Chapter 15
Global Environmental Regulations for Management of Pesticides

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15.1 Introduction

Excessive and improper pesticide usage results in contamination and deterioration of soil and aquatic ecosystems and disturbs ecological equilibrium (Hui et al. 2003; Morillo and Villaverde 2017; Spina et al. 2018; Sun et al. 2018; Bhat et al. 2019; Kumar et al. 2019). Pesticides are extremely deleterious due to their persistence, toxicity, bioaccumulation potential, and long range environmental transport potential (Teran et al. 2012; Pariatamby and Kee 2016; Bharat 2018). During the past decade, pesticides have drawn mass public, political, and scientific concern due to their carcinogenic, immunotoxic, mutagenic, and neurotoxic prospective (Dixit et al. 2019). Although new harmless pesticides with relatively enhanced safety profile and novel modes of action have been developed as a substitute to extremely toxic ones (Gill and Garg 2014; Dixit et al. 2019); however, due to the dearth of a comprehensible pesticides management approach, large amount of obsolete pesticide residues have already stockpiled over the time (Dasgupta et al. 2010).

Pesticide exposure occurs primarily through improper pesticide storage, pesticide mishandling and leakage, inappropriate and indiscriminate use, inadequate disposal, and by consuming pesticide contaminated food and water (Morillo and Villaverde 2017; Dixit et al. 2019). A mixture of toxic banned pesticide residues have been detected in large quantities (above WHO's maximum daily intake) in a wide variety of food items that we eat like eggs, fish, flour, fruits, grains, milk, poultry, pulses, rice, vegetables, and wheat, which cause several chronic human diseases (Pimentel et al. 1992; ICMR 2001; Rani and Dhania 2014; Pandey et al. 2018). World Health Organization (WHO) estimated that globally there occur 3,000,000 cases of pesticide poisoning which result in approximately 220,000 deaths annually (Lah 2011; Dixit et al. 2019).

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Nowadays, besides some traditional means of monitoring pesticides residues, several novel and innovative technologies are being applied (Xing-lu et al. 2019). Several developed regions have established pesticide risk assessment models which are of great significance for environmental sustainability (Xing-lu et al. 2019). These models play a crucial role in creating mass awareness and thus, facilitate involvement of all the stakeholders in successful recuperation and restoration of pesticide contaminated environs.

In addition to the application of various scientific methods for the treatment of pesticide pollutants, there is an immediate need to develop global guidelines, management policies, and standard regulations for overseeing pesticide usage and restoration of pesticide contaminated environments (Gill and Garg 2014; Varjania et al. 2019). Pesticide pollution causes various human health and environmental safety issues, which instigated varied global governmental and non-governmental organizations to frame environmental regulations for management and mitigation of pesticide pollution for global environmental safety, sustainable development, and human welfare. Pesticide pollution is one of the major drivers of ecosystem degradation. The United Nations General Assembly declared 2021–2030 as the "International Decade on Ecosystem Restoration" with one of the main focus on restoration of degraded ecosystems globally for sustainable development (Tripathi et al. 2019).

15.2 Environmental Risk Assessment of Pesticides

Risk assessment is a promising multi-disciplinary procedure inured to assess environmental and health risks propounded by chemical pollutants (Singh et al. 2009). Assessing the environmental providence of pesticide residues and their imminent exposure risks to environment and public health is essential for formulating risk-based management strategies for risk reduction (Rice et al. 2007; Singh et al. 2009); however, the development of environmental risk assessment of pesticides is extremely complex and challenging because of the disparity in nature and quantity of pesticide sprayed, ecotoxicity of pesticides, exposure pathways (direct and indirect), period and intensity of exposure, and environmental characteristics of the pesticide application site (Pandey et al. 2018; Spina et al. 2018; Xing-lu et al. 2019). Moreover, the regulatory and risk assessment approaches are concerned with the impact of the pollutant, rather than the pollutant concentration (Beesley et al. 2011).

Several developed regions like North America, European Union, and others have framed and established their own territory-specific pesticide risk assessment models (Xing-lu et al. 2019). Realistic and valid environmental risk assessment of pesticides furnishes fundamental information for management of risk and formulation of remediation decisions (Sun et al. 2017). SCI-GROW risk assessment model of pesticides was established to envisage the risk of five widely used pesticides in China (Cheng et al. 2007; Xing-lu et al. 2019). Levitan et al. (1995) subsequent to analyzing various categories of environmental risk assessment like anecdotal assessments, composite environmental impact rating systems, directory-format and tabular databases, economic assessments, holistic assessments, single and multiple-parameter assessments, and site-specific assessment tools reported that a comprehensive pesticide impact assessment system is still lacking.

