Chapter 7
Arsenic Contamination of Soil in Relation to Water in Northeastern South Africa

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Abstract Little is known about the arsenic contamination of soil in relation to water in South Africa. In fact, there is a gap in knowledge about the topic as far as Africa as a whole is concerned. This chapter addresses the limited information on the presence and threat of arsenic in South Africa's environment. The focus of this chapter is on soil (and indirectly water) contamination in the former Venda tribal area in northeastern South Africa where for many decades the apartheid government used arsenic-based dip solutions to treat East Coast Fever among cattle. Soil samples taken at 5-m, 20-m and 100-m at a depth of 300-mm from 10 old dip tanks revealed 11 readings above 2.0 mg/kg and 2 readings above 30 mg/kg. We found that these old contaminated dip sites were not rehabilitated and that houses are now being built as close as 50-m from the centers of contamination. It is clear that the problem of arsenic contamination of soil and water in South Africa, a water scarce country, deserve more attention from researchers and the various levels of government.

1 Introduction

Arsenic (As) as a chemical compound was discovered in the eighth century, but it was not until the grand-scale commercial production of arsenic trioxide (As_2O_3) from 1850 onwards, that the danger inherent to this substance became clear (Piracha et al. 2016). Arsenic is a natural hard metal found most of the time in low levels in the environment (Musingarimi et al. 2010). It is viewed as one of the most toxic natural elements found on earth (Smith et al. 1998; USEPA 1999; Singh 2017).

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Chronic exposure to arsenic-contaminated materials such as soil, water, food, and atmospheric gasses may lead to arsenicosis, a chronic illness that produces skin disorders, gangrene and various forms of cancer (Ryan et al. 2001; UNICEF 2008; Roychowdhury 2010). The ingestion of, and exposure to, arsenic also may cause cardiovascular and respiratory diseases and neurological malfunctioning (Korte and Fernando 1991). According to the World Health Organization (WHO 1981), the fatal human dose for ingested arsenic is between 70 and 180 mg.

An explanation and discussion of arsenic in the environment should involve four interactive strata: (1) arsenic compounds, (2) chemical configurations, (3) source materials, and (4) contact/transfer media (see Fig. 7.1). The first stratum of the arsenic complexity is the differentiation between the compounds organic arsenic, inorganic arsenic, and arsine gas. Of these three, arsine gas is the most toxic compound (Sami and Druzynski 2003). According to the World Health Organization (WHO 2000), organic arsenic and inorganic arsenic include a trivalent assemblage and a pentavalent assemblage. In both organic and inorganic compounds, the trivalent assemblage is more toxic than the pentavalent assemblage. The second stratum of the arsenic complexity consists mainly of two different chemical composites, namely arsenite (AsO_3^{3}) and arsenate (AsO_4^{3-}), with arsenite being more toxic than arsenate (Smith et al. 1998). In the third stratum of arsenic complexity, three main groups of arsenic source materials, namely geogenic arsenic materials, arsenic materials of anthropogenic origin, and atmospheric source materials (see, amongst others, ATSDR 2000), are taken into consideration. Geogenic arsenic material is usually found with background geological materials (soil and rocks) and is specifically associated with minerals such as antinomy, copper, gold, iron, lead, nickel, silver and uranium (Sami and Druzynski 2003). Arsenic in the envi-

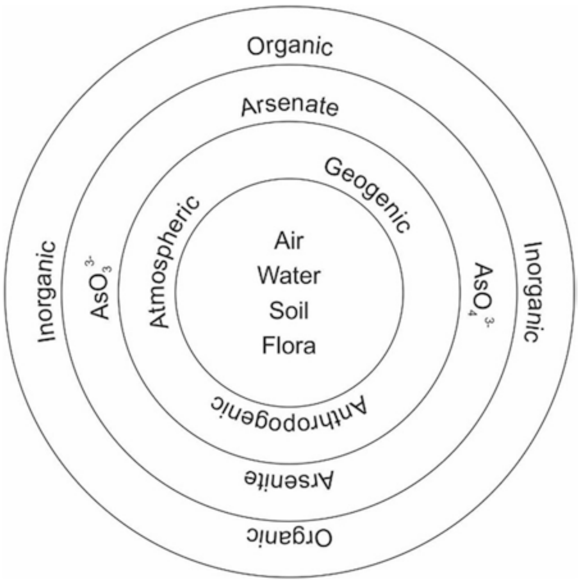

Fig. 7.1 Arsenic strata

ronment that is the result of anthropogenic activities is amongst others related to mining, the treatment of wood, the pharmaceutical and glass industries, fertilizers and pesticides (Piracha et al. 2016). Atmospheric source materials can be of both natural origin (e.g., volcanic activity) and anthropogenic origin (see below). At the core of the arsenic, complexity are interactive contact/transfer mediums such as air, water, soil, and flora.

