

Well-studied is the effect of climate change on the phenology of the Japanese cedar [20]. A change in pollen release duration as well as in the quantity of pollen in Japan was shown. With a continual trend (warmer spring) a comparable development can be expected within the next 10 years for the birch pollen season in Europe, that could start on average 6 days earlier [21, 22].

A cluster analysis of pollen release in Germany also on a time-space basis was conducted by the German National Meteorological Service [23] which does not allow for projection of future changes yet.

The use of the phenologic model for prognosticating climate effects still demonstrate a too low internal validity of the model, so that these estimates are too insecure [17, 18].

It is interesting that not only an increased temperature, but also increased emission of CO₂ by humans affects phenology and plant growth. It was shown that the pollen production of ragweed rises by up to 61 % with a doubled CO₂ content [24].

Numerous studies on the development of phenology allow for qualitative statements on the temporal development of

pollen released, it is not possible to describe the effects on the allergic patient.

Climate factors are not of great significance alone, but also their interaction with land utilization. It can be expected that rape will be increasingly cultivated (increasing demand for alternative fuels) and that the burden of rape pollen will increase. A similar situation exists for ragweed. The plant favors disturbed grounds (refuse dumps, old industrial wastelands, roadside, etc.) as living space. It is imaginable that structural change leads to extension of such areas and thus to a spread of the plant.

Significance of meteorological factors for infectious diseases

Beyond phenology as main factor for allergic rhinitis meteorological factors such as temperature and UV radiation have been studied in connection with skin infections. Important diseases studied are leishmaniasis and tick-borne diseases.

With regards to leishmaniasis an analysis from Hesse postulates that a spread of leishmaniasis can only be expected in case of strong migrational movement or poor health care [25]. The few cases that have become known in Germany primarily affected persons who due to age or other diseases (especially HIV infection) were less resistant to the pathogen and usually traveled more to southern countries [26]. A further or increased northern spread of the sandfly from the Mediterranean due to warming cannot be excluded [27, 28] as temperature represents an important survival factor.

Studies on tick-borne diseases (Central European encephalitis, borreliosis) have been much more frequent. Similar to leishmania temperature and moisture are key factors for the spread of ticks.

In Sweden the on average milder winters and the earlier spring periods since the mid 1980s have been held responsible for the increasing spread of Central European encephalitis [29]. Further the (climate-dependent) distribution of host animals (deer, elks) as well as landscape change plays a role [30, 31]. A further factor also relevant in Germany for the incidence of Central European encephalitis is human behavior in nature (hiking, cycling, etc.), which increases the probability of infection. The increased frequency of Central European encephalitis has been proven in

the past years [32]. The effects of climate change on this still remains unclear.

UV radiation and skin cancer

The association of UV radiation and skin cancer in connection to climate change has been discussed in only a few papers. Fundamental studies on the causal relationship of the axis climate-ozone-UV do exist [3, 33, 34]. It has been described that changes in stratospheric ozone has led to increased UV radiation in middle latitudes by up to 10 % (since 1980) [33]. This development will continue to about 2020 and will result in an increased prevalence of skin cancer in Europe and the USA. With the help of the UV measuring network run by the Federal Environment Agency and the Federal Office for Radiation Protection at various locations in Germany the erythemalogenic UV exposition is permanently analyzed. Between 1995 and 1999 already a mild increase of near ground UV radiation was observed that continued in the following years [35].

In addition to annual UV radiation expositional behavior of man can affect the incidence of skin cancer in the future [3, 34, 36]. Altered recreational time behavior is expected with longer outdoor stays and thus increased exposition time towards natural UV light [36]. As a result of an increased mean annual temperature greater heat exposure is expected. Heat exposure (but also cold stimuli) can be taken from a nationwide bioclimate map [37]. Heat exposure is directly significant for the occurrence of cardiovascular diseases, but can also indirectly influence exposition behavior of humans (e. g. more frequent wearing of more strongly exposing clothes) [36]. In view of the significant scattering of UV radiation seeking shady places only in part protects from UV-induced lesions [38]. A study on mice has shown that there is a relationship between temperature (heat radiation) and tumor growth [39]. If this result also applies to humans, this factor in addition to UV radiation may also favor the increase of skin cancer in a warming climate.

Meteorological factors in inflammatory skin diseases

No publications were found on the effects of climate change on inflammatory skin diseases. On the other hand, the

effects of weather and meteorological factors on atopic dermatitis has been studied repeatedly [40–42]. It was shown that temperature and humidity play important roles with regards to itching [40]. In further studies two clinically known patterns of climate and weather dependency in atopic dermatitis were found [41]: on the one hand, temperature and moisture-induced dermatitis in the winter and, on the other, pollen- or allergy-induced dermatitis in the summer.

To what extent the mentioned meteorological factors are affected by climate change has not been analyzed in any study. The results on atopic dermatitis are important aspects for future prognostic models.

