Contamination mapping and land use categorization for Tsumeb, Namibia

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Abstract: Tsumeb, located in the central northern part of Namibia has a long history of mining and smelting copper ores, dating back to the early 1900s. These activities have created a legacy of contamination in and around the town, which prompted the Namibian government to initiate various studies to establish levels of contamination and identify areas affected. It was found that the general distribution of Arsenic and other toxic metals in Tsumeb soils is higher closer to the smelter, trending towards the northwestern side of the smelter facility and Tsumeb Town. Recommendations were given to the Tsumeb Town Council to direct residential development to the southern and southwestern areas, where contamination does not reach critical levels, and to discontinue agricultural activities near the smelter, especially in the areas towards the northwest of this industrial complex. Building on these earlier investigations, the aim of the current project was to provide land use category maps, which will guide future development in and around Tsumeb.

Keywords: Heavy metals; Land use categorization; Soil contamination; Environment; Tsumeb, Namibia

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Introduction

Tsumeb, located in the northern central part of Namibia, has a long history of mining and smelting copper ores, dating back to the early 1900s. Smelting activities in this town created a legacy of contamination affecting the soil quality of the town and surrounding areas. Contamination was confirmed by the Geological Survey of Namibia (GSN) during the soil contamination mapping campaigns conducted between 2005 and 2011, which indicated high levels of arsenic and other heavy metals mainly on the northern side of the town.

In September 2012, the Division of Engineering and Environmental Geology under a project led by the Ministry of Environment and Tourism (MET), investigated health and environmental effects caused by the Namibian Custom Smelter. A geochemical soil survey aimed at mapping contamination levels was conducted, and land use categorization maps produced from the findings. The latter are to be used in guiding further developments in and around the town.

History of copper smelting at Tsumeb

In 1907 two Pb-Cu blast furnaces were built in Tsumeb by the Otavi Minen- und Eisenbahn-Gesellschaft (OMEG) to smelt local ores (Fig. 1). Later, in 1963, new Cu-Pb smelters were built, and in the early 1980s a slag mill was added to the complex to re-process old Cu reverbatory slag. The first ores to be processed were the carbonate ores from the upper part of the Tsumeb ore body, but later sulfide ores from deeper levels of the ore body, consisting mainly of chalcocite, enargite, galena and sphalerite, were processed. Currently the Tsumeb smelter is still in full operation with concentrates imported from Bulgaria, Chile, Peru, Greece, Zambia and South Africa (Kaira, 2009).

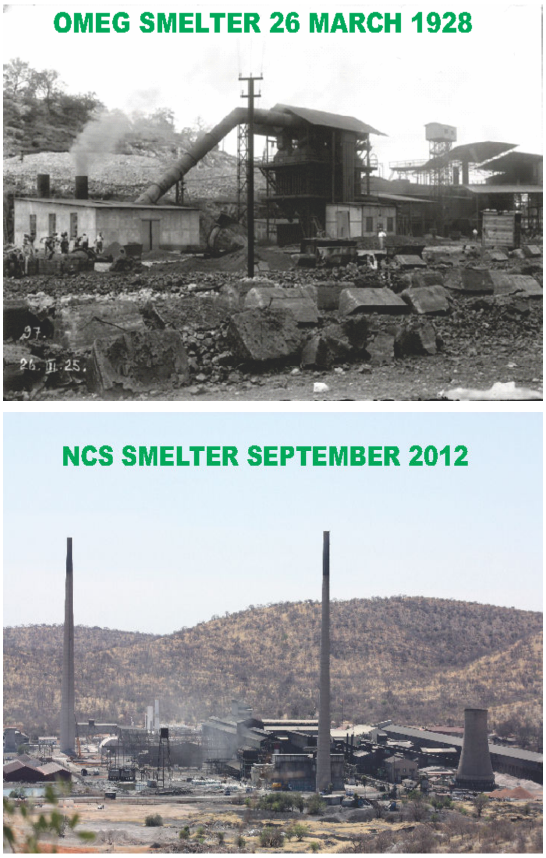

Figure 1. Tsumeb Smelters in 1928 and 2012

Geology

Tsumeb is located on the edge of the Otavi Mountainland, the major part of the current urban area being underlain by deeply weathered arkosic sandstone and shale of the Tschudi Formation (Mulden Group) and carbonate rocks of the Hüttenberg Formation (Tsumeb Subgroup; Fig. 2). The dolomites and limestones of the latter are in some places heavily fractured due to faulting, which caused deep karstification (Miller, 1983). The overlying Tschudi Formation consists of up to 1,600 m of well-cemented arkose and feldspathic sandstone with minor basal greywacke. The sedimentary rocks of the Tschudi and Hüttenberg formations host the base metal mineralisation in the Tsumeb area (Miller, 1983).

