Environmental, Health, and Safety Guidelines for Pesticide Manufacturing, Formulation, and Packaging

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment

Applicability

The EHS guidelines for pesticides manufacturing and formulation address the synthesis, optimization of the active ingredients, process development (manufacturing), the formulation and packaging of pesticides from these active ingredients. The main pesticide groups that are formulated include insecticides, herbicides, fungicides, acaricides (or miticides), nematicides and rodenticides.

This document is organized according to the following sections:

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

1.0 Industry-Specific Impacts and Management

This section provides a summary of EHS issues associated with pesticide manufacturing, formulation, and packaging, which occur during the operational phase. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

Pesticide manufacturing, formulation, packaging and distribution should be conducted in compliance with applicable international standards including:

- Stockholm Convention on Persistent Organic Pollutants (POPs), which bans or restricts the manufacture and trade of intentionally produced POPs, including some pesticides;[2]
- World Health Organization (WHO) Recommended Classification of Pesticides by Hazard, which lists active ingredients considered to be obsolete or discontinued for use as pesticides;[3]
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade;[4]
- Food and Agriculture Organization's International Code of Conduct, which includes requirements on the application of the life-cycle concept in the production, management, packaging, labeling, distribution, handling, application, use, and control, including post registration activities and disposal of all types of pesticides, including used pesticide containers;[5]
- Food and Agriculture Organization's Revised Guidelines on Good Labeling Practice for Pesticides.[6]

1.1 Environmental

Environmental issues associated with pesticides manufacturing, formulation and packaging include:

- Air emissions
- Wastewater
- Hazardous Materials
- Wastes
- Energy consumption/efficiency
- Water consumption/efficiency

Air Emissions

Emissions to air generated during pesticide manufacturing, formulating and packaging processes include volatile organic compounds (VOC), fine particulates, exhaust gases, and greenhouse gases.

Volatile Organic Compounds (VOC)

VOC may be emitted from reactor vents, filtering systems during separation processes, purification tanks, and dryers during chemical synthesis and extraction activities. VOC emissions may also be generated when solvent-based liquid formulations are produced (e.g. preparation of granulated products by impregnation and use of emulsifiable concentrate products), and during equipment cleaning with solvents.

[2] Stockholm Convention on Persistent Organic Pollutants (POPs) (http://www.pops.int/)
[3] World Health Organization (WHO) Recommended Classification of Pesticides by Hazard (http://www.who.int/ipcs/publications/pesticides_hazard/en/) also includes guidance for prior informed consent, labeling, and worker safety information (Materials Safety Data Sheets (MSDSs)).
[4] Rotterdam Convention on the Prior Informed Consent Procedure (http://www.pic.int/)
[5] FAO International Code of Conduct (http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/Pesticid/Default.htm)
[6] FAO Revised Guidelines on Good Labeling Practices (http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/Pesticid/r.htm)

Recommended measures to <u>prevent</u> VOC emissions include the following:

- Consider use of non-halogenated and non-aromatic solvents (e.g. ethyl acetate, alcohols and acetone) instead of more toxic solvents (e.g. benzene, chloroform and trichloroethylene);
- Contain and enclose batch reactors and install closed feed systems. Undertake regular monitoring of emissions from pipes, valves, seals, tanks and other infrastructure components with vapor detection equipment and perform maintenance or replacement of components as needed;
- Implement vapor balancing during design and operations, as necessary;
- Reduce of operating temperatures;
- Install nitrogen blanketing on pumps, storage tanks and during formulation processes (e.g. emulsifiable concentrate products);
- Install process condensers (e.g. distillation condensers, reflux condensers, condensers before vacuum sources, condensers used in stripping and flashing operations, and cryogenic condensers) after the process equipment to support a vapor-to-liquid phase change and to recover solvents[7];
- Use closed equipment for cleaning of reactors and other equipment.

Recommended measures to <u>control</u> VOC emissions include the following:

- VOC vapors from solvent handling activities and processes should be collected and the venting ducts should be connected to air control devices, including the following:
    - Wet scrubber or gas absorber systems. Water, caustic, and acidic scrubbers may be used in pesticides manufacturing for organic and inorganic gas emission abatement. Hypochlorite solutions may be added to reduce odor nuisance;
    - Activated carbon adsorption, achieving a VOC removal efficiency of 95 - 98 percent;
    - Thermal oxidation / incineration systems, achieving VOC destruction efficiencies of up to 99.99 percent;[8]
    - Catalytic oxidation systems;
    - Biofiltration treatment, if VOCs are biodegradable.

