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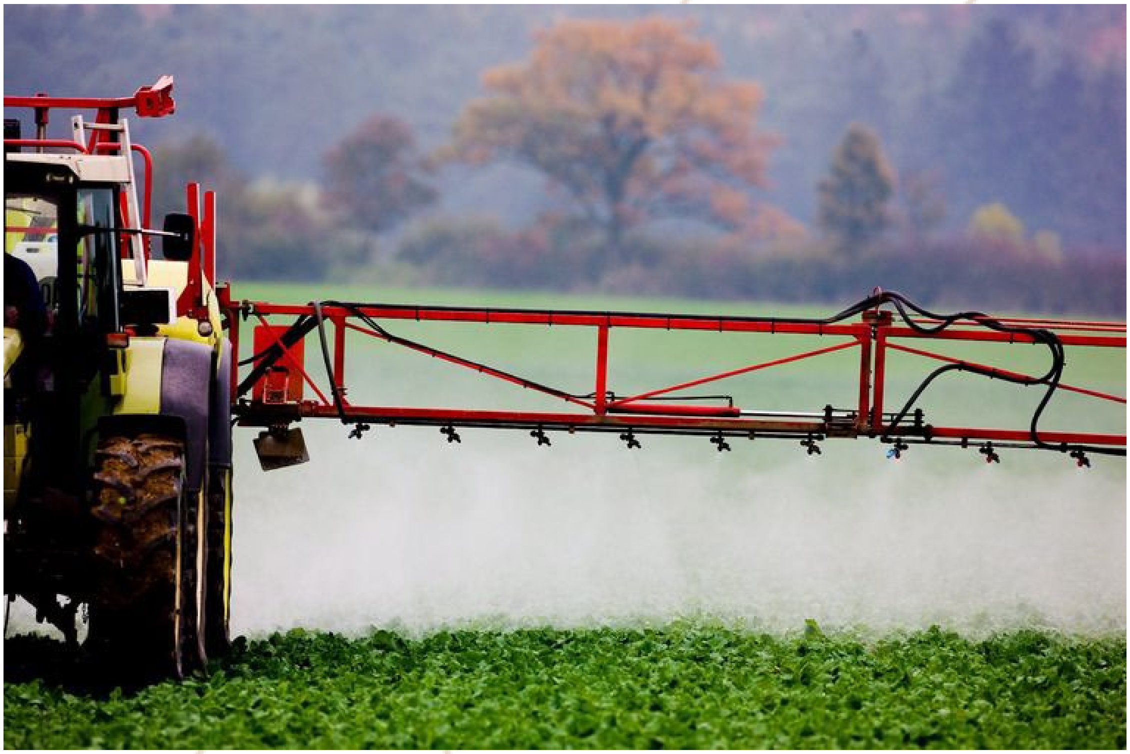
LIFE for Falcons

Excessive use of pesticides in Romania and Bulgaria



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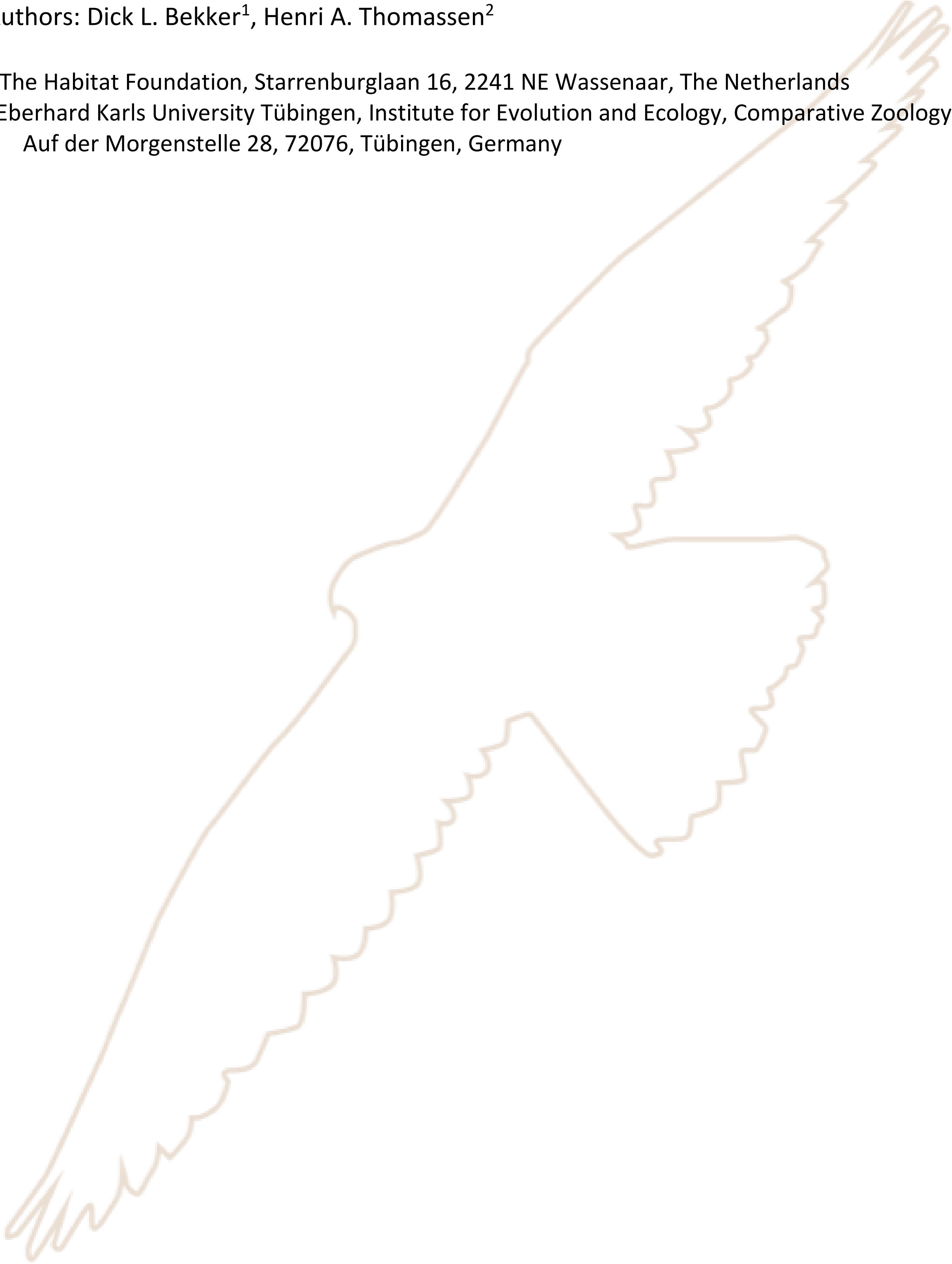

