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Pollution des sols et des eaux souterraines par les pesticides dans la région d'Akkar au nord du Liban : Evaluation des risques sanitaires.

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Dedications

To Mom and dad,

To my lovely sisters, and to my brother…

Who always encouraged me to go any adventure
especially this one

"Keep your dreams alive. Understand to achieve anything requires faith and belief in yourself, vision, hard work, determination, and dedication. Remember all things are possible for those who believe".

Gail Devers

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شكراً

Abstract

Akkar is the second agricultural zone in Lebanon and it covers 798 km^2 area in the north, near the Syrian borders. It is characterized by a coastal plain reaching a maximum width of 9 km to the Sea and High Mountains to the east. Potatoes, citrus, fruits, and vegetables crops are the main crops in this region. Pesticides are intensely applied in agricultural activities in this region, and the groundwater has been reported to be highly contaminated by some pesticides. Due to the absence of a public network for water distribution, groundwater is used as the main source for drinking water of local inhabitants. The present study focus firstly on the evaluation of groundwater and soil contamination by pesticides including organochlorines (OCPs), organophosphorus (OPPs) and organonitrogen (ONPs) and by heavy metals in order to better characterize the degree of contamination of Akkar groundwater. Secondly, the work is focusing on the risk assessment of pollution on the population of Akkar.

High levels of OCPs, OPPs, and ONPs were detected in many villages in Akkar plain groundwater. Similarly, high concentration levels of OCPs were detected in agricultural soil. A huge difference between the contamination levels in cultivated area and tillage land. Moreover, a significant variation has been also established between soil depth from 0 cm to 1 m. The results showed that some prohibited pesticides including DDTs and HCHs are still currently use in Akkar plain. To complete the background of pollution in Akkar plain, trace metallic element such as As, Pb, Cr, Cu, Zn and Cd have been studied. The result showed that Akkar soils are moderately polluted by Cd. In parallel a health study was conducted, the prevalence of nervous diseases; birth defects and mental disorders; cancer and other chronic diseases were tangled and found exceeded those values reported in other regions. The significant correlations have been established between wells water consumption and the appearance of some diseases.

More researches could be realized to identify pesticides levels in human blood, serum or urine, and in vegetables of Akkar. Also it will be necessary to manage pesticides use in this region to reduce their effects on human health.

<u>Keywords</u>: Akkar; groundwater; soil; contamination; human health; pesticides; heavy metals; diseases.

Résumé

Akkar est la deuxième zone agricole au Liban, elle couvre une superficie de 798 km^2 au nord, près de la frontière syrienne. Elle se caractérise par une plaine côtière qui atteint au maximum 9 km de la mer et des hautes montagnes à l'est. Les principales cultures sont :la pommes de terre, les agrumes, des fruits et les légumes., Les pesticides sont utilisés de façon excessive dans les activités agricoles et en conséquence, les eaux souterraines d'Akkar ont été fortement contaminées. En raison de l'absence d'un réseau public de distribution d'eau, les eaux souterraines sont utilisées comme principale source d'alimentation en eau potable brute sans aucun traitement à Akkar. Cette étude se concentre d'abord sur l'évaluation de la contamination des eaux souterraines et des sols par des pesticides organochlorés (OCPs), organophosphorés (OPPs) et organoazotés (ONPs) et par des métaux lourds afin de mieux caractériser le niveau de la contamination. La deuxième partie de ce travail se focalise sur l'évaluation des risques de la pollution sur la population d'Akkar.

Des niveaux élevés d'OCPs, OPPs et ONPs ont été détectés dans les eaux souterraines de nombreux villages d'Akkar. De même, des concentrations élevées d'OCPs ont été détectées dans le sol agricole d'Akkar. En outre, une variation significative a également été observée en fonction de la profondeur du sol de 0 cm à 1 m. Les résultats ont montré que certains pesticides, déjà interdits comme les DDT et les HCH, sont actuellement utilisés dans la plaine d'Akkar. Pour compléter les travaux sur l'état de la pollution dans la plaine d'Akkar, les éléments traces métalliques (ETM) à savoir As, Pb, Cr, Cu, Zn et Cd ont été initiés. Les résultats ont montré que les sols sont modérément pollués par le Cd. Parallèlement, la prévalence des maladies nerveuses ; Anomalies congénitales et troubles mentaux ; le cancer et d'autres maladies chroniques ont été étudiés et les résultats montrent des valeurs supérieures comparées à d'autres régions. Des corrélations significatives ont été établies entre la consommation de l'eau des puits polluée et l'apparition de certaines maladies.

D'autres recherches pourraient être réalisées pour confirmer les résultats obtenus en effectuant des mesures du niveau de concentration en pesticides dans le sang humain, le sérum ou l'urine, et dans les légumes d'Akkar. De plus, il est souhaitable de mieux gérer l'utilisation des pesticides dans cette région pour réduire leurs effets sur la santé de la population.

Mots clés : Akkar ; contamination ; eaux souterraines ; sol ; pesticides ; métaux ; santé humaine ; maladies.

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List of Acronyms

≈	Approximately
%	percent sign
°C	degree Celsius
µL	Micro liter
Mm	Micrometer
µS/cm	Micro Siemens per centimeter
4-HPPD	4-hydroylphenyl-pyruvate
ACCase	Acethyl Coenzyme A Carboxylase
Ach	Acethylcholine
AChE	Acetylcholinesterase
CAN	Acetonitrile
AcOEt	Ethyl acetate
AD	Alzheimer Disease
ADWG	Australian Drinking Water Guidelines
ALS	Acetohydroxyacid synthase
AMS	Ambient mass spectrometry
As	Arsenic
ASE	Accelerated solvent extraction
B.C.	Before Christ (or before 1st century)
BHC	beta-Hexachlorocyclohexane
Ca	Calcium
Cd	Cadmium
CE	capillary electrophoresis
ChE	Cholinesterase
Cis	confidence intervals
CM	Congenital Malformation
cm^3	Cubic centimeter

CO_2	Carbon dioxide
COPD	chronic obstructive pulmonary disease
Cr	Chromium
Cu	Copper
DCE	Directive cadre Européenne
DCM	Dichloromethane
DDLME	dispersive liquid–liquid microextraction
DDT	Dichlorodiphenyltrichloroethane
DHP	Dihydropteroate
DL	Deciliter
DNA	Deoxyribonucleic acid
DO	Dissolved Oxygen
e.g.	Example
ECD	Electron-capture detection
EF	Enrichment factor
EPA Agency	Environmental Protection Agency
ESPR	Environmental Science and Pollution Research
ETM	trace metallic element
EU	European Union.
FAO	Food and Agriculture Organization
Fe	Iron
FID	Flame Ionization Detector
FPD	Flame Photometric Detector
FRAC	Fungicide Resistance Action Committee
G	Gram
GC	Gas chromatography
GDP	Gross domestic product
GDWQ	Guidelines for Drinking-Water Quality
GHS	Globally Harmonized System of Classification and Labelling of Chemicals

GPS	Global Positioning System
Ha	Hectare
HAP	Hydrocarbures Aromatiques Polycycliques
HCB	Hexachlorobenzene
HCH	hexa-chlorocyclohexanes
HCl	Hydrochloric acid
HDL	High-density lipoproteins
He	Helium
HF-LPME	hollow-fiber liquid-phase microextraction
Hg	Mercury
HLB	hydrophilic-lipophilic balanced
HM	Heavy metals
HPLC	High performance liquid chromatography
HRAC	Herbicide Resistance Action Committee
HS	Headspace
IARC	International Agency for Research on Cancer
ICP- AES	Inductively coupled plasma-atomic emission spectrometry
IFCS	Intergovernmental Forum on Chemical Safety
IPCS	International Program on Chemical Safety
IRAC	Insecticide Resistance Action Committee
IUGR	Intra-Uterine Growth Retardation
K	Potassium
Kg	Kilogram
KOH	potassium Hydroxide
kV	KiloVolt
L.S.S.E	Laboratoire des Sciences de l'Eau et de l'Environnement
LASIR	Laboratoire de Spectrochimie Infrarouge et Raman
LC	Liquid chromatography
LD_{50}	Lethal dose

LLE	Liquid–liquid extraction
LLME	liquid-liquid microextraction
LOD	Limit of detection
LOQ	Limit of quantification
LPME	Liquid-phase microextraction
mA	milliAmpere
MCLG	Maximum Contaminant Level Goals
MCLs	The maximum contamination levels
MeOH	Methanol
min	minutes
mL	Milliliter
Mn	Manganese
MoA	Ministry of Agriculture
MOA	Mode of Action
MoE	Ministry of Environment
MS	Mass spectrophotometry
MW	Molecular Weight
m/z	mass-to-charge ratio
MΩ	Megaohm
Na	Sodium
NH_2COOH	carbamic acids
NHMRC	National Health and Medical Research Council
Ni	Nickel
NPD	nitrogen–phosphorus detection
NPDWRs	National Primary Drinking Water Regulations
OCPs	Organochlorine pesticides
ONPs	Organonitrogen pesticides
OPPs	Organophosphorus pesticides
OSPs	Organosulfur pesticides

Pb	Lead
PCB	polychlorinated biphenyls
PCNB	Pentachloronitrobenzene
PD	Parkinson Disease
PDS	phytoene desaturase step
pH	potential of hydrogen
POPs	Persistent organic pollutants
Ppbs	parts per billion
Ppms	parts per million
PPO	protoporphyrinogen oxidase
QA	quality assurance
QC	Quality control
RGVs	regulatory guidance values
RT	Retention time
S.D	Standard deviation
SDME	Single drop microextraction
SDWA	Safe Drinking Water Act
SFE	Supercritical fluid extraction
SMCLs	secondary maximum contaminant levels
SPE	Solid Phase Extraction
SPMD	semi-permeable membrane device
SPME	Solid-phase microextraction
S/N	Signal-to-noise ratio
SSM	suspended solid matters
t1/2	half time
TDI	tolerable daily intake
U.S; USA	United states of America
UAE	United Arab Emirates
UIPP	Union of Industries of the Protection of Plants

UNDP	United Nations Development Program
UNEP	United Nations Environment Program
USD	United States Dollar
USEPA	United States Environmental Protection Agency
V	Volume
VOCs	Semi volatile organic compounds
WHO	World Health Organization
WSSA	Weed Science Society of America
χ^2	Chi-square
Zn	Zinc

General Introduction

Environmental pollution has an increasing concern worldwide problems for these last decades. Human activities such as industrial, agricultural and other emit several types of organic and inorganic pollutants which can be transported for a long distance between the different environmental matrices including air, aquatic system, water, soil, and underground water. The anthropogenic pollutants have a large variety of physic-chemical characteristics. This study has been focused on some pollutants the most abundances and the most toxics. 35 pesticides bellow to the class of ONs, OPs, OCs and eight metallic elements have been determined in grounds water and agricultural soil of Akkar plain.

Pesticides are chemicals that became an integral part of current modern agriculture. The growing world population need growing food production. Consequently, the use of pesticides is increasing to ensure good harvest. Pesticides with their different group including organochlorine (OCPs), organophosphorus (OPPs) and organonitrogen (ONPs) pesticides are among the most dangerous environmental pollutants because of their stability, mobility and long-term effects on living organisms. Due to their widespread use, the important amounts of pesticides are accumulated in the environment especially in developing countries and agricultural areas. They can bioaccumulate through different environmental matrices including in biota. Thus, they can be transported throughout the food chain. Pesticides can be locally and globally dangerous for ecosystem. Human can be exposed directly and/or indirectly to the residue of pesticides through several ways such as dermal contact, inhalation and ingestion. The long-term exposure to these chemicals become a risk to human population health; which induce certain negative effects on nervous system, reproductive, respiratory, digestive system. Furthermore, due to their toxicity, the use of some pesticides have been banned or regulated under the Stockholm convention, WHO, Water Framework Directive (DCE: Directive Cadre sur l'Eau) and United States Environmental Protection Agency (US-EPA). A numerous of epidemiological studies have been established and confirm the association between pesticides and human diseases in exposure population.

In addition, trace metallic element (ETM) such as Pb, Hg, Ni, As, Cd, Cr, Zn and Cu, which can be found in the environment, are inorganic toxic pollutants. They were also studied in this work to complete the background of the total pollution degree. The behaviors of ETM in the different environmental matrices depend on the characteristics of the matrix, the type and the nature of ETM, and the climate conditions.

The objectives of the present study were to determine the OCPs, OPPs and ONPs in groundwater and soil of Akkar plain. Their concentration in the wells water of 15 villages in the plain of Akkar have been determined and the potential adverse effects on human health was evaluated in parallel in the same area. The contamination of agricultural soil by pesticides and ETM in six of villages were also evaluated.

This work was performed as part of a PhD thesis between the Lebanese University and the University of Lille 1. Analytical analysis was carried out in the Laboratoire de Spectrochimie Infrarouge et Raman of LASIR -UMR CNRS at Lille 1 University in France. And, the sampling, pretreatment of samples was achieved in the Laboratory of Water Science and Environment in the Faculty of public Health III, Tripoli in Lebanon. In addition, the epidemiological study was carried out in the plain of Akkar. This thesis is organized into three parts.

The first part is a bibliographic study giving a general information about the pesticides and ETM. It was divided in three parts. The first section is a literature review about pesticides including definition of pesticides, their different type of classification, their behavior in the environment, their toxicity, regulations and the analytical methods. Section 2 gives the information about heavy metals; the definition, regulations and their toxicity have been reported in this part. Moreover, the third one describe the development of the agricultural sector in Lebanon to better understand the studied context.

The second part focuses on the description of the study area, sampling techniques for water and soil samples. In addition, the analytical methods used for extraction and analysis for the determination of pesticides and ETM have been also reported in this part. Creation of questionnaire, data collection and statistical analysis is also described.

The third part presents the results in the forms of article chapters. The 1st paper is about the "Assessment of pesticide contamination in Akkar groundwater, northern Lebanon" and has been published in the *Environmental Science and Pollution Research* (ESPR) journal. The 2nd paper focuses on the "Relationship between the consumption of contaminated water by pesticides and the risk of nervous disorders (Alzheimer and Parkinson) in Akkar – Lebanon" and it has been submitted to *Environmental Research Journal*. The 3rd paper concerns the "Distribution of Organochlorine pesticides and heavy metals in Lebanese agricultural soil (Case study of Akkar plain)". It is in preparation for submission in *water, air and soil pollution*. The 4th paper is "A cross-sectional study on pesticides use in agricultural area and their risk assessment on inhabitants (Case study of Akkar-Lebanon)". It is the Screening of some diseases in an agricultural zone in Lebanon and study of the correlation between them and the consumption of contaminated water by pesticides. This is a part of the results of the epidemiologic study and it is under preparation for submission. Finally, a conclusion with prospects of thesis research work is presented.

Literature Review

I. Pesticides- Generalities

I.1. Pesticide's Definition:

Food and Agriculture Organization of United Nations (FAO) and the World Health Organization (WHO), defined a **"pesticide"** as any substance, or mixture of substances of chemical or biological ingredients, or microorganisms including viruses, intended for regulating plant growth; repelling, destroying or controlling any pest, including vectors of human or animal disease, nuisance pests, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feeding stuffs, or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies (WHO, 2010 ; FAO,1986).

I.2. History of pesticides

The use of pesticides in agriculture dates from antiquity. Nevertheless, the worldwide pesticide usage has increased dramatically during the last two decades as a consequence of the intensive agriculture and the changing of farming practices (Konstantinou et al 2006).

The first recorded use of insecticides started since 2500 years before B.C. by Sumerians who rubbed foul smelling sulfur compounds on their bodies to control insecticides and mites. Ancient Egyptians also experimented with pesticides. The Ebers' Papyrus, the oldest known medical document (dated around 1550 BC) describes over 800 recipes containing recognizable substances used as poisons and pesticide. Around 1000 B.C., natural substances have been used as pesticides. Among them, sulphur has been used for pest control in the Greece and Romanian. About the same time, the Chinese were using compounds made from mercury and arsenic to control body lice. (Taylor et al, 2007; Smith & Kennedy, 2002)

In approximately 300 B.C. Theophrastus, around 300 B.C., Theophrastus was the first to write about various pests' damage. At that moment, Cato, a Censor of the Roman state, advocated the use of a spray made from the oils of the hellebore plant to kill rodents and insects. Later, Amurca was recommended by Varro began to be the base ingredient for many pest remedies. In 800 A.D., arsenic was recommended by Pliny (the Natural History of Pliny) and products arsenicals are known in China as early as the 16th century. Rotenone a toxic crystalline substance obtained from the roots of derris and related plants was used as an insecticide in 1649 in South America. Tobacco and the roots of *Lonchocarpus or* Derris and Lonchocarpus were reported at the same time.

During the 19th century, scientists had a better understanding of fungi. In 1807, a copper sulfate solution was used to control bunt disease in wheat. In Europe and United States (US), the fungicidal treatments were based on sulfuric acid, iron sulfate, copper sulfate including blue vitriol and the famous Bordeaux mixture, copper & arsenic mixture (including Paris green, 1867) and copper nitrate. While arsenite, acetoarsenite copper and lead arsenate has been used for insecticide treatments. The Pyrethrum, a powder from flowers of the genus chrysanthemum was introduced as an insecticide at the same period. Moreover, the first selective herbicide, iron sulfate, was found in 1896 to kill broad leaf weeds. Soon after, the famous Salvarsan, an organo-arsenic compound, was invented in 1907 (Ehrlich, 1909). It induced, on 1913, the development of organic mercury compounds, which became extremely successful as seed disinfectants (Zadoks & Waibel, 2000). These treatments became routine until the 1960s when all mercury-containing pesticides were removed from the market due to its toxicity to humans. However, the first aerial application of an insecticide was not until 1921 when Ohio farmers battled the catalpa Sphinx Moth.

The early, modern chemicals were developped from environmentally stable compounds. They were found to accumulate in the body fat of non-target organisms. In 1934, the fungicide, thiram, was developped which led to the development of a series of effective and widely used fungicides over the next ten years. Two important generations of pesticides can be identified. The first generation pesticides were highly toxic compounds, such as arsenic and hydrogen cyanide. Their use was banished because they were either ineffective and/or toxic. While the second generation refers to the synthetic organic compounds.

The breakthrough of organic pesticides came with Dichlorodiphenyltrichloroethane (DDT
). It was firstly synthesized by Zeidler (Zeidler, 1874) and its insecticidal properties were discovered in 1939 by a Swiss chemist (Paul Muller**)** (MÜLLER, 1955). An innovation that later earned him the Nobel Prize. Since then DDT had been in worldwide scale until 1970s. In that period approximately 2 million tons of this persistent organic pollutant (POP) were produced worldwide (Agency for Toxic Substances and Disease Service,2002) In 1950s, during World War II; the compound was used in large quantities in non-agricultural applications such as preventive medicine (destroying typhus-carrying lice and malaria-carrying mosquitoes in residential areas, control typhus and in agriculture (elimination of the Colorado potato beetle). (Van den Berg, 2009; Romanic, 2012).

Thus, the period from 1940 to 1960 was dominated by the production and the use of synthetic organochlorines, organophosphorus and carbamates insecticides (Kaushik & Kaushik, 2007). In reality, After World War II, chemicals and technologies initially developed for warfare were later rerouted for pest management such as parathion (marketed in 1943), DDT, BHC, Aldrin, Dieldrin, endrin and phenoxy herbicides such as 2,4-D; 2,4-DP (1944); and 2,4,5- T (1945) (Zadoks & Waibel, 2000).

In the period from 1950 to 1955, urea derivate were developped as herbicides in the USA. The fungicides captan and glyodin appeared, and Malathion was introduced by American Cyanamid Company. Other new products herbicidal triazines (atrazine, paraquat, and picloram) and quaternary ammonium herbicides were developed in 1955, 1958 and 1960, Dichlobenil, trifluralin, and bromoxynil were described between 1960 and 1965 and the systemic fungicide benomyl in 1968. The leaf acting herbicides glyphosate was introduced soon afterwards.

Since 1945, more than 15,000 individual chemicals and 35,000 formulations have been used as agricultural pesticides (Forget et al., 1993) for controlling agricultural pests, but they also represent a significant source of occupational and non-occupational exposure to potentially toxic agents (Ergene et al., 2007). Then, things began to change notably after the publication of Rachel Carson’s book "Silent Spring," in 1962. This book was the first widely read warnings about pesticides, and predicted massive destruction of the planet's fragile ecosystems unless more was done to halt what she called the "rain of chemicals."

Nevertheless, the worldwide use of pesticide has increased dramatically during the last few decades due to the intensive agriculture and the changing of farming practices.

In 1973, DDT was eventually banned in Europe, USA; but it opened up a long line of production of new organic chemical insecticides, which are more effective at lower dose than the older pesticides. They comprise synthetic light-stable pyrethyroid, which have been developped from the naturally occurring pyrethrins. In the recent years; after 1991; neonicotinoid insecticides have started to replace pyrethroid, organophosphorus and carbamate insecticides; a step taken out of necessity, as pests had become extremely resistant to the other pesticides (Tankiewicz et al., 2010)**.** The following table explains the history of pesticides use (Table 1).

The use of pesticides has increased since the year (1970) (ESDO, 2005a). Nowadays more than 1000 active ingredients (In 2007; 1,055 active ingredients are registered) are marketed as pesticides (Mostafalou & Abdollahi, 2013) and the global market for pesticides accounted for more than $37 billion in 2009 according to the Union of Industries of the Protection of Plants (UIPP, 2009). In particular, Europe and the United States are respectively the first and second global consumer with a percentage of 32 and 23% respectively (Fig. 3). The quantity of pesticides applied in the agricultural land vary between countries depending on the type of crops, China was one of the first nations to begin using pesticides and till now, it is considered as one of the large consumer of pesticides (6.5-59.45 kg of pesticides/ha based on FAO statistics) (Fig. 1)

Table 1 Chronological evolution of the use of the three classes of pesticides from 1900 to our days (data of the Union of Industries of the Protection of Plants UIPP)

	Herbicides	***Fongicides***	***Insecticides***
Avant 1900	Copper sulfate Iron sulfate	SulfurCopper salts	Nicotine
1900-1920	Sulfuric acid		Arsenic salts
1920-1940	Nitrate dyes		
1940-1950	Phytohormones		Organochlorine Organophosphorus
1950-1960	Triazines, Substituted ureas, Carbamates	Dithiocarbamates Phtalimides	Carbamates
1960-1970	Dipyridyles, Toluidines	Benzimidazoles	
1970-1980	Aminophosphonate Propionate	Triazoles Dicarboximides Amides, Phosphites Morholines	Pyrethyroïdes Benzonyl-ureas (Growth regulators)
1980-1990	Sulfonyl ureas		
1990-2000		Phenylpyrroles Strobilurins	

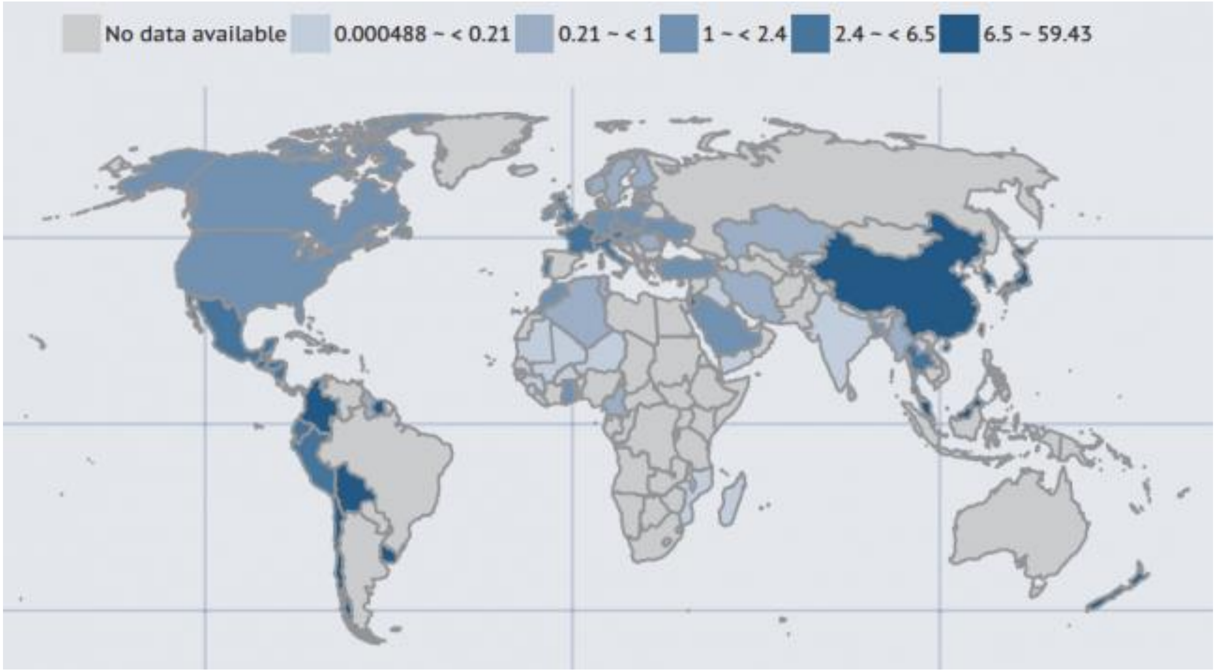


Figure 1 Pesticides per ha of arable land (kg/ha), 2005-2009 – FAO (Adapted from Yearbook, 2013)

I.3. Composition and classification

Pesticide products contain one or a mixture of active ingredients. The actives ingredients are generally mix with inert ingredients. Active ingredient can be identified by name on the pesticide product's label together with its percentage by weight. For example, the active ingredients in an insecticide are the ingredients that kill insects. Several categories of active ingredients existed such as conventional, antimicrobial and bio pesticides. While inert ingredient refers to any substance or group of substances that is intentionally combined with active ingredients in a pesticide product to make the satisfactory performance and usability of the pesticide. They are chemicals, compounds, and other substances, including common food commodities and some natural materials Examples of inert ingredients include emulsifiers, solvents, carriers, aerosol propellants, fragrances and dyes, certain edible oils, spices and herbs, beeswax and cellulose (USEPA, 2017a; National pesticides information center, 2015)

Usually, pesticides may be classified in a number of different ways including target organisms or pests, chemical structure (organic and inorganic, synthetic, and pediculicide), physical state; hazard toxicity. These classifications can provide useful information about the pesticide chemistry, mode of action, target site and pests, etc.

I.3.1. Classification by chemical nature or origin:

One of the main classifications of pesticides is the traditional one. It places them in one of two categories: organic and inorganic pesticides. Organic pesticides contain carbon as the basis of their molecular structure while inorganic pesticides contain carbon, which can be found only under the form of carbonate or cyanide. The chemicals in organic pesticides are more complex than those of inorganic pesticides, and usually do not dissolve easily in water. Further organic pesticides can be subdivided into two additional groups: the natural organics pesticides “organics” that are derived from naturally occurring sources such as plants, animals or micro-organisms and the synthetic organic pesticides "synthetics" which are produced artificially by chemical synthesis (Fig. 2).

