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Seasonal distribution of mercury and methylmercury at the closed Berg Aukas mine, Namibia

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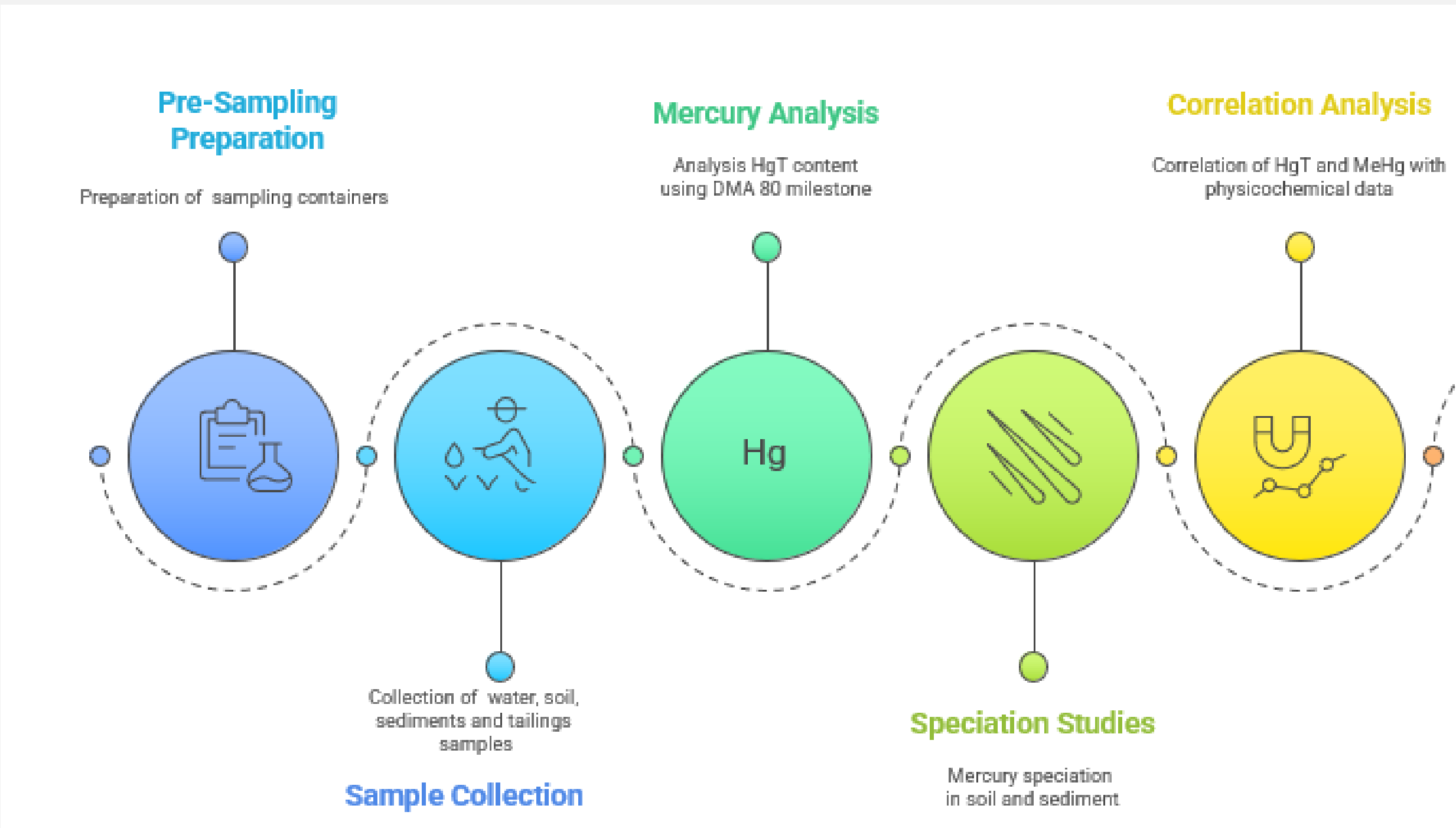
ABSTRACT