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Introduction

Widespread use of pesticides in agriculture creates global conservation concern for biodiversity. As approximately 45% of the annual food production is lost due to pest infestation, a wide range of pesticides is used to manage pests and to increase crop production (Abhilash & Singh 2009).

The application of synthetic pesticides started in the late 1930s and exponentially grew after World War II. From the early 1960's onwards, the synthesis of pesticides increased enormously. In 1958, India for example manufactured over 5000 metric tons of pesticides, which increased to 85000 metric tons in the mid-1990s, with the registration of 145 different types of pesticides (mostly insecticides) (Gupta 2004). In 2019 over 2.0 million tons of pesticides were utilized annually worldwide (Sharma et al. 2019), and usage is still increasing.

In the 1960s, the rising awareness of the global organochlorine pesticide contamination and its impact on many different species in the wild has led to more strict regulation of synthetic pesticides and the ban of many persistent organic pollutants (POPs). Plant protection products (PPPs) are now among the chemicals with the strictest regulations. These include "maximum residue limits", defined as the maximum pesticide concentration in food considered safe to humans as set by the Codex Alimentarius Commission and the joint Food and Agriculture Organization/World Health Organization meeting on pesticide residues (Zikankuba et al. 2019). Despite these regulations and the continued development of new pesticides that are supposed to be less toxic to non-target species, the negative impacts of PPPs on biodiversity are still widespread and severe. Species that are heavily affected include small mammals and predatory and scavenging birds.

1.1 Types of pesticides

In this paper we focus on two types of pesticides: banned and restricted pesticides (BRPs) and currently used pesticides (CUPs). Theoretically, CUPs are only licensed for use if they do not persist in the environment and if they do not bioaccumulate. In practice, however, there is evidence that also CUPs may be environmentally persistent (e.g. Hoferkamp et al. 2010), and can accumulate in living organisms in remote regions (Morris et al. 2014, 2016). Thus, despite being licensed, CUPs may be harmful to wildlife and human health. At the same time, there is ample evidence that BRPs are still being used in various regions of the world.

CUPs

CUPs are designed and regulated in order to be safer (e.g. less persistent, less bioaccumulative, more targeted) than BRPs. The use of synthetic pesticides has increased over the past four decades in terms of total amount, diversity of molecules and geographic expansion. Nowadays, more than 500 active substances, belonging to more than 100 chemical classes with various modes of action are used worldwide (Fritsch et al. 2022).

Despite national or federal plans aiming at reducing the use of pesticides, this trend is not expected to be reversed. According to projections for 2100, a tenfold increase in PPP use is even expected, partly as a result of climate change and the growth of the human population.

Although CUPs generally pose lower risks to non-target species than BRPs, several compounds approved in the EU pose risks for reproductive and endocrine functioning (Fritsch et al. 2022). Indeed, approximately 50 compounds meet two criteria among the "persistent, bioaccumulative, and toxic" classes (Hvězdova et al. 2018), and several have been shown to accumulate in the environment (Geissen et al. 2021; Pelosi et al. 2021; Sabzevari & Hofman 2022).

BRPs

BRPs and their breakdown products are still present in the environment due to legacy contamination and long persistence, and they can be remobilized due to current practices on arable soils. Their impact on biodiversity and the environment may thus persist long after they have been banned from use.

Although CUPs are overall less persistent and bioaccumulative than BRPs, several approved PPPs in Europe still pose a chronic risk to reproduction and/or are classified as endocrine disruptors. Around 50 PPP-compounds meet two criteria of the 'persistent, bioaccumulative and toxic' class of substances. Moreover, recent studies showed accumulation of several CUPs in soils of various habitats within the agricultural landscapes. Recent large-scale surveys across Europe and worldwide monitoring studies of multi-class PPPs in arable soils showed a high occurrence of residues of both BRPs and CUPs (Fritsch et al. 2022).

1.2 Major pesticides and their effects

A wide variety of pesticides (both BRPs and CUPs) exist, and it goes beyond this report to discuss all of them. Below, however, are some examples of pesticides that have been widely used in the past, but still persist in the environment, or that are currently still often applied.