Particulate Matter

Fine particulates of pesticide dust may be suspended in air during material handling, processing, and storage. Dust generated by pesticide formulation (e.g. milling, mixing) and packaging processes contain active ingredients that may be toxic to humans and the environment. Recommended measures to prevent and control particulate emissions include the following:

- Collect fine particulates of pesticides (e.g. wettable and dust powders) with air filtration units (e.g., cyclones, baghouse / fabric filters, or wet scrubbers) and, where possible, recycle the recovered particulates into the formulation process;
- Install separate dedicated dust filtration units for each production line (e.g. granulation, dust or granule blending mills) to maximize recycling of pesticide dust;
- Install filters in the HVAC systems to control emission of particulates in the exhaust air, and prevent indoor air contamination;

[7] VOCs may be condensed by indirect cooling of exhaust gases prior to downstream exhaust gas treatment, and the solvents can be recovered by distillation in tray evaporators. Cryogenic condensers reduce the gas stream temperature below dew point. Cryogenic condensers may have a higher removal efficiency than other types of condensers, but they may have higher energy consumption

[8] If co-incineration of halogenated waste solvents together with exhaust gases from production is implemented, sufficient temperature, residence times and turbulence in the combustion chamber should be ensured in order to prevent emissions of dioxins / furans. Combustion temperatures of =1100 °C and residence times of =2 seconds should be generally applied. The temperature profile should be carefully controlled to prevent re-formation during cooling.

- Segregate ventilation air ducts to prevent air cross-contamination from different processes;
- Install automatic, enclosed cut-in hoppers to prevent opening and emptying of pesticide dust containers during formulation and packaging;
- Use wet scrubbing and wet electrostatic precipitators after combustion / thermal oxidation treatments.

Exhaust Gases

Exhaust gas emissions produced by the combustion of gas or diesel in turbines, boilers, compressors, pumps and other engines for power and heat generation are a significant source of air emissions from pesticides manufacturing, formulation, and packaging facilities. During equipment selection, air emission specifications should be considered.

Guidance for the management of small combustion processes designed to deliver electrical or mechanical power, steam, heat, or any combination of these, regardless of the fuel type, with a total, rated heat input capacity of 50 Megawatt thermal (MWth) is provided in the **General EHS Guidelines**. Guidance applicable to processes larger than 50 MWth is provided in the **EHS Guidelines for Thermal Power**.

All attempts should be made to maximize energy efficiency and design facilities to minimize energy use. The overall objective should be to reduce air emissions and evaluate cost-effective options for reducing emissions that are technically feasible. Additional recommendations on energy efficiency are addressed in the **General EHS Guidelines.**

Wastewater

Industrial process wastewater

Liquid effluent discharge from pesticides manufacturing and formulation facilities include organic biodegradable compounds (e.g. oxygenated organic solvents, such as methanol, ethanol, acetone, isopropanol, and phenol; organic acids; and organic esters), recalcitrant organic compounds (e.g. chloro-derivatives and fluoro-derivatives), suspended solids, and certain inorganic material (including inorganic acids, ammonia, and cyanide). Trace amounts of active pesticide ingredients may be of significant concern. Biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and pH are the main water quality indicator parameters.

Pesticide Manufacturing Wastewater

Wastewater generated from pesticides manufacturing processes consists of reaction water from chemical processes, process solvent water, process stream wash water, product wash water, spent acid and caustic streams, condensed steam from strippers and sterilization, air pollution control scrubber blowdowns, and equipment and facility wash water.

In biopesticide manufacturing, spent fermentation broth usually contains sugars, starches, proteins, nitrogen, phosphates, mineral salts, and other nutrients with high biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS).

Recommended pollution prevention and abatement measures include the following:

- Reuse and recycling of equipment washdown waters and other process water as makeup solutions for subsequent batches;
- Installation of equalization systems before the wastewater treatment units to manage flow and / or concentration spikes;
- Solvent waste streams from different sources should be combined to optimize treatment;
- Recovery of solvents:
    - Fractioned distillation to remove low-boiling compounds from wastewater stream

