Regulation of radiation doses received during high altitude mountaineering expeditions

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Abstract: Radiation dose rates from cosmic radiation increase with altitude. Every year, numerous people spend significant amounts of time working on the ground at high altitude supporting mountaineering expeditions. The occupational radiation doses received by workers in this environment have not previously been measured.

The objective of this study was to measure radiation dose rates, at various altitudes that are occupationally accessed, using a range of radiation detectors to allow an assessment of occupational radiation doses for workers in this environment.

This paper presents the results of radiation dose rate measurements made during the pre-monsoon season of 2013 on Mount Everest and assesses the occupational dose received by various workers in this environment. Many workers receive a significant dose (i.e. about 1 millisievert) from their prolonged time working at high altitude. The majority of workers are unaware of the additional risk associated with their occupational radiation doses. The additional risk arising from this occupational radiation dose is low when compared to other acute risks in this hazardous working environment.

The regulatory context of radiation doses received at high altitude is discussed in relation to those occupationally exposed workers supporting mountaineering expeditions and recommendations for consideration by the International Commission on Radiological Protection (ICRP) are made to inform future international radiation protection regulation of radiation doses received at ground level at high altitudes.

KEYWORDS: Everest, radiation, dose, cosmic ray, high altitude, mountain guide, worker, Sherpa, member of the public, client, risk.

1. Introduction

Radiation dose rates from cosmic radiation increase with altitude. Cosmic radiation doses received when above ground level are included in the scope of the European Basic Safety Standard (BSS) [1] (i.e. applicable to aviation industry workers). High altitude mountaineering involves being present for prolonged periods of time at ground level at altitudes frequented by the aviation industry. The BSS does not apply to cosmic radiation doses received at ground level.

Sometimes individual members of the public participate in high altitude mountaineering expeditions as their own self-contained team. More commonly individuals enter into a contract with an expedition company to provide logistical support and to provide mountain guides to assist them achieve their high altitude mountaineering goals. Expedition companies either directly, or indirectly through other companies, employ personnel to support the delivery of the contracted expedition. The persons involved in the delivery of commercial expeditions are “High Altitude Workers”. The occupational radiation doses received by these workers has not previously been measured or estimated.

The objective of this study was to measure radiation dose rates, at various altitudes that are occupationally accessed on Mount Everest, to allow an assessment of occupational radiation doses for high altitude workers in this environment.

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2. High Altitude Workers

On Mount Everest, there are three distinct groups of High Altitude Worker employed on the mountain. These are mountain guides, mountaineering support staff and base camp staff.

The mountain guides are often directly employed by European, or other Western, expedition companies. The mountain guides on Everest do not guide paying clients up the mountain in the traditional sense of guiding. On Everest, expeditions are guide assisted meaning that the guide will assist clients to move safely on the mountain but are not with their clients at all times. The mountain guides usually have the same cosmic radiation exposure as their clients and make decisions about the itinerary adopted by their clients.

Expeditions on high altitude peaks such as Everest often require substantial numbers of mountaineering support staff to put in place the necessary arrangements on the mountain to allow the paying clients to have a relatively safe expedition. The mountaineering support staff are critical to the success or failure of an expedition. This group of workers spends significant periods of time at high altitude preparing a roped route to the summit of Everest, transferring supplies, oxygen and equipment to high camps before often acting as personal assistants for the summit push, then transferring remaining supplies and equipment back down the mountain after the summit attempt(s). This group of workers are very hard working and are often exposed to the greatest level of personal risk on the mountain.

With high altitude peaks such as Everest, the clients attempting to climb the mountain normally have three progressively higher rotations on the mountain to help acclimatise their bodies. Between rotations the clients will spend a significant amount of time at base camp relaxing, resting and recovering from their exertions higher up on the mountain and will track how their mountaineering support team are doing high on the mountain. Everest base camp is at about 5,200m altitude and the human body struggles to exist at this altitude. The clients are often made more comfortable at Everest Base Camp by being supported by cooks, kitchen staff and people ferrying supplies up to Base Camp.

All high altitude workers on the mountain play their part in whether an expedition is successful for their clients and all persons are exposed to elevated cosmic radiation doses.