DDT affects people's health and is a possible human carcinogen. Animal studies showed that DDT exposure can affect the liver and reproduction. In birds, chronic ingestion of *DDT* resulted in production of eggshells that were significantly thinner and lighter than those of controls (Kolaja & Hinton 1977).

Dichlorodiphenyldichloroethylene (*DDE*) is a breakdown product of *DDT*. *DDE* is particularly dangerous because it is fat-soluble like other organochlorines. It is rarely excreted from the body, and concentrations tend to increase throughout life. *DDE* causes the same health issues as *DDT*, but appears to be more potent (ATSDR 2022).

γ-hexachlorocyclohexane (*lindane*) has been used as an agricultural insecticide. In humans, *lindane* affects the nervous system, liver, and kidneys and may well be a carcinogen.

α-hexachlorocyclohexane is a byproduct of the production of *lindane* and is still contained in commercial grade *lindane* used as insecticide. It is a persistent organic pollutant (POPs), that is persistent in the environment and bioaccumulative.

Diazinon is an organophosphorus pesticide used to control pest insects in soil and on fruit and vegetable field crops. It breaks down rather rapidly. There is no evidence that long-term exposure to low levels of *diazinon* causes any harmful health effects in people.

Dichlorvos is an insecticide to control household pests, and protecting stored products from insects. Its toxicity extends well beyond insects. Since 1988, *dichlorvos* cannot be used as a plant protection product in the EU.

Neonicotinoids are a family of insecticides applied by spraying or coating of seeds. These types of insecticides are not degraded easily, and thus remain in the environment for years. For example, the half-life of neonicotinoids in soil can exceed 1,000 days (Bonmatin et al., 2015). Neonicotinoids can also be easily bioaccumulated throughout the food web. As a result, they are known to be devastating to non-target insects/wildlife, and cause developmental abnormalities in embryos and eggs of birds. They have also been shown to cause neurological damage to mammals. Despite a ban on their use by the EU, neonicotinoids continue to be applied by several member countries, including Romania and Bulgaria. Bulgaria has only recently (2023) banned the emergency authorization for imidacloprid, a neonicotinoid often used in corn (maize) production.

1.3 Mammals and pesticides

Free ranging animals, inside and outside the agricultural context in Europe, are exposed to the (mostly) unintentional impacts of pesticides (i.e. all sorts of fungicides, herbicides, rodenticides, and insecticides). Indeed, wildlife exposure to pesticide mixtures is a rule rather than an exception (Fritsch et al. 2022). Research has shown that synthetic pesticides are important drivers of a severe global decline of wildlife and widespread loss of farmland biodiversity. The studies dealing with (currently used) pesticides in free-living fauna have shown the potential for non-target wildlife to be exposed and even to bioaccumulate these substances, highlighting the relevance and need for further research and data on this issue (Sharma et al. 2019).

Small mammals are central in environmental risk assessments (ERAs) of new pesticides as “mammalian indicator species” or “generic focal species”. ERAs mostly focus on small rodents and insectivores (EFSA 2009). Assessments usually are limited, however, to laboratory experiments of single compounds, without monitoring of the additive effects of multiple compounds, or those of bio-accumulation.

Most of the BRPs are known as persistent, lipophilic, bioaccumulative compounds that have the potential to biomagnify in food webs. Small mammals feeding at a higher trophic level are therefore expected to exhibit a greater contamination (number of compounds or concentrations) by BRPs. Indeed, an overall higher contamination was found in shrews (higher trophic level) than in rodents (Fritsch et al. 2022). This same research showed a higher contamination in animals captured in hedgerows and cereal crops than in grasslands, but no differences between conventional and organic farming (Fritsch et al. 2022).

Actual measurements of the exposure of small mammals to PPPs under realistic field conditions are rare (but see for instance Fritsch et al. 2022; Barber et al. 2003). This is unfortunate, because small mammals have a major functional role in terrestrial ecosystems and several species are considered as beneficial organisms in agro-ecosystems, because they feed on invertebrates and the seeds of weeds that are harmful to crops. Moreover, as abundant and widespread prey for numerous vertebrates, small mammals are involved in the transfer of pollutants in food webs, and in secondary poisoning of predators, including the Saker Falcon. Although acute poisoning of individuals of wild populations have become increasingly rare as a result of the banning of first-generation pesticides, the chronic exposure and the accumulation of toxic chemicals in secondary and tertiary consumers is still a major cause for concern (e.g. Köhler & Triebskorn 2013). One of the rare field studies on pesticide exposure in small mammals was conducted at a relatively large scale in France. It showed that exposure of small rodents and insectivores to dozens of legacy and currently used pesticides is pervasive (Fritsch et al. 2022). Interestingly, contrary to the expectations, currently used pesticides are not detected in hotspots of exposure, but rather uniformly distributed across the landscape. Moreover, these compounds are permitted partly because of their supposedly non-bioaccumulating properties, but they appeared to do so after all (Fritsch et al. 2022).

Although small mammals may be directly sprayed with pesticides when they are residing in or near crop fields, the exposure pathway is usually through the ingestion of contaminated food. Granivorous and omnivorous species may for instance eat seeds that are coated with pesticides. However, exposure may also be indirect, through eating contaminated (insect) prey or drinking contaminated water.