- Inert gas stripping and condensation to remove volatile compounds from wastewater stream
    - Solvent extraction of organic compounds (e.g. high or refractory halogenated compounds and high COD loads)
- Installation of reverse osmosis or ultrafiltration systems to recover and concentrate active ingredients;
- Installation of pH adjustment and neutralization systems, as needed;
- Use of filtration and settling ponds to reduce TSS and BOD associated with particulate matter;
- Installation of biological treatments (e.g. activated sludge systems, trickling filters and / or rotating biological contactors) to control BOD, COD, and TSS concentrations, and to degrade organic constituents;
- Installation of a pretreatment stage for wastewater with biodegradability less than 80 percent, such as:
    - Cyanide destruction through alkaline chlorination, hydrogen peroxide oxidation and hydrolysis treatments, where cyanide based-reagent is generally used for pesticide and / or intermediate synthesis
    - Active ingredient detoxification through oxidation, using ultraviolet systems or peroxide solutions
    - Installation of granular activated carbon adsorption systems to treat BOD / COD and organic compounds
    - Steam and / or air stripping to treat wastewater containing organics and ammonia, the latter through pH adjustment to values of 10-11
    - For biopesticide manufacturing, oxidation of residual products and potential pathogens through hypochlorite and / or other disinfection / sterilization methods
- Bio-monitoring and testing of effluents for toxicity to fish, daphnia, algae, etc., after biological treatment and before discharge;

Pesticide Formulation Wastewater

Wastewater from pesticide formulation is mainly associated with cleaning, cooling and heating of equipment and process areas used for liquid pesticide blending, mixing and storage. Wastewaters from formulation and packaging operations typically have low levels of BOD, COD and TSS, and pH is generally neutral. Their level of toxicity and biodegradability depends on the presence of chemicals such as pesticide residues, organic solvents, and other compounds necessary for formulation which may be toxic to aquatic organisms.

In addition to the wastewater and stormwater treatment systems for effluents from pesticide manufacturing facilities, described above, additional recommended pollution prevention and control measures include the following:

- Installation of pretreatment systems to enhance biodegradability and lower toxicity of liquid effluents (e.g. emulsion breaking by temperature control and acid addition);
- Collection of cleaning fluids (solvents and rinse water) for reuse. Equipment wash waters and other process water should be reused in subsequent batches;
- Use of wiper blades, automatic wall scrapers, and other mechanisms to clean mixing tanks and reduce solvent contamination of wash water;
- Use of low-volume, high efficiency cleaning systems (e.g. high pressure spray nozzles, water knives. and steam cleaners);
- Periodic cleaning of lines, using a plastic or foam “pig”;
- Piping design to facilitate draining of the lines.

Process Wastewater Treatment

Techniques for treating industrial process wastewater in this sector include source segregation and pretreatment of concentrated wastewater streams, especially those associated with active ingredients. Typical wastewater treatment steps include: grease traps, skimmers, dissolved air floatation or oil water separators for separation of oils and floatable solids; filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; biological treatment, typically aerobic treatment, for reduction of soluble organic matter (BOD); chemical or biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; dewatering and disposal of residuals in designated hazardous waste landfills.

Additional engineering controls may be required for (i) containment and treatment of volatile organics stripped from various unit operations in the wastewater treatment system, (ii) removal of recalcitrant organics and active ingredients using activated carbon or advanced chemical oxidation, (iii) reduction in effluent toxicity using appropriate technology (such as reverse osmosis, ion exchange, activated carbon, etc.), and (iv) containment and neutralization of nuisance odors.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams & Water Consumption

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**.

Hazardous Materials

Pesticide manufacturing, formulation, and packaging facilities use and manufacture significant amounts of hazardous materials, including raw materials and intermediate / final products. The handling, storage, and transportation of these materials should be managed properly to avoid or minimize the environmental and health impacts. Recommended practices for hazardous material management, including handling, storage, and transport, are presented in the **General EHS Guidelines**.

Wastes

Pesticides manufacturing, formulation and packaging processes generate both hazardous and non-hazardous solid and liquid wastes. Solid or semisolid wastes include residues and filtrates from chemical synthesis processes, contaminated with spent acids, bases, solvent, active pesticide ingredients, cyanides and metals; off-specification products not accepted for packaging; used air filter media (e.g. fabric filters, spent activated carbons); packaging waste; dry sludge from wastewater treatment processes; wastes from laboratory activities; filter cakes from fermentation (biopesticides manufacturing) and chemical processes, and spent process solids containing intermediates, inorganic salts, organic by-products, metal complexes by-products, residual products, and nutrients (the latter in the case of fermentation processes). Decontamination of the solid-based pesticide blending mills may generate a solid dilutant, consisting of clay or sand, contaminated with pesticides.

Liquid wastes include spent solvents; spent acid and caustic solutions; and residues from distillation (still bottoms) in chemical synthesis.

