Case Study

Pesticide handling and waste management: a case study on DDT and HCHs from the Southern Caucasus

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Received: 20 September 2021 / Accepted: 28 February 2022
Published online: 22 March 2022

Abstract
This study presents a survey on pesticide use, pesticide storage and pesticide disposal among 100 residents near a former pesticide store in rural Georgia using a standardized paper questionnaire. More than one quarter of the participants responded that the age of the pesticides they use is higher than 20 years. Based on this finding, it cannot be excluded that persistent organic pollutants like Dichloro-diphenyl-trichloroethane and hexachlorocyclohexanes still are released to the environment. Knowledge about active ingredients of pesticides is lacking among farmers: More than two thirds state that they know the active ingredients, while less than 10% mention an active ingredient matching the brand name they report. Purchasing pesticides in containers without labels appears to be common practice. Information about the pesticides is mainly obtained from the pesticide retailer, while the label is less important as a source of information. More than 95% of the participants store the pesticides in a separate store, but appropriate possibilities of hazardous waste disposal seem to be insufficient in rural areas in the region. The finding that pesticides are purchased and stored in repacked secondary containers, poses direct risks and hampers communication of risks to users. Improving (implementation of) regulations for pesticide handling and strengthening local knowledge through better vocational training can improve soil and groundwater protection and sustainable use of resources.

Article highlights

- One of the main findings is that residents report using the pesticides for a long time. Not only are the pesticides used way longer than they may remain suitable for use, but also the pesticides could be dating from before international legislation entered into force which was set up to protect from long-lived organic pollutants (the Stockholm Convention). Our results show that often pesticides are repacked and stored in alternative containers such as plastic containers for detergents. This means users cannot find important information on how to use pesticides safely on these alternative containers. The label cannot be used as a source of information for example regarding health risks. This may lead to poisoning of users.
- In Georgia, the transition process results in poor implementation of environmental regulations such as laws about waste management. The results show that educational level has a positive influence on choosing safe

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42452-022-04999-w.

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storage options such as a separate store. The results indicate that especially in rural areas possibilities of proper disposal of old pesticides or other dangerous chemicals are poor. This has implications for the health of residents.

- Efforts to better implement environmental regulations should be strengthened especially in rural areas to overcome the legacy of long-lived pesticides which are now banned. Old pesticides might still be in use because they are difficult to dispose of safely.

Keywords Pesticide use · Waste management · Stockholm convention · Dichloro-diphenyl-trichloroethane · Hexachlorocyclohexanes · Persistent organic pollutant · Risk communication

1 Introduction

1.1 Legacy of persistent organic pollutants

Soils play an important role in attaining the United Nations Sustainable Development Goals. Contamination of agricultural soils is an obstacle for providing food for the world's growing population. In particular, in former Soviet countries in the Southern Caucasus Region the legacy of past pesticide use poses a risk to human health and food safety [1–3]. In this region, organochlorine pesticides like DDT (dichloro-diphenyl-trichloroethane) or HCH (hexachlorocyclohexane) were used excessively in the past. Due to their persistence these pesticides can be found in elevated concentrations on agricultural land, especially at hazardous waste sites where pesticides were dumped [4], in areas around former pesticide distribution centers [5, 6], but also resulting from diffuse contamination, e.g., due to large scale spraying of pesticides with planes in areas of cotton cultivation [7, 8]. Most of the contaminated sites in former Soviet countries are legacy sites with environmental contamination dating back to the past [9, 10]. After the fall of the Soviet Union, beginning nations started to develop legislation also in the field of environmental protection and management of environmental resources. In the early years of the transition, weak capacity and a lack of financial resources available for environmental management and enforcement are reported for several countries in the region [11]. Until today compliance with emerging national and existing international environmental regulations is seen as a challenge and a potential barrier for trade [11]. National and international regulations for authorization, marketing, use and disposal of pesticides differ substantially between countries. In Europe, these issues are thoroughly regulated for pesticides [12] for example through Directive 2009/128EC on sustainable use of pesticides [13] as well as regulation EC 1107/2009 about placing pesticides on the market [14].

1.2 Pesticide use and environmental regulations in Georgia

In Georgia, regulation of pesticide marketing and use is currently under development [15]. In the context of European Neighborhood Policy, Georgia and the EU signed the EU-Georgia Association Agreement in 2014, which entered into force in 2016. This agreement reinforced a process of alignment of policies and legislation to EU standards. Because of the Association Agreement legal regulations for environmental governance, water quality and waste management are currently being set up in the region [15]. Some progress was already made [16], current developments regarding the alignment of environmental legislation are positive. Nevertheless, sustainable use of resources in agricultural, mountain and coastal regions is an issue [17]. Sustainable land use and the implementation and control of waste management remain challenging. Waste and especially hazardous chemicals such as outdated obsolete pesticides require further legislative and regulatory efforts in the Southern Caucasus region [18]. In Georgia, the national waste management action plan was adopted in 2016 [15]. However, the implementation of waste management regulations in rural areas faces obstacles in practice. Currently, waste collection systems are functioning in urban but not in rural areas. Therefore, obsolete pesticides are considered an important waste management issue in the region [19]. In the past high amounts of pesticides were used in Georgia, some authors report that about 30 kg of pesticides was applied per ha agricultural land during the socialist period [20]. Similar values are reported for neighboring countries [6, 21]. Such high application values contributed to pollution of agricultural soils, several hundred µg/kg for the sum of DDT isomers and their most important metabolites are reported for agricultural soils in rural Georgia [20] and several hundreds of µg/kg of HCHs [22]. Organochlorine pesticides were used in high amounts until the ban for use. Legal use of DDT in Georgia ended in the 1980s [20]. In 2012, the total amount of obsolete stockpiles of POPs pesticides in Georgia, mainly DDT and HCHs, was estimated to be 3057 t. The main part of these obsolete stockpiles (2700 t) was buried at Iaghluja landfill, a landfill in use since the ban of organochlorine pesticides in the mid-1970s [23]. A small part of these obsolete stockpiles of pesticides (357 t) temporarily remained at 214 different small former storage locations mainly in rural areas of Georgia [24]. At these abandoned storage locations obsolete pesticide stocks were left in unsafe and unguarded situations, often in immediate vicinity of residential and agricultural land. In the early 1990s during the period of political change and economic decline, reuse of obsolete pesticides from former pesticide stores by local people on agricultural land is reported, also for neighboring countries [23, 25]. To safeguard unsupervised stocks, international projects on clean-up of obsolete pesticide stocks were set up. In the period between 2011 and 2016, obsolete POPs pesticide stockpiles from former pesticide stores have been repacked and collected from these individual stores throughout the country. Subsequently, the pesticides have been transferred to Iaghluja landfill or sent abroad for destruction [26]. However, after the removal of the obsolete pesticide stockpiles, the soil around the former obsolete pesticides stores still contains high amounts of pesticides. In Georgia, concentrations of DDTs and HCHs in soil often exceed maximum allowable concentrations of 0.1 mg/kg by a factor of 4–12 or more [20, 25]. Elevated levels of these substances in soils pose a risk to human health and the environment in the region [5, 7, 27]. Evidence is growing that these hotspots of soil contamination require safeguarding and awareness raising measures, which is recognized increasingly [26, 28]. In an evidence-based assessment of research needs in the region of Eastern Europe and Central Asia, the contamination of the environment with pesticides is shown to be one of the research areas with the largest need for research and capacity building [28]. In Georgia, like in other countries in the Caucasus and Central Asia regions, farming is an important sector, more than half of the population lives in rural areas and a large part of the farms are small and fragmented [29, 30]. Like in other countries in the region, subsistence farming plays an important role. In Georgia, the average farm size is small, usually about 1 ha [29, 31], the contribution of small-scale individual farming to agricultural productivity is high. People running a farm often have not received appropriate vocational training in farming [30] and work individually.