The importance of the exposure of small mammals to toxic compounds in combination with bioaccumulative properties of these compounds can hardly be overstated. Small mammals serve as prey for many predatory mammals and birds, thus exposing these species to the same chemicals. Interestingly, the development of new types of pesticides that are not lethal to small mammals may enhance exposure of predatory species. Chronic exposure of small mammals can affect physiological processes and their behavior, making them easy prey for predators. Thus, predators may preferentially prey on individuals that are suffering from the effects of pesticides.

At the same time, predators are also heavily impacted by rodenticides, i.e. pesticides that target rodents and aim to kill them as quickly as possible. A recent review compiled the evidence for the effects of rodenticides on secondary and tertiary consumers (Gomez et al. 2022). Rodenticides are usually anticoagulants that not only affect rodents, but also other mammals and birds. They are often lethal after secondary exposure, but may also cause sublethal effects, such as impaired mobility or anemia. The impacts of anticoagulants on individual secondary and tertiary consumers are thus well documented and often severe. The effects on the population level are less well established. Yet, given the above, anticoagulants are also very likely to cause population declines in predatory and scavenger species.

1.4 Raptors and pesticides

It is well known that raptors are sensitive to certain pesticides. Many pesticides are not or only partially broken down, and thus persist throughout the food chain. The toxic chemicals and their derivative metabolites are stored in for instance liver and fatty tissues, and bioaccumulate further up the food web. Top predators and scavengers are therefore often exposed to high levels of a diversity of pesticides. Also the Saker Falcon (*Falco cherrug*), a raptor of mainly open grasslands and feeding on small rodents and birds, may therefore be subjected to high concentrations of pesticides.

Raptors are not only particularly at risk from toxic pesticides because of the bio-accumulative effects in the food web. They may also exhibit a higher sensitivity than other bird species to certain compounds, such as organophosphates and carbamates (Mineau et al. 1999; El-Sherif et al. 2009). However, risk assessments by the European Food Safety Authority do not include raptors and scavengers (e.g. EFSA 2009). This is unfortunate, because the risks to these species of pesticide use are therefore likely underestimated.

There is a general lack of field monitoring of raptor exposure to pesticides (Gómez-Ramírez et al. 2014). Current studies are limited to specific events or compounds. Moreover, an expansion of studies in Eastern Europe is urgently needed (Gómez-Ramírez et al. 2014).

Exposure of raptors and scavengers to toxic pesticides occurs through their prey items. Prey species may on the one hand be the target of extermination practices with pesticides, such as certain insect species (where larger species may be part of the raptor's natural diet), or rodents that are considered pests. On the other hand, prey may be accumulating pesticides in their tissue, for instance through eating seeds treated with pesticides. Raptor and scavenger species that forage in agricultural areas experience the highest risks of exposure to toxic chemicals. At the same time, food availability for prey species is usually higher in agricultural areas than elsewhere. Agricultural areas may therefore be particularly attractive to raptors and scavengers due to the high densities of their preferred prey (e.g. Evans et al. 2005). Because raptors and scavengers often travel large distances in little time, nest sites do not need to be close to agricultural fields where pesticides are being used for the birds to be exposed.

One of the best-known examples of pesticide poisoning of raptors is that of DDT, which brought the North American Peregrine Falcon to the brink of extinction and severely reduced population sizes of many other species (mostly because of effects on eggshell thickness; Anderson & Hicky, 1972; Kolaja & Hinton 1977). Not only DDT, but many other pesticides are toxic to raptors, and secondary poisoning of raptors is a continuing issue, even within the European Union (Kitowski et al. 2021). Despite a ban on many older types of pesticides, remaining stocks are likely still being used up, and even replenished through the illegal import from non-EU countries such as Ukraine, Moldova and Turkey (Rucevska et al. 2020). For instance, carbofuran is known to be very toxic to birds (e.g. Osten et al. 2005), and have resulted in population declines in several common bird species in Canada (Mineau & Whiteside 2006). Due to its toxicity, carbofuran has been banned in the EU since 2008, but poisoning of raptors of high conservation concern has even recently been reported in Hungary and Poland (Deak et al. 2021; Kitowski et al. 2020), likely as a result of illegal extermination of mammalian predators by farmers and their subsequent consumption by raptors. Poison baits have also caused severe declines in raptors in Spain (Hernández & Margalida 2008; 2009; Mariano González et al. 2008; Márquez et al. 2013).

Pesticides may not need to be lethal to have a significantly negative effect on raptor populations. First, insecticides and rodenticides may deplete prey populations, causing their predators to starve (e.g. Newton 1998; Boatman et al. 2004; Poulin et al. 2010). Yet, there may also be direct non-lethal effects on raptors and scavengers. Case in point is again DDT, which did not kill individual birds, but inhibited the formation of thick, protective eggshells through its metabolite DDE (e.g. Anderson & Hicky, 1972). Similarly, organophosphate and carbamate pesticides are acutely neurotoxic (Donovan et al. 2011) and affect thermoregulation, activity and aggression levels, migration, and foraging behavior (e.g. Grue et al. 1982; Fleischli et al. 2004; Story & Cox, 2001; Vyas et al. 1995). Even when a complete mechanistic understanding of how pesticides affect birds is lacking, negative impacts have become apparent. For instance, although neonicotinoids have been suggested to have direct effects on birds and mammals (Goulson 2013 and references therein), the mechanisms are largely unclear. Yet, large-scale impacts on populations of many bird species in the Netherlands have been shown (Hallmann et al. 2014). Hence, even when direct effects of pesticides on individual birds appear to be absent, or the mechanisms are unclear, longer-term negative impacts may nevertheless exist. This is particularly relevant when considering the use of pesticides based on risk assessments by the European Food Safety Authority, which do not evaluate these kinds of physiological and behavioral impacts.

