Legal measures to prevent and manage soil contamination and to increase food safety for consumer health: the case of Spain

Francisca Ramón [a,1], Cristina Lull[b,1,*]

[a]Department of Urbanism, Universitat Politècnica de València, Camí de Vera s/n, E-46022 Valencia, Spain

[b]Research Institute of Water and Environmental Engineering (IIAMA), Universitat Politècnica de València, Camí de Vera s/n, E-46022 Valencia, Spain

[*] Corresponding author. *E-mail:* clull@upvnet.upv.es

[1]Both authors contributed equally to this work.

Abstract

This article contains a brief overview of the European and Spanish environmental law framework for the prevention of soil contamination, for the management of contaminated soils and for consumers health protection in relation to agricultural crops. Some important aspects of the legislative framework for the prevention and management of soil contamination include recognising the possible risk to both human health and ecosystems that certain agricultural and industrial activities pose given the use of organic and inorganic chemical substances of a hazardous nature and pathogenic microorganisms. It is worth highlighting the milestone that many national constitutions include about the right to the environment. This right entails the obligation to protect it and to, therefore, protect soil from any degradation, including contamination. Legislation that protects soil from contamination and, consequently human health and ecosystems, is related mainly to agricultural activities (use of sewage sludge on farmlands, use of wastewater for irrigation, use of organic

fertilisers and pesticides), and to industrial and commercial soil-contaminating activities. Consumer protection may be achieved through a legal system of environmental liability, specific measures to prevent contaminants entering soil, managing contaminated soils and a food traceability system. It is crucial to make the penalties for soil contamination offenses, and for violators of protective prohibitions, effective, proportionate and dissuasive. Global standards and guidelines on soil contamination could provide national legislative systems with substantive and procedural legal mechanisms to help prevent and manage soil contamination.

Main finding of the work

A sound legal framework for soil contamination prevention and management is not only critical for food production and food safety, but also for soil conservation and human health.

Keywords: soil contamination, legislation, human health, ecosystems, risk assessment

1. Introduction

The environment includes ecosystems and natural biotic and abiotic resources, such as air, water, soil, fauna and flora, and the interaction among these factors (Barboza, 1995). Humankind all over the world is confronting tremendous environmental challenges that come in the form of global warming, deforestation, desertification, contamination and loss of biodiversity (Leib, 2011). The degradation of the environment affects human health, our livelihood and ecosystems.

Environmental pollution and food safety are two of the most important issues of our time. Soil contamination is a common worldwide concern because soil is a major food production resource, and it supports each country's prosperity and security. Moreover,

the consequences of soil contamination negatively affect the environment, human health, food safety, and soil and water quality (Lu et al., 2015; Zeng et al., 2015; Zhang et al., 2015; Ma et al., 2016; Rodrigues and Römkens, 2018).

According to Tóth et al. (2016), soil plays a central role in food safety as it determines the possible composition of food and feed at the root of the food chain. Soil contaminants pose an important threat to human health as they may enter the food chain and make crops unsafe to be eaten (FAO and ITPS, 2015). Many articles have dealt with the soil contamination and food safety issue, mainly in relation to heavy metals in agricultural soils (Lu et al., 2015; Hussain et al., 2019; Rai et al., 2019). For example, He et al. (2019) studied heavy metal contamination in a soil-rice grain system in Wenling (China) and found that farmland soil could pose potential risks to ecosystems, food safety and, ultimately, to human health. These authors observed moderate contamination by Cd, Cu, Zn and Ni in soil and that 20.7% of rice grain samples exceeded the Cd threshold value. Likewise, Mao et al. (2019) studied the concentrations of heavy metals in soil, and in rice shoot and rice grain samples in the Yangtze River Delta area (China). They found that > 50% of soil samples were contaminated by high Cd and Zn levels. Some grain samples exceeded the As concentrations set by a government standard for grain, while the Cu and Zn levels fell within a range that could potentially cause health problems.

Around the world, a wide range of industrial activities, waste disposal in uncontrolled landfills, mining, applications of agrochemicals, sewage sludge, and livestock waste, and environmental accidents, have left a legacy of contaminated sites (Mirsal, 2008; Li et al., 2017; Cachada et al., 2018; Gómez-Lavín et al., 2018; Gu et al., 2018; Romero-Baena et al., 2018). Contaminated soil can be found in agricultural land, forests, and urban and industrial areas (Li et al., 2018; Sun et al., 2018). Some soil contaminants that have caused concern are polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCBs),

dioxins and furans, pesticides, heavy metals, radionuclides, and pathogenic microorganisms. New soil contaminants, such as nanomaterials, veterinary medicines, microplastics and surfactants, have emerged with industrialisation and globalisation (Liu et al., 2013; Valentín et al., 2013; Hu et al., 2018a; Khelfi, 2018; Loureiro et al., 2018; Rillig and Bonkowski, 2018).

In the Revised World Soil Charter (FAO, 2015), among the Guidelines for actions taken by Governments we find the establishment and implementation of regulations to limit contaminants from accumulating beyond set levels to safeguard human health and well-being, and to facilitate the remediation of contaminated soils that exceed these levels when they pose a threat to humans, plants and animals.

To protect soil against the threat of soil contamination, countries should have effective laws that provide a legal basis to prevent and manage soil contamination. According to Van Liedekerke et al. (2018), "management includes tasks such as setting up an inventory, investigations, risk assessment and remediation, and the establishment of recommendations on land use (restrictions)". These laws and regulations need to be supported by a clear management framework to guide all those involved in soil contamination prevention, the management of legacy soil contamination, and the remediation of future contaminated soils.

Soil contamination regulations should at least address the: i) protection of clean soils, especially the soils used for farming and forestry. Hence it is essential to monitor soil quality; ii) remediation of contaminated sites and legacy sites; iii) optimisation of the use of remediated or cleaned-up soils; iv) establishment of quality standards for both soil and groundwater; v) assessment of human and ecosystem risks; vi) definition of liability systems; vii) funding mechanisms to insure that the law is applied and to build capacity;

viii) offer of technical guidance (CCICED, 2015). Furthermore, the legal system should also address the soil chemical, biological and radiological contamination types.

A soil quality assessment is a key instrument to manage soil contamination. According to Bone et al. (2010), the effects of anthropogenic contamination can be assessed by monitoring soil quality indicators over time. Typically, a soil quality assessment has looked mainly at chemical properties, measured by chemical indicators (Bone et al., 2010). Filip (2002) states that in order to prevent negative ecological consequences, microbiologically-related parameters should be involved in the indication of soil quality. Other soil quality assessment approaches involve using pollution indices (Kowalska et al., 2018), screening values, and risk assessments of terrestrial and aquatic ecosystems and human health (Swartjes et al., 2008; Rodrigues et al., 2009), etc.

The Revised European Charter for the Protection and Sustainable Management of Soil provides several recommendations to prevent soil contamination and to promote the restoration and rehabilitation of contaminated soils (Box 1) (Council of Europe, 2003). The basic underlying principles in any soil contamination legislation are the prevention principle, the polluter-pays principle and the rehabilitation-reclamation principle. Nowadays, contamination prevention in industry generally draws more attention. However, efforts in the agricultural sector are just as important. The polluter-pays principle should be followed to establish a liability mechanism. The rehabilitation-reclamation principle states that it is the responsibility of the present-day society to repair as much as possible the damage that has resulted from past errors rather than passing it on to future generations.

The international community has established global regimes to minimise pollution from hazardous chemicals and waste, and to support countries to take measures to fulfil this objective (Petrović et al., 2014; FAO, 2018). The China Council for International

Cooperation on Environment and Development states that the recommendation of developing a Law about Soil Environment Protection in China is based on the lessons learnt from other countries' soil environment legislative experience (CCICED, 2015).

It is worth highlighting the studies conducted by Kovalick and Montgomery (2014, 2017), which summarise the rationale and the major policy, legislation, regulatory, implementation and organisational issues involved in creating a contaminated site programme, especially for low- and middle-income countries.