It should be noted that the term “Sherpa” or “Sherpa-climber” is often heard as a term for the High Altitude Workers performing the mountaineering support staff roles. These workers often come from the area local to Everest however the term “Sherpa” or “Sherpa-climber” conflates a job description with an ethnicity that frustrates ethnic Sherpas who want to distinguish themselves from other ethnic groups performing this type of work. The Nepali government now promotes the term high altitude worker [2] and this paper uses this term.

3. Measurement of cosmic radiation doses on Everest

Mount Everest is 8,848m (29,029 ft) above sea level and is one of the most extreme environments on the planet. Temperatures can drop below -60°C and winds at ground level can exceed 200 mph. Air pressure at the summit is about a third of that at sea level.

Measurement of cosmic radiation at ground level in this extreme environment has never previously been performed. In order to perform measurements in this environment the parameters that required consideration were the:

- radiation field being measured
- weight of the detector
- temperature operation range of batteries
- battery life and recharging in the field capability
- physical operation of the detector
- dependence on the functionality of LCD screens
- detector operating temperature range
- detector operating pressure range.

A prototype of Mirion Technologies Instadose v2.0 direct ion storage device (set to record accrued dose every two hours) and the Tracerco T404 Personal Electronic Dosemeter (PED)

were selected as instruments to attempt to assess the varying radiation dose rates at different altitudes. It was known that these instruments could not detect all of the radiations present in this environment however by application of conversion factors determined from reference 3 it is possible to infer the total dose from the measured dose at different altitudes. Both of these detectors were carried and used on an expedition to climb Mount Everest in the pre-monsoon season of 2013.

Large daily temperature fluctuations are experienced on Everest particularly inside tents. The accrued dose results from the prototype Instadose v2.0 direct ion storage device were found to be influenced by the extreme temperature fluctuations and as such the results were not reliable. Testing of the prototype unit in this extreme environment has led to the supplier performing additional work to remove or reduce the impact of temperature fluctuations on the accrued doses measured in later versions of the unit.

The information outputs from the Tracerco T404 PED, which is a compensated Geiger Müller detector, was not noticeably temperature dependent and due to using a duty and standby detector arrangement it was possible to successfully log data every minute for the entire duration of an Everest expedition. The detectors were recharged when not in use using a solar panel.

4. Dose received by mountain guides

Mountain guides, along with their clients, undertake acclimatisation at increasing altitudes during their typical two month long expeditions. As a result at different stages of their expedition they are exposed to varying cosmic radiation dose rates.

Figure 1 below shows the variation in dose rate, as measured on the Tracerco T404 PED, during the 2013 Everest expedition and the annotation provides information on the activities being performed at different times.