2 Examples of excessive use of pesticides

Excessive use of pesticides can have consequences on different levels and in different degrees.
- It can affect a target species, and if this target species is consumed by (not targeted) organisms on a higher trophic level, these substances can be incorporated in these organisms with dire consequences. For example, the (excessive) use of DDT (an insecticide) has had a deleterious effect on species on higher trophic levels, and also on us humans (UNEP 2001).
- It also can develop resistance in pests, thus making it difficult to control their populations. There are various examples of a dramatic increase in the population of herbicide-tolerant plants after excessive use of specific herbicides to specific target these organisms (Broster et *al*. 2011, Owen et *al*. 2014).
- It can have an effect on human health. Human exposure is rather common with high levels occurring in occupational settings (production and spraying activities in agriculture), low levels in households (garden and lawn treatments), and as residues in food. Human exposure may result in acute and delayed health effects. Acute pesticide poisoning accounts for significant morbidity and mortality worldwide. Delayed health effects associated with pesticide exposure include leukemia, lymphomas, soft-tissue sarcomas, and brain, bone, and stomach cancers in farmers, sprayers, and production workers. A relationship between parental exposure and childhood cancers has been reported in human studies. Pesticides may also play a role in the occurrence of Parkinson's disease and developmental defects (Bolognesi 2011; Evangelou et al. 2016; Guyton et al. 2015).

In Bulgaria, Romania and other in countries in their vicinity, different examples exist of excessive use of pesticides in the past that still have consequences on soil, animals and humans.

2.1 Bulgaria

Agriculture, and therefore the use of pesticides, is much more intensive in NE Bulgaria than in other areas. Nevertheless, there are clear trends for the intensification of agriculture throughout the country. The Bulgarian register lists a total of 159 types of insecticides, 294 types of herbicides and 305 types of fungicides, which were mostly produced by Bayer, BASF and Singenta. Many, though not all were found to be frequently used in three study regions in the south and east/northeast of the country (Kostadinova et al. 2020). Also, several BRPs were reported by the Bulgarian Food Safety Agency (BFSA) to be used with certainty, including *Agrimetal*, *Bandit*, *Inferno*, *Ratimor*, *Effect Rodent*, *Brodirat* and *Sniper* (Kostadinova et al. 2020). One of the nine most frequently used insecticides in Bulgaria, *Kung-fu 5 EK*, is a BRP and officially banned by the Bulgarian Food Safety Agency in 2007 (Kostadinova et al. 2020). Other insecticide-BRPs used in Bulgaria are *Agrimetal*, *Bandit* and *Sniper*.

A broader survey suggested that a diverse set of 71 different active substances are likely to be used in Bulgaria as ingredients in pesticides sold under various brand names (Kostadinova et al. 2020; Table 1). These 71 substances comprise 32 BRPs, i.e. chemicals that are not permitted under EU-legislation, but may still be permitted under federal law or are used illegally. Many of the 71 substances are moderately to highly toxic to mammals and/or birds at high acute or lower chronic doses, even if they are listed as a CUP (Table 1).

Although it is beyond the purpose of this report to describe the toxicity of each of the substances likely used in Bulgaria and Romania, a telling example is that of the insecticide ethoprophos, the active ingredient in for instance *Mocap*. This product is used to control wireworms in potato - and vegetable crops such as tomatoes, eggplants, peppers, cucumbers, zucchini and in some cases on melons, watermelons and pumpkins. The Bulgarian Food Safety Agency (BFSA) has authorized and even subsidizes the use of ethoprophos, although the European Commission has banned this highly toxic substance (EURACTIV Bulgaria 2021). Bulgarian officials state that “without *Mocap* not a single potato can be grown in the country”, which underlines the widespread use of this BRP-substance, which may be classified as excessive use. However, ethoprophos is toxic to fatal in mammals through oral, dermal, and inhalation routes (reviewed in EFSA, 2018). At low but chronic doses, reproductive toxicity was observed, resulting in reduced litter size and increased postnatal mortality (EFSA, 2018). Carcinogenic effects remained unclear, but are likely (EFSA, 2018). As a result, ethoprophos is also considered very toxic to humans by inhalation and dermal absorption, and a probable carcinogen (Pesticide Properties Database; http://sitem.herts.ac.uk/aeru/ppdb/en/Reports/279.htm; Lewis et al. 2016). For birds, data suggest high acute toxicity for birds eating soil-contaminated food, those eating seeds or seedlings that have been treated with ethoprophos, as well as those eating earthworms with residues (EFSA, 2018). Data on secondary toxicity in for instance raptors is still lacking, but seems likely, given the observed toxicity to birds through eating e.g. earthworms. Also, high toxicity to non-target arthropods, such as honeybees has been conclusively shown (EFSA, 2018).

Compared to insecticides, rodenticides seem to be almost missing in the practice of Bulgarian farmers. In their survey, Kostadinova et al. (2020) found only two farmers using these substances, but at the same time pharmacies in Bulgaria in 2018 still sold at least 5 types of non-licensed rodenticides (BRPs), such as *Ratimor*, *Effect Rodent* and *Brodirat*. The fact that these rodenticides were not detected by Kostadinova et al. (2020) may be due to an asynchrony in the timing of use and sampling. Alternatively,

Table 1. Chemicals with high likelihood to be actively used in Bulgaria, based on detection in samples from the field and interviews with farmers and resellers of pesticides (Kostadinova et al. 2020). BRP = banned and restricted pesticide; CUP = currently used pesticide.

