**Original article**

# Rodent proliferation in urban and agricultural settings of sub-Saharan Africa

## The dark side of synthetic chemical rodenticides.

Ambroise DALECKY[#1,2], Madougou GARBA[3], Abdoul Aziz IBRAHIM DANZABARMA[4,5], Jonas ETOUGBÉTCHÉ[6], Sylvestre BADOU[6], Henri-Joël DOSSOU[6], Ibrahima SOW[1,2,7], Cheikh Tidiane NIANG[1,2,7], Ousmane DIENE[8], Idrissa DIALLO[9], Mohamed Seyidna Ali SAGHIRI[10], Mohamed El Hady SIDATT[11], Frank VAN STEENBERGEN[12], Amadou Bocar BAL[2,7], Luwieke BOSMA[12], Gualbert HOUÉMÉNOU[6], Solimane AG ATTEYNINE[13], Karmadine HIMA[4], Gauthier DOBIGNY[#5,14], Yonas MEHERETU[#15,16]

[1]IRD, Aix Marseille Univ, LPED, Marseille, France

ambroise.dalecky@ird.fr
ambroise.dalecky@univ-amu.fr

[2]BIOPASS 2, IRD, UGB, Cirad, ISRA, Saint-Louis, Sénégal

[3]Direction générale de la protection des végétaux, Niamey, Niger

garba_madougou@yahoo.fr

[4]Université Abdou Moumouni, faculté des sciences et techniques, Niamey, Niger.

az.danzabarma@gmail.com
karmadine@gmail.com

[5]CBGP, Univ Montpellier, CIRAD, INRAE, Institut Agro, IRD, Montferrier-sur-Lez, France

gauthier.dobigny@ird.fr

[6]École polytechnique d'Abomey-Calavi, Laboratoire de recherche en biologie appliquée, Unité de recherche sur les invasions biologiques, Université d'Abomey-Calavi, Cotonou, Bénin

jonas.etougbetche@gmail.com
sylvestre.badou@gmail.com
dossou_hjoel@yahoo.fr
gualbert.houemenou@gmail.com

[7]UFR S2ATA, Université Gaston Berger, Saint-Louis, Sénégal

amadou-bocar.bal@ugb.edu.sn
sow.ibrahima9@ugb.edu.sn
niangcheikhtidiane@yahoo.fr

[8]Direction de la protection des végétaux, Dakar, Sénégal

odiene16@yahoo.com

[9]Service d'hygiène, Saint-Louis, Sénégal

diallorh@yahoo.fr

[10]Direction de la protection des végétaux, Nouakchott, Mauritanie

msa.saghiri@gmail.com

[11]Bureau sous-régional de la FAO, Tunis, Tunisie

MohamedelHady.Sidatt@fao.org

[12]Rodent Green, Amsterdam, Pays-Bas

fvansteenbergen@metameta.nl
lbosma@metameta.nl

[13]Laboratoire de rodontologie, Institut d'économie rurale, Bamako, Mali

solimane.ag-atteynine@ird.fr

[14]Institut Pasteur de Madagascar, Unité peste, Antananarivo, Madagascar

[15]Department of Biology and Institute of Mountain Research & Development, Mekelle University, Mekelle, Éthiopie

[16]Department of Wildlife, Fish & Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Suède

yonas.meheretu@slu.se

#. Equal contribution.

**Abstract**
Globally, about 400 million people are affected by rodent-associated zoonoses annually. In addition, at least 280 million cases of undernourishment could be prevented worldwide through effective management of rodent pest populations. Therefore, the management of rodent populations that are reservoirs of pathogens or pests of stocks and crops is an issue for both food security and public health. In terms of public policy, many African countries have implemented agricultural intensification programs aiming at improving food self-sufficiency, with direct risks of rodent proliferation. In this paper, which is a first part of a diptych, we present the background of rodent control in Africa in rural and urban settings, followed by an overview on rodenticide regulation and uses, and document the resulting problematic situations with illustrative case reports. The use of synthetic chemical rodenticides is the most commonly practiced rodent management method, which is not only poisonous for humans, other animals and the environment, but also poorly effective against rodent populations (e.g., resource consuming, evolution of resistance, bait avoidance). The uncontrolled circulation and use of these rodenticides in many African countries is associated with considerable health and environmental risks without any significant improve in terms of rodent control or rodent nuisance mitigation.