Because of the mobility of arsenic, the direct and indirect interaction of its compounds, chemical configurations, source material, and contact/transfer mediums are so complex that one of the mediums cannot be researched in isolation. This chapter presents a case study of soil contamination in a particular region in South Africa, but is, at the same time sensitive to the entire complexity of arsenic in the environment.

2 Global Locations of High Arsenic Concentrations

Supported by a considerable volume of sources, Mukherjee et al. (2006) identified 42 main arsenic contamination locations across the globe. Most of the evidence concerning high levels of soil and water arsenic contamination relates to Asian countries such as Bangladesh, Cambodia, China, India, Japan, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Vietnam (see, for example, Guha Mazumder et al. 2010; Roychowdhury 2010; Singh et al. 2016). High concentrations of arsenic (largely due to geogenic events and anthropogenic activities) also have been reported in European countries such as Bulgaria, the Czech Republic, Finland, Germany, Greece, Hungary, Romania, Spain, Sweden, and Switzerland. Further concentrations of arsenic-related to one medium or another have been detected in Australasia (Australia, New Zealand and Tasmania), Central America (Mexico), the Middle East, North America (Alaska, Canada and the USA), South America (Argentina, Chile, Brazil), and the United Kingdom (Nordstrom 2002; Sarkar et al. 2007; Singh 2017).

Ahoulé et al. (2015) and Singh (2017) referred to the limited amount of research on arsenic contamination in Africa. Mukherjee et al. (2006) mentioned only two important arsenic locations in Africa: Egypt and Ghana. In both these countries, the detected arsenic is of natural origin. Fatoki et al. (2013) referred to a few reports on arsenic contamination in Botswana, Burkina Faso, Ghana, Nigeria, the Rift Valley of Ethiopia, and South Africa. Singh (2017) mentioned that only 15 countries in Africa have so far been identified as having challenges of arsenic contamination. In this regard, Ahoulé et al. (2015) referred to specific work conducted by researchers.[1]

[1] Higy and Cordey (2011) (Benin); Huntsman-Mapila et al. (2006), and Mladenov et al. (2013) (Botswana); Smedley et al. (2007), Somé et al. (2012), Nzihou et al. (2013), and Ouédraogo and Amyot (2013) (Burkina Faso); Abdel-Moati (1990) (Egypt); Reimann et al. (2003), Rango et al. (2010, 2013), and Dsikowitzky et al. (2013) (Ethiopia); Amonoo-Neizer and Amekor (1993),

Although Ahoulé et al. (2015) refer to several research efforts conducted in Africa,[2] Fatoki et al. (2013) believe that the lack of information on arsenic contamination in Africa is, firstly, the result of limited research on the topic related to the continent and, secondly, the lack of international attention to reports on arsenic contamination on the continent.

The presence of arsenic in the South African environment is, in the first place, related to the residues of geogenic source materials (Hammerbeck 1998) and various types of anthropogenic actions (see below). Large parts of the South African environment is geologically dominated by the Karoo Supergroup and the Witwatersrand Basin that have been distorted by, amongst others, geological events, meteoric incidents, climate variations, and the change of sea levels over an extended period. The crust material is rich in minerals, including, cobalt, copper, gold, lead, manganese, nickel, platinum, silver, uranium and zinc, as well as coal that, together with anthropogenic actions, are directly or indirectly associated with arsenic in the environment. Secondly, anthropogenic activities such as the burning of coal and fly ash, stockpiling of residual material from gold mines on waste heaps, fossil fuel power plants, the production of fossil fuel petroleum products, the timber industry, and the use of pesticides, insecticides and stock dips further contribute to the presence arsenic in the South African environment (see, for example, Botes et al. 2007; McCarthy 2011; Niyobuhungiro et al. 2013).

Despite the limited evidence on South African waters mentioned by Ahoulé et al. (2015), authors such as Sami and Druzynski (2003), Dzoma et al. (2010), Ogola et al. (2011), and Akinsoji et al. (2013) indicated the presence of arsenic of more than 0.05 mg/L in South Africa's waters. Such occurrences are five times the maximum safe permissible value (SMPV) for drinking water recommended by the World Health Organization (WHO 2012).

Based on data collected over many years by the South African Department of Water Affairs and Forestry (DWAF), Kempster et al. (2007) reported on several readings of arsenic above 1 mg/L. At the same time, Kempster et al. (2007) highlight the lack of a formal national monitoring programme of arsenic levels in South Africa's water resources.

Despite the relationship between arsenic in soil and water, this topic – with reference to South Africa – has received only little attention from researchers (see Dzoma et al. 2010; Ogola et al. 2011), and it is to this matter that the attention of this contribution now shifts.

