Environmental Impact Assessment Review 63 (2017) 128–135

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

Threatened southern African soils: A need for appropriate ecotoxicological risk assessment

Herman Eijsackers [a], Adriaan Reinecke [b], Sophie Reinecke [b], Mark Maboeta [a,*]

[a] Unit for Environmental Sciences and Management, North-West University, Private Bag X6001, Potchefstroom 2520, South Africa
[b] Department of Botany & Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa

ARTICLE INFO

Article history:
Received 14 October 2016
Received in revised form 8 December 2016
Accepted 11 December 2016
Available online xxxx

Keywords:
Southern Africa
Soils
Ecotoxicology
Risk assessment
Soil fauna

ABSTRACT

In southern Africa arable soils are limited due to low rainfall and are threatened by anthropogenic activities like agriculture and mining making it susceptible to degradation. The aim of this study is to review the existing information available with regards to soil contamination and its possible threats towards biodiversity and quality of southern African soils. Some of the issues being addressed in this paper include the focus areas of ecotoxicological research in southern African countries, levels of contaminants in soils, the impacts of climate on soil animals and the representativity of standardised test species. In order to address this, we report on a literature search, which was done to determine the main focus areas of soil ecotoxicological research, highlighting strengths and research needs in comparison to approaches elsewhere in the world. Further, to address if the risk assessment approaches of Europe and the USA are valid for southern African environmental conditions; this in the light of differences in temperature, rainfall and fauna. It is concluded that risk assessment procedures for Europe and the USA were based on non-southern African conditions making it necessary to rethink risk assessment studies; although limited, in southern Africa. We recommend future research that has to be undertaken to address these issues. This research should include investigating species sensitivities in responses to contamination and including insects likes ants and termites in ecological risk assessment studies.

Contents

1. Introduction

Soils in southern Africa; comprising, among others, South Africa, Namibia, Botswana, Zambia and Zimbabwe are, in terms of area, not a limited resource, but they are limited in terms of arability. With an annual average rainfall of only 450 mm soil in South African can e.g. be classified as dry and prone to degradation (Department of Environmental Affairs and Tourism DEAT, 2006) which includes biophysical and socio-economic factors (Hoffman and Todd, 2000). Moreover, soil quality is threatened by a number of anthropogenic activities, of which mining is the most prominent. Some of the major sources of soil contamination in South Africa (Wahl et al., 2012), Zimbabwe (van Straaten, 2000), Zambia (Ettler et al., 2011) and Botswana (Gwebu, 2008) are mines.

* Corresponding author.
E-mail address: mark.maboeta@nwu.ac.za (M. Maboeta).

http://dx.doi.org/10.1016/j.eiar.2016.12.003
0195-9255/

In South Africa, approximately 4.9% of land is degraded and 0.14% (175,421 ha) impacted by mines and quarries (Fairbanks et al., 2000) but, the degree to which these areas impact arable land (±12% of the total land area) is unknown (GCIS, 2012). Few studies from southern Africa have focussed on how mining impacts soil e.g. platinum mining in southern Africa (Jubileus et al., 2013, Maboeta et al., 2008), tailings dams in Zimbabwe (Meck, 2013) and South Africa (Blight, 2012). When compared to water, soils in these areas are not considered as a scarce resource (Eijsackers et al., 2006); a fact that is reflected in the literature searches of e.g. "soil South Africa" (359 results) vs. "water South Africa" (1760 results) in the title (Google Scholar).

The aim of this review is to determine our current knowledge of soil contaminants and the threats they may pose to soil quality and soil biodiversity in southern African soils. Although it may be obvious for the soil ecotoxicology specialist, it has largely been ignored in other climatic zones of the world and needs to be brought to the table as a need to address. The current approach, in at least South Africa as far as toxicity testing is concerned, is to follow northern hemisphere testing outcomes. This paper questions this for several reasons because environmental conditions pertaining to soil moisture and temperature is vastly different and so is the soil fauna. A further aim is therefore to determine if current ecotoxicological studies and risk assessment approaches in Europe and the USA are equally valid and applicable for this region in the light of differences in environmental conditions and biological composition between the regions. In order to achieve this we performed a literature search to determine the extent and main focus areas of soil ecotoxicological research in southern Africa in order to establish strengths and research needs in comparison to approaches elsewhere.

2. Focus areas of soil ecotoxicological research in southern African countries

Based on CAB-abstracts, an analysis by 'southern Africa explode' was undertaken on the research carried out in Malawi, Mozambique, Zimbabwe, Zambia, Botswana, Namibia, Angola, South-Africa, Lesotho, Saint Helena, Swaziland and Comoros. The search profile was as follows: Soil? AND (contamin* or pollut* or heavy metals OR pesticides) AND (Southern Africa explode). The result: 410 publications of which 119 from 2012 or later.