Pesticides in inorganic group are minerals that are mined from the earth and ground into a fine powder. The earliest chemical pesticides were inorganic, and included substance such as sulfur and lime. Older "inorganics" included such highly toxic compounds as arsenic, copper, lead and tin salts. But Current inorganic pesticides are relatively low in toxicity and have low environmental impact.

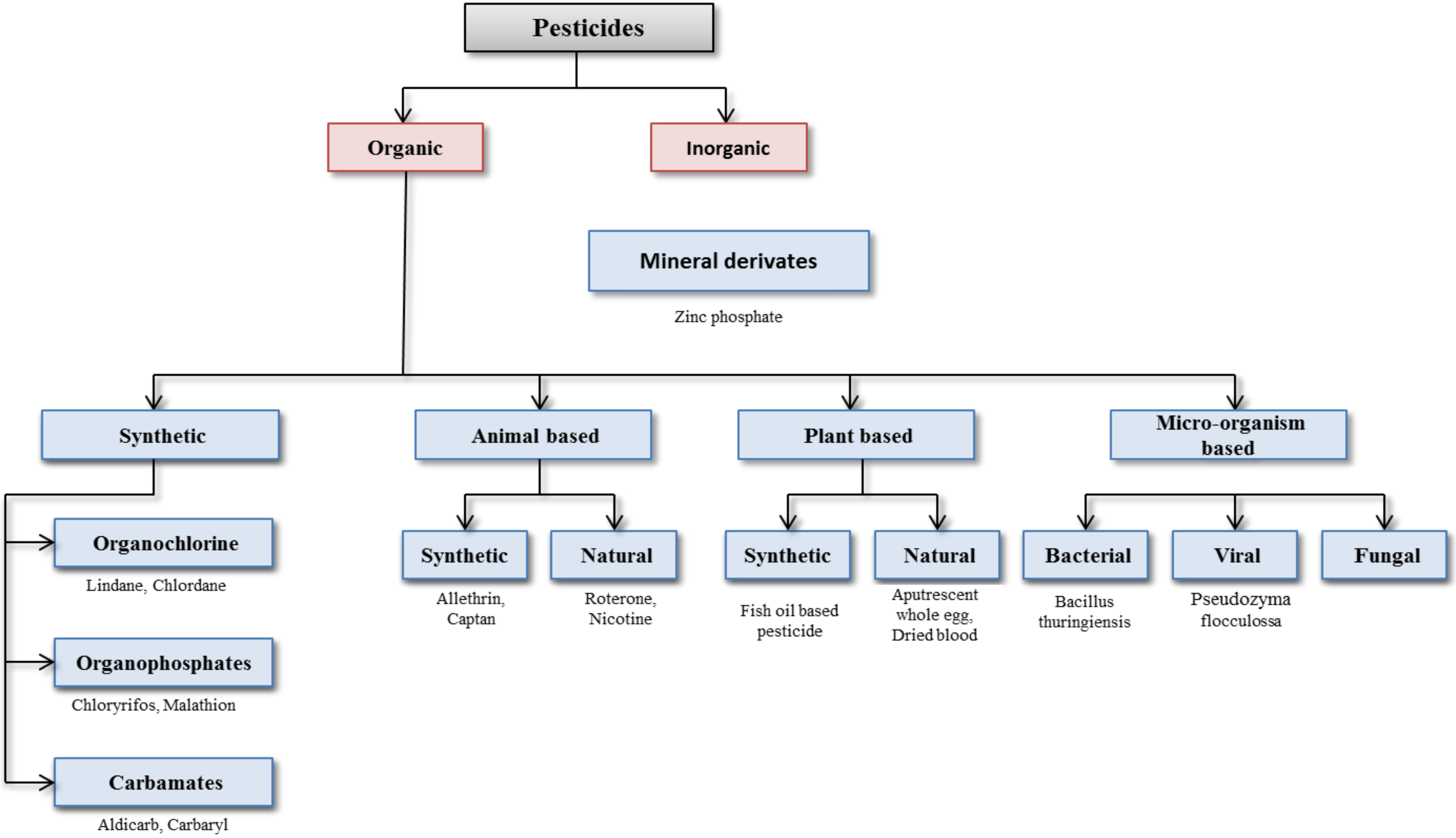


Figure 2 Classification of pesticides

I.3.2. Classification by target pest species and pesticide function

This system of classification is based on the type of specific pest against which pesticides are directed to control. There are many different types of pesticides such as Insecticides, herbicides, fungicides, acaricide. Each one is meant to be effective against specific pests (Table 2).

Table 2 Target pest of each pesticide family (npic, 2016)

Pesticide Family	Target pest
Herbicide	Weeds
Insecticide	Insects
Fungicide	Fungi
Acaricide	Mites, ticks
Algaecide	Algae
Anticoagulant	Rodents
Attractant	Attracts insects or birds
Avicide	Birds
Bactericide	Bacteria
Defoliant	Plant leaves
Desiccant	Disrupts water balance in arthropods
Growth regulator	Regulates insect and plant growth
Rodenticide	Rodents
Silvicide	Woody vegetation
Miticide	Mites
Molluscicide	Snails, slugs
Nematicide	Nematodes
Piscicide	Fish
Predacide	Vertebrate predators
Repellent	Repels vertebrates or arthropods

Regarding the nature of the pesticides, herbicides are the most pesticides applied in agricultural activity on the whole of the cultures of the world (≈ 46% of the market in 2009), followed by fungicides (26%) and insecticides (24%) (Fig. 3) (Bergkvist et al., 2012; ESDO, 2005a).

The geographical layout plays an important role. In effect, the herbicides represent 70 to 80% of the pesticides used in Europe and the United States, while in the tropics, 50% of the products used are insecticides (Observatoire des résidus de pesticides, 2017; Institut français de l'éducation, 2008)

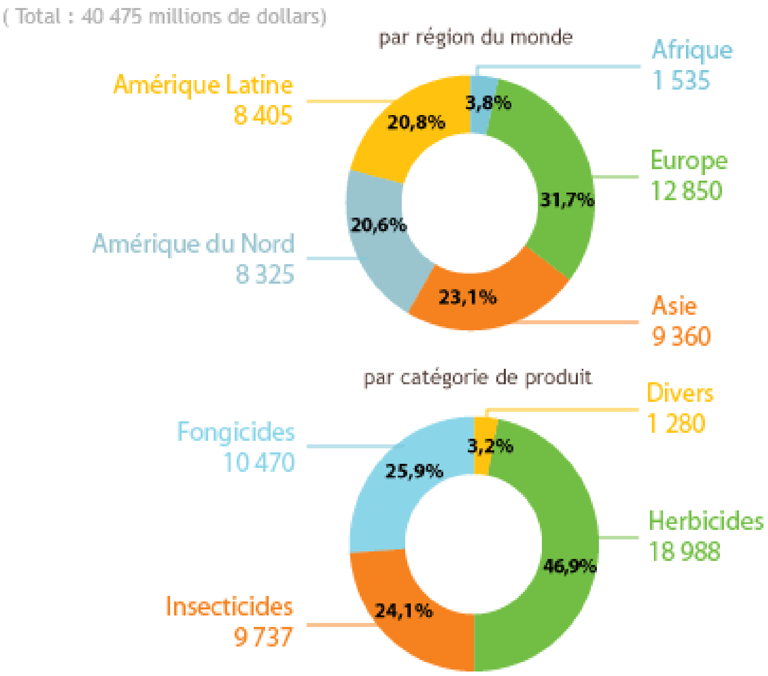


Figure 3 Worldwide distribution of pesticides by regions, and by the type.

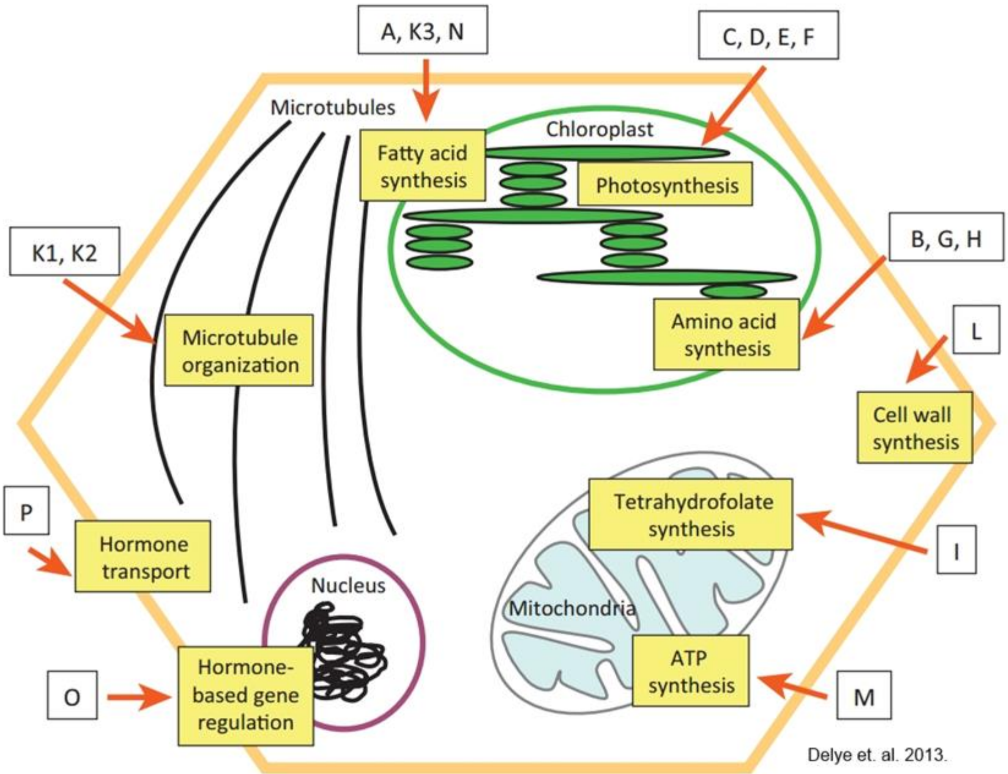
I.3.2.1. Herbicides

The herbicides represent the most employed pesticides used in the world, mainly in industrialized countries. In Poland, herbicides present 55% of all used pesticides (EUROSTAT, 2016). Also commonly known as weed killers, herbicides are chemical substances used to kill unwanted plants, to reduce the density of weeds, and promote the growth of desirable species, which leaves unperceived secondary effects (EPA, 2011). They are used for the maintenance of the roadway systems and for the gardening of individuals.

The herbicides are classified by HRAC and WSSA alphabetically according to their target sites, sites of action on the plants. They can be endocrine regulation of a hormone, "the auxin" which is the main hormone acting on the increase in the size of the cells, photosynthesis, or inhibitors of cell division, the synthesis of lipids, of cellulose or amino acids (Table 3 and Fig. 4). The mechanism of the action of herbicides for killing a weed must undergo the following processes, in the sequential order: Contact – Absorption – Movement - Toxicity and Death (Sherwani et al., 2015; de Boer et al., 2006).

Selective herbicides control specific weed species associated with a specific crop without harming or killing the non-target plants. While leaving the desired crop relatively unharmed, most of the herbicides used in agriculture and related industries are highly selective. Although non selective herbicides have a limited use in agriculture and other related industries, but they can be used in different tasks such as forestry, pasture, control of wildlife habitats, and cleaning of waste grounds, industrial sites, railways and railway embankments (Vargas-Bernal et al., 2012; Thrall et al., 2011; Pretty, 2008).

Figure 4 Cellular targets of herbicide action and herbicide classification by mode of action according to the Herbicide Resistance Action Committee (HRAC). Adapted from (Délye et al., 2013)



Many introduced invasive plants can be effectively managed using herbicides. However, there are two issues associated with herbicide use. Firstly, herbicides can negatively affect biotic communities, and pose environmental problems and risks (Relyea, 2005). Secondly, there are a number either of weeds that are intrinsically resistant to specific herbicides or to a broad spectrum of herbicides (Owen & Zelaya, 2005; Sherwani et al., 2015). Then, after prolonged exposure, weeds developed resistance (McNaughton et al., 2005; Schooler et al., 2010). Further, using nonselective herbicides on invasive plants can reduce interspecific competition, and spread of the weed population over that desired species.

Table 3 HRAC and WSSA classifications of herbicides.

HRAC group	*Mode of action*	*WSSA classification group*
A	Inhibition of acetyl CoA (ACCase)	1
B	Inhibition of acetolactate synthase ALS (acetohydroxyacid synthase)	2
C1	Inhibition of photosynthesis at photosystem II	5
C2	Inhibition of photosynthesis at photosystem II	7
C3	Inhibition of photosynthesis at photosystem II	6
D	PSI Electron Diverter	22
E	Inhibition of protoporphyrinogen oxidase (PPO	14
F1	Bleaching: Inhibition of carotenoid biosynthesis at the phytoene desaturase step (PDS)	12
F2	Bleaching : Inhibition of 4-hydroylphenyl-pyruvate(4-HPPD)	27
F3	Bleaching: Inhibition of carotenoid biosynthesis (unknown target)	11
G	EPSP synthase inhibitors	9
H	Inhibition of glutamine synthetase	10
I	Inhibition of DHP (dihydropteroate) synthase	18
K1	Microtubule assembly inhibition	3
K2	Inhibition of mitosis / microtubule polymerization inhibitor	23
K3	Inhibition of cell division (Inhibition of very long chain fatty acids)	15
L	Inhibition of cell wall (cellulose) synthesis	20,21,26
M	Uncoupling (Membrane disruption)	24
N	Inhibition of lipid synthesis - not ACCase inhibition	8, 26
O	Synthetic auxins (action like indoleacetic acid)	4
P	Inhibition of auxin transport	19
Z	Unknown	17, 26, 25

(Herbicide resistance action committee, 2013; Retzinger & Mallory-Smith, 1997).

I.3.2.2. Insecticides:

Insecticides are chemicals intended for preventing the plants, destroying, repelling or mitigating the effect of any insect in all stages of growth: Egg, larva, and insect (Ji et al., 2016).

Table 4 Mode of action of each type of insecticides with example of active ingredients

Insecticide Type	**Mode of Action**	Example **of Active ingredients**
Organochlorine	Most act on neurons by causing a sodium/potassium imbalance preventing normal transmission of nerve impulses (Breda et al., 2017; IRAC, 2016)	DDT ; Methoxychlor
	Act on the GABA-gated chloride channel blockers (γ-aminobutyric acid) receptor preventing chloride ions from entering the neurons causing a hyperexcitable state characterized by tremors and convulsions	Cyclodiene organochlorine (Chlordane, Endosulfan)
	Some Act with unknown or uncertain mode of application	Dicofol
Organophosphate	Cause acetylcholinesterase (AChE) inhibition and accumulation of acetylcholine at autonomic and some central synapses and at autonomic postganglionic and neuromuscular junctions, As a consequence, ACh binds to, and stimulates, muscarinic and nicotinic receptors, thereby producing characteristic features and causing rapid twitching of voluntary muscles and eventually paralysis (Vale & Lotti, 2015; IRAC, 2016) Generally, they are the most toxic of all pesticides to vertebrates.	Acephate, Azinphos-ethyl, Azinphosmethyl, Chlorfenvinphos, Chlorpyrifos, Chlorpyrifos-methyl, Diazinon, Dichlorvos/ DDVP, Dimethoate, Dimethylvinphos, Disulfoton, EPN, Ethion, Famphur, Malathion, Mecarbam,Parathion, Parathion-methyl
Carbamates	Inhibit AChE which results in accumulation of acetylcholine (ACh) at autonomic and some central synapses and at autonomic postganglionic and neuromuscular junctions causing central nervous system effects (Vale & Lotti, 2015) Acts by keeping open the sodium channels in neuronal membranes affecting both the peripheral and central nervous systems producing a hyper-excitable state causing such symptoms as tremors, incoordination, hyperactivity and paralysis Highly toxic to fish.	Aldicarb, Bendiocarb, Benfuracarb, Carbaryl, Carbofuran, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Pirimicarb, Propoxur, Thiodicarb,Thiofanox, Triazamate,
Pyrethroids, pyrethrins	All pyrethroids interact with the sodium channel; by keeping it open longer, they increase the likelihood of action potentials developing, thus creating a condition of hyperexcitability, whose main clinical sign is tremors (Lotti & Bleecker, 2015)	Acrinathrin, Allethrin, Bioallethrin, Cycloprothrin, Cyfluthrin, Cypermethrin, Cyphenothrin, Deltamethrin, Esfenvalerate, Flumethrin, Halfenprox, Resmethrin, Silafluofen, Transfluthrin, beta-Cyfluthrin, d-cis-trans Allethrin, Alpha and beta-Cypermethrin, d-trans Allethrin,

Insecticides act to eliminating or preventing the reproduction of harmful insect by acting upon the nervous system of the insect or by acting as growth regulators or endotoxins (EPA, 2017a). Their classification is based on their structure and mode of action. We can find the full version of mode of classification by IRAC (Insecticide Resistance Action Committee, 2016) at the link http://www.irac-online.org/modes-of-action/. Insecticides can be natural substances such as nicotine, pyrethrum; or synthesized products. Insecticides are commonly used in agricultural, public health, and industrial applications, as well as household and commercial uses (e.g., control of roaches and termites). They have been used in various forms from hydrocarbon oils (tar oils), arsenical compounds, organochlorine, organ phosphorous compounds carbonates, dinitrophenols, organic thiocynates, sulfur, sodium fluoride, pyethroids, rotenone to nicotine, in solid or liquid preparation (Ji et al., 2016).

I.3.2.3. Fungicides

Fungicides are agents used to prevent or eradicate the undesirable fungi, fungal spores and bacteria from plants or seeds in agriculture. They are applied to protect tubers, fruits and vegetables during storage or they are also directly applied to ornamental plants, trees, field crops, cereals and turf grasses. (Gupta & Patwardhan, 1988; Gupta, 2012). Fungicides are used also in livestock to fight against fungal infections in animals (Vargas-Bernal et al., 2012). Their classification is according to their mobility in the plant, their role in protection of plants, breadth of activity, their chemical structures (such as dithiocarbamates, Triazoles) and their mode of action (Table 4, 5). According to the mode of application, fungicides are grouped as foliar, soil and dressing fungicides. Foliar fungicides are applied as liquids or powders to the aerial green parts of plants, producing a protective barrier on the cuticular surface and systemic toxicity in the developing fungus. Soil fungicides are applied as liquids, dry powders, or granules, acting either through the vapor phase or by systemic properties. Dressing fungicides are applied to the postharvest crop as liquids or dry powders to prevent fungal infestation of the crop, particularly if stored under less than optimum conditions of temperature and humidity.

Thus, fungicides can interact differently on the plants either in inhibiting the respiratory system; damaging cell membranes or division; disrupting the synthesis of amino acids, inactivating critical enzymes or protein or carbohydrate metabolism. The FRAC (**fungicide resistance action committee)** lists commercial fungicides according to their mode of action, their chemical group; and resistance risk the most important bactericides are also included. (Maltby et al., 2009; Fungicide resistance action committee, 2016).

The other classifications are detailed in the table 5 (Mueller et al., 2008). An effective fungicide must be protective or curative and should possess the five following properties. First, they should have low toxicity to the plant/animal but high toxicity to the particular fungus. Then, they should have the ability to convert themselves into toxic intermediates; the ability to penetrate fungal spores or the developing mycelium to reach the site of action; low Eco toxicity; and the ability to form a protective, tenacious deposit on the plant surface that will be resistant to weathering by sunlight, rain and wind (Young et al., 2001).

Table 5 Classification of fungicides

Way of classification	*Type*	*Description and characteristics*
Mobility in the plant	Contact fungicide	Remains on the surface where it is applied but does not go deeper; these fungicides have no after-infection activity. (Repeated applications are needed)
	Systemic fungicide	Is absorbed into plant tissue and may offer some after-infection activity. Very few fungicides are truly systemic however, some are upwardly systemic and some are locally systemic.
Breath of activity	Single-site fungicide	Actives against only one point in one metabolic pathway in a fungus or against a single critical enzyme or protein needed by the fungus. (less toxic to plants ; lend to have systemic properties)
	Multi-site fungicide	affects a number of different metabolic sites within the fungus
Role in protection	Preventative activity	Occurs when a fungicide is present on the plant as a protective barrier before the pathogen arrives or begins to develop
	Early-infection activity	Occurs when the active ingredient of a fungicide can penetrate the plant and stop the pathogen in the plant tissues, usually most effective 24 to 72 hours after infection occurs, depending on the fungicide. (fungicide has also preventative activity and are most effective when applied before infection occurs)
	Eradication	The ability to stop disease development after symptoms has developed. Very few fungicides have this capability, and growers must not rely on this as a means of disease control.
	Anti-sporulant activity	The ability to prevent spores from being produced. In this case, disease continues to develop, but spores are not produced or released, so the amount of inoculums available to infect surrounding plants is reduced.
Chemical structure	Dithiocarbamates	Their molecules contain a metal atom that determines their name. Thus, there are, for example, Maneb (Mn), Ziram and Zineb (Zn), and Mancozeb (Mn and Zn). They have low acute toxicity by the oral, dermal, and respiratory routes. Upon chronic exposure, adverse effects are seen in the thyroid.
	Triazoles	They are the systemic broad-spectrum fungicides with the unique 1, 2, 4-triazole ring. Some of them are applied as non-steroidal antiestrogens (Sheehan et al., 1999). Many triazole fungicides were reported to be the potential endocrine disruptors and can interfere with steroid hormone biosynthesis in mammals (Vinggaard, 2006; Poulsen, 2015; Yu et al., 2013). These pesticides may exert the androgenic disruption through different potential mechanisms (Robitaille et al., 2015; Mueller et al., 2008; Lv et al., 2017).

I.3.3. *Classification according to their chemical structure*

Chemical pesticides are divided according to their chemical structure in many group, the main groups that can be detected are organochlorine (OCPs), organophosphorus (OPPs), organonitrogen pesticides ONPs (carbamates herbicides, triazines). The chemical structures of some classes of pesticides are presented in Fig. 5. This classification does not allow defining in a systematic way a compound. Some pesticides may be composed of several chemical features and can then be classified in one or several chemical families as shown in table 6.

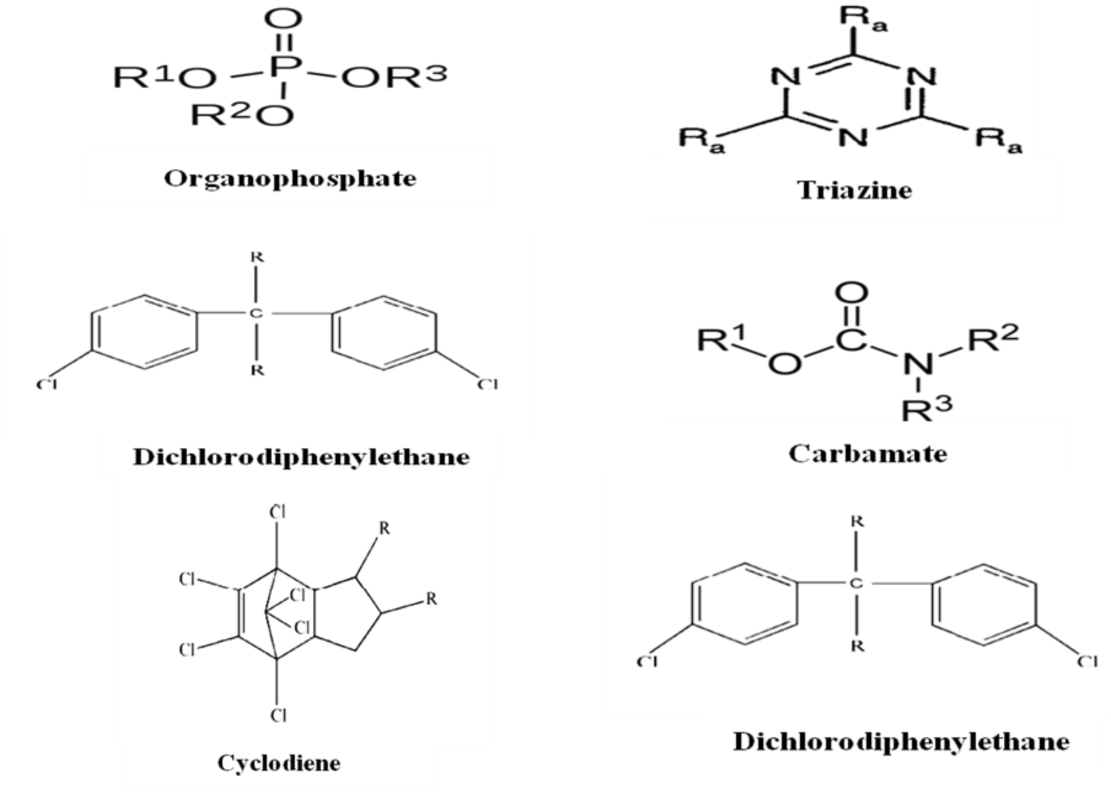

Organophosphate
Triazine
Dichlorodiphenylethane
Carbamate
Cyclodiene
Dichlorodiphenylethane

Figure 5 General structure of OPPs, Triazines, Carbamates, Dichlorodiphenylethane and Cyclodiene

Organochlorine pesticides (OCPs) are synthetic pesticides that were widely used in agriculture throughout the world, the latter half of the 20th century (Vargas-Bernal et al., 2012; Li & Macdonald, 2005; Wong et al., 2005) to combat pests in agriculture, industry and in sanitary purposes such as DDTs, HCHs, chlordane and dieldrin (van den Berg, 2009; Lee, 2016; Sánchez-Osorio et al., 2017). OCPs are insecticides derived from chlorinated hydrocarbons and containing at least one covalently bonded chlorine atom. They are as other organ chlorine compounds (including polychlorinated biphenyls; PCBs) referred to be persistent organic pollutants or POPs (Darko & Akoto, 2008; Salem et al., 2013). The OCPs have been the most abundant of pesticides on account of their high efficacy, their low price (cost) and high effectiveness (Wang , 1991; Wong et al., 2005) and are of global concern due to their physicochemical characteristic in the environment such as their ubiquity, their high chemical stability, high toxicity and persistence, semi volatility, capability of long range transport, resistance to environmental degradation, lipophility, poor water solubility and low vapor pressures (Bouwman et., 2008; Van Leeuwen et al., 2013) Therefore they apt to bio accumulate and biomagnified up the food chain thereby posing adverse effects on human and animals. (Liu & Meng, 2011; Jones & De Voogt, 1999; Bernanke & Köhler, 2008; UNEP, 2002a & 2014a; Röllin et al., 2009; Arrebola et al., 2012; El-Shahawi et al., 2010).

