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Research article

Assessment of the generation of empty pesticide containers in agricultural areas

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ABSTRACT

Data about the generation of empty pesticide containers (EPC) is scarce, even in countries where an EPC collection system is applied. In most cases, data refers to the total amount of EPC collected, which is lower than EPC generated depending on the extent of application of the collection project. Moreover, results are not correlated to the kind of crops, area and number of farmers involved, making impossible to use them elsewhere. This study aims at estimating EPC generation indices. It focuses on the indirect assessment of EPC generation based on information given by the agronomists of agricultural supplies stores and agricultural cooperatives (stakeholders) consulting farmers. For the study area (Pella prefecture in Greece), EPC waste production was estimated for arable crops, fruits and vegetables and it was found to range from 0.9 to 35.3 pieces/hectare depending on the crop type. The weight of empty plastic pesticide containers ($EPPC_{weight}$) indices were calculated at 0.97 kg/ha and 4.36 kg/farmer/year which are close to the scarce available literature data. These results can be the basis for the design of an EPC management program in areas where data of this type of wastes is lacking. Other results of this survey indicate that stakeholders (depending on their capacity) could be motivated to organize and operate EPC collection stations as well as to help farmers to comply with the national management plan. Based on the above findings, three alternative scenarios for EPC management are proposed to provide a basis for designing an applicable regional EPC management program.

1. Introduction

Empty pesticide containers (EPC) are the most common agrochemical wastes posing a potential hazard to human health and the environment, since they contain pesticide residues (Jones, 2014). Empty plastic pesticide containers (EPPC) is a subcategory of EPC that can be recycled, and the estimation of their generation rate is of utmost importance for designing EPC management projects. Historically, plastic has been used as a raw material for constructing pesticide containers in the United States since 1970 and has gradually been massively adopted by industries, as the main material for this use. It is relatively inexpensive, it can take various shapes and sizes, it is unbreakable and recyclable (US EPA, 1992). Nowadays, the plastic pesticide containers are made of high density polyethylene (HDPE) or polypropylene (PP) or polyterephthalate (PET) or are COEX multi-layer bottles (Freires, 2010).

Empty pesticide wastes, containing pesticide residues are classified as hazardous waste according to the European waste catalog (EWC). On the basis of the EU Regulation N. 1272/2008 (CLP), the remaining pesticide is a mixture for which the content of the active substance has to be calculated and compared with the eco toxicity limits to be classified as "dangerous" or "non-hazardous" waste (EPA Ireland, 2012). It is obvious that, EPC are "hazardous waste" if residues of "dangerous" chemicals, especially the active substance, remain above the critical levels according to EU legislation. It is expected for containers that previously contained agrochemicals, after a specific triple rinse process even in the most difficult cases, to contain the active substance at less than 0.1% (based on the combined mass of the container and the pesticide residue), which makes containers "non-hazardous waste", following the strictest limits of EWC. They can, therefore, be deposited at collection stations, for recycling or energy recovery. The methodologies for cleaning empty pesticide packaging are triple rinsing, rinse under pressure, rinse in the field and solvent washing for oils (González, 2014). Triple rinsing saves money since the wasting of the agrochemical

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products is reduced, prevents water and soil pollution, minimizes the risk of human exposure to "dangerous" chemicals and it is essential for all management systems (European Commission, 2007; Hellenic Ministry of Rural Development and Food, 2012; FAO and WHO, 2014). Studies show that triple rinsing, is more effective than pressurized rinsing (EPA Ireland, 2012). Although it remains difficult to reduce the pesticide residue below the 1000 mg kg^{-1} container limit for very toxic substances by applying this practice (Huyghebaert et al., 2002), triple rinsing is described as effective in the case of insecticides used in olive cultivation (Karasali et al., 2015). In 1990, the US Environmental Protection Agency presented a study according to which, triple washing of empty packages removes 99.999% of the residues in plastic containers of 1, 2.5 and 5 gallons (US EPA, 1992; US EPA, 2008). Manufacturers set up a protocol for proper triple washing and pressure washing procedures that was officially adopted, after a public consultation.

However, there is no confidence in the results of triple washing by farmers, and trained personnel must check the cleanliness of containers (US EPA, 1992; American Plastics Council, 1994). Farmers in Brazil, believe that small label size and technical terminology, are obstacles in the use of agrochemicals (Recena and Caldas, 2008). Older farmers have difficulty in reading labels on packages, a usual phenomenon at rural areas in China (Fan et al., 2015). As a result, farmers around the world, reject EPC in the fields and even worse, burn them with the possibility of releasing toxic substances, from both pesticide residues and the packaging materials (American Plastics Council, 1994; Reed et al., 2000; Huyghebaert et al., 2002; Recena et al., 2006; Mello and Scapini, 2016). In some cases of poor countries, EPC are used to store products such as water and food (Jones, 2014). Exhaust gas from burning empty HDPE pesticide packages contains dioxins, dibenzofurans (PCDDs/PCDFs), polycyclic aromatic hydrocarbons (PAHs) and suspended solids (PM10 and PM2.5). The presence of herbicide residues even only on the packaging increases in some cases the emissions of PCDDs/PCDFs and PAHs, while there is no influence on the emitted suspended solids (CleanFarms Inc, 2011; Gullett et al., 2012).