1.3 Education and pesticide use in Georgia

Educational opportunities in agriculture, both vocational and academic are limited in the country [17]. The individualization process of farms also has an impact on available knowledge and knowledge structures in post-Soviet countries. In Georgia, the individualization of farms occurred in a short period between 1992 and 1996 [29, 31]. Several authors emphasize that it is important to take local knowledge and the specific situation of smallholder farms in the region into account [29, 32]. Resources at these smallholder farms are limited, e.g., in terms of financial resources [29, 30, 33], but also with regard to technical equipment and access to knowledge fitting individual needs. Knowledge of farmers is described as outdated, too specialized and too narrow [30] as the farmers partly gained their work experience under the system of large collective farms, where they had specialized functions. In the region this leads to a situation where professional knowledge is lacking in the agricultural sector and traditional knowledge is lost over time. These processes were intensified through the transition after the end of the Soviet Union [34–36]. Individual farms are often run based on practical "every day"- knowledge, which is transferred within the family and related to local farming practice [34]. In the past many projects in the region did not integrate local practical knowledge and the perspective of smallholders sufficiently.

Sound use of pesticides requires knowledge about crops and pests, pesticide application and pesticide disposal. Knowledge and understanding of health risks is an important element of risk management of pesticides on farms. Knowledge regarding safe use and disposal of pesticides on farms is often described as inadequate not only in post-Soviet countries [35]. The educational level as well as attitude of individuals has an influence on pesticide use as well as current exposure of farmworkers and release of pesticides into the environment [37, 38]. In different countries evidence for a positive influence of knowledge about safe use and handling practices is somewhat inconclusive [39]. Observations of positive effects of knowledge about safe use seem to occur more frequently [40] than reports of no effect of knowledge about safe use. It seems that additionally to knowledge more factors can affect pesticide use and handling practices on farm level.

1.4 Rationale of this study

The local situation in the broad sense interacts with knowledge and behavior of the farmer, this comprises local structures of pesticide supply, e.g., whether information on pesticides is easily available or whether technical infrastructure for professional pesticide application is available.

Together local supply structures as well as technical infrastructure and farmers knowledge can affect the pesticide use patterns on farm level [37]. Results of research on influence of knowledge about health effects of pesticides and use of pesticides, as well as pesticide storage and disposal in the Southern Caucasus region are still scarce. To fill this gap, this study addresses local knowledge at farm level regarding pesticide use and handling. Knowledge at farm level about pesticides, sources of information about these products and subsequent waste disposal options are investigated on farm level. Smallholder farms are typical for the region [29, 31], this is why this form of farming is addressed in this study. The situation in rural Georgia can be seen as a case study yielding insights representative for other countries in the region. It is expected to increase understanding of environmental and human health risks of pesticide use among farmers in countries with agricultural transition processes in progress. In Georgia, independence was attained over 25 years ago and the transition process, like in other countries in the region, is still ongoing [41]. Strengthening sustainable use of environmental resources through legislation and corresponding implementation and enforcement has made some progress in the region. But continued efforts are required for pesticide management, especially with regard to enforcement and monitoring [16, 42]. Accessible information and knowledge about pesticide use, pesticide disposal and about alternatives to pesticide use are reported to be limited in the region [42–44]. On farm-level at smallholder farms, pesticide use and disposal practices are influenced by individual decisions about pesticide use and structures of public services and legislation regarding pesticide management. In particular near former storage locations which represent potential hotspots, awareness of farmers and knowledge about health risks of pesticides is important for decision making. The main hypothesis for the present study is that knowledge and education has a positive influence on safe pesticide handling and safe disposal of pesticides at farm level at smallholder farms in Georgia. To investigate knowledge, the educational level as well as knowledge about pesticides and health risks of pesticides are taken into account. Also, the specific issue of potential continued use of old pesticide stocks forms part of the study. Aspects of safe pesticide handling considered here include informed application of pesticides, use of personal protective equipment, safe storage and appropriate disposal of pesticides.

Following the introduction, this article presents the preparation of the questionnaire, the methods of data collection and evaluation. Subsequently, demographic data of the participants are described along with resulting patterns of pesticide use, knowledge about active ingredients, disposal and knowledge about alternatives. This is followed by a discussion and interpretation of the findings regarding farmers' knowledge and sources of information as well as influence of educational level, ultimately recommendations and conclusions are presented. Supporting information for this article presents the list of the questions used in the survey.

2 Methods

2.1 Preparation of questionnaire

The methods were performed in accordance with relevant guidelines. The study including the questionnaire was reviewed by the institutional Ethics Committee at Justus-Liebig University Giessen. A standardized questionnaire was prepared containing 34 closed, half-open and open questions on pesticide use, knowledge about active ingredients, storage and disposal of pesticides as well as past experience of health- and environmental effects of pesticides and remediation. Details regarding the list of questions are available in the supplementary material. This paper reports findings on pesticide use and knowledge about pesticides including storage and disposal (questions 1–21). The questionnaire was set up in three different languages (German, English and Russian). Prior to the field study the Russian version of the questionnaire was pretested with students of Rhine-Waal University of Applied Sciences studying Mobility and Logistics (i.e., studying in a field not related to agricultural or environmental health topics). After the pre-test the questionnaire was finalized.

2.2 Data collection

The study was conducted with a paper-pencil survey within a radius of 5 km around a former pesticide store in the municipality of Marneuli in the Kvemo Kartli Region of Southern Georgia. The legacy of remaining pesticide stocks at the store had been removed in the context of implementation of the Stockholm Convention in Georgia. The topsoil in the immediate surroundings of the former pesticide store is contaminated. Currently, the site is fenced and not in agricultural use. The villages in this area chosen for the survey are considered to represent typical rural villages of the region dominated by smallholder farms. Data were collected by handing out a standardized questionnaire in Russian language to 100 households visited in the area. The data were recorded on several subsequent days in May and June 2018. If required the questions were translated on the spot into Georgian language. Information on age of pesticides used, methods of pesticide storage and disposal was self-reported by the participants. Occasionally storage facilities were checked to see whether self-reported and actual form of storage match.