Active substance	Type	BRP/CUP (EU)	toxicity to mammals/birds *
amidosulfuron	herbicide	CUP	moderate/moderate
aminopyralid	herbicide	CUP	low/low-moderate
azoxystrobin	fungicide	CUP	low/moderate
bentazone	herbicide	CUP	moderate/moderate
bixafen	fungicide	CUP	low/moderate
boscalid	fungicide	CUP	low/low
brodifacum	rodenticide	BRP	high/high
bromadiolone	rodenticide	BRP	high/moderate
bromoxynil	herbicide	BRP	moderate/moderate
carbaryl	insecticide	BRP	moderate/low
carbofuran	insecticide	BRP	high/high

carboxin	fungicide	BRP	low-high/moderate
chlorothalonil	fungicide	BRP	moderate/low-moderate
chlorpyrifos-ethyl	insecticide	BRP	moderate/moderate
cyhalothrin	insecticide	BRP	moderate-high/low
cypermethrin	insecticide	CUP	moderate/u
DDT/DDE legacy **	insecticide	BRP	moderate/high
deltamethrin	insecticide	CUP	high/moderate
dicamba	herbicide	CUP	moderate/moderate
dichlorprop	herbicide	BRP	moderate/moderate
difenacum	rodenticide	BRP	high/high
dimethenamid	herbicide	BRP	moderate-high/moderate
dimethoate	insecticide	BRP	high/high
dimoxystrobin	fungicide	CUP	moderate/low-moderate
epoxiconazole	fungicide	CUP	moderate/moderate
ethoprophos	insecticide	BRP	high/high
fenoxaprop-P-ethyl	herbicide	CUP	high/low-moderate
fenpropimorph	fungicide	(BRP)***	moderate-high/low-moderate
florasulam	herbicide	CUP	low/moderate
fludioxonil	fungicide	CUP	moderate/low-moderate
flumioxazin	herbicide	CUP	low-moderate/low-moderate
fluroxypyr	herbicide	CUP	moderate/low-moderate
foramsulfuron	herbicide	CUP	low/low
imazamox	herbicide	CUP	low/low-moderate
imidacloprid	insecticide	BRP	moderate/moderate
iodosulfuron	herbicide	BRP	u/u
isoxadifen-ethyl	herbicide safener	BRP	u/u
isoxaflutole	herbicide	CUP	moderate/low-moderate
lambda-cyhalothrin	insecticide	CUP	high/moderate
linuron	herbicide	BRP	high/moderate
mancozeb	fungicide	BRP	low-moderate/low-moderate
MCPA	herbicide	CUP	moderate-high/moderate
mesotrione	herbicide	CUP	moderate/moderate
metalaxyl-M (mefenoxam)	fungicide	CUP	moderate-high/moderate
metaldehyde	insecticide	CUP	moderate/moderate-high
methiocarb	insecticide, acaricide, molluscicide, bird repellent	BRP	high/high
methomyl	insecticide	BRP	high/high
metosulam	herbicide	BRP	moderate/low
metrafenone	fungicide	CUP	moderate/moderate

metsulfuron-methyl	herbicide	CUP	low/low-moderate
nicosulfuron	herbicide	CUP	low-moderate/low-moderate
omethoate	insecticide, acaricide	BRP	high/high
pinoxaden	herbicide	CUP	moderate/low
pirimiphos-methyl	insecticide	BRP	moderate/moderate
propamocarb	fungicide	CUP	u/u
propamocarb hydrochloride	fungicide	CUP	moderate-high/moderate
propargite	acaricide	BRP	moderate/low
propiconazole	fungicide	BRP	moderate-high/low-moderate
prothioconazole	fungicide	CUP	moderate/low-moderate
S-metolachlor	herbicide	BRP	moderate/low
spiroxamine	fungicide	CUP	moderate/moderate
tebuconazole	fungicide	CUP	moderate/moderate
terbuthylazine	herbicide	CUP	high/moderate
thiabendazole	fungicide	CUP	moderate/low-moderate
thiacloprid	insecticide	BRP	high/high
thiamethoxam	insecticide	BRP	moderate/moderate
thiencarbazone - methyl	herbicide	CUP	low/low
thiophanate-methyl	fungicide	BRP	low-moderate/moderate
timbotrione	herbicide	CUP	low/low
triadimenol	fungicide	BRP	high/moderate
tribenuron methyl	herbicide	CUP	moderate/low-moderate

* As listed in the Pesticide Properties DataBase: http://sitem.herts.ac.uk/aeru/ppdb/en/index.htm (Lewis et al. 2016); u = unknown

** although DDT is not known to be used anymore, the chemical (or its breakdown product DDE) is still regularly detected in environmental samples

*** BRP under EU-legislation, but permitted in many EU countries

these BRPs may not be used in the sampled study area, but elsewhere, where they could pose considerable threats to secondary and tertiary consumers.

Finally, a non-licensed (BRP) herbicide that is nevertheless sold in Bulgaria is *Inferno*. *Inferno* is commonly combined with glyphosate, another chemical with strong indications to be a health hazard and potentially carcinogenic.