Smedley (1996), Smedley et al. (1996), Serfor-Armah et al. (2006), Asante et al. (2007), Baumah et al. (2008), Kortatsi et al. (2008a, b), Akabzaa et al. (2009a, b), Rossiter et al. (2010), Akabzaa and Yidana (2012), Bhattacharya et al. (2012), and Kusimi and Kusimi (2012) (Ghana); Pritchard et al. (2007, 2008) and Mkandawire (2008) (Malawi); El Hachimi et al. (2005, 2007) (Morocco); Asubiojo et al. (1997) and Gbadebo (2005) (Nigeria); Dzoma et al. (2010), Ogola et al. (2011), and Akinsoji et al. (2013) (South Africa); Bowell et al. (1995), Taylor et al. (2005), and Kassenga and Mato (2009) (Tanzania); Rezaie-Boroon et al. (2011) (Togo); and Jannalagadda and Nenzou (1996) (Zimbabwe).

[2] See footnote 1.

3 Arsenic in the Soils of NE South Africa: A Case Study

The general occurrence of low levels of arsenic in soil is a natural occurrence. According to the WHO (1981), arsenic concentrations in uncontaminated soil are in the range of 0.2–40 mg/kg. Stock dipping in the past that caused arsenic contamination received attention in Australia, New Zealand and the southern states of the USA (McLaren et al. 1997; Mukherjee et al. 2006; Sarkar et al. 2007; Piracha et al. 2016). Here, we report on arsenic contamination of soil related to past cattle dipping processes in the Vhembe district (Limpopo province, South Africa). This study has also been reported on in other, different formats by us (see Ramudzuli 2014; Ramudzuli and Horn 2014).

3.1 The Study Area and Its People

Venda was the ethnic 'homeland' of the Venda people during the South African apartheid era (1948–1994), but remained under the overarching governance of the Republic of South Africa during this period (Horn 1998). In 1979, Venda decided to accept the offer from the South African government to become an 'independent' homeland (Horn 1998). In 1994, after the first democratic election in South Africa that included all the country's people, Venda, the study area, became part of the country at large as the Vhembe district of the Limpopo province, the northernmost of the nine provinces of South Africa (Fig. 7.2).

Traditionally, cattle farming occupied a central role in Venda society. Notwithstanding their monetary value, cattle pulled ploughs, sledges and wagons, and carried baggage. More importantly, cattle ownership defined the economic and social status of its owner. Consequently, *lobola* (payment for a bride), was traditionally determined in 'cattle currency' (Ramudzuli 2014).

3.2 East Coast Fever

Towards the end of the South African War in (1898–1902), there was a shortage of cattle in southern Africa (Norval et al. 1992). This shortage resulted in the importation of cattle from Australia and India. On the way, cattle were offloaded at the harbor of Mombasa (Kenya), an endemic area of a cattle disease known as East Coast Fever (ECF) (Cranefield 1991). On arrival in South Africa, this at the time unknown disease quickly spread through the cattle herds in entire Southern Africa (Cranefield 1991).Therefore, from around 1900 to the 1960s, Southern Africa was in the grip of ECF (Norval et al. 1992). The veterinarian Arnold Theiler discovered in 1910 that ECF is a cattle disease caused by an intracellular protozoan of the genus *Theileria parva* transmitted by ticks of the species *Rhipicephalus appendiculatus*

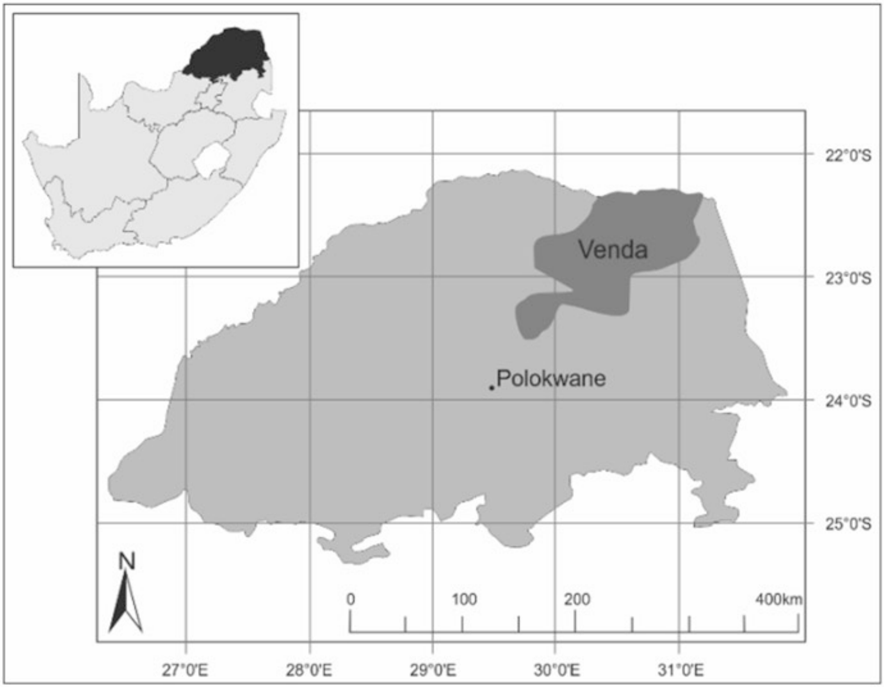

Fig. 7.2 Study area (Venda) in Limpopo province, South Africa

(brown ear tick) (Theiler 1971; Davies 2004). Ordinance No. 38 of 1904 (NASA LC442/05 1904; NASA TAB-A341/15 n.d.) resulted in an attempt to curb the disease in parts of South Africa using arsenic-based animal dipping compounds, already introduced in South Africa in 1893 (Norval et al. 1992).