Previous work

Work previously conducted in the Tsumeb area by GSN and partner institutions includes three reports:

1) Geochemical investigation of soils in the area of the proposed town extensions Nomtsoub 6 and 7 (Geological Survey of Namibia, 2006a)
Soil samples were taken to determine the extent of dust fall-out in the proposed settlement. The analyses showed varying but generally high contaminations of As, Cd, Cu and Pb exceeding by far international standards for soil in residential areas. For example, As-concentrations exceeded guideline values by two to four times in the east of both proposed extensions and three times in the northwest of Extension 7. Due to the generally high contamination of the soil, the report recommended that most of the proposed Extension 7 should be definitely excluded for residential purposes, and a detailed mapping of the soil quality was proposed to determine which parts of the proposed Town

Extension 6 are suitable for development as residential areas.

2) Mapping of soil contamination (Geological Survey of Namibia, 2006b)

The highest contamination was found in the northern parts of Tsumeb, the concentration of contaminants in the soil increasing towards the smelter. Also contributing to soil contamination is the local morphology, which controls the sedimentation of dust emitted from the smelter. A recommendation was made to exclude the northern part of the Tsumeb-Nomtsoub area from development for residential purposes and agricultural use.

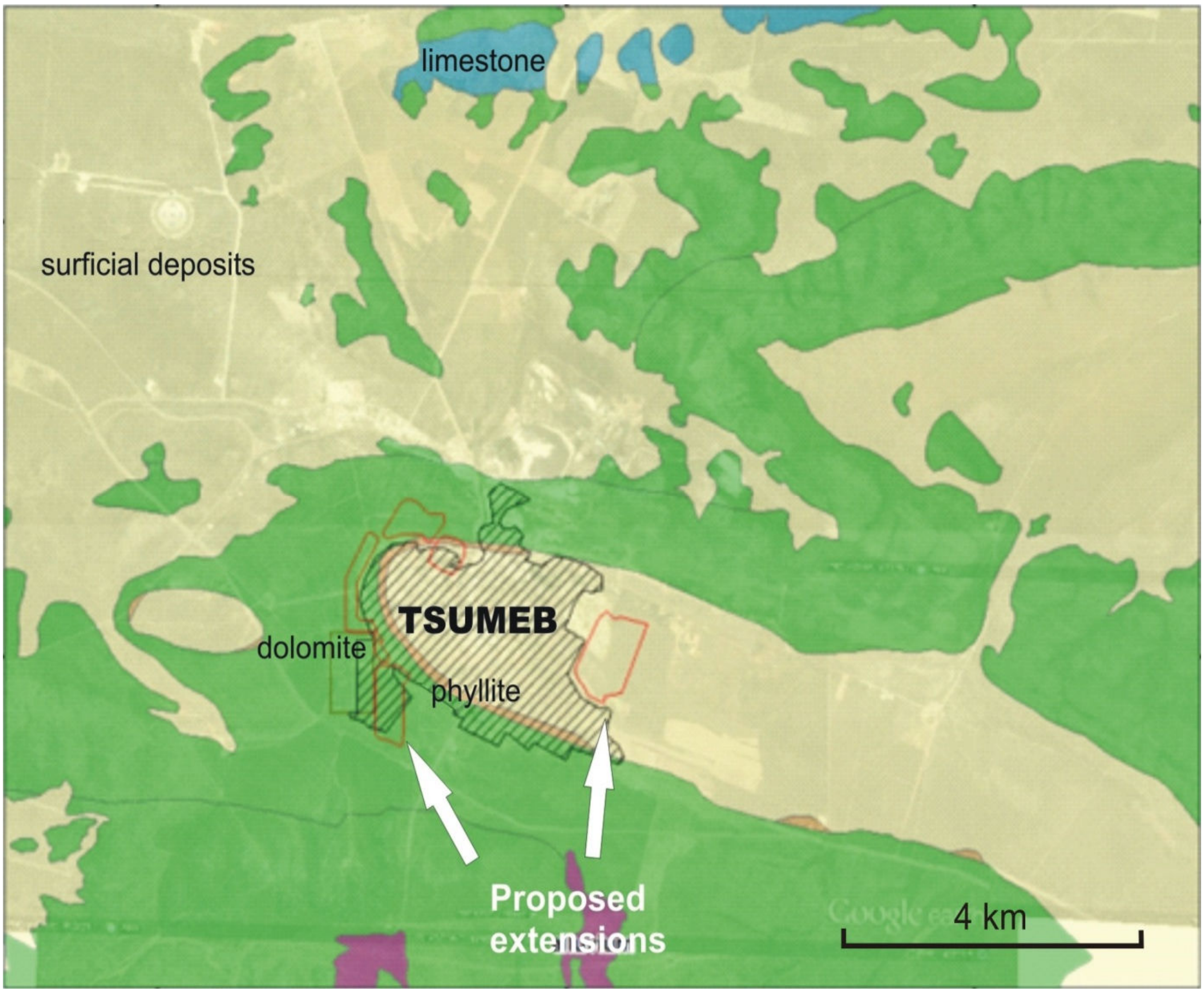

Figure 2. Geology of Tsumeb and surrounding areas overlain on Google Earth satellite image.