Discussion

The goal of the present study was a systematic search and review of literature on the relationship between climate change and skin diseases. For this purpose an extensive literature search in medical and scientific data bases was undertaken. The selection and evaluation of articles was done according to a previously agreed upon method. It was seen that a certain level of studies on this question exist with 320 publications found, but only few original papers exist. Quantitative statements on the effects of climate change on the prevalence of skin diseases and allergies (in Germany) have hardly been published. One reason among others is the high degree of complexity of the causal chain (from climate change to the health consequences for man) which makes research difficult [43]. This causal chain is further being studied by a variety of different scientific disciplines with results published in various specialty journals.

In view of the undoubted existence of climate change with various scenarios for the consequences for health interdisciplinary cooperations and publications are of great importance for the future. This is already evident during the review of available literature, where in terms of original publications an almost total lack of interdisciplinary projects exists. The present paper represents a first inventory of publications on the effects of climate change on skin diseases. One limitation is that only papers in English or German could be considered. The Medline search (PubMed) showed that

relevant papers in other languages practically did not exist. Another limitation of the present paper could lie in the method where rarely quoted publications not included in the common data banks are not considered. This was countered by a careful manual search including all secondary quotations found.

On the basis of publications available today no secure predictions on possible changes in prevalence and incidence of skin and allergic diseases due to climate change can be made. It can at best be speculated that the most climate-sensitive skin diseases are infectious and allergic diseases on the one hand and UV-induced diseases such as melanocytic and epithelial cutaneous malignancies on the other. Future studies should increase data integrity on the causal factors. Further, complex causal models must be developed with which on the basis of climate models such as REMO (regional climate model of the Max Planck Institute for Meteorology) a reliable prognosis is made possible.

Conflict of interest

None.

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References

- 1 Füßel H-M, Klein RJT. Conceptual frameworks of adaptation to climate change and their applicability to human health. PIK Report No. 91 Potsdam Institute for Climate Impact Research, Potsdam, 2004.
- 2 Max-Planck-Institut für Meteorologie. Klimaprojektion für das 21. Jahrhundert. Hamburg, 2006.
- 3 McMichael AJ, Campbell-Lendrum DH, Corvalán CF, Ebi KL, Githeko AK, Scheraga JD, Woodward A. Climate Change and human health: risks and responses. World Health Organisation, Geneva, 2003.
- 4 Williams R. Climate change blamed for rise in hay fever. *Nature* 2003; 434(7037): 1059.
- 5 Umweltbundesamt. Klimafolgen und Anpassung an den Klimawandel in Deutschland – Kenntnisstand und Handlungsnotwendigkeiten. Dessau, 2005.
- 6 Bundesministerium für Bildung und Forschung. Umwelt und Gesundheit – Beispiele aus der Forschungspraxis. Berlin, 2003.
- 7 World Health Organisation. Health and climate change: „The now and how” A policy action guide. Geneva, 2005.
- 8 IPCC – Intergovernmental Panel on Climate Change. Third assessment report – Climate change 2001. Cambridge University Press, Cambridge, UK.
- 9 McMichael A, Githeko A. Human Health. In: IPCC – Intergovernmental Panel on Climate Change, Third assessment report – Climate change 2001. Cambridge, UK: Cambridge University Press, 2001: 453–485.
- 10 Gubler DJ. Climate change: implications for human health. *EHP* 1998; 109(2): 223–233.
- 11 Jendritzky G. Einwirkungen von Klimaänderungen auf die Gesundheit des Menschen in Mitteleuropa. Klimastatusbericht 1998. Deutscher Wetterdienst, Offenbach, 1998.
- 12 Kovats RS, Menne B, McMichael AJ, Bertollini R, Soskolne C. Early human health effects of climate change and stratospheric ozone depletion in Europe. Third ministerial conference on environment and health. World Health Organisation, London, 1999.
- 13 World Health Organisation. Phenology and human health: allergic disorders. Rome, 2003.
- 14 Menzel A. Phenological anomalies in Germany and their relation to air temperature and NAO. *Clim Change* 2003; 57(3): 243–263.
- 15 Menzel A, Fabian P. Karten der Phänologie unter veränderten Klimabedingungen. *Annalen der Meteorologie* 1997; 34: 101–102.
- 16 Osborne CP, Chuine I, Viner D, Woodward FI. Olive phenology as a sensitive indicator of future climatic warming in the Mediterranean. *Plant Cell Environ* 2000; 23: 701–710.