The Disease of Stock Act 14 of 1911, as well as the Dipping Tanks (Advances) Act 20 of 1911, facilitated the implementation of a limited dipping program (Marole 1967). Thereafter, the Pretoria Conference of 1929 introduced a countrywide ECF Control Programme of regular cattle dipping with the use of mainly arsenic oxide (As_2O_5) and trioxide (As_2O_3) compounds (Ramudzuli and Horn 2014). The programme expected white (European) commercial farmers, assisted by state subsidies, to administer their dipping, whereas the Native Affairs Department (NAD) carried the responsibility to provide the service to black African communal areas such as the later Venda homeland (Mbeki 1964; Beinart 2003). The distribution of the brown ear tick in South Africa determined the location and building of thousands of dip tanks (Fig. 7.3).

According to Fletcher (2000) and Turton (2004), plunge dipping was a common method of tick control. The first plunge dip tank in Venda (Fig. 7.4) was built in 1915 (Marole 1967; Nemudzivhadi 1985). In spite of these attempts, approximately 1.4 million ECF affected cattle died in South Africa between 1902 and 1945.

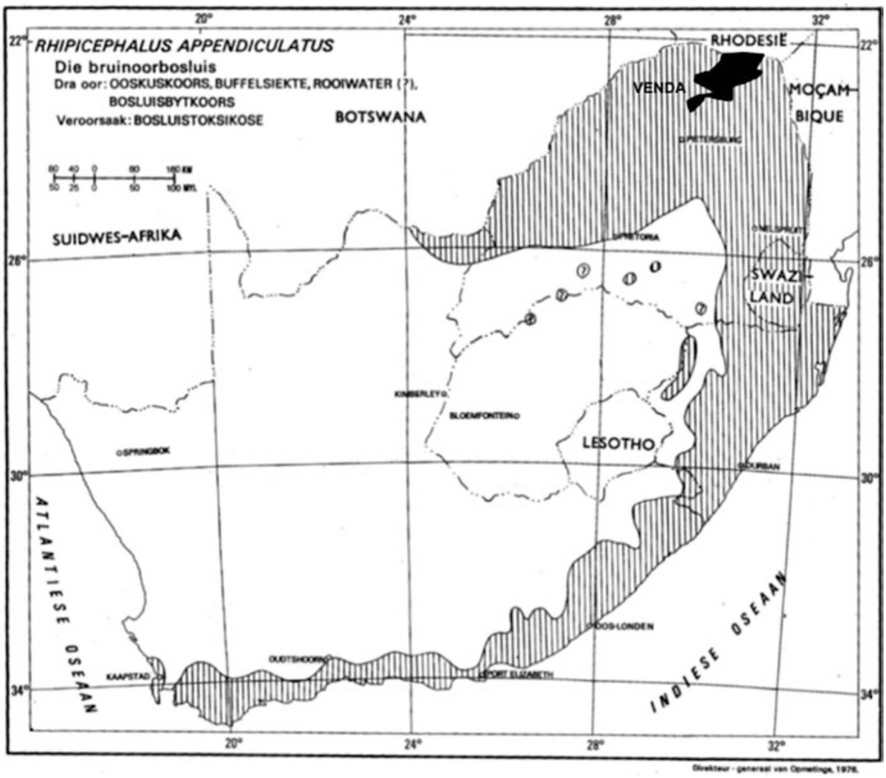

Fig. 7.3 Distribution of the brown ear tick in South Africa. (Reproduced from South Africa 1983)

At the time of the eradication of ECF in South Africa around 1954, when compulsory cattle-dipping and cattle-control restrictions were lifted in the private agricultural sector, it became clear that the populace in the tribal areas (homelands) did not have the required resources to continue cattle dipping on their own (Tomlinson 1955). As a result, the compulsory dipping program continued in these areas under new provisions of the Animal Disease and Parasite Act 13 of 1956, in order to control other tick-borne diseases and to provide a general state-led veterinary service to these communities. Initially the NAD, in cooperation with the respective tribal councils, was responsible for the erection and maintenance of cattle-dipping tanks in the tribal areas. The Native Affairs Department's Division of Veterinary Services in liaison with Native Affairs Commissioners and tribal chiefs and territorial councils provided technical services (NASA TAB-A341/15 n.d.; Linington 1949; P.J. Sefara, InterVet consultant, personal communication, 4 August 2011). Ten million cattle were dipped every 7–14 days (Norval 1983).