For these reasons, the production and the use of 14 OCPs namely aldrin, endrin, dieldrin, chlordane, dichlorodiphenyltrichloroethane (DDT), heptachlor, hexachlorobenzene (HCB), mirex, toxaphene, alpha hexachlorocyclohexane, beta hexachlorocyclohexane, chlordecone, lindane and pentachlorobenzene have been banned and restricted globally under the Stockholm Convention on POPs (Tokuç, 2013; Stockholm Convention, 2001; UNEP, 2016). For example, DDT continues to be available for vector control where approved by the World Health Organization, but is otherwise banned (Sánchez-Osorio et al., 2017). Among the organochlorine pesticides, only the endosulfan, whose two isomers α and β, are still allowed. It acts on many insects for a wide variety of cultures. OCPs comprise of a large group of structurally diverse compounds used to control agricultural pest and vectors of humans which are further divided into five groups: Dichlorodiphenyltrichloroethane(DDT)and its analogs; Isomers of benzene hexachloride (BHC); Cyclodiene insecticides (including heptachlor, chlordane,and aldrin) ; Caged structures(e.g. mirex and chlordecone) ; Toxaphene (Smith , 1991).
From these groups, dichlorodiphenyltrichloroethane (DDT) and hexachlorocyclohexane (HCH) were the most extensively used (Li & Macdonald , 2005). China, Mexico, Brazil, and other countries were among those where DDT was intensively used, while China, India, France, and Egypt were among the higher users of BHC (Semeena, 2005). They are known to resist biodegradation and therefore they can be concentrated through food chains and produce a significant magnification of the original concentration at the end of the chain. It has been cited that the degradation of DDT in soil is 75–100% in 4–30 years (Shang et al., 2011; Sankararamakrishnan et al., 2004)

OPPs on the other hand are the chemical substances which are produced due to reaction between phosphoric acid and alcohols including derivatives of phosphoric, phosphorus, thionophosphoric, and thion-thiolo phosphoric acids esterified with methyl or ethyl and different alcohol groups (Mariani et al., 2010). So structurally, they are usually esters and degrade rapidly and faster than OCPs depending on their formulation, method of application, climate and the growing stage of the plant (Sankararamakrishnan et al., 2004) they are very poorly soluble in water, but are more so in organic solvents and fats.

These molecules act as insecticides extensively used in agriculture for crop protection and fruit tree treatment (Chen et al., 2016) owing to many advantages, such as relatively low cost, a broad spectrum of activity, and high impact on insects (Li et al., 2012). In 2001, 33,000 tons of OPPs were sprayed onto crops in the USA. More than 8500 tons were applied for non-agricultural purposes as insecticides and as additives to grain stored in elevators (Kamel et al., 2009). By comparison, 1902.25tonnes of OPPs were applied in Poland in 2008 (Tankiewicz et al., 2010). OPPs are highly neurotoxic to human beings and other animals in our ecosystems (USEPA, 2001; Viswanathan et al., 2009) by inhibiting the action of enzyme acetyl cholinesterase (AChE).

ONP is an umbrella term covering a large number of different compounds. In practice, one uses the names of the various chemical groups in a particular category of plant-protection products. In the literature, ONP is taken to mean carbamates and triazines and their derivatives (Rubio et al., 2007)
Carbamates are esters of carbamic acids (NH_2COOH). These also include mainly of insecticides such as aldicarb , carbofuran , carbaryl , ethienocarb, fenobucarb, oxamyl, and methomyl; with other fungicides and herbicides. Carbaryl was the first carbamate compound, manufactured by Geigy Company in Switzerland in 1956 (Kaushik & Kaushik, 2007).
Their mode of action is inhibiting acetyl cholinesterase similar to that of the organophosphates but the bond formed for inhibition is less durable and thus reversible.
While triazine is another class of nitrogen-containing heterocycles .The parent molecules' molecular formula is $C_3H_3N_3$. They exist in three isomeric forms, 1,3,5-triazines being common. The atrazine, which has an herbicide effect, is characterized by an s-triazine cycle was forbidden within the European Union since 2003, it has still been used in USA and about 80 countries all over the world and is one of the most employed pesticides (Kyle, 1985). Triazine half-lives are typically between 30-60 days (Leonard, 1988)

Table 6 Classification of pesticides by their family, their types with some examples of common used pesticides (USEPA, 2014b).

Family	Type	Common name
Organochlorine	Insecticides	HCHs; DDTs ; Aldrin; Dieldrin, Heptachlor; Endosulfan(I,II) Metoxychlor; Endrin ketone
Organophosphorus	Acaricide, insecticide	Malathion
	Acaricide, insecticide, Nematocide	Dimethoate including its oxygen analog
	Fungicide	Fosetyl-aluminium (Aluminum tris(O-ethylphosphonate))
	Herbicide	Bensulide; Glufosinate ammonium
	Insecticide	Diazinon Phosphorothioic acid (Chlorethoxyphos) (O,O-diethyl 0- (l.2.2.2-tetrachloroethyl) ester)
	Insecticide, Nematocide	Disulfoton Ethoprop (ethoprophos)
	Insecticide, acaricide	Azinphos-methyl ; Coumaphos
	Nematocide	Fosthiazate
	Nematocide, acaricide, insecticide	Phorate ; Chlorpyrifos
	Nematocide, insecticide	Cadusafos
	Plant growth regulator	Tribuphos (tribufos)
Organophosphate	Insecticide, acaricide	Naled ; Dichlorvos ; Crotoxyphos (S-[2-(Ethylsulfinyl) ethyl) 0,0-di- methyl phosphorothioate)
	Insecticide, Nematocide	Fenamiphos
Organothiophosphate	Insecticide	Methyl parathion ; Methidathion ; Phosmet ; Fenitrothion ; Chlorpyrifos-methyl
	Insecticide, acaricide	Acephate ; Phosalone ; Pirimiphos-methyl
Carbamates	Fungicide	Iprovalicarb ; Pyraclostrobin ; Benthiavalicarb-isopropyl
	Insecticides	Methomyl
	Herbicide	Asulam
	Nematocide, acaricide, insecticide	Carbofuran ; Oxamyl ; Aldicarb
	Plant growth regulator, acaricide, insecticide	Carbaryl
Dithiocarbamate	Fungicide	Sodium o-nitrophenolate
Thiocarbamate	Herbicides	Cycloate (S -Ethyl cyclohexylethyl thiocarbamate) Triallate ; Thiobencarb
Triazines	Herbicide	Indaziflam
	Insecticide	Pymetrozine

I.3.4. Classification according to the degree of toxicity

Pesticides are toxic and they are potentially hazardous to humans, animals, other organisms, and the environment. They can be classified according to their degree of toxicity. The classification of WHO distinguishes pesticides between the more and the less hazardous forms of each one based on the toxicity of the technical compound and on its formulations (solid or liquid form). The classification is based primarily on the acute oral and dermal toxicity of pesticides to the rat since. While The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) have estimated the acute toxicity related to the experimentally-derived LD_{50} value just for oral exposure. WHO has used the Acute Toxicity Hazard Categories from the GHS as the starting point with time in consultation with countries, international agencies and regional bodies for changing the 1975 WHO classification in order to develop a new version. The revised version used by WHO before 2009 is figured on the table below (Table 7) (WHO, 2009; 2010). We note that the acute hazard to man differs from that indicated by LD_{50} assessments alone.

Table 7 WHO classification

WHO Class		**LD50 for the rat (mg/kg body weight)**	
		Oral	***Dermal***
Ia	*Extremely hazardous*	< 5	< 50
Ib	*Highly hazardous*	5–50	50–200
II	*Moderately hazardous*	50–2000	200–2000
III	*Slightly hazardous*	Over 2000	Over 2000
U	*Unlikely to present acute hazard*	5000 or higher	

II. Pesticides in the environment

Pesticides found in the environment are mainly originated from manufacturing, transportation, and agricultural applications (Farajzadeh et al., 2009). They enter into the environment in various forms. They can be in form of powder, moistened powders, powders for preparing aqueous solutions, and concentrates for making up emulsions or sprays. More than 95% of sprayed insecticides and herbicides on crops reach a destination other than their target species. They can be transported over long distances in the atmosphere and may eventually end up in soil or water where they have not been used (Sankararamakrishnan et al., 2004; UNEP, 2002b; Kuranchie-Mensah et al., 2012) (Fig 6).

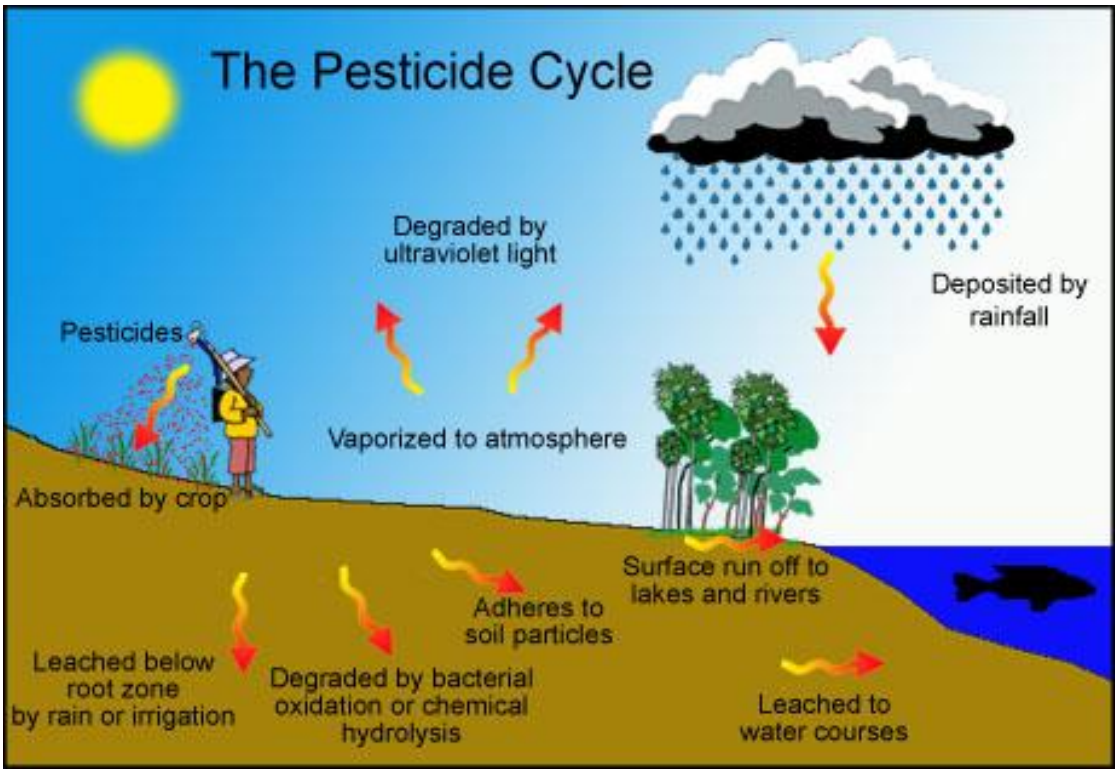


Figure 6 Cycle of pesticides (Stobart, 2016)

The concentration and type of pesticides found in the environment depend on many factors such as their persistency and the compartment in which they are found. The ingredients in the pesticide, the intensity of application and the types of crops grown, the weather conditions and the season can also affect the pesticides in the environment. Above all, the physical–chemical properties of the pesticides such as their solubility in water, their capacity to be retained in the soil, their persistence, and soil conditions control their persistency in the environment (Carabias-Martínez et al., 2003).

Once introduced into the environment, pesticides may adsorb, transfer, and degrade. An understanding of the fate processes can help every pesticide applicator ensure that applications are not only effective, but are also environmentally safe. Indeed, immediately after application, pesticides came into the atmosphere by volatilization from soil or plant surfaces or through wind erosion. From 30 to 50% of sprayed pesticides found in the air in gaseous form, adsorbed on suspended particles or dissolved in water vapor (Kosikowska & Biziuk, 2010; Wong et al., 2008). Soil particles with adsorbed pesticides enter the troposphere and can remain there for several days or weeks following pesticide application. Depending on their stability, pesticides in the atmosphere may be transform by the action of sunlight, water, atmospheric radical or other chemicals (oxidizing agents), or microorganisms, such as bacteria. This degradation process usually leads to the formation of less harmful breakdown products but in some instances can produce products that are more toxic. The parent and decomposition products can be transported over great distances before settling (Namieśni et al., 2003) and can deposited on the land soil and aquatic water by pesticides through rainfall (wet deposition), or gases and particulates deposition (dry deposition) (Cerejeira et al., 2003). Despite its low persistence in water, most of pesticides have the tendency to accumulate in the naturally occurring organic matter present in soil ultimately leading to bioaccumulation for several years (Weber et al., 2010).

Soil and sediment were the repository of all their types; they therefore play an important role in global distribution and fate of the POPs. They not only have a large retention capacity but also re-emit into environment as secondary source (Zheng et al., 2009) which indirectly resulted in water and atmospheric contamination (Fu et al., 2003; Bidleman, & Leone, 2004). These compounds can reach water bodies through surface runoff and air drift from nearby agricultural fields (Miglioranza et al., 2002; Cerejeira et al., 2003) and cause adverse effects to non-target aquatic animals. In aquatic environment, pesticides are subject to a variety of processes. It can be subject to the physical processes such as accumulation, deposition, dilution, and diffusion. And also, they can undergo the (photo)chemical such as hydrolysis, photolysis, (photo)oxidation. It can be also subject to the biodegradation, biotransformation and bioaccumulation. Moreover, despite their low persistence in water, most of pesticides have the tendency to accumulate in the organic matter present in soil ultimately leading to a cycle of bioaccumulation for several years (Weber et al., 2010). Soil and sediment were the receptor of all their types; they therefore play an important role in global distribution and fate of the POPs. They not only have a large retention capacity but also re-emit into environment as secondary source (Barra et al., 2005; Zheng et al., 2006; Zeng & Venkatesan, 1999) which indirectly resulted in water and atmospheric contamination (Fu et al., 2013; Bidleman & Leone, 2004).

In many cases, mobilized pesticides is driven to streams by runoff or washed into the underground water by infiltration. Water in confined aquifers is believed to be less polluted because their disconnection with the surface and is often preferred to bank filtrate (Fig. 6). However, contamination of drinking water wells in confined aquifers by surface water has been observed (Borchardt et al., 2007; Hunt, 2008). Indeed, the widespread use of pesticides and their long-term release lead to not only worldwide spread pesticides into the environmental compartments but also in food chains (Boyd, 2000; Cerejeira et al., 2003; Xue et al., 2005; Hildebrandt et al., 2008; Anwar et al., 1997; Net et al., 2015; Sun, 2016; Zhang et al., 2011; Fenik, 2011; Ballesteros & Parrado, 2004; Chen et al., 2016; UNEP, 2009; Driss et al., 1993; Tsakiris et al., 2015; Wu et al., 2013).

III. Pesticides- Regulation

Pesticides used in agriculture can spread into troposphere, deposit and associate strongly to soil or infiltrate into ground water. Most of the synthesized pesticides are hazardous on health and for the ecosystem (EPA, 2017b). Thus, they can affect human health through direct contact with soil, via inhalation or via groundwater consumption. For this purpose, in order to control pollution in environmental waters and soil, pesticide levels are legislated by several directives, where maximum values are set.

III.1. Drinking water regulation

In order to provide the cleanest, safest and most reliable drinking water and to protect the health of the most vulnerable members of society such as children and the elderly the regulation has been set. The objective is to prevent and improve both the human health and the aesthetic quality aspects of drinking water. Among the regulation and recommendation organizations, the most popular are cited in the following section.

III.1.1. WHO recommendation

The origin of WHO Guidelines for Drinking-Water Quality (GDWQ) goes back to the 1950s. The first drinking water standard has been established in 1958 (Babbitt, 1958).

Following a series of expert consultations culminating in a meeting in 1956 in Geneva, the International Standards for Drinking-Water were published in 1958, revised in 1963 and 1971 (WHO, 1958; 2004; 1963 & 2010; Jablensky et al., 1992). The international standards have been in existence for over a decade until they were superseded by the WHO Guidelines for Drinking-Water Quality (GDWQ) in 1984. The primary objective of the WHO- GDWQs is the protection of public health. The change from Standards to Guidelines has enabled that the Guidelines have been used in numerous countries as a basis for the development of their national standards that, the implementation of their own standards (WHO, 1993; 2003) will ensure the safety of drinking water supplies through the elimination, or reduction to the minimum of hazardous constituents in drinking water.

The second edition of the GDWQ Volume 1, was published in 1993 followed by Volume 2 in 1996 and Volume 3 in 1997 (Yamamura et al., 2003). Guidelines values were calculated using a tolerable daily intake (TDI) for chemicals showing a threshold for toxic effects. In the case of genotoxic and carcinogenic, the International Agency for Research on Cancer (IARC) classification for carcinogenic compounds was taken in consideration for the calculation of the guidelines value. These values are presented in the table 7. WHO recommendations are considered as an approach, which are being implemented to identify the risk and to clarify and elaborate ways of implementation in risk management coming from the other sources such as food and air. They give the pesticides concentration that does not have any toxic effect on the health of consumers.

III.1.2. European directives on water

The EU has adopted a strategy for the sustainable use of pesticides. EU legislation requires pesticides to be effective and have no harmful effects. The European commission sets maximum levels of pesticide residues in food and feed. In addition, pesticides levels in water are subject to many directives. Firstly, the Directive 2000/60/EC (Water Framework Directive) aims at a coherent and integrated approach to water management across the EU. It sets limits to the levels of particular chemicals in the aquatic environment and includes provision for monitoring of pesticides. While, Directive 2008/105/EC specifies limits on concentrations of some pesticides and other substances in surface waters. In January 2012, the European Commission made a new proposal (COM(2011)876) to amend these two directives. The proposal includes a revised list of priority substances (including some pesticides), and provisions to improve the functioning of the legislation (Erbach, 2012).

Concerning drinking water, the European Union Drinking Water Directive (1998) adopted the Council Directive 98/83/EC of 3 November 1998 relating to the quality of water intended for human consumption. The maximum recommended limit of pesticides in drinking water is fixed at **0.1 µg/L** for individual pesticides with their related products and at **0.5 µg/L** for the sum of all pesticides (Narita et al., 2014; Hurtado-Sánchez et al., 2013; DCE, 1993) but in the case of aldrin, dieldrin, heptachlor and heptachlor epoxide, the individual parametric value of these pesticides is 0.03 µg/l. EU countries had to incorporate this directive into national law by 25 December 2000. In 2015, the Commission adopted Directive (EU) 2015/1787 introducing new EU rules to improve monitoring of drinking water. The directive allows EU countries greater flexibility as to how drinking water is monitored across the EU (DCE, 2017).

III.1.3. USEPA Standards

The Safe Drinking Water Act (SDWA) are enacted on a congress in 1974, amended and reauthorized in 1986 and 1996. They declare the main federal law that ensures the quality of Americans' drinking water and authorizes the United States Environmental Protection Agency (US-EPA) to set national standards for drinking water to protect public health against certain contaminants provided by public water systems. Therefore, US-EPA has worked with states, localities, and many other partners to implement the SDWA provisions (EPA, 2012). EPA has established two regulations.

The National Primary Drinking Water Regulation (NPDWRs), that set mandatory water quality standards for drinking water contaminants, are enforceable standards called "Maximum Contamination Levels or MCLs". MCLs are established to protect the public health against the contaminants including pesticides in drinking water (EPA, 2012, 2017c). The MCLs and maximum contaminant level goals (MCLGs) for each pollutant have been determined. Furthermore, EPA has established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards for 15 contaminants. The secondary maximum contaminant levels or SMCLs are established as guidelines to assist public water systems in management of drinking water for organic contaminants and for aesthetic considerations, such as taste, color, and odor in their drinking water (EPA, 2017b).

III.1.4. Other guidelines

Australian Drinking Water Guidelines (ADWG) and Canadian drinking water supplies are established to provide an authoritative reference to their citizen's community and the water supply industry on what defines safe, good quality water, how it can be achieved and how it can be assured (Australian Drinking Water Guidelines, 2011 updated on 2016). The ADWG have been developed on 2011 by the National Health and Medical Research Council (NHMRC) and undergo rolling revision to ensure they represent the latest scientific evidence on good quality drinking water. While Health Canada was worked with the provincial and territorial governments to develop the Canadian drinking water supplies (Australian Drinking Water Guidelines, 2010). Each guideline set the values, which can be different compare to others. A comparison between the different guidelines values for pesticides molecules in drinking water was detailed in table 8.

Table 8 WHO, US-EPA, Canadian and Australian guidelines values for pesticides in drinking water in mg/L.

Chemicals	WHO (mg/l)	MCLGs (mg/l)	MCLs (mg/l)	USEPA Cancer description	Canadian Guideline (mg/l)	Australian Guideline (mg/l)
Alachlor	0.02	0	0.002	B2		
Aldicarb	0.01	0.001	0.003	D	0.009	0.004
Aldicarb sulfone		0.001	0.002	D		
Aldicarb sulfoxide		0.001	0.004	D		
Aldrin & Dieldrin	0.000 03	-	-	B2	0.0007	0.0003
Atrazine and its metabolites	0.1	0.003	0.003	N	0.005	0.02
Azinphos-methyl					0.02	
Baygon		-	-	C		
Bromacil		-	-	C		0.4
Chlordane	0.000 2	0	0.002	B2		0.002
Chlorpyrifos	0.03	-	-	D	0.09	
Cyanazine	0.000 6	-	-	-	0.01	
Diazinon		-	-	E	0.02	0.004
DDT and its metabolites	0.001					0.009
Dichlorprop	0.1					
Dicofol						0.004
Dimethoate	0.006				0.02	
Disulfoton		-	-	E		
Diuron		-	-	L	0.15	
Endosulfan						0.02
Endrin	0.0006	0.002	0.002	I		
Fenoprop	0.009					
Glyphosate		0.7	0.7	D	0.28	
Heptachlor		0	0.0004	B2		0.0003
Heptachlor epoxide		0	0.0002	B2		
Hexachlorobenzene		0	0.001	B2		
Hydroxyatrazine (Atrazine metabolite)	0.2					
Lindane	0.002	0.0002	0.0002	S		0.01
Malathion		-	-	S	0.19	
MCPA	0.002					
Mecoprop	0.01					
Methyl parathion		-	-	N		
Metolachlor	0.01	-	-	C	0.05	
Methoxychlor	0.02				0.9	
Metribuzin		-	-	D	0.08	
Molinate	0.006					
Paraquat		-	-	E	0.01	0.02
Parathion					0.05	0.02
Phorate					0.002	

Propachlor	-	-	L		
Propazine	-	-	N		
Simazine	0.004	0.004	N	0.01	0.02
Toxaphene	0	0.003	B2		
Trifluralin	-	-	C		

The Cancer Descriptors in the 2005 EPA Guidelines for Carcinogen Risk Assessment are as follows:
H: carcinogenic to humans
L: likely to be carcinogenic to humans
L/N: likely to be carcinogenic above a specified dose but not likely to be carcinogenic below that dose because a key event in tumor formation does not occur below that dose”
S: suggestive evidence of carcinogenic potential
I: not likely to be carcinogenic to humans
N: inadequate information to assess carcinogenic

B2, C, D, E cancer classification are the same of the IARC classification.

III.2. Soil regulation

Soil contamination is a worldwide health concern; it can be caused by the presence of xenobiotic chemicals or other alteration in the natural soil. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, HAP, heavy metals and pesticides. Regulatory jurisdictions are developed based on human health risk considerations for several types of exposures. The majority are developed based on human health risk considerations in scenarios such as residential, commercial, or industrial exposures. The highest levels of concern yielding the lowest, most restrictive values are often applied to residential soil where children uptake contamination by ingestion, inhalation, and dermal contact. Here, all of these values are referred to as regulatory guidance values (RGVs) which specify the maximum allowable “concentration” (in units of mg/kg) of a pollutant that may be present in the soil without prompting some form of action (Sánchez-Osorio et al., 2017).

RGVs for soil contamination were applied in worldwide scale to regulate exposure to surface soil pollution. In the United States, element guidance values have been promulgated by at least 6 federal agencies, 46 states, and several regional, city, county, territorial, and autonomous Native American jurisdictions. Guidance values have been published in at least 72 other United Nations member states

(Jennings & Li, 2015; 2014). Although the number and type of regulated pollutants varies from a few well-known inorganics such as Cd or Pb, to hundreds of organic compounds common in manufacturing and agriculture. There is a little agreement on the magnitude of the guidance values applied to pollutants. Chemicals have been identified by several orders of 10 magnitudes. Indeed, variations of five or six orders of magnitude are common (Jennings & Li, 2014; Zhao et el., 2016).

To date, a total of 1667 RGVs were applied for many persistent organic pollutants HAP, benzene and chlorinated benzene (Jennings & Li, 2014; Jennings, 2009; 2012 a; b; c; 2011c), toluene, ethylbenzene, xylenes, naphthalene, chlorinated methanes, ethanes, and ethenes (Jennings, 2011a; b), with the exception of Mirex which is less frequently regulated. For pesticides, RGVs of Stockholm Convention POPs 2001 have focused on Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptachlor, Mirex, and Toxaphene. Additional pesticides were added to the Stockholm Convention POPs 2009 and 2011 (Jennings, 2015). Stockholm convention created against a list of 12 POPs that became known as the “dirty dozen”, nine of which are pesticides in order to reduce and/or eliminate their emissions or discharges (Table 9). It was signed on May 2001; and entered into force on 17 May 2004, 90 days after being ratified by the 50th nation. Currently there are 178 signatory nations to the convention, but these do not include the United States, the Occupaying State of Israel, Malaysia, and Italy (Secretariat of the Stockholm Convention, 2008). This convention was developed by the Intergovernmental Forum on Chemical Safety (IFCS) and the WHO International Program on Chemical Safety (WHO/IPCS) in response to the request of the Governing Council of the United Nations Environmental Program (UNEP, 2017) on May 1995. The following table summarize information on 8 POP pesticides (table 9).

Table 9 Statistics Original Stockholm convention POP pesticides

	Aldrin	*Chlordane*	*DDT*	*Dieldrin*	*Endrin*	*Heptachlor*	*Mirex*	*Toxaphene*
Arithmetic Mean of all RGVs (mg/kg)	11.3	41.3	93.2	276.0	42.3	15.9	185.0	23.0
Arithmetic Mean of U.S.-related RGVs (mg/kg)	17.8	51.3	40.9	589.0	67.5	21.8	245.0	26.8

IV. Pesticides Analysis

IV. 1. Pesticides extraction:

Related to their extensive use, traces of pesticides can be detected in air, water, soil, sediments and food at low levels varied from few ppb to few ppm. Furthermore, the complexity of environmental matrices and their types and the wide variations in physical and chemical properties of the pesticides and their products of degradation need to develop selective analytical methodologies with high sensitivity to pesticides and lower cost-benefit ratios for fast monitoring and risk assessment of these organic pollutants residues in the environment (de Souza Pinheiro & de Andrade, 2009).