3) Investigation of vegetative material for heavy metal contamination in the surroundings of the Tsumeb Smelter Complex (Geological Survey of Namibia, 2007)

The contamination of topsoils and crops traces back to both old and recent smelter emissions as well as to windborne dust derived from the tailings and slag dumps of the smelter complex. The concentrations of arsenic, lead and cadmium in most of the fruits and vegetables (marula fruit, pumpkin, chilli and tomato) correlate with the heavy metal values of the underlying contaminated topsoils.

Sampling and Analysis

In 2011, additional samples were collected from areas not previously covered by GSN and the Ministry of Environment and Tourism's (MET) contracted specialist Dr J. Masinja. A few samples were also obtained from areas already sampled, in order to validate older contamination data. A total of 51 topsoil samples (0-10 cm depth) were collected from areas such as the proposed Nomtsoub Extensions 6 and 7 to the northeast of the town, the industrial area, the Kuvukiland informal settlement southwest of the town and the surrounding Townlands (Fig. 3). Analyses of the soil samples were carried out by Analytical Laboratory Services (ALS) in South Africa, using HF-HNO_3-$HClO_4$ acid digestion, HCl leach, ICP-AES and ICP-MS analytical methods.

Figure 3. Sampling in the informal settlement area of Tsumeb.

Contamination distribution

Heavy metals and other contaminants, e.g. SO_2, have been emitted from the smelter since its inception. These spread into the environment as solid and gaseous emissions, which extend over a large area to the west and northwest of the smelter (Fig. 4) a fact that was also noted in the studies conducted by GEO-Consult (1996) indicating an area of approximately 20 km^2.

