Are Solar Cookers Dangerous to the Eyes?

by Paul Krämer

Summary

When solar cookers are publicly demonstrated in Europe, a frequently asked question regards the possibility of eye damage. This article discusses different effects of excess light on the eye – relative (or physiological) and psychological dazzling, absolute dazzling and pathological effects. The dangers of solar cookers are those of solar radiation, that is visible, infrared (IR) and ultraviolet (UV) light. For comparison, optic radiation exposure – especially UV – in industry and leisure time are mentioned and relevant regulations by government and professional bodies in Germany as well as WHO recommendations are pointed out. Eye diseases due to excess light, especially in tropical countries, are briefly discussed. In the case of solar cookers, radiation is reflected from below (or horizontally), a situation comparable to that while skiing. Recommendations for protective measures are proposed. To put matters in perspective, the possible damaging health effects of other household fuels in developing countries are also discussed, and more so the lack of fuel for cooking..

Introduction

When solar cooking is publicly demonstrated in Germany, the majority of people is positively impressed. A minority takes a sceptical or even depreciating position, arguing the possibility of dazzling. Therefore the present paper examines the forms of dazzling and other effects on the eyes. After that, I am going to present a preliminary assessment of the dangers of sunlight reflected by solar reflector cookers and to recommend protective measures. The assessment refers also box cookers, if these are equipped with a mobile reflecting surface. The effects on the skin and the immune system are not studied here. Finally the dangers of other cooking fuels are considered and the complex relationships between light – including artificial light – and health disturbances are mentioned.

1 What is dazzling?

If the eye is adapted to a low level of illumination, a sudden burst of light leads to dazzling. Something similar happens with technical measuring instruments if the pre-selected range of measurements is exceeded (over-range). Dazzling in this sense occurs when we are momentarily blinded at night by the glaring lights of a vehicle running in opposite direction. This has nothing to do with eye damage.

The eye adapts automatically to the level of luminance of the visual field and the surroundings. The luminance is defined as the strength of light per unit surface, be it light emitting or only reflecting, and it is measured in Candela per unit surface (cd/m2 or cd/cm2). It is therefore a measure of brightness. We see because of differences of luminance and colour contrasts of our environment. The possibility of adaptation allows seeing in a wide range of luminances – about 1011 according to Schmidt and Thews [1995]. We are able to perceive luminances of some micro-candela/ m2 on a clouded sky by night up to several million candela/m2 on a glaring snowfield in the sun. “The spectral reflectance of object surfaces, colour contrasts and bright/dark contrasts determine the appearance of objects” [Schmidt & Thews, 1995, 283]. Colour contrasts however need not be considered in our context.

Differences of luminance in our visual field normally do not exceed a relation from 1 to 40. If the difference is bigger, there may be dazzling. This can occur even if the disturbing light is not very strong in absolute terms. Full moonlight may hamper perception of small stars, and on a dark screen reflexes from a light source behind the back of the worker (e.g. a window) may interfere with proper recognizability. Dazzling is further dependent on the luminance of the disturbing light source, its duration and the angle of entry. Dazzling is particularly intense after prolonged adaptation to darkness. These forms of dazzling are termed relative or physiological dazzling.
If the disturbing light is pulsating and the difference of luminance sufficiently great, attention and the direction of look may be deflected unwillingly to the disturbing light, leading to ever repeated adaptation processes. This is called psychological dazzling [Handbuch NIR, Kap. 5].
Above 100000 cd/m² absolute dazzling occurs. We don't see objects any more, but only light. In case of even stronger light flux with damage of eye tissues we talk of pathological dazzling.

2 Optic radiation and danger to the eyes

The term optic radiation is used to designate infrared, ultraviolet and visible light. The question of possible eye damage due to optic radiation of the sun and comparable artificial radiation sources should be asked in general terms, the more so as there are nearly no observations of harmful effects in relation to solar cookers. The relative quantities of radiation of the different spectral ranges are also important.
The sun produces a an irradiation of 1367 W/m2 above the atmosphere (solar constant). The atmosphere reduces the parts of the spectrum to different degrees.

spectral range	outside the atmosphere	On the ground (sea level)
infrared	44 %	42 %
visible light	47 %	52 %
ultraviolet	9 %	6 %

Tab. 1: Distribution of optic irradiation on the ground and outside the atmosphere [according to „Handbuch NIR der BG der Feinmechanik u. Elektrotechnik”].

