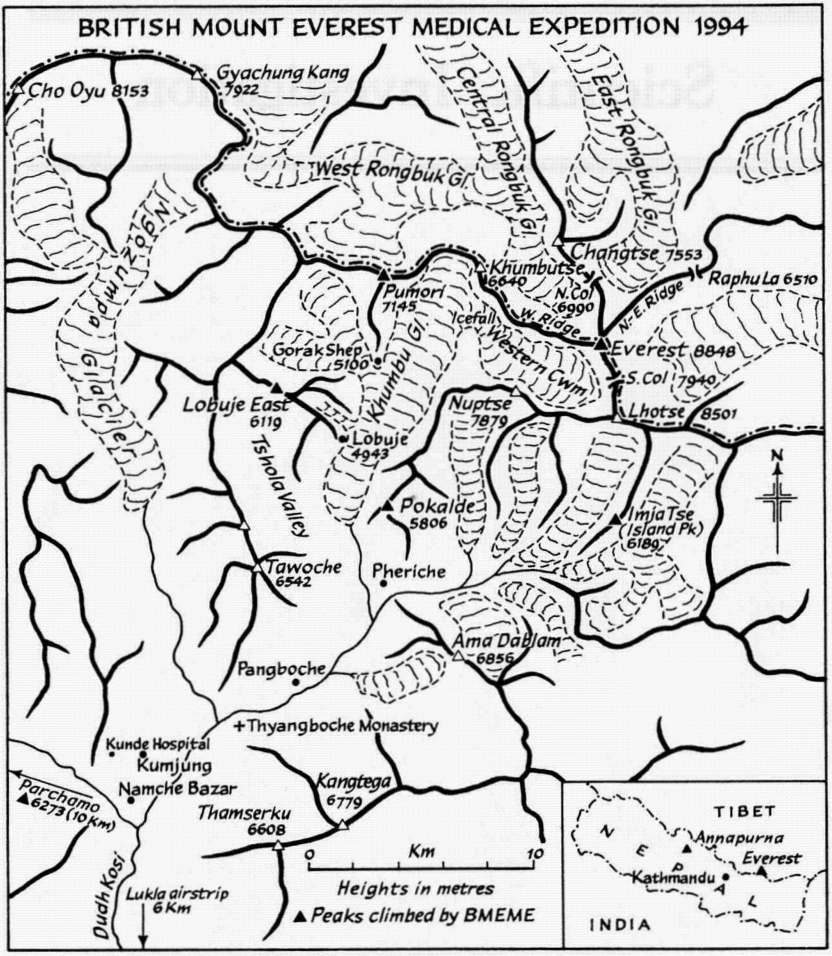
Scientific Investigation



The Everest Region

In addition to its research programme, the British Mount Everest Medical Expedition 1994 climbed the following peaks:

Everest, 8848m
Pumori, 7145m
Parchamo, 6273m
Imja Tse (Island Peak), 6189m
Lobuje East, 6119m
Pokalde, 5806m

DAVID COLLIER, SIMON CURRIN & ANDREW POLLARD

Science on Mount Everest

The British Mount Everest Medical Expedition 1994

(*Plates 59–61*)

In 1994 a team of seven climbers attempted to climb Mount Everest in the post-monsoon season, placing two doctors on the summit on 13 October. But the British Mount Everest Medical Expedition intended more than just another ascent of Everest. A group of more than 30 doctors, physiologists and environmental scientists studied every aspect of human exposure to altitude and the environmental impact of climbing and trekking in Nepal. This article outlines the 21 medical, physiological and environmental projects which were undertaken by them.

Changes in Spirometry at Altitude

The flow of air out of the lungs was measured in 52 trekkers and climbers at Everest Base Camp (EBC, 5300m) with a pocket spirometer (Micro Medical, UK). The peak expiratory flow (PEF) was shown to increase by about 25% at 5300m when compared with sea level. The increased flow was accounted for by the lower density of air at altitude (air pressure at EBC was 530mB, compared with 1012mB at sea level) which produces less resistance to flow through the airways. In asthmatics expiratory flow is reduced and these findings may explain why many of them have fewer symptoms at altitude: the reduced barometric pressure increases their expiratory flow, making it easier for them to breathe. For some asthmatics the lack of environmental allergens (such as cat hairs, house dust mite and pollen) at altitude, which normally worsen symptoms, probably also helps. Other devices for measuring PEF, such as the commonly used (mini-) Wright peak flow meter (which is used by many asthmatics), are not reliable at altitude as they are affected by air density and under-read by up to 30% in our study.