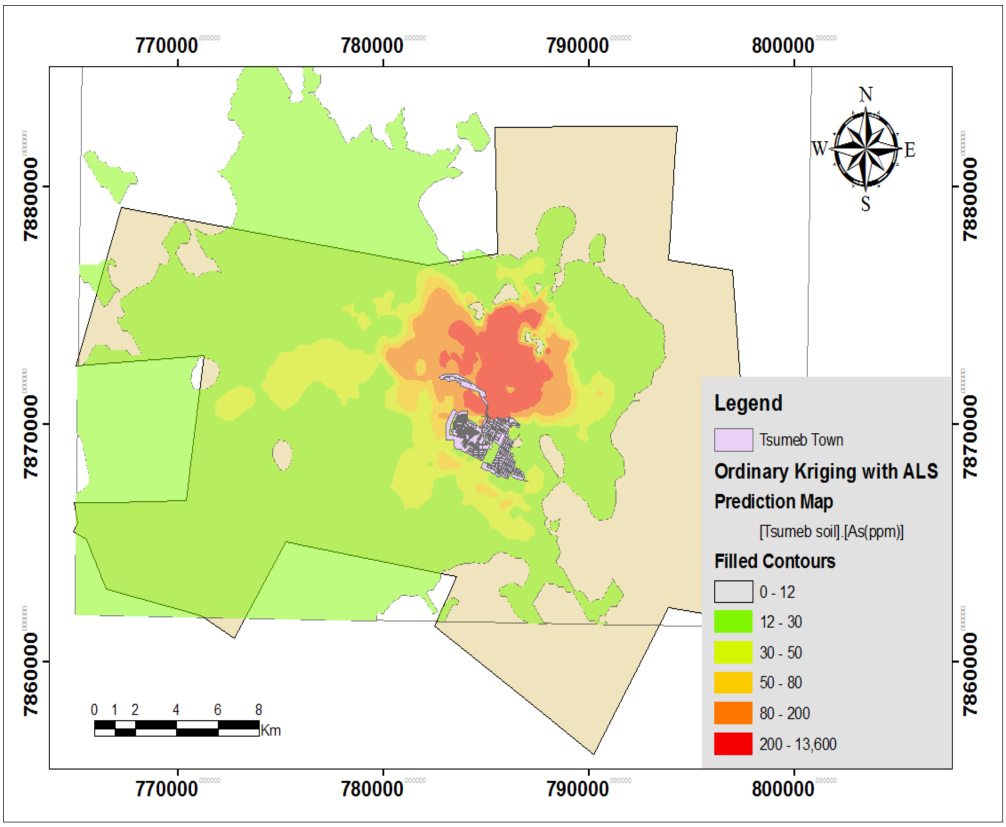

Figure 4. Arsenic contamination plume showing a north-westerly trend.

Land use Categorization

In the absence of local Soil Guideline Values, Australian and New Zealand Guidelines for heavy metals in soil were used for categorizing the land for various purposes (Table 1).

Table 1. Australian and New Zealand Soil Guideline Values.

Landuse	Soil Guideline Values for Heavy Metals (Australia and New Zealand) mg/kg (NEPC, 1999)					
	As	Cd	Cu	Pb	Ni	Zn
Residential	100	20	1000	300	600	7000
Agri/ Allotment	200	40	2000	600	600	
Commercial	500	100	5000	1500	3000	35000