EPC management programs have been developed worldwide and applied usually by non-profit organizations under government supervision. Table 1 summarizes information about some of these actions which are official national projects with measurable outcomes, the country of application as well as their official websites. Specific documents provide detailed information on establishing an EPC management system (CropLife International, 2010).

Data of EPC generation and collection in several counties (e.g. USA, Canada, Peru, France, Belgium etc) reported by FAO/WHO (2008) show a discrepancy between generation and collection rates. In the case Brazil, a country with high pesticide consumption, the legislation and successful EPC collection projects resulted in a continuously increasing collection of EPC; from 7800 tons (2003), 15,300–15,700 tons (2004) to 45,000 tons (2015) (Sato et al., 2006; FAO/WHO, 2008; CropLife International, 2015a, b; Labinas and Correa de Araujo, 2016). Sato et al. (2006) reports that the cultivated areas were 62,553 thousand hectares and based on the collection amount in 2004 (15,300–15,700 tons), an estimation of 0.24 ton per hectare was made which is the only index of this kind found in literature. Generally, data of generation or collection of EPC is not correlated with the cultivated area, the crops or farmers involved. The aim of this study is to provide such indices through an indirect methodology, based on the advice given by the professional agronomists to farmers about the agrochemicals they should use to protect their crops. The study area is Pella prefecture in Greece which is mainly an agricultural area whose primary and secondary agricultural production is the main economic sector.

In Greece, agricultural wastes include livestock manure, crop residues agricultural films, fertilizer films, agrochemicals, irrigation materials and parts of agricultural machinery. The management of agro-forest residues and livestock waste is regarded as the responsibility of the producers and is carried out according to the Codes of Good Agricultural Practice (Ministerial Decision 125347/568, 2004). Total quantities of agricultural waste produced were estimated at 10,781,000 tons in 2011, accounting for the 31% of country's total waste production (Hellenic Ministry of Environment and Energy, 2015). However, there is no data available on the quantities of EPC produced. Moreover, improper land disposal and open combustion are common practices (Hellenic Ministry of Environment and Energy, 2015; Damalas et al., 2008; Heliospho Ltd, 2015). Although farmers handle agrochemicals carefully, they do not the same with EPC (Lithourgidis et al., 2016). According to a recent research, more than half of the professional users dispose empty packages in common waste bins, while 19.6% are burned or buried (Hellenic Ministry of Rural Development and Food, 2016). Therefore, this study concludes on various possible scenarios for EPC management based on the professional agronomists' responses in Greece. Moreover, the estimated EPC generation indices, can be used to make rough estimations on the anticipated generation EPC quantities in the absence of pilot collection projects (or in combination with them), which may help in designing the EPC management programs more effectively.

2. Materials and methods

Sixty-eight agricultural supplies stores (60% of the total) and fourteen co-operative organizations (51% of the total), participated voluntarily in the first part of the survey (totally 82 entities). Both categories of stakeholders (stores and co-operative organizations) employ

Table 1
EPC management projects.

Project	Organization	Country	Source
EPC recycling	Ag Container Recycling Council ACRC	U.S.A	FAO/WHO (2008); CropLife International (2015a, b); ACRC
EPC recycling	CleanFARMS	Canada	CropLife Canada; CleanFARMS
EPC recycling	DrumMUSTER	Australia	CropLife International, 2015a, b; DrumMUSTER
Campo Limpo	InPeV	Brazil	Sato et al., 2006; FAO/WHO, 2008; CropLife International, 2015a, b; Labinas and Correa de Araujo, 2016
Agrolimpio	CASAFE	Argentina	CropLife International, 2015a, b
AgriRecover	Phytofar	Belgium	Phytofar
EPC collection	ADIVALOR	France	ADIVALOR; EPRO
EPC recycling	PAMIRA	Germany	FAO/WHO, 2008; EPA Ireland, 2012; CropLife International, 2015a, b
Fee-per-bag collection service	Irish Farm Film Producers Group's (IFFPG) and Farm Plastics Recycling Ltd	Ireland	IFFPG
EPC recycling	Sigfito Agroenvases SL	Spain	SIGFITO
EPC recycling	STORL	Netherlands	CropLife International; STORL
Disposal to a waste or recycling contractor	The Voluntary Initiative	United Kingdom	The Voluntary Initiative
EPC recycling	Green Dot Cyprus Public Co. Ltd	Cyprus	Green Dot Cyprus Public Co. Ltd