How far are we from “pesticide emission factors to the atmosphere” ?

C. Bedos[1], C. Guiral[1], B. Ruelle[4], E. Barriuso[1], C. Basset-Mens[2], P. Cellier[1], T. Eglin[3]

[1]INRA UMR 1402 EcoSys, 78850 Thiverval-Grignon, France
[2]CIRAD UR HortSys, 34398 Montpellier, France
[3]ADEME, 49004 Angers Cedex 01, France
[4]IRSTEA UMR ITAP, 34196 Montpellier Cedex 5, France

CONTEXT and OBJECTIVES : Air contamination by pesticides and its effects on health and on the environment are issues of growing concern. An emission factor (EF) is a representative value relating the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. The pesticide EF from agriculture activity are needed for emission inventories or life cycle analysis of agricultural and food products, and to assess their impact on air quality. Pesticide EF provides also input data for population exposure models via inhalation, allowing the development of lists of priority pesticides for risk assessment, the evaluation of mitigation actions and the construction of monitoring plans.

⇒ This study aimed at reviewing the literature to identify:
- existing EF from EEA*, EPA* and LCA* and analyze their relevance for current agricultural practices;
- existing tools which could be used to derive EF;
- potential levers of actions to reduce emission to the atmosphere.

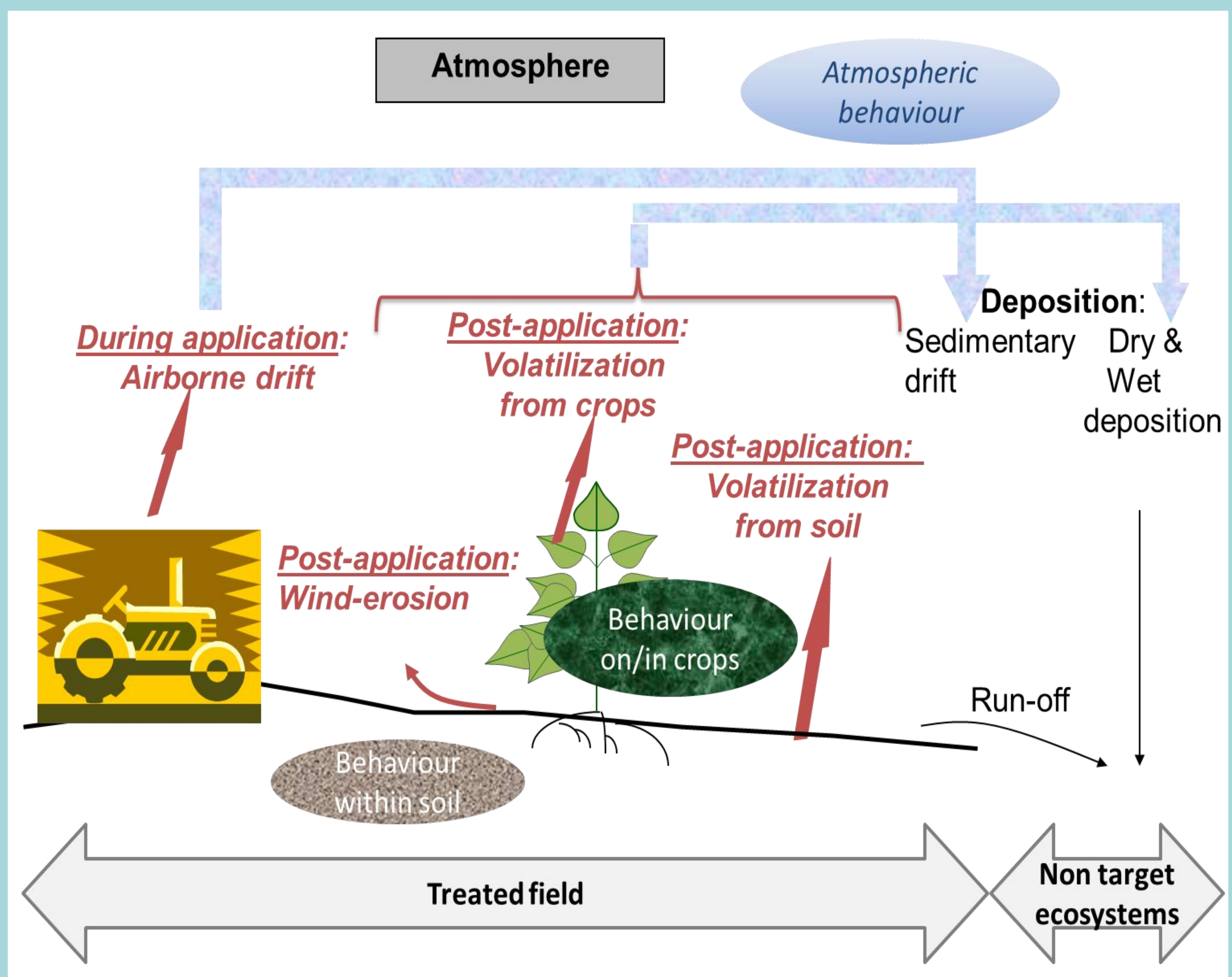


Figure 1: ***Schematic presentation of the processes involved in pesticide emission to the atmosphere and further behaviour in the atmosphere. In red are the processes considered in this studied (aatmospheric sinks - degradation or deposition- were not within the scope of the study)***