Environmental impact assessment of pesticides influences characterization of previously permitted pesticides, approval of new pesticides, and establishment of remediation goals along with maintenance of environmental quality (Song et al. 2017; Dixit et al. 2019). New pesticides registrations based solely on strict environmental risk assessment procedures can help in combating the menace of hazardous pesticides (Schwarzenbach et al. 2010; Xing-lu et al. 2019). Moreover, biotoxicity tests reflect the biological impacts of toxicants, thus serve as important tools in environmental risk assessment (Prokop et al. 2016).

15.3 Pesticide Management Strategies

Pesticides incur adverse impacts on biodiversity, human health, and environment (Marican and Durán-Lara 2018; Dixit et al. 2019). So, management of pesticide pollution assumes great significance and demands immediate action. Novel pesticide management tools and techniques with greater reliability are being developed for improved safety and mitigation of adverse pesticide impacts.

Pesticide management strategies encompass assorted pest as well as pesticide management strategies (Fig. 15.1). Various pest management strategies are categorized as: biological control strategies (such as adoption of integrated pest management-IPM systems by introduction of biocontrol agents, use of biopesticides like biofungicides, bioherbicides, and bioinsecticides), cultural control strategies (such as

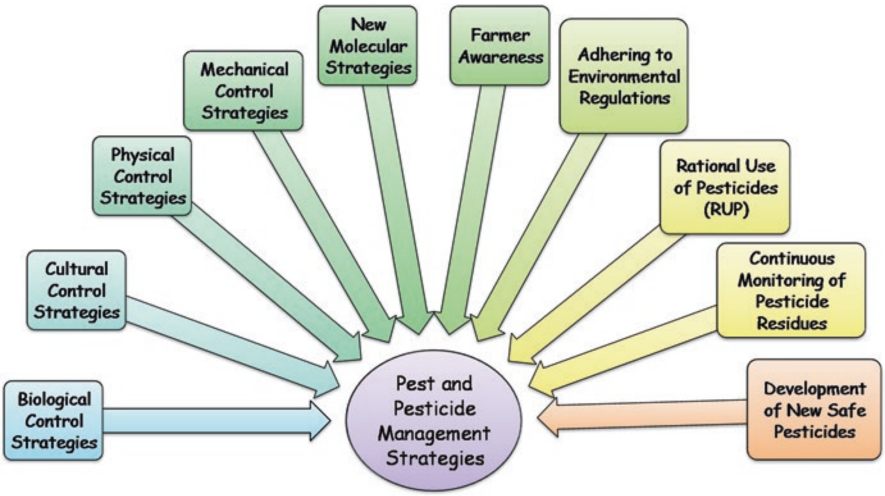

Fig. 15.1 Pest and pesticide management strategies

adoption of integrated crop management-ICM, crop rotation, intercropping, allelopathy, certified seeds, use of pest resistant varieties, farmyard manure, and organic farming), physical control strategies (like sun exposure, light traps, steaming, and moisture management), mechanical control strategies (include use of manual devices like handpicking, clipping, trapping devices, pest exclusion by barriers, and crushing/pruning of pest infested part), new molecular strategies (for instance, development of pest resistant genotypes). Pest management by proficient alternative approaches rationalizes the pesticide consumption (Dhaliwal et al. 2006; Abhilash and Singh 2009; Gill and Garg 2014; Dixit et al. 2019).

Several effective and reliable pesticide management strategies are farmer education and awareness about basic safety guidelines in selection and application of pesticides, adhering to the environmental regulations (precautionary measures as well as safety guidelines) during all the phases of pesticide handling, rational use of pesticides-RUP (apposite pesticide selection and meticulousness in their application over space and time), continuous monitoring of pesticide residues in agricultural commodities, alteration of formerly existing pesticide formulations for secure formulations and development of new pesticides with enhanced safety profiles (Abhilash and Singh 2009; Gill and Garg 2014; Dixit et al. 2019).