The volume of air which can be expelled from the lungs after a deep breath in is the forced vital capacity (FVC) and this was reduced by 5% at EBC.

Spirometry and chronic hypoxia

Chronic hypoxia (lack of oxygen) due to lung disease causes a decrease in expiratory flow in adults with bronchitis and emphysema, which is

reversible with oxygen. We used the lack of oxygen in the atmosphere at altitude as a model to study the effect of chronic hypoxia on spirometric measurements, using a pocket turbine spirometer. However, Peak Expiratory Flow at Everest Base Camp was not associated with variations in oxygen levels in the blood and there was no improvement in Peak Expiratory after administering oxygen for five minutes. We found that lower levels of both oxygen and carbon dioxide in our team weakly correlated with lower lung volumes (using FVC). We think this is because the blood vessels in the lungs become more leaky at altitude, causing extra fluid to build up in the lungs and take up more space. Alternatively, the small airways may collapse earlier than normal, so that more air is trapped in the lungs and less can be expelled.

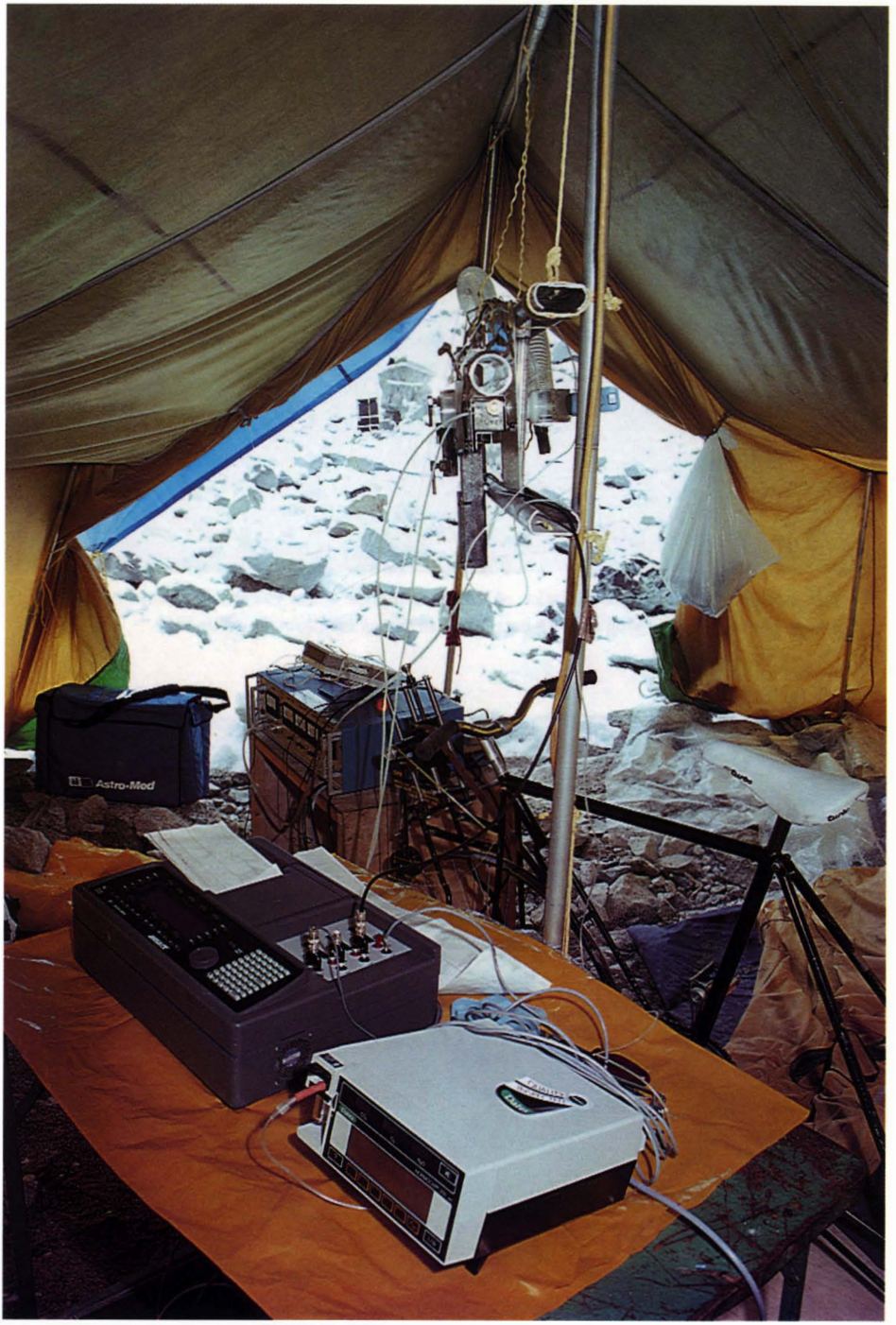
Does hypoxic vasoconstriction predict risk of high altitude pulmonary oedema (HAPE)?

