predicted by meteorological theory.[4]

These findings are relevant to medium distances from the pollution source only. It was not possible to test the model for greater distances because the observed concentrations for monitoring sites situated far from the sources are routinely below detection limit. Similarly, the model does not hold for short distances between source and receptor because of the role played by local turbulence in this type of situation.

Conclusion

Using a very simple model, sulphur dioxide concentrations were observed to confirm the meteorological theory[4] that suggests that tall stacks are scientifically correct and environmentally sound in providing a means of dispersing pollution emitted from power stations. The observations further confirmed that the study period was typical of winter conditions and that stack heights greater than 220 m or so are not necessary to achieve adequate plume dispersion.

We are encouraged by the success of this model in describing conditions over the relatively short time span of two weeks. Our experience demonstrates that the use of simple numerical techniques, perhaps with refinements to take account of wind speed, atmospheric stability and plume rise, should prove effective when used in conjunction with Eskom's extensive air quality data base.

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Gingival temperatures in the baboon and vervet monkey

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This paper reports an investigation to record gingival temperature in 21 baboons and 21 vervet monkeys. Using an electronic thermometer and a fine thermocouple, gingival temperatures were measured alongside six teeth, an incisor, a premolar and a molar in each jaw. The mean sublingual temperatures were 37.4 ± 1.2 °C in the baboon and 36.1 ± 1.5 °C in the vervet monkey. Buccal gingival temperatures in the monkey were higher than in the baboon and were closer to values in man.

In hierdie artikel word verslag gedoen oor 'n ondersoek waartydens die tandvleistemperatuur by 21 bobbejane en 21 blouape aangeteken is. Die tandvleistemperatuur is met behulp van 'n dun termokoppel langs ses tande gemeet, nl. langs 'n snytand, 'n voorkiestand en 'n kiestand in elke kaak. By die bobbejane was die gemiddelde temperatuur onder die tong 37,4 ± 1,2 °C en by die blouape 36,1 ± 1,5 °C. By die blouape was die tandvleistemperatuur in die mondholte hoër as by die bobbejane, en nader aan wat by die mens aangetref word.

Internal or surface temperature has long been used as a diagnostic aid in man and animals. Recently, attention has been focused on temperature variations in different parts of the mouth. The absolute temperature of the human gingival sulcus has been shown to be lower alongside incisor than alongside molar teeth and lower in the mandible than in the maxilla.[1–3] After correcting for basal temperature variations between individuals and using fine thermocouples, Volchansky *et al.*[4] confirmed these observations and noted that there was an irregular variation in temperature differentials in healthy gingivae among mesial, labial, distal and lingual sites around teeth. In a further study of repeated gingival temperature measurements in humans,[5] Volchansky and co-workers used a five-way analysis of variance to determine which of tooth type, jaw, position around a tooth, time of measurement as well as subject most influenced mucosal temperature recordings. The factors of greatest significance were choice of tooth and jaw, whereas time of examination was the least important.

Information of the same type on non-human primates is lacking but is needed to allow experimental evaluation of diseases of the gingiva. The purpose of the present study was therefore to measure and compare oral mucosal temperature around selected teeth in the baboon and vervet monkey.

Materials and methods

The protocol was first approved by the University of the Witwatersrand's Animal Ethics Committee (clearance no. 87/88). The temperature measuring device was a Bailey Instruments (Saddlebrook, New Jersey) digital thermometer (model BAT12) with a fine thermocouple point made from copper and copper/nickel wires, soldered together to give a measuring point of 0.3 mm diameter (Fig. 1). This was calibrated before use against an accurate mercury thermometer; the high reproducibility of measurement has been reported elsewhere.[4] Twenty-one adult baboons (*Papio ursinus*) and 21 adult vervet monkeys (*Cercopithecus pygerythrus*), in quarantine from the wild, were used in the study. The clinically healthy animals were immobilized with phencyclidine hydrochloride (1 mg/kg body weight) and the temperature recordings were made at the same time of day under the same environmental conditions for each group. The first measurement made in each instance was the sublingual temperature, which was used as the baseline reference mark for the temperature differentials. Six standard reference teeth used with periodontal disease indices[4] were used; their international dental notations are indicated in parentheses in what follows. The sites of measurement were at the crest of the gingival margin, at the bucal, lingual, mesial and distal aspects of the following permanent teeth: maxillary left lateral incisor (22), right first premolar (14) and right first molar (26), as well as manibular right lateral incisor (42), left first premolar (34) and right first molar