15.4 Pesticide Ban

The unsustainable production and use of pesticides over past few decades resulted in colossal environmental contamination. As stated by Food and Agriculture Organization (FAO) inventory (2001), approximately 500,000 tons of obsolete pesticide residues have accumulated in several countries and are threatening the public and environmental health (FAO/UNEP/OECD/SIB 2001). Many cases of pesticide poisoning that either caused adverse impacts on human health or even death have been reported across the world. For instance, (a) The first case of pesticide poisoning in India was reported from Kerala in 1958, wherein around 100 people died due to the consumption of wheat flour that was found to be contaminated with pesticide parathion (Boudh and Singh 2019), (b) In Brazil, 123 persons suffered from severe pesticide poisoning between 1992 and 2002 (Weiss et al. 2016), (c) In 2013, 23 school children died in eastern India, after eating school lunch that was later found to be contaminated with residuals of monocrotophos (banned pesticide) (Weiss et al. 2016). During the former decade, there was an enormous increase in public concern regarding deleterious impacts of pesticide residues.

Pesticide ban is an important regulatory stride taken for the management of deleterious pesticides. Globally, several highly persistent and toxic pesticides have been banned hitherto. In 1995, a convention held in Stockholm proposed to ban 12 (Dirty dozen) toxic persistent organic pollutants (POPs), most of which are pesticides (Morillo and Villaverde 2017). However, pesticides that are currently banned in developed countries are still used or stockpiled in developing countries due to lack of awareness regarding hazardous pesticide impacts, dearth of reliable risk assessment protocols, lack of infrastructure, environmental controls and regulations in such countries (Carneiro et al. 2012). Moreover, pesticides persist even for centuries in ecosystems due to their stability and degradation resistance. The pesticides that have been banned since several decades, their residues are still today found in water and sediments (Ballesteros et al. 2014).

15.4.1 Case Study of Pesticide Dichlorodiphenyltrichloroethane (DDT)

Insecticide “Dichlorodiphenyltrichloroethane” (DDT) was discovered by a Swiss entomologist Paul Muller in 1939. Following World War II, DDT was used in large quantities. DDT was the first organic chemical to be used as a pesticide, and it protected several economical crops and eradicated malaria from numerous parts of the world (Kumar et al. 2018). Alternatively, DDT has resulted in universal environmental contamination due to its slow degradation rate that has been estimated to range from 4 to 30 years (Abhilash and Singh 2009; Pandey et al. 2018; Boudh and Singh 2019). DDT causes eggshell thinning in birds by inhibiting synthesis of prostaglandin in eggshell gland mucosa (Lundholm 1997). DDT is known to have huge bioaccumulation and biomagnification potential at higher trophic levels (Gill and Garg 2014). Thus organisms at the higher trophic levels of food chain are at more risk. DDT exposure causes cancer, endocrine hormone disruption, liver damage, neurological disorders, and reproductive abnormalities (Persson et al. 2012; Pandey et al. 2018; Dixit et al. 2019).

In 1972, production and use of DDT was entirely banned in the USA and other developed countries due to vast array of side effects like non-target toxicity, bioaccumulation, and environmental persistence (Pandey et al. 2018). However, many developing countries (including India) were exempted from DDT ban and were allowed to use DDT till March 2013 for the control of vector-borne diseases (Bharat 2018). Since the ban, large quantity of DDT have stockpiled under improper conditions in developing countries, where it pose a serious risk to human and environmental health (Weiss et al. 2016).

15.5 Global Environmental Regulations for Pesticide Management

Several national and international regulatory authorities conceded various laws and regulations regarding secure manufacture, import, export, sale, transport, proper use, and application of pesticides (FAO 1955, 1988; IPSMC 1999; Lallas 2001; Rotterdam Convention Secretariat 2004; WHO 2004; MEA 2005; FAO 2006a, b, 2007; UNEP 2006; Abhilash and Singh 2009; ECHA 2011; Teran et al. 2012; Pesticide Action Network International 2014; GlobalGAP 2016; Bharat 2018). Numerous initiatives and conventions were instigated for pesticide management during the past two decades. The initial regulations for pesticide management were introduced in the beginning of 1970 with the ban on production and use of pesticide DDT and restricted use of other harmful pesticides in the USA (Teran et al. 2012). Subsequently, several international regulations dealing with pesticide management came into force since 1980. Some of the imperative global environmental regulations for management of pesticides are:

(a) *The International Code of Conduct and Use of Pesticides (Code of Conduct)*: In 1985, the 23rd session of the main governing body of Food and Agriculture Organization (FAO) formulated and adopted the International Code of Conduct and Use of Pesticides (Code of Conduct) for providing universal principles of conduct of pesticide management for pesticide industry and national governments. This code of conduct was once amended in 1989 and then again in 2002 (FAO 2006a, b).
(b) *The Montreal Protocol*: The Montreal Protocol was adopted in 1987 with the aim to limit the production and use of substances (such as pesticide methyl bromide) that cause ozone layer depletion (Abhilash and Singh 2009). This protocol came into force in 1989.
(c) *The Rotterdam Convention*: The Rotterdam Convention was adopted in 1988 for the regulation of international trade of hazardous chemicals and pesticides (Kumer 1999; Rotterdam Convention Secretariat 2004). It later came into force in the year 2004. Its main objective is to control and ban the international trade and stockpiling of perilous pesticides. Furthermore, it promotes labelling of deleterious chemicals with safety directives and pictograms (United Nations Environment Programme, Food and Agriculture Organization 2013).
(d) *The Basel Convention*: The Basal Convention dealing with the trans-boundary passage of perilous wastes and their disposal was adopted in 1989 and came into force in 1992 (Basel Convention 2006).
(e) *The Stockholm Convention*: In 1995, a convention held in Stockholm proposed to ban 12 toxic persistent organic pollutants (POPs) (Dirty dozen), to which more chemicals were added afterwards. Later in 2001, an international legal treaty named as “Stockholm Convention” was opened for ratification and was finally signed by 179 countries, which then came into power in 2004, around after a decade after UNEP’s (United Nations Environment Programme) call for global action on POPs in 1995 (UNEP 2009). This convention proposed to ban or restrict the production, release, and use of selected harmful chemicals including polychlorinated biphenyls (PCBs) and a range of organochlorine pesticides (OCPs) in all participant countries (UNEP 2009; Morillo and Villaverde 2017; Bharat 2018). Furthermore, SC amendments in 2011 engorged the list up to 22 POPs (United Nations Environment Programme 2013a).
(f) *The International POPs Elimination Network (IPEN)*: The International POPs Elimination Network (IPEN) is a non-profit organization that was established in 1998 in Sweden. IPEN deals with the sound chemical management policies and practices, as a strategy for global economic development and environmental protection (Bharat 2018).

(g) *The International Labor Organization Convention No. 184 (ILO Convention 184)*: ILO Convention 184 deals with all aspects of safety and health while chemical application in agriculture sector (ILO 2000). It was adopted in 2001 and later came to force in 2003.
(h) *The Global Harmonized System of Classification and Labelling of Chemicals (GHS)*: The GHS has been devised for the safety of human beings and the environment during the handling, use, and transport of hazardous chemicals (FAO 2006a, b).
(i) *Strategic Approach to International Chemicals Management (SAICM)*: Strategic Approach to International Chemicals Management (SAICM) is a global policy framework for proper chemical management. It was adopted by International Conference on Chemicals Management (ICCM) in 2006 (Bharat 2018). It recognizes the role of chemicals in the current scenario as well as the potential threat to sustainable development by chemical mismanagement. SAICM goals together with the support of United Nations Economic Commission for Europe (UNECE) and UNEP deal with the chemical management, environment, and sustainable development in alliance and deem in achievement of these goals by the year 2020 (Teran et al. 2012; Bharat 2018).
(j) *Registration, Evaluation and Authorisation of Chemicals (REACH)*: In 2007, a legislation called as Registration, Evaluation and Authorisation of Chemicals (REACH) was adopted and enforced by the European Union (EU) with the rationale of information gathering on chemicals entering European markets without prior knowledge vis-a-vis their detrimental impacts on environment and human health (EU 2006; EEA 2007; ECHA 2008). This is achieved through the recognition of appropriate pesticide risk assessment models for the screening, proper approval, and registration of these new pesticides being marketed in Europe, with the purpose of reducing future exposure risks (ECHA 2011). REACH encompass registration, evaluation, authorization, and restriction elements.
(k) *The Clean Sweep Program*: The Convention on Persistent Organic Pollutants along with the Food and Agriculture Organization (FAO) are setting up global efforts for decreasing the occurrence as well as abundance of detrimental pesticides. In this direction, for apposite disposal of pesticides "Clean Sweep Program" was instated in several regions within the USA (Dixit et al. 2019).
(l) *The Codex Alimentarius Commission*: The Codex Alimentarius Commission formulated several standards on the presence of pesticide residues in food (Abhilash and Singh 2009).
(m) *Global Good Agricultural Practices (GlobalGAP)*: The Global Good Agricultural Practices (GlobalGAP) is a European non-profit organization that delineates good agricultural practices like using small quantity of pesticides for sustainable production (GlobalGAP 2016).
(n) *Pesticide Action Network organization (PAN)*: The Pesticide Action Network organization (PAN) is a network of over 600 NGO's and institutions, operational in around 90 countries. Its main aim is to substitute deleterious chemical pesticides by ecologically sound approaches (Pesticide Action Network International 2014).