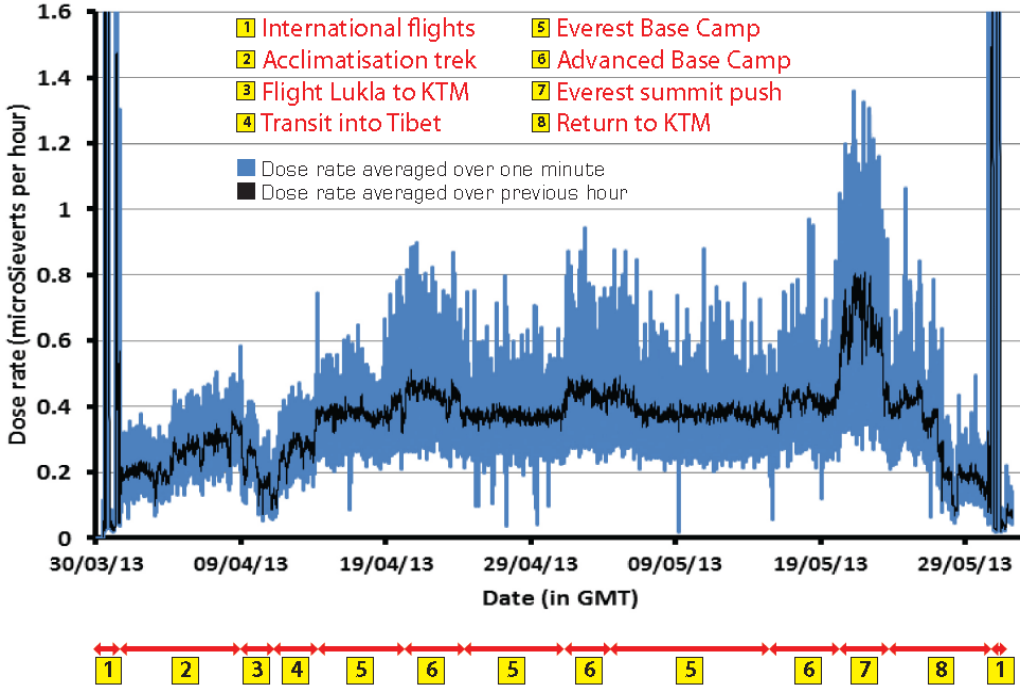

Figure 1: Dose rate measured on a Tracerco T404 PED during the 2013 Everest expedition.

Mountain guides, and their clients, are exposed to cosmic radiation and to natural radiation when not on expedition. Therefore the amount of radiation dose received by a mountain guide on a high altitude expedition is equal to the radiation dose received during travel to/from the expedition plus the radiation dose received whilst at ground level on expedition minus the radiation dose that would have been received if they had remained at home for the duration.

For the purposes of this assessment it is assumed that the mountain guide is from Scotland. Figure 2 illustrates the total dose accrued (from figure 1) and the total dose that would have been received if the mountain guide had been in Scotland for the duration of the expedition.

The additional dose detected by the Tracerco T404 PED, was of the order of 400 microsieverts for the two month long expedition. The Tracerco T404 PED does not detect all of the radiations that are present in this environment. If it is assumed that the instrument detected everything except neutrons and if it is assumed that an average altitude of 5,500m is occupied then 5/9ths of accrued dose comes from unassessed neutron dose then based on the total dose curves in reference 3 then the total additional radiation dose received by a typical Westerner mountain guide climbing Mount Everest is of the order of 1 millisievert. It should be noted that their clients, who are members of the public, are also receiving a similar amount of cosmic radiation dose.

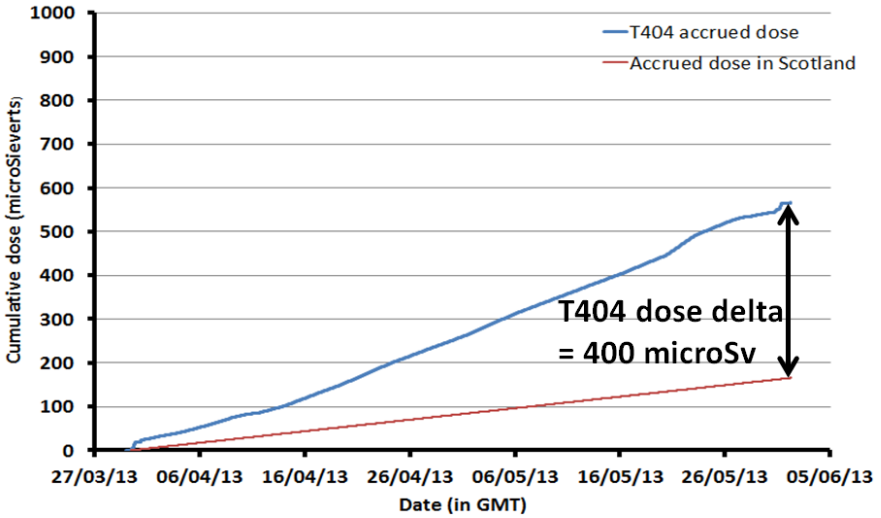

Figure 2: Typical mountain guide total dose accrual during the 2013 Everest expedition and the comparative dose that would have been received if they had not performed the work.

5. Dose received by mountaineering support staff

Mountaineering support staff tend to be supplied from within communities in proximity to the mountain being climbed. With Everest expeditions, it is common for Nepali citizens to perform the mountaineering support staff role. These individuals are often based in either Kathmandu or the Khumbu valley. These staff members are not subjected to elevated cosmic radiation doses during international flights to the country. For the purposes of this assessment, it has been assumed that the support staff originate from either Kathmandu (~1,400m altitude) or from the village of Namche Bazar (~3,400m) which is a mid-point elevation on route to Everest Base Camp.