Due to the low concentration level in natural environment, pesticide quantifications need an extraction and purifications step to isolates the interest compounds. A variety of extraction methods can be used to screen these components. In general, in view of the aqueous samples, liquid–liquid extraction (LLE) and solid-phase extraction (SPE) are the most frequently used sample pretreatment methods for the isolation and/or enrichment of pesticides. Nerveless, the development of several new extraction approaches, including solid-phase micro extraction (SPME) semi-permeable membrane device (SPMD), and supercritical fluid extraction has been induced to reduce the overall sample preparation time and the quantities of organic solvents needed for the extraction of organic pollutants from environmental samples. Although, ASE (Accelerated solvent extraction) is the method commonly used for extraction of organic compounds from solid samples.

Many studies were recorded on the optimization of extraction technique.

IV.1.1. Liquid-liquid extraction or LLE

Traditional liquid–liquid extraction or LLE is among the oldest of the pre-treatment techniques in analytical chemistry (Fatoki et al., 2003). LLE is based on the different distribution of the components to be separated between two immiscible liquid phases usually water and organic solvent. It depends on the relative solubility of the component in the two liquids. In single separation is achieved by adding of solvent and extraction is performed in mixer–settler equipment or extraction columns. While in multiple extractions operational mode the separation process is repeated several times by using either the same or a different extractant in the successive stages (Fig. 7). However, LLE requires large amounts of expensive toxic organic solvent and need a large time-consuming procedure (Font et al., 1993; Bedendo et al., 2012).

For these reasons, the miniaturization of the LLE (LPME) has made the effort of eliminating or minimizing all these disadvantages (Xu et al., 2007).

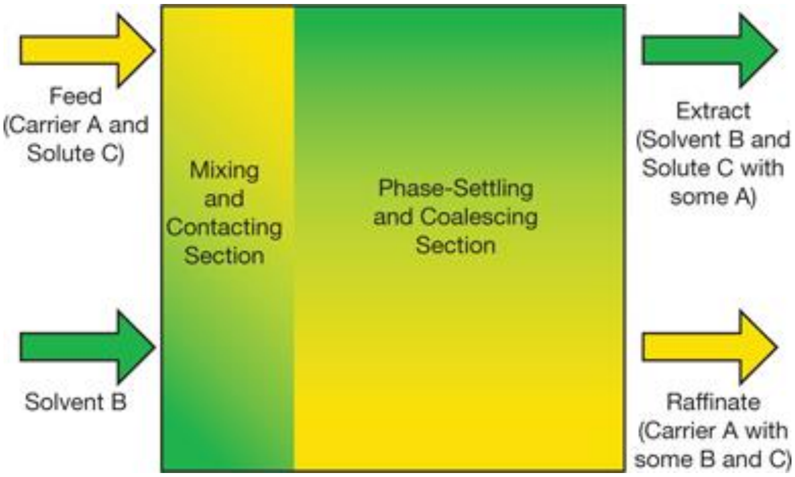


Figure 7 Concept of LLE extraction

IV.1.2. Solid phase extraction or SPE

Solid phase extraction (SPE) is the most commonly used extraction method to extract multi residue compounds from water sample in many environmental fields (Ahmadi et al., 2006; Yao et al., 2001; Jiawei et al., 2008; Cortada et al., 2004). It bases on the partitioning of compounds between a liquid and solid phase whereby the intermolecular forces between the phases influences retention and elution. Numerous SPE products are now available, such as column cartridges, disks, well plates. Various SPE sorbents are now widely available providing a wide range of interactions (non-polar or ionic). C18 and HLB are the most popular sorbents used for POPs analysis.

SPE aims to reduce the overall analytical time and solvent consumption, to increase the recovery, to facilitate the operation by automated incorporation. However, SPE can be relatively expensive (Font et al., 1993) and needs pretreatment and further requires toxic organic solvent for the elution step (Ahmadi et al., 2006; Jiawei et al., 2008; Yao et al., 2001). The efficiency of the extraction depends on the physical-chemical properties of each interest compound and various operational conditions. The type of the cartridge, the solvent used for extraction, pH, volume of extracted sample and ionic force are the principle parameters. These parameters should be controlled and optimized previously (Sabik & Jeannot, 2000).

IV.1.3. Solid-phase micro-extraction or SPME

Solid-phase micro-extraction (SPME) is a more recent procedure than SPE. It is a solvent-free sample pretreatment technique invented by Arthur and Pawliszyn in the early 1990s for pretreatment of a variety of environmental samples (de Fatima Alpendurada, 2000; Ahmadi et al., 2006; Zambonin et al., 2004; Arthur & Pawliszyn, 1990; Cortada et al., 2009) (Table 10).. Due to its non-exhaustive nature and the availability of several calibration strategies, SPME is considered to be a most promising tool for simultaneous analysis of drugs from complex matrices (Lambropoulou et al., 2004a).

With SPME method, target analytes with low or medium polarity are extracted from aqueous or gaseous samples by a contact with a fiber of fused silica covered with a film of solid selective polymeric fiber attached to a thin needle on a syringe. After adsorption, the fiber is transferred to an analytical instrument where the analytes are desorbed, separated and quantified. SPME extraction can be performed either in the headspace (HS) or through direct insertion of fiber into the sample (Mmualefe et al., 2009). For separation and detection of the enriched analytes, SPME is generally compatible with gas chromatography (GC) or high performance liquid chromatography (HPLC) techniques (Spietelun et al., 2012). It can also be coupled directly to MS without chromatographic separation, and these methods are mainly used for rapid analysis of ultra-compounds in environmental and biological samples. Among them, SPME-AMS method is the most attractive one (Deng et al., 2014).

However, several parameters including fiber type, the time and temperature of extraction, sample volume added to the extraction flask, duration and temperature of desorption are the principal factors influencing the recovery (Stalikas et al., 2009). Today, SPME counts numerous applications for the extraction of organic pollutants from a variety of environmental samples. Two different SPME exist: fiber and in-tube SPME and these two SPME are presented in the figure 8 (Kataoka, 2003). The significant difference between these methods is that, the analytes are adsorbed on the outer surface of the fiber from agitated sample solution with the first one, and, with in-tube SPME, they are adsorbed on the inner surface of the capillary column from following sample solution. Furthermore, with in-tube SPME, it is necessary to prevent plugging of the capillary column and flow lines by filtering the sample solution before extraction (Kataoka, 2003). The advantages of SPME are solvent-free, fast, portable and easy to use. It includes simultaneous sampling, isolation, extraction and preconcentration of analytes from aqueous samples into one step. However, SPME is an expensive technique and its fiber is fragile and has limited lifetime and the sample carry-over can be also a problem (Ahmadi et al., 2006).

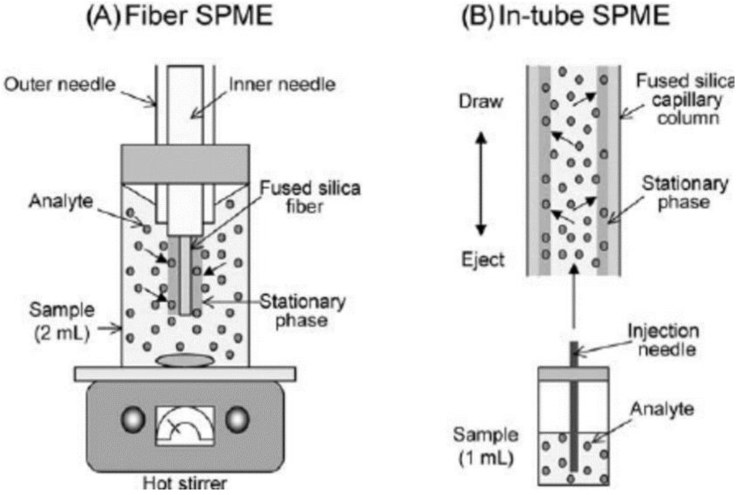


Figure 8 Transfer of analytes in fiber SPME (A) and in-tube SPME (B)

IV.1.4. **Liquid-phase micro-extraction or LPME**

Liquid-phase micro-extraction (LPME) has been introduced by He and Lee in 1997 to eliminate all the problems disrobed above in LLE, SPE and SPME techniques. It is a solvent minimized based pretreatment method of LLE (Pusvaskiene et al., 2009) in which only several μL of solvent are required to concentrate analytes from various samples. (Moinfar & Housseini et al., 2009). This technique uses a porous polypropylene hollow fiber as an extraction (Ho et al., 2002; Halvorsen et al., 2001). The fiber is compatible with capillary gas chromatography (GC), capillary electrophoresis (CE) and HPLC. In LPME, the extraction takes place into a small amount of a water-immiscible solvent, which is an acceptor phase, from an aqueous sample containing analytes which is a donor phase (Sarafraz-Yazdi & Amiri, 2010). SPME can be divided into three main categories widely applied for the extraction of pesticides from different matrices. These methods are such the following:

1- Single-drop micro-extraction (SDME)
2- Dispersive liquid–liquid micro-extraction (DLLME)
3- Hollow-fiber micro-extraction (HF-LPME)

IV.1.4.1. Single drop micro-extraction or SDME

Single drop micro-extraction (SDME) was developed as a solvent-minimized sample pretreatment procedure. SDME has been increasingly used the analysis of pesticides because it is a simple, quick, cheap, fast and effective. Moreover, SDME is a green technique methodology since very little toxic organic solvent is used (Palit et al., 2005; Romero-González et al., 2008). Currently, SDME has become a powerful tool for the determination of numerous organic compounds including pesticides in water (López-Blanco et al., 2005; Zhao et al., 2006; Psillakis & Kalogerakis, 2002; López-Darias et al., 2010; Lambropoulou et al., 2004b).

The SDME procedure has been described in several papers (Ahmadi et al., 2006; Lambropoulou et al., 2004b; Xie et al., 2014). It depends on the principle of a distribution of analytes between an organic solvent microdrop and an aqueous phase. Directly, the analytes with high partition coefficient are transferred by diffusion from a 1-5 ml of sample to a microdrop of organic solvent (5–50 µL) suspended to the tip of a microsyringe immersed into a water sample containing the analytes (Zhao et al., 2006). The needle hangs a drop of the solvent while the sample is stirred. After extracting for a prescribed period of time, the microdrop is aspirated back into the microsyringe and then injected into a GC or LC for further analysis (de Souza Pinheiro et al., 2009; Pinto et al., 2010; Lambropoulou et al., 2004a) (Fig. 9).

The SDME procedure has the advantages of high extraction speed and extreme simplicity, it combines both a pre-concentration and sample introduction steps into a single-step extraction which can widely be used in the determination of organic (Zhang et al., 2008) and inorganic analytes (Verma et al., 2009). In addition, this technique uses inexpensive apparatus and virtually eliminates solvent consumption. However, microdrop can be instable and loss solvent during extraction caused by a fast stirring speed and air bubbles. These are the main problems that may reduce the repeatability of SDME procedure (Pedersen-Bjergaard & Rasmussen, 2005).

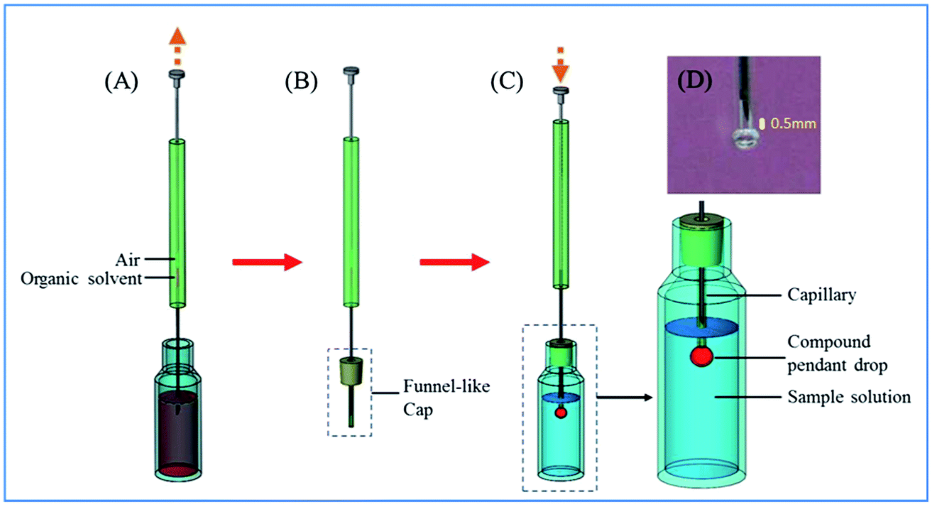


Figure 9 Steps of SDME technique

IV.1.4.2. Dispersive liquid–liquid micro-extraction or DLLME

DLLME was developed in 2006 by Assadi Rezaee? and co-workers (Rezaee et al., 2006) for the pre-concentration of organic analytes from aqueous matrices. This method is a miniaturized LLE that uses microliter volumes of extraction solvent which is based on the equilibrium distribution process of the target analytes between sample solution and extraction solvent (Xiao-Huan et al., 2009). It is based on a ternary component solvent system, in which a certain volume of sample solution is placed in a 10 mL screw cap glass test tube with conic bottom (A), extraction and disperser solvents are rapidly injected by syringe into the aqueous sample (B). After centrifugation, a cloudy solution namely extraction solvent is sedimented at the bottom of the tube (C) and taken with a micro syringe for its later chromatographic analysis (D) (Xiao-Huan et al., 2009; Herrera-Herrera et al., 2010; Cortada et al., 2009; Zgoła-Grześkowiak & Grześkowiak et al., 2011). The extraction steps of DLLME are illustrated in figure 10.

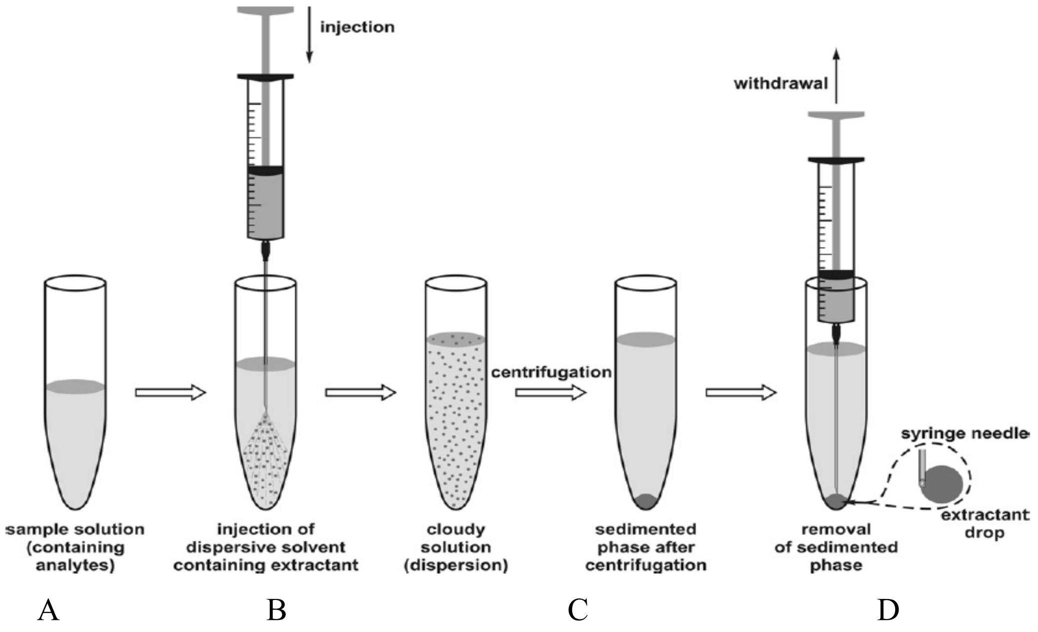


Figure 10 Dispersive liquid-liquid micro extraction procedure

The extraction efficiency of DLLME is influenced by several factors including solubility of extracting solvent in water, types and volumes of extracting and disperser solvents, sample volume, extraction time, pH, and salt addition to the sample (Cortada et al., 2009; Zgoła-Grześkowiak & Grześkowiak et al., 2011). LLME method conserve the advantages of SDME and has its special advantages such as simplicity of operation, rapidity, low cost, high-recovery, high enrichment factor (enrichment factor is defined as the ratio of the concentration of analyte in the sedimented phase to the initial concentration of analyte in the sample), drop stability and environmental benignity (Cortada et al., 2009; Xiao-Huan et al., 2009; Rezaee et al., 2006) Consequently, this technique was used in the extraction of various family of organic compounds including pesticides in water samples **(**Table 10).

IV.1.5. Hollow-fiber microextraction HF-LPME

Hollow-fiber liquid phase micro extraction (HF-LPME) is introduced by He and Lee in 1997 (Sun et al., 2012) with as an attractive alternative to conventional LLE and LPME techniques. It is in a growing number of important applications to organic compounds present in complex matrices including environmental matrices (Zorita et al., 2007; 2008). HF-LPME can be accomplished both in the two- and three-phase mode. In two-phase HF-LPME, the analytes are extracted by passive diffusion from the sample into the hydrophobic organic solvent supported by the fiber. While in three-phase HF-LPME, the analytes were extracted through an organic solvent immobilized in the pores of fiber and further into a new aqueous phase in the lumen of fiber (Payán et al., 2010; Sarafraz-Yazdi et al., 2008). The surface area for the rod-like configuration, the disposable nature of the hollow fiber and the small pore size aim to have more sensitivity of LPME, to eliminate the possibility of sample carryover, ensure reproducibility, and prevents the entrance of large molecules and particles from the accepting phase.

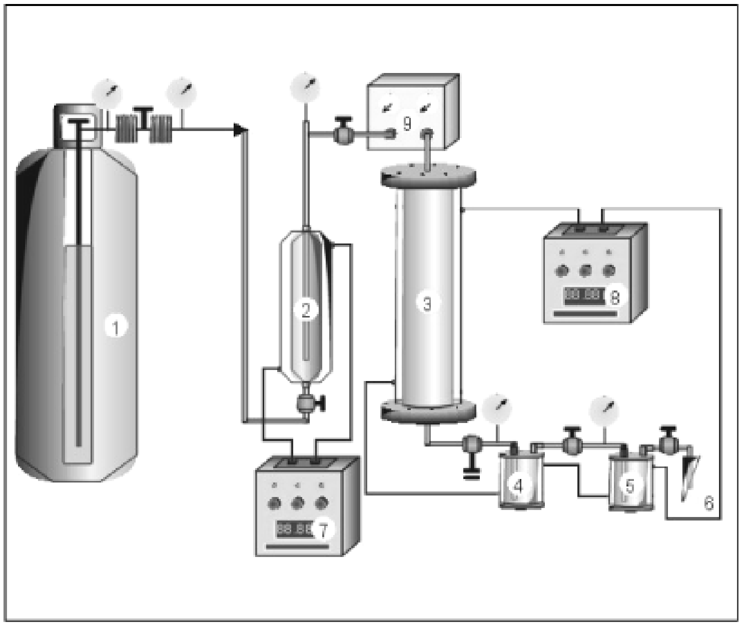
This micro-extraction method is based on the use of single, low-cost, disposable, porous, hollow fibers made of polypropylene. The LPME technique is simple, fast, and more sensitive and economic than LLE and SPE. Additionally, it gives more enrichment of analytes, and reduce the consumption of solvent up to several hundred or several thousand times. It consumes a small volume (a few microliters) of organic extracting solvent, the extracted samples do not require further concentration prior to analysis but it is directly compatible with GC, HPLC, and CE (capillary electrophoresis) (Payán et al., 2010; Sarafraz-Yazdi et al., 2008; Rasmussen et al., 2000).

IV.1.6. Supercritical fluid extraction or SFE

Supercritical fluid extraction (SFE) can be applicable for separating chemical component from the matrix (solid or liquid) using supercritical fluids as the extracting solvent. Due to the low critical temperature 31°C of carbon dioxide (CO_2), this last is the most used fluid, which can be sometimes modified by co-solvents such as ethanol or methanol. In SFE method, the sample is placed in an extraction vessel and pressurized with CO_2 to dissolve the sample and then transferred to a fraction collector, the contents are depressurized and the CO_2 loses its solvating power causing the desired material to precipitate (Fig. 11) (Sarmento et al., 2006).

Extraction conditions for supercritical CO_2 are above the critical temperature of 31°C and critical pressure of 74 bar. For natural materials, type of solvent, temperature, and pressure of the method should be optimized (Sapkale et al., 2010). SFE has extra advantages compared to traditional extraction techniques. Because it is a flexible process due to the possibility of continuous modulation of the solvent power/selectivity of the SFE, allows the elimination of polluting organic solvents and of the expensive post-processing of the extracts for solvent elimination. However, it can also be relatively expensive.

SFE extraction with CO_2 supercritical fluid was an efficient and rapid method for the isolation of pesticides from complex matrices (Rissato et al., 2004; Rezaei et al., 2015; Rezaei et al., 2016). For pesticide, SFE has been reported to has better recovery of pesticides in Honey with 88-98 % compare to LLE with 75-89% (Rissato et al., 2004).



1. CO_2 cylinder;
2. surge tank;
3. extractor;
4 and 5. separators;
6. collector and gas-measuring device,
7 and 8. thermostatic baths;
9. isocratic pump.

Figure 11 SFE unit

For pesticides extraction from solid matrices ASE was the mostly used.

IV.1.7. Accelerated solvent extraction ASE

ASE was first described in 1995 (Richter et al., 1996). It is a liquid solvent extraction technique that uses aqueous and organic extraction solvents at high temperatures and pressures to extract environmental solid sample such as soil, sediment and particulate matter (Li et al., 2003; Giergielewicz-Możajska et al., 2001). For the first time, later it has been proven useful for laboratories performing extractions in food, pharmaceutical and polymer industries. A schematic diagram of an ASE system is shown in figure 12 (Kettle, 2013).

Briefly extraction procedure consists of a combination of dynamic and static flow, extraction cells containing the sample is introduced in the ASE machine. Then, the sample cell is heated at temperatures exceeding the boiling point of the solvent which implies that the pressure inside the extraction cell must be kept high in order to maintain the solvent in a liquid state and be able to move the solvent through the sample cell in a short period of time (Luthria et al., 2004). The extraction process is simplified by 3 steps: Desorption of analytes from a solid particle, diffusion through the solvent located inside a particle pore, and the extract was transferred to the collection vial. The process takes advantage of increasing analyte solubility at high temperature thus the kinetic processes for analytes desorption from the solid matrix is also accelerated. However, few parameters should be previously optimized for better the recoveries. Among them, the type of solvent, pressure, temperature, matrix composition, extraction time, number of extraction cycles, and flow rate are the parameters influencing the process efficiency (Giergielewicz-Możajska et al., 2001; Dean, 1998).

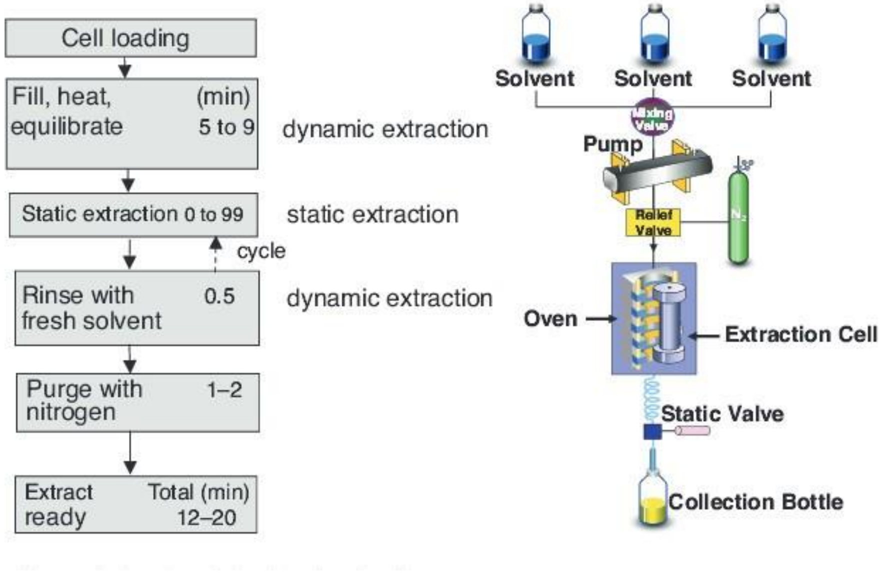


Figure 12 Accelerated solvent extraction process

IV.2. Identification and quantification of pesticides

Because pesticides are usually detected at low concentrations in water environmental matrices including water and soil, it is necessary to combine the extraction procedures in order to improve the LOQ. As such, pesticides can be quantified with good efficiency at the concentration level below regulated values. In this purpose, chromatographic techniques are commonly used for separation such as GC or LC coupled with several type of detection (nitrogen–phosphorus (NPD), electron-capture (ECD), diode-array, fluorescence or mass spectrometry (MS) detection systems (Sabik & Jeannot. R, 1998; Ahmadi et al., 2006).

It was difficult to develop a method for the simultaneous determinations of multi-class pesticides. Indeed, pesticides have a large variety of physicochemical properties depend on their chemical classes or structures. GC and LC constitute the most analytical approaches used in residue control, isolating and purification of chemicals especially in complex mixture (Paz et al., 2015). The principle difference between these two techniques is the mobile phase, which is a gas in GC (He) and liquid (Organic solvents) in LC. GC and HPLC have been effective in separating volatile and non-volatile compounds like OCPs and OPPs (Hurtado-Sánchez et al., 2013). However, LC allows the rapid and efficient determination of many compounds that have been rarely explored or determined with difficulties by using GC or other procedures (Pérez-Ruiz et al., 2005) such as amitraz, coumaphos, and carbendazim.

GC was firstly introduced in 1959 by James and Martin (James et al., 1952) and it is characterized by its efficient chromatographic separation, sensitivity, selectivity, and quantification appropriate to wide range polarities of pesticides. The mobile phase is usually an inert gas such as helium. The stationary phase is a granular solid or a granular solid coated with a thin film of nonvolatile liquid. Moreover, the separation of compounds with GC method depends on the choice of capillary columns, pre-column and the length and the temperature of the column under which the analysis is carried out. These conditions must be optimized for a particular analysis.

Several types of column can be used for organochlorine, organonitrogen and organophosphorus pesticides analysis. There are among them: capillary column fused-silica capillary column (30m, 0.32 mm; 0.25 μm film thickness) (de Souza Pinheiro et al., 2011; Hu et al., 2012; Salem et al., 2014); DB column such as DB-1column (coated with 5% diphenyl and 95% dimethyl polysiloxane) (Salem et al., 2014); DB-1701 column (with 15m of length, 0.32 mm ID and 0.25 μm film thickness) (Carpenter et al., 2014); DB-5 column (Xia et al., 2012; Yao et al., 2013); DB-608 column (El-Saeid and Al-Dosari, 2010); Rtx-Dioxin II capillary column (length of 40 m, ID of 0.18 mm and 0.18 μm film thickness) (Botaro et al., 2011) ; BPX-Dioxin-I column (i.d. 0.15 mm×30m) (Kanazawa et al., 2012); RH-12ms column (column (i.d. 0.25mm×30m); HP-5 capillary column (0.32 mm id, 0.25 μm film thickness and 35 m length) (Mishra & Sharma, 2011); Agilent HP-5MS fused silica capillary column (60 m×0.25 mm×0.25 μm) (Lu et al., 2012); VF-5-Ms Factor-four Varian column (30m×0.25mm, 0.25 µm) (Cortada et al., 2009); CP-Sil 8 CB capillary column (50 m, 0.25 mm, 0.25 µm) (Syed et al., 2013).