Around 1960, ECF was eradicated in Southern Africa, including Basuthuland/Lesotho, but compulsory cattle dipping with arsenic-based cattle dipping com-

Fig. 7.4 The second author (MR Ramudzuli) standing at the ruins of the first dip tank built in Venda in 1915. (Reproduced from Ramudzuli 2014)

pounds continued in South Africa's homelands. There were two reasons for this practice: Firstly, the South African government felt obliged to provide veterinary services to the black African homelands; and secondly, some of the black African tribal areas such as that of the Venda, Shangaan, and Swazi people bordered on the Kruger National Park (KNP). Because of the danger of diseases such as Foot and Mouth Disease (FMD), Corridor Disease, Anthrax, and Tuberculosis carried by game (J. Nethengwe, Vhembe District Veterinary Section, personal communication, 13 December 2013), the area next to the KNP was divided into an infected zone, a protection (buffer) zone and an FMD surveillance zone, almost parallel to the border of the KNP (Fig. 7.5). Although the diseases indicated above are not treatable through dipping, the compulsory scheduled dipping events provided excellent opportunities to observe the cattle for possible symptoms.

After claiming independence from South Africa in 1979, Venda established its own Directorate of Veterinary Service residing under the Venda Department of Agriculture and Forestry. However, seconded officials from the South African Government were still overseeing the application of the service (The Republic of Venda 1979). Dipping took place once a week during summer and fortnightly during winter (N.E. Mafhara, Limpopo Province Department of Agriculture, Veterinary Division, personal communication, 2 July 2004). Although declared illegal in 1983, the unofficial use of stocked arsenic dipping solutions continued for some time (Norval et al. 1992).

Dipping under the supervision of local officials assisted by officials seconded by the national government of South Africa continued until 1994 when the post-apartheid government took over the government of the country. Since then, the

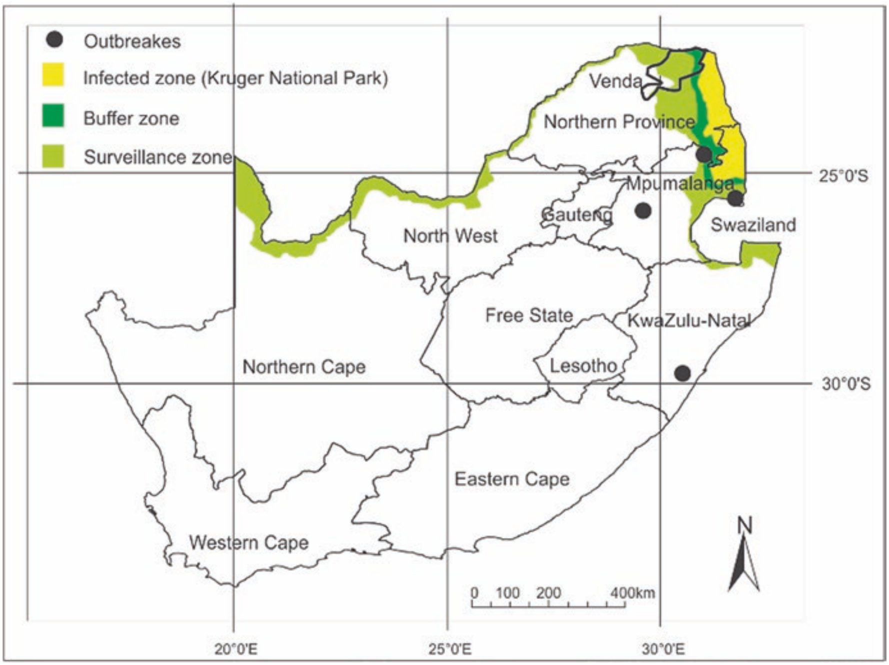

Fig. 7.5 Cattle disease control zones in South Africa

'100%' (composite) dipping program was scaled-down. Eventually, the official dipping system in Venda (now the Vhembe district of the Limpopo province) collapsed (M. Mafhara, Limpopo Province Department of Agriculture, Veterinary Division, personal communication, 13 June 2015).

New outbreaks of FMD since 2001 resulted in a re-evaluation of the direct and indirect role of cattle dipping to control cattle diseases (J. Nethengwe, Vhembe District Veterinary Section, personal communication, 13 December 2013). Although the gradual introduction of a new government-driven dipping programme through the Veterinary Section of the National Department of Agriculture (NDA), it is estimated that only 50% of the dip tanks in Vhembe is still operational (J. Nethengwe, Vhembe District Veterinary Section, personal communication, 5 March 2015).

Even though the post-apartheid South African government has not as yet published a new policy on stock dipping, it has established a national task team to draft a new policy (Mampane 2004, 2011). In the meantime, the Animal Diseases Act 35 of 1984 remains enacted, although the Animal Diseases Regulations under this Act was amended as recently as 2014.[3]

[3] See: Animal Diseases Act 35 of 1984, Animal Diseases Regulations as published by Government Notice No. R. 2026 (1984) and amended by Animal Diseases Regulations: Amended, by Government Notice No. R. 865 (2014).