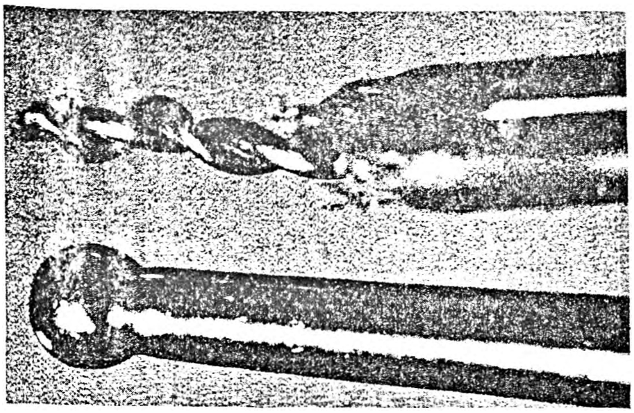

Fig. 1. Thermocouple end with 0.5-mm diameter ball tip of WHO periodontal probe for size comparison. The glass-fibre resin insulation of the sides of the thermocouple has been omitted for clarity of demonstration. × 25.

(46). The tip of the thermocouple was placed on the site at right angles to the surface and held in place until the digital readout had stabilized, which was generally within 5 – 10 seconds. Care was taken to close the mouth of the animal between site measurements for at least 10 seconds to minimize heat loss. A total of 984 temperature recordings was made.

Both the baboon and the vervet monkey have been used for experimentation at our university for many years. During this period, it has been observed that gingival inflammation is common, particularly in the incisor regions in both species, in animals brought in from the wild or those that have eaten a laboratory diet. In order to compensate for this during data analysis, gingival inflammation was recorded for the buccal gingiva of each experimental tooth by using a simple system, a modification of the gingival index of Loe[6] as follows: score 1 = no gingival bleeding and minimal inflammation; score 2 = inflammation plus minimal bleeding when the thermocouple was placed onto the gingival margin; score 3 = marked inflammation with spontaneous bleeding.

The data were analysed using the Statistical Analysis System.[7] A temperature differential was calculated by subtracting the sublingual temperature for a particular animal from the gingival site measurement in the same animal, in order to allow for variations in basal temperature between animals. Sites warmer than sublingual temperature are indicated in subsequent tables as a positive value and those cooler have been displayed with a negative value in the tables. The lower the differential the closer the site temperature is to sublingual temperature.

The General Linear Models procedure was used in the statistical analysis and comprised a multiple regression analysis for the variables, species, tooth, site around the tooth and inflammation as well as one-way analysis of variance for differences between baboon and monkey gingival temperatures at the same tooth site and level of inflammation when two or more recordings were available. The critical level of statistical significance chosen was $P<0.05$.

Results

The mean sublingual temperatures (± standard deviation) were baboon 37.4 ± 1.2°C and monkey (36.1 ± 1.5°C). The mean temperature differentials in the baboon and monkey, for all sites (i.e. with and without inflammation), are shown in Table 1. The highest differential (–6.1°C) was seen for labial gingiva alongside tooth 22 in the baboon, and the lowest (–0.9°C) was for distal gingiva alongside tooth 26 and lingual gingiva of tooth 46 in the monkey. The coolest sites were in the incisor region and the warmest in the molar area. In all instances the mean differentials were cooler than sublingual temperature. For 21 of the 24 sites measured, the gingiva was warmer in the monkey than the baboon. The temperature differential was lower in the mandible than in the maxilla, i.e. sites were cooler in the maxilla. There were also smaller temperature differentials around the molars, indicating that the gingival tissue was warmer around the molars of both species.