2. A right-based approach to a healthy clean environment, and to adequate food

The "right to environment" is considered a solidarity or collective right. Leib (2011) categorised substantive environmental rights into six subrights: the rights of nature, the right to a clean environment, the rights to natural resources, the right to water, the right to food and, Indigenous land rights. The right to a clean environment is related with preventing pathogens, toxins and contaminants entering soil that may post a high risk for ecosystems and human health.

There is no doubt that humanity has taken a giant step forward in environment matters. Today the concept of a human right to a healthy environment is widely recognised in international law and endorsed by an overwhelming number of countries (Boyd, 2012). According to Boyd (2012), the constitutions of 177 of the 193 UN member nations recognise the right to a healthy environment, environmental legislation, court decisions or the ratification of an international agreement. The right to a suitable environment is a statutory right in most national constitutions. In 1976 and 1978, Portugal and Spain were respectively the first countries to include the right to a healthy environment in their constitutions (Boyd, 2012). Article 66 of the Portuguese constitution states, "1. Everyone has the right to a healthy and ecologically balanced human living environment and the

duty to defend it. 2. In order to ensure the right to the environment within an overall framework of sustainable development, the state, acting via appropriate bodies and with the involvement and participation of citizens, is charged with: a) Preventing and controlling pollution and its effects and the harmful forms of erosion", and Article 45 of the Spanish constitution states "1. Everyone has the right to enjoy an environment suitable for personal development, as well as the duty to preserve it. 2. The public authorities shall safeguard rational use of all natural resources with a view to protecting and improving the quality of life and preserving and restoring the environment, by relying on essential collective solidarity. 3. Criminal or, where applicable, administrative sanctions, as well as the obligation to make good the damage, shall be imposed, under the terms established by the law, against those who violate the provisions contained in the previous clause".

Therefore, the protection of soils, as an integral part of the environment, from contamination is a duty. It should be noted that soils are finite natural resources that can be considered non-renewable within the time frame of human activities (Breure et al., 2018). The right to natural resources constitutes, along with the right to a clean and healthy environment, the building blocks of environmental rights (Leib, 2011). Nowadays, many countries recognise the right to an 'unpolluted', 'clean' and healthy environment and, consequently, to clean soils.

Another right related to healthy soils is the right to adequate food. General Comment 12 of the UN Committee on Economic, Social and Cultural Rights (CESCR) of 1999 defines the right to adequate food as the right of everyone to have physical and economic access at all times to adequate food or to means of its procurement. The UN Committee considers that the core content of the right to adequate food implies the availability of food in a quantity and quality sufficient to satisfy the dietary needs of individuals, free from

adverse substances and acceptable within a given culture. The right to food is protected in Article 25 of the Universal Declaration of Human Rights, in Article 11 of the International Covenant on Economic Social and Cultural Rights, and in Article 24 of the Convention on the Rights of the Child. Article 24.2(c) states that "To combat disease and malnutrition, including within the framework of primary health care, through, inter alia, the application of readily available technology and through the provision of adequate nutritious foods and clean drinking-water, taking into consideration the dangers and risks of environmental pollution".

Article 51 of the Spanish constitution stipulates that public authorities shall guarantee the protection of consumers and shall, by means of effective measures, safeguard their safety and health. Article 43 recognises the right to health protection and proclaims the competence of public authorities to protect public health by means of preventive measures. According to the last two articles, public authorities should prevent soil contamination in order to protect human health.

Since air and water quality are inextricably associated with soil properties, the latter should be considered to form part of the "right to environment" and the "right to adequate food", especially if we take into account that soils contribute to biodiversity and are the basis for food production.

3. Supranational soil contamination instruments: the case of the European Union

Although an explicit European Union (EU) policy that focuses on soil protection does not exist, there is a wide range of EU legal instruments for soil contamination prevention. The European Commission (EC) considers that soil protection in this stage can be best achieved via a strategy based on: 1) integration into other policies: mainly environmental,

199 agricultural, regional development, transport and research policies; 2) soil monitoring; 3)
200 the future development of new actions based on monitoring results (EC, 2002).
201 The EU legislation that is relevant mainly for soil contamination prevention is:
202 - Community legislation on water (such as Nitrates Directive (91/676/EEC) and Water
203 Framework Directive (2000/60/EC)) sets standards to prevent surface and groundwater
204 from being contaminated by hazardous substances or excessive nutrients leaking from
205 soils.
206 - Community legislation on air pollution includes Directive 2008/50/EC on ambient air
207 quality and cleaner air for Europe, Directive 2004/107/EC on arsenic, cadmium, mercury,
208 nickel and polycyclic aromatic hydrocarbons in ambient air, and Directive 2001/81/EC
209 on national emission ceilings for certain atmospheric pollutants. Contaminants in polluted
210 air due to emissions from industry, traffic and agriculture most likely reach soil directly
211 or with precipitation, and include heavy metals (e.g. cadmium, lead arsenic, mercury),
212 soils-acidifying contaminants (e.g. SO_2, NO_x), and several organic compounds (e.g.
213 dioxins, PCBs, PAHs) (EC, 2002).
214 - Most directly linked to soil contamination prevention is Directive 86/278/EEC on the
215 protection of the environment, particularly soil, when sewage sludge is used in
216 agriculture.
217 - In more general terms, the Waste Framework Directive (2008/98/CE) requires waste is
218 to be disposed without endangering soil.
219 - The objective of the Landfill Directive (1999/31/CE) is to prevent or reduce as much as
220 possible negative effects on the environment, particularly the contamination of surface
221 water, groundwater, soil, air and human health. Soil protection is achieved by combining
222 geological barriers and the collection of leachates.

- Further specific waste legislation, such as the Waste Incineration Directive (2000/76/EC) and the Urban Waste Water Directive (91/271/CEE), may contribute to prevent soil contamination.

- The purpose of the Environmental Liability Directive (2004/35/EC) is to establish a environmental liability framework based on the polluter-pays principle to prevent and remedy environmental damage.

Recently, Paleari (2017) assessed the soil protection status in EU environmental legislation.

4. National soil contamination instruments

Over the past four decades, many countries have introduced policies and practices to manage contaminated soil (Castelo-Grande et al., 2018). Strategies to deal with soil contamination are being developed through a variety of regulatory systems. Only in the 1970s and from that time onwards, and in response to severe damage to human health and the environment due to soils being polluted by waste, countries all around the world have begun to enact laws to both protect clean soils and to clean up existing contaminated sites (CCICED, 2015). Currently, an international common practice exists to develop laws and regulations that protect soils. Some of these regulations are the Comprehensive Environmental Response Compensation and Liabilities Act (CERCLA) in the US, Part 2A of the Environmental Protection Act 1990 in the UK, the Recommended Canadian Soil Quality Guidelines in Canada, the Soil Protection Act in the Netherlands, the Code in the Environment (Legislative Decree No. 152/2006) in Italy, the Contaminated Soil Act No. 895/2015 in Denmark, the Law on the Remediation of Contaminated Sites (ALSAG 1989) in Austria, and the Soil Contamination Countermeasures Act in Japan and the most recent amendments. The legal basis for soil protection in Germany is the

Act on Protection against Harmful Changes to Soil and on Rehabilitation of Contaminated Sites (Federal Soil Protection Act 1998) and the Federal Soil Protection and Contaminated Sites Ordinance (1999). In China, an Action Plan for the Prevention and Control of Soil Pollution was published in 2016 (Hu et al., 2018b) and the Soil Pollution Prevention and Control Law came into force in January 2019 (Li et al., 2019). Many other countries are preparing regulations for contaminated soils, such as Colombia (Arias Espana et al., 2018).