2.3 Data evaluation

The answers reported for half-open and open questions were categorized. To achieve this, the answers were grouped into categories as shown in Table 1. Frequencies were analyzed with IBM SPSS Statistics 24.Ink. To investigate the influence of education, cross-tables were set up for the variable educational level in combination with other variables (frequency of pesticide use, knowledge about active ingredients, sources of information, protective equipment used, as well as storage and disposal practices and alternatives to pesticide use). Expected frequencies with values higher than five in the cross-table were evaluated with Chi square test, if expected frequencies in the cross-table were lower than five, the exact test according to Fisher was applied [38]. For the number of alternatives to pesticide use and the number of effects of DDT on health, a correlation was calculated. To assess validity of self-reported data, responses regarding specific issues, e.g., affiliation to ownership groups, access to vocational training or waste management options were compared to recent census data for the region [45, 46].

3 Results

3.1 Demography of study participants

Demographic data of respondents show that about half of the respondents were female and half of them were male (Table 2).

The largest part of the participants was 45–64 years old, thus many of the respondents were already in working age at the time before the individualization of farms in Georgia. Almost half of the participants (44%) stated to be farmers, one quarter reported to be employees, about one fifth (21%) reported to be unemployed. Most of the respondents (40%) have an academic degree, whereas the second largest group of the respondents (39%) left school after an intermediate school degree. Over 80% of the respondents report to do farming and or subsistence farming. All participants produce crops. Mainly vegetables and fruit, especially grapes, are grown. The majority of those surveyed (67%) also do livestock farming (mainly cows were mentioned). Statistical tests regarding effects of age or gender did not yield significant results.

3.2 Patterns of pesticide use

Pesticide use is very widespread among the respondents. About half of the respondents reported to use pesticides regularly (47%) or occasionally (47%), whereas only 6% stated that they never use pesticides. Most of the participants (72%) stated that pesticides used are older than 5 years, i.e., substantially older than the recommended shelf life, which usually is two years. More than one quarter (26.8%) stated that pesticides used are even older than 20 years. This means the pesticides potentially date back from a time before the Stockholm Convention has entered into force. These results are shown in Fig. 1. To check whether educational level has an influence on the reported age of the pesticides used, educational data were regrouped into high educational level (A-level and university degree) and low educational level (primary school and intermediate school). Also, the reported age categories of the pesticides were regrouped into three categories of pesticide age (up to 4 years, 5–20 years and more than 20 years). For the dataset obtained, statistical evaluation showed a significant influence of educational level on reported age of pesticides; however the association is weak ($p = 0.036$, Kendall $\tau = 0.122$).

3.3 Active ingredients and sources of information

As shown in Fig. 2, more than 70% of the participants reported to know active ingredients of the pesticides they use. Most of the people who could name active ingredients (71%) had A-levels, this means that respondents with higher educational level were more likely to mention active ingredients than participants with low educational level. The difference between educational levels was significant based on Fisher's exact test ($p = 0.015$). Respondents with higher educational level reported a higher number of active ingredients. When asked about presence of DDT in pesticides used, more than three quarters of the respondents (77%) confirm that they know about DDT in the pesticides used. For eight of the participants the active ingredient mentioned matched the reported brand name of the pesticide, e.g., copper mentioned as active ingredient and Bordo as corresponding brand name or Glyphosate as active ingredient and Roundup as corresponding brand name. Occasional validation of the pesticides used revealed that most of the pesticides were not purchased in original containers, but were repacked in various secondary containers. These secondary containers usually are not labeled (see Fig. 3), which can explain that only one fifth of the respondents reported to be able to name the pesticide used. The most frequently mentioned source of information about the pesticides is the pesticide retailer (39.7%), followed by label (23.3%) and family or friends

Table 1 Categories formed for open questions in the standardized questionnaire on pesticide use in the Kvemo Kartli region (total number of respondents, *N* = 100)

Question number	Topic	Categories
11	Active ingredients	Copper, macronutrients, glyphosate, bifenthrin, sulfur, others
14	Brand or product names	Karate™, Fastac™, Bi-58™, Kuproksat™, others (including Bordo, Talstar™, Ridomil™ and Black Jack)
19	Effect of DDT on environment	Health effects, environmental effects, effects on animal husbandry and agriculture
20	Protective measures	Gloves, face mask, safety goggles, protective clothing
21	Negative effects of pesticides	Health effects, environmental effects, allergies, others

Table 2 Demographic data of study participants of the villages in the surroundings of the former pesticide store (total number of respondents *N* = 100)

	Percentage of respondents	Number of valid answers
Gender		
Male	51	100
Female	49	
Age		
18–24	4	100
25–44	37	
45–64	44	
65 +	15	
Occupation		
Farmer	39	100
Employee	25	
Unemployed	21	
Student	6	
Retired	8	
Other	1	
Educational level		
Primary school	6	100
Intermediate school	39	
High school	15	
Academic degree	40	

(19%), see Fig. 2. There was no significant influence of educational level regarding the pesticide retailer as a source of information. Respondents with high educational level were more likely to report the label as a source of information compared to respondents with low educational level ($Chi^2 = 7.425$, $p < 0.006$). The ingredients and products mentioned were largely synthetic pyrethroids or copper or sulfur-containing substances (see Table 1) and did not include Stockholm Convention POPs.

3.4 Use, storage and disposal

More than two thirds (69%) of the participants stated that they use personal protective equipment (PPE). Among the different forms of PPE, the most frequently mentioned ones are gloves (46%), followed by masks (25%) and goggles (23%). As shown in Fig. 4, almost half of the respondents (48%) reporting to use PPE have a university degree. This means that people with higher educational level more likely reported PPE use (Fisher's exact test results in a significant difference for respondents attending primary school and university graduates, $p = 0.024$). Respondents with higher educational level reported a higher number of different forms of PPE (Chi^2 test value 7.936, one-sided test, $p = 0.0235$). The respondents' ability to report health effects of DDT did not have an influence on PPE use. Most participants (96%) stored the pesticides in a dedicated separate pesticide store, only a small number of respondents reported to store them in a store together with other materials (2%) or in the house (2%). The educational level of respondents had an influence on the selection of storage options (Fisher's exact test, $p = 0.024$). Those respondents with a higher educational level chose for safer storage locations. Inspection of some of the storage facilities showed that the separate pesticide stores are informal inadequate stores such as repacked containers in plastic bags fixed to the ceiling of general storage compartments. In practice this informal way of storing pesticides aims at keeping pesticides out of reach of children and farm animals. However, it is not a safe storage location. Adequate waste disposal options in rural Georgia are limited, only about one third of total generated household waste is collected. In particular, in rural areas suitable disposal options are not available. The most frequently reported options of pesticide waste disposal in this survey were disposal in domestic waste (53.1%) and burning (42.9%). Even though dedicated disposal facilities for hazardous waste are often not available in rural areas, in this survey 15.3% of respondents report this option. People with high educational level are more likely to report disposal via domestic waste than people with lower educational