4 ECF and the Contamination of Soil

The second author, Ramudzuli, supervised by the first author of this contribution, collected soil samples from 10 dip sites in the Vhembe district in South Africa (for detail see Ramudzuli 2014). The dip sites were selected based on the dates of construction of the various dip tanks, soil characteristics, and eco-regions. The dip tanks were situated at the villages of Khubvi, Mukula, Rambuda, Sambandou, Thengwe, Tshandama, Tshifudi, Tshikuwi, Tshituni and Tshivhulani (Table 7.1).

The level of arsenic concentration was measured at distances of 5-m, 20-m and 100-m from the respective dip tanks (Fig. 7.6). The 5-m collection site enclosed the splash area (point 1 on Fig. 7.6) and was usually close to the poison trench where solution waste accumulated when the tanks were cleaned. The 20-m distance covered a draining pen in which the cattle were huddled whilst still wet with dip solution (point 2 on Fig. 7.6). The 100-m distance (point 3 on the figure) covered a radius around the tanks from where the cattle dispersed and served as the control point.

Single, linear point soil samples following the contours of the terrain were taken at a depth of 300-mm and placed in clean, labeled plastic bags. The packaged soil samples were chemically analyzed for arsenic by an accredited soil laboratory of

Table 7.1 Location of dip tanks selected based on ecological and soil characteristics of surroundings. (Reproduced from Ramudzuli and Horn 2014)

Site	Latitude	Longitude	Date built	Eco-regions and soil characteristics
Established before 1948				
Tshivhulani	22°55.35′ S	30°30.12′ E	Early 1920s	ER 2.01 (Central Highland): Deep red clays predominate
Khubvi	22°49.52′ S	30°34.03′ E	1923	ER 2.01 (Central Highland): Heavily weathered, compacted red clay
Rambuda	22°47.05′ S	30°27.06′ E	1940	ER 5.04 (North-Eastern area): Red loam with a high level of organic matter
Tshikuwi	22°53.83′ S	29°58.91′ E	1940	ER 5.03 (Western area): Heavily weathered, compacted red loam
Tshituni	22°56.82′ S	30°02.57′ E	1940	ER 5.03 (Western area): Gravelly with traces of brown clay
Established from 1948				
Sambandou	24°49.59′ S	30°39.33′ E	1948	ER 5.04 (North-Eastern area): Sandy loam with a very high level of organic matter
Tshifudi	22°48.24′ S	30°43.27′ E	1948	ER 2.01 (Central Highland): Sandy loam with prevalent organic matter
Makula	22°51.00′ S	30°36.59′ E	1948	ER 2.01 (Central Highland): Weathered, compacted red clay
Thengwe	22°49.59′ S	30°32.58′ E	1950	ER 5.04 (North-Eastern area): Sandy with little organic matter
Tshandama	22°30.07′ S	30°45.05′ E	1950	ER 5.04 (North-Eastern area): Sandy with little organic matter

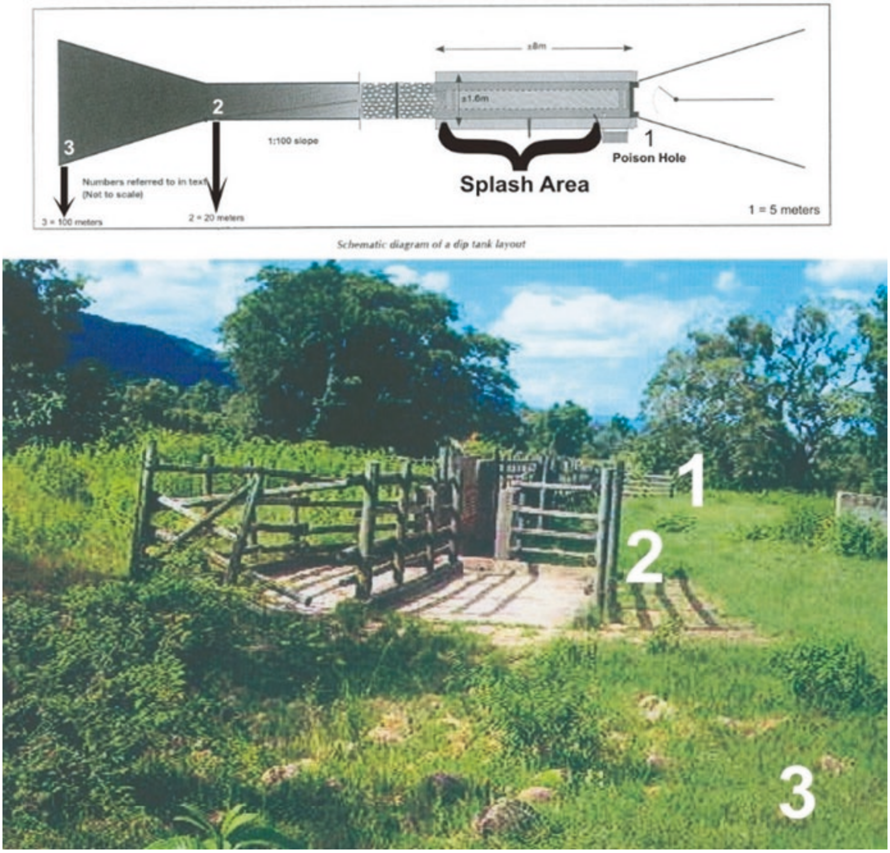

Fig. 7.6 Sampling points of soil at 5-m (1), 20-m (2), and 100-m (3) distances from dip tanks. (Reproduced from Ramudzuli and Horn 2014)