METHODS : the study focuses on:
- **Pesticides** used for agricultural purposes, as plant protection products;
- **Emission pathways** (1) during application (aerial spray drift excluding deposited drift) and **(2)** after application (volatilization from plant, soil or aquatic surfaces) (Figure 1);
- **Emission factors (EF)** giving the fraction of the applied pesticides emitted to the atmosphere, **existing tools able to derive EF**, **existing datasets obtained at the field scale** and **available levers of action.**

The scientific literature review was based on:
- The analysis of 230 publications and technical reports inventoried from international bibliographical databases (CAB Abstracts, Environment Complete, Web of Science, Scopus, Agricola, Agris) and national institutional libraries;
- Interviews of a panel of experts from various domains.

RESULTS

- **Existing EF** concern mainly volatilization from soil and from crops after application;
They show a lack of documentation and validation on current practices and products.

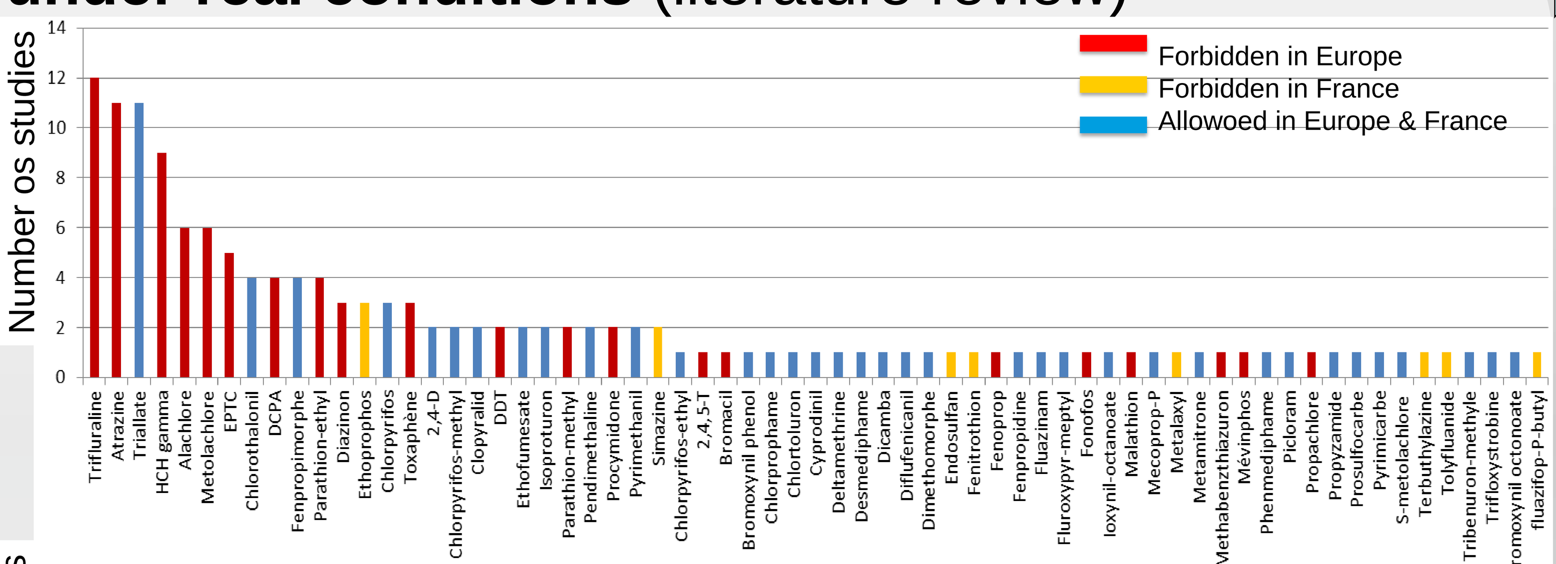
- **The tools which could be used to derive emission factors** range from empirical relationships to process-based models, allowing estimation of instantaneous and/or cumulated fluxes.
They require further developments to extend their domain of application to different crops and pedoclimatic conditions.
Several limits and gaps have been identified *e.g.* the effect of the formulation on the compound behaviour or uncertainties on physico-chemical properties