HAPE kills climbers every year. Those affected have fluid in the lung airspaces and cough up frothy spit. Studies comparing climbers with a good history of altitude climbing with those who became ill with HAPE have shown that the latter tend to shut down their lung blood vessels more when they are exposed to low oxygen levels (Hypoxic Pulmonary Vasoconstrictor Response).

Our study aimed to measure HPVR before the expedition and see if any member who developed HAPE could have been predicted to be at risk. Fortunately for members – but alas for the study – we had only one member with clear evidence of HAPE. He had shown a strong tendency to shut his lung blood vessels when exposed to low oxygen levels in London. Our study may be combined with other similar studies to assess the value of HPVR measurement. If we could predict who is at high risk of HAPE, they could benefit from taking a drug (nifedipine) to protect them against it. Nifedipine is an effective treatment for HAPE and was used successfully on our subject. But because of our healthy expedition, the data will need to be added to further studies to give enough statistical power to answer this question.

Can simple measurements predict day-to-day performance at altitude?

There are no accepted criteria for predicting who will perform well at high altitude, except previous history of success. There are also no accepted ways of telling who will perform well on a given day, or who might become ill. Because of the large number of people on the expedition, we had a unique opportunity to study these questions. All members of the team performed many simple measurements each day before and during their ascent to altitude. Measurements included blood pressure, heart rate, oxygen saturation, acute mountain sickness score and lung volumes. We are beginning to analyse this enormous pool of data, but it will be many months before the task is complete.



59. British Mount Everest Medical Expedition 1994. The 'control of breathing' tent, showing (on the table) Astro-med chart recorder and Datex CO2 analyser. Small volumes of carbon dioxide could be added to the inspired air at different times during each breath. (*David Collier*) (p163)

Respiratory defence: muco-ciliary clearance at altitude

Obstruction of the nasal passages significantly increases the work of breathing and subjective feelings of breathlessness. Such obstruction may also affect performance at altitude. Mucous lining the respiratory tract is cleared by the action of microscopic hairs (cilia) beating in waves to carry secretions to the pharynx. We studied members of the expedition at altitudes up to 5300m. Subjects recorded their nasal patency (as patent, partially blocked or blocked) for both nostrils on two occasions each day of their ascent. The saccharin test, a measure of muco-ciliary transport, was undertaken at sea level, on arrival at 5300m, and after 10-14 days at 5300m. A small amount of saccharin was placed 1cm from the front end of the inferior turbinate (the lower part of the inside of the nose) of one nostril. The time taken for the saccharin to be tasted, representing transport to the pharynx, was noted. Nasal patency was reduced with ascent to altitude (ie the nose was more often blocked) and saccharin times were increased. These results indicate impaired muco-ciliary transport and increased blockage of the upper airway at altitude, so that the tiny hairs which help clear the airways do not seem to work so well. We do not know if this is due to altitude per se, or is a result of the low air temperatures and humidity experienced during the expedition. The results of light and electron microscopy of tissue samples of the cilia (hair cells) in the nose are awaited.

Respiratory defence at altitude: cough threshold

The first systematic studies (nocturnal cough monitoring) of cough and airway defences at altitude showed that cough does indeed increase with altitude. Cough challenges with mists of weak acids showed that the cough response is produced more easily after a prolonged stay at altitude.