In most studies, the gas chromatography oven was programmed starting with an initial temperature between 50-80 °C, the temperature continues to increase with time to reach elevated values of 280 °C-300 °C.

While LC of HPLC can be carried out either in a column or on a sheet with a liquid mobile phase and solid support as the stationary phase. The mobile phase travels down the stationary phase bringing along the components of the sample separated during chromatography. In LC, the interaction between sample molecules and the chromatography medium may be based on several factors such as size, charge, affinity binding, or hydrophobicity.

For the quantification objective GC or LC should be equipped with a detector which the most currently and sensitive is mass spectrometry detector (MS). With the MS detector, the pesticides can be identified based on their ion characteristics (m/z). Furthermore, GC-MS is a powerful tool to separate, identify and quantify volatile organic compounds including the pesticides in the most types of complex matrices (Rodrigues et al., 2011). A second phase of mass fragmentation can be added to the second MS detector namely tandem mass spectrometry (MS/MS) which leads to quantify low levels of concentration even in a high sample matrix background. GC combined with electron capture detector (GC-ECD) is reported to be appropriate for some pesticides and high sensitive was obtained with the pesticides containing electronegative functional group (Zhao.X et al., 2016). Other detectors are sometime reported effective for pesticides. The table 10 illustrates extraction methods used for the analysis of pesticides in different samples.

Table 10 Examples of different extraction method used for pesticides analysis.

Extraction techniques	**Method**	**Studied molecules**	**Samples**	***References***
LLE	GC/ECD	15 OCPs	Water samples	(1)
	GC-ECD	9 OCPs (isomers of HCHs and DDTs)	Ground water	(2)
	GC/ECD	14 OCPs	River water	(3)
	GC/ECD	3OPPs ; 10OCPs	Groundwater	(4)
SPE	GC/MS	OPPs	Underground water	(5)
	GC/ECD	20 OCPs	Fish	(6)
	GC/MS/MS	80 pesticides	Water samples	(7)
	GC/ECD/MS	82 pesticides	River water	(8)
SPME	GC/ECD	OCPs	Groundwater	(9)
	GC/ECD	19 OCPs	Groundwater	(10)
	GC/MS	10 OPPs	Cow milk	(11)
	GC/MS	OPPs	Wine and fruit juice	(12)
SDME	GC/MS	4 OPPs and pyrethroid pesticides	Water	(13)
	GC/ FPD	OPPs	Water samples	(14)
	GC/MS	OPPs	Water	(15)
	GC/FPD	7OPPs	Juice	(16)
	GC/FPD	OPPs and pyrethroid pesticides	Water samples	(17)
DD-LME	GC/FPD	6 organosulfur pesticides (OSPs)	Lake water, wells water and green tea beverage	(18)
	GC/FID	OPPs (Diazinon, Malathion)	Water samples	(19)
	GC/MS	4 triazine herbicides	water samples	(20)
LPME	HPLC	2 OPPs	water samples	(21)
	GC/FPD	8 OPPs	Water samples	(22)
	GC/MS	5 Carbamate pesticides	Water samples	(23)
HF-LPME	GC/FPD	6 organosulfur pesticides (OSPs)	lake water, wells water and green tea beverage	(19)
	GC/MS	14 OPPs and OCPs	Wells water	(24)
	GC/MS	4 OPPs	Aqueous samples	(25)
SFE	GC/NPD/ ECD	14 pesticides, six groups (pyrethroid insecticides, herbicides, fungicides, acaricides, OPPs,OCPs)	Dates samples	(26)
	GC/FPD	organophosphorus pesticide	leafy vegetables	(27)
	GC/EC & GC/MS	OPPs, ONPs, organohalogen,pyretroids	fruit and vegetables	(28)
ASE	GC/MS	109 (OCPs ; OPPs ; triazines, ONPs…)	Foods of animal origin	(29)
	GC/MS/MS	22 OCPs , 23 OPPs	muscle of chicken, pork, lamb	(30)
	GC/MS	24 ONPs	particulate and sedimentary phases from river	(31)

(1) Fatoki & Awofolu, 2003; (2) Hu et al., 2011; (3) Kuranchie-Mensah et al., 2012; (4) Sankaramakrishnan et al., 2005; (5) Ma et al., 2009; (6) Barriada-Pereira et al., 2010; (7) Ruiz-Gil et al., 2008; (8) Zheng et al., 2016; (9) Tomkins & Ilgner, 2002; (10) Júnior & Re-Poppi et al., 2007; (11) Rodrigues et al., 2011; (12) Zambonin et al., 2004; (13) Pinheiro et al., 2011; (14) Ahmadi et al., 2006; (15) Lambropoulou et al., 2004; (16) Zhao et al., 2006; (17) de Souza Pinheiri & de Andrade, 2009; (18) Xiong & Hu, 2008. (19) Hassan & Sarkouhi, 2013; (20) Nagaraju & Huang, 2007; (21) Zhou et al., 2008; (22) Khalili-Zanjani et al., 2008; (23) Zhang & Lee, 2006; (24) Hou et al., 2003; (25) Chen & Huang, 2006; (26) El-Saeid & Al-Dosari, 2010; (27) Jicheng et al., 2011; (28) Rissato et al., 2005; (29) Wu et al., 2011; (30) Frenich et al., 2006; (31) Net et al., 2015

V. Toxicity of pesticides

V.1. Exposure to pesticides and their toxicity to human health

Pesticides present in the environment can accumulate in human body and affect human health. As shown in figure 13, the human uptake pesticides through multiple pathways and routes such as of ingestion, inhalation, or dermal exposure (EFSA, 2008). It is important to differentiate between the human exposure occurring directly from occupational sources such as (i) storing working equipment in the house, contamination of clothes (Andreotti et al., 2015; González-Alzaga et al., 2014), (ii) agricultural and household use, and (iii) indirectly through the diet (Clementi et al., 2008; Tankiewicz et al., 2010). Pesticides can be swallowed and entered into the digestive track, where they can be absorbed directly or transformed and then absorbed into the blood stream. The accumulation of pesticides can take place through the food chain and drinking water (Luo & Zhang, 2009) especially when the ground water aquifers constitute the main drinking water resources for rural areas and adjacent urban areas (Tuxen et al., 2000). For some case, more than 90% of contamination come from the ingestion of contaminated food (Li et al., 2008).

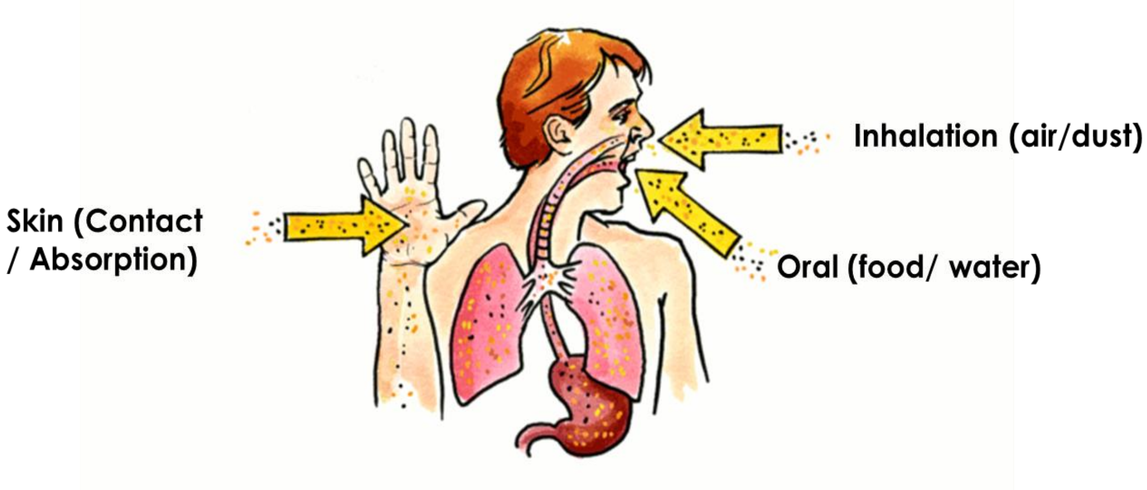


Figure 13 The primary routes of pesticide exposure: ingestion, inhalation, and physical contact through skin.

Furthermore, breathing can be an important source of blood contamination. Indeed, breathing the ambient air contaminated by the pesticides leads to the contamination of lungs and then the pesticides can absorb into the blood stream. Pesticides can be inhaled directly in large amounts when the pesticides are being handled or applied by either the applicator or people in the direct vicinity. In agricultural areas, the outdoor and indoor air can be polluted by pesticides and inhabitants can be exposed to these volatile ingredients (Sanborn et al., 2002). Human can be also exposed to pesticides via their deposition on food or on other surface areas. People residing near pesticide treated areas or in agricultural regions can be also exposed to such compounds (Naksen et al., 2016). Moreover, the dermal exposure by the direct skin contact during pesticides application can be a very serious exposure route for pesticides especially for agricultural workers when they are handling open containers.

Two types of toxicity are identified, acute and chronic toxicity. If humans are exposed to a large amount of active ingredient for a single time, it results a poisoning, which can be evaluated by the DL50 of the toxicant. While, the chronic toxicity is determinate by a long term exposure to low doses of these chemicals. All pesticides are toxic. Their toxicity and their corresponding harmful environmental effects are increasingly evident with their large scale use (Loubières et al., 1999). Type and severity of adverse health effects of pesticides are determined by the individual chemical category (in other ways the active ingredient in pesticide which control the pest) and its toxicity, the way, the dose, the duration of exposure and the exposure route (Hernández et al., 2013). An interaction between different types of pesticides has been possible and contributes to multiple responses for the reason that exposure to pesticides may induce birth defects, immune system dysfunction and increase the appearance of chronic disease including cancer (Alavanja, Hoppin & Kamel, 2004; Alavanja , Ross & Bonner, 2013), neurodegenerative diseases, reproductive problems (reduce male fertility) and developmental toxicity, and respiratory effects (Lee et al., 2016; Shirangi et al., 2011; Crinnion, 2000; Smith-Warner et al., 2001). Vulnerable population such as Children, pregnant women, the elderly, the immune-compromised and malnourished are more sensitive to pesticides effects than others. In addition, farmers, farmworkers, pest control operators are exposed to a high risk (Damalas, & Koutroubas, 2016; Payán et al., 2010). Table 11 listed some research results focusing on the relationship between exposure to pesticides and effects on humans.

V.1.1. Pesticides and neurological system

Many pesticides, which are targeting nervous systems, are also neurotoxic to humans. These chemicals can attack the human brain by inhibiting the secretion of acetylcholinesterase (ACHE) (USEPA, 2006). The acute poisoning by pesticides especially by OPPs develop psychiatric problems especially depression. While neurological, and neurobehavioral, syndromes, cognitive impairment and dementia at a long term (Parrón et al., 2011). Alzheimer and Parkinson are the common neuro degenerative disease developed in humans exposed to pesticides (Baltazar et al., 2014). Prenatal and postnatal exposure to pesticides induced impaired mental and psychomotor development, and abnormal reflex and lower motor skills (González-Alzaga et al., 2014; Naksen et al., 2015; Muñoz-Quezada et al., 2013) during early childhood.

V.1.2. Pesticides and Cancer

Pesticides can affect the genetic material and damage the structural function of the chromosomes, DNA and proteins contributing to cell homeostasis (George & Shukla, 2011). The discussion on the Geno toxicity of pesticides has been reported by Bolognesi (2003). The carcinogenic properties of pesticides have been studied and established by the International Agency for Research on Cancer or IARC (IARC, 2008). Several factors such as age, sex, individual susceptibility, and exposure to other chemicals may influence the appearance of cancer. Breast cancer, prostate, lung, may be associated with pesticides. The cancer risk in people exposed to pesticides has been examined by several studies (Table 11).

V.1.3. Pesticides and other chronic diseases

Numerous epidemiological studies have confirmed that a long-term exposure to pesticides increased the risk of respiratory diseases including Coronary artery disease and Ashtma in adults and children (Salameh et al., 2003; Abdullah et al., 2011; Hernández et al., 2011), and the risk of chronic obstructive pulmonary disease or COPD in farmers (Arifkhanova et al., 2006; Ubaĭdullaeva, 2006; Chakraborty et al., 2009; Hoppin et al., 2007). Furthermore, pesticides particularly OCs and metabolites can produce a higher risk of developing Cardio-vascular diseases such as Hypertension Atherosclerosis, Diabetes Type 1, 2 (Sylvie- Azandjeme et al., 2013; Lee et al., 2010; Montgomery et al., 2008; Saldana et al., 2007) and changes in thyroid hormone.

Table 11 Pesticides effects on human health

Diseases	**Reference Studies**
Reproductive problems	
Birth defects	Ren et al., 201 ; Chevrier et al., 2011 ; Nassar et al, 2010
Reduction in male fertility	Kamijima et al., 2004; Perry et al., 2007; Jager et al., 2006; Petrelli & Figa-Talamanca, 2001; Sheiner et al., 2003
Reduction in female fertility	Ouyang et al., 2005; Fuortes et al., 1997; Arbuckle et al., 2001; Cordier, 2008
Cancer	
Leukemia	Purdue et al., 2007; Beane Freeman et al., 2005; Wigle et al., 2009; Turner et al., 2011
Breast cancer	Ventura et al., 2015; Beane Freeman et al., 2005; Brody et al., 2004
Rectum cancer	Hou et al., 2006; Weichenthal et al., 2010; Purdue et al., 2007
Pancreatic cancer	Andreotti et al., 2009
Colon cancer	Lee et al., 2007; van Bemmel et al., 2008; Purdue et al., 2007
Lung cancer	lavanja et al., 2004; Beane Freeman et al., 2005 ; Lee et al., 2004a,b
Prostate cancer	Band et al., 201 ; Multigner et al., 2010; Settimi et al., 2003
Brain cancer	Lee et al., 2004b; Van Wijngaarden et al., 2003; Shim et al., 2009
Non-Hodgkin's	Purdue et al., 2007; Spinelli et al., 2007; Eriksson et al., 2008
Neurologic dysfunction	
Depression	Stallones and Beseler, 2002; Wesseling et al., 2010; Ross et al., 2010
Neuro degenerative disorders	Starks et al., 2012 ; Baltazar et al., 2014 ; Van Maele-Fabry et al., 2012.
Parkinson	Manthripragada et al., 2010; Gatto et al., 2009; Tanner et al., 2011
Alzheimer	Parrón et al., 2011; Androutsopoulos et al., 2011; Hayden et al., 2010
Respiratory defects (Asthma)	Henneberger et al., 2014
Other chronic disease	
Diabetes type 1,2	Jaacks & Staimez, 2015; Sylvie Azandjeme et al., 2013; Lee et al., 2010;
thyroidal disorders	Blanco-Muñoz et al., 2016; Eskenazi et al., 2007; Aguilar-Garduño et al., 2013

VI. Heavy metals (or ETM)

VI.1. Generalities

Heavy metals (HM) are natural metallic elements, metals or metalloids characterized with relatively high densities (>5 g/cm^3) and high atomic numbers (Z >11) (Miquel, 2001). In general, oligo-elements or trace metals such as calcium (Ca), Copper (Cu), potassium (K), sodium (Na), manganese (Mn), and iron (Fe) are considered as essential nutrient for the body function of living beings in trace and large amounts. Others such as cadmium (Cd) and mercury (Hg) are toxic at high concentrations (Burges et al., 2015; Guney et al., 2010) and can affect the function of nervous, reproductive system. Table 12 shows the source and toxicity of eight heavy metals (Pb, Hg, Ni, As, Cd, Cr, Zn and Cu). According to the USEPA, cadmium (Cd), lead (Pb), Nickel (Ni), Mercury (Hg), chromium (Cr), Arsenic (As), Zinc (Zn) are classified as priority control pollutants (USEPA, 2014b).

HM can come naturally from geological parent material by lithogenic and pedogenic processes "pedogenesis" (Kabata-Pendias, 2011; Liu et al., 2015). Or from anthropogenic inputs such as metalliferous industries, mining, vehicle exhaust, agricultural practices (use of fertilizers and pesticides), petroleum contamination, wastewater treatment plants, paints and coal combustion (Alloway, 2013; Zhang, 2006; Rivera et al., 2015; Wang et al., 2012). HMs are characterized by their high stability in the environment (no degradation (Mmolawa et al., 2011) and their persistence (Zhong et al., 2014). They are present in the atmosphere, water, aquatic system, plants; soil and in the sediments. The concentration of these HMs were found the highest in the soil and sediments compared to the other environmental matrices. Consequently, soil and sediments are considered as their ultimate storage source (Santos et al., 2005). The behavior and their existed form of HM in the environmental matrices depends on the soil type, the characteristics and the nature of the individual heavy metal (Kabata-Pendias, 2011). Weather conditions including the amount of precipitation (Słowik et al., 2008) and their transport by wind (Gu et al., 2016) can also influence on the behavior of HMs.

The accumulation of HMs in Human body can take place through 3 primary routes namely the ingestion inhalation, and the skin absorption (Lee et al., 2006). The toxicity of some HMs are summarized in the table 12. Numerous studies have focused on environmental pollution by heavy metals (Chabukdhara and Nema, 2013; Li et al., 2014; Zhao et al., 2012; Zheng et al., 2010; Idaszkin et al., 2017) and the potential risk assessment for inhabitants in vulnerable regions such as mining areas (Sipter et al., 2008; Zheng et al., 2007; Zhuag et al., 2009).

VI.2. Toxicity of heavy metals

Table 12 Source and toxicity of eight heavy metals (Pb, Hg, Ni, As, Cd, Cr, Zn and Cu)

Heavy metals	*Use and Source of exposure*	*Toxicity*
Lead (Pb)	Gasoline, industrial processes, lead containing pipes or lead-based solder in water supply systems, coal combustion, battery recycling, grids and bearings, lead-based paints (Flora et al., 2012).	For a concentration 100-120 µg/dL. The acute toxicity was manifested by muscle and abdominal pain, headache, vomiting and coma. Renal acute nephropathy At long term for lead levels in blood between 40-60 µg/dL affects : - The nervous system causing many symptoms including the Encephalopathy, dullness, irritability, poor attention span, headache, muscular tremor, loss of memory. And paralysis, coma and ataxia at high levels (Flora et al., 2006). - Lead cause renal breakdown, hypertension, hyperuricemia (Rastogi, 2008) and cerebrovascular accidents and peripheral vascular disease (Navas-Acien et al., 2007). - Reproductive effects such as reducing the number and the motility of sperm, causing infertility, abnormal prostatic function and changing in serum testosterone, miscarriage, premature membrane rupture (Flora et al., 2012).
Mercury (Hg)	Volcanic eruptions, erosion and leaching from the earth's crust, earthquakes.	Poisoning by Hg cause dyspnoea, paroxysmal cough, chest pain, nausea and vomiting. Chronic intoxication (urinary levels > 4300 mg Hg/L) produces erethis, stomatitis with salivation. - In children, it causes tremor, decreased in memory and motor function, social withdrawal, irritability, perspiration, rash and paraesthesia, deficit in language (Magos & Clarkson, 2006). - Hg induces nervous disorders in adults. The symptoms are manifested by loss of memory, deficit in attention, hypoesthesia, ataxia, dysarthrea, Alzheimer and Parkinson. - Hg alters normal cardiovascular homoeostasis

		- Hg decreases the immune system of the human body and the fertility in both males and females (Zahir et al., 2005).
Nickel (Ni)	Natural (earth's crust, weathering and volcanoes). Ni is used in modern industry and commercial applications such as electroplating, electroforming, mining, milling. and metallurgical processes, from the production of batteries, catalysts, ceramics, pigments and electronics, jewellery and medical prostheses (Denkhaus & Salnikow, 2002; Schaumlöffel, 2012) and from the combustion of fossil fuels.	Ni causes: - Skin allergies, lung fibrosis, variable degrees of kidney and cardiovascular system poisoning and stimulation of neoplastic transformation - Cellular homeostasis via change, DNA damages of intracellular (Denkhaus & Salnikow, 2002). - Lung and nasal cancer at concentration higher than 10 mg/dL (Schaumlöffel, 2012).
Arsenic (As)	Arsenic naturally occurs in the Earth's crust, As Came from leaching, erosion, and mining	- Arsenic poisoning includes burning and dryness of the mouth and throat, dysphasia, colicky abnormal pain, projectile vomiting, profuse diarrhea, hematuria, muscular cramps , cardiac abnormalities and dehydration (Schlottmann & Breit, 1992) - - Arsenicosis (Romero-Schmidt et al., 2001), developmental effects, cardiovascular disease, skin and lung cancer are associated with long-term exposure to arsenic in humans (Wang et al., 2006).
Cadmium (Cd)	Volcanic activity. Cd can be found in PVC products, nuclear power plants, and in nickel-cadmium batteries.	Cd damages: - Respiratory system by causing pneumonitis, and destructing of the mucous membranes. - Kidney by causing proteinuria, kidney stones, glomerular and tubular damages - Reproductive system by causing testicular necrosis, estrogen-like effects, and affection of steroid-hormon synthesis

		- Skeletal System such as the loss of bone density and Itai-Itai disease (Godt et al., 2006)
Chromium (Cr)	Natural sources (Earth's crust, erosion of chromium-containing rocks, and volcanic eruptions) Cr and its products are used to harden steel, to manufacture stainless steel and to produce several alloys and to produce chromium plate plastics. They are also used as industrial catalysts and pigments.	Cr increases: - The incidence of liver and kidney problems - The incidence of lung cancer (Goldhaber, 2003).
Zinc	Zn is present in the second metal before the Fe in the human body	Zn deficiency: - Affect the immune system, wound healing, the senses of taste and smell, and impairing DNA synthesis. - Is associated with malnutrition Acute and chronic exposure to Zn altered Fe function, reduced immune function, and reduced levels of HDL (Hamilton et al., 2000)
Copper (Cu)	Cu is used to make coins, along with silver and gold. It is used in electrical equipment such as wiring and motors and Copper sulfate is considered as an agricultural poison (algicide)	The ingestion of 200 mg/kg-day of Cu cause human deaths The acute toxicity of Cu cause: - Gastro- intestinal effects characterized by abdominal pain, cramps, nausea, diarrhea, and vomiting (Fraga, 2005) - Liver damages (Goldhaber, 2003) Chronic Cu toxicity is rare. It is frequently identified liver damage. Cu deficiency leads to normocytic, hypochromic anemia, leucopenia and neuropenia, and inclusive osteoporosis in children (Kanumakala et al., 2002). Excessive dietary Zn can cause Cu deficiency.

VII. Agricultural sector in Lebanon

Lebanon situated on the eastern shores of the Mediterranean, covers a total area of 10 452 km^2. It has a complex geomorphology with a narrow coastal strip bordered by steep hills and mountains and is characterized by the abrupt change in elevation within a distance of less than 20 km between sea level and 1 750 m above mean sea level and by the presence of two mountain chains (Asmar, 2011).

The climate is overall moderate and allows the cultivation of a wide variety of crops that would normally grow in both cold and tropical countries. Lebanon's location, topography, and natural endowments, moderate climate, rich soil, and water resources provide enabled the existence of a diversified agriculture sector; from quasi-tropical products on coastal plains to orchards in high-altitude mountains, with a full range of possible intermediary crops in between. The country is endowed with the highest proportion of agricultural land in the Middle East, and is considered as the main export market for agricultural products remains the Middle East (Saudi Arabia, Egypt, Kuwait, UAE and Jordan) accounting for 93.9% of total exports in 2015. Vegetables exports accounted for 42.4% of agricultural export, fruits for 46.2% and cereals for 11.3% (Invest in Lebanon, 2016). Lebanon is also rich with major rivers and water resources with a high storage capacity through hill lakes and dam (Invest in Lebanon, 2015; Haydamous & El Hajj, 2016; Ministry of Agriculture, 2016). The level of rainfall is abundant and ranges from less than 200 mm to more than 1,200 mm of rain per year (Traboulsi & Traboulsi, 2017)

Overall, the Agriculture sector including livestock count almost 4.7% of Lebanon's GDP. It employs roughly 10% of the Lebanese labor force, and is the 4th largest employer in the country (Haydamous & El Hajj, 2016). Based on FAO data, 65% of Lebanese territory is covered by agricultural areas. The major agricultural regions are used for crops, meadows and pastures cultivation mainly concentrated in the Bekaa and Northern Lebanon (42.1% and 27.2% respectively), and Southern Lebanon accounting for 12.6%, Nabatieh and Mount Lebanon count for 9% each (Ministry of Agriculture, 2013). As shown in figures 1 and 15, the mainly crops are vegetables (such as potatoes, tomatoes, and maize) which account for 48% of total production; fruits (mainly apples, citrus, grapes and bananas) which account for 26% of total agricultural and other products including animal products (such as dairy product, poultry meat, fish, eggs, and honey) olives, tobacco and cereals (mainly wheat and barley). Livestock production has also been picking up in recent years (Invest in Lebanon, 2015; Ministry of environment/UNDP, 2011) with a total production value estimated to 1.2 billion USD (table 13)

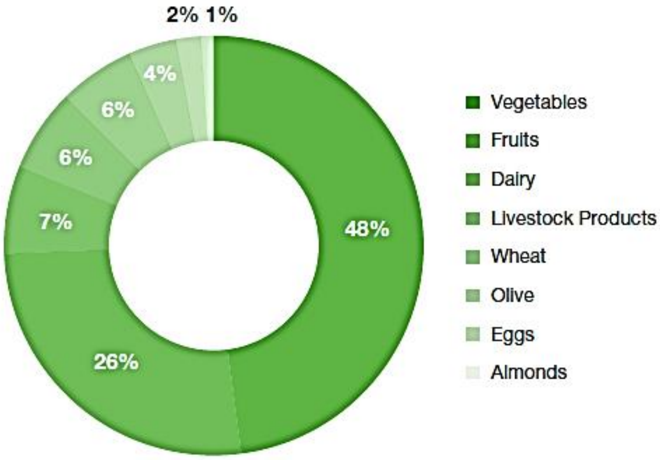


Figure 14 Agriculture Output by Sub Sector, 2012

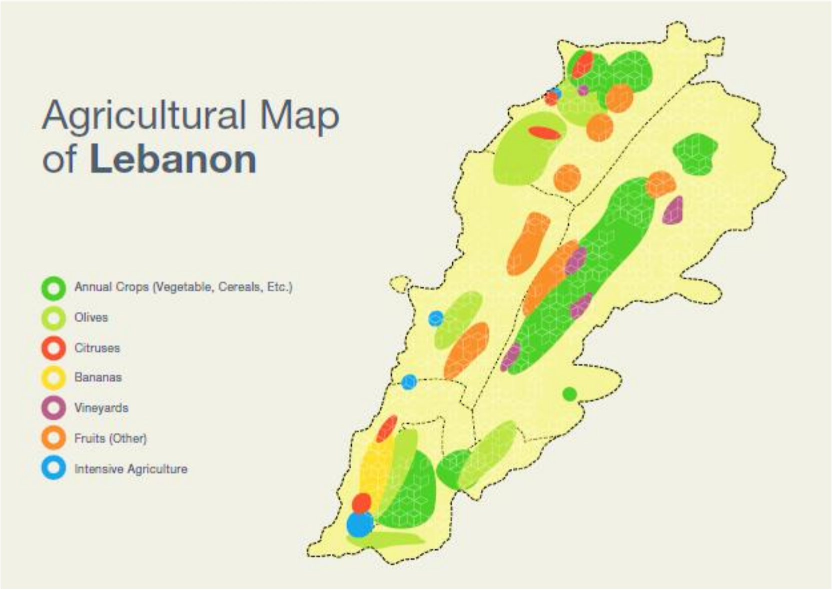


Figure 15 Agricultural map of Lebanon for the different crops (FAO, 2010)

Table 13 The total utilized area and the production for different crops in Lebanon in 2009

Crops	Area (ha)	Productions (Tones)
Wheat	50 000	153 000
Barley	16 000	34 000
Chick pea	2 000	1 500
Sorghum	645	3 600
Pulses	7 439	1 327
Vegetables	27 213	11 647
Fruit	73 885	851 138
Citrus fruits	17 091	961 297
Sugar beet	700	292 000
Vetches	3 014	37 000
Coarse grain	17 954	39 436
Olives	57 000	83 500

Agriculture is one of the most vulnerable economic sectors to climate change as it is directly affected by changes in temperature and rainfall. The hot and dry climate (MoE, 2011), the decreasing of soil moisture and the increasing of the aridity thus affecting the overall agricultural yield of crops by decreasing the productivity for most of the crops and fruit trees (MOE-Republic of Lebanon, 2017).