Some other international conventions that are of great importance are: The Mediterranean Action Plan for the Barcelona Convention (MAP) (UNEP 1978); The Arctic Monitoring and Assessment Programme (AMAP) (Arctic Council 1991); The Chemical Weapons Convention 1993; The Convention for the Protection of the marine Environment of the North–East Atlantic (OSPAR); Northern Contaminants Program (NCP) (NCP 2003); The Environmental Monitoring and Governance in the East Asian Hydrosphere-Monitoring of POPs (EMGEAH), and European Monitoring and Evaluation Programme (EMEP http://www.emep.int). Furthermore, globally, several acts were passed for management of pesticides such as The Prevention of Food Adulteration Act, 1954; The Insecticide Act, 1968; The Insecticide Rules, 1971; The Environment Protection Act, 1986; and The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (Frazar 2000; Abhilash and Singh 2009).

Environmental regulations play an indispensable role in effectual pesticide management along with maintenance of environment. However, these regulatory frameworks are not appropriately and effectively implemented even in developed countries (Morillo and Villaverde 2017). In developing countries, the environmental regulations governing pesticide application, storage, and disposal are scarcely implemented (United Nations Environment Programme 2013b, 2014). So, relying only on legislation for pesticide management is not a practicable solution. Globally, governments should adopt environmentally sustainable approaches for pest and pesticide management like public awareness campaigns, training programs regarding proper pesticide application, mass awareness about use of minimum-risk products, and adoption of integrated pest management (IPM) system. Nonetheless, a firm legislative and regulatory framework strengthens all of these approaches.

15.5.1 Legal Penalty for Violating Environmental Regulations

For strengthening the environmental regulations, several global organizations framed legal penalty for violating environmental regulations. For instance, depending on the location and nature of landfill site, the landfill operators are bound to make financial assurances and are charged different amounts of licence fees by Environment Protection Agency (EPA). Any kind of unauthorized waste disposal draws legal penalty up to US$60,000 per individual (Kuppusamy et al. 2016).

15.6 Conclusion

Extensive use of pesticides has become a serious ecological and human health hazard globally. Due to the dearth of a comprehensible pesticides management approach, large amount of obsolete pesticide residues have already stockpiled over the time. So, there is an immediate need to develop technique for the degradation and removal of pesticides from contaminated sites. Assessing the environmental providence of pesticide residues and their imminent exposure risks to environment and public health is essential for formulating risk-based management strategies for risk reduction. Environmental impact assessment of pesticides influences characterization of previously permitted pesticides, approval of new pesticides, and establishment of remediation goals along with maintenance of environmental quality. Several developed regions have established pesticide risk assessment models which are of great significance for environmental sustainability. Biological control strategies, cultural control strategies, physical control strategies, mechanical control strategies, new molecular strategies, Farmer education and awareness, adhering to environmental regulations, rational use of pesticides (RUP), continuous monitoring of pesticide residues, and development of new pesticides with enhanced safety profiles are some effective and reliable pesticide management strategies. Pesticide ban is an important regulatory stride taken for the management of deleterious pesticides. Globally, several highly persistent and toxic pesticides have been banned hitherto with DDT ban an exemplary one. This chapter provides an overview of global environmental regulations framed for management of pesticides. The International Code of Conduct and Use of Pesticides, The Montreal Protocol, The Rotterdam Convention, The Basel Convention, The Stockholm Convention, The International POPs Elimination Network (IPEN), The International Labor Organization Convention No. 184 (ILO Convention 184), The Global Harmonized System of Classification and Labelling of Chemicals (GHS), Strategic Approach to International Chemicals Management (SAICM), Registration, Evaluation and Authorisation of Chemicals (REACH), The Clean Sweep Program, The Codex Alimentarius Commission, Global Good Agricultural Practices (GlobalGAP) and Pesticide Action Network organizations (PAN) are some imperative global environmental regulations framed for management of pesticides.

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