Blood gas analysis

Initial analysis shows a significant reduction in carbon dioxide levels (PCO2), and a significant increase in oxygen levels (PO2) and haemoglobin with acclimatisation. The arterial-capillary comparisons showed higher capillary CO2 and standard bicarbonate and lower (less negative) base excess. There was no discernible difference between arterial and capillary pH or PO2, but the numbers are very small. We could perhaps argue that this data shows that the difference between arterial and capillary gases, taken under our experimental conditions, is small in a clinical sense, and therefore our use of capillary sampling is justified.

Sex differences in blood gases during acclimatisation

There have been few large-scale studies of blood gas measurements (oxygen and carbon dioxide) during acclimatisation. This study investigated the changes in capillary blood gas tensions on arrival at 5300m and after acclimatisation to that altitude. We studied 29 members of the expedition on arrival at 5300m, and 33 members after acclimatisation to this altitude,

using a Ciba-Corning 248 blood gas analyser. During acclimatisation PCO2 fell from an average of 3.46kPa (KPa = Kilo Pascals, units of pressure) to 3.27kPa; the decline was greater in the women studied to 2.85kPa compared with 3.34kPa in the men.

Capillary oxygenation improved with time at 5300m, from a mean of 5.83kPA on arrival to 6.00kPA after acclimatisation, but although women showed a greater improvement, to a mean of 6.18kPa (compared with 5.97kPa in men), this effect did not approach significance. Capillary pH (acidity) did not alter overall, from a mean of 7.43 to 7.44 after acclimatisation. Bicarbonate estimations showed little overall fall from a mean of 19.8mmol to 19.5mmol after acclimatisation (not significant), but as you would predict from the above, bicarbonate fell significantly more in the women studied, to 18.6mmol compared with 19.6mmol in men. The same was true of estimates of base excess, which showed a greater decline in women, –7.0mmol compared with –5.6mmol in men. As both men and women appeared to have kept the acidity of the blood constant, the results suggest that the changes in breathing experienced during a long period of low oxygen may be superior in women.

Heart rate variability and autonomic tone at altitude

More advanced mathematical methods of analysis have recently allowed the various frequencies of change in heart rate to be studied. Briefly, the two major nerve controls to the cardiovascular system alter heart rate at different speeds – the vagus nerve acts quickly in response to changes in blood pressure and other stimuli. The sympathetic system alters heart rate more slowly. So we can begin to separate some of the influences on heart rate just by recording heart rate and later looking for patterns of change in the records. Funded by the British Heart Foundation, we collected large numbers of 24-hour recordings on support group members, and also significant amounts of recordings on climbers at extreme altitudes up to about 8600m, just below the South Summit of Everest. The recordings require sophisticated analysis for detailed interpretation but preliminary viewing of the data shows that heart rate increases on ascent to altitude but settles with time at altitude. There is an increase in sympathetic tone and a decrease in parasympathetic activity which returns to normal over 10-14 days.

Balance and auditory function at high altitude

Exposure to low oxygen environments can produce subtle but lasting damage to the brain. Previous work has shown that the ability to locate the direction of a sound is poorer after reaching a new altitude, but is restored after acclimatisation to that altitude. Our work included the first large-scale study of hearing threshold at altitude. The results show that high frequency hearing is less sensitive on arrival at 5380m, and is slightly worsened after acclimatisation. Thankfully, hearing was restored on return to sea level. The other section of the work was on balance – we measured

postural sway ('wobble') using a force plate to determine the amount of changes in position of the body when standing 'still'.

Blood pressure at high altitude

Although there have been several studies, there is no agreement on the changes in arterial blood pressure which may take place during ascent to high altitude, and acclimatisation thereto. There are many confounding factors which may affect the quality of the results, but we hope that the measurements made on most members of the team every day will provide an insight into the changes seen in lowlanders' blood pressure on ascent.