# Introduction: the ever increasing need of rodent control in Africa

Rodents (reviewed in [1]) form the most speciose mammalian order, are present on all continents and evolve in almost all environments, including deeply human-modified ones. Some species may be very prolific, with large litter sizes and short generation times. They may display various diets, from very specialized to highly diversified and opportunistic ones. In addition, they are characterized by a continuous dental growth that oblige them to gnaw permanently in order to avoid teeth overgrowth and subsequent death. Finally, rodents are known to host a wide panel of microorganisms and parasites (bacteria, viruses, protozoa, helminths), many of them being potential zoonotic pathogens. Altogether, this makes rodents major pests for human infrastructures, food security and health, with billions US dollars of damages, massive depredation on crops and food stocks that represent food for at least 280 million people per year [2]; [3] as well as up to 400 million cases of human infections annually by zoonotic pathogens whose ecology involves rodents [4]; [5]. It should be noted that these global figures are likely underestimates. In such a framework, rodent eradication or control campaigns have been carried out for centuries all over the world, using various practices. The latter ones have always been highly resource-demanding and unambiguously representing important financial costs for farmers, enterprises, inhabitants and/or public services. Unfortunately, rodent control appears as an inescapable issue of agricultural, environmental and public health issues, especially in Africa that currently faces a combination of societal challenges.

For example, food production in West Africa is constrained by a combination of social, political, economic, climatic and environmental factors, as well as recurrent pest infestations, including rodent ones. Many West African countries are dependent on imports and a series of public policy actions have been implemented, aiming to move towards food self-sufficiency [6]. Indeed, figures from 2014 indicate that Africa accounted for 10% of the world's population, but 32% of world rice imports. Only 7% of the rice produced in the world is sold on the international market, and Asia, currently a major exporter of rice, could become a net importer of rice within the 2020's. This represents a major challenge to food security in many African countries and justifies the launching of agricultural intensification programs that frequently result in increased rodent abundance, hence rodent-associated damages [7].

In parallel, Africa currently undergoes an exponential growth of the number of city dwellers [8]. This rapid urbanization is often difficult to control and to accompany in terms of urban planning and management, thus leading to the creation and the sprawling of wide informal urban areas that are characterized by elevated human densities, precarious habitats, the rarity or absence of waste management, sanitation, electricity and water supplies [9]. In these overcrowded and insalubrious areas, rodents are offered board and lodge, and proliferate in very close promiscuity with often socio-economically vulnerable inhabitants [10], thus further illustrating the critical rodent control issue in Africa.

# Rodenticide regulation and uses in Africa

Currently, most of anti-rodent actions rely on chemicals, usually acute poisons or anticoagulants. For instance, the use of synthetic chemical rodenticides was the most frequently declared rodent management method by farmers in Tanzania (80%), South Africa (58%) [11] and Senegal (47%) (I. Sow *et al.*, unpublished data), as well as by urban dwellers in Benin (55%) [12]. When used in a wide and/or uncontrolled fashion, these molecules have well documented detrimental effects, including human and non-target animal species intoxication [13]; [14]; [15] as well as the evolution of resistance to anticoagulant rodenticides used [16]. Moreover, there has recently been growing concern about the impact of rodenticides in terms of animal welfare [17]; [18].

In sub-Saharan Africa, beyond officially registered distributors, many large informal chemical rodenticide markets exist where rodenticides without indications of active ingredients, proper labelling, expiry dates, and user instructions are openly and massively traded. In some countries, they are sold on the street, sometimes together with other pesticides and industrial and traditional medicines, by people who are often young, poor, have no access to formal education and operate in the informal economy [12]. Citing Granjon & Duplantier ([19], p. 53): *'(…) a lot of so-called rat poison products can be found on local markets, in anonymous sachets, without any indication of the active ingredient, concentration, etc. At best, they are harmless to rodents (we have already found plaster, cement or coloured powders of indefinite origin in these sachets* [note that the use of such ineffective compounds diverts actors from proper practices]*), at worst they are dangerous for the person using them (acute poisons in wrong or overdosed, concentrated and outdated insecticides, etc.)'*. Yet, in most countries, officially authorized pesticides are formally listed. For example, in the countries of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS – http://portails.cilss.bf), the official list of the Sahelian Pesticides Committee (since expanded to West African Pesticides Homologation Committee) as of November 2020 included only one authorized chemical rodenticide (Brodifacoum) out of a total of 474 pesticides. This may be surprising given the widespread and often explicit use of many other chemical compounds for rodent control in Sub-Saharan countries, such as Aluminium Phosphide, Zinc Phosphide, Alphachloralose, Chlorophacinone, Bromadiolone, Difenacoum, Difethialone, and even highly toxic broad-spectrum insecticides such as Methomyl. In Malawi, Zinc Phosphide was the only rodenticide officially authorized for use in rural and urban settings [20]. However, Brodifacoum and

Aluminium Phosphide were available in informal markets and were indeed used for rodent management in rain-fed farming and warehouses on a regular basis [20]. Another astonishing example is the use of a non-steroidal anti-inflammatory drug (Indomethacin) for humans diverted from its original medical purpose to poison rodents at home and in farms, e.g. in Benin, Nigeria, Tanzania and Malawi [11]; [21]; [22]; [23]; [24] . Even more surprisingly, in some countries, unauthorized rodenticides are available not only in informal markets but also from storefront commercial pesticide distributors (our own observations). This poor control of rodenticides as well as the widespread use of unauthorized chemicals may lead to highly problematic situations, as illustrated here below through a couple of case reports.

