Small Ruminant Research 135 (2016) 66–74

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Review article

# Sheep farming and the impact of environment on food safety☆

G. Scortichini[a,*], M. Amorena[b], G. Brambilla[c], R. Ceci[d], G. Chessa[e], G. Diletti[d], M. Esposito[f], V. Esposito[g], V. Nardelli[h]

[a] Istituto Zooprofilattico Sperimentale dell'Umbria e delle Marche, 06126 Perugia, Italy
[b] Facoltà di Bioscienze e Tecnologie Agro Alimentari e Ambientali, Università degli Studi di Teramo, 64100 Teramo, Italy
[c] Istituto Superiore di Sanità, Reparto di Chimica Tossicologica, 00161 Roma, Italy
[d] Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise, 64100 Teramo, Italy
[e] Istituto Zooprofilattico Sperimentale della Sardegna, 07100 Sassari, Italy
[f] Istituto Zooprofilattico Sperimentale del Mezzogiorno, 80055 Portici, Napoli, Italy
[g] ARPA PUGLIA, Dipartimento di Taranto, 74123 Taranto, Italy
[h] Istituto Zooprofilattico Sperimentale della Puglia e Basilicata, 71121 Foggia, Italy

ARTICLE INFO

*Article history:*
Available online 19 December 2015

*Keywords:*
Sheep
Dioxins
Food safety
Food security
Environment

ABSTRACT

Sheep flocks are sensitive to the top soil intake, via their grazing activity and the ingestion of soil particles incorporated into the hay especially during harvesting operations. Such intake is estimated between 2 and 20% of the dry matter from grass and hay and may vary accounting for seasonal and geographical differences in the quality of pastures. The persistent organic pollutants accumulated in soil such as polychlorodibenzo-*p*-dioxins and -furans (PCDD/Fs), and dioxin-like polychlorinated biphenyls (DL-PCBs), may transfer through the food chain. In this paper, the authors consider the quality of soils and the toxicokinetic factors that allow the transfer of the contamination to milk and the edible tissues in sheep. The wide range of PCDD/F concentration reported in milk (0.05–30 pg $WHO_{1998}$-TEQ/g fat), meat (0.18–4.9 pg $WHO_{1998}$-TEQ/g fat) and liver (4.8–161 pg $WHO_{1998}$-TEQ/g fat) from extensively reared flocks in areas of European countries under different industrial and urban pressures, indicate the opportunity to adopt risk management options based on environmental quality standards and good agriculture practices, able to support the access to a safe and nutritious food. With respect to the PCDD/F and DL-PCB intake, liver represents the most contaminated food item, for its ability to bind such lipophilic contaminants irrespective of its lipid content. Case-studies from the Mediterranean area are illustrated, to support the environment and health approach also in terms of sustainability of family farms production.


## 1. Introduction

Sheep production has many potential outputs, such as milk, meat, skin, wool. In 2012, the Food and Agriculture Organization of the United Nations (FAO) estimated a world sheep milk production of 10.52 million tons against a sheep meat production at 13.76 million tons (FAO, 2015). Most sheep milk is produced in the Mediterranean region, and most dairy sheep breeds are found in this region and the Near East. On the contrary, meat production is more relevant in Asia and Oceania. More than half of the world's sheep population is in developing countries: 39% in Asia, 20% in Africa, 16% in Oceania, against 15% in Europe, and 10% in America. The worldwide sheep density reports area with >250 heads/km$^2$ in the Mediterranean and North Africa regions, in the United Kingdom, Mid- and Far-East, in New Zealand, and in some districts of Australia (Fig. 1).

Sheep are of great importance as a major source of livelihood of the small farmers and the landless in rural communities. This highlights the potential impact of the management of the sheep rearing on food safety and on food security issues in some districts. In rural and extensive farming systems, the strong interaction of sheep with the environment makes the environmental quality of soils, air, and sediments related to water supply, a key factor to guarantee a safe and secure alimentary intake of sheep derived foods. Food of animal origin represents the main source of exposure for the general population to persistent organic pollutants such as dioxins and polychlorobiphenyls framed within the Stockholm Convention adopted under the coordination of the United Nations Environment Program (UNEP, 2001). In this paper, we wish to bring the Italian

☆ This paper is part of a Special Issue entitled "SIPAOC Conference 2014". Guest Edited by Annunziata Giangaspero, Agostino Sevi and Maria Manfredi.

* Corresponding author.
*E-mail address:* g.scortichini@izsum.it (G. Scortichini).