Rodrigues et al. (2009) reviewed and analysed several national contaminated land policy regimes that were already in place to assess common elements and to identify specific needs for developing of national soil policies. Li et al. (2017) reported advanced legal strategies to prevent soil contamination in the US, the Netherlands and Great Britain. Swartjes et al. (2012) reviewed the state of the art of contaminated site management in the Netherlands regarding policy framework and risk assessment tools. Li et al. (2017) collected contaminated site management policies from 31 regions in China.

Obviously, legislation and regulations on soil contamination are tailored to each country's views and needs.

5. National soil protection towards soil contamination prevention and management, and to protect consumer health: the case of Spain

Soil degradation should be avoided by taking regional, national and European measures. The numerous EU provisions must be implemented into national law. In Spain, the State has the exclusive competence over basic legislation on environmental protection, without prejudicing the powers of Spanish Autonomous Communities to take additional protection measures. Box 2 is an overview of legal instruments that protect soils from contamination and consumer health in Spain.

5.1. Environmental Liability

Establishing a clear liability system is basic to clarify the responsibilities for the remediation of legacy, current and future contaminated sites. In 2007 the Law 26/2007 on Environmental Liability was enacted in Spain. It includes an administrative regime on environmental liability. It defines land damage as contaminated land that poses a significant risk for human health due to chemical or biological pollution because of organisms or microorganisms. This law develops on Article 45 of the Spanish constitution on the rational use of natural resources, and two fundamental principles of EU legislation on the environment come into effect: the principle of prevention and the polluter-pays principle. This law expects companies to respond to the damage caused to natural resources, such as soil, water, wildlife and protected habitats, riverbanks and rivers, but risks to people are not explicitly considered in it. In 2008 the Spanish Government adopted Royal Decree 2090/2008, which enacts the partial implementation of the regulations of the Environmental Liability Law 26/2007. In 2014 the Government approved Law 11/2014 by amending Law 26/2007. Law 11/2014 introduces a new section (number 6) in Article 3, which indicates that with public works of general interest, which are the competence of the General State Administration, this law shall be applied to any damage caused to waters and soils, among others, if they are caused by the economic or professional activities listed in its Annexe III, even if there is no fraud, fault or negligence. In 2015 Royal Decree 183/2015 was adopted by amending the regulation on the partial development of Spanish Law 26/2007, adopted by Royal Decree 2090/2008.

5.2. Agricultural activities

The main sources of pollutants in farmland soils include the use of sewage sludge as a fertiliser, wastewater to irrigate crops, organic fertilisers and the application of pesticides.

When they are applied to soil, they contain heavy metals, poorly biodegradable trace organic compounds, and potentially pathogenic organisms, which may pollute soils and affect food safety.

5.2.1. Use of sewage sludge on farmlands

In Spain, Royal Decree 1310/1990 sets out the legal framework for the use of sewage sludge on farmlands. While sewage sludge contains nutrients and organic matter that are beneficial for soil, it may also contain pollutants; e.g., heavy metals, organic compounds and pathogens. This regulation requires sludge to be treated before being applied to farmlands by means of biological, chemical or heat treatment, long-term storage or any other appropriate process that significantly reduced its fermentability and the health hazards that result from its use. Sludge should be used by considering plants' nutrient requirements, and that the quality of soil and of both surface- and groundwater is not impaired. This legislation sets limit values for seven heavy metals in both soil and sludge, and it imposes restrictions by prohibiting the use of sludge on and in soil in various circumstances. In Spain, the legislation of the Autonomous Basque Community (Decree 453/2013) is more advanced than in the rest of Spain as it contains restrictions for heavy metals in soil, and also in relation to heavy metals, organic pollutants and pathogens in sewage sludge. While applying sewage sludge to farmlands, sludge is considered waste. The non-compliance of the obligations that derive from Royal Decree 1310/1990 and Order AAA 1072/2013 is considered an administrative infraction. The system of penalties for waste-related infractions is set out in the Law 22/2011 on Waste and Contaminated Soils.

The European Commission (EC, 2008) provides an overview of key EU legislation that influences sewage sludge.

5.2.2. Use of treated wastewater

Water availability is essential for agriculture to reach sustainable crop production. Agricultural production is a water-intensive low-return industry (Rodell et al., 2018). Worldwide, the agricultural sector accounts for 85% of the global blue water (surface or groundwater) use (Shiklomanov, 2000). Rodell et al. (2018) observed that freshwater is rapidly disappearing in many of the world's irrigated agricultural regions. According to Flörke et al. (2018), urban water demand will increase globally by 80% by 2050, while climate change is altering the timing and distribution of water. Droughts occur naturally, but climate change has generally accelerated hydrological processes to make them set in more quickly and more intensely (Mukherjee et al., 2018). Therefore, more water is required to face the rising demands of irrigation, population increase and rapid urbanisation. The UN Sustainable Development Goal on Water (SDG 6) specifically targets a substantial increase in recycling and safe reuse globally by 2030. The potential role of treated wastewater reuse as an alternative water supply source has been well acknowledged and is included in international, EU, national and regional strategies. Water reuse is a priority area in the Strategic Implementation Plan of the European Innovation Partnership on Water, and maximisation of water reuse is a specific objective of the Communication "Blueprint to safeguard Europe's water resources" (EC, 2012).

In Spain, Royal Decree 1620/2007 sets the legal framework to reuse treated wastewater (ASERSA, 2017; Navarro, 2018). For the purposes of this Royal Decree, water reuse is defined as the application of water before it is returned to the public water domain or the coastal-marine domain, which has undergone the suitable wastewater treatment process or processes set out in the corresponding effluent disposal permit, as well as any other necessary processes to accomplish the required quality for its ultimate use. This

348 regulation establishes basic conditions for reusing treated wastewater by taking into
349 account the quality criteria for its reuse according to its intended use. For agricultural
350 uses, it distinguishes three water qualities. Quality 1 for crop irrigation using a system
351 whereby reclaimed water comes into direct contact with edible crop parts that are to be
352 eaten raw. Quality 2 for a) crop irrigation for human consumption using application
353 methods that do not prevent water coming into direct contact with edible plant parts,
354 which are not eaten raw, but after an industrial treatment process; b) irrigation of pasture
355 land for milk- or meat-producing animals. Quality 3 for a) localised tree crop irrigation
356 whereby reclaimed water is not allowed to come into contact with fruit for human
357 consumption; b) irrigation of ornamental flowers, nurseries and greenhouses whereby
358 reclaimed water does not come into contact with crops; c) irrigation of industrial non-
359 food crops, nurseries, silo fodder, cereals and oilseeds. For the three qualities, Royal
360 Decree 1620/2007 establishes maximum acceptable values of intestinal nematodes,
361 *Escherichia coli*, B, As, Be, Cd, Co, Cr, Cu, Mn, Mo, Ni, Se, V, and refers to other
362 legislation for organic contaminants. This regulation also contemplates environmental
363 uses, such as irrigation of woodlands and green areas, silviculture and aquifer recharge.
364 When treated wastewater is used for aquifer recharge, the amount of total nitrogen and
365 nitrates must be limited. The non-compliance of the obligations that derive from the terms
366 and conditions of water reuse concessions and permits is subject to the penalties laid out
367 under Heading IV of the amended Water Act. However, the infractions committed by
368 those responsible for maintaining water quality from the delivery point of reclaimed water
369 to the usage location are regulated by Chapter VI of the General Law on Health 14/1986
370 (MARM, 2010).
371
372 **5.2.3. Use of organic fertilisers**

