From Athletes to Ecosystems: Environmental Risks of Sports Drugs

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RESEARCH BACKGROUND AND RATIONALE:

The use of performance-enhancing drugs in sports has long been recognized as a serious social issue (Altman, 2025). Various synthetic drugs and hormonal agents, administered to enhance athletic performance, not only pose significant health risks to individual athletes but also undermine the fundamental value of fair competition (Wei & Wang, 2023). Nevertheless, despite these enhanced measures, the clandestine use of performance-enhancing drugs persists. Particularly in winter sports, which take place at high altitudes and under specific environmental conditions, research on the patterns of drug usage and their potential ecological consequences remains limited.

Previous studies have largely focused on the physiological effects of performance-enhancing agents on humans, the development of detection techniques, and their pharmacokinetics (Thevis et al., 2025; Watson et al., 2022). However, little is known about how these substances are transformed within specific sport environments such as ski resorts, or how they affect the biotic components of the ecosystems (Kumar et al., 2025).

RESEARCH QUESTIONS OR OBJECTIVES:

Ski resorts, during thawing periods, accumulate snow rapidly, which has a direct impact on the surrounding ecosystems. Under such conditions, performance-enhancing drugs derived from human excreta, medical waste, or illicit disposal could accumulate in snow and soil, only to be released abruptly during thawing.

To evaluate the ecological and environmental risks of performance-enhancing drugs (PEDs), I constructed a ski-resort snowmelt model. I also assessed the leaching, bioaccumulation potential, and biological effects of furosemide and testosterone.

RESEARCH METHODOLOGY:

1. Construction of a Ski resort model for Drug Exposure Assessment.

To stimulate drug exposure in a ski resort environment, a laboratory-scale model system was constructed. A rectangular transparent plastic container was used as the framework, with the bottom uniformly packed with a soil layer and the upper section overlaid with ice to mimic artificial snow.

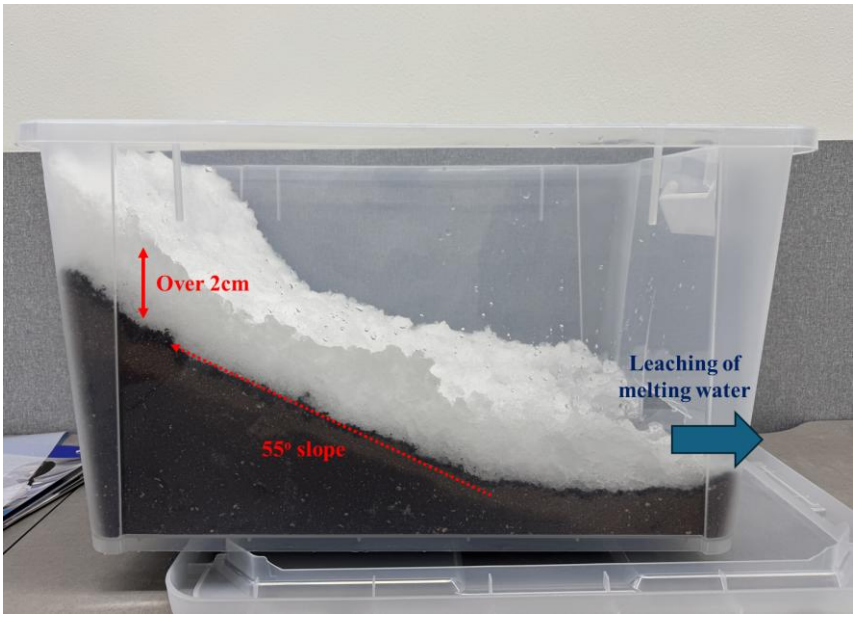

Figure 1. A laboratory-scale ski slope model incorporating soil and artificial snow layers for drug exposure analysis.

2. Material

The representative drugs used in this study were furosemide and testosterone, both purchased from Sigma-Aldrich (USA). All chemicals used for solvent preparation in the HPLC analysis of furosemide and testosterone were of HPLC grade and obtained from Sigma-Aldrich (USA).

3. Drug Exposure Experiment Using the Ski Resort Model

Drug exposure experiments were conducted using the constructed ski resort model. The representative drugs, furosemide and testosterone, were prepared at concentrations of 10 mg/L*day and applied continuously for seven days using a spray. This approach was designed to simulate the accumulation of human excreta or illegally disposed substances within the snowpack of an actual ski resort.

4. Evaluation of the Effects of Drug Exposure on Daphnia magna

Twenty individuals of Daphnia magna were cultured in 2 L of M4 medium in glass beakers (Hu et al., 2018), following the OECD guideline No. 211 at 20 ± 1 °C under a 16:8 h light:dark photoperiod. The acute toxicity test was conducted in accordance with OECD Guideline No. 202. For each replicate (n=5, five neonates (< 24 h old) were exposed to 10 mL of test solution for 48 h. Test solutions contained furosemide and testosterone at concentrations corresponding to the final levels detected in the leachate analysis.

5. Evaluation of the Effects of Drug Exposure on Euglena

The Euglena strain was cultivated under phototrophic conditions using modified Hutner's medium. Cells were exposed for seven days to furosemide and testosterone at the final concentrations determined in the leachate analysis.

EXPECTED RESULTS OR IMPACT:

This study employs a ski-resort snowmelt model to integrate assessments of leaching, bioavailability, and ecological effects of doping-related compounds. The two test substances display distinctly different environmental behaviors and toxicological profiles. Using leachate-derived exposures for seven days, Euglena exhibits treatment-dependent growth inhibition: cell density, dry weight, and chlorophyll-a dramatically decrease (testosterone), and elicited pronounced chronic immobilization in Daphnia magna. The diuretic exhibits indications of delayed impacts plausibly mediated by matrix sorption and localized persistence.

This indicates that PED residues can impair both primary producers and primary consumers, even after excretion and transport via meltwater and surface flows. This result shows that avoiding such substances is not only an ethical obligation to preserve fair competition and safeguard athlete health, but also an environmental imperative.

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