# Case reports

A first example of problematic chemical (mis)use was identified following a rodent outbreak during the 2020-2021 cropping seasons in the middle valley of the Senegal River where Alphachloralose rodenticide was applied in rice and vegetable fields [25]. This rodenticide was imported from Morocco to Mauritania by an agri-business firm without proper governmental authorization under the trade name "Coumafar 50". Following our own observations, the alert to the Mauritanian authorities led to the seizure of additional fraudulent imports at the northern border of the country. It turns out that the inscription on the packaging was ambiguous, if not misleading (e.g., Anti-Poison Centre in Morocco, pers. comm., April 2021): Coumafar is the trade name of a first generation anticoagulant poison belonging to the Coumafen (or Warfarin) family for which there is an antidote (i.e., vitamin K; [26]), while Alphachloralose is an acute neurotoxic and narcotic poison which has a different mode of action than anticoagulants, and for which there is no specific antidote [27]. Chemical analyses confirmed that so-called “Coumafar 50” was composed of 2% Alphachloralose (report of analysis made by Centre wallon de Recherches agronomiques, CRA-W, Gembloux, Belgium, provided to FAO sub-regional office for North Africa). Yet, the use of Alphachloralose is strictly regulated and is not allowed in CILSS countries. According to European and Moroccan legislations, Alphachloralose should only be used by informed experts against house mice (*Mus musculus*) in very specific conditions such as buildings (sheds, ports), but never outdoors (see Box 1). This is clearly stated on the packaging of "Coumafar 50" as observed in Mauritania (also known as “RATICIDE 50” in Morocco): *"not applicable against field rodents"* and *"there is no specific antidote"*. However, it should be noted that these statements only appear in the French version of the label, unfortunately not in the Arabic version, which is highly questionable and problematic. The use of Alphachloralose requires preventive measures for users and must follow strict guidelines (e.g., the bait must not be accessible to organisms other than rodents). In Southern Mauritania, this toxicant was imported in large quantities and was applied massively by farmers/producers in open fields such as rice plots and intensive vegetable crops (e.g., onion, tomato, gumbo, cabbage). Some of these crops were close to maturity, hence soon ready to be sold. In addition, we were able to document the presence of two species of rodent pests (*Arvicanthis niloticus* and *Mastomys* cf. *erythroleucus*) in the treated plots, demonstrating that the treatment was neither adequate nor effective for rodent eradication (Figure 1). These rodent species (diurnal and nocturnal, respectively) are likely to make up part of a large panel of the diet of local predators (e.g., raptors and owls, reptiles, wild and domestic carnivores), suggesting that the poison application may impact several non-target species. Even more worrying, the product was reportedly distributed by the same agri-business firm to the inhabitants of surrounding villages where rodent infestations had also been reported. The wide-scale and massive use of this toxicant, its transfer to inexperienced users, its release into the environment (at proximity of the Senegal River) and the fate of the crops produced in the plots where the poison was applied would have required a rigorous evaluation as well as urgent implementation of awareness raising campaigns in order to avoid major environmental and public health catastrophes that could be associated with this unauthorized use of Alphachloralose in Mauritania. The use of Chloralose (under the trade name "RATICIDE 50") was also documented in October 2022 in the village of Tuabou, Department of Bakel, Senegal, close to the border with Mauritania (C. A. Diagne, pers. comm.; April 2023).