Optic radiation may induce photochemical and/or thermal damage to living tissue. In this context, we have to distinguish between short-term and long-term exposure. Photo-allergic and photo-toxic reactions need not be considered here, because they will manifest themselves and need treatment even without any contact with solar cookers. I only want to mention that albinos, who not rare in Africa, should not come close to solar cookers, because they lack protective pigment in the skin and eyes.

2.1 Infrared and visible light

The IR part of the spectrum is further divided as follows:
IR-A: von 780 nm bis 1400 nm
IR-B: von 1400 nm bis 3000 nm
IR-C von 3000 nm bis 1mm

2.1.1 Long-term exposure

Long-term exposure to IR (and UV) radiation may lead to cataract of the eye. In southern countries, where the sun is strong, the peak incidence of cataract is about ten years earlier than in temperate climates. Extraction of the lens is therefore one of the most frequent eye operations in the tropics. Ophthalmologists have coined the term cataract belt for these countries [V. Klauß, 1993].

In Europe, opacities of the lens are known as fire cataract, heat cataract or glass workers cataract. To prevent this happening, it is recommended to limit infrared exposure to 100 W/m2 and /or the duration of exposure.

2.1.2 Short-term exposure

Infrared radiation may produce acute thermal effects (heat) in the eye. However, for photochemical reactions or ionisation to occur, the energy of infrared radiation is not sufficient. Animal experiments have shown that the absorption of high energy infrared radiation (1-4 kW/m^2) in the lens and its surroundings (cornea, iris, anterior chamber) can lead to acute cataract. Potential emission sources of this type are usually broad spectrum sources like the sun. Due to protective reflexes to glare, radiation of this kind usually does not reach the unshielded eye. Only in case of emission sources with a minimal part in the visible spectrum is there a possibility of infrared exposure [Arbeitskreis Nicht-Ionisierende Strahlung der BG Feinmechanik und Elektrotechnik, AK-NIR].

Such a situation might be artificially created by the use of light protection goggles without infrared protection component; therefore I do not recommend these goggles when working with the solar reflector cooker, in order not to increase the danger of cataract already existing in the tropics. However, the relative importance of IR and UV in the causation of cataract is difficult to assess.

Protective measures against optic radiation is also necessary during welding; visible light has to be reduced not only to protect the eye, but also to allow observation of the welding process without dazzling. Current regulations for the protection of the work-force in Germany require shielding against visible, IR and UV light.

Apart from welders, other professional groups are also exposed to intensive light, e.g. actors, who must keep their eyes open even in limelight, thus suppressing the closing reflex of the lid.

2.2 Ultraviolet radiation

For a number of years a considerable increase in the number of skin cancer cases has been observed in several countries. This has been attributed mainly to changes in off-duty activities with increased UV-exposure. On the other hand, partial break-down of the protective ozone stratospheric shield is also important. UV radiation on the ground is determined by a number of factors such as season of the year, time of the day (position of the sun), ozone content of the atmosphere, aerosols, clouds, height above sea level and the reflectance of the environment (albedo).

The UV spectrum may be subdivided as follows:

- UVC 100 - 280 nanometer
- UVB 280 - 315 nanometer
- AVA 315 - 400 nanometer

2.2.1 The UV-Index

The Agenda 21, which was decided by the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro in 1992, includes also measures against the dangers of ultraviolet radiation. Therefore, the World Health Organization (WHO), together with the UN-Organization for the Environment (UNEP) and other international bodies has put up criteria in 1994 to allow assessment of these dangers [WHO, Environmental Health Criteria 160], and has launched the global project "Intersun", to promote research and to aid in the implementation of results. One outcome of this project is the definition of a global UV-index, which aims at a temporal and spatial risk assessment and at alerting the public to the dangers of UV radiation.

The UV-index is defined as the mean daily maximum of erythema-provoking irradiance in W/m^2 and multiplied with 40. The index can take values between 0 and 20 (near the equator, at noon, if the sky is clear). In Germany in march 3 may be obtained, in southern Germany up to 7 or 8 in the summer. In the tropics values above 8 are commonly observed; these are values which require protection according to the project "Intersun". This statement applies generally, without any reference to solar cookers.