373 Fertilisers can contain substances that may potentially pose a risk for human and animal
374 health, and also for the environment. Royal Decree 506/2013 (modified by Royal Decree
375 535/2017 and Royal Decree 999/2017) sets the legal framework for using inorganic and
376 organic fertilisers. This regulation considers that using fertiliser products made from
377 organic waste must consider a maximum limit value for both pathogens and heavy metals
378 (Table 1). It is important to point out that regulations advance, and nowadays many
379 countries require analyses for not only total chromium, but also for hexavalent chromium
380 that is toxic and can cause cancer if found in high levels. Exposure to chromium occurs
381 from eating contaminated food or drinking water, or by breathing contaminated
382 workplace air. Regarding non-compliance, the provisions of Royal Decree 506/2013 are
383 applied, and Royal Decree 1945/1983 regulates infringements and penalties related to the
384 protection of both consumers and agri-food production, without prejudicing any other
385 legislation that may be applicable in the affected area.
386
387 **5.2.4. Use of pesticides**
388 Plant protection products (also referred to as 'pesticides') applied to crops can enter soil
389 and pose the risk of negatively affecting non-target species in both terrestrial and aquatic
390 ecosystems. Pesticides can contaminate soil in several ways, and in the area where they
391 are applied, by improper disposal of empty pesticide containers, waste disposal in
392 landfills or while pesticides are being produced. According to Silva et al. (2019), soil
393 contamination by pesticide waste has become an issue of increasing concern given
394 some pesticides' high soil persistence and toxicity to non-target species. The Law
395 43/2002 on Plant Health is the basic legislative framework that allows administrations to
396 take the necessary phytosanitary measures to prevent and eradicate harmful organisms
397 that could pose a risk to crops and forest masses. Among its objectives we find the

prevention of risks for humans, animals and the environment from using pesticides. Before any pesticide can be placed on the market or be used, it must be approved by National Authorities. Royal Decree 971/2014 aims to regulate the procedure followed to assess plant protection products. In this assessment, it should be taken into account that the leaching of pesticides may be influenced by the effect of soil properties (e.g. organic carbon and clay content) on transformation and adsorption. Royal Decree 1311/2012 establishes an action framework to ensure the sustainable use of plant protection products. The sustainable use of pesticides implies establishing systems for the collection and safe disposal of empty packaging and remnants of pesticides and systems for the safe disposal of expired pesticides. As pesticides are hazardous products, containers of pesticides should be managed by their owners as hazardous waste by them following the provisions set out in the Law 22/2011 on Waste and Contaminated Soils, which includes penalties for those that leave, pour or dispose uncontrolled hazardous waste. However, given the particular characteristics of pesticide packaging and the volume of generated waste, Royal Decree 1416/2001 on the packaging of phytosanitary products was established to reinforce the shared responsibility, producer responsibility and polluter-pays principles. Royal Decree 1416/2001 requires pesticide packaging to be placed on the market following a deposit and return system or an integrated management system.

In order to protect consumers, the European Commission sets maximum residue levels (MRLs) for pesticides, i.e. the highest levels of pesticide residues that are legally tolerated in or on food or feed, including imported products.

5.3. Industrial and commercial activities

The following instruments regulate soil contamination due to industrial and commercial activities: Law 22/2011 on Waste and Contaminated Soils, Royal Decree 9/2005 that provides a list of potentially soil-contaminating activities, criteria and standards to declare soils as being contaminated, and Royal Legislative Decree 1/2016 recast the text of the Integrated Contamination Prevention and Control Act.

Law 22/2011 on Waste and Contaminated Soils defines contaminated soil as a soil whose characteristics have been negatively altered by the presence of hazardous chemical components from anthropogenic activities and at concentrations that imply an unacceptable risk for human health or the environment, and have been declared contaminated by Regional Authorities. This legislative act establishes that the Government will approve and publish a list of potentially soil-contaminating activities, and the owners of potentially soil-contaminating activities are required to periodically submit reports to the corresponding Regional Authority containing any information that may serve as a basis to declare that a soil is contaminated. The requested information shall allow the detection of: i) improper use, the handling or management of hazard substances; ii) an inappropriate design of facilities; and iii) poor conditions of facilities and circumstances that lead to an environmental risk being suspected. Declaring soil as contaminated makes the parties responsible for contamination take the necessary actions to proceed with its remediation. Regional Authorities will form an inventory with the soils declared as contaminated. The Regional Authority will draw up a list of priority actions on soil decontamination based on its risk to human health and the environment. The law establishes the parties responsible for remediating contaminated soils and allows agreements to be reached between the responsible parties and those authorised by the Regional Authority for the remediation and restoration of contaminated soils. The law allows economic incentives to be established

447 with public funding to help cover the costs of cleaning up and restoring contaminated
448 soils, but it takes into account that the possible capital gains of soil should revert to the
449 public administration that funded the economic incentive .
450 Lastly, the law allows voluntary soil remediation and restoration, but the competent body
451 of the Regional Authority shall approve the remediation and restoration project
452 beforehand.
453 Royal Decree 9/2005 establishes the criteria and standards required to determine if soil
454 is contaminated. The criteria for establishing whether soil is contaminated include a
455 risk that is unacceptable for human health or ecosystems. Spain has adopted risk-based
456 land management (RBLM). According to Kuppusamy et al. (2017), RBLM integrates
457 risk assessment practices with more traditional site-specific investigations and
458 remediation activities, and RBLM is considered to be practical, scientifically
459 defensible and cost-effective. Soils that require a risk assessment are soils for which
460 analytical evidence exists that the concentration of any contaminant is higher than the
461 screening values (called “generic reference level (GRL)” in Spanish legislation), soils
462 that present concentrations of total petroleum hydrocarbons above 50 mg/kg, and for
463 the protection of ecosystems when bio-toxicity is demonstrated based on any of the
464 biotests referred to in Annexe III.2 of this Royal Decree. This bio-toxicity is assessed
465 using a battery of terrestrial and aquatic organisms (Box 3). Royal Decree 9/2005
466 defines the elements that contain a risk assessment. There are some situations in which
467 no risk assessment is available, but soil can be determined as contaminated (see Box 3).
468 These situations are: 1) when the concentration of any contaminant in soil exceeds 100
469 times the established GRL for the protection of human health; 2) in terrestrial ecosystems,
470 when the lethal or effective median concentration, $L(E)C_{50}$, for soil organisms obtained
471 in toxicity tests is lower than 10 mg of contaminated soil/gram of clean soil; 3) in aquatic

ecosystems when the lethal or effective median concentration, $L(E)C_{50}$, for aquatic organisms obtained in toxicity tests is lower than 10 ml of leachate/litre of clean water. Therefore, a soil quality assessment is approached with screening values and site-specific risk assessments. Royal Decree 9/2005 considers three land use scenarios for human health: industrial, residential and others (those which are neither urban nor industrial, and are suitable for carrying out agricultural, forestry and livestock-raising activities). The owners of the potentially soil-contaminating activities shall be required to submit a preliminary report to the competent body to assess the possibility that significant contamination has occurred or may occur. The preliminary report must contain information about: pavement (type, condition, percentage of the total covered surface), drainage network, wastewater treatment network, accidents or irregularities that have occurred at the site, hazardous materials consumed, intermediate or end products of a hazardous nature, waste or by-products generated, the form of storage of each product or waste, production areas and historical activities. If it is necessary to establish, extend or close a potentially soil-contaminating activity, it is mandatory to analyse soil to determine its quality because this will facilitate the assignation of responsibilities in a future soil contamination case. If a potentially contaminating activity is restricted, soil quality must be assessed to study if the activity has had any negative effects on soil quality (MMA, 2007). Some Spanish Autonomous Communities have developed technical guidelines to analyse in which cases a report must be submitted to the Regional Authority. By way of example, the technical guideline of the Autonomous Community of Madrid describes the content of the report that a newly established potentially soil-contaminating activity shall include. It includes both an initial characterisation and a subsequent analytical characterisation. If the historical activity of the site is unknown, the analytical characterisation shall include for soils the

following: pH, electrical conductivity, organic matter, clay, total petroleum hydrocarbons (TPH) and heavy metals (As, Cu, Cr, Co, Cd, Ni, Pb, Hg, Zn); for groundwater: pH, electrical conductivity, TPH and heavy metals (As, Cu, Cr, Co, Cd, Ni, Pb, Hg, Zn). If a potentially soil-contaminating activity is stopped, a detailed characterisation and a risk assessment shall be carried out. The system of penalties of the Law 22/2011 on Waste and Contaminated Soils for industrial and commercial activities that can contaminate soils include both actions and omissions that violate this law, which are considered administrative infractions. Infractions are classified as minor, serious and very serious. Very serious infractions are considered when failing to carry out the works of cleaning up and restoring soil that has been declared as contaminated in line with the Regional Authority's requirements, and when failing to fulfil the existing obligations arising from voluntary or conventional agreements for the clean-up and restoration works of contaminated soils. Such infractions entail paying fines that range from 901 to 1,750, 000 euros, depending on the seriousness of the infraction.