2.2 Romania

In Romania in 2020, 3877 tons of fungicides and bactericides were sold, as well as 4125 tons of herbicides, desiccants and anti-moss agents, 453 tons of insecticides and acaricides, 9304 tons of products to control snails and slugs, 111 tons of other plant protection products and 121 tons of plant growth regulators (www.agrointel.ro). Although overall pesticide use has been reduced since 2011, trends vary among the types of pesticides. In particular the use of fungicides and other PPPs has increased considerably, and information on the use of rodenticides is lacking[1].

Although the European Commission fully banned neonicotinoids (neurotoxic insecticides) in 2018, Romania still considers these substances as the only effective means to protect crops against insects, and therefore uses them until today (PoliticoPro 2023). Indeed, the EU continues to grant derogations to Romania for the use of neonicotinoids. The excessive use of these insecticides is particularly damaging for Romanian beekeepers, while they are also used to fields of sunflower, corn and colza, all crops highly attractive to pollinators. These practices have led to an enormous rate of bee colony losses.

Despite having been banned for a long time already, a wide array of BRPs was found in water, food and soil samples in the Central Romanian region (Ferencz & Balog 2010). The most significant pollutants were *α-hexachlorocyclohexane*, *γ-hexachlorocyclohexane*, *diazinon*, *dichlorvos* in different water samples. The level of *DDT* was 20 µg/kg and that of *DDE* 50 µg/kg in the contaminated soil. Concentrations in soil and water samples in several cases exceeded limits set by Romanian or EU legislation. Although the half-life of DDT is long (~ 2000 days), that of other BRPs is much shorter. These results suggested that several of these BRPs were still being used in Romania at the time of the study.

Another study in Romania (Gurzau et al. 2008) describes the particular situation in Romania regarding the uncontrolled use of pesticides. Risk zones for health and the environment were identified, with the goal of reduction and control of the risk sources. The pesticide applicators lacked the necessary knowledge about safety and exposure. Educational campaigns are needed to raise the awareness of the population on the danger of uncontrolled use of pesticides.

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[1] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_consumption_of_pesticides#Analysis_at_EU_and_country_level

3 Acute human poisoning by pesticides

As early as 1990 it was estimated that about one million unintentional pesticide poisonings occurred annually, leading to approximately 20,000 deaths (WHO 1990). Currently no clear picture of global pesticide poisoning exists, despite an increase in global pesticide use. Yet, on the **WHO Mortality Database** mortality data reported annually by Member States is compiled, and includes data on acute pesticide poisoning. It is estimated that about 385 million cases of acute pesticide poisoning (APP) occur annually world-wide, including around 11,000 fatalities. Based on a worldwide farming population of approximately 860 million, this means that about 44% of farmers are poisoned by pesticides every year. There is robust evidence that APP is an ongoing major global public health challenge. There is a need to recognize the high burden of non-fatal acute pesticide poisoning, particularly on farmers and farmworkers (Boedeker et al. 2020).

Pesticide drift, which is the off-target movement of pesticides, is recognized as a major cause of pesticide exposure affecting people as well as wildlife and the environment. Pesticide drift has been reported to account for 37-68% of pesticide illnesses among agricultural workers in the United States (Calvert et al. 2008). Residents in agricultural areas are at risk of exposure to pesticide drift from nearby fields. As much as 31% of acute pesticide illnesses that occurred at schools in the United States were attributed to drift exposure (Alarcon et al. 2005).

3.1 Examples of acute human poisoning by pesticides

There are numerous examples of acute pesticide poisoning (APP), ranging from illness within farming communities to acute deaths of individuals.

United States
During 2007-2011, cases of acute pesticide-related illness were identified in the United States (Calvert et al. 2016). Rates of illness among farmers were 37 times greater than the rates for nonagricultural workers. Most affected persons were exposed to insecticides or herbicides. Among persons exposed to insecticides, pyrethroids, organophosphates, sulfur compounds and pyrethrins were most involved. Among persons exposed to herbicides, glyphosate and the dipyridyls were most involved. A total of 80% of cases were classified as low severity, 18% as moderate severity, and 1% as high severity. Two affected persons died from the exposure.

Iran
A study in Western Iran (Afshari et al. 2018) showed that 60% of the farmers and farm workers who applied pesticides suffered from work-related APP. Most frequent symptoms were runny nose (29.8%) and headache (25.1%). Major risk factors were number of farming years, number of spraying years, place of pesticide storage and type of sprayer.

South Korea
A study in South Korea examined the incidence of acute occupational pesticide poisoning among male farmers. The incidence rate of APP in 2010 was over 24% for male farmers. Poisoning occurred mainly when farmers were applying pesticides during summer.

Indonesia
A study was conducted to understand the association between organophosphate exposure and farmers' health near Yogyakarta from the perspectives of physical, emotional and social health. From the farmers (mostly male) around 71% experienced tremor, 17% dizziness and 8% nausea-vomiting after pesticide application. The farmers used pesticides 1.4 hours/day, three times per week and almost everyone used incomplete personal protective equipment. The farmers' quality-of-life scores are lower than the scores of the normal population in Yogyakarta: organophosphate exposure affects the farmers' physical health and quality of life (Perwitasari et al. 2017).

Colombia
In 2009 and 2010 Uribe et al. (2012) studied the effect of the use of organophosphoric, carbamates and organochlorated pesticides in tomato crop farmers. Of the laborers 78% sprayed at least once a week and 22% applied pesticides every 15 days or more. The most frequently used toxicological category was II (highly toxic), followed by I (extremely toxic). Most reported illness was headache (44%), followed by dizziness (39%), weakness (36%), ocular burning (35%) and redness of eyes (32%).