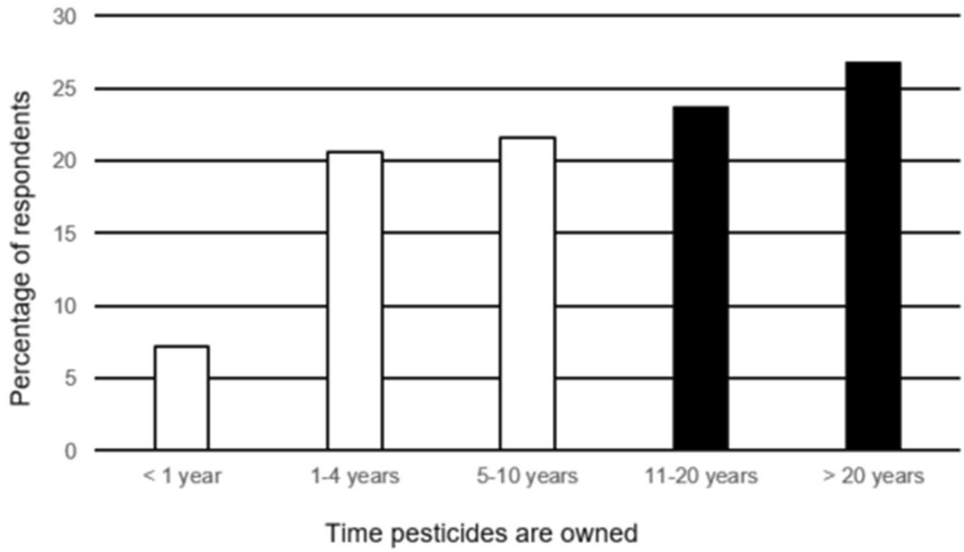

Fig. 1 Period of time for which pesticides belong to the residents (as stated by the residents, $N=97$). Light bars represent time periods after the Stockholm Convention came into force, dark bars represent time periods of more than 11 years. The latter pesticides potentially date back into a time before the Stockholm Convention came into force in Georgia

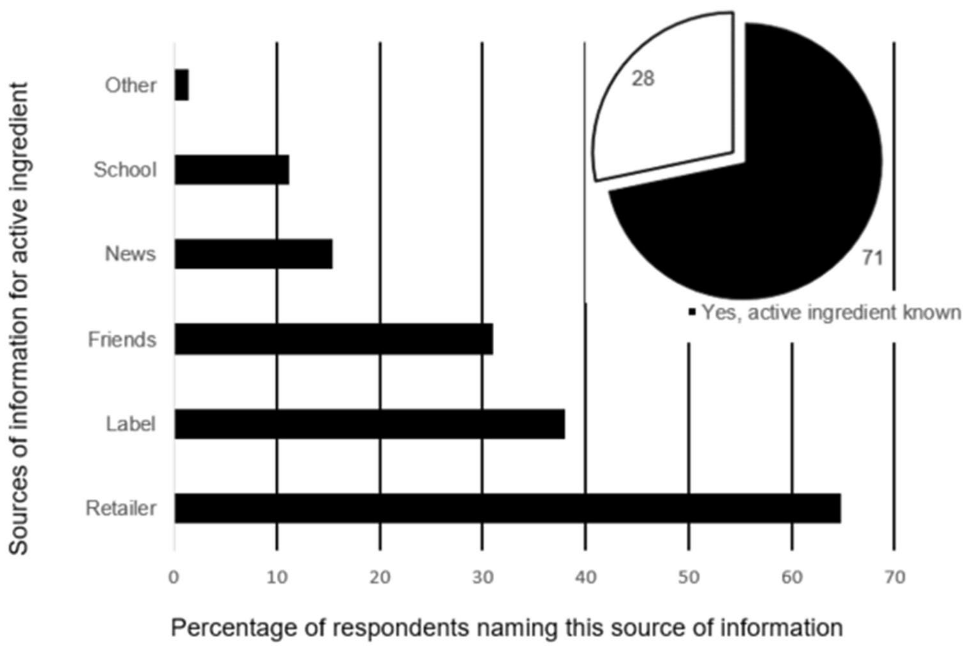

Fig. 2 Percentage of respondents who state that they know the active ingredient of their pesticides and sources of information regarding the pesticides (as stated by the participants). The majority of the respondents reports to know the active ingredients. Retailers are the most important source of information regarding pesticides

level, the influence of educational level is significant based on Fisher's exact test, $p=0.024$. For the option of burning pesticide waste, no influence of educational level could be established ($p=0.645$). These somewhat inconclusive results might reflect insufficient possibilities of adequate disposal options for hazardous waste in the study area.

3.5 Alternatives to pesticide use and environmental effect of DDT

A large part of the respondents had heard of alternatives to pesticide use. Almost half of the participants named organic farming as alternative to pesticide use, about 30% named biological pest control. Only about one quarter of the participants (24.4%), reported not to know alternatives to pesticide use. Educational level did not seem to influence the ability to generally name alternatives to pesticide use, but for the specific alternatives organic farming and biological pest control significant influence of educational level and knowledge about these specific alternatives was found (exact test Fisher, two-sided $p=0.006$ and $p=0.031$, respectively). More than two thirds (71%) of the respondents could provide information as to whether pesticides can be harmful. Also, for this question, an influence of educational level was observed, half of the people who could provide information, have a university degree, whereas

Fig. 3 Photograph of an informal storage facility for pesticides. The pesticides are repacked in secondary containers without labels (taken by A. S.)

only 4.2% of the respondents able to give information left school after primary education. ($p = 0.0005$, Fisher's exact test, one-sided test). The question about effects of DDT on the environment was only answered by about three quarters of the respondents, a majority could not provide information about effects known (no effects known 51%, effects known 27%, not answered 22%). The effects reported were grouped into effects on human health, the environment and agriculture including animal husbandry. Human health effects were reported most frequently here. There was no significant influence of educational level on reported effects on the environment.