Measures to manage solid and liquid wastes include the following:

- Consider material substitution to reduce generation of hazardous and non-recyclable wastes (e.g. substitution of toxic solvents with less toxic nonhalogenated and nonaromatic solvents);

- Sterilize equipment and products from fermentation activities in biopesticides manufacturing with steam and non-hazardous chemicals (e.g. phenols, detergents and disinfectants)
- Use of distillation, evaporation, decantation, centrifugation and filtration to maximize recycling and reuse of spent solvent;
- Use of metering and control of quantities of active ingredients to minimize waste;
- Use of automated filling systems for reactors, tanks and drums to minimize spills.
- Use of technologies and processes that reduce generation of waste, such as the scheduling of production in groups to reduce the number of changeovers, which reduces the required number of equipment cleanings;
- Re-use or recycle waste as raw material where and when possible, such as waste from cleaning of drums and shipping containers.

Detailed guidance on the storage, handling, treatment, and disposal of hazardous and non-hazardous wastes is provided in the **General EHS Guidelines**.

1.2 Occupational Health and Safety

Occupational health and safety issues have to be considered an important part of a comprehensive hazard or risk assessment, for example, a hazard identification study [HAZID], hazard and operability study [HAZOP], or a quantitative risk assessment [QRA].

The occupational health and safety issues that may occur during the construction and decommissioning of pesticide manufacturing and formulation facilities are similar to those of other industrial facilities, and their management is discussed in the **General EHS Guidelines**. As a general approach, health and safety management planning should include the adoption of a systematic and structured approach for prevention and control of physical, chemical, biological, and radiological health and safety hazards described in the **General EHS Guidelines.**

Occupational health and safety issues specific to pesticide manufacturing, formulation and packaging plants include:

- Process safety
- Chemical exposure
- Pathogen exposure
- Fires and explosions

Process Safety

Process safety programs should be implemented, due to industry-specific characteristics, including complex chemical reactions, use of hazardous materials (e.g. highly toxic and reactive materials, lachrymators and flammable or explosive compounds), and operations in bulk pesticide manufacturing, especially where multi-step organic synthesis reactions (e.g., pyrethroid manufacturing) are conducted.

Process safety management include the following actions:

- Physical hazard testing of materials and reactions;
- Hazard analysis studies to review the process chemistry and engineering practices, including thermodynamics and kinetics;
- Examination of preventive maintenance and mechanical integrity of the process equipment and utilities;
- Worker training;
- Development of operating instructions and emergency response procedures.

Chemical Exposure

Occupational health risks may derive from worker exposure to hazardous chemical substances, including active ingredients and pesticide dusts, during all production phases. Worker exposure to solvent vapors may occur during manufacturing and formulation processes, including operations for recovering or isolating products; handling wet cakes in drying operations; wet granulation; uncontained filtration equipment; equipment cleaning; and fugitive emissions from leaking pumps, valves and manifold stations (e.g. during extraction and purification steps).

In pesticides formulation and packaging processes, workers may be exposed to airborne dusts during drying, milling and mixing operations. Occupational hazards are associated with exposure to mixtures containing high proportions of active ingredients, and with exposure to carriers / fillers and additives. These agents, although inert in terms of pesticide activity to the target pest, may be toxic and should be assessed for occupational health impacts.

Recommended hazard prevention and control measures include:

- Unloading of toxic raw materials and products with a gas balancing system to minimize fugitive emissions and prevent worker exposure;
- Gravity charging from enclosed containers, and enclosed vacuum, pressure, and pumping systems during charging and discharging operations to minimize fugitive emissions;
- Partitioning of workplace areas with dilution ventilation and / or differential air pressures. Where toxic materials are processed, consider maintaining the plant under slight overpressure (e.g. nitrogen blanketing);
- Installation of laminar ventilation hoods or isolation devices where toxic materials are handled;
- Installation ventilation systems with high efficiency particulate air (HEPA) filters, especially in sterile product manufacturing areas for biopesticides manufacturing;
- Liquid transfer, liquid separation, solid and liquid filtration, granulation, drying, milling and blending should be carried out in well ventilated work areas;
- Installation of local exhaust ventilation (LEV) with flanged inlets to capture fugitive dusts and vapors released at open transfer points;
- Granulators, dryers, mills and blenders should be enclosed and should be vented to air-control devices;
- In the biopesticides manufacturing, sterilization vessels should be located in separate areas with remote instrument and control systems, non-recirculated air, and LEV to extract toxic gas emissions. Gas sterilization chambers should be operated under vacuum and purged with air to minimize fugitive workplace emissions before sterilized goods are removed;
- Equipment used for the packing of solid pesticides should be maintained to minimize leaks, and all surfaces should be designed to avoid accumulation of dust;
- Liquid pesticide packs should not be overfilled, and filling equipment should be designed to avoid splashing / foaming;
- Use of vacuum cleaners with HEPA filters during cleaning operations of areas and equipment where hazardous substances and high-potency active ingredients are handled and manufactured;
- Positive-pressure respirators, in addition to other PPE (e.g. protective gowns), should be maintained where highly toxic solvents and dangerous compounds are handled and processed.