It is assumed that within a few days of arrival at Everest Base Camp that the mountaineering support staff undertake their work of constructing camps, transporting equipment and supplies and rigging ropes to the top of Everest. Based on information gained during the 2013 expedition about the activities of these workers, it was possible to reconstruct their accrued doses based on measurements made whilst the detecting equipment was at the same locations. These workers spend considerable periods of time at high altitude and a reconstruction of their dose accrual is shown in figure 3 below. The mountaineering support workers accrued in the region of 600 microsieverts of radiation dose during the period of their involvement in the expedition as measured by the T404 PED. If they had not been involved then they would have accrued in the region of 250 to 370 microsieverts as measured by the T404 PED depending on whether they lived in Kathmandu or Namche Bazar respectively. Therefore the range in additional doses received are of the order of 230 to 350 microsieverts.

The Tracerco T404 PED does not detect all of the radiations that are present in this environment. If it is assumed that the instrument detected everything except neutrons and if it is assumed that an average altitude of 5,500m is occupied then 5/9ths of accrued dose comes from unassessed neutron dose based on total dose curves in reference 3 then the total additional radiation dose received by a typical mountaineering support worker on Mount Everest is of the order of 0.5 to 0.8 millisievert.

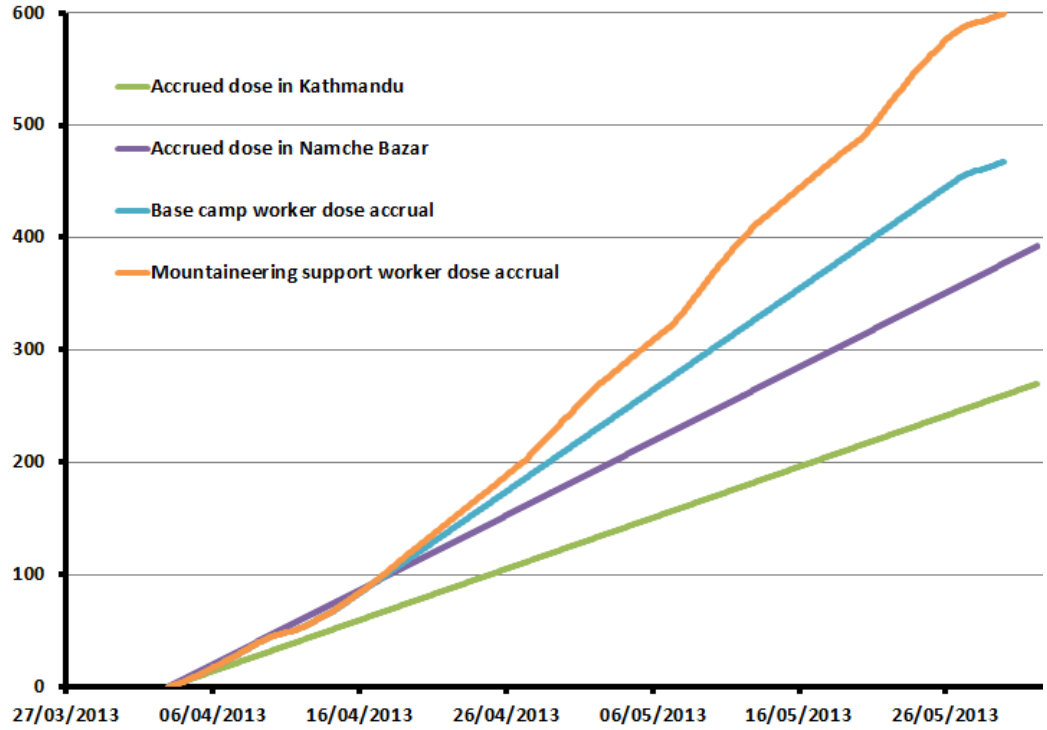

Figure 3: Typical mountaineering support worker and base camp worker total dose accrual during the 2013 Everest expedition and the comparative dose that would have been received if they had not performed the work by staying in Kathmandu or Namche Bazar.