Gingival inflammation of the buccal mucosa was present in both species (Table 2) alongside all the specified teeth, and was more severe in the baboon than the vervet monkey. Inflammation and therefore the gingival index score decreased posteriorly. In order to compare species, allowance must be made for the confounding effect of inflammation. In Table 2 the mean temperature differentials on the bucal surface are listed by gingival index. Comparison was made horizontally, between species within the same gingival index, when five or more observations are available. Vertical comparisons are beyond the scope of the study. The human values presented for comparison were from an earlier investigation.[4] At a gingival index of 1 for teeth 34, 26 and 46, the gingival temperatures in humans were much closer to the monkey than to the baboon. For gingival indices 2 and 3, comparison between monkey and baboon showed that baboon mucosa was always cooler than the monkey's, a result similar to that seen in Table 1 when allowance was not made for inflammation.

Statistical analysis showed that species, individual tooth, site of measurement and level of inflammation significantly affected gingival temperature (Table 2). Of 12 comparisons made, in the seven that were statistically significant, monkey gingival temperature was higher than in the baboon, and close to human gingival temperature. (Statistical comparison with earlier results in humans was considered to be inappropriate because the humans were not anaesthetised at the time of measurement.)

Discussion

The thermocouple used in this study was small enough to provide 'pin-point' positioning and was an improvement on earlier,

Table 1. Mean (s.d.) temperature differentials (°C) by tooth site and species; n = 21 for each site. (Negative values = cooler than sublingual temperature)

	Site	Baboon	Vervet monkey
Tooth 22	mesial	–5.6 (1.4)	–3.2 (1.9)
	buccal	–6.1 (1.6)	–3.3 (2.0)
	lingual	–5.7 (1.3)	–2.9 (1.8)
	distal	–4.6 (1.1)	–1.4 (1.7)
Tooth 42	mesial	–4.6 (1.4)	–4.7 (1.8)
	buccal	–4.7 (1.4)	–5.0 (3.0)
	lingual	–4.8 (1.1)	–4.3 (1.8)
	distal	–3.0 (1.6)	–2.1 (1.6)
Tooth 14	mesial	–4.3 (1.7)	–3.3 (1.7)
	buccal	–4.6 (1.8)	–3.0 (1.8)
	lingual	–4.1 (1.3)	–2.5 (1.6)
	distal	–3.9 (1.4)	–2.1 (1.7)
Tooth 34	mesial	–4.3 (1.2)	–2.4 (1.9)
	buccal	–4.0 (1.2)	–2.1 (1.8)
	lingual	–3.5 (1.2)	–1.8 (1.5)
	distal	–3.0 (1.3)	–1.0 (1.2)
Tooth 26	mesial	–4.6 (0.9)	–1.8 (1.3)
	buccal	–4.1 (1.6)	–1.4 (1.4)
	lingual	–3.2 (1.3)	–0.9 (1.3)
	distal	–3.3 (1.2)	–0.7 (1.1)
Tooth 46	mesial	–3.1 (1.3)	–2.9 (1.2)
	buccal	–2.9 (0.9)	–2.4 (1.2)
	lingual	–2.1 (0.9)	–1.7 (1.3)
	distal	–1.2 (0.9)	–0.9 (1.2)

Table 2. Mean (s.d.) temperature differentials (°C) for the buccal surface by tooth and gingival index in the monkey and baboon. Temperatures at similar sites in humans are shown for comparison.