Exposure to Pathogens

Exposure to pathogens is an occupational hazard associated with isolation and growth of micro-organisms in laboratories and during fermentation processes in biopesticide manufacturing. Recommended hazard prevention and control measures include the following:

- Non-pathogenic microbes should be selected;
- Process equipment should be enclosed and spent broth should be treated before discharge;
- Implementation of appropriate biohazard control measures (e.g. process modifications, material handling and transfer minimization, local exhaust ventilation (LEV), filtration and inertization, decontamination, administrative practices, and use of personal and respiratory protective equipment);
- Installation of downward and inward, laminar flow biological safety hoods.

Fire and Explosions

Fire and explosion hazards may arise during solvent use, handling, and storage. Organic synthesis reactions may generate major process safety risks. Pesticides formulation processes (e.g. granulation, mixing, and drying and / or packaging activities), may create a flammable or explosive atmosphere. Pesticide dusts can be highly explosive. Recommended hazard prevention and mitigation measures include the following:

- Learn from previous experience (study previous cases);
- Ban smoking in and around facilities;
- Provide local fire department with list of products stored on the premises;
- Control the potential effect of fires or explosions by segregation and distancing of process, storage, utility, and safe areas. Safety distances can be derived from specific safety analyses for the facility, and through application of internationally recognized fire safety standards.[9]
- Avoiding potential sources of ignition (e.g. by configuring the layout of piping to avoid spills over high temperature piping, equipment, and / or rotating machines, and by removing combustible debris);
- Reduction of solvent flammability by dilution with water in filtration and recovery steps;
- Full assessment of physical properties of pesticide dusts prior to processing and treatment;
- Use of explosion-proof equipment and conductive materials to control risks associated with potentially explosive pesticide dusts.
- Implementation of good operating practices and minimization of operations such as material handling and transfer;
- Installation of vapor- and dust-tight electrical equipment and utilities;
- Grounding and bonding of equipment;
- Installation of fire and smoke detectors and emergency alarms.
- Training of staff (workers and managers)

1.3 Community Health and Safety

The most critical community health and safety hazards during the operation of pesticides manufacturing, formulation and packaging derive from accidental leaks of toxic compounds, and the presence of flammable gases and liquids. Plant design and operations should include safeguards to minimize and control hazards to the community through the following:

- Identifying reasonable design leak cases;
- Assessing the effects of the potential leaks on the surrounding areas, including groundwater and soil pollution;
- Assessing the risk due to hazardous material transport and selecting the most appropriate transport routes, minimizing

[9] An example of further information on safe spacing is the US National Fire Protection Association (NFPA) Code 30.

the risks with respect to community interference and third party interaction;

- Properly selecting the plant location with respect to inhabited areas, meteorological conditions (e.g. prevailing wind directions), and water resources (e.g. groundwater vulnerability), and identifying safe distances between the plant area, especially the storage tank farms, and the community areas;
- Identifying the prevention and mitigation measures required to avoid or minimize the community hazards;
- Developing an Emergency Management Plan, prepared with the participation of local authorities and potentially affected communities.

Guidance on the transport of hazardous materials, the development of emergency preparedness and response plans, and other issues related to community health and safety is discussed in the **General EHS Guidelines**.

Product Safety

Pesticides manufacturers should promote the concept of "product stewardship" or "Life-cycle stewardship" approach, starting from the research and development, manufacture, formulation, transport, storage, use and, where feasible, disposal of waste (e.g. empty containers and obsolete stocks). Pesticides should only be manufactured under license and registered and approved by the appropriate authority and in accordance with the Food and Agriculture Organization's (FAO's) International Code of Conduct on the Distribution and Use of Pesticides.[10] All products should be labeled in accordance with international standards and norms, such as the FAO's Revised Guidelines for Good Labeling Practice for Pesticides.[11]

[10] FAO (2002c)

[11] FAO (2002c)

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions and Effluent Guidelines

Tables 1 and 2 present emission and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document.