Royal Legislative Decree 1/2016 on approving the recast text of the Integrated Pollution Prevention and Control Law aims to prevent, reduce and control atmospheric, aquatic and edaphological pollution by establishing a preventive system and the integrated control of pollution to achieve global environmental protection. Regional Authorities may consider that the industrial activities which are subject to this regulation do not need to submit the reports requested by Royal Decree 9/2005 because the requested information is included in the documents submitted to request integrated environmental authorisation.

5.4. Food safety and health protection

Currently in Spain, food safety policies are not integrated with soil contamination management policies. However, the compliance of the aforementioned regulations entails

a reduced risk of pollutants entering the food chain. The Law on Food Safety and Nutrition 17/2011 regulates food traceability. According to Opara (2003), traceability in relation to a product "represents the ability to identify the farm where it was grown and sources of input materials, as well as the ability to conduct full backward and forward tracking to determine the specific location and life history in the supply chain by means of records". Royal Legislative Decree 1/2007, modified by Law 3/2014, is of particular importance for the protection of consumers as traceability is mentioned as a quality control system.

6. Conclusions

Soil is a resource that should be protected to guarantee sustainable development. Soil quality should be preserved to avoid propagating harmful elements through the food chain. Many people all over the world are suffering from health risks because they live near highly contaminated sites. We all have the right to a clean environment, to adequate food and to health, which means that we should maintain soils healthy to obtain healthy food and to preserve both human health and ecosystems. Both the EU and Spain have legal instruments to prevent soil contamination, but the EU has no legal soil contamination framework. Spanish legislation clearly defines contaminated soil in its legislation on both the environmental liability and soil contamination due to industrial and commercial activities. Spanish legislation on agricultural activities has been oriented to establish guidelines that preserve soils and consumer health by limiting contaminants from sewage sludge and wastewater entering soil. Moreover, with wastewater it establishes soil quality criteria and lays down mandatory limit values for certain contaminants in soil for sewage sludge. Due to industrial and commercial activities, Spanish legislation for soil contamination develops a decision-making process that

follows a risk-based approach where a site-specific risk assessment is the main decision support tool to guarantee the remediation of polluted soils. It takes into account that remediation should ensure permanent solutions and should be carried out by applying the best available techniques. It can be stated that Spain has a regulatory system that includes measures to prevent soil contamination, to manage polluted soils, and to develop an environmental liability system. However, there are still some elements that can further enrich the regulatory system; for example, introducing food safety into the current regulations on soil contamination, or providing an alignment between groundwater policies and soil quality policies. Spanish legislation could also introduce economic, social and other factors into risk management. It is also important to prepare technical guidelines that clarify the implementation of risk assessments and that introduce into risk assessments new research insights into this topic. For example, in Spain a risk assessment of contaminated soils is based on determining the total contaminant concentration. However, Brand et al. (2013) assumed that only the bioavailable fraction is capable of exerting adverse effects on the soil ecosystem, which is why they suggested taking bioavailability into account to make more effect-based risk assessments. Similarly, Kuppusamy et al. (2017) pointed out that the consideration of contaminant bioavailability may lead to a more sophisticated risk-based approach being developed. However, Ren et al. (2018) studied the effect of exogenous carbonaceous materials (ECMs) on the bioavailability of organic pollutants. These authors observed that, in most cases, the sorption behaviour of ECMs decreases the bioavailability of organic pollutants, but the physiological properties of soil organisms complicated this. Other key points include supporting sustainable green remediation strategies and supporting land re-use on site because it provides environmental benefits by preventing large volumes of waste being transported to landfills. Introducing measures that decrease unsustainable remediation

solutions (dig and dump) is needed; e.g., increasing landfill taxes. In Spain, Royal Decree 9/2005 makes no difference between legacy and current contaminations. Therefore, mid- and long-term plans are needed for the remediation of legacy contaminated soils.

A contaminated soil management framework provides benefits to the environment and human health. It also offers a legal framework for the remediation and restoration of contaminated soils and, hence, the use and maintenance of the economic value of soil. This paper could be useful to policymakers and stakeholders in Spain, and it also sets a legal reference for other countries.

Acknowledgements

This research was conducted as part of Project DER2015-65810-P, funded by the Spanish Ministry of Economy and Competitiveness, and by Project GVPROMETEOII2015-014, funded by the Regional Ministry of Culture, Education and Sport of the Valencian Autonomous Community, and by Projects HYDЯOSIL (CGL2011-28776-C02-02) and SILWAMED (CGL2014-58127-C3-2), funded by the Spanish Ministry of Science and Innovation and FEDER funds.

References

Arias Espana VA, Rodriguez Pinilla AR, Bardos P, Naidu R. 2018. Contaminated land in Colombia: a critical review of current status and future approach for the management of contaminated sites. Sci Total Environ 618:199–209. https://doi.org/10.1016/j.scitotenv.2017.10.245

ASERSA. 2007. Royal Decree 1620/2007: Spanish Regulations for Water Reuse (English Translation). Asociación Española de Reutilización Sostenible del Agua, Madrid, Spain.

Barboza, J. 1995. Eleventh report on international liability for injurious consequences arising out of acts not prohibited by international law, UN. Document A/CN.4/468. Yearbook of the International Law Commission. Vol. II(1).

Bone, J., Head, M., Barraclough, D., Archer, M., Scheib, C., Flight, D., & Voulvoulis, N. 2010. Soil quality assessment under emerging regulatory requirements. Environment International, 36(6), 609-622. https://doi.org/10.1016/j.envint.2010.04.010

Boyd, D.R. 2012. The Constitutional Right to a Healthy Environment. Environment: Science and Policy for Sustainable Development, 54:4, 3-15, DOI: 10.1080/00139157.2012.691392

Brand, E., Lijzen, J., Peijnenburg, W., & Swartjes, F. (2013). Possibilities of implementation of bioavailability methods for organic contaminants in the Dutch Soil Quality Assessment Framework. Journal of hazardous materials, 261, 833-839. https://doi.org/10.1016/j.jhazmat.2012.11.066

Breure, A. M., Lijzen, J. P. A., & Maring, L. 2018. Soil and land management in a circular economy. Science of The Total Environment, 624, 1125-1130. https://doi.org/10.1016/j.scitotenv.2017.12.137

Cachada, A., Rocha-Santos, T., & Duarte, A. C. (2018). Soil and Pollution: An Introduction to the Main Issues. In Soil Pollution (pp. 1-28). https://doi.org/10.1016/B978-0-12-849873-6.00001-7

Castelo-Grande, T., Augusto, P. A., Fiúza, A., & Barbosa, D. (2018). Strengths and weaknesses of European soil legislations: The case study of Portugal. Environmental Science & Policy, 79, 66-93. https://doi.org/10.1016/j.envsci.2017.10.010

CCICED. (2015). Special Policy Study on Soil Pollution Management. China Council for International Cooperation on Environment and Development.