For these reasons, farmers use uncontrolled dose of pesticides to protect their crops and increase their productivity, which contribute to soil degradation and water resources contamination. Furthermore, farmers often irrigate with contaminated water, especially in the summer month to offset water shortages. The greatest risk lies in the applied pesticides and fertilizers that comprise nitrates. Agriculture will not then be the only victim of environmental pollution but also for animals and humans (Kayrou & Atala, 2015). Moreover, around 20 to 25% of the active population has some activity in agriculture on a full time or part time basis, including seasonal family labor. In the poorest regions of the country such as in Akkar, Dinnyeh, the Northern Bekaa and the South, agriculture-related activities account for up to 80% of the local GDP (FAO, 2017).

In addition, there is no control for the excessive use of pesticides. Furthermore, the lack of awareness in farmers amongst the toxicity of these chemicals, the extensive use of pesticides and the consumption of wells water as drinking water were the main reasons to choose Akkar as our study location. Akkar in one of the poorest agricultural areas in northern Lebanon (the valley of Akkar) which the pollution in this area has been the objective of several studies (El Osmani et al, 2014, Halwani et al., 1999). It covers 798 km^2 in the north of Lebanon, near the Syrian borders. It is the second most agricultural plain in the country after the Bekaa. Potatoes, wheat, fruit trees, and vegetables are the most dominant crops. This region is characterized by a high application of pesticides to protect agricultural products and to increase yields. The type of land and the characteristics of this zone (size, color and depth, soil conditions) are conducive to pesticide transport and make this aquifer extremely vulnerable to pollution and anthropogenic impacts. Furthermore, the ground water is used for drinking water due to the absence of a public network for water distribution.

Materials and Methods

1. **Introduction**

The use of pesticides for crop protection and improving agricultural production in the plain of Akkar was increased the last years, which became eventually a risk to humans because the pesticides induce certain negative effects. Above all, for environmental study, the first step was to identify and quantify the interest compounds. Our study is focused on three families of pesticides (OPPs, OCPs, ONPs) in wells water. Indeed, wells water of Akkar plane is the main water resources in this region and many diseases have been observed on the population inhabit on Akkar plane. Consequently, this work aimed firstly to identify the nature of pesticides in groundwater and their level of concentration in wells water. Then prevalence of different human diseases has been calculated after the analysis of the questionnaires. At the end, statistical tests have been used to establish the existing relation between wells water consumption and the prevalence of the diseases. All precautions in sampling, storage, transportation, water samples analysis, questionnaire creation, data collection and analysis of statistical data were taken into consideration for getting significant results with the minimum of contamination and errors.

This chapter is divided in two sections: an analytical study followed by an epidemiological study that was embedded in the residents of plain of Akkar (Fig 16). Firstly, the description of the materials and methods used for the detection and analysis of OCPs, OPPs and ONPs (sampling, extraction, purification and GC/MS analysis), location and characteristic of studied sites both wells water and soils samples were presented. In addition, the inorganic pollution (trace metals) in the agricultural soils of the Akkar plain has been also studied to complete the contamination background. Identification and quantification the level of pesticides in groundwater are the important step to evaluate the quality of the groundwater before the beginning of the survey.

The second section was established to get a screening view about the human chronic diseases in inhabitants of the studied area and to study the existed correlation between these diseases and the consumption of contaminated water. Creation of questionnaire, collection of the surveys and the analysis of the data are also described.

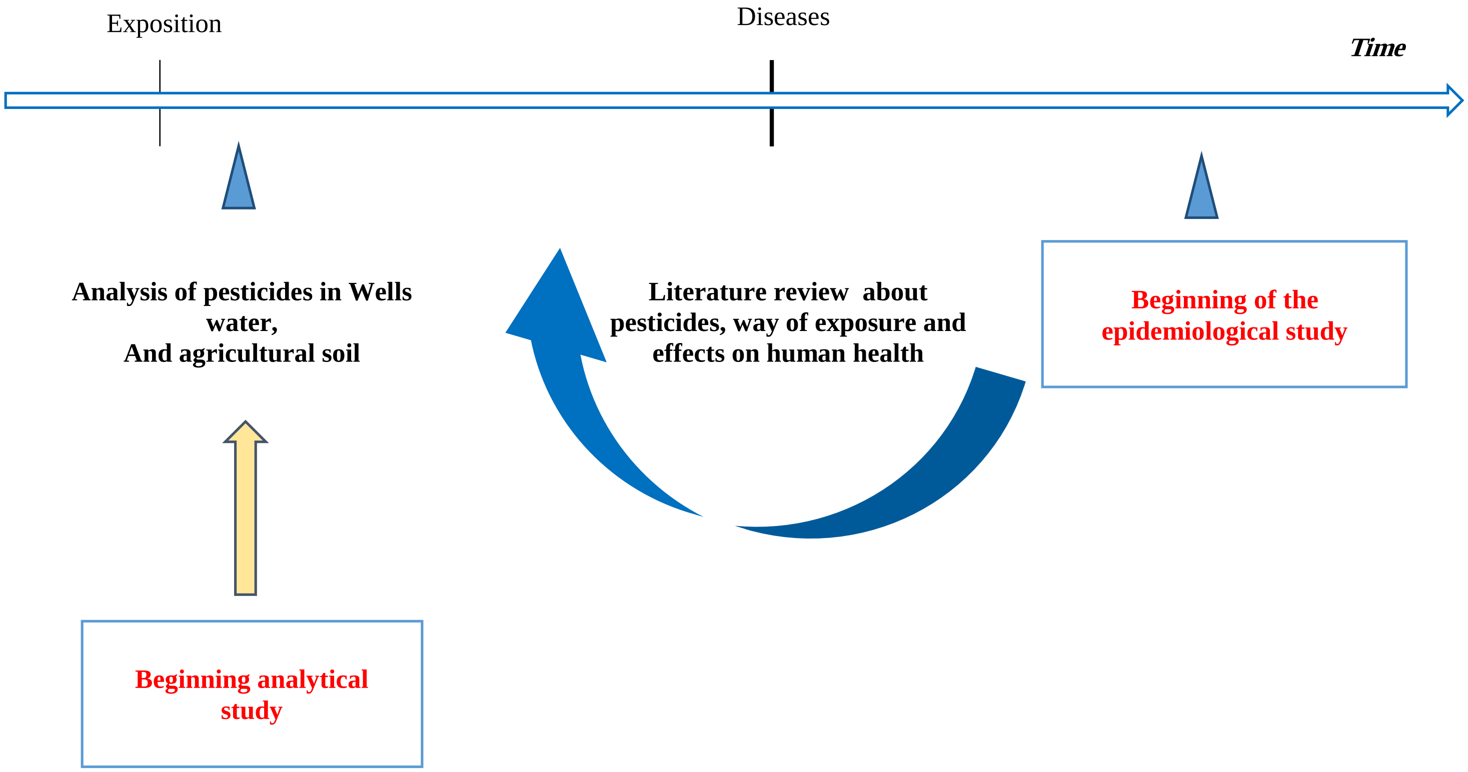


Figure 16 process of our study

Study area

Akkar is considered the most rural district of Lebanon (80,000 hectars of agricultural land), with a rural population of 80 percent. The cultivated area represented third of the total area of Akkar. Akkar is located in the North Governorate of Lebanon with the Mediterranean Sea on its western border, Hermel to the east, Syria to the north (with a 100 km of borders on common and two official crossing points: El Aarida and El Aboudiyeh) and the Bared River and the district of Minieh-Dinnieh to the south. It covered an area of 798 km^2 with a high density of population.The UNHCR estimated the population of the governorate at 389,899 in 2015, including 126,339 Syrian and Palestinian refugees The population is composed by a majority of Sunni Muslims followed by a large minority of Christians including Greek Orthodox, Maronites and Melkite. Furthermore, Alawite communities and very few Shiites (UNHCR, 2015).

A significant part of the local population is directly and/or indirectly involved in agricultural activities. Akkar governorate can be divided into 121 municipalities. Halba is the capital city of Akkar, and the largest cities are Halba, Biri Akkar and Al-Qoubaiyat (Localiban, 2017)

The governate is characterized by the presence of a relatively large coastal plain to the west, with high mountains to the east.

The geology of Akkar varied from the west to the east at the following order from quaternary colluvial deposits to fluvial deposits, volcanic rocks and non-clastic mesozoic sedimentary rocks (figure 17)

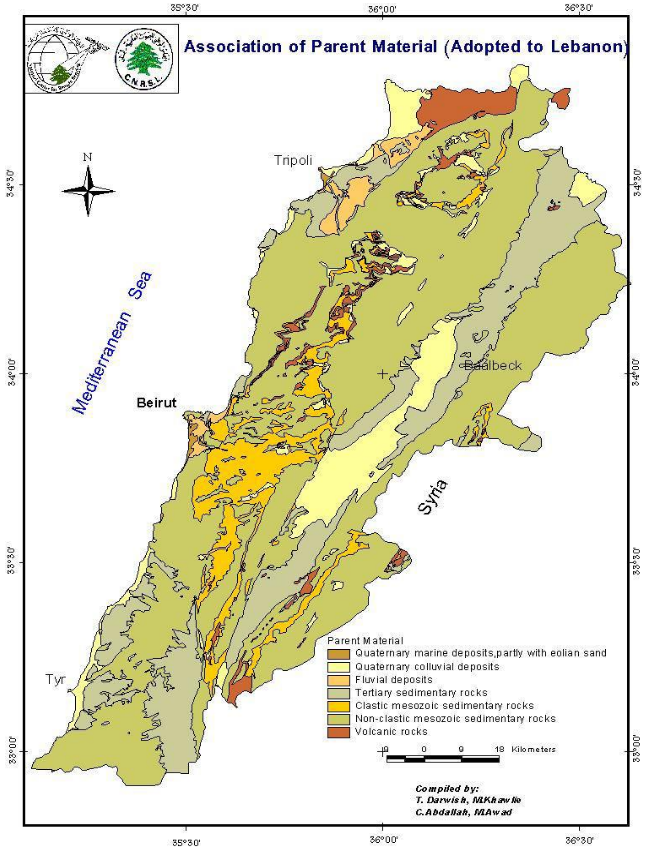


Figure 17 Geological map of Lebanon (Darwish et al., 2012)

Agriculture and employment, primarily in the army, are the main economic activity in Akkar. Therefore, the governorate can be divided into two agricultural regions: (i) the mountainous region, where olive trees and all kinds of fruit trees are cultivated, and (ii) the plain of Akkar where is concentrated the main crop production regions such as Tabaco, citrus trees, cereals, potatoes, grapes, vegetables and vegetables are grown. Our study was focused on fifteen villages located in the plain of Akkar. Base on size and agricultural production, Akkar is considered as the second agricultural zone of Lebanon after the Bekaa. Akkar is rich in water resources, having numerous springs and huge underground lakes, such as in Joumeh (Mouchref, 2008).

Akkar was considered as one of the poorest segment of the population in the country which has the lowest average individual income level and highest illiteracy rate in Lebanon. It suffers from a lack of services of all kinds, as well as the absence of governmental and nongovernmental organizations in most villages. Furthermore, due to the absence of a public network for water distribution in this region, groundwater is the main water sources of drinking water for the inhabitants. Previous studies (El-Osmani et al., 2014) reported that the organochlorine pesticides have been notably used both to protect agricultural products and to increase yields. In addition, their residues have been detected at high levels in groundwater of some villages in Akkar. However, only very few data are available in the literature concerning effects of environmental contamination by pesticides in this area on human health.

A. Analytical study

1. Materials and chemical reagents

All pesticides standard solutions used in this work were purchased from Sigma Aldrich with purity of ≥95% for all pesticides. Standard solutions were purchased as mixt solutions for each family: organochlorine pesticides (CLP Organochlorine Pesticides Mix 4S7426-U), chlorinated pesticides (Chlorinated pesticides 47557-U), organophosphorus pesticides (Organophosphorus pesticides 48469), and organonitrogen pesticides (Organonitrogen pesticides QC1400). The chemical formula and characteristics of each pesticide was detailed in table 14 and figures 18, 19. Working solutions were obtained by diluted standard solutions in Hexane and stored at -4 or -10 °C. All solvents were pesticide and GC grade. Ultra-pure water with 18.2 MΩ/cm resistivity was obtained using a Milli-Q system (Merck Millipore). pH was adjusted by using Hydrochloric acid HCl (37%) and potassium Hydroxide (KOH, 0.5 mol. L^{-1}) purchased from Sigma Aldrich . Filters used for the separation of suspended solid matters (SSM) from dissolved phase were Whatman GF/A circles filter (ø 110 mm, 0.7µm) and were purchased from Whatman (England). For trace metallic element, standard solution multi element (ASTASOL - Mix) has been used for the preparation of the series of standards for the calibration of the ICP- AES. Reference standards solid materials (HISS 1 and MESS3) were provided by the National Research Council of Canada for quality control for trace metallic element analysis.

Contamination from the glassware can be significant. Rigorous procedures are required to minimize sample contamination and to maintain a low background concentration. These procedures include prewashing the laboratory material and equipment. All laboratory glassware should be washed with an appropriate procedure. All glassware was soaking for 2-3 hours in detergent (Milli-Q/Decon®, East Sussex, UK), then washed with Ultra-pure water, and then transferred into another tray containing Milli-Q/HCl (30%) for 2-3 hours, and then washed with ultrapure water then keep drying at 80°C. Then, dried glassware was rinsed with acetone or dichloromethane and newly dried in the stove at 120ºC prior to use. Supel-Select Hydrophilic-lipophilic-balanced (HLB) SPE cartridges (200 mg/6 mL) were provided from Sigma-Aldrich (Saint-Louis, USA). ASE glass fiber filters were purchased from Whatman (England).

Before water sampling, bottles were washed once with potassium dichromate lotion, rinsing with ultra-pure water and drying in an oven at 80°C. Aluminum foil and stainless steel grab (scoop) used to hold pesticides were washed before using with methanol and dried in oven at 100°C while sterile plastic bucket has been used to collect soil samples for heavy metals analysis. For ASE cells, between each use, they were rinsed with tap water, ultrasonic with ultra-pure for 2 times and 2 minutes each time, and then ultrasonic with an Acetone/Methanol mixture for 2 times and during 2 minutes each time. Then, the cells were dried and rinsed in ASE related to the method of developed by Tronczynski et al. (2005). The ASE cleaning conditions were MeOH/DCM (v/v 1/1), 5 min preheat at 100°C, 100 bars of pressure, 5 minutes of extraction time, 1 cycle, 50% of flush volume and purge during 100 seconds.

Table 14 Detected pesticides with their classification group, function, retention time, LOD, and identified ions

Compounds	**Mw (g/mol)**	**Function**	**Chemical formula**	**RT (min)**	**Identified Ions (m/z)**
Organochlorine and chlorinated pesticides					
α-HCH	290.83	Insecticide	$C_6H_6Cl_6$	15.21	183-185, 217
β-HCH	290.83	Insecticide	$C_6H_6Cl_6$	16.23	181-185, 217
γ-HCH	290.83	Insecticide	$C_6H_6Cl_6$	16.57	181-185, 217
δ-HCH	290.83	Insecticide	$C_6H_6Cl_6$	17.83	181-185, 217
Heptachlor	373.32	Insecticide	$C_{10}H_5Cl_7$	19.84	274-276, 100
Aldrin	364.9	Insecticide	$C_{12}H_8Cl_6$	21.62	65, 67

Heptachlor Epoxide	389.32	Insecticide	$C_{10}H_5Cl_7O$	23.65	81, 263
Endosulfan I	406.93	Insecticide, Acaricide	$C_9H_9Cl_6O_3S$	25.14	274-276
4,4' DDE	318.02	Insecticide	$C1_4H_8Cl_4$	26.95	213, 243-248
Dieldrin	380.91	Insecticide	$C_{12}H_8Cl_6O$	27.11	77- 78
2,4' DDD	320.04	Insecticide	$C_{14}H_{10}Cl_4$	27.29	235-237
Endrin	380.91	Insecticide	$C_{12}H_8Cl_6O$	28.25	281-282
Endosulfan II	406.93	Insecticide, Acaricide	$C_9H_9Cl_6O_3S$	28.88	204-205, 242
2,4' DDT	354.48	Insecticide	$C_{14}H_9Cl_5$	29.34	237-239
4,4' DDT	354.48	Insecticide	$C1_5H_9Cl_5$	29.41	237-239
Endrin aldehyde	380.91	Insecticide	$C_{12}H_8Cl_6O$	29.75	335, 337
Endosulfan sulfate	422.92	Insecticide	$C_9H_6Cl_6O_4S$	31.15	376, 377
4,4' DDD	320.04	Insecticide	$C_{14}H_{10}Cl_4$	31.56	235-237
Endrin ketone	380.91	Insecticide	$C_{12}H_8Cl_6O$	34.39	246-247
Metoxychlor	365.65	Insecticide	$C_{16}H_{15}Cl_3O_2$	35.99	191-193, 225
Organophosphorus pesticides					
O,O,O-Triethylphos phorothioate	198.22	Insecticide	C6H15O3PS	6.8	121, 198
Thionazin	248.24	Nematicide	$C_8H_{13}N_2O_3PS$	13.22	106-107, 143
Sulfotep	322.32	Insecticide	C8H20O5P2S2	14.54	146, 210
Phorate	260.36	Insecticide, Acaricide	$C_7H_{17}O_2PS_3$	14.98	249, 251-253
Dimethoate	229.26	Insecticide, Acaricide	$C_5H_{12}NO_3PS_2$	15.65	86, 87
Disulfoton	274.4	Insecticide	$C_8H_{19}O_2PS_3$	17.48	88, 89
Methylparathion	263.21	Insecticide	$C_8H_{10}NO_5PS$	19.44	263-265, 125

Parathion	291.26	Insecticide	$C_{10}H_{14}NO_5PS$	19.45	109, 97, 235
Famphur	325.34	Insecticide	$C_{10}H_{16}NO_5PS_2$	30.6	218-219
Organonitrogen Pesticides					
Molinate	187.3	Herbicide	$C_9H_{17}NOS$	12.34	98, 126
Atrazine	215.68	Herbicide	$C_8H_{14}ClN_5$	16.22	122, 132
Acetochlor	269.767	Herbicide	$C_{14}H_{20}ClNO_2$	19.18	223-224
Alachlor	269.767	Herbicide	$C_{14}H_{20}ClNO_2$	19.59	188
Metolachlor	283.79	Herbicide	$C_{15}H_{22}ClNO_2$	21.48	162, 238
Butachlor	311.85	Herbicide	$C_{17}H_{26}ClNO_2$	25.56	160, 176, 238

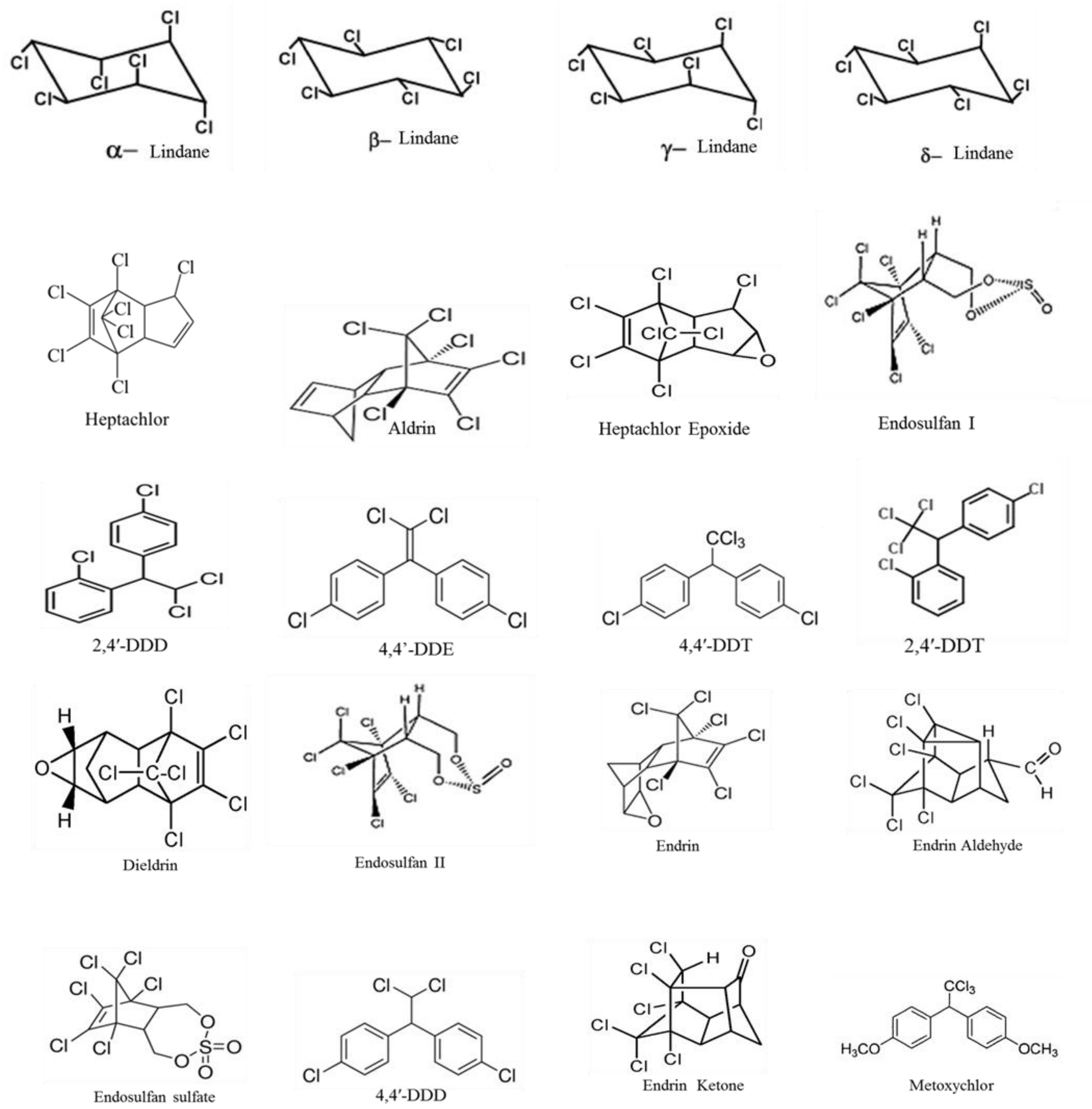
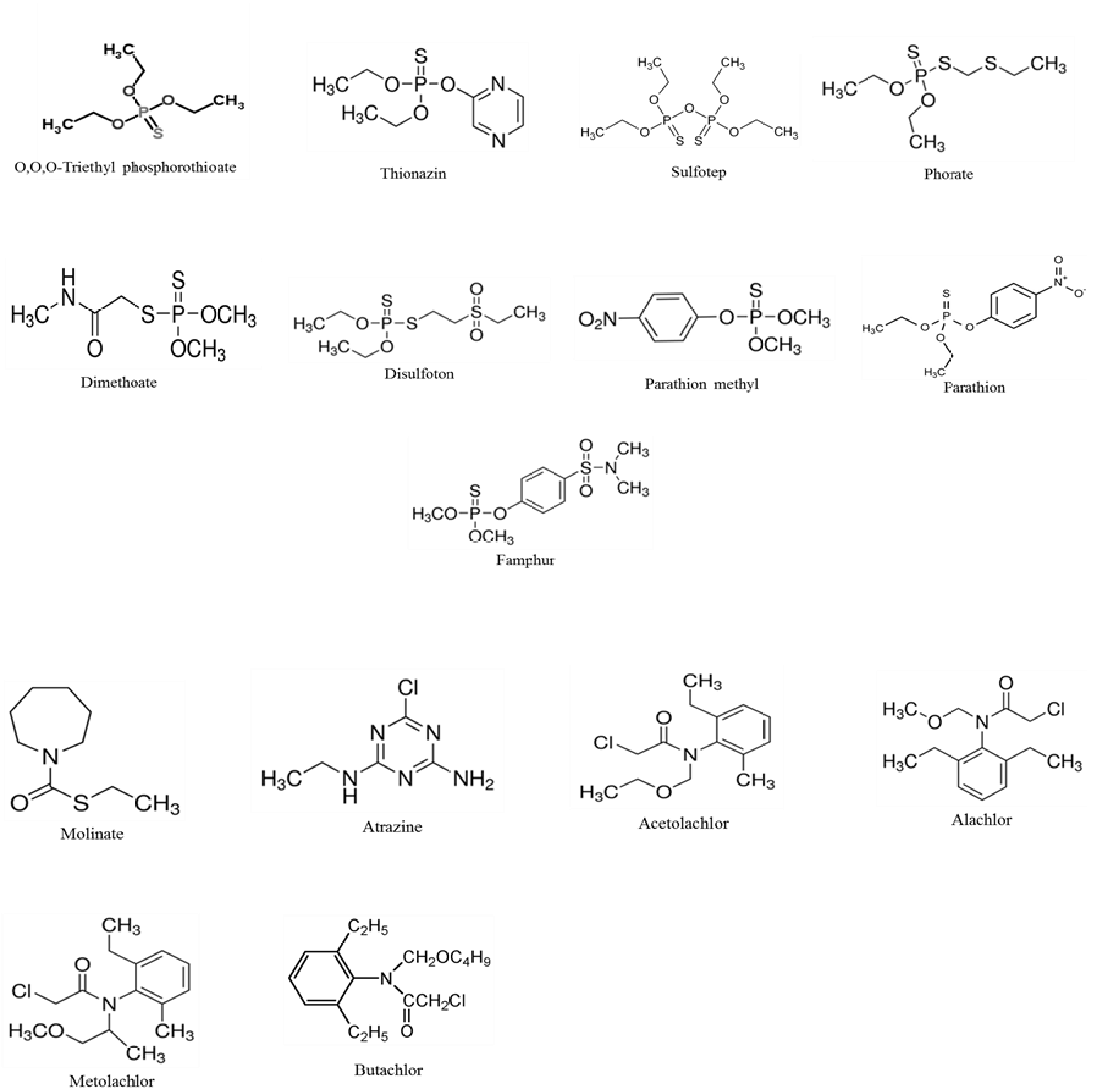


Figure 18 Structure of studied Organochlorine and chlorinated pesticides



O,O,O-Triethyl phosphorothioate

Thionazin

Sulfotep

Phorate

Dimethoate

Disulfoton

Parathion methyl

Parathion

Famphur

Molinate

Atrazine

Acetolachlor

Alachlor

Metolachlor

Butachlor

Figure 19 Structure of studied Organophosphorus and Organonitrogen pesticides

2. Sampling and preparation

The characteristics of organic pollutants such as pesticides demand usually special procedures for sampling and sample preparation to achieve an excellent analytical determination. Sensitivity in choosing sampling site, season of sampling and methods are very critical to have a representative sample in the studied zone. All precautions must be taken to avoid the contamination of the samples on the place of sampling and during transport to the laboratory for analysis.

a. Water sampling

In this study, ground waters have been collected after a rainfall season during May 2015 from 15 sites located in Akkar. Table 15 presents the names, characteristics and localization of the 15 sampling sites. Sampling was performed, in duplicate, in individual famers' closed wells using pre-cleaned 1.5 L amber glass bottles. Ground water was pumped 10 minutes before sampling using the drilling pump installed for each well. The bottles were rinsed three times with samples (wells waters) without passing air bubbles through the samples. Physico-chemical parameters of each site are presented in table 15. During the sample collection, a global positioning system (GPS) was used to locate the sampling sites. After sampling, the samples were transported to the LSEE laboratory (Laboratoire des Sciences de l'Eau et de l'Environnement) and extracted directly.