Table 1. Air Emissions Levels for Pesticides

Pollutant	Units	Guideline Value
Particulate Matter	mg/Nm^3	20; 5[a]
Total Organic Carbon	mg/Nm^3	50
VOC	mg/Nm^3	20
Chloride	mg/Nm^3	5
Bromines (as HBr), Cyanides (as HCN), Fluorines (as HF), Hydrogen Sulfide	mg/Nm^3	3
Chlorine	mg/Nm^3	3
Ammonia, Gaseous Inorganic Chlorine Compounds (as HCl)	mg/Nm^3	30

Notes:
[a] Where very toxic compounds are present

Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with steam and power generation activities from sources with a capacity equal to or lower than 50 megawatts thermal (MWth) are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Table 2. Effluents Levels for Pesticides

Pollutant		Units	Guideline Value
pH		S.U.	6-9
BOD_5		mg/l	30
COD		mg/l	150
TSS (Lower end for pesticide manufacturing. Higher end for pesticide formulation (monthly average) but in no case more than 50 mg/l)		mg/l	10-20[1]
Oil and Grease		mg/l	10
AOX		mg/l	1
Phenol		mg/l	0.5
Arsenic		mg/l	0.1
Chromium total		mg/l	0.5
Chromium (hexavalent)		mg/l	0.1
Copper		mg/l	0.5
Chlorinated organics		mg/L	0.05
Nitrorganics		mg/L	0.05
Mercury		mg/l	0.01
Zinc		mg/l	2
Active Ingredient (each)		mg/l	0.05
Bioassays Toxicity	Toxicity to:	TU	
	Fish		2
	Daphnia		8
	Algae		16
	Bacteria		8
Ammonia		mg/l	10
Total Phosphorus		mg/l	2

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in the use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines.** These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Waste Generation / Emission Loads

Tables 3 and 4 provides example of indicators in waste and wastewater generation. Industry benchmark values are provided for comparative purposes only and individual projects should target continual improvement in these areas.

Table 3. Waste Generation / Emission Load

Parameter	Unit	Industry Benchmark
Wastewater Total Organic Carbon effluents	Kg/batch mother liquor	180 (110 refractory)
Waste Manufacturing	Kg/ton of active ingredient manufactured	200
Formulation	Kg/ton of formulated product	3 - 4

Source:
EU IPPC BREF (2006)

Table 4. Load-Based Effluents Levels for Pesticides

Pollutant	Units		Guideline Value
pH	S.U.		6-9
BOD_5	kg/t	Daily max	5.3
		Mo. avg	1.2
COD	kg/t	Daily max	9.4
		Mo. avg	6.5
TSS	kg/t	Daily max	4.4
		Mo. avg	1.3
Active Ingredient (each)	kg/t	Daily max	2.8×10^{-9} – 3.4
		Mo. avg	1.3×10^{-6} – 1.0

Source: U.S. EPA Effluent Guidelines for Pesticide Chemicals, Organic Pesticide Chemicals Manufacturing Subcategory, New Source Performance Standards, 40 CRF Part 455. Levels for specific active ingredients are listed in Table 3 of the regulation.

kg/t = kg of pollutant per metric ton of organic active ingredients.

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),[12] the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),[13] Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),[14] Indicative Occupational Exposure Limit Values published by European Union member states,[15] or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)[16].

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals[17] as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines.**

[12] Available at: http://www.acgih.org/TLV/ and http://www.acgih.org/store/
[13] Available at: http://www.cdc.gov/niosh/npg/
[14] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
[15] Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/
[16] Available at: http://www.bls.gov/iif/ and http://www.hse.gov.uk/statistics/index.htm
[17] Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

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Annex A: General Description of Industry Activities

Pesticide industry activities consist of the following three main production lines:

- Pesticide manufacturing, involving the industrial synthesis of molecules produced or modified to provide compounds (active ingredients);
- Pesticide formulation, involving the formulation of chemical groups of gas (fumigants), solid or liquid pesticides from active ingredients;
- Pesticide packaging, involving packaging systems designed from materials that can effectively contain and the pesticide to optimize its handling and application and reduce health or environmental risks to humans or ecosystems as a result of drift or runoff.

Pesticides manufacturing, formulation and packaging should employ current Good Manufacturing Practice (cGMP) procedures to ensure product quality, a safe working environment, and prevention of environment impacts.

Pesticides Manufacturing

Pesticides manufacturing is a part of organic fine chemical manufacturing. The principal manufacturing steps include (a) preparation of process intermediates; (b) introduction of functional groups; (c) coupling and esterification; (d) separation processes (e.g. washing and stripping); and (e) purification of the final product (e.g. dissolution, dissolution and extraction, or ultra-filtration). Cooling and / or heating, and the application of vacuum or pressure conditions, are often necessary. All steps, and particularly the reactions, may generate air emissions, effluents, and waste / byproducts.