4 Discussion

4.1 Pesticide use

Pesticide use is common in the region, but the amounts applied currently are substantially lower than before agricultural transition [20]. The product names mentioned in this survey as well as traditional pesticides such as copper sulfate and sulfur match well with product names mentioned in reports about pesticide use in a neighboring country and other countries in the region [20, 47]. None of the active ingredients self-reported by the participants belongs to the Stockholm-convention POPs such as DDT or HCH [20, 23]. Looking at the reported age of the pesticides, the results show that pesticides are used for a long time, well beyond their shelf life. Shelf life usually is two years if the pesticides are stored in the original unopened container. One important reason seems to be, that financial resources in smallholder farms are limited [29, 33] or available package sizes do not fit needs of smallholder farms. Also, it might be seen as a form of resource efficiency to rather use remaining pesticides as long as possible instead of disposing of old pesticides at the end of the use period. Continued use of old pesticides may lead to continued input of banned pesticides into the environment, mainly the soil. This poses additional threats, because expired pesticides may have lost their effectiveness and thus they may be applied in higher dosage. Even if inefficient due to high age, the substances can still be harmful to human health and the environment. The continued use of old pesticides (which could potentially still contain DDT) is also reported by other authors for the region [11, 23, 47]. Also, the reporting of these familiar names of old pesticides like DDT could be erroneous [47]. Some authors report that based on the presence and concentrations of DDT and degradation intermediates, there is no indication of current input of DDT on agricultural land: For the area where the survey was performed, some authors [20] report ratios for the sum of DDT compared to the sum of DDT and degradation products to be low, which may indicate that there is no recent input of DDT into the agricultural system in the villages surveyed. On the other hand, other authors find indications of recent input and persistence in countries in the region [47]. For another former Soviet country, DDT levels in lake sediments were shown to largely match the period of legal use, whereas for HCHs input on agricultural land after the 1990s might have occurred [48]. The presence of buried remains of formulated pesticides around former storage locations which are released slowly into the environment over time could mimic ongoing input. This stresses the need for more efforts to address the

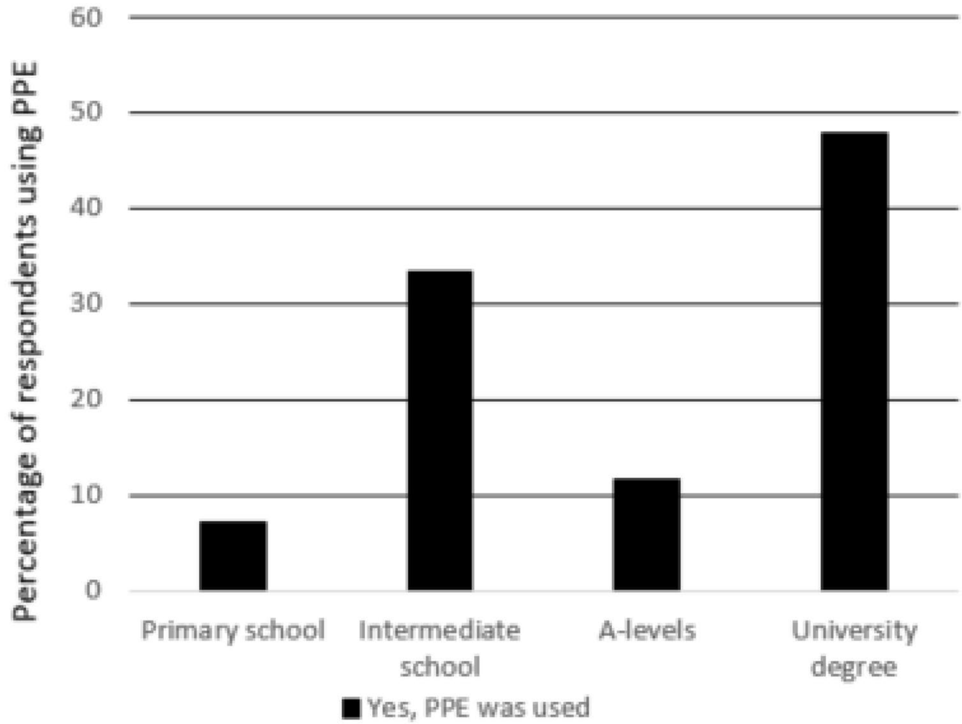

Fig. 4 Percentage of respondents stating that they use PPE. Almost half of the respondents who state that they use PPE have a university degree, among people with A-levels or intermediate school level, only a minority of respondents reported to use PPE (*N* = 100). A detailed version of the figure is given in the supplementary material

environmental situation at former storage locations and to address waste management issues.

4.2 Farmers' knowledge and sources of information

Access to vocational education in rural areas in Georgia is difficult, this holds also for the region of study Kvemo Kartli. Kvemo Kartli is characterized by low access to secondary education compared to the country average [17, 45]. In Georgia, there are large differences between urban and rural areas, in the regions vocational training institutions are accessible to more than half of the villages, whereas for the Kvemo Kartli region, vocational training institutions are accessible for less than 30% of the villages [45]. So it can be concluded that professional agricultural knowledge is not easy to access for the rural population in the study region. This might be a reason why professional knowledge about crops, pests and plant protection is not reflected in current use practices of pesticides in the study area. Pesticide use is very common, even though the majority of participants reported to know alternatives to pesticide use. However, the knowledge about alternatives does not seem to translate into a larger number of farmers not using pesticides. The apparent use of pesticides refilled into secondary containers is also mentioned by other authors, e.g., in a study from an African country [49]. This common practice leads to a lack of specific knowledge about active ingredients, hazards and recommendations for dosage and application. In the study reported here respondents state that they know active ingredients. Detailed structured knowledge about pesticide use would also mean that respondents are able to name an active ingredient which matches corresponding brand names. This ability was studied in two questions of the survey. Only for eight participants the names of active ingredients and the names of brands or products reported by the participants matched. This shows that vital information about the substances used currently does not reach the farmers. In this situation it is difficult to take informed decisions about dosage, application and disposal of the pesticides used. The use of secondary containers means that information of labels is not available on the farm prior to use. Labels are meant to be a universally understandable and easy to grasp concise tool for the communication of pesticide risks. Some authors report these to be a very important source of information [38, 50], and see them as key elements of pesticide risk management [51]. Labels should be consulted by users before buying, storing, using and disposing pesticides [52]. There are numerous reports of safety symbols and or labels not being comprehensible to users [52, 53], aspects causing main challenges differ between countries, in low-income countries difficulties arise from all aspects of the label, high-income countries mainly struggle with technical aspects, PPE and hazard phrases [52]. Risk communication strategies in developed countries do not per se exhibit higher quality than risk communication strategies in less developed countries [54]. But in general, to be a functional element of risk communication the label needs to be present on the container. Furthermore, the text on the container should be given in appropriate language, the users need to have an adequate literacy level and sufficient access to equipment and facilities [50]. However, good practice of risk communication shows that label and pictograms are important, but as a sole tool in risk communication they are not sufficient. To achieve sufficient understanding of relevant issues, label and pictograms actually need to be combined with other methods of risk communication [39, 55]. If, as revealed by this study, labels are not present on the containers, other sources of information are more important such as family, the dealer or retailer, which is the dominant source of information reported here. Further studies have shown that generally more trusted sources often are preferred over information on the label [52], together with friends, family and dealer, the retailer is one of the most important sources of information [56]. So retailers or agricultural advisors could play a role in pesticide risk communication in the region [32], e.g., by offering training or explaining the label. Education and knowledge about pesticides are often reported to positively influence dedicated use of PPE [47, 57]; however, this is not always the case [39]. Sometimes incompliance is reported to be linked to a lack of awareness [39], whereas sometimes also the environmental situation is reported to play a role. There are reports about farmworkers near hotspots of pesticide contamination not using PPE due to lack of training and low awareness of health risks related to pesticide use [58]. Even though the study area of the survey reported here is also located near a former pesticide store, the results of the present study show that the majority of the farmers do use PPE. In this study education positively influences the use of PPE. This corroborates findings of other authors [57–59], who found that education is key to safe handling of pesticides. Also, farm structure (size) as well as access to information about pesticides and training are reported to be important [56, 57, 59], with smaller farm sizes having a negative influence on compliant PPE use. These results underline the importance of adequate training for different types of farms, including smallholder farmers. Furthermore, it is important to note, that PPE actually should be the last option in a hierarchy of measures to control exposure risks of pesticide handlers [51]. A recent review of the role of PPE in the prevention of risks of pesticide use in farming showed that the strong emphasis often placed on compliant PPE use is necessary to obtain authorization to market pesticides. However, the effectiveness of PPE may not be as good as generally assumed [60], also due to the diversity of technical, social and economic conditions of farming in different agricultural sectors and different regions [60]. This again, stresses that other strategies of risk management would be more efficient in risk reduction than strong emphasis on PPE use [51]. Such strategies of risk management include avoidance or banning very hazardous substances and a shift to less hazardous and biological plant protection products. These strategies could be especially useful for individualized smallholder farms.