- 17 Kramer K, Leinonen I, Loustau D. The importance of phenology for the evaluation of impact of climate change on growth of boreal, temperate and Mediterranean forests ecosystems: an overview. *Int J Biometeorol* 2000; 44: 67–75.
- 18 Chuine I, Cour P, Rousseau DD. Selecting models to predict the timing of flowering of temperate trees: implications for phenology modelling. *Plant, Cell and Environ* 1999; 22: 1–13.
- 19 Arnold J, van Vliet H, Overmeem A, De Groot RS, Adrie F, Jacobs G, Frits T, Spijksma M. The influence of temperature and climate change on the timing of pollen release in the Netherlands. *Int J Climatol* 2002; 22: 1757–1767.
- 20 Teranishi H, Kenda Y, Katoh T, Kasuaya M, Oura E, Taira H. Possible role of climate change in the pollen scatter of Japanese cedar *Cryptomeria japonica* in Japan. Department of Public Health, Toyama Medical and Pharmaceutical University, Sugitani, 2000.
- 21 Emberlin J, Detandt M, Gehrig R, Jaeger S, Nolard N, Rantio-Lehtimäki A. Responses in the start of Betula (birch) pollen seasons to recent changes in spring temperatures across Europe. *Int J Biometeorol* 2003; 47(2): 113–115.
- 22 Bissolli P, Schnadt K. Analyse der raumzeitlichen Veränderungen von ausgewählten phänologischen Phasen in Deutschland. Deutscher Wetterdienst, Offenbach, 2002.
- 23 Staiger H. Clusteranalyse des Pollenfluges an Messstellen der Stiftung „Deutscher Polleninformationsdienst (PID)“. Deutscher Wetterdienst, Offenbach, 2003.
- 24 Wayne P, Foster S, Connolly J, Bazzaz F, Epstein P. Production of allergenic pollen by ragweed (*Ambrosia artemisiifolia* L.) is increased in CO₂-enriched atmospheres. *Ann Allergy Asthma Immunol* 2002; 8: 279–282.
- 25 Uphoff H, Hauri A. Auswirkungen einer prognostizierten Klimaänderung auf Belange des Gesundheitsschutzes in Hessen. Hessisches Landesprüfungs- und Untersuchungsamts im Gesundheitswesen, Dillenburg, 2005.
- 26 Naucke TJ, Schmitt C. Is Leishmaniasis becoming endemic in Germany? *Int J Med Microbiol* 2003; 293(37): 179–181.
- 27 Feldmeier H. Leishmaniasis in Germany. *Emerg Infect Dis* 2003; 7(1): 2–9.
- 28 Kuhn K. Global warming and Leishmaniasis in Italy. *Bulletin of Tropical Medicine and International Health* 1999; 7(2): 1–2.
- 29 Lindgren E. Tick-borne encephalitis in Sweden and climate change. *The Lancet* 2001; 358(9275): 16–18.
- 30 Randolph SE. The shifting landscape of tick-borne Zoonoses encephalitis and Lyme borreliosis in Europe. *Philos Trans R Soc Lond B Biol Sci* 2001; 356(1411): 1045–1056.
- 31 Randolph SE. Evidence that climate change has caused emergence of tick-borne diseases in Europe? *Int J Med Microbiol* 2003; 293(37): 5–15.
- 32 Kampen H, Rotzel DC, Kurtenbach K, Maier WA, Seitz HM. Substantial rise in the prevalence of Lyme borreliosis spirochetes in a region of western Germany over 10-year period. *Annals of Applied Environmental Microbiology* 2004; 15(3): 1576–1582.
- 33 Martens P, Huynen M. Future Health: The health dimension in global scenarios. International Center for Integrative Studies (ICIS), Maastricht, 2002.
- 34 Bentham G. UV-radiation. In: Expert Group of Climate Change and Health in the U.K. Health Effects of Climate Change in the U.K. London, 2001: 218–227.
- 35 Steinmetz M, Matthes R, Hofmann P, Brix G. Erfassung und strahlenhygienische Bewertung der solaren UV-Exposition in Deutschland. Bundesamt für Strahlenschutz, Neuherberg, 2001.
- 36 Diffey B. Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. *Physics in Biology and Medicine* 2004; 49(1): 1–11.
- 37 Jendritzky G, Tinz B. Bioklimakarten als Grundlage für die Klimafolgenforschung im Humanbereich. FA Biomet, Freiburg, 1999.
- 38 Sandmann H. Über die Verteilung der diffusen, im Himmelgewölbe gestreuten ultravioletten Strahlung: Spektrale Messungen und Szenarien für eine medizinische Bewertung. Dissertation, Christian-Albrechts-Universität Kiel, 2002.
- 39 Van der Leun JC, de Gruijl FR. Climate change and skin cancer. *Photochem Photobiol Sci* 2002; 1(5): 324–326.
- 40 Vocks E, Busch R, Frohlich C, Borelli S, Mayer H, Ring J. Influence of weather and climate on subjective symptom intensity in atopic eczema. *Int J Biometeorol* 2001; 45(1): 27–33.
- 41 Krämer U, Weidinger S, Darso U, Mohrenschlager M, Ring J, Behrendt H. Seasonality in symptom severity influenced by temperature or grass pollen: results of a panel study in children with eczema. *J Invest Dermatol* 2005; 124(3): 514–522.
- 42 Weiland SK, Husing A, Strachan DP, Rzehak P, Pearce N. Climate and the prevalence of symptoms of asthma, allergic rhinitis, and atopic eczema in children. *Occup Environ Med* 2004; 61(7): 609–615.
- 43 Von Trepte S, Winkler P. Langfristige Veränderung von relevanten meteorologischen Parametern mit Bezug zur solaren Strahlung am Hohenpeißenberg. Deutscher Wetterdienst, Offenbach, 2002.