The number of pesticide raw materials is extensive, including materials common to most pesticide manufacturing processes (e.g. chlorine, hydrogen cyanide, carbon disulfide, various amines and concentrated acids and caustics), and materials that are common to specific families of pesticides (e.g. chloroanilines, chloroformates, cresols, dichlorobenzenes, diethylamine, dioxane, fluoroanilines, zinc nitrate, zinc sulfate). Intermediates are also numerous and diverse.

Pesticides banned by international organizations / conventions are not considered acceptable for manufacturing, formulation or use.[18]

Pesticide Formulation

Pesticides are not applied full strength. The main purpose of pesticide formulation is to manufacture a product that has optimum biological efficiency, is convenient and economical to use, and minimizes impacts to human health and the environment. The nature of the active ingredient and the intended use define in large part the type of formulation used.

The formulation of pesticides involves mixing, blending, or diluting one or more pesticide active ingredients and inert ingredients to obtain a product used for additional processing or as a final product. Active ingredients are mixed with solvents, adjuvants (or boosters), and carriers (or fillers) and specific anti-dusting and anti-foaming agents, as necessary to achieve the desired formulation.

The solvents used in pesticide formulation belong to polar (e.g. ketones, esters, glycol ethers, and acid amides) and non-polar groups (e.g. hydrocarbons and petroleum distillates). The adjuvants and surfactants are added to pesticide formulations to

[18] Refer to International Agreements on Pesticides considered acceptable for manufacturing and use. For example, see International Programme on Chemical Safety; the WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2004, Corrigenda published by April 12, 2005 incorporated; and the Plant Protection Products EU Directive (91/414/EEC). The banned pesticides in the European Union are listed in Council Directive 79/117/EEC dated 21 December 1978 and its amendments. The list of banned pesticides in US is presented in the webpage of US EPA on Pesticides: Regulating Pesticides. Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade should be also consulted.

improve performance characteristics of formulations. The most important adjuvants include deactivators (e.g. organic substances such as ketones, esters, sulfoxides); anti-caking agents (e.g. diatomaceous earth and microfine synthetic silica); dry lubricants (e.g. powdered graphite, some metal stearates); protective colloids (e.g. polymeric materials such as polyvinyl pyrrolidone, methylcellulose, blood allumine); and stickers (e.g. polyethylene polysulfide). The most important dry powdered carriers and dilutants used in pesticide formulations are inorganic materials, including minerals (e.g. diatomite, vermiculite, attapulgite, montmorillonite, talc, and kaolinite). Granular carriers are particulate materials typically of mineral or vegetable origin; attapulgite and montmorillonite are most commonly used.

Pesticide formulations are classified into gas formulations (aerosols and fumigants), liquid formulations and solid formulations. Liquid formulations include emulsifiable concentrates, soluble concentrates, oil in water emulsions, liquid flowables, oil-based suspension concentrates, and suspoemulsions, solutions, and microencapsulates. Solid formulations include dust powders, wettable powders, dry granules, pellets, dry flowables, soluble powders and water dispersible granules. Other types of formulations include controlled release (the active ingredient is released from a polymeric carrier, binder, absorbent, or encapsulant at a slow and effective rate into the environment), aerosols, seed dressings, poison baits, encapsulated formulations, and Ultra Low Volume formulations.

Other formulation components include adjuvants (wetting agents, spreders, stickers, drift retardants, stabilizing agents, penetrants), and synergists, such as Piperonyl butoxide commonly used to boost the activity of pyrethroid insecticides

The main pesticide formulation products include herbicides, fungicides, insecticides, rodenticides, and other chemical groups (e.g. nematicides, acaricides, biocides, bactericides, avicides, etc.).

Formulating, packaging, and repackaging are performed in a variety of ways, including both automated formulation and packaging lines and manual lines. The dry products are formulated according to various methods, including mixing powdered or granular active ingredients with dry inert carriers; spraying or mixing a liquid active ingredient onto a dry carrier; soaking or using pressure and heat to force active ingredients into a solid matrix; mixing active ingredients with a monomer and allowing the mixture to polymerize into a solid; and drying and hardening an active ingredient solution into a solid product. Typical liquid formulating lines consist of storage tanks or containers to hold active ingredients and inert materials and a mixing tank for formulating the pesticide product . Formulations are packaged by transferring the final product into containers or boxes, either manually by gravity feeding or automatically.