Table 15 water sampling site and their characteristics

N°	Site Names	DO (mg/L)	pH	Conductivity (µS/cm)	GPS Coordinates		Depth (m)
					Latitude	Longitude	
1	Koubet Al Choumra	3.72	6.81	669	34^0 32' 37''N	36^0 00' 06'' E	54
2	Mqaitaa	4.91	6.71	1264	34^0 33' 26''N	35^0 59' 39'' E	0
3	Qaabarine	5.32	7.15	232	34^0 34' 25''N	36^0 00' 54'' E	24
4	Qlaiaat	5.25	6.77	1221	34^0 35' 13''N	36^0 01' 03'' E	39
5	Tall Mehyen	5.82	6.83	1154	34^0 35' 27''N	36^0 02' 25'' E	58
6	Ballaneh Al Hissa	5.27	6.92	906	34^0 35' 51''N	36^0 02' 35'' E	59
7	Hissa	5.55	6.88	1245	34^0 35' 21''N	36^0 03' 22'' E	107
8	Masaoudieh	4.74	7.03	782	34^0 36' 00''N	36^0 03' 39'' E	78
9	Tal Andi	3.93	6.81	2505	34^0 36' 33''N	36^0 04' 24'' E	54
10	Al Chaykh Ayach	4.19	7.28	783	34^0 37' 28''N	36^0 05' 18'' E	140
11	Tal Biri	n.d	7.22	868	34^0 35' 04''N	36^0 03' 54'' E	188
12	Tal Abbas El Gharbi	n.d	7.43	660	34^0 34'27''N	36^0 04' 38'' E	181
13	Kouikhat	n.d	7.45	586	34^0 34' 27''N	36^0 05' 22'' E	260
14	Tal Abbas El Charqi	n.d	7.48	716	34^0 35' 18'' N	36^0 04' 41'' E	257
15	Al Mahmra	n.d	7.37	849	34^0 30 '29'' N	35^0 57' 58'' E	70

b. *Soil sampling*

To represent a general background historic soil pollution by pesticides along the plain of Akkar, agricultural soil has been collected on 21 November 2015 from 6 villages which had different degree of groundwater pesticide's contamination (Kobbet Choumra, Tal Mehyen, Mqaitaa, Mhamra, Qlaiaat and Qaabarine).

For each area, as shown in the figures 20a and 20b, we took at least 5 samples (depth: surface or 0 cm; 25 cm; 50 cm; 75cm; 1m). Each sample was represented only one soil type or area for example, a lawn, and vegetable garden or perennially landscaped area in order to simplify the interpretation of our results. Information on the location were summarized in the table 16. Soils samples have been performed using a spade or a shovel in stainless steel by digging a V-shaped hole from different depth.

Figure 20 Soil sampling method (a) and different depth of studied area (b)

For pesticides analysis, three to five slices of soil have been collected at each depth station, followed by thorough mixing on an aluminum tray in order to obtain a more representative soil sample. All samples were then transferred into stainless steel and plastic grab for pesticides and heavy metals analysis respectively, and kept it in a portable freezer during transportation to France. Collected samples were freeze- dried, sieved at 224 μm and stored at -10°C until analyses. While for heavy metals analysis, it was necessary to avoid contact between the samples and the metallic materials. Soils were collected in sterile Petri dish, packed into poly- ethylene bags, brought back to the lab and freeze during transportation to France. The soil samples were then air-dried, ground, sieved, and then dried and sieved at 63 μm before using.

Table 16 Characteristics of studied lands

Name of villages	Characteristic of lands
Tal Mehyen	tillage land (in progress)
Qobbet Bchamra	Vegetable land (lettuce)
Qlaiaat	Non cultivated zone (tillage land)
Mhamra	Soil from Greenhouses
Qaabarine	Sandy soil
Mkayteh	Sandy soil (100 m near the sea)

3. Mineralogical analysis of the soil (RDX)

Analysis was established in « Laboratoire d'Océanologie et de Géosciences, UMR 8187 » at the university of Lille 1.

Briefly, Dried soil samples were micro-crushed until a cohesive powder is obtained, and then a pellet was made by pressure (Total fraction). Samples were then analyzed using one of a BRUKER D4 Endeavor diffractometer equipped with a copper anticathode coupled to a Lynxeye fast detector (with a voltage of 30 kV, an intensity of 35 mA). The angular scan extends from 1.49 to 32.5 °C.

Samples were disintegrated in distilled water. They have been then decarbonized by treatment with hydrochloric acid diluted to N / 5. The excess acid was removed by successive rinsing with distilled water until deflocculating of the material. The suspensions obtained were placed in pillboxes and he micro aggregates are removed using a micro-homogenizer. The fraction with particle size less than 2 µm has been extracted by withdrawing the upper part of the suspension (1.5 cm) after decantation for 1 h 15 min by means of a syringe. The fraction thus obtained was centrifuged at 3500 rpm for 45 min, and the obtained pellet was spread by means of a slide on a slotted glass.

The diffractometric analysis of the clay fraction (<2 μm) was carried out on three preparations: (1) Natural test: air-dried sample, (2) Glycol test: saturated sample with ethylene glycol for 12 hours under vacuum, (3) Heated test: sample heated at 490 ° C for 2 hours to kaolinite destruction and dehydration of smectic minerals. Samples were then analyzed using one of a BRUKER D4 Endeavor diffractometer; The identification of clay minerals have been performed by comparing the position of the main lines and harmonics on the three tests performed (Brindley & Brown, 1980). The semi-quantitative analysis (Biscaye, 1965) was based on the integration of the main peak signal (I / Io = 100) characteristic of each of the clay minerals present using the MacDiff software. Every mineral was characterized by its peak which can be varied between the 3 preparations. The reproducibility of the analysis has been established by 3 measurements by X-ray diffraction from 5 aliquots of the same preparation.

4. Extraction

The determination of organic contaminants in the environment at a very low concentration (ng/L to µg/L for liquid matrix and from ng/kg dw to µg/kg dw for solid matrix) requires the use of appropriated analytical methods that varied between the matrices. In this study, water has been extracted by Solid Phase Extraction (SPE) while soils were extracted by Accelerated Solvent Extraction (ASE).

a. SPE Extraction

Groundwater was filtered through a 0.7 μm particle retention glass microfiber filter. Then, 750 ml of filtered water was used for SPE extraction. A known quantity of Pentachloronitrobenzene (PCNB) 100 mg/L (35 μL) has been added as an internal standard for each sample before the extraction. Water pH 6 was adjusted using HCl (37%) and NaCl was added to a final concentration of 100 g/L to justify the ionic strength. After the pH and ionic strength adjustment, water samples were extracted rapidly as possible using a SPE technique according to the method developed by El-Osmani et al. (2014). Briefly, HLB copolymer SPE cartridges were firstly conditioned with 5 mL of a MeOH/AcOEt (1/1 v/v) mixture followed by 5 mL of methanol and 10 mL of ultra-pure water. Filtered sample was then passed through the cartridge at a flow-rate of (2-5 mL/min) by mean of a vacuum SPE manifold. Once the retention step was completed, the cartridge was washed with 5 mL of ultra-pure water followed by 5 mL H_2O/MeOH (95/5 v/v), and then dried under a nitrogen flow for 5 min. The SPE cartridges were wrapped in aluminum foils in order to protect them from contamination and were kept frozen before elution. In France, retained components were then eluted with 2 x 5 mL of a MeOH/AcOEt (1/1 v/v) mixture. The eluate was collected into a round bottom flask and dehydrated with pre-baked sodium sulfate and then concentrated to 2mL using rotary evaporator at 45 °C for the purification step.

b. ASE Extraction

i. Choice of extraction method

Soil samples collected from each area were dried, finely ground and sieved at 224 µm. Akkar agricultural soil was used for the optimization and validation of the methods. Recoveries were carried out by spiking soil (5g) with known volumes of the appropriate working mixtures of pesticides and then they were extracted by ASE using 4 different methods (Table 17). The repeatability and reproducibility of tested methods were evaluated. And the 2 methods with the highest recovery were chosen for the analysis of our samples, the four ASE procedure were detailed in the table below.

Table 17 ASE extraction's methods

	Method 1 *(Zhoa et al., 2010)*	**Method 2** *(Tronczynski et al., 2005)*	**Method 3** *(Chen et al, 2014 ; and applicated by Zhang et al., 2015*)	**Method 4** *(Zhang et al., 2009)*
Solvents	Hexane /Acetone (1/1 ; v/v)	DCM (100%)	Hexane /DCM 1/1 v/v	DCM/Acetone
Pressure (bar)	103.45	138	103.4	103.45
Temperature (° C)	100	100	150	100
Heating time (minutes)	10	5	5	6
Extraction time (minutes)	10 minutes ; 4 cycles	5 minutes ; 2 cycles	8 minutes, 2 cycles	5 minutes, 2 cycles
Purge time (seconds)	180	180	18	6
Volume $_{\text{purge}}$ (%)	60	35	85	60

ii. Samples soil extraction

Pesticides residues associated to soil were extracted using ASE (ASE 200, Dionex Corp., USA) equipped with stainless steel extraction cells. Glass fiber filters were placed in the outlet of cell prior to begin loaded with the sample. A known mixture of internal standard was added before each blank and sample extraction. Approximately 15~20 g of each sample was extracted successively cells with method 1 and 2 detailed in the table 17. Firstly, the sample was extract with Hexane/acetone (1/1 v/v) according to the method developed by Zhoa et al., 2010. briefly, the extraction condition was preheating 10 min, temperature 100 °C, static solvent extraction time 10 min with 4 static cycles, pressure 103.45 bars and purge 3 min with a volume of 60 %. Secondly the extraction was performed with DCM as extracting solvent according to the method developed by the extraction conditions were heat 5 min, temperature 100 °C, static solvent extraction time 5 min with 2 static cycles, pressure 138 bars and purge 3 min with a volume of 35 %. High purity nitrogen was employed as the purge gas. The extracted fractions of each sample were combined together. Two grams of activated copper chips was added to remove elemental sulfur from the extracts and Na_2SO_4 to remove water. The extracts were concentrated to ~1–2 mL using a rotary evaporator.

5. Purification:

For both water and soil samples, the extracts were purified and fractioned by liquid chromatography on a silica column to eliminate organic interferences. (Fig 21)

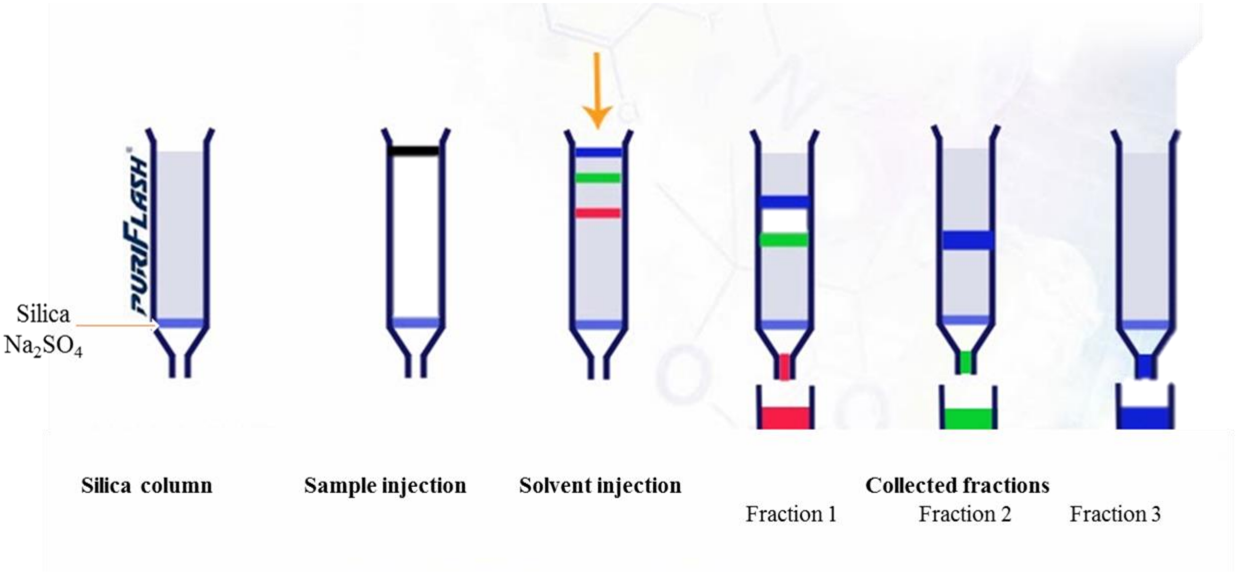


Figure 21 Steps of purification by silica column

For soil extract, molecular sulfur was removed by addition of activated metallic copper to the extracts. Targeted compounds were recovered by successive elution with 20 mL of hexane (F1), 15 mL of hexane/DCM mixtures (3/1 v/v) (F2.1) followed by 15 mL of hexane/DCM mixture (1/1 v/v) (F2.2), 15 mL DCM (F3) and then 15 mL of ACN (F4). For each sample, all fractions were combined, and the mixed was concentrated to 2 ml using rotary evaporator at 45 °C and to 100-500 µl for water and soil samples respectively under a gentle nitrogen stream. The final volume was analyzed directly with GC-MS.

6. GC/MS Analysis

The analyses of pesticides were performed by using a Varian 3900 Gas Chromatograph (GC) equipped with a deactivated fused-silica guard column (5 m, 0.53 mm i.d.) and coupled to a Varian Saturn 2000 Ion Trap Mass Spectrometer (MS) detector, the fused-silica capillary 5-MS (60 m length, 0.25 mm i.d., 0.25 µm film thickness) was used. The carrier gas was Helium at a constant flow rate of 1 mL/min. An injection of 1 µL sample volume was performed in the split less mode at 280 °C and the injector was purged with helium after 1 min. Temperature of the GC oven was programmed as follows: the initial temperature of 80 °C (hold 1 min), increased to 170 °C at 10 °C/min (hold 10 min) then increased to 230 °C at 3 °C/min (hold 5 min) and finally increased to 280 °C at 5 °C/min (hold for 20 min), with a total acquisition time of 65 min.

Full scan analysis of a standard solution (m/z 40-300) was used to identify and determinate the chromatographic and MS characteristics of the different compounds. Each compound was identified according to its retention time (RT) and mass spectrum (m/z) acquired in full scan mode. For better selectivity in quantitative determination, the single ion storage (SIS) mode was used. The accuracy of the method was routinely checked by using standard samples. The LODs and LOQs were estimated as the analyses concentration with an S/N of 3 and 10 respectively. The final SIM conditions for each pesticide including retention times (RT), and target ions were given in the table 14.

7. Heavy metals analysis

Concerning the study of the heavy metals contamination (As, Cd, Cr, Cu, Mn, Ni, Pb, Zn) in the soil of Akkar, the soil fraction < 63 µm has been used for the total mineralization view its affinity and its ability to retain the largest concentrations in trace metals (Lesven 2008; Hamzeh et al; 2012). This attack was achieved according to the protocol proposed by Ouddane (1990) and modified by (Billon, 2001). Approximately 200 mg of each soil sample has been weighed with a 0.01 mg balance precision in Teflon tubes and introduced into a reactor. Samples have been digested with a concentrated mixture acid (HCl and HNO_3 (3:1 v/v) by adding 3 ml of hydrochloric acid 37% and 1 ml of nitric acid 65%. The mineralization was realized in a heating block to 100-105°C for 24 hours. At the end of the neutralization, 10 ml of milli-Q water has been added, filtered and the analyzed by ICP-AES. Therefore, for quality control (QC) and quality assurance (QA), blank control, and the 2 standards of reference (HISS 1 and MESS3) have been used for verification and validation of the procedure. We noted that standards for the different metals have been prepared from the initial solution (100 ppm) in ultra-pure water, and the calibration range was 25, 50, 100 µg/L.

B. Epidemiological study

In order to collect information about human chronic diseases (Reproductive disorders, Chronic respiratory disease, nervous disorders such as Parkinson and Alzheimer, other chronic diseases, Birth defects and developmental toxicity) in the plain of Akkar which present the main agricultural area in this region, a cross-sectional study or in another terms, an observational-transversal study was carried out from July 2015 to November 2015 in the cited 15 studied villages located in the plain of Akkar-Lebanon which their wells water has been analysed. Our environmental epidemiology seeks to understand how exposure to pesticides by wells water consumption and other socio-economic factors affect human health. This survey was conducted by the Lebanese University, Faculty of Public Health III. It was approved by the research committee for PhD degrees at the Lebanese university and the university of Lille 1-France. The language of questionnaire was Arabic and related publication was the English. Verbal consent form was obtained from all interviewed families. The participants were asked about their health behaviors, medical history, and regular medication.

Face to face interviews with all the families have been conducted from the different villages, with a total of 1264 families with a participation rate of 87 % of the total resident families (Table 1). Non Lebanese inhabitants (Syrians and Palestinians) were excluded. All subjects living in studied villages were eligible for the study, with a total of 10774 inhabitants (Table 18).

Table 18 Number of questionnaires and number of inhabitants collected from the studied villages in Akkar

Name of village	**Number of questionnaires**	**Number of mothers**	**Number of fathers**	**Number of children**	**Total Number of inhabitants**
Kobbet bchamra	28	27	25	186	238
Mqaitaa	58	58	57	381	496
Qaabarine	54	54	51	374	479
Qlaiaat	179	176	164	1200	1540
Tal Mehyen	228	227	218	1525	1970
Balanet Hisa	102	102	93	710	905
Hisa	54	53	46	364	463
Masoudiyeh	132	129	116	840	1085
Tal Andi	87	87	84	574	745
Al Chaykh Ayach	79	79	74	503	656
Ta Briri	68	66	65	421	552
Tal Abbas Gharbi	49	49	48	317	414
Kwaykhat	51	50	49	323	422
Tal Abbas Charki	16	16	16	79	111
Al Mhamra	79	78	72	548	698
Total	**1264**	**1251**	**1178**	**8345**	**10774**

1. Questionnaire

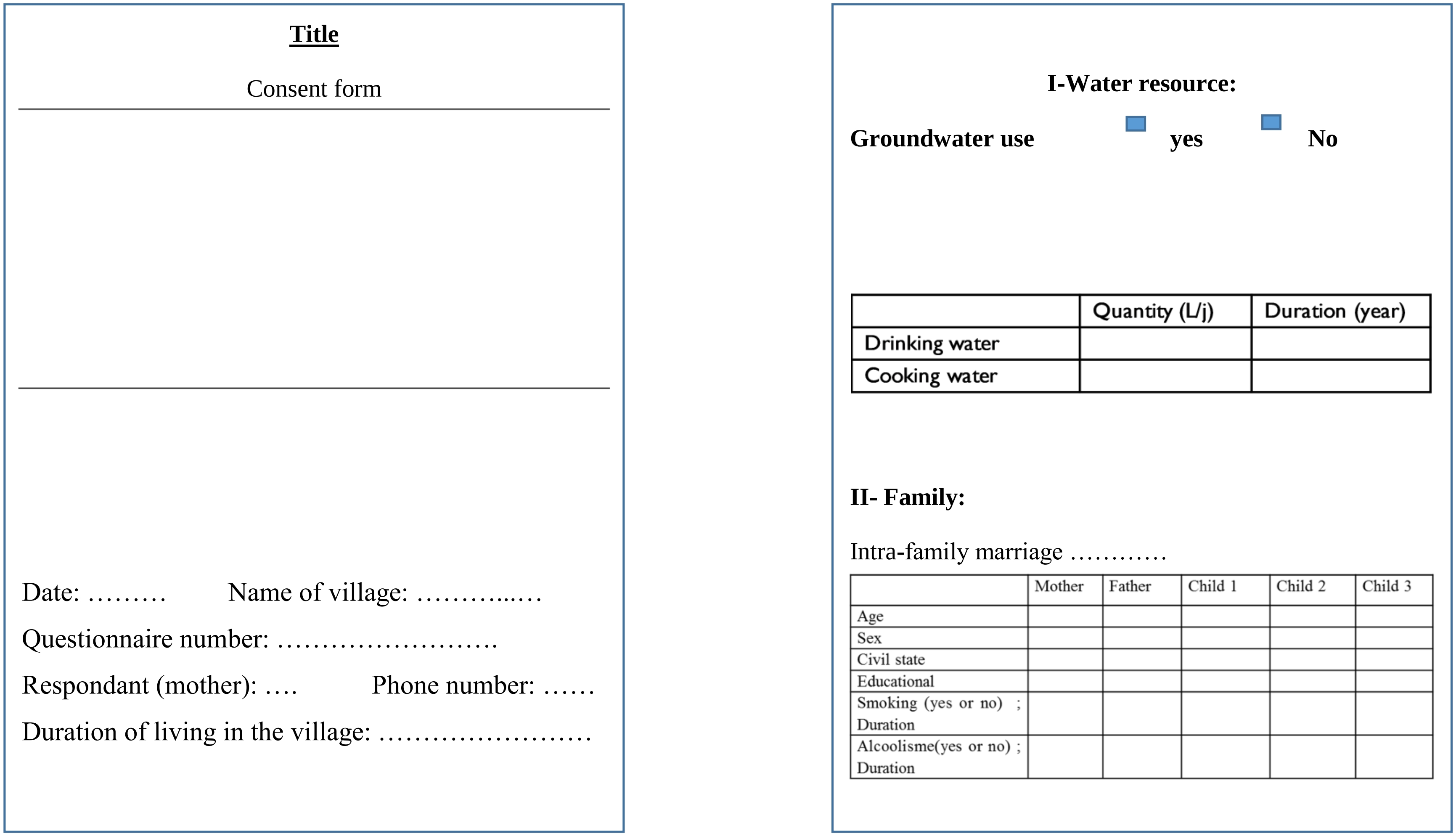
Before creating the questionnaire, a literature review concerning the toxicity of pesticides and their effects on human health has been performed. Then a brainstorming meeting with an epidemiologist and physicians in various specialties has taken place in the syndicate of doctors in Tripoli-Lebanon to discuss our project, identified the type of survey, formulate the questions, and selected the population study. And then, a provisional version of the questionnaire was created. In our survey, asked questions have been formulated and confirmed by doctors to identify diseases by their symptoms. Figures 23 and 24 show the design of the 4th pages of the questionnaire.

The questionnaire has been tested on a 20 families from Tal Mehyen. Before the application an audit step has been important to adjust the questionnaire. Some things were reworded, introductions were added, or rearranged, and some questions were deleted to obtain a final version ready to the application with a maximize clarity, comfortable and understandable questions as possible, high accuracy, minimum confusion and bias. The structured questionnaire was beginning with a consent form which is considered as an introduction that explain who is the creator of this questionnaire, the name of the university whom he is collecting data, and the objectives of the study. The name, addresses and phone numbers were obtained from the registered population; at enrollment, and were used to collect information on demographic characteristics, disease history, age, sex and civil State of each participant (Fig 23, 24) The investigations have been collected by a group of volunteer students of the Faculty of Public Health-III (Fig 22)

Figure 22 Volunteer group for data collection

2. Statistical analysis

Data analysis was performed using the "IBM SPSS statistics 20" software package. Prevalence is defined and calculated as the total number of persons with an AD and PD within a given population at a fixed point in time. It was calculated according to the international calculation method for each disease. Descriptive statistics are presented as percentages and means ±1 standard deviation (S.D.). Point estimates of indicators are reported with 95% confidence intervals (CIs). Univariate analysis has been made by the test Chi-square X^2, T-test and the Annova tests were used in multi-varied analysis for the comparison of groups in order to assess associations between the prevalence of diseases and the levels of pesticides in the wells water. Significance level was established for a p-value <0.05.



Title

Consent form

Date: ……… Name of village: ………..…

Questionnaire number: …………………….