This study examined seasonal distribution, speciation, and behaviour of mercury (Hg) at Berg Aukas, an abandoned Pb–Zn–V mine in Namibia. A total of 146 samples of water, soil, sediment, and tailings were collected during wet and dry seasons. Total mercury (HgT) and methylmercury (MeHg) were analysed with a DMA 80, while environmental parameters (EC, TDS, ORP, pH) were measured *in situ*. Anions were quantified by ion chromatography, and Hg in soils and tailings was extracted using the BCR sequential extraction procedure. Tailings contained higher HgT (1.64 mg/kg dry season; 2.34 mg/kg wet season) compared to soils (0.803 mg/kg dry season; 0.858 mg/kg wet season). MeHg ranged from 0.006–1.14 mg/kg, with elevated concentrations recorded in the dry season. Water contained no detectable Hg in the wet season, but up to 0.013 mg/kg in the dry season. Most Hg occurred in the residual fraction (98.9%), with slightly more labile forms under wet conditions. Findings highlight seasonal controls on Hg mobility, methylation, and risk in post-mining landscapes.

INTRODUCTION

- Mercury (Hg) is a persistent toxic metal of global concern due to its volatility, bioaccumulation, and transformation into methylmercury (MeHg)—its most harmful form
- MeHg readily accumulates in food chains, posing risks to human and ecological health
- Mining activities, particularly for Pb, Zn, and V, are major Hg sources. Even long after closure, abandoned mines release Hg via tailings, drainage, and soils
- In regions with wet/dry cycles, rainfall remobilises Hg from soils and tailings, increasing runoff to water bodies
- Seasonal hydrological and biogeochemical changes (redox, organic matter, microbial activity) also control Hg methylation to MeHg
- The Berg Aukas mine (Namibia), closed in 1979, but remains a legacy pollution hotspot
- Research on Hg/MeHg dynamics, especially seasonal variations, is limited here
- Objectives:**
 - To determine Hg and MeHg levels in water, soil, sediments and tailings during wet/dry seasons
 - To assess how physicochemical parameters (pH, ORP, conductivity, SO_4^{2-} , S^{2-}) influence Hg speciation