the Agricultural Research Council (ARC) of South Africa (Ramudzuli 2014). The analysis performed involved a scan of an ammonium EDTA extract. An ammonium EDTA solution was added to soil samples, and the solution was filtered to isolate the chemicals. The findings are reported in Table 7.2.

The two highest As readings were at Sambandou (46.76 mg/kg at 5-m) and Tshivhulani (30.18 mg/kg at 5-m). The highest mean As values for the three distances was 18.24 mg/kg at Sambandou and 10.13 mg/kg at Tshivulani. Readings above 0.2 mg/kg occurred at Tshifudi, Khubvi, Rambuda, and Mukula at the 5-m distance, at Sambandou, Khubvi, Rambuda, Mukula, and Tshifudi at the 20-m distance, and at Rambuda, Khubvi and Sambandou at the 100-m distance. The decline of contamination values varied. The values of Sambandou (−39.88 mg/kg) and Tshivhulani (−29.99 mg/kg) revealed big differences between the 5 and 20-m sampled points. Results further indicated a rapid decrease in the arsenic concentration values between 5-m sample points and 100-m sample points, with the exception of Rambuda. The explanation of the increased level of contamination at 100-m at

Table 7.2 Arsenic levels and soil qualities at sample points

	As concentration (mg/kg)				Change		
Dip sites	5-m	20-m	100-m	Mean	5 to 20-m	20 to 100-m	Comments
Sambandou	46.76	6.88	1.09	18.24	−39.88	−5.79	Sandy loam with very high level of organic matter
Tshivhulani	30.18	0.19	0.01	10.13	−29.99	−0.18	Predominating deep red clays
Tshifudi	3.85	0.23	0.15	1.41	−3.62	−0.08	Sandy loam with prevalent organic matter
Khubvi	3.65	3.69	3.60	3.65	+0.08	−0.09	Heavily weathered, compacted red clay
Rambuda	3.53	3.63	3.70	3.62	+0.10	+0.07	Red loam with high level of organic matter.
Mukula	2.30	1.20	0.08	1.20	−1.10	−1.12	Weathered compacted red clay; steep slope.
Thengwe	0.14	0.07	0.09	1.19	−0.07	+0.02	Sandy with little organic matter
Tshikuwi	0.08	0.12	0.02	0.07	+0.04	−0.10	Heavily weathered, compacted red loam
Tshituni	0.02	0.06	0.01	0.06	+0.40	−0.05	Gravelly with traces of brown clay
Tshandama	0.00(2)	0.00(3)	0.00(2)	0.00(2)	+0.00(1)	−0.00(1)	Sandy with little organic matter
Mean	**9.05**	**1.46**	**0.88**	**3.96**	**−7.44**	**−0.73**	

Notes: In the ‘Change’ columns the symbol ‘−’ indicates a decreasing and the symbol ‘+’ indicates an increasing arsenic levels between sampling points

Rambandou may be related to the drip of dip solution from the treated cattle, which congregate in the unpaved drip yard before they are dispersed, and the overland flow of dip solution and overflow of dip sites as during flooding (Ramudzuli and Horn 2014).

To explain the differences in As concentrations between various dip sites, three factors were taken into account: soil properties, the presence of organic matter, and locational influences. In the case of the highest reported reading at Sambandou (46.76 mg/kg at 5-m), the soil property is a sandy loam with a high level of organic matter. At Tshivulani (30.18 mg/kg at 5-m), the soil is a deep red clay, but it should also be taken into account that the dip tank is located in a topographical depression. A reading of 3.85 mg/kg was obtained from Tshifudi at a 5-m distance where the soil is a sandy loam with prevalent organic matter. The fourth highest reading at a distance of 5-m from the dip tank occurred at Khubvi (3.65 mg/kg) where the soil is a heavily weathered, compacted red clay. However, a clear explanation of the environmental circumstances for the variations between the measurements at these four sites is not possible with the information available.

Arsenic in soil is an accumulative and non-degradable substance and presents a danger to humans and animals (Smith et al. 1998; Ramudzuli and Horn 2014). The real danger of arsenic in the soils of the study area that resulted from cattle dipping with arsenic-containing liquids is the direct contact with contaminated dipping tanks and dipping remnants, and the use of polluted surface water and groundwater.