Brazil
Santana et al. (2013) found records of 679 deaths of agricultural workers in Brazil in the period 2000-2009 due to poisoning by pesticides.

China
China is the largest user of pesticides worldwide and possible 53.300-123.000 Chinese people are poisoned every year. Zhang et al. (2016) conducted a study to examine the impact of recent pesticide poisoning on neurobehavioral function and the relationship between years worked in agriculture. It was found that recent occupational pesticide poisoning was associated with reduced neurobehavioral function and increased psychiatric morbidity in Chinese farm workers. Also, the number of years Chinese farm workers work in agriculture is associated with reduced neurobehavioral function and increased psychiatric morbidity.

Ecuador
In the period 2001-2007 Gonzalez-Andrade et al. (2010) registered over 14.000 cases of pesticide poisoning. Of these, over 10.000 cases were due to the effects of the insecticides organophospate and carbamate. In Ecuador, pesticide poisoning mostly occur in individuals who are between 15 to 25 years old and work in adverse conditions as agricultural farmers. The poisoning especially occurs in flower and banana plantation workers. Of these cases 71% are due to organophosphate and carbamate poisonings, which cause death in 4% of the cases of which 57% die in the first 48 h, possibly because of the acute action of AChE inhibitors. The long-term effects of pesticides are still unclear.

4 Alternatives

There have always been alternatives for the use of chemical pesticides, but pesticides have mostly been considered as being the easiest, cheapest and most effective way to protect crops from all sorts of pests or diseases.

Some cases of poisoning of raptors in Eastern Europe may be related to uncareful use or misuse of pesticides (e.g. Deak et al. 2021, Kitowski et al. 2020). However, increased awareness and careful use of pesticides have not resulted in fewer cases of raptor and scavenger poisoning in North America, but instead, only the application of chemicals with lower toxicity or other alternatives have decreased the impacts (EFSA, 2009 and references therein). One likely reason for this is that despite careful application, toxic chemicals bio-accumulate and end up reaching high concentrations in secondary and tertiary consumers.

In Romania the relation was studied between the perceived effect of pesticides and the willingness to exchange conventional pesticides with bio-pesticides, and the willingness to pay for these bio-pesticides (Petrescu-Mag et al. 2019). The effectiveness of conventional pesticides and their effects on human health can predict farmer willingness to implement alternative pest-control systems such as bio-pesticides. The study gives information on strategies for raising awareness of the adverse effects of pesticide products, both at the food consumer and farmer levels.

Below are a few alternatives that present a different way of thinking.

4.1 Example 1: Alternatives to the use of the insecticide lindane

With the banning of lindane many countries have established non-insecticidal alternatives to effectively prevent harm to seeds and crops without the use of lindane. The currently known strategies include:
- crop rotation where a non-host species is planted to reduce the damage of infestation and maintain low levels of pests;
- site selection and monitoring to determine if a crop-damaging pest is present;
- fallowing the area for a few years before planting, to starve the pests;
- careful seed selection and reseeding with resistant crops;
- timing of seeding and planting;
- zero or reduced tillage regimes;
- increasing seeding rates;
- shallow seeding; good seed to soil contact;
- balanced fertility levels to ensure that plants are not predisposed to disease;
- use of more competitive crop varieties to limit losses from these pests.

Other nonchemical alternatives to lindane include:
- biological control methods that utilize predators of the target pest to reduce populations;
- methods employing the use of microbials. These are technically feasible, efficacious and commercially available.

Chemical alternatives used to replace lindane:

- in the neonicotinoid class: *imidicloprid* and *thiamethoxam*, which are considered less environmentally harmful than lindane. Yet, neonicotinoids themselves have devastating effects on non-target insect species. Moreover, integrated pest management and organic methods replace the need for any chemical insecticidal treatments.

4.2 Example 2: Biopesticides as an alternative for chemical pesticides

Biopesticides are living things or compounds that deter pests. Many of these pest deterrents are naturally found in the environment (Caldwell 2020).

- Biopesticides can be microbial organisms such as bacteria and fungi, which for example can produce proteins that are toxic to immature insects or larvae. Because these toxic proteins act specifically on certain larvae, they pose minimal risk to humans and other animals. Bacteria and fungi used as biopesticides are often target-specific, so they can be used to control specific weeds or insect pests.
- Also, plant-derived substances (like corn gluten, black pepper and garlic compounds) can be used as biopesticides to control insects.
- Other types of biopesticides are naturally occurring insect hormones (which can repel bugs, disrupt their mating habits or limit their growth) and synthetic substances that have the same molecular formulas and use the same modes of action as their natural counterparts.
- Genetically modified plants are also considered forms of biopesticides, because they have been engineered with pest-deterring genes and proteins from natural sources.

4.3 Example 3: Alternatives to the use of the rodenticides

An excellent alternative to the use of rodenticides is promoting the presence of raptors that prey on pest species in agricultural areas (e.g. Kross et al. 2012; 2016; 2018), with proven increase in profitability of the farms where this strategy has been implemented (e.g. Kross et al. 2012; Shave et al. 2018). Promoting a diversity of species that prey on different pest species is most beneficial, and requires strategies tailored to each raptor species. These can include installing nestboxes and artificial perches. These strategies can be very effective. For instance, a farmer in Hungary installed T-shaped wooden perches along his fields, resulting in a 90% decrease in numbers of common vole (Press Office of the Ministry of Rural Environment 2011).

5 Literature

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