4.3 Educational level and storage as well as disposal of pesticides

The results presented indicate that educational level has a positive influence on choosing safe storage options for pesticides. A study on pesticide use in rural Africa also showed that storage outside home is related to educational level [56]. In the study presented here, the majority of respondents seeks to store the pesticides in a safe manner, this is also reported elsewhere [61]. However, in many low and middle income countries, pesticides are usually not disposed of safely [38] either because of a lack of awareness [62] or a lack of safe disposal options. In these countries, management of hazardous waste and establishing safe disposal options for hazardous waste requires further efforts to reduce health risks to communities in the surrounding of these locations [63]. Safe waste disposal options are limited in Georgia [46, 64]. Landfills in Georgia including Kvemo Kartli are largely unmanaged [65] and potentially represent environmental risks. This underlines that Georgia needs to take further steps: Out of the four stages of implementing the Stockholm Convention (inventory, preparation of measures, implementation and completion of implementation) Georgia is reported to have accomplished the first two, while continuing efforts are needed to enforce the complete waste chain and to support adequate waste disposal [42]. Also, for other countries in the region, there are reports about poor implementation of waste management legislation and very high environmental concentrations, e.g., in soils due to unmanaged burial of obsolete POPs pesticides [66]. Not only obsolete POPs pesticides, but also out of date pesticides in general are hazardous waste. If it is impossible to dispose of these substances properly after use, reuse of old pesticides might seem to be an option, especially if financial resources on farm level are limited or available container sizes at the shops do not match small scale demand. Another reason for continued use of old stocks of pesticides might be a lack of knowledge about alternatives to pesticide use such as integrated pest management or biological farming.

4.4 Recommendations for the future

Reduced reliance on pesticides and more sustainable use of pesticides require knowledge, e.g., about adequate use and disposal, but also about alternatives to pesticide use such as biological pest control, organic farming or integrated pest management. More detailed knowledge about alternatives to pesticide use could reduce reliance on classical chemical pesticides and lead to more sustainable use of resources. Such knowledge can be transferred in vocational education and other forms of training. Policies to strengthen vocational education should be implemented.

Improving risk communication and risk management can help to strengthen and integrate existing structures into emerging regulations. Retailers and advisors can have active roles in communication of pesticide risks. Policies supporting active roles of retailers and advisors can also further improve the development of private sector activities in agriculture. Both education and training can strengthen more sustainable agricultural activities in the region, as agriculture economically is an important sector in the region. Improving agricultural productivity and professional knowledge in the sector can help to empower local communities. Empowerment is an important prerequisite for further development of rural communities [67].

All three aspects of waste management (strengthening existing regulations, enhancing implementation and enforcement) need further initiatives and resources in the region, e.g., because grazing cattle ranges freely on common land. This holds especially for rural areas where former storage locations represent health and environmental risks for the immediate surroundings. Many of these hotspots in Georgia and other countries in transition are not addressed yet [8]. Further policy initiatives for better hazardous waste management should be launched.

5 Conclusion

The current study provides insight in pesticide use and waste management for a region which is currently not well represented in scientific literature. The results might help to interpret findings on concentrations of DDT and its degradation products or HCHs in soils and sediments in the region. The results also provide insight into the current status of implementation of environmental regulations regarding waste management in rural areas from the perspective of smallholder farmers.

On smallholder farms in the region, pesticides are commonly used for a long time, often well beyond shelf life and partly even long enough that presence of Stockholm Convention pesticides might still be in use occasionally. This has consequences for available information on farm level about active ingredients, health risks and adequate application of the substances. A lack of disposal options and a lack of knowledge about safe disposal may lead to unsafe storage and disposal practices and thereby create further risks for human health and the environment in the future, e.g., through burning of pesticides on-farm. Vocational agricultural training could strengthen knowledge about alternatives to pesticide use and thereby open additional alternative options to chemical pesticide use. This would support the development of sustainable agriculture in the region, reduce dependency on chemical plant protection and improve sustainable use of environmental resources.

Authors' contributions Conceptualization and methodology were performed by DL, R-AD and AS. Formal analysis and investigation were performed by AS, DL and BK. DL and AS were involved in writing—original draft preparation. All authors were involved in writing—review and editing and collected resources. R-AD and DL were involved in funding acquisition. DL and R-AD were involved in supervision.

Funding Open Access funding enabled and organized by Projekt DEAL. The research presented has received funding from Bundesministerium für Bildung und Forschung (Germany) under grant number 01DK17030B which is gratefully acknowledged.

Data availability The main part of the data generated and analyzed has been included in this article. Further information can be made available upon reasonable request to the corresponding author.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no conflict of interest to declare that are relevant to the content of this article.

Consent to participate Informed consent to participate was obtained from survey participants prior to participation.

Consent for publication Consent for publication was obtained.

Ethics approval The Ethical Committee of Justus-Liebig-University waived the necessity of a vote of the Ethical Committee for the study (file number 31/21) as the survey was conducted with anonymous volunteers upon informed consent and addressed a non-personal topic. Data were collected anonymously without recording or referring to the identity of respondents.