Endothelin and high-altitude pulmonary oedema (HAPE)

Endothelin is a naturally occurring chemical, made by the cells which line the blood vessels of the body. It is remarkable as the most potent substance known to vasoconstrict (shut down) blood vessels. Endothelin has been shown to be involved in several serious lung problems at sea level including adult respiratory distress syndrome. We know that climbers who have had high-altitude pulmonary oedema ('water on the lung') also shut down their blood vessels in the lungs most strongly when exposed to low oxygen levels. This powerful shutting down of lung blood vessels may well be important in the development of HAPE, and endothelin is a strong suspect as the chemical which may do so. We have taken many blood samples from members at sea level and again at various altitudes. Thankfully, we had a very low level of HAPE on the expedition with only one case, but this may also reduce our ability to reveal the role of endothelin in HAPE.

The control of breathing at altitude

Studies designed to help separate the contribution of different chemical receptor groups to the process of acclimatisation were performed before and after acclimatisation to 5380m. Results so far analysed show:

1. The speed at which breathing adjusts at the start of exercise is increased after a period of acclimatisation. (This may be due to an increase in drive to breathe from the peripheral chemoreceptors.)
2. Breathing small amounts of carbon dioxide at different times during each breath in causes more increase in breathing when the CO2 is given early in each breath at sea level. Brief exposure to low oxygen at sea level abolishes this effect of CO2, and it is not restored when you arrive at Everest Base Camp (partly acclimatised).

Acclimatisation restores this 'fast' response to CO2, and even enhances it in those who have climbed higher (to Pumori 7145m or Everest 8848m). This work is the first to explore 'fast' peripheral chemoreceptor responses to CO2 in man at high altitude. These changes may help to explain why you can do more, and feel better after a period of acclimatisation at base camp even though the blood gas changes of acclimatisation are almost complete when you reach base camp.

Visual function at altitude

A wide range of experiments was performed, investigating many aspects of visual function at altitude. These included simple measurements of visual acuity (fine vision), intraocular pressure (pressure inside the eye), adaptation to the dark, colour vision, visual field assessment and photography of the back of the eye.

Perhaps the most exciting finding was a reduction in the perception of movement at altitude. The experiment was undertaken to test the idea that hypoxia can cause reversible visual field defects. This could have a huge impact on clinical ophthalmology, as one theory of the cause of glaucoma is that the blood supply to the optic nerve is reduced, causing low oxygen tension in the nerve resulting in permanent optic nerve damage. If the disease could be treated sufficiently early damage could be prevented. By testing subjects free of eye disease under hypoxic conditions any visual field changes could be said to be due to hypoxia of the visual system, but not just the optic nerve. In this experiment a large group of subjects with normal visual fields at sea level (measured two ways – the 'standard' now used for most eye research, and the movement detection method) underwent visual field testing using the movement detection system at an altitude of 5300m. The results showed that perception of movement was impaired at altitude, and became more impaired with time spent at altitude. The changes had returned to pre-expedition values three months after return to sea level.

Assessment of visual function at altitude using movement detection perimetry

Objectives: to compare visual function at sea level with that at altitude, using the detection of movement within the central visual field.

Method: The central visual field of 62 subjects was studied at sea level and at 5300m using vertical bars moving horizontally on the screen of a lap-top computer.

Results: Visibility of moving targets at altitude was reduced compared to sea level values. Visual function, as measured by this test, had returned to pre-expedition values three months after return to sea level.

Conclusion: Movement detection perimetry provides a method for assessing visual function at altitude. Detection of movement within the central visual field is impaired at altitude.

Changes in scotopic and photopic vision at altitude

Psychometric testing of scotopic and photopic vision (ie vision in the light and in the dark) was performed on 65 subjects at sea level and altitude, and the results analysed for changes. The results were not as had been expected. Dark adaptation and colour luminance vision improved at altitude. The improvement in dark adaptation may reflect a learning effect, ie people got better at doing the test the more they did it, although repeat



60. Part of Base Camp showing one of the three research tents: the McInnes Box, courtesy of Hamish McInnes, a rebuilt survivor of the 1975 SW Face Expedition. Along with other research tents, it was later flattened by avalanche blast. (*David Collier*) (p163)



61. Dr Catherine Collier pedalling at 60 watts on the exercise bicycle. The oxygen cylinder in the foreground was used in later experiments artificially to simulate 'descent' to a lower altitude. (*David Collier*) (p163)

sea-level testing does not bear this out. The colour and luminance improvement may be due to environmental effects on the equipment, eg as the ambient conditions became colder the video screen produced more contrast, making the letters easier to see.