621 Council of Europe. 2003. Revised European Charter for the Protection and
622 Sustainable Management of Soil adopted by the Committee of Ministers of the Council
623 of Europe at its 840th meeting on 28 May 2003.
624 European Commission (EC). 2002. Communication "Towards a Thematic
625 Strategy on Soil Protection", COM(2002)179, 16/4/2002.
626 European Commission (EC). 2008. Environmental, economic and social impacts
627 of the use of sewage sludge on land. Final Report. Part III: Project Interim Reports.
628 European Commission. (2012). Communication "A blueprint to safeguard
629 Europe's water resources", COM(2012)673, 14/11/2012.
630 FAO. 2015. 39th Conference, Rome 6–13 June 2015, Global Soil Partnership -
631 World Soil Charter, Doc. C 2015/31 of April 2015, 1.
632 FAO, ITPS. 2015. Status of the World's Soil Resources (SWSR)–Main Report.
633 Food and Agriculture Organization of the United Nations and Intergovernmental
634 Technical Panel on Soils, Rome, Italy.
635 FAO. 2018. Concept note. Global Symposium on Soil Pollution. Co-organized by
636 FAO, GSP/ITPS, UN Environment, Basel, Rotterdam and Stockholm Conventions and
637 WHO. 2-4 May 2018 http://www.fao.org/3/I8411EN/i8411en.pdf
638 Filip, Z. 2002. International approach to assessing soil quality by ecologically-
639 related biological parameters. Agriculture, Ecosystems & Environment, 88(2), 169-174.
640 https://doi.org/10.1016/S0167-8809(01)00254-7
641 Flörke, M., Schneider, C., & McDonald, R. I. 2018. Water competition between
642 cities and agriculture driven by climate change and urban growth. Nature Sustainability,
643 1(1), 51. https://doi.org/10.1038/s41893-017-0006-8
644 Gómez-Lavín, S., San Román, M. F., Ortiz, I., Fernández, J., de Miguel, P., &
645 Urtiaga, A. 2018. Dioxins and furans legacy of lindane manufacture in Sabiñánigo

(Spain). The Bailín landfill site case study. Science of The Total Environment, 624, 955-962. https://doi.org/10.1016/j.scitotenv.2017.12.162

Gu, Q., Guo, G., Ma, J., Zhou, Y., Yan, Z., Xie, Y., ... & Xue, N. 2018. Progress in the Risk Management of Contaminated Sites: Research Activities and Environmental Management of Contaminated Sites at CRAES. In Twenty Years of Research and Development on Soil Pollution and Remediation in China (pp. 65-87). Springer, Singapore. https://doi.org/10.1007/978-981-10-6029-8_5

He, M., Shen, H., Li, Z., Wang, L., Wang, F., Zhao, K., ... & Xu, J. 2019. Ten-year regional monitoring of soil-rice grain contamination by heavy metals with implications for target remediation and food safety. Environmental Pollution, 244, 431-439. https://doi.org/10.1016/j.envpol.2018.10.070

Hu, W., Huang, B., Borggaard, O. K., Ye, M., Tian, K., Zhang, H., & Holm, P. E. 2018a. Soil threshold values for cadmium based on paired soil-vegetable content analyses of greenhouse vegetable production systems in China: Implications for safe food production. Environmental Pollution, 241, 922-929. https://doi.org/10.1016/j.envpol.2018.06.034

Hu Q., Zhu Y., Lin S., Wang H., Gao J. 2018b. The Development of China's Contaminated Site Remediation Industry: A Decade in Review. In: Luo Y., Tu C. (eds) Twenty Years of Research and Development on Soil Pollution and Remediation in China. Springer, Singapore. https://doi.org/10.1007/978-981-10-6029-8_8

Hussain, R., Luo, K., Liang, H., & Hong, X. 2019. Impact of the coal mining-contaminated soil on the food safety in Shaanxi, China. Environmental geochemistry and health, 1-24. https://doi.org/10.1007/s10653-018-0233-6

Khelfi, A. 2018. Sources of Soil Pollution. In Handbook of Research on Microbial Tools for Environmental Waste Management (pp. 190-218). IGI Global.

671 Kovalick, W.W. Jr., Montgomery, R.H. 2014. Developing a Program for
672 Contaminated Site Management in Low and Middle Income Countries. World Bank,
673 Washington, D.C.
674 Kovalick Jr, W. W., & Montgomery, R. H. 2017. Models and lessons for
675 developing a contaminated site program: An international review. Environmental
676 Technology & Innovation, 7, 77-86. https://doi.org/10.1016/j.eti.2016.12.005
677 Kowalska, J. B., Mazurek, R., Gąsiorek, M., & Zaleski, T. 2018. Pollution indices
678 as useful tools for the comprehensive evaluation of the degree of soil contamination–A
679 review. Environmental Geochemistry and Health, 1-26. https://doi.org/10.1007/s10653-
680 018-0106-z
681 Kuppusamy, S., Venkateswarlu, K., Megharaj, M., Mayilswami, S., & Lee, Y. B.
682 (2017). Risk-based remediation of polluted sites: A critical perspective. Chemosphere,
683 186, 607-615. https://doi.org/10.1016/j.chemosphere.2017.08.043
684 Leib, L.H. 2011. Human Rights and the Environment: Philosophical, Theoretical
685 and Legal Perspectives. Martinus Nijhoff Publishers. Leiden. 73 pp.
686 https://www.jstor.org/stable/10.1163/j.ctt1w8h1t2
687 Li, X., Jiao, W., Xiao, R., Chen, W., & Liu, W. 2017. Contaminated sites in China:
688 Countermeasures of provincial governments. Journal of cleaner production, 147, 485-
689 496. https://doi.org/10.1016/j.jclepro.2017.01.107
690 Li, G., Sun, G. X., Ren, Y., Luo, X. S., & Zhu, Y. G. 2018. Urban soil and human
691 health: a review. European Journal of Soil Science. https://doi.org/10.1111/ejss.12518
692 Li, T., Liu, Y., Lin, S., Liu, Y., & Xie, Y. 2019. Soil Pollution Management in
693 China: A Brief Introduction. Sustainability, 11(3), 556.
694 https://doi.org/10.3390/su11030556

Liu, X., Song, Q., Tang, Y., Li, W., Xu, J., Wu, J., ... & Brookes, P. C. 2013. Human health risk assessment of heavy metals in soil–vegetable system: a multi-medium analysis. Science of the Total Environment, 463, 530-540. https://doi.org/10.1016/j.scitotenv.2013.06.064

Loureiro, S., Tourinho, P.S., Cornelis, G., Van Den Brink, N. W., Díez-Ortiz, M., Vázquez-Campos, S., ... & Van Gestel, C.A. 2018. Nanomaterials as Soil Pollutants. In Soil Pollution (pp. 161-190). https://doi.org/10.1016/B978-0-12-849873-6.00007-8

Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A. J., ... & Wang, T. 2015. Impacts of soil and water pollution on food safety and health risks in China. Environment international, 77, 5-15. https://doi.org/10.1016/j.envint.2014.12.010

Ma, L., Wang, L., Jia, Y., & Yang, Z. 2016. Arsenic speciation in locally grown rice grains from Hunan Province, China: Spatial distribution and potential health risk. Science of the Total Environment, 557, 438-444. https://doi.org/10.1016/j.scitotenv.2016.03.051

Mao, C., Song, Y., Chen, L., Ji, J., Li, J., Yuan, X., ... & Theiss, F. (2019). Human health risks of heavy metals in paddy rice based on transfer characteristics of heavy metals from soil to rice. CATENA, 175, 339-348. https://doi.org/10.1016/j.catena.2018.12.029

Ministerio de Medio Ambiente (MMA). 2007. Guía Técnica de aplicación del RD 9/2005, de 14 de enero, por el que se establece la relación de actividades potencialmente contaminantes del suelo y los criterios y estándares para la declaración de suelos contaminados.

Ministerio de Medio Ambiente y Medio Rural y Marino (MARM). 2010. Guía para la aplicación del Real Decreto 1620/2007 por el que se establece el Régimen Jurídico de la Reutilización de las Aguas Depuradas.