EXPOSURE CATEGORY	UVI RANGE
LOW	< 2
MODERATE	3 TO 5
HIGH	6 TO 7
VERY HIGH	8 TO 10
EXTREME	11+

Table 1: UV radiation exposure categories

Fig. 1: Exposure categories by UV Index. Source: ‚Global UV Index, A Practical Guide'. With kind permission by the World Health Organization.

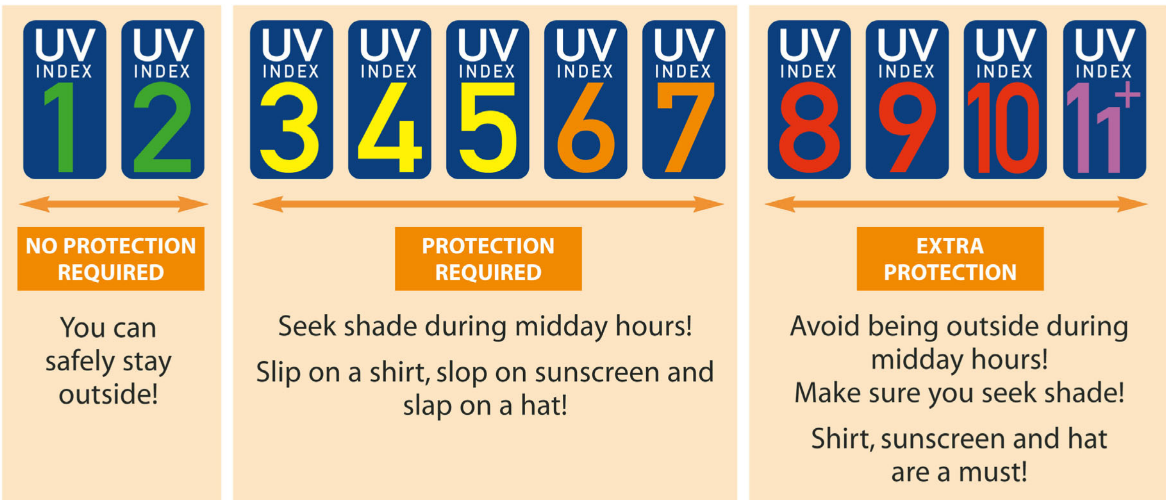

Figure 2: Recommended sun protection scheme with simple "sound bite" messages

Fig 2: Recommended scheme of protection against solar UV radiation. Source: ‚Global UV Index, A Practical Guide', with kind permission of the WHO.

2.2.2 Impact of UV light due to modern ways of life.

Which are the other potentially dangerous exposures to light brought about by our modern way of life? Sports and free time activities range high in this respect according to the German "Radiation Protection Commission" [infos Nr. 6 and 8, SSK].
Excessive exposure to light – including UV radiation – with dazzling and skin damage is possible in the following situations:

- Winter sports: dazzling by snow
- Sailing: Dazzling by the reflecting water surface.
- In the mountains
- In solariums
- When sun-bathing
- Using halogen lamps
- Using Hg low pressure lamps
- Using Hg high pressure lamps
- Using discharge lamps (containing neon)
- Undergoing certain medical treatment procedures
- In Regions with thinned atmospheric ozone layer (here also UVC may play a role; UVC is otherwise held back by the ozone layer).

Apart from these factors, certain technical processes requiring ultraviolet light, like drying or hardening procedures, have to be mentioned.

2.2.3 Diseases due to excessive ultraviolet light.

The cornea of the eye may be damaged by UV radiation. In this case the uppermost cell layer is destroyed. Pain in the eyes appears six to eight hours after exposure, but disappears 1-2 days later due to the high regenerative capacity of the cornea. This is generally termed photo-keratitis, or, depending on the specific cause, "welders flash", "arc eye" or snow blindness. One case of photo-keratitis was observed after demonstration of solar cookers in a staff member of a scientific institution. The conjunctiva may also be affected (photo-conjunctivitis)
The pterygium, a growth on the conjunctiva and/or cornea, is also believed to be at least partially provoked by UV light. It is harmless in general but may become infected, and, if progressive, tends to cover the pupil and interfere with vision.
Possible effects on the lens consist in the formation of a cataract [WHO 1994, see also NIR-Handbuch, chapter 6, and SSK 1996]. According to estimates by the WHO there are 12 - 15 million blind people worldwide, and in 20 % of these sunlight is the main cause [WHO „Intersun, The Global UV Project"]. However, it is difficult to estimate the relative contributions of the IR and UV spectral ranges in the causation of light induced cataracts.
UV radiation may provoke photo-chemically or thermally induced changes in the middle of the retina, leading to blind spots or localized colour vision disturbances (retinitis actinica, i.e. radiation-induced retinitis). The blue part of the spectrum (short wave radiation below 500 nm) and down to 300 nm — is particularly responsible. Regeneration is slow, if it occurs at all.
The age-dependent degeneration of the macula – the spot of sharpest vision on the retina – has also been attributed to UV light exposure. The same is true of malignant tumours like melanoma of the eye ball and basal cell carcinoma of the lids.