Do benzodiazepine sleeping tablets improve or impair oxygen levels during sleep at altitude?

Sleeping tablets of this type have been shown to improve the quality and duration of sleep at high altitude, but they may also reduce the drive to breathe and expose the brain to even lower oxygen levels. This study looked at the saturation of the blood with oxygen during sleep with either active or dummy sleeping tablets. The active tablets did improve sleep, but they also reduced the average saturation of the blood with oxygen. Although the average blood saturation was reduced, the unstable 'periodic' breathing which causes up to half a minute without breathing between spells of deeper breathing, was less frequent with the tablets. These 'dips' in oxygen levels during unstable breathing may well be harmful, and so sleeping tablets may actually be of overall benefit to oxygenation at night.

Intestinal absorption at altitude

Climbers at high altitude, and also patients exposed to low oxygen through lung disease, do not absorb all of the food they eat. Both groups tend to lose weight. We do not understand the reasons why this poor absorption happens. This study aimed to look at two separate ways in which the intestine absorbs sugars from the food. The results of the assays of the samples for the complex sugars used in the tests are still awaited.

Benzolamide reduces acute mountain sickness

Acetazolamide, better known by its trade name 'diamox', has been used for some years to speed up artificially the natural process of acclimatisation; but it does cause several side effects, mostly mild, that can stop people using it. For example, it is very fat soluble and so passes easily into the brain, making some people feel slightly odd. We studied benzolamide (a sister drug of diamox) which does not pass into the brain and may, in theory, cause fewer side effects.

Twenty-two members of the expedition took either dummy tablets or benzolamide each day from the day before the start of the trek until they reached Everest Base Camp (5430m). When the secret code was broken, members taking benzolamide were found to have suffered roughly half as much acute mountain sickness (AMS) as those who had taken the placebo. Although a few of those taking benzolamide noticed occasional tingling sensations or altered taste of fizzy drinks, this was less frequent than we would have expected with diamox, and several taking benzolamide thought they were taking dummy tablets. We are now going to compare the effectiveness and side effects of diamox and benzolamide to see if they are equally

effective, and if the latter has fewer side effects. But do not pester your local GP for benzolamide, as it is not generally available. Like diamox, benzolamide has potential for use in eye problems and has been used for research at Moorfields; so it may be manufactured again in the future, albeit for a tiny market.

Environmental Research Report

1 Kathmandu

Although the expedition had essentially no remit in Kathmandu, the environmental and associated problems could not be overlooked. The city has a stated population of around 800,000. Unofficially it is thought to be in the region of 2.2 million. The main problem areas are traffic management and pollution, solid waste management, and potable water and sewerage provision.

The management of solid waste has, to all intents and purposes, ceased in any real sense of the word. Solid wastes are discarded onto the streets where they are allowed to accumulate. Dogs, pigs, cows and children are to be found scavenging on the piles of rotting vegetation. The wastes are removed occasionally and are deposited along the river bank. In some areas the river has receded some 15m as a result of this form of landfilling. There are no engineering controls in place and the waste is simply dumped and subsequently pollutes the river. However, in health terms it is perhaps the absence of a safe potable water supply and a sewerage system which is of most significance. It is generally accepted that all supplies used for drinking purposes by the local population are contaminated – as the cholera wards testify.

2 Trekking route to Everest Base Camp

Most of the area covered by the walk-in is located within Sagarmatha National Park. Approximately 5000 people inhabit the park. However, the numbers swell considerably during the two short trekking seasons.

The National Park area is policed by the Sagarmatha Pollution Control Committee (SPCC), based in Namche Bazar, who dig pits for infilling, have a mobile incinerator and a fixed unit at Lukla and collect reusable glass bottles which are flown free of charge by Asian Airlines from Namche to Kathmandu. The Committee also employ litter pickers. One of the most important tasks of the Committee is to attempt to educate trekkers to adopt environmentally friendly practices when in the Park. Specifically they ask that local water sources are disinfected and used instead of bottled water and that only lodges using fuel other than timber are frequented.

Sanitary accommodation throughout the park is by 'Thunderbox' which is simply a cabin with a hole cut in the floor. The extent of solid and human waste pollution is greatly exaggerated. The solid waste pits seem to be used in

the larger settlements and the present generation rate can be disposed of without unduly affecting the local environment. Similarly, it is doubtful whether the present practice of human waste disposal has significant environmental consequences. However, it is likely that the practice is a cause of much of the gastro-intestinal illness amongst tourists who eat from local tea houses.