http://dx.doi.org/10.1016/j.smallrumres.2015.12.013
0921-4488/

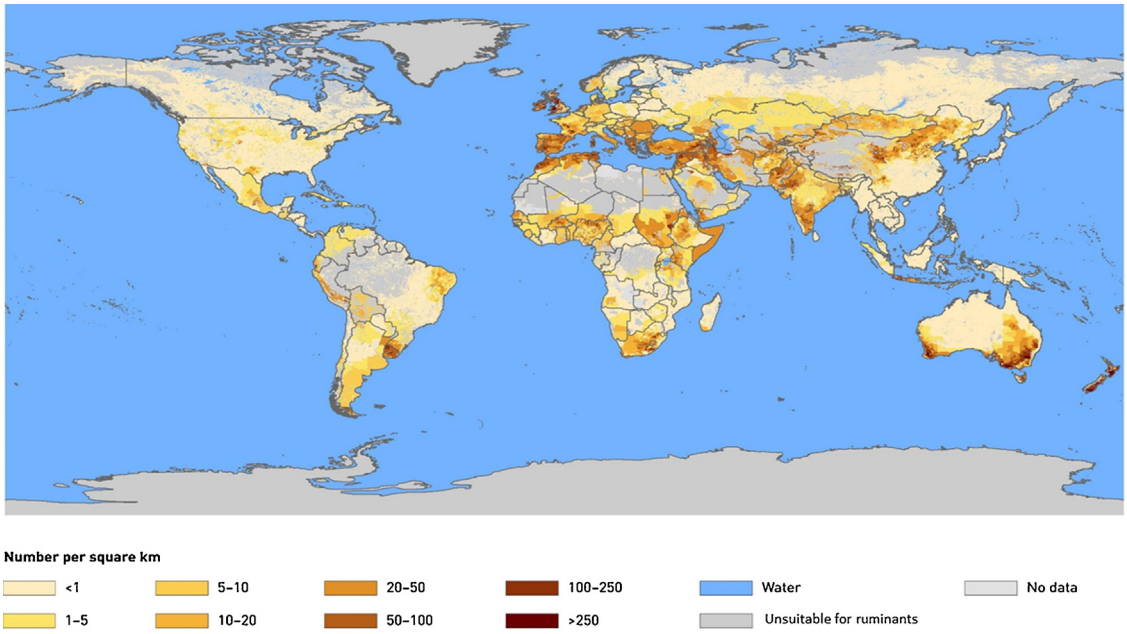


**Fig. 1.** Density of the sheep stocks all over the world. Data referred to 2005 census.
(Source: FAO, Animal Production and Health Division. Available at: http://www.fao.org/ag/againfo/resources/en/glw/Density_maps/sheep_census-2005.jpg)

knowledge and experience about the environmental exposure of sheep flocks to PCDD/Fs and DL-PCBs into a worldwide scenario, to illustrate the potential consequences of the environmental quality of soils, including pasture and derived forages, on food safety and food security.

## 2. Food and feed risk management

### 2.1. Hazard assessment

Dioxins is a term used for a selected group of 210 chlorinated compounds consisting of two subgroups, the polychlorinated dibenzo-*p*-dioxins (PCDDs, 75 congeners) and the polychlorinated dibenzofurans (PCDFs, 135 congeners), characterized by resistance to metabolic degradation and bioaccumulation in human and animal fatty tissues. Among congeners, only 17 have significant toxicity because of the substitution of hydrogen with chlorine atoms at least in the 2,3,7,8-positions (van den Berg et al., 1998, 2006). The polychlorobiphenyls (PCBs) are a group of 209 related compounds, among which 12 congeners exhibit dioxin-like properties in terms of persistence and effects.

The presence of dioxin-like compounds in the environment occurs principally as a result of anthropogenic sources. In most cases contamination with PCDD/Fs results from their formation as undesirable by-products from incineration, combustion, industrial and accidental sources, and their mobilization from contaminated soils or sediments (Kulkarni et al., 2008; Weber et al., 2008). As concerning PCBs, they were mainly used in the past as lubricants by the power industry in electrical transformers, capacitors, hydraulic equipment. Current sources of these compounds are accidental releases of products or materials containing PCBs, landfills, open burning of products containing PCBs, waste incineration and revolatilization of previously released PCBs from environmental reservoirs (Breivik et al., 2002).

These compounds have a similar toxicological profile to that of the most toxic congener (2,3,7,8-TCDD) that brings about a wide variety of toxic and biochemical effects via aryl hydrocarbon receptor (AhR)-mediated signaling pathways. The AhR is a key transcriptional regulatory protein involved in the gene expression encoding for enzyme associated with xenobiotic metabolism (Mandal, 2005). The toxic responses include dermal toxicity, immunotoxicity, carcinogenicity, and adverse effects on reproduction, embryo development, and endocrine functions (IARC, 1997; Lundqvist et al., 2006; Schecter et al., 2006; Yamada et al., 2006; Cordier et al., 2010; Imura et al., 2010; Puga, 2011; IARC 2012).

The lipophilicity and low biodegradability of dioxin-like compounds determine their ubiquitous presence in the environment and their passage in the food chain, mainly in the fatty tissue of animals. More than 90% of human exposure to dioxins is through the food supply, mainly meat and dairy products, fish and shellfish, whereas animals can accumulate dioxins through ingestion of contaminated feed, vegetation and also from roughage directly exposed to the air (SCF, 2001; Costera et al., 2006).

### 2.2. Risk management

A series of incidents related to dioxins and PCBs in the feed and food chain occurred in the 1990s and the related potential over-exposure of a considerable part of the European population with respect to the guidance values for chronic alimentary intakes, induced the European Union (EU) Commission to develop a strategy to reduce the presence of dioxins and PCBs in the environment and in the food chain. The legislative measures comprised maximum levels and action levels for feed and food to bring most of the population below a tolerable weekly intake (TWI) (SCF, 2001; Malisch and Kotz, 2014).

Maximum levels were first set for PCDD/Fs according to the principle “strict but feasible” and based on background levels, then extended to the sum of PCDD/Fs and DL-PCBs (EC, 2001, 2002, 2006a,b). Action levels acting as an early warning system of higher than desirable levels were set for PCDD/Fs and for DL-PCBs separately because they are emitted from different sources. Action levels are designed to prompt competent authorities and operators to identify a source of contamination and to take measures for its reduction or elimination.

Food and feed limits, as well as health based guidance values, are expressed as toxic equivalent (TEQ) calculated by multiplying each dioxin-like compound concentration to their respective toxic