3 Protection

3.1 Quality management, protective measures and training.

Everybody knows and accepts that working with gas or electricity requires special professional qualifications, preventive measures and security regulations. But in the case of solar cookers everybody upon whom the sun shines, deems himself to be competent. However, handling solar cookers requires at least a minimum of training for craftsmen, vendors and promoters and users to guarantee safe and reliable functioning. This has often been disregarded in the past. These safety measures (recommendations partly based on the multilingual solar cook book by Imma Seifert [2002]) comprise mainly the following :

- The geometry of the paraboloid has to be safeguarded, deviations lead to loss of output and may cause dazzling;
- If the cooker is not used, the vault should be upside (as in the SK 14) or the wings tilted in a vertical position (as in the “papillon” or butterfly type).
- When putting the cooking vessel in place or removing it, the reflectors have to be tilted to guard against the sun,
- Do not use small or shallow pots or pans, in order not to allow the radiation to pass the focal area (after passage the rays become again divergent),
- The surface of the vessel has to be blackened. A shining metallic surface would not only diminish heat absorption and thus prolong cooking time, but also increase stray radiation.
- Do not look into the reflector, if the pot is not in place or if the cooker is not directed against the sun,
- Third persons should not look into the reflector from aside, but should stand behind the cooker (seen from the side of the sun) like the cook: eventually a barrier rope may be useful,
- As the cooker is used when the sun is high, protection against direct isolation is also recommended; this may be done by using a large-brimmed hat to protect face and neck or using the sunscreen mountable on the papillon. But these appliances do not shield against reflected sun rays coming in horizontally or from below.

3.2 Reflected Radiation and the geometric position of the eye.

The direct radiation of the sun reaches the body mainly from above. This means the eyes are well protected by their position in the orbital cavity and by the prominent supra-orbital rim, the brows and lids. Reflected radiation however reaches the eyes horizontally or from below, so that the eyes are not shielded by their position. This happens in front of snow fields, water bodies, sand surfaces and chalk quarries, and we understand why in sledge dogs in the artic light induced cataract is a common veterinary problem [information sheet of the University of Colorado’, „UV Radiation and the Eye“].

The conclusion is that individual protection is recommended when using solar reflector cookers, as an increased exposure to reflected optic radiation has to be assumed. This protection should shield against visible, UV and IR light.

3.3 Protective appliances.

Hints for the choice of protective goggles are given (in German) in [BGR 192 „Benutzung von Augen- und Gesichtsschutz“, appendix 2]. Goggles including protection against IR (and of course UV) should be chosen.

When choosing filters for use for solar cooking in sunny countries, we should remember that exposure to the sun is strong and life-long, no matter if solar cookers are used or not. The additional impact of solar cookers has to be weighted against this background. For 2003, photometric measurements are planned in collaboration between the Federal Office for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin) in Dortmund, Germany, and several solar cooking initiatives. Geographic and climate data will then allow extrapolation to be made to other climates and latitudes. For this reason a particular level of protection is not yet recommended.

4 Further criteria for assessment

The Question, whether solar cookers are dangerous or not, should not be answered in isolation. The following points are also very important:

- What are the dangers of other available cooking fuels, especially in developing countries?
- What are the consequences of the non-availability of alternative fuels as well as of solar cookers?