3 Base Camp

This is situated on the Khumbu glacier at the base of the Khumbu icefall. It is a most inhospitable place with little or no discernible ecology. A $4000 'bond' system is used to ensure that all solid waste is managed off-site. Waste consignments to the SPCC incinerator are taken by porter or yak from Base Camp to Namche Bazar. An analysis of this waste was carried out at BC and found to comprise almost two-thirds putrescible waste.

The SPCC take a much more relaxed view of human waste disposal. There are no prescribed requirements in this regard, as is obvious by the faecal contamination of the entire site. To try to improve matters the environmental team organised a toilet (a 60 litre plastic barrel) into which the expedition members were requested to defecate. The resulting soil was emptied onto plastic sheeting and dried. The much-reduced mass was then taken to Namche Bazar for incineration.

Experiments on the water quality at Base Camp were undertaken and interestingly found viable faecal organisms. Samples of human faeces as they dried on the glacier are currently being processed to ascertain the level of kill which might be effected at Base Camp by fluctuating temperatures and intense UV light. Fresh yak faeces are currently being examined for the presence of protozoans. It may be that yak faeces are an important source of gastro-intestinal pathogens. The local populace use the faeces as fuel and to render buildings. Thus those same persons who cook meals for tourists habitually handle yak dung.

The area most in need of engineering (and scientific) help is undoubtedly the Kathmandu valley. The environmental damage being occasioned is enormous and only radical and expensive measures are likely to succeed in altering the situation. However, one single issue could save lives and misery and that is the provision of a safe drinking water supply. This is a simple technical engineering task but logistically and politically may well prove to be beyond the reach of the Nepalese.

Disposal of Human Waste

1 Current practice at Everest Base Camp

It is common practice for expeditions to provide no toilet facilities at all at Base Camp – people simply going behind rocks etc. The immediate consequence of this is that the camp becomes surrounded with small piles of excrement and toilet paper. This is unsightly, there is often a pervading

offensive smell, and it presents a significant health hazard to the camp occupants. In addition, precipitation and/or glacier melt results in some of the excrement being washed away and contaminating the surface water which flows down the glacier.

In some cases a latrine is provided which restricts the affected area – provided the camp occupants use the facility – which is unlikely unless it is well maintained. On striking camp the excrement is covered over with ice/rocks, which reduces the visual impact, but will not prevent continuation of runoff.

2 Alternatives

In the habitable regions it is common practice to use composting latrines – in which excrement is progressively covered with dried plant material, eg rhododendron leaves, which provide the carbon source and bulk to facilitate the composting process. These latrines are often sited beside fields to facilitate use of the compost as a manure. This is a good approach in the habitable areas where (i) the ambient environment is temperate and with adequate oxygen levels, allowing the composting process to take place, and (ii) there is a use for the compost close at hand. However, at Base Camp, where the greater altitude results in lower temperatures and oxygen levels, composting would be slow and this would be compounded by the relatively short stay of expeditions. The adverse conditions and short time available mean that adequate composting could not realistically be achieved. In addition, even if it were possible to produce compost, it would be necessary to transport it to a lower altitude if it were to be used in agriculture.

3 Drying

In many respects incineration is an attractive option. Provided it is carried out appropriately, it is a process which minimises the quantity of residue and potential hazard from pathogens. The main drawback is the high water content of excrement (typically 90%), requiring the use of auxiliary fuel to achieve satisfactory combustion. Alternatively, provided the excrement can be dried sufficiently, not only will fuel no longer be required, but it can become a source of fuel: dried animal dung is used as fuel in many countries, dried yak dung is used in Nepal, especially in the Sagarmatha National Park where it is no longer permitted to use wood for domestic fuel.

Even if it is not appropriate to carry out incineration (this is not permitted in the vicinity of Everest Base Camp for religious reasons), drying substantially reduces the bulk and weight of faeces, and makes it less offensive, making subsequent disposal more practicable.