In 2018, we revisited the sites where we conducted our original research and came to the following conclusions:

1. Several contaminated dip sites are still in use at present and cattle often have immediate access to surface water, such as streams and ponds, after dipping.
2. Old dilapidated sites have not been disinfected and properly fenced-off.
3. The design of dipping sites, such as those in Rambuda constructed in 1940, is still dangerous for humans and animals. The poison hole at Rambuda is situated approximately 20-m away, at a level lower than the dip tank, and is connected to the tank by a narrow furrow.
4. Present day human activities increase the danger of contact with the old dip sites. Khubvi tank is now situated in the middle of a maize field. The Rambuda site is utilized for mud brick making. Continuous ploughing and brick making may shift the soil downslope, and thereby assist in the migration of arsenic. Moreover, houses have been built next to some unenclosed dip sites (see Fig. 7.7). At a larger scale, the proximity of old dip tanks to rivers and streams in the study area poses great concern (see Fig. 7.8).

Fig. 7.7 Houses built next to an unenclosed dip tank at Tshandama

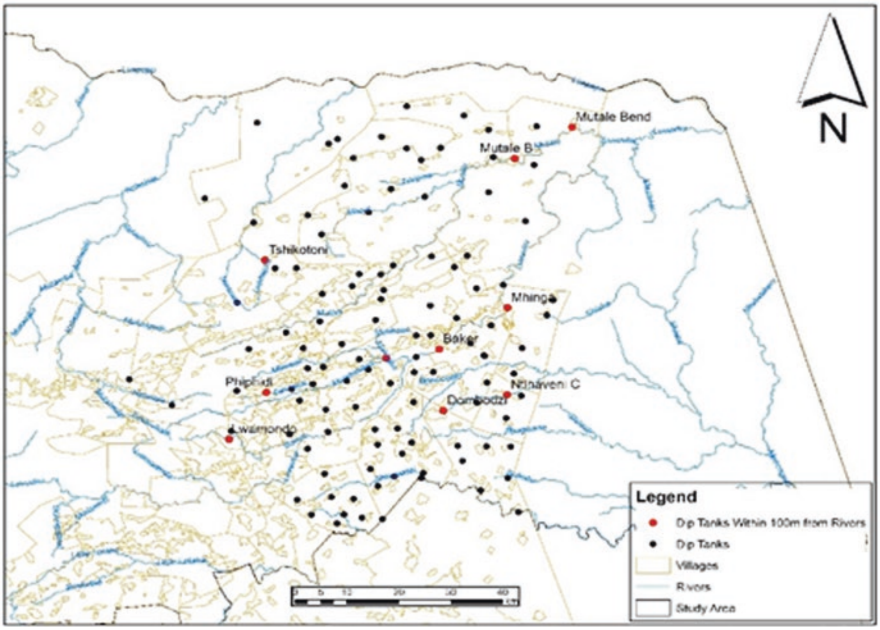

Fig. 7.8 Map showing the proximity of rivers and streams to historical cattle dip sites in Northeastern South Africa

5 Conclusion

According to the available literature, South Africa is not a main arsenic contamination location in the world. This chapter reflected upon a number of reasons that may spearhead a different mindset. We have evaluated the geology[4] and human activities associated with the presence of arsenic in the local environment in South Africa. However, the case study presented in this chapter focused on soil contamination caused by past cattle dipping with arsenic-based solutions to treat East Coast Fever in the country, and the continued use of stockpiled arsenic-based solutions for cattle dipping even after the use of it became illegal in 1983. We collected 30 soil samples at 10 cattle dipping sites at a depth of 300-mm in the former Venda homeland of South Africa and tested the samples for the presence of arsenic remnants. Only two samples contained levels of arsenic exceeding median readings in

[4] More detail on arsenic related geological formations in Northeast South Africa includes the Mount Dowe Group of the Beitbridge Complex; the Nzhelele, Sibasa and Tshifhefhe Formation of the Soutpansberg Group; the Schiel Complex; the Phalaborwa Complex; the Rooiwater Complex, and the Gravelotte Group (Kempster et al. 2007). The location of these formations are closely connected with the South African greenstone belt starting at the border with Swaziland, reaching northwards to the study area and then turns westwards, covering both sides of the Limpopo river towards the Beitbridge linking South Africa and Zimbabwe.

the United States of America and Australasia where stock dipping is also the cause of concerning levels of arsenic in soil. However, the uncoordinated planning and development of post-apartheid South Africa's former 'homeland' areas is a serious concern. For example, the rehabilitation or enclosure of old arsenic contaminated dip tank sites in these areas have not received the required attention. At a larger scale, South Africa is prone to high levels of arsenic contamination in the future because of the reasons mentioned above. South Africa is a water scares country, and its water requires proper protection. The arsenic contamination of water is researched from many angles with different intentions. However, the close link between arsenic in soil and arsenic in water, and the reciprocal impact of arsenic in these two mediums remains an under-researched topic in South Africa and Africa in general.

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