Main Pesticide Groups

Fungicides

Agricultural fungicides are chemicals that prevent or minimize crop losses caused by phytopathogenic fungi. Fungicides can be divided conveniently into non-systemic and systemic types, although some overlap occurs with compounds that have a local penetrating effect:

- Non-systemic fungicides (also called contact or residual protective fungicides), including inorganic compounds, organometallic compounds, dithiocarbamates; N-trihalomethylthio, phthalimides; dicarboximides.
- Systemic fungicides, including organophosphates; benzimidazoles; carboxanilides; phenylamides; phosphites; inhibitors of sterol biosynthesis, such as triazoles, imidazoles, pyridines, pyrimidines, piperazines, morpholines, and strobulins.

Herbicides

Herbicides may be defined as agents that destroy, damage or inhibit plant growth. The main groups include:

- Plant Growth Regulators
- Defoliants and Desiccants
- Foliage-Active Contact Herbicides: (a) bipyridiliums (e.g. paraquat, diquat); (b) benzonitriles include bromoxynil and ioxynil; (c) propanil; (d) bentazon;
- Foliage-Active Translocated Herbicides:
    - Growth regulators, or auxin-type herbicides, including 2,4-D, MCPA, 2,4,5-T, picloram, dicamba, clopyralid, triclopyr
    - Fatty acid synthesis inhibitors (e.g. diclofop, fluazifop-P, sethoxydim, quizalofop, tralkoxydim, and clethodim)
    - Glyphosate
    - Sulfonyl ureas (e.g. chlorsulfuron, metsulfuron, sulfometuron, rimsulfuron, chlorimuron, primisulfuron, triasulfuron)
    - Imidazolinones (e.g. imazamethabenz, imazapyr, imazaquin, imazethapyr).

Insecticides

Insecticides include any of a large group of substances used to kill insects in all development stages. The main pesticide groups include:

- Organochlorines (e.g. DDT and derivatives; hexachlorocyclohexane; cyclodienes; chlorinated camphenes)
- Organophosphates (primarily triesters of phosphoric acid and phosphorothioic acid, including: phosphoric acid anhydrides; vinyl phosphates; aliphatic phosphorothioate esters; phosphorothioate esters of phenols; phosphorothioate esters of heterocyclic enols; phosphorothioate esters of S-methyl heterocycles;)
- Organosulfurs
- Carbamates
- Pyrethroids
- Synthetic Pyrethroids (e.g. allethrin, cyfluthrin, deltamethrin, chrysanthemate analogues);
- Insect growth regulators (Biorationals, such as methoprene, fenoxycarb, buprofezin, hydrazine))
- Acaricides
- Biopesticides
- Botanical pesticides (derived from plants)
- Nicotinoids
- Bacterial fermentation products (e.g. Spinosad, Abamectins, Ivermectins, etc.)
- Pyrroles or Pyrazoles)
- Diacylhydrazines
- Dinitrophenols: (e.g. dinoseb and dinocap)

Rodenticides

Rodenticides are a group of toxic substances that are used to kill rodents. The main pesticide groups include:

- Rodenticides used in poisoned baits (e.g. zinc phosphide, Red Squill, calciferol, bromethalin);
- First-Generation Anticoagulants (e.g. hydroxycoumarins, warfarin, coumafuryl, coumatetralyl, indandiones, diphacinone, chlorophacinone);
- Second-Generation Anticoagulants, including hydroxyl-coumarins (e.g. difenacoum, bromadiolone, difethialone, brodifacoum)

Other Pesticides

- Bactericides: Substances used to kill bacteria (bactericides) or inhibit their growth (bacteriostats), such as quinolones, fluoroquinolones, gatifloxacin and moxifloxacin
- Miticides, including:
    - Compounds from diphenyloxazoline

- Compounds from abamectin
- Pyridazinone class

- Nematicides, including:
  - Halogenated aliphatic hydrocarbons
  - Compounds related to methylisothiocyanates
  - Organophosphates
  - Carbamates

Biopesticides

Biopesticides are types of pesticides that are derived from pathogenic micro-organisms (e.g., bacteria, viruses, fungi, protozoa, rickettsiae and nematodes). These are often referred to as Biological or microbial pesticides while Botanical pesticides are those derived from plants. Biopesticides are divided into three groups:

- Microbial pesticides (microorganisms that work to kill certain pests), including biological insecticides (e.g. microbial larvicides Bacillus sphaericus and Bacillus thuringiensis israelensis)
- Biochemical pesticides (naturally occurring substances that control pests through non-toxic routes);
- Plant-incorporated protectants (substances that result from genetic material (i.e. Bacillus thuringiensis) being incorporated into a plant).