RESEARCH METHODS



RESULTS AND DISCUSSION

1. Total Mercury and Methylmercury Analysis

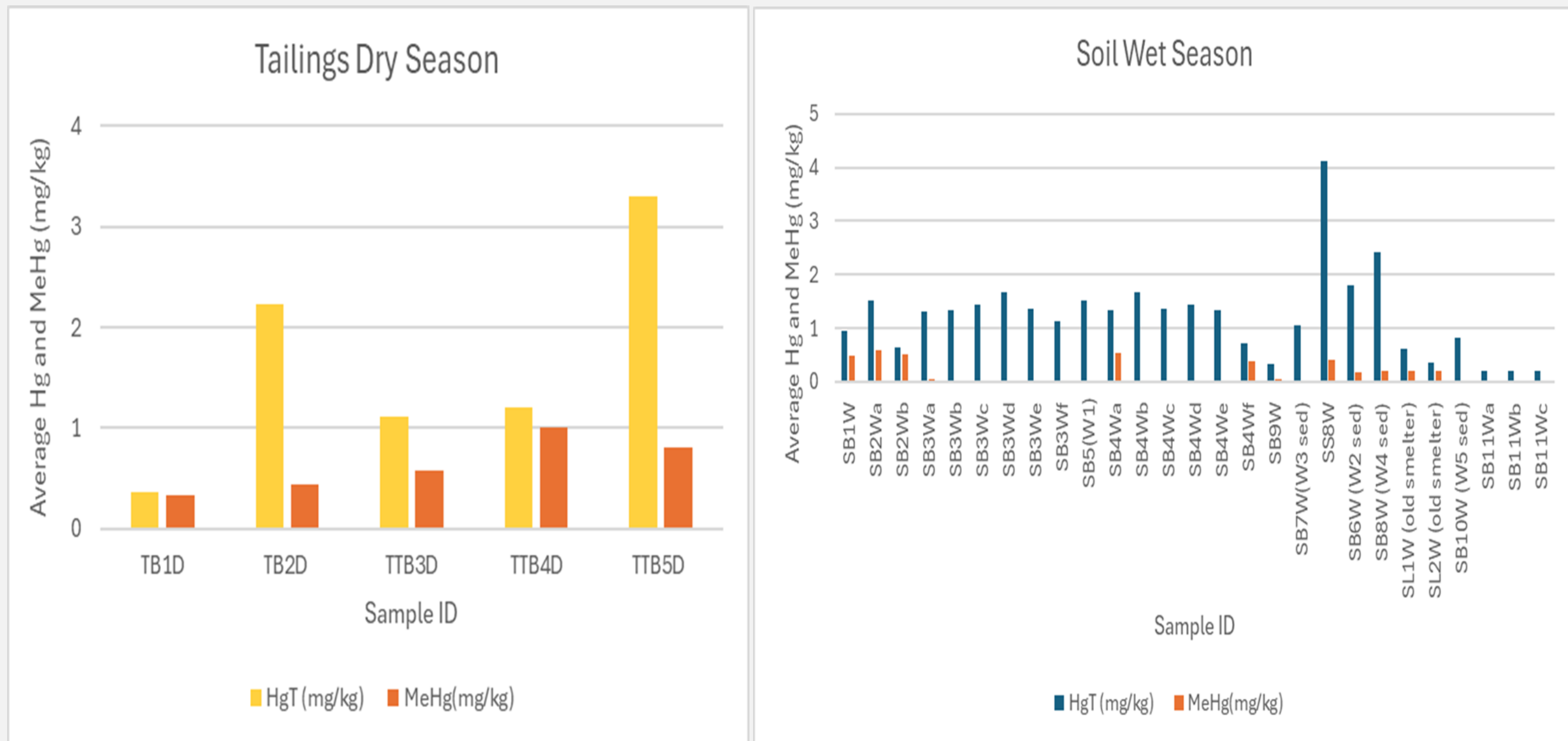


Figure 1: Total mercury and methylmercury

Dry season

- HgT: 0.205–3.30 mg/kg (highest in tailings, 3.30 mg/kg)
- MeHg: 0.03–1.01 mg/kg
- High %MeHg: SB1Da 95.8%, TB1D 90.8%
- Sediment hotspot: WB3 Sed – HgT 1.71 mg/kg, MeHg 1.14 mg/kg (66.2%) → aquatic-linked methylation

Wet season

- HgT: 0.20–4.13 mg/kg (highest at SS8W, 4.13 mg/kg)
- MeHg: 0.006–0.58 mg/kg (peak at SB2Wa, 0.58 mg/kg)
- Elevated %MeHg hotspots: SB2Wb 80.2%, SL2W 57.3%, SB4Wf 51.9%