6. Dose received by base camp staff

Base camp staff tend to be supplied from within communities in proximity to the mountain being climbed. With Everest expeditions, it is common for Nepali or Tibetan citizens to perform the base camp staff role. These individuals are also often based in either Kathmandu or the Khumbu valley. Upon arrival at base camp, these individuals tend to spend the majority of their time working at the same altitude until the expedition departs the mountain. Based on the information gained during the 2013 expedition about the activities of these workers, it was possible to reconstruct their accrued doses based on measurements made whilst the detecting equipment was at the same locations. A reconstruction of their dose accrual is shown in figure 3 above. The base camp staff accrued in the region of 465 microsieverts of radiation dose during the period of their involvement in the expedition as measured by the T404 PED. If they had not been involved then they would have accrued in the region of 250 to 370 microsieverts as measured by the T404 PED depending on whether they lived in Kathmandu or Namche Bazar respectively. Therefore the range in additional doses received are of the order of 100 to 220 microsieverts.

The Tracerco T404 PED does not detect all of the radiations that are present in this environment. If it is assumed that the instrument detected everything except neutrons and if it is assumed that an average altitude of 5,500m is occupied then 5/9ths of accrued dose comes from unassessed neutron dose based on total dose curves in reference 3 then the total additional radiation dose received by a typical base camp staff on Mount Everest is of the order of 0.22 to 0.5 millisieverts.

7. Discussion

The mountaineering support workers spend the greatest amount of time at extreme altitude and receive measurable radiation doses. Surprisingly, as the majority of mountaineering support workers live at altitudes higher than Western mountain guides, this means that the additional dose received working on Everest expeditions is not as significant for the support workers as it is for the Western mountain guides who live at low altitudes.

The above assessment has shown that the High Altitude Workers that receive the greatest additional dose as a result of their work are the Western mountain guides and their additional doses from cosmic radiation are of the order of 1 millisievert per Everest expedition.

The majority of high altitude workers are unaware of the additional risk associated with their occupational radiation doses.

The risk of death at some point in the future from 1 millisievert of additional radiation dose is of the order of 1 in 10,000. This dose must be kept in context as the overall risk of death on Mount Everest was 1 for every 28 successful assents at the end of 2013.

The European BSS [1] does not apply to cosmic radiation doses received at ground level. High altitude workers are often working at similar altitudes to those in the aviation industry. The BSS applies to cosmic radiation doses received in aviation. In the aviation industry if employees are likely to receive greater than 1 millisievert of dose per annum then records need to be kept and produced of their exposure to cosmic radiation. In the aviation industry it is also necessary to inform the workers of the health risks resulting from cosmic radiation doses received during their work. Consideration should be given to implementing similar arrangements for Western mountain guides operating at high altitude as it is possible for them to participate in multiple expeditions per annum and receive significant cosmic radiation doses.

8. Conclusions

The high altitude workers that receive the greatest additional occupational cosmic radiation dose on expeditions to Mount Everest are Western mountain guides. This group of workers receive about 1 millisievert of additional dose from cosmic radiation per expedition. It should be noted that their clients, who are members of the public paying companies to provide these expeditions, are also receiving these additional doses.

It is possible for high altitude workers, and their clients, to participate in multiple expeditions per annum and receive significant additional cosmic radiation doses.

Most high altitude workers and their clients are unaware of being exposed to cosmic radiations. Expedition companies are not breaching current legislation in relation to the cosmic radiation doses being received by their employees and clients.

Consideration should be given in future recommendations from the International Commission on Radiological Protection (ICRP) to aligning the recommendations for exposure to cosmic radiation at high altitude ground level with the requirements that currently exist on employers of personnel working in the aviation industry.

References

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[2] Buried in the Sky by Peter Zuckerman and Amanda Padoan, ISBN 978-0-393-34541-4.
[3] Journal of the ICRU, Volume 10, No 2, 2010. ICRU Report 84: Reference Data for the Validation of Doses from Cosmic-Radiation Exposure of Aircraft Crew. ISSN 1473-6691.