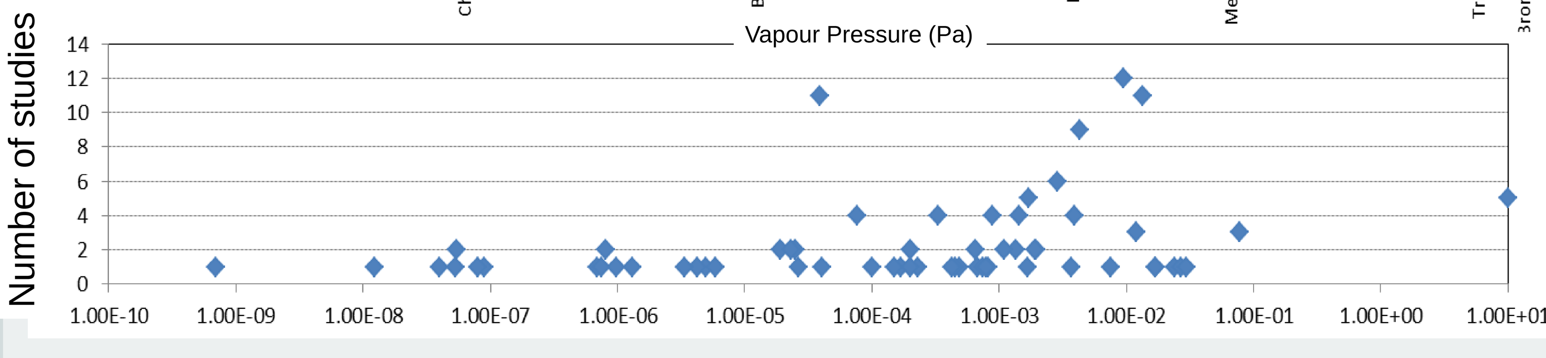
Synthesis on available EF and existing tools

Type	Nature	Inputs[1]	Outputs[2]	Ease of use.	Limits e.g: validation level	Usable for French practices?	Uses[3]
Classes	Empirical	PC	Classes	+++	Low	YES	Volatility score, Sph’Air and I-Phy tools
Relationships	Empirical	PC, P, CP	IF, CF	+++	Low	YES	Sph’Air and I-Phy tools, NMI EI, PestLCI, USES
EF EPA and EMEP/EEA	Empirical	PC	rates / uses	+++	Low	≈	EI, atmospheric dispersion model
EF (LCA)		PC, P, CP					LCI
Fugacity		PC, CP	CO; LRT (level II)	++	Depends on levels and assumptions		
Models : Emission during application	Empiric al or Mechanistic	P, meteo, C	Sedimentary deposition	+	Depends on models	Generally, YES	atmospheric dispersion model
Models : Emission Post application	Mechanistic	PC, P, CP	IF, CF	+	On given conditions	YES	EI spatialized atmospheric dispersion model
Models : Environment (PRZM, MACRO, PEARL)	Empirical or Mechanistic	PC, P, CP, C	IF, CF	+ (be careful with real scenarii)	Source code unavailable	YES mainly for annual crops but also used for perennial crops.	

[1] PC: physico-chemical properties; P: agricultural practices; CP: pedoclimatic conditions; C: crops
[2] IF: Instantaneous Fluxes ; CF: Cumulated Fluxes; CO: Concentrations; LRT: Long Range Transport
[3] EI: Emission Inventory; LCI: Life Cycle Inventory

Datasets on emission by volatilization obtained under real conditions (literature review)





Existing datasets show that for:
- emission by aerial drift : only few datasets (about 20) have been identified;
- emission by volatilization: more than 60 active substances have been studied since the 90’s, showing a large range of vapor pressures (even if most of the studies focused on compounds with vapor pressure between 1E-5 and 1E-1 Pa). However, half of these substances are presently forbidden in France. Moreover, the measurement protocols differ between studies. No references were found under tropical conditions.

Available levers of action

How to limit emission during application	How to limit emission after application
Agroequipments	
Limiting drift nozzles Sprayers (with recovery panels, face to face, …)	
Products	
Adjuvants	Use less volatile compounds (but difficult to identify) Use formulation choice (formulation typology required)
Agricultural practices	
Nozzle height, sprayer velocity, … Relevant application dose in function of crop development (annual crop)	Considering crop development for the application Soil Incorporation when possible
Meteorological conditions	
Wind speed, Humidity, Temperature	Application time (but difficult to define)

Research Priorities

(1) Improve and harmonize protocols for field measurements (a project is underway);
(2) Produce field emissions datasets in close relation with model development needs;
(3) Improve the level of information on current plant protection practices at regional level (actives substances x application practices x crops x pedo-climatic conditions);
(4) Improve the reliability on available information on pesticide physico-chemical properties; improve the knowledge on effect of formulation on active ingredient environmental behaviour;
(5) Analyze together all emission pathways to quantify their relative contribution and define common levers of action.

*EEA : European Environmental Agency, EPA : US Environmental Protection Agency, LCA : Life Cycle Assessment

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