Respondant (mother): …. Phone number: ……

Duration of living in the village: ……………………

I-Water resource:

Groundwater use ☐ **yes** ☐ **No**

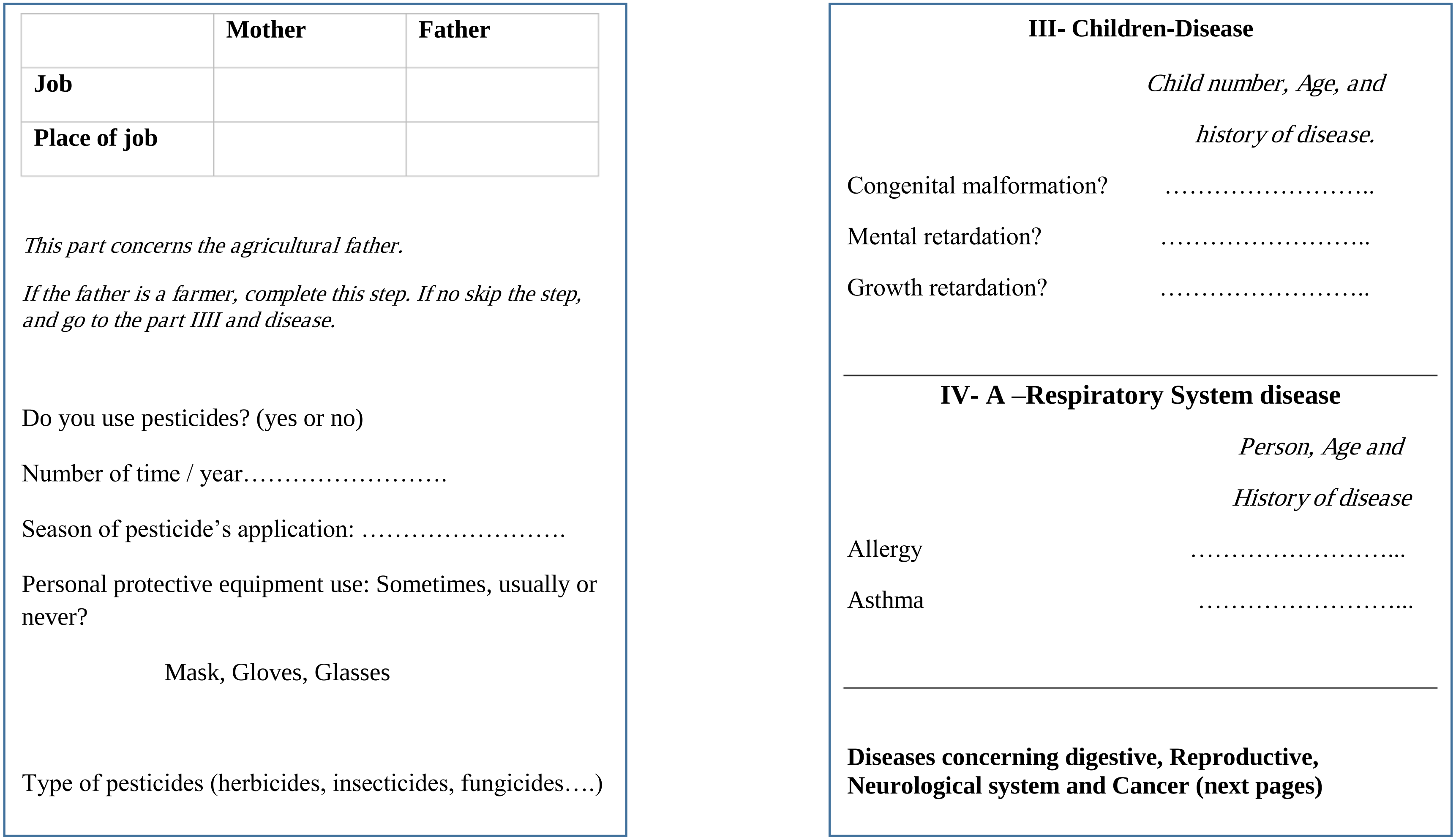
	Quantity (L/j)	Duration (year)
Drinking water		
Cooking water		

II- Family:

Intra-family marriage …………

	Mother	Father	Child 1	Child 2	Child 3
Age					
Sex					
Civil state					
Educational					
Smoking (yes or no) ; Duration					
Alcoolisme(yes or no) ; Duration					

Figure 23 First 2 pages of the questionnaire



	Mother	**Father**
Job		
Place of job		

This part concerns the agricultural father.

If the father is a farmer, complete this step. If no skip the step, and go to the part IIII and disease.

Do you use pesticides? (yes or no)

Number of time / year…………………….

Season of pesticide's application: …………………….

Personal protective equipment use: Sometimes, usually or never?

Mask, Gloves, Glasses

Type of pesticides (herbicides, insecticides, fungicides….)

III- Children-Disease

Child number, Age, and

history of disease.

Congenital malformation? ……………………..

Mental retardation? ……………………..

Growth retardation? ……………………..

IV- A –Respiratory System disease

Person, Age and

History of disease

Allergy ……………………...

Asthma ……………………...

Diseases concerning digestive, Reproductive, Neurological system and Cancer (next pages)

Figure 24 Pages 3 and 4 of the questionnaire

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Results and discussion

Chapter 1.

Assessment of pesticides contamination in groundwater of Akkar (Northern- Lebanon)

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Abstract

According to its high production and value, Akkar is considered as the second agricultural region in Lebanon. Groundwater constitutes the principal source of water in Akkar including drinking water of local inhabitants in Akkar. As such, the contamination of groundwater by organic pollutants can impact directly the population health. In this study, we evaluated the contamination status of groundwater in this region. Three classes of pesticides including 19 organochlorine pesticides (OCPs), 8 organophosphorus pesticides (OPPs) and 6 organonitrogen pesticides (ONPs) were monitored in fifteen groundwater samples collected from different villages on the Akkar plain. Samples were extracted by using solid phase extraction (SPE) and analyzed by gas chromatography coupled with mass spectrometry (GC-MS). The results showed high contamination of Akkar groundwater by OCPs with levels that can reach 58.87 µg/L. They were detected in the majority of the sample and represent 95-100% of ∑pesticides. Our results showed the recent use of these molecules with an average level of 0.3 and 0.39 µg/L for ∑HCHs and DDTs respectively. Their concentrations were higher than those observed in the same region in 2014 and other region elsewhere. OPs were also detected at high levels and among them, methyl parathion was the predominant OPP detected (44.6 µg/L). For ONPs, lower levels were measured in all samples with a mean value of 5.6 µg/L. As a conclusion of this work, groundwater on the plain of Akkar was remarkably contaminated by the studied pesticides; indefinitely more efforts should be taken to manage the pesticide use in this region, assess and reduce their effects on human health. In the future, the application of organic farming can be a great solution to the ground water contamination problem.

Keywords: Groundwater, SPE, GC-MS, Organochlorine pesticides, Organophosphorus pesticides, Organonitrogen pesticides.

1. Introduction

Groundwater is vital for agricultural development globally. Widespread use of pesticides in the past several decades leads to their ubiquitous presence in the environment. Nowadays, pesticides are detected in all the environmental matrices including air, soil, water and biota (Sankararamakrishnan et al., 2005; Aly and El-Gendy, 2014; Net et al., 2015) and pose adverse effects on the environment and human health (Hu et al., 2011). Once water has infiltrated the soil it either, percolates down to the ground water table, or becomes part of the subsurface runoff process (Dabrowski et al., 2002). Numerous factors such as rainfall intensity, slope, soil texture and type, vegetation types, water content of the soil, irrigation, soil temperature and physiochemical properties of the pesticides (water solubility, partitioning coefficients, stability etc.) play an important role in controlling infiltration movement of pesticides into groundwater. In that context Organochlorine (OCP) pesticides have been found in surface and ground water of many agricultural areas (Hu et al., 2011; Li et al., 2007; Huang et al., 2008; Kong et al., 2004; Zhao et al., 2009) with maximum values ranged in the hundreds of ng/L.

Water contamination by pesticides is such a worldwide concern that various governmental and nongovernmental organizations regulate the concentrations of pesticides in drinking water to reduce the risk to human health. For example, the World Health Organization (WHO, 2011) lists 48 active pesticide ingredients and the United States Environmental Protection Agency (USEPA) lists 21 pesticides and their related products, in their Drinking Water Quality Guidelines and national Primary Drinking Water Regulations respectively (USEPA, 2009). The European Union Drinking Water Directive (DCE, 1998) specifies acceptable concentrations of 0.1 µg/L for individual pesticide and 0.5 µg/L for ∑pesticides (Hu et al., 2011), with the exception for aldrin, dieldrin, heptachlor and heptachlor epoxide where the level is set at 0.03 µg/L (European Union, 1997).

Lebanon is endowed with the highest proportion of agricultural land in the Middle East; it also has significantly more major rivers and water resources than the regional average. The agriculture sector is the third most important sector in the country after the tertiary education and industrial sectors employing 10% of the working population and contributing nearly 4.7% to GDP (*Gross* domestic product). Bekaa, and the North of Lebanon (Akkar and Koura regions), are the most important agricultural zones. More than 650,000 hectares of the land are used in the north for the production of different types of crops. In that context, this represents 23, 23, 40, 15, 28 % of the total land used in Lebanon for production of cereals, fruit trees, olives, industrial crops and vegetables respectively (MoA/FAO, 2000; MoA, 2007). The topography of the Lebanese territories allows for a distribution of precipitation that ranges widely from less than 200 mm to more than 1400 mm of rain per year. In the future years, this value can reach 500 mm of rain per year in Akkar (Ministry of environment/ UNDP, 2011). Groundwater is a main source for agricultural activity in Lebanon. For instance, 61% of groundwater is used for irrigation (Ministry of energy and water, 2010). Gravity irrigation accounts for 64 % of the total irrigated land and is the predominant method of irrigation with surface water. Compared to sprinkler and drip irrigation, gravity irrigation inherently carries high water losses, due to low system efficiencies and high evaporation losses.

In 2001, the Lebanon Government signed the Stockholm Convention and introduced rules to manage the application of pesticides to avoid the contamination of food supplies and environment. However, recent studies showed that the Akkar plain groundwater is contaminated by nitrate, nitrite and organochlorine pesticides (Halwani et al., 1999; Baroudi et al., 2012; El-Osmani et al., 2014). Thus, further, a study is still needed to evaluate the status of contamination of this vulnerable area both by monitoring more compounds and by conducting epidemiology study more detail on the local population.

In the continuation of the previous work conducted by our group, the objectives of this study were to further investigate the distribution and the contamination levels of pesticides in groundwater of Akkar. The study was focused on three classes of pesticides including some organochlorines (OCPs), organophosphorus (OPPs) and organonitrogen (ONPs). The samples were analyzed using solid phase extraction (SPE), followed by gas chromatography coupled to mass spectrometry (GC-MS) for identification and quantification.

2. Materials and methods

2.1. *Data Sampling and preparation*

As shown in figure [25], Akkar covers an area of 798 km^2 in the north of Lebanon, near the Syrian borders. This district is characterized by the presence of a large coastal plain with high mountains to the east. Akkar is the second most agricultural plain in the country after the Bekaa. Potatoes, wheat, fruit trees, and vegetables are the most dominant crop. The North (Akkar and Koura regions) host 40 % of the land area used for olive production in the country. Fruit trees cover 24 % of the total cultivated area and vegetables cover 28 %. In addition, two-thirds of the potatoes production comes from the Bekaa plain and one-third from the Akkar plain (MoA, 2007; MoE, 2001).

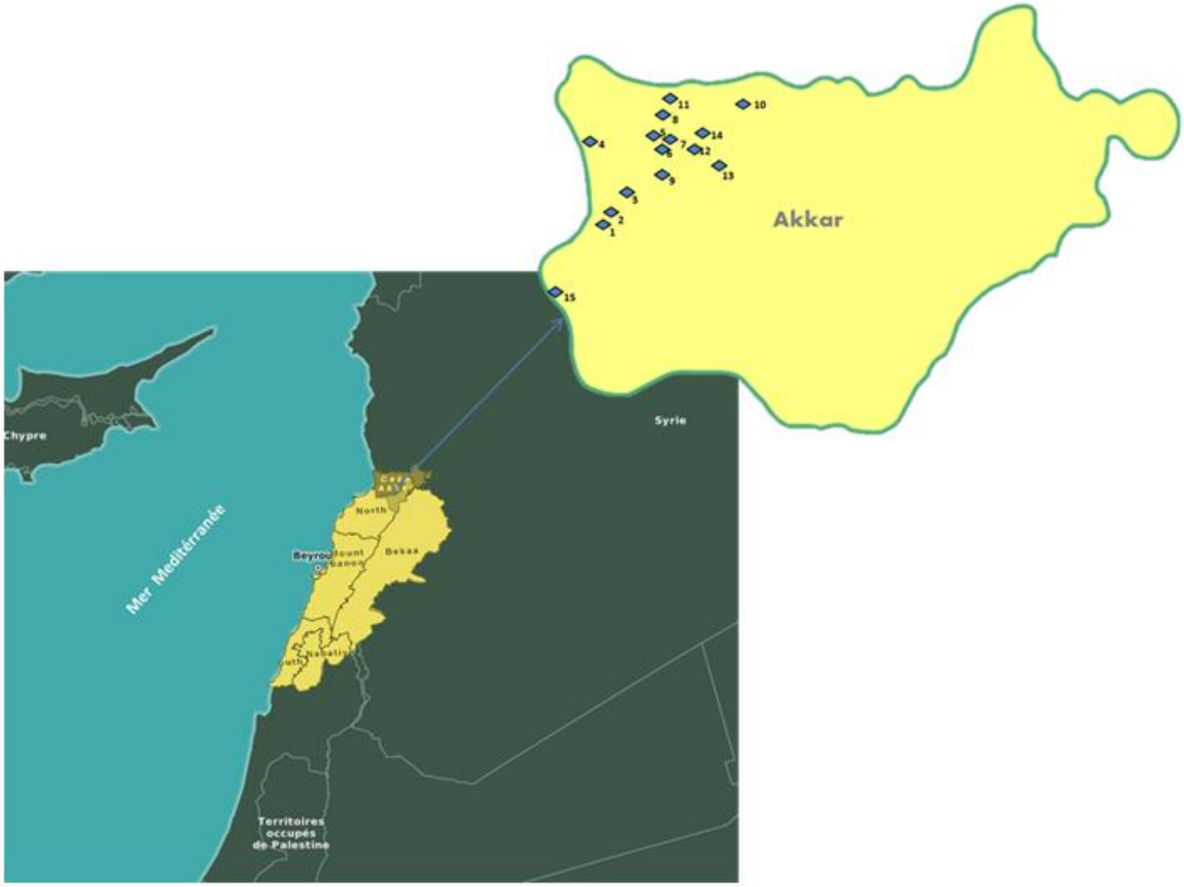


Figure 25 Location of the 15 sampling sites

Pesticides have been largely used both to protect agricultural products and to increase yields. On 2000, more than 10.7 kg of pesticides was used for the culture of 1 ha of vegetables in Lebanon. In Akkar, the majority of the land is karst, mainly made up under limestone formations (DAR IAURIF, 2004). However, due to the formation and development of rocky desertification and fracturations the karst system has little or no soil cover, which leads to poor filtration, poor pre-purification (Liu et al., 2010) and rapid infiltration. In addition, the phreatic zone which supply the wells and the sources of drinking water at low depth (<20m). Therefore, the characteristics of this zone (size, color and depth, soil conditions) are conducive to pesticide transport and make this aquifer extremely vulnerable to pollution and anthropogenic impacts (Jiang and Yan, 2010).

Due to the absence of a public network for water distribution, groundwater is used for drinking water. The Fig.25 and Table 19 present the location and characteristics of collected groundwater from 15 sites located in Akkar after a rainfall season during March 2015. The sampling was performed in duplicate, using pre-cleaned 1.5 L amber glass bottles in individual famers' closed wells. Groundwater was pumped

10 minutes before sampling using the drilling pump installed for each well and was coming exclusively from the stream which not considered as the natural aquifer flow. The bottles were rinsed three times with samples (wells waters) without passing air bubbles through the samples. Physico-chemical parameters of each site are presented in Table [19]. After sampling, the samples were transported to the laboratory and directly extracted.

Table 19 Description of sampling sites in Akkar-Lebanon

N°	Site Names	Conductivity (µS/cm)	Localization	Depth (m)
1	Koubet Al Choumra	669	N:340 32' 37"N E:360 00' 06"	54
2	Mqaitaa	1264	N:340 33' 26" E:350 59' 39"	0
3	Qaabarine	232	N:340 34' 25" E:360 00' 54"	24
4	Qlaiaat	1221	N: 340 35' 13" E:360 01' 03"	39
5	Tall Mehyen	1154	N: 340 35' 27" E:360 02' 25"	58
6	Ballaneh Al Hissa	906	N:340 35' 51" E:360 02' 35"	59
7	Hissa	1245	N:340 35' 21" E:360 03' 22"	107
8	Masaoudieh	782	N:340 36' 00" E:360 03' 39"	78
9	Tal Andi	2505	N:340 36' 33" E:360 04' 24"	54
10	Al Chaykh Ayach	783	N :340 37' 28" E:360 05' 18"	140
11	Tal Biri	868	N:340 35' 04" E:360 03' 54"	188
12	Tal Abbas El Gharbi	660	N:340 34'27" E:360 04' 38"	181
13	Kouikhat	586	N:340 34' 27" E:360 05' 22"	260
14	Tal Abbas El Charqi	716	N:340 35' 18" E:36 04' 41"	257
15	Al Mahmra	849	N:340 30 '29" E:350 57' 58"	70

2.2. Reagents

All pesticides standards were purchased from Sigma Aldrich (France). Stock solutions were prepared at concentrations ranging from 0.1 ng/mL to 10 µg/mL in hexane and stored at -10 °C.

Ultra-pure water with resistivity <18.2 MΩ.cm was obtained from a Milli-Q Ultrapure Water Purification System apparatus (Merck Millipore). Prior to use, glassware was systematically washed with detergent (Decon, East Sussex, UK), rinsed with ultrapure water and acetone and finally dried at 120ºC. All solvents used in this study were pesticide grade. Not all pesticides could be monitored. Thirty three pesticides were selected in this study in such a way as to be representative of the uses, toxic and persistent pesticides that should be controlled in this region. (i) *Nine OPPs*: O,O,O-Triethylphosphate, Thionazin, Phorate, Sulfotep, Dimethoate, Disulfon, Methylparathion, Parathion and Famphur. *(ii) Six ONPs:* Molinate, Atrazine, Acetochlor, Alachlor, Metolachlor and Butachlor. *(iii) Nineteen OCPs:* α-HCH, β-HCH, γ-HCH, δ-HCH, Aldrin, 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, 2,4'-DDT, 4,4'-DDT, Dieldrin, Endosulfan, Endrin, Endrin aldehyde, Endosulfan sulfate, Endrin ketone, Metoxychlor, Heptachlor and Heptachlor Epoxide (Table 20).

Table 20 The chemical formula, class, detection limit (LOD), for studied OCs, OPs and ONs pesticide

Compound	**Chemical formula**	**MW (g/mol)**	**Class**	**Product ions (m/z)**	**Log K$_{OW}$^{1}**	**Log K$_{OC}$^{2}**	**LOQ (µg/L)**	**LOD (µg/L)**
Organochlorine Pesticides								
α-HCH	$C_6H_6Cl_6$	290.83	Insecticide	183-185, 217	3.8	3.57	0.01	0.005
β-HCH	$C_6H_6Cl_6$	290.83		181-185, 217	3.78	3.57	0.02	0.01
γ-HCH	$C_6H_6Cl_6$	290.83		181-185, 217	3.72	3.0 - 3.57	0.02	0.01
δ-HCH	$C_6H_6Cl_6$	290.83		181-185, 217	4.14	3.8	0.02	0.01
Aldrin	$C_{12}H_8Cl_6$	364.9		65, 67	5.68 - 7.4	5.38-7.67	0.01	0.005
2,4' DDD	$C_{14}H_{10}Cl_4$	320.04		235-237	5.87	5.19	0.001	0.0005
4,4' DDE	$C1_4H_8Cl_4$	318.02		213, 243-248	6.51	4.70	0.002	0.001
4,4' DDT	$C1_5H_9Cl_5$	354.48		237-239	6.91	5.18	0.002	0.001
2,4' DDT	$C_{14}H_9Cl_5$	354.48		237-239	6.79	5.35	0.001	0.0005
4,4' DDD	$C_{14}H_{10}Cl_4$	320.04		235-237	6.02	5.18	0.002	0.001
Heptachlor Epoxide	$C_{10}H_5Cl_7O$	389.32		81,263	5.40	3.34- 4.37	0.01	0.005
Dieldrin	$C_{12}H_8Cl_6O$	380.91		77- 78	4.32 -6.2	6.7	0.01	0.005
Endosulfan I	$C_9H_9Cl_6O_3S$	406.93	Insecticide, Acaricide	274-276	3.83	4.03	0.02	0.05
Endosulfan II	$C_9H_9Cl_6O_3S$	406.93		204-205, 242	3.62	4.13	0.05	0.02
Endrin	$C_{12}H_8Cl_6O$	380.91	Insecticide,	281-282	5.34-5.6	4.53	0.001	0.0005
Endrin aldehyde	$C_{12}H_8Cl_6O$	380.91		335, 337	3.1- 5.6	3.63	0.05	0.02
Endosulfan sulfate	$C_9H_6Cl_6O_4S$	422.92		376, 377	3.63	3.51	0.1	0.05
Endrin ketone	$C_{12}H_8Cl_6O$	380.91		246-247	4.99	-	0.1	0.02
Metoxychlor	$C_{16}H_{15}Cl_3O_2$	365.65		191-193, 225	4.68-5.08	4.9	0.1	0.05
Heptachlor	$C_{10}H_5Cl_7$	373.32		274-276, 100	5.44	4.34	0.005	0.001
Organophosphorus pesticides								
Thionazin	$C_8H_{13}N_2O_3PS$	248.24	Insecticide, Fungicide, Nematocide	106-107,143	-	-	0.05	0.02
Phorate	$C_7H_{17}O_2PS_3$	260.36	Insecticide, Acaricide	231-233	3.86	3.22	0.02	0.01
Dimethoate	$C_5H_{12}NO_3PS_2$	229.26		125,212	0.78	1.18	0.05	0.01

Disulfoton	$C_8H_{19}O_2PS_3$	274.4	Acaricide	97,89	4.02	3.19	0.02	0.01
O,O,O-Triethylphophorothioate	$C_6H_{15}O_3PS$	198.22	Insecticide	121, 198	-	-	0.05	0.01
Sulfotep	$C_8H_{20}O_5P_2S_2$	322.32		321-323	3.99	3.54	0.05	0.02
Methylparathion	$C_8H_{10}NO_5PS$	263.21		263-265, 125	2.90	3.17	0.02	0.01
Parathion	$C_{10}H_{14}NO_5PS$	291.26		291-292,109	3.83	2.50-4.2	0.05	0.01
Famphur	$C_{10}H_{16}NO_5PS_2$	325.34		218-219	2.28	2.62	0.05	0.02
Organonitrogen Pesticides								
Atrazine	$C_8H_{14}ClN_5$	215.68	Herbicide	122, 132	2.6–2.71	1.96- 3.38	0.1	0.02
Acetochlor	$C_{14}H_{20}ClNO_2$	269.767		223-224	4.14	1.99-2.53	0.1	0.05
Alachlor	$C_{14}H_{20}ClNO_2$	269.767		188	2.63	2.07	0.1	0.05
Metolachlor	$C_{15}H_{22}ClNO_2$	283.79		162, 238	2.89-3.13	2.30	0.05	0.01
Butachlor	$C_{17}H_{26}ClNO_2$	311.85		160, 176, 238	4.42	2.97-3.15	0.1	0.05
Molinate	$C_9H_{17}NOS$	187.3		98, 126	2.86- 3.21	2.79	0.1	0.05

[1] https://pubchem.ncbi.nlm.nih.gov/; https://www.atsdr.cdc.gov/; http://www.sigmaaldrich.com/

[2] https://pubchem.ncbi.nlm.nih.gov/; https://www.atsdr.cdc.gov/; http://www.sigmaaldrich.com/

2.3. Extraction procedures

Each water sample was extracted according to the method developed by El-Osmani et al., (2014). Briefly, 750 ml of sample was filtered through a 0.7 µm glass microfiber filter. The filtered water was spiked with 35 µL of a 100 mg/L solution of pentachloronitrobenzene prepared in pure Hexane. Spiked water was adjusted to pH 6 using hydrochloric acid (37%) and NaCl was added up to a concentration of 100 g/L. Water was then extracted using a SPE technique. Supel-Select Hydrophilic-lipophilic-balanced (HLB) copolymer SPE cartridges (500 mg/12 mL) were purchased from Sigma Aldrich (USA) and were firstly conditioned with 5 mL of a MeOH/AcOEt (1/1 v/v) mixture followed by 5 mL of methanol and 10 mL of ultra-pure water. Filtered sample was then passed through the cartridge at a flow-rate of (2-5 mL/min) by mean of a vacuum SPE manifold. Once the retention step was completed, the cartridge was washed with 5 mL of ultra-pure water followed by 5 mL of a H_2O/MeOH (95/5 v/v) mixture, and then dried under a nitrogen flow for 5 min. The SPE cartridges were wrapped in aluminum foils in order to protect them from contamination and were kept frozen before elution. Retained components were then eluted with 2 x 5 mL of a MeOH/AcOEt (1/1 v/v) mixture. The eluate was collected into a round bottom flask and concentrated using rotary evaporator at 45 °C followed by evaporation under a slight stream of nitrogen to fix the final volume, by using microliter syringe (100 µL), in a amber glass vials to 100 µL for GC-MS analysis.

2.4. GC-MS Analysis

Analyses were performed using a Varian 3900 gas chromatograph (GC) equipped with a deactivated fused-silica guard column (5 m, 0.25 mm i.d.) and a fused-silica capillary 5-MS (60 m length, 0.25 mm i.d., 0.25 µm film thickness) and coupled to a Varian Saturn 2000 Ion Trap Mass Spectrometer (MS). The carrier gas was Helium at a constant flow rate of 1 mL/min. An injection of 1 µL sample volume was performed in the splitless mode at 280 °C and the injector was purged with helium after 1 min. Temperature of the GC oven was programmed as follows: the initial temperature of 80 °C (hold 1 min), increased to 170 °C at 10 °C/min (hold 10 min) then increased to 230 °C at 3 °C/min (hold 5 min) and finally increased to 280 °C at 5 °C/min (hold for 20 min), with a total acquisition time of 65 min.

For identification, a standard solution was analyzed in full scan mode in a range of masses between 40 and 300 m/z. Each compound was identified according to its retention time (RT) and mass spectrum (m/z) acquired in full scan mode. Quantification was then performed in the single ion storage (SIS) mode for better selectivity. The accuracy of the method was routinely checked by using standard samples. The LODs and LOQs were estimated as the analyses concentration with an S/N of 3 and 10, respectively (Table 20).

3. Results and discussion

Pesticides are applied on land (Kuranchie-Mensah et al., 2012) and end up by runoff in ground water where they can persist for a long time. Since the samples were collected during rainy seasons, our results showed the presence of organochlorines (OCPs), organophosphates (OPPs) and organonitrogens (ONPs) pesticides in all the samples collected from Akkar