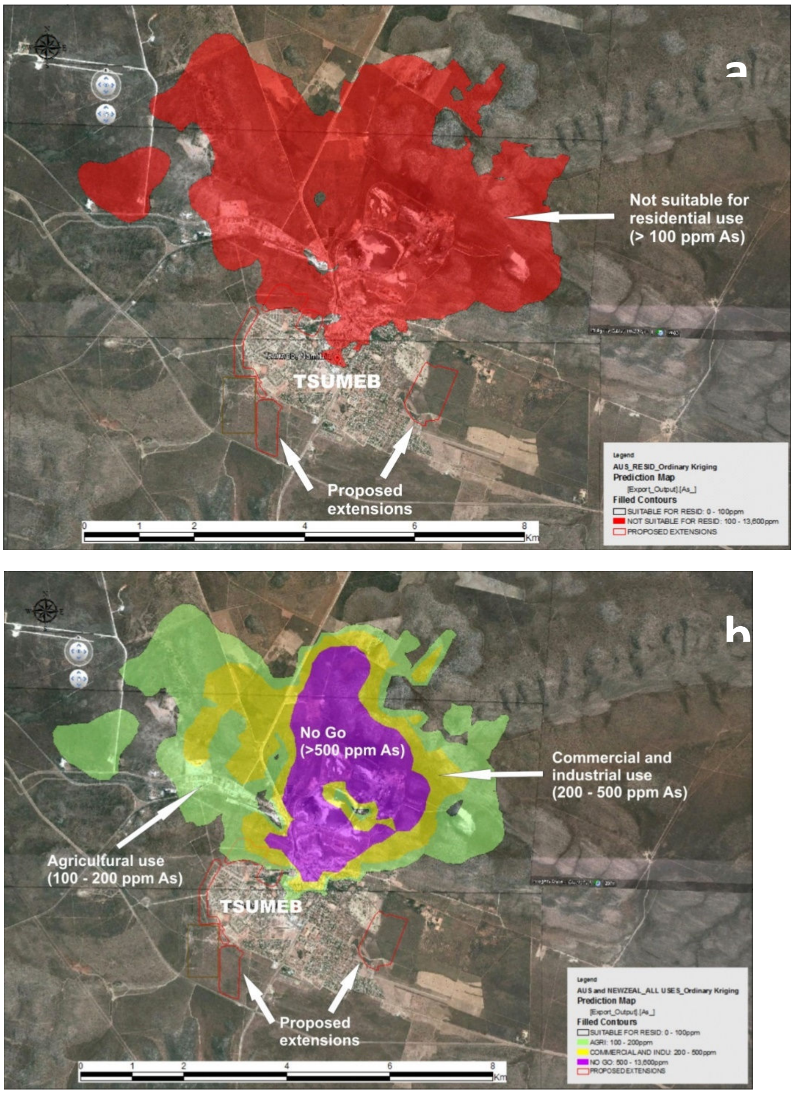

Figure 5. Land use categorization at Tsumeb (A) highlighting arsenic (As) as a contaminant; (B)

Findings by the Geological Survey of Namibia showed As concentrations as high as 13,600 ppm in areas closest to the smelter. Apart from As, other toxic elements such as Pb, Cu, Cd and Zn were found to exhibit similar contamination trends within the town and surrounding townlands. To interpolate surface sampling data the geostatistical technique of Kriging (ESRI-ARCGIS, 2010) was used. The resulting land use categorization maps highlight contaminated and uncontaminated areas under each land use category (i.e. residential, agricultural and commercial) and will provide guidance to the Tsumeb Town Council in planning residential extensions and other developments in and around the town. In the maps below, the red area in Figure 5a indicates arsenic concentrations exceeding maximum allowable values for residential purposes, while Figure 5b depicts recommendations for agricultural and commercial / industrial use, as well as an area to be excluded from any development. ("No Go" zone).

- Residential: As < 100 ppm
- Agricultural: As < 200 ppm
- Industrial and Commercial: As < 500 ppm.

Potential Receptors

Amongst the contamination receptors identified in the area are gardening or crop farming activities (Fig. 6a), as well as humans inhaling or ingesting contaminated dust (children are at a higher risk as they often play on the contaminated ground; Fig. 6b).

Figure 6a. Vegetable gardens belong to the identified contamination receptors.

Figure 6b. Receptors of contamination in the informal settlement near Tsumeb.

Summary

Deleterious metals including Pb, Cd, Cu, Zn and As have been emitted from the Tsumeb copper smelter since the early 1900s. Generally distribution of As and other toxic metals in Tsumeb soils shows high levels of contamination to the northwestern side of the smelter facility and Tsumeb Town. High concentrations of Pb, Cd and Zn reaching 53,400 ppm, 335 ppm, and 48,500 ppm, respectively, have been recorded in areas closest to the Smelter.

Recommendations

Recommendations given by the Geological Survey to the Tsumeb Town Council include the development of residential areas to be directed towards the south and southwest of the existing town, where contamination is not at critical levels.

The study recommends the discontinuation of any agricultural activities in the vicinity of the smelter, especially in the areas towards the west and north.

The guideline value for industrial land use is higher (500 ppm) compared to residential and agricultural use, so that industrial development could occupy the area situated nearer the smelter surrounding the "No Go" zone (Fig. 5b).

Acknowledgements

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References

ESRI-ARCGIS, 2010. http://help.arcgis.com/en/arcgis-desktop/10.0/help/index.html#/Kriging/.

Geo-Consult, 1996. Environmental Audit of the Smelter Complex. Report for European Union and Republic of Namibia, Windhoek.

Geological Survey of Namibia, 2006a. Tsumeb - Geochemical Investigation of Soils in the Area of the Proposed Town Extensions Nomtsoub 6 and 7. *Environmental Monitoring Series*, No.1, Windhoek, Namibia.

Geological Survey of Namibia, 2006b. Mapping of soil contamination in Tsumeb. *Environmental Monitoring Series*, No.7, Windhoek, Namibia.

Geological Survey of Namibia, 2007. Investigation of Vegetative Material for Heavy Metal Contamination in the Surrounding of the Tsumeb Smelter Complex. *Environmental Monitoring Series*, No.11, Windhoek, Namibia.

Kaira, C. 2009. *The Chamber of Mines of Namibia 2010*, p 36.

Miller, R. McG. 1983. The Pan-African Damara Orogen of South West Africa/Namibia. *In*: Miller R. McG. (Ed.) Evolution of the Damara Orogen of South West Africa/Namibia. *Geological Society of South Africa Special Publication*, **11**, 431-515.