Tooth	Gingival index	*n*	Monkey mean	s.d.	*n*	Baboon mean	s.d.	ANOVA *P* value	*n*	Human mean	s.d.
22	1	6	−2.2	2.0	1	−7.0		–	30	−2.6	0.7
	2	8	−3.3	1.4	10	−6.3	1.6	***			
	3	5	−4.2	2.5	9	−5.6	1.8	NS			
42	1	5	−3.2	1.1				–	30	−2.0	0.6
	2	9	−5.8	4.2	11	−5.0	1.7	NS			
	3	5	−5.2	1.2	8	−4.3	0.9	NS			
14	1	13	−2.6	1.9	2	−7.0	1.9	**	30	−2.2	0.8
	2	6	−3.3	1.0	11	−4.7	1.8	NS			
	3				7	−3.9	1.2	–			
34	1	13	−1.8	2.0	6	−4.7	1.6	**	30	−1.1	0.3
	2	6	−2.1	1.0	9	−3.9	1.0	**			
	3				5	−3.2	0.4	–			
26	1	14	−1.1	1.3	7	−3.3	1.1	***	30	−1.1	0.4
	2	5	−1.7	0.8	10	−4.5	2.0	**			
	3				3	−4.6	1.0	–			
46	1	13	−2.7	1.1	8	−2.4	0.5	NS	30	−0.7	0.3
	2	5	−1.9	0.6	11	−3.1	1.2	*			
	3				1	−3.8		–			

* = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$; NS = not significant; – = no test.

larger devices.[1,2] We are confident that the temperatures measured with our method showed the temperature only at the site of measurement. If absolute temperature measurements such as reported by Ng *et al.*,[1] Mukherjee[2] and Holthuis and Chebib[3] are to be used for comparison, confusion can arise unless the average 'normal' basal or sublingual temperature in the species is known. More importantly, unless temperature differentials have been calculated for each individual the effect of fever or physiological rises in temperature, such at at ovulation, will be included in the results. In humans the average normal oral temperature is 36.7 – 37.0°C, and rectal temperature is approximately 0.6°C higher.[8] Zurovsky *et al.*[9] reported the average daily temperature of five unrestrained baboons, measured by radiotelemeters implanted in the abdominal cavity, to be 38.0°C (s.d. 0.3°C), the same as rectal temperature reported previously for unanaesthetised baboons in restraining chairs.[9] If the difference between rectal and oral temperature in the baboon is as in man, then 37.4°C would be 'normal', i.e. similar to man. This was found to be so in the present investigation. Published values for monkeys could not be found. In the present study the mean sublingual temperature for the vervet monkey was 36.1 ± 1.5°C, i.e. 1.3°C lower than in man and the baboon. Because of this variation between species and possibly between individuals, the temperature differential calculated and presented in this paper is a practical means of comparing relative temperature variations between individuals and species.

Early in the investigation it was commonly noticed that the amount of inflammation and gingival bleeding present adjacent to the incisor and canine teeth in the baboon was greater than at comparable sites in the vervet monkey. We can give no explanation for this difference, as the individuals of both species had been in captivity for approximately the same time and their diets were similar and balanced. Experience over some 20 years has also shown us that, even if oral hygiene procedures are carried out, inflammation persists at the sites mentioned. It is the view of Page and Schroeder[10] that gingivitis seems to differ significantly from one species of non-human primate to another. These authors report a study by Avery and Simpson[11] and Simpson and Avery,[12] who examined 10 baboons (*P. anubis*). In their three adult animals, the interdental papillae of the anterior teeth were more inflamed than those in the molar region, while in the young animals the papillae of the premolar region were the most severely affected. No reports on the vervet monkey could be found, but a study of Simmons *et al.*[13] on the marmoset indicated more gingival inflammation around the incisal teeth than around the posterior teeth.

The vervet monkey was seen to have less inflammation and gingival temperatures closer to man than did the baboon. For experimentation in the anterior gingival region, therefore, unless the inflammation in baboons can be reduced beforehand, the vervet monkey appears to be the experimental animal of choice.

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