2. Mercury Speciation

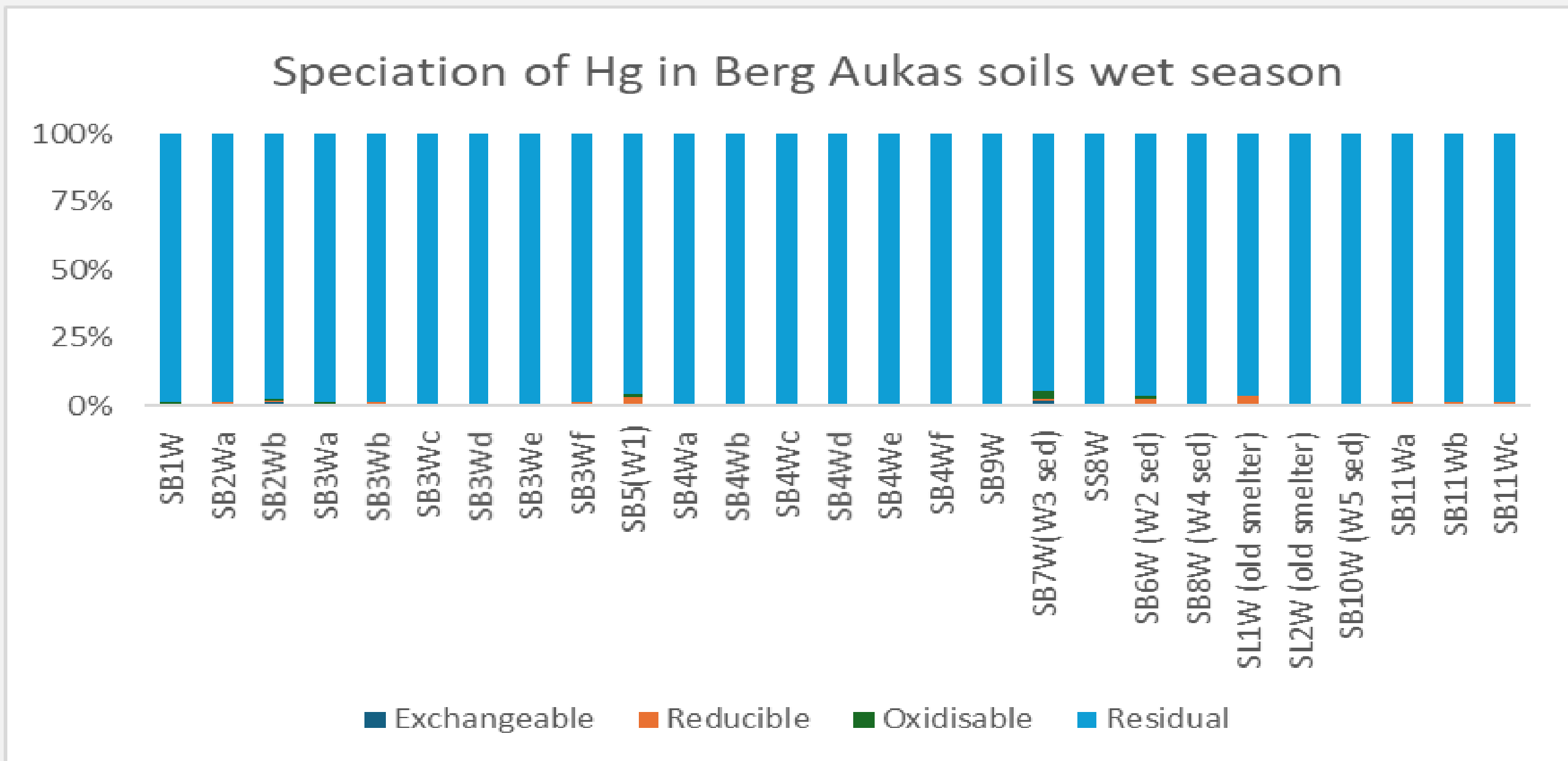


Figure 2: Speciation of Hg in soils in the wet season

- Residual Hg dominated both seasons (>90%), largely immobile.
- Non-residual fractions <0.05 mg/kg, low bioavailability.
- Exceptions:SB3Dc (dry season): higher reducible Hg (0.0336 mg/kg) → Fe/Mn oxide-bound.
- SB7W (wet season): higher exchangeable (0.0183) & oxidisable (0.0311 mg/kg).

3. Correlation Analysis

	HgT	MeHg	pH	ORP	Ec	TDS	Temp	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻
HgT	1									
MeHg	.457*	1								
pH	.139	.137	1							
ORP	-.042	.194	.735**	1						
Ec	-.252	-.024	-.759**	-.477**	1					
TDS	-.259	-.040	-.756**	-.476**	.998**	1				
Temp	.366*	.017	-.036	-.189	-.214	-.199	1			
Cl ⁻	-.733**	-.405	.436	-.690*	-.300	-.270	-.372	1		
SO ₄ ²⁻	.286	.611**	.103	.193	-.047	-.054	-.026	-.584*	1	
NO ₃ ⁻	-.034	.389*	-.223	.148	.364*	.352	-.132	-.590*	.565**	1

Figure 3: Correlation analysis of HgTand MeHg with physicochemical parameters during dry season

Dry season

- HgT positively correlated with temperature ($r = 0.366$, $p < 0.05$)
- MeHg positively correlated with SO_4^{2-} ($r = 0.611$, $p < 0.01$) and NO_3^- ($r = 0.389$, $p < 0.05$)
- HgT vs MeHg: moderate positive correlation ($r=0.457$, $p < 0.05$)
- Seasonal trend: stronger MeHg–anion associations in dry season → enhanced microbial methylation

Wet season

- HgT vs MeHg: weak correlation ($r = 0.04$)
- MeHg: no strong associations with geochemical parameters
- EC, TDS, ORP: strongly intercorrelated (EC–TDS: $r = 0.994$)

CONCLUSIONS

- This study showed that mercury contamination at Berg Aukas is seasonally dynamic, with dry season conditions favouring higher detection of HgT and stronger MeHg associations with redox-sensitive ions
- Speciation results confirm that most Hg is locked in mineral-bound residual phases, reducing short-term mobility but posing long-term release risks
- Seasonal hydrology plays a key role in controlling mercury distribution, mobility, and methylation potential, emphasising the need for continuous monitoring under changing environmental conditions.

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