References

1. Li YF, Zhulidov AV, Robarts RD et al (2006) Dichlorodiphenyltrichloroethane usage in the former soviet union. Sci Total Environ 357:138–145
2. Aliyeva G, Halsall C, Alasgarova K et al (2013) The legacy of persistent organic pollutants in Azerbaijan: an assessment of past use and current contamination. Environ Sci Pollut Res 20:1993–2008
3. De Lurdes DM, Fuiza A (2013) Exposure assessment to hazardous pesticides – strategies to reduce human and environmental risks. Environmental security assessment and management of obsolete pesticides in southeast europe nato science for peace and security series c: environmental security. Springer, Dordrecht, pp 69–83
4. Ericson B, Caravanos J, Chatham-Stephens K et al (2013) Approaches to systematic assessment of environmental exposures posed at hazardous waste sites in the developing world: the toxic sites identification program. Environ Monit Assess 185:1755–1766
5. Nurzhanova A, Kalugin S, Zhambakin K (2013) Obsolete pesticides and application of colonizing plant species for remediation of contaminated soil in Kazakhstan. Environ Sci Pollut Res 20:2054–2063
6. Dvorská A, Šír M, Honzajková Z et al (2012) Obsolete pesticide storage sites and their POP release into the environment—an Armenian case study. Environ Sci Pollut Res 19:1944–1952
7. Aliyeva G, Kurkova R, Hovorkova I et al (2012) Organochlorine pesticides and polychlorinated biphenyls in air and soil across Azerbaijan. Environ Sci Pollut Res Int 19:1953–1962
8. Abbasov R, Cervantes de Blois CL, Sharov P et al (2019) Toxic site identification program in Azerbaijan. Environ Manag 64:794–808
9. Sharov P, Dowling R, Gogishvili M et al (2016) The prevalence of toxic hotspots in former Soviet countries. Environ Pollut 211:346–353
10. Vijgen J, Weber R, Lichtensteiger W et al (2018) The legacy of pesticides and POPs stockpiles—a threat to health and the environment. Environ Sci Pollut Res 25:31793–31798
11. Turner T (2003) Water and Environment issues in the black, caspian, and aral seas. Probl Econ Transit 46:6–77
12. Handford C, Elliott C, Campbell K (2015) A review of the global pesticide legislation and the scale of challenge in reaching the global harmonization of food safety standards: global harmonization of pesticide legislation. Integr Environ Assess Manag 11:525–536
13. European commission (2009) Directive 2009/128/EC of the European parliament and of the council of 21 October 2009 establishing a framework for community action to achieve the sustainable use of pesticides http://data.europa.eu/eli/dir/2009/128/oj. Accessed 26 Jan 2022
14. European commission (2009) Regulation No. 1107/2009 21 October 2009 concerning the placing of plant protection products on the market, replacing council directives 79/117/EEC and 91/414/EEC. Off J Eur Commun L 309, 24.11.2009, p 1, https://eur-lex.europa.eu/eli/reg/2009/1107/2014-06-30. Accessed 26 Jan 2022
15. Emerson M, Kovziridze T (eds) (2016) Deepening EU–Georgian relations: what, why and how? Rowman and Littlefield International, London
16. Chatrchyan AM, Wooden AE (2005) Linking rule of law and environmental policy reform in Armenia and Georgia. In: Waters CPM (ed) The state of law in the South Caucasus. Euro-Asian Studies, Palgrave Macmillan, London
17. Stiftung B (2018) BTI country report Georgia. Bertelsmann Stiftung, Gütersloh
18. European environment agency (EEA) (2011) European neighbourhood and partnership instrument Georgia country report. https://wedocs.unep.org/bitstream/handle/20.500.11822/9477/-Georgia_Country_Report_EEA-2011GEORGIA_COUNTRYREPORT_2011.pdf.pdf?sequence=3&isAllowed=y. Accessed 26 Jan 2022
19. International Business and Economic Development Center (IBEDC) (2016) Waste management issues in Georgia. Tbilisi: IBEDC. http://ibedc.ge/images/pdf/report.pdf. Accessed 26 Jan 2022
20. Kalandadze B, Matchavariani L (2019) Soil pollution. In: Matchavariani L (ed) The soils of Georgia. Springer, Cham, pp 153–166
21. Sargsyan V, Sargsyan A (2006) Pesticide applications and sustainable agricultural development in Armenia. In: Simeonov L, Chirila E (eds) Chemicals as intentional and accidental global environmental threats. NATO security through science series. Springer, Dordrecht, pp 493–500
22. Simon MP, Knuth D, Böhm L et al (2021) A miniaturized method for fast, simple, and sensitive pesticide analysis in soils. J Soils Sediments. https://doi.org/10.1007/s11368-021-03080-0
23. Sopadze G (2006) Survey of the POPs-related situation in the Republic of Georgia. International POPs elimination project (IPEN) https://ipen.org/sites/default/files/documents/1geo_georgia_country_situation_report-en.pdf Accessed 26 Jan 2022
24. Government of Georgia (2012) Persistent organic pollutants national implementation plan of Georgia 1st edn. Ministry of environment protection of Georgia. http://chm.pops.int/Countries/CountryProfiles/tabid/4501/Default.aspx. Accessed 26 Jan 2022
25. Legashvili I (2008) Persistent organic pollutants (POPs) management in Georgia. In: Mehmetli E, Koumanova B (eds) The fate of persistent organic pollutants in the environment NATO science for peace and security series. Springer, Dordrecht, pp 65–79
26. Government of Georgia (2018) Persistent organic pollutants national implementation plan 2018–2022. COP4 update. Government of Georgia http://chm.pops.int/Countries/CountryProfiles/tabid/4501/Default.aspx. Accessed 26 Jan 2022
27. Tepanosyan G, Sahakyan L, Belyaeva O et al (2020) Studying DDTs in agricultural soils of selected rural communities of Armenia. Acta Geochim 39:487–496
28. Coman A, Cherecheş RM, Ungureanu MI et al (2015) An assessment of the occupational and environmental health needs in seven Southeastern European and West-Central Asian countries. J Epidemiol Glob Health 5:375–384
29. Hornidge A-K, Shtaltovna A, Schetter C (2016) Agricultural knowledge and knowledge systems in post-soviet societies. Peter Lang, Bern
30. Röing T (2016) Creating business mentalities: knowledge and rural development in georgia from a discursive perspective. In: Hornidge A-K, Shtaltovna A, Schetter C (eds) Agricultural knowledge and knowledge systems in post-soviet societies. Peter Lang, Bern, pp 179–200

