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THE USE OF THALLIUM AS A RADIOACTIVE SOURCE IN AUTORADIOGRAPHIC DEVICES FOR PENGUINS AT SEA

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Abstract.—Recently developed remote sensing devices have provided information on behavior of penguins at sea. We describe the use of thallium in autoradiographic devices that record the speed and distance travelled and may be used in remote areas or over extended periods of at least 24 d.

EL USO DE TALIO COMO FUENTE RADIOACTIVA EN APARATOS AUTORADIOGRÁFICOS PARA RASTREAR PINGUINOS EN EL OCÉANO

Resumen.—Los aparatos de rastreo remoto desarrollados recientemente han provisto información sobre el comportamiento de los pinguinos en el océano. Se describe el uso de talio en aparatos autoradiográficos para determinar la velocidad y distancia recorrida por los pinguinos y que podría utilizarse por períodos de por lo menos 24 días.

The difficulty of observing penguins at sea has precipitated the development of new radiotelemetry techniques (Trivelpiece, Bengtson, Trivelpiece, and Volkman, Auk 103:777–781, 1986) and remote sensing devices (Wilson and Bain, J. Wildl. Manage. 48:1077–1084, 1984a; 48: 1360–1364, 1984b) for studying their behavior at sea. The remote sensing devices of Wilson and Bain record data autoradiographically. Recently, one such device has been used to estimate foraging ranges of two species of penguins at sub-Antarctic Marion Island (46°52′S, 37°51′E) (Brown, J. Field Ornithol. 58:118–125, 1987). We describe a modification that may be useful in such remote areas.

Autoradiographic devices work on the principle of ionizing radiation from a point source, fixed on the indicator of the gauge, exposing film immediately adjacent to this source. Previously, the radioactive source used was phosphorus 32 (^{32}P), a pure beta emitter (E_{max}1.71 MeV) with a half-life of 14.3 d, in the form of the insoluble salt barium orthophosphate. The optical density of blackening of the film can be used to calculate the exposure time and the location of blackening can be used to determine the magnitude of the parameter being measured, e.g., speed.

For a film response (optical density of blackening) that is linearly

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related to the irradiation dose, the error incurred due to exposure sometime during a known wearing period of X half-lives is approximately:

$$100Ae^{-0.69x}/A\%$$

where A is the activity of the isotope when the device was first put on the bird. Radioactive decay from such an isotope will result in large errors if measurements are made over a significant proportion of the isotope half-life. Moreover, the half-life limits the storage life of the source prior to deployment, that is, for a short half-life there is a limited period over which the bead is viable for field use. We suggest the use of thallium 204 (^{204}Tl) as an alternative isotope in situations where devices may be worn for long periods of time or fresh supplies of ^{32}P are not readily available. ^{204}Tl fulfills the requirements of a suitable radioactive source for autoradiography, having both pure beta emission (E_{max}0.77 MeV, with associated mercury X-rays of 0.7% occurrence) and a high specific activity, but a half-life of 3.8 yr.

The radioisotope was obtained in the form of thallium sulphate ($TlSO_4$) in 0.5 m H_2SO_4 with an activity better than 1 microcurie per milligram (μCi mg^{-1}: 3.7×10^4 radioactive disintegrations per second per milligram) (supplier: Amersham International Ltd., Amersham, Buckinghamshire, U.K.). We precipitated thallium iodide (solubility at 20 C: 0.0006 mg $cm^3 \times 10^2$) by adding potassium iodide. We prepared beads by dipping the tip of a fine glass rod into epoxy glue (Wilson and Bain 1984a). This in turn was dipped into the dried thallium iodide. A further application of glue was used to seal the radioactive salt. Once dry the tip was coated with polyurethane and the glass rod broken off flush with the surface of the bead. By maintaining the glass rod in a vertical position while drying, the bead attained a spherical shape.

The radioisotope was field tested on speedmeters (Wilson and Bain 1984b) consisting of the radioactive bead mounted in wax on a bung attached to a spring and encased in a cylindrical tube. A lightproof, waterproof plastic sachet, containing a strip of X-ray sensitive film, taped along the length of the tube recorded the position of the bead at various speeds (Wilson and Bain 1984b). The accuracy of time-based data is critically dependent on film to bead separation (Wilson and Bain 1984a). This is particularly the case with ^{204}Tl because of its lower energy radiation relative to ^{32}P. It is therefore important to insure the X-ray film is placed as close as possible to the radioisotope and that the bead to film distance is kept constant.

We attached four speedmeters to the dorsal feathers of Gentoo Penguins *Pygoscelis papua* resident at Marion Island using hose clamps and recovered the birds when they returned after foraging. The results from one field trial indicated that a nonbreeding Gentoo Penguin travelled for 18 h at 8.0 km/h, covering a total of 144 km (for trace analysis techniques see Wilson and Bain 1984a,b). The speedmeter was on the penguin for a total of 24 d, the bead having been fabricated 7 mo previously. The maximum error due to decay during the time the meter was on the bird was 1.2% (assuming the unlikely event of all travelling taking place at the end of the wearing period), far less than the 70% error that would have occurred using ^{32}P. Moreover, after 7 mo the activity of ^{204}Tl was reduced by only 10% of the original activity, whereas the activity of ^{32}P would have been reduced by 99.997% over the same period and probably would not have been usable. Activity loss due to leaching while the device is in water may be a consideration when used in depth gauges (see Wilson and Bain 1984a) and additional tests should be conducted to determine the extent of this. However, radioactive beads used in speedmeters are encased in wax and the problem does not arise here.

Activities of individual beads are low and, in view of the low beta energy, constitute a very minor health hazard; an unshielded 3.7 kilobecquerel ^{204}Tl source (kBq: one thousand radioactive disintegrations per second) results in a dose rate of less than 6 microgray per hour ($\mu Gy \cdot h^{-1}$: energy absorbed in microjoules per unit mass of absorber in kilograms per hour) at a depth of 5 mm in tissue (Birkoff, *in* K. Z. Morgan and J. E. Turner, eds. Principles of radiation protection. J. Wiley & Sons, New York, 1967). This is less than the 18 $\mu Gy \cdot h^{-1}$ for an equivalent ^{32}P source. The total dose received will of course be greater for the longer wearing period. However, in practice the shielding provided by the device and water layer will considerably reduce the dose to the skin from the beta radiation but as an added precaution a thin (~0.1 mm) layer of copper foil may be inserted between the device and the bird.

The remoteness and consequent difficulty of obtaining regular supplies at isolated sites such as Marion Island and the potential for leaving autoradiographic devices attached for extended periods (e.g., the chick-rearing period) make the use of a radioisotope with the extended half-life of ^{204}Tl particularly appropriate.

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