4 Objectives of the research programme

Two processes were considered: (i) Probably the most obvious option is to dry the excrement in the sun – the method already used for drying animal dung. Drying at altitude should be assisted by the low air pressure, and by

stronger winds, but inhibited by lower temperatures. (ii) A second option is to use freezing and thawing. It is well established that the dewatering of sewage sludge is facilitated by freezing and then thawing – freezing appears to break the affinity of the sludge solids for the water, such that on thawing much of the water readily drains away. The ambient temperature at Base Camp tends to alternate between mild or even warm during the day and sub-zero at night (the rapid changes occurring because of the thin atmosphere). This could provide the means to freeze and then thaw the excrement. It was not known to what extent raw faeces (rather than sewage sludge) would dewater using a freeze-thaw cycle, nor how effectively this might be achieved using the ambient conditions at Base Camp.

As a second objective, recognising that incineration at Base Camp may not be permitted, it was decided to investigate the options for disposing of the dried material – preferably to identify a recycling agricultural use. Such a disposal method would also be suitable for compost.

5 Experimental method

Essentially it comprised a 0.5m square (0.25m square area) container, 100mm deep, open at the top, and with a mesh at the bottom which supported a filter cloth.

6 Results

The excrement was spread in the unit in a relatively thin layer, about 25mm to facilitate changes in temperature as well as to aid drying. After 60 hours (the shortest run) about 40% weight loss had occurred, and this increased to about 60% after 140 hours (the longest run). Almost all of the weight/water loss was due to evaporation. Some water was lost as filtrate, but only after the first night, and amounted to only 2-3% of the total weight.

When each run was stopped, the surface of the excrement appeared substantially dry, but on removing it from the unit it was found to be quite wet underneath, despite being spread in a thin layer. Clearly, drying would be expedited by turning the solids from time to time.

It is apparent from this that drying faeces at Base Camp (or similar environments) is a practical proposition, and that it should be dry enough for combustion without the use of auxiliary fuel within one week. This, however, is dependent on favourable weather conditions. As most of the drying was by evaporation rather than filtration, a simple open-ended box would be sufficient (or even just laying the excrement out on a flat surface), there seems little value in including a facility for filtration. Also, it seems more important to have good ventilation to allow water vapour to escape than to have a 'greenhouse' which achieves higher temperatures. It would of course be useful to be able to protect the drying material from rain and snow. Simple drying on rocks or plastic sheets may be the practical method for future expeditions prior to transport from Base Camp and incineration.

Summary: The British Mount Everest Medical Expedition put two climbers on the summit on 13 October 1994. Also, a group of over 30 doctors, physiologists and environmental scientists studied every aspect of human exposure to altitude, and the environmental impact of climbing and trekking in Nepal. 21 medical, physiological and environmental projects were undertaken and reported on.

CONTRIBUTORS:

Mr S Archibald
Prof G B Arden
Dr P Barry
Prof A Bird
Dr C Clark
Dr C J Collier
Dr D J Collier (Research Leader)
Dr S Currin (Expedition Leader)
Dr A Datta
Prof A Dayan
Ms D N Depla
Dr G Dubowitz
Dr F Fitzke
Prof R J Flower
Dr J France
Dr R S Frazer
Ms A M Fry
Mr M Giles
Dr C H Hogg
Ms K A Howard
Ms I Martin
Dr N P Mason
Dr J S Milledge (Research Adviser)
Dr M Mullen
Dr J Nathan
Dr A Nickol
Dr C O'Callaghan
Dr A Peacock
Dr A J Pollard (Deputy Leader)
Mr P F A Pollard
Dr R C Pollard
Dr M Rosenberg
Mr K Stewart (Environment Leader)
Prof E Swenson
Dr D Swift
Dr S Travis
Dr D Webb
Dr C Wolff

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the many individuals, firms and organisations who contributed to the success of this expedition and, in particular, to our patrons Lord Hunt, Sir Christian Bonington and Charles Clarke. We would also like to thank the 75 members of the 1994 British Mount Everest Medical Expedition for agreeing to be subjected to the research projects outlined above.

We acknowledge a debt of gratitude to Alison Hargreaves and her family who participated in several of these projects before and after her first attempt to climb Everest without oxygen. We shared Base Camp with Alison and also with Benoît Chamoux, Pierre Royer and Jeff Lakes; all four climbers have since died on 8000m peaks. We miss them all.