As an additional illustration of major public health risks, we may quote a retrospective study of human poisoning cases declared between January 2008 to December 2014 at the Moroccan Anti-poisoning and Pharmaco-vigilance Center which shows that rodenticides were responsible for 29% of 6,800 acute pesticides poisoning cases [28]. An even more recent retrospective study in Moroccan hospitals described 398 human cases of acute poisoning reported between January 2014 and September 2020, with the identity of pesticides determined by chromatographic analyzes [29]. In this study, 33% of the investigated cases were due to rodenticide poisonings, and all of those were confirmed to be Alphachloralose poisoning. Similarly, out of 914 hospital cases of acute pesticide poisoning admitted to eight major referral hospitals in Zimbabwe from January 1998 to December 1999, 49% were due to oral exposures to rodenticides [30]. In the same manner, in Ethiopia, under severe infestation conditions, rodenticides are used in storage areas and houses, potentially threatening the health of humans and domestic animals. For instance, a retrospective cross-sectional study from Debre Tabor general district hospital, Ethiopia, revealed that, out of the 102 patients admitted to the hospital presenting acute poisoning between September 2013 to August 2016, rodenticide poisoning accounted for 57% of the cases [31]. In another study conducted in northern Ethiopia, ~ 93% of surveyed cereal farmers mentioned the use of zinc phosphide rodenticide in rain-fed crop fields in order to manage pest rodents [32]. About 87% of the farmers decided to buy and to apply this acute poison after noticing intense rodent activities in the fields, suggesting that rodent management is essentially symptomatic. In Senegal, the National Crop Protection Service often distributes chemicals to agricultural advisors or farmers, Chlorophacinone for a supervised use in the fields, and Methomyl and Aluminium Phosphide for use in stocks (A. Samba, pers. comm.; Jan. 2020), during periods of high rodent infestation, when rodent management would have been more effective prior to these periods, i.e. when rodent abundance is low. The authorized use by derogation of Chlorophacinone has also resulted in the poisoning of non-target species, as illustrated by two recent confirmed cases of death of domestic animals, including a working horse and a herd of goats, which led to legal proceedings (B. Diouf, pers. comm., 2018; A.M. Baldé, pers. comm., 2018, A. Gueye, pers. comm. 2022). In Niger, reports of rodent infestations within Niamey are recorded on daily basis by Crop Protection officers, who respond to such complainants by supplying with rodenticide (Brodifacoum) under their supervision. But such individual actions remain largely ineffective because they are followed by a re-infestation after a few weeks (M. Garba, pers. obs.). In Mali, too, rodent management is based essentially on the use of chemical rodenticides (Brodifacoum, Difenacoum, Zinc Phosphide; the latter two being not approved in western Africa; [33]) for which the Office du Niger (in charge with the ca. 100,000 ha irrigation scheme of the western inner delta of River Niger in Mali) spends more than 30 million F CFA/year (> 45,000 €/year; A. K. Konaté, comm. pers., May 2022) for it, with questionable effectiveness.

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Figure 1.
Illustration of the problematic use of Alphachloralose rodenticide in Mauritania in 2021.

## Box 1. Additional information linked to the reported case of Alphachloralose rodenticide use in rice and vegetable fields of Mauritania, 2021.

The clinical features of poisoning with Alphachloralose may include coma and generalized convulsions (Thomas et al. 1988). The symptoms in humans are neurological disorders and bronchial congestion which, in the case of a non-fatal dose, can be alleviated in intensive care through administration of activated charcoal, atropine and/or benzodiazepines. This corroborates the statements on the original packaging (Figure S1): *"Treatment of intoxication is purely symptomatic and aimed at controlling convulsions and bronchial hypersecretion"*. In Morocco, where “Coumafar 50” was produced, its valid and registered trade name is "RATICIDE 50" and its use in the field is not authorized, with the only exception being in storage facilities against house mice (*Mus musculus*) infestation of crawl spaces (source Office National de Sécurité Sanitaire des Produits Alimentaires du Maroc[1]). There is therefore a notable contradiction in the packaging of this toxicant as observed in the field. Informations hereafter are given according to the Pesticide Properties DataBase[2]. There are considerable gaps in reported data for environmental fate in the literature. Alphacholoralose is volatile, highly soluble in water, highly toxic to birds and moderately toxic to mammals and fish, with a high potential for bioaccumulation. According to the European Standing Committee on Biocidal Products[3] in 2008, Alphachloralose has been evaluated for its use as a rodenticide for the specific control of house mouse (*Mus musculus*), and has been classified as harmful and dangerous for the environment, harmful by inhalation and if swallowed, very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment, is not expected to undergo abiotic degradation by hydrolysis or photolysis in water. Due to its low adsorption onto soils and being readily soluble in water, this toxicant is expected to move from soil into water. It is non-biodegradable and hydrolytically stable, and contamination of surface and groundwater may thus occur. It is very toxic to aquatic organisms and be regarded as potentially persistent or very persistent in marine environment.

[1] http://www.onssa.gov.ma/fr/152-intrants-agricoles/homologation-des-intrants-chimiques/413-pesticides-a-usage-agricole & http://eservice.onssa.gov.ma/IndPesticide.aspx

[2] http://sitem.herts.ac.uk/aeru/ppdb/en/Reports/130.htm

[3] https://circabc.europa.eu/sd/a/0a566792-98a3-4b34-8c6f-62bb51d23af8/Alphachloralose_final%20AR.pdf