4.1 Dangers and disadvantages of other forms of energy for cooking:

- Wood: townspeople rarely have the opportunity to collect enough wood, they depend on the market; there is danger of burns for children and people with epileptic seizures, danger of diseases of the conjunctiva and the respiratory system due to inhalation of wood smoke – Acute Respiratory Infections, (ARI) due to Indoor Air Pollution (IAP) when cooking inside houses without proper ventilation. This is responsible for about 2 million additional deaths in developing countries, mainly between women and children below 5 years of age, and for about 4 % of the global burden of disease [Nigel Bruce, Rogelio Perez-Padilla & Rachel Albalak, 2000].
- Charcoal: Accelerated exhaustion of wood resources due to the low carbonisation efficiency [Hafner et al. 2002], important emissions of methane, carbon monoxide and dust during production, prices of small quantities sold to the poor are sometimes grossly inflated[1].
- Liquefied pressurized gas (LPG): very high prices, difficult transport in the absence of a vehicle, non-availability in small quantities and hence unreachable for the poor, frequent supply cuts due to foreign exchange difficulties of the importing country,
- Kerosene (a mixture of paraffinic, naphtholic and aromatic hydrocarbon compounds): Burns are frequent according to the experience of the German medical aid organization „Hammer Forum“, for instance in Eritrea and Yemen, where they account for approximately 70 % of all burns. They were documented in the communications of the forum. There is danger of vapour explosions when mixing with air; intoxication is also possible by accidental ingestion (lung damage is possible) if household vessels are used, Kerosene is more expensive than wood and gives an unpleasant taste to food due to kerosene vapours.

[1] In Kenya sometimes by a factor of 8. Source: [„Adding fuel to the fire“, “Ecoforum” editorial, Nairobi 5/4 2002, S. 9].

Fig 3. Indoor air pollution: the grey haze is due to wood smoke particles in a kitchen in south west Burkina Faso (Photo: Krämer)

Fig. 4: Sequelae of burning with kerosene in Yemen. The head and left hand of the boy are more or less fixed due to extensive scar formation with contraction. (Photo: Dr. Th. Emmanouilidis)

4.2 Lack of cooking possibilities :

If there is no or only insufficient possibility of cooking, there may be malnutrition, even if food is not lacking. The possibility of cooking belong to the basic needs, if not satisfied, social unrest is inevitable. Refugee in African camps are reported to have exchanged some of their scarce food against fuel, when all accessible wood around the camps had been felled and consumed.

5 Which are the dangers of light in general?

In the industrial countries the break-up of the day/night rhythm by artificial light is not questioned in the public at large, but this break-up has inherent risks, which are usually not known to critics of solar cookers. Man is dependent on the daily cycle of bright and dark like animals and plants. This is a condition for the proper functioning of his immune system. In May 2002, a Symposium was held in Cologne, Germany, to look into the complex relations between visible light and cancer. The subject was „Light, Endocrine Systems and Cancer. Facts and Research Perspectives". The centre of the debate was the possible cancer promoting effect of light at night (LAN), and the idea was proposed, that light not only makes life possible, but also limits it.

May be our nocturnal illumination, television and work by night is far more detrimental to the health of northerners than the stray radiation of solar cookers to the health of people of the southern hemisphere, who frequently has no access to electricity, but who urgently need alternative sources of energy for cooking.

Parabolic cookers like the SK 14 (by EG Solar, Altötting, Germany) or the new Papillon, developed in the "Solar-Institut Jülich" (Germany) are effective and can be used without harm. But further development of these appliances is not excluded; users and developers are working together.

Solar cookers, like hydropower, wind, photovoltaic, geothermal installations and others can provide energy outside the carbon cycle, that is without carbon emissions. Their unique advantage is the possibility of decentralized use for cooking in sun-rich countries. That is important, because part the fuel consumption of the 2 million people who use wood or charcoal for cooking stems from unsustainable production. If this part could be replaced by solar cookers, that would be a considerable gain for climate protection.

Possible harmful effects of solar cookers have nothing specific. The effects are those of reflected solar radiation. An excess of solar radiation is harmful – that is the message of the project "Intersun" of the WHO. In northern latitudes dangers of optic radiation result mainly from off-work and out-door activities; in southern countries people receive a high dose of optic radiation all the year round. But an increment due to solar cookers should seen as possible and preventive measures should be taken accordingly. Training in the handling of solar cookers is necessary, and the instructions for use have to be observed. Additionally, individual protection may be recommended to shield against stray reflections.

Solar cookers probably have far less dangers and disadvantages than their more "modern" alternatives, if these are available at all. Lack of fuel means hunger. This has to be understood metaphorically, but also literally: hunger for fuel and hunger for cooked food. An "energy aid" as fuel supply by the north that might be necessary according to Minvielle [1999], is no alternative in a world of competition. Vulnerability vis-à-vis fuel shortages can only be diminished by regional and local renewable resources. This however needs international cooperation.

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