719 Mirsal, I. 2008. Soil pollution: origin, monitoring & remediation. (2nd
720 ed.), Springer, Berlin Heidelberg. DOI: 10.1007/978-3-540-70777-6
721 Mukherjee, S., Mishra, A., & Trenberth, K.E. 2018. Climate Change and Drought:
722 a Perspective on Drought Indices. Current Climate Change Reports, 1-19.
723 https://doi.org/10.1007/s40641-018-0098-x
724 Navarro, T. 2018. Water reuse and desalination in Spain–challenges and
725 opportunities. Journal of Water Reuse and Desalination, jwrd2018043.
726 https://doi.org/10.2166/wrd.2018.043
727 Opara, L.U. 2003. Traceability in agriculture and food supply chain: a review of
728 basic concepts, technological implications, and future prospects. Journal of Food
729 Agriculture and Environment, 1, 101-106. https://doi.org/10.1234/4.2003.323
730 Paleari, S. 2017. Is the European Union protecting soil? A critical analysis of
731 Community environmental policy and law. Land Use Policy, 64, 163-173.
732 https://doi.org/10.1016/j.landusepol.2017.02.007
733 Petrović, Z., Manojlović, D., Jović, V. 2014. Legal protection of land from
734 pollution. Economics of Agriculture, 61 (3), 723-738.
735 Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K. H. (2019). Heavy metals
736 in food crops: Health risks, fate, mechanisms, and management. Environment
737 international, 125, 365-385. https://doi.org/10.1016/j.envint.2019.01.067
738 Ren, X., Zeng, G., Tang, L., Wang, J., Wan, J., Feng, H., ... & Tang, X. (2018).
739 Effect of exogenous carbonaceous materials on the bioavailability of organic pollutants
740 and their ecological risks. Soil Biology and Biochemistry, 116, 70-81.
741 https://doi.org/10.1016/j.soilbio.2017.09.027

742 Rillig, M. C., & Bonkowski, M. 2018. Microplastic and soil protists: A call for
743 research. Environmental Pollution, 241, 1128-1131.
744 https://doi.org/10.1016/j.envpol.2018.04.147
745 Rodell, M., Famiglietti, J. S., Wiese, D. N., Reager, J. T., Beaudoing, H. K.,
746 Landerer, F. W., & Lo, M. H. 2018. Emerging trends in global freshwater availability.
747 Nature, 557, 651-659. https://doi.org/10.1038/s41586-018-0123-1
748 Rodrigues, S. M., Pereira, M. E., da Silva, E. F., Hursthouse, A. S., & Duarte, A.
749 C. 2009. A review of regulatory decisions for environmental protection: Part I—
750 Challenges in the implementation of national soil policies. Environment International,
751 35(1), 202-213. https://doi.org/10.1016/j.envint.2008.08.007
752 Rodrigues, S.M., & Römkens, P.F. 2018. Human Health Risks and Soil Pollution.
753 In Soil Pollution (pp. 217-250). https://doi.org/10.1016/B978-0-12-849873-6.00009-1
754 Romero-Baena, A.J., González, I., & Galán, E. 2018. Soil pollution by mining
755 activities in Andalusia (South Spain)—the role of Mineralogy and Geochemistry in three
756 case studies. Journal of Soils and Sediments, 18(6), 2231-2247.
757 https://doi.org/10.1007/s11368-017-1898-7
758 Shiklomanov, I. A. (2000). Appraisal and assessment of world water resources.
759 Water international, 25(1), 11-32. https://doi.org/10.1080/02508060008686794
760 Silva, V., Mol, H. G., Zomer, P., Tienstra, M., Ritsema, C. J., & Geissen, V.
761 (2019). Pesticide residues in European agricultural soils–A hidden reality
762 unfolded. Science of the Total Environment, 653, 1532-1545.
763 https://doi.org/10.1016/j.scitotenv.2018.10.441
764 Sun, J., Pan, L., Tsang, D. C., Zhan, Y., Zhu, L., & Li, X. 2018. Organic
765 contamination and remediation in the agricultural soils of China: A critical review.

766 Science of the Total Environment, 615, 724-740.
767 https://doi.org/10.1016/j.scitotenv.2017.09.271

768 Swartjes, F. A., Carlon, C., & de Wit, N. H. (2008). The possibilities for the EU-
769 wide use of similar ecological risk-based soil contamination assessment tools. Science of
770 the Total Environment, 406(3), 523-529. https://doi.org/10.1016/j.scitotenv.2008.07.034

771 Swartjes, F.A., Rutgers, M., Lijzen, J.P.A., Janssen, P.J.C.M., Otte, P.F.,
772 Wintersen, A., ... & Posthuma, L. 2012. State of the art of contaminated site management
773 in The Netherlands: Policy framework and risk assessment tools. Science of the Total
774 Environment, 427, 1-10. https://doi.org/10.1016/j.scitotenv.2012.02.078

775 Tóth, G., Hermann, T., Da Silva, M. R., & Montanarella, L. (2016). Heavy metals
776 in agricultural soils of the European Union with implications for food safety.
777 Environment international, 88, 299-309. https://doi.org/10.1016/j.envint.2015.12.017

778 Valentín, L., Nousiainen, A., & Mikkonen, A. 2013. Introduction to organic
779 contaminants in soil: concepts and risks. In Emerging Organic Contaminants in
780 Sludges (pp. 1-29). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2012_208

781 Van Liedekerke, M., Masson, J., Paya Perez, A., Jones, A., Geissen, V., Baritz,
782 R., Havlicek, E., Silva, V., Yang, X. Regional status of soil pollution: Europe. In: FAO.
783 2018. Proceedings of the Global Symposium on Soil Pollution 2018. Rome, Italy, Food
784 and Agriculture Organization of the United Nations. pp. 30-55.

785 Zeng, F., Wei, W., Li, M., Huang, R., Yang, F., & Duan, Y. 2015. Heavy metal
786 contamination in rice-producing soils of Hunan province, China and potential health
787 risks. International journal of environmental research and public health, 12(12), 15584-
788 15593. DOI 10.3390/ijerph121215005

789 Zhang, X., Zhong, T., Liu, L., & Ouyang, X. 2015. Impact of soil heavy metal
790 pollution on food safety in China. PLoS One, 10(8), e0135182.
791 https://doi.org/10.1371/journal.pone.0135182

792 **Captions for Boxes and Table 1**

793 Box 1. Recommendations for preventing soil contamination, and for promoting the
794 restoration and rehabilitation of contaminated soils (Council of Europe, 2003).

795 Box 2. Overview of legal instruments to protect soils from contamination and consumer
796 health in Spain.

797 Box 3. Criteria to determine if a soil is contaminated in Spain (Royal Decree 9/2005).

798 Table 1. Criteria applicable to fertiliser products made from waste and other organic
799 compounds in Spain.

800

Boxes:

Box 1. Recommendations for preventing soil contamination, and for promoting the restoration and rehabilitation of contaminated soils (Council of Europe, 2003).