31. Lerman Z (2004) Successful land individualization in trans-Caucasia: Armenia, Azerbaijan, Georgia. In: Macey D, Pyle W, Wegren S (eds) Building market institutions in post-communist agriculture: land, credit, and assistance. Lexington Books, Lanham, pp 53–75
32. Shtaltovna A (2015) Knowledge gaps and rural development in Tajikistan: agricultural advisory services as a panacea? J Agr Educ Ext 22:25–41
33. Heiny J, Mamniashvili G, Leonhäuser I (2017) The socio-economic situation of private households in the Kazbegi region—first insights based on quantitative data. Ann Agrari Sci 15:31–39
34. Fey L (2016) Which knowledge, which agriculture? local farmers and agricultural development in Georgia. In: Hornidge A-K, Shtaltovna A, Schetter C (eds) Agricultural knowledge and knowledge systems in post-soviet societies. Peter Lang, Bern, pp 93–126
35. Toleubayev K, Jansen K, van Huis A (2010) Knowledge and agrarian de-collectivisation in Kazakhstan. J Peasant Stud 37:353–377
36. Assche K, Hornidge A-K, Shtaltovna A et al (2013) Epistemic cultures, knowledge cultures and the transition of agricultural expertise. Rural development in Tajikistan, Uzbekistan and Georgia. University Center for Development and Research (ZEF), Bonn, pp 18–22
37. Mengistie BT, Mol APJ, Oosterveer P (2017) Pesticide use practices among smallholder vegetable farmers in Ethiopian central rift valley. Environ Dev Sustain 19:301–324
38. Zyoud S, Sawalha AF, Sweileh WM et al (2010) Knowledge and practices of pesticide use among farm workers in the West Bank, Palestine: safety implications. Environ Health Prev Med 15:252–261
39. Yuantari M, Van Gestel CA, Van Straalen NM et al (2015) Knowledge, attitude, and practice of Indonesian farmers regarding the use of personal protective equipment against pesticide exposure. Environ Monit Assess 187:4371
40. Hashemi S, Peshin R, Feola G (2014) From the farmers' perspective: pesticide use and pest control. In: Pimentel D, Peshin R (eds) Integrated pest management. Springer, Dordrecht, pp 409–432
41. Oedl-Wieser T, Dax T, Fischer M (2017) A new approach for participative rural development in Georgia – reflecting transfer of knowledge and enhancing innovation in a non-European Union context. Stud Agr Econ 119:48–54
42. International HCH and Pesticides Association (IHPA) (2016) Improved pesticides and chemicals management eastern Europe, Caucasus, Central Asia https://www.greens-efa.eu/legacy/fileadmin/dam/Documents/Events/2016_09_29_Management_of_agrochemicals/RoadMap-SUMMARY-IHPA-v2-2.1-LR.pdf. Accessed 26 Jan 2022
43. Toleubayev K, Jansen K, Van Huis A (2011) From integrated pest management to indiscriminate pesticide use in Kazakhstan. J Sustain Agric 35:350–375
44. International Pollutants Elimination Network (IPEN) (2020) Production and use of highly hazardous pesticides in Armenia, Kazakhstan, Russia, Ukraine and Uzbekistan: trends and perspectives for transition to safe alternatives. https://ipen.org/sites/default/files/documents/final_overall_hhp_summary_in_5_eecca_countries_18_may_2020.pdf. Accessed 26 Jan 2022
45. Fuenfzig M (2013) Regional disparities in Georgia: evidence from microdata MPRA paper 76694. University Library of Munich, München
46. Geostat (2018) Statistical yearbook of Georgia. National statistics office of Georgia https://www.geostat.ge/media/20931/Yearbook_2018.pdf. Accessed 26 Jan 2022
47. Tadevosyan A, Tadevosyan N, Kelly K et al (2013) Pesticide use practices in rural Armenia. J Agromed 18:326–333
48. Rosen MR, Crootof A, Reidy L et al (2018) The origin of shallow lakes in the Khorezm province, Uzbekistan, and the history of pesticide use around these lakes. J Paleolimnol 59:201–219
49. Ngowi AVF, Mbise TJ, Ijani ASM et al (2007) Smallholder vegetable farmers in northern Tanzania: pesticides use practices, perceptions, and cost and health effects. Crop Prot 26:1617–1624
50. Rother H-A (2018) Pesticide labels: protecting liability or health?—unpacking "misuse" of pesticides. Curr Opin Environ Sci Health 4:10–15
51. Andrade-Rivas F, Rother H-A (2015) Chemical exposure reduction: factors impacting on South African herbicide sprayers' personal protective equipment compliance and high risk work practices. Environ Res 142:34–45
52. Dugger-Webster A, LePrevost CE (2018) Following pesticide labels: a continued journey toward user comprehension and safe use. Curr Opin Environ Sci Health 4:19–26
53. Thao C, Burke N, Ha S et al (2019) Pesticide knowledge, attitudes, and practices among small-scale hmong farmers in the San Joaquin Valley of California. J Integr Pest Manag 10:32–33
54. Klaschka U, Rother H-A (2013) Read this and be safe!' comparison of regulatory processes for communicating risks of personal care products to European and South African consumers. Environ Sci Eur 25:30–48
55. Emery SB, Hart A, Butler-Ellis C et al (2015) A review of the use of pictograms for communicating pesticide hazards and safety instructions: implications for EU policy. Hum Ecol Risk Assess 21:1062–1080
56. Lekei EE, Ngowi AV, London L (2014) Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health 14:389
57. Jørs E, Lander F, Huici O et al (2014) Do bolivian small holder farmers improve and retain knowledge to reduce occupational pesticide poisonings after training on integrated pest management? Environ Health A Glob Access Sci Sour 13:75
58. Quinteros E, Ribó A, Mejía R et al (2017) Heavy metals and pesticide exposure from agricultural activities and former agrochemical factory in a Salvadoran rural community. Environ Sci Pollut Res 24:1662–1676
59. Sapbamrer R, Thammachai A (2020) Factors affecting use of personal protective equipment and pesticide safety practices: a systematic review. Environ Res 185:109444
60. Garrigou A, Laurent C, Berthet A et al (2019) Critical review of the role of PPE in the prevention of risks related to agricultural pesticide use. Saf Sci 123:104527
61. Afshari M, Poorolajal J, Rezapur-Shahkolai F et al (2019) Which factors influence farmers' use of protective measures during pesticides exposure? Workplace Health Saf 67:338–349
62. Tadevosyan N, Poghosyan SB, Khachatryan BG et al (2019) Residues of xenobiotics in the environment and phytotoxic activity in Armenia. J Environ Sci Health A 54:1–8
63. Caravanos J, Gualtero S, Dowling R et al (2014) A Simplified risk-ranking system for prioritizing toxic pollution sites in low- and middle-income countries. Ann Glob Health 80:278–285
64. Clean up Georgia (2012) Report on municipal solid waste management in Georgia Georgian greens/friends of earth Georgia and eco-vision. http://www.cleanup.ge/documents/report_eng.pdf. Accessed 26 Jan 2022
65. Buachidze N, Chikviladze Kh, Kuchava G et al (2019) The impact of some uncontrolled landfill sites on the ecosystems of surrounding areas of eastern and western parts of Georgia. Open J Ecol 9:25–33

66. Ukalska-Jaruga A, Lewińska K, Mammadov E et al (2020) Residues of persistent organic pollutants (POPs) in agricultural soils adjacent to historical sources of their storage and distribution-the case study of Azerbaijan. Molecules 25:1815
67. Schmidt S, Busse S, Nuriyev E (2017) Government and biodiversity governance in post-soviet Azerbaijan: an institutional perspective. Environ Dev Sustain 19:1953–1980