In a first selection of papers on soil degradation with 'policy' included in the search profile, most papers were on physical degradation due to agricultural activities or husbandry (rangeland). Contamination from mining activities did not figure prominently, with only one paper by Leteinturier and Malaisse (1999) on Cu-mining and a paper by Aihoon et al. (1997) on salinization. However, some papers have been published on policy-related topics.

Without 'policy' as search term, a distinction has been made between different aspects of soil degradation and contamination. Table 1 summarizes the numbers of papers dealing with these different topics.

After initial analyses of the collected literature the following main focus areas were identified which will be discussed in more detail in the following sections. These include background values of contaminants, ecotoxicological risk assessment; focus areas of soil ecotoxicological research in southern African countries, impact of temperature on functioning and sensitivity of soil animals, impact of moisture on functioning and sensitivity of soil animals as well as the validity of "standard" or general test species for the southern African soil fauna.

3. Background levels of contaminants

There have been only a few studies on background or reference levels of metals in soils of the southern African region. Several of these studies focussed on mining complexes and smelters. Herselman et al. (2005) provided an extensive inventory of metals in South Africa reporting on 4500 collected soil samples from all over the country. Ekosse (2009) investigated the spatial distribution of Mn minerals at an abandoned Mn oxide mine in Botswana and Ikenaka et al. (2010) undertook a small metal pollution survey of lake sediments and soil for Zambia. Ayeni et al. (2010) evaluated river beds and accompanying riverbanks around Cape Town. Ettler et al. (2011), Vítková et al. (2011a) and Vítková et al. (2011b), studied the surroundings of the Nkama copper smelter in Zambia, while Rauch and Fatoki (2013) sampled an area around the platinum mines in the Bushveld Igneous Complex in South Africa. Similarly Ekosse et al. (2005), and Ekosse and Fouche (2005) investigated areas around a Ni-Cu smelter in Selebu-Phikwe and manganese mining in Botswana.

Specific locations such as mine tailing disposal facilities (TDFs) have attracted special attention. They consist of intensively extracted (physically and chemically) discard ores. The ore discard is typified by a fine particle size slurry mixture with varying pHs (depending on extracted mineral ores) and low organic matter content which is deposited over large surfaces of land comprising many km^2. These TDFs consist of unstructured soil-like material without vegetation (revegetation may take many years) and are prone to water and wind erosion. Due to this erosion metal-loaded soil particles might become dispersed over a wide area. Table 2A summarizes background data of Ayeni et al. (2010), Ekosse et al. (2005) and (Herselman, 2007). Table 2B provides specific data of gold mine TDFs and its natural and cultivated surroundings compiled by Voua Otomo et al. (2013b) which illustrates the sometimes enormous differences in amounts between mine tailings and neighbouring natural soils, while agricultural soils (AS) in general show the lowest amounts of various heavy metals presumably due to the mixing of the upper 20–30 cm of the soil by cultivation.

There are several other industrial and agricultural sources of soil contaminants in southern Africa but exact figures of environmental levels and the extent of the surface area affected, are scarce. Land farming of oil refinery waste and landfills also introduce several highly toxic substances into the soil (Reinecke et al., 2015, Reinecke et al., 2016a, Reinecke et al., 2016b). Little is known about existing background levels of biocides in most agricultural soils in southern Africa (Quinn et al., 2011). Based on usage figures vast amounts of biocides of different kinds may reach soils as a result of crop protection programmes

Table 1
Numbers of southern African papers relating to various aspects of soil degradation and contamination.

Type of degradation	Aspects investigated	Number of papers
Physical	Erosion	32
	Agriculture or husbandry	10
	Soil transport	1
Inorganic contamination	Husbandry	9
	Agriculture	16
	Salinization	7
	Remediation	13
	Ecotoxicology	93
Organic contamination	Ecotoxicology	13
	Remediation	14
	Climate	22

Table 2A
Summary of background metal concentrations (mg kg^{-1}) in contaminated (Ayeni et al., 2010, Ekosse et al., 2005) and uncontaminated (Herselman, 2007) soils from Botswana and South Africa (SA).

		Cd	Co	Cr	Cu	Fe	Ni	Se	Zn
Ekosse et al. (2005) - Botswana	Min	0.64	12.4	23	20	21.7	22.3	0.06	2.06
	Max	3.1	56.1	177.5	371.6	251.4	266.6	0.9	4.47
Herselman (2007) SA	Min	0.62	1.51	5.82	2.98		3.43		12
	Max	2.74	68.5	353	117		159		115
Ayeni et al. (2010) SA	Min	0	0.2	0.3		402	0.02		2.4
	Max	9.3	2.7	2.1		2460	2.6		212