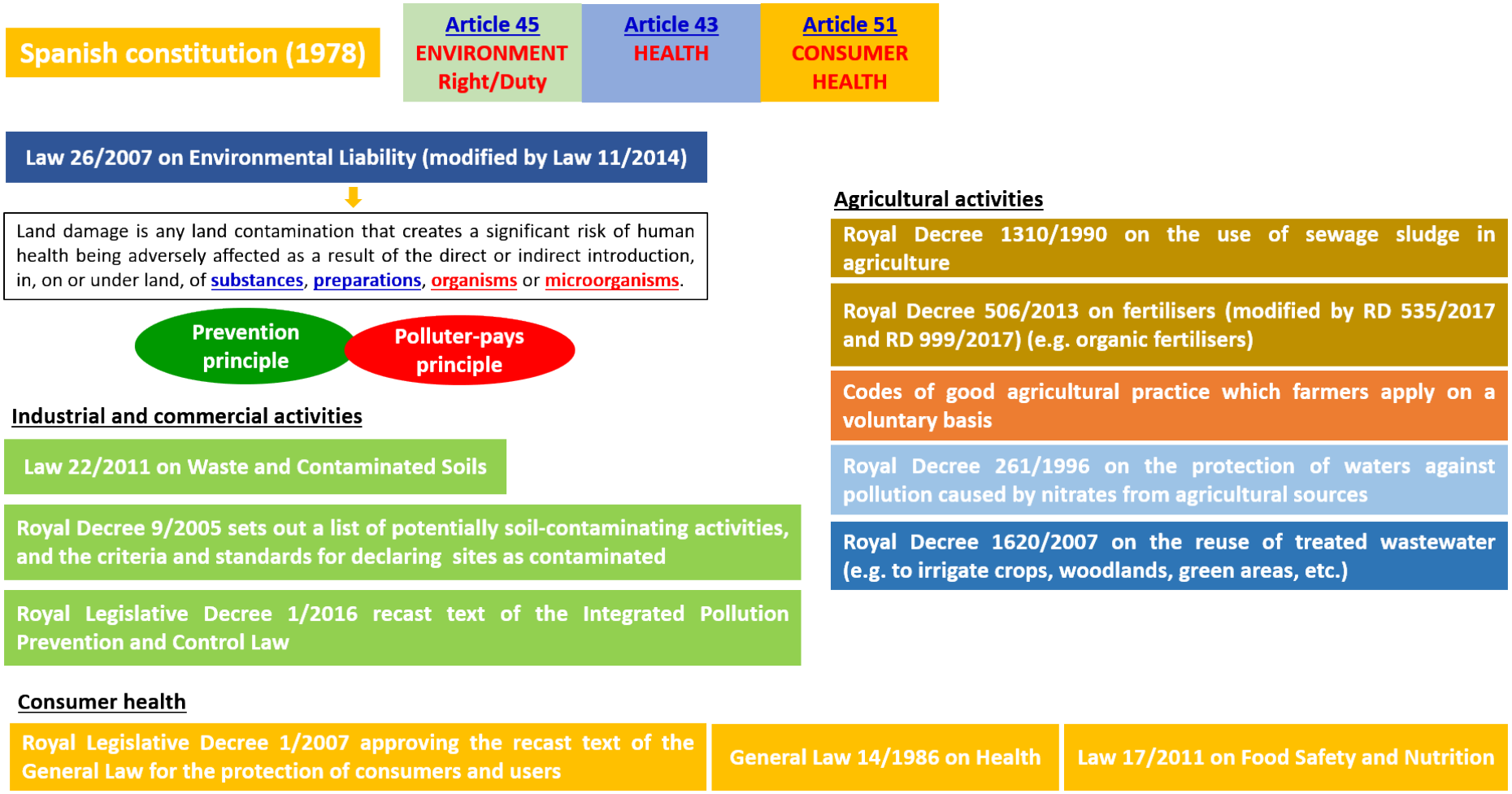
Prevention of soil contamination

- Strict control of installations, storage areas and dumps, that are above or below ground.
- Permanent monitoring of sites and surrounding areas.
- Any incidents should be immediately and appropriately dealt with.
- Any change in site ownership should be preceded by an environmental audit and should be reported to the public authorities.

Restoration of contaminated soils

- Systems enabling the identification of potential harm to soil resources, and appropriate action being taken.
- Spatial and town planning regulations that include measures to ensure that any subsequent use of former polluted sites is suitable, and based on risk assessments.
- Determining with the technical and financial responsibility for restoring contaminated soil according to the "polluter-pays principle".
- Selection of restoration techniques using physical, chemical or biological processes. However, it may be preferable to sometimes leave polluted sites as they are to avoid reactivating certain contaminants that have been immobilised.

806 Box 2. Overview of legal instruments to protect soils from contamination and consumer health in Spain.



807

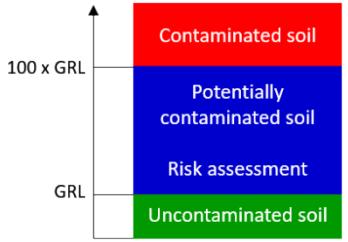
Box 3. Criteria to determine if a soil is contaminated in Spain (Royal Decree 9/2005).

A **A risk assessment is made**

Soil shall be declared contaminated after determining that an **unacceptable risk** for the protection of **human health** or **ecosystems** exists given the presence of any **chemical contaminant**.

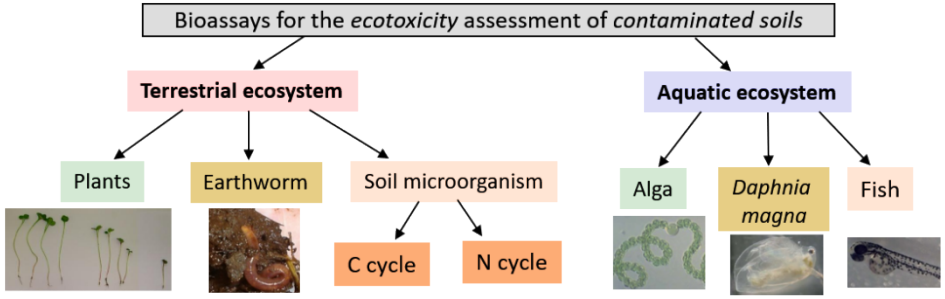
B **No risk assessment is made**

1. In cases in which the main priority is to **protect human health**: when the concentration in soil of any chemical contaminant exceeds 100 times the established GRL set to protect human health in accordance with land use.



Generic reference level (GRL): the concentration of a contaminant in soil that does not pose a level of risk higher than the acceptable maximum for human health or ecosystems

2. In cases in which the main priority is to **protect ecosystems**:



The lethal or effective median concentration, $L(E)C_{50}$, for soil organisms obtained in toxicity tests:

- ✓ OECD* 208 (Test of Seedling Emergence and Growth of **Terrestrial Plants**)
- ✓ OECD 207 (Acute **Earthworm** Toxicity Test)
- ✓ OECD 216 (**Soil Microorganisms: Nitrogen** Transformation Test)
- ✓ OECD 217 (**Soil Microorganisms: Carbon** Transformation Test)
- ✓ or such tests that may be regarded as equivalents for assessment purposes by the Minister of the Environment

is **lower than 10 mg of contaminated soil/gram of clean soil**.

* Organisation for Economic Co-operation and Development

The lethal or effective median concentration, $L(E)C_{50}$, for aquatic organisms obtained in toxicity tests:

- ✓ OECD 201 (**Algal** Growth Inhibition Test)
- ✓ OECD 202 (***Daphnia magna*** Immobilisation Test)
- ✓ OECD 203 (**Fish** – Acute Toxicity Test)
- ✓ or such tests that may be regarded as equivalents for assessment purposes by the Minister of the Environment

carried out with leachates obtained using the standard DIN-38414 method, is **lower than 10 ml of leachate/litre of clean water**.

Table 1 Criteria applicable to fertilizer products made from waste and other organic compounds in Spain.

Heavy metal	**Concentration limits** Solids (mg kg^{-1} dry matter) liquids (mg kg^{-1})		
	Class A*	**Class B****	**Class C*****
Cd	0.7	2	3
Cu	70	300	400
Ni	25	90	100
Pb	45	150	200
Zn	200	500	1000
Hg	0.4	1.5	2.5
Cr total	70	250	300
Cr VI	Non-detectable	Non-detectable	Non-detectable
Pathogens	Maximum limit values		
Salmonella spp.	No *Salmonella* species in 25 g finished product		
Escherichia coli	1000 CFU/g product		

* Class A: The content of heavy metals does not exceed any of the values in column A.
** Class B: The content of heavy metals does not exceed any of the values in column B.
*** Class C: The content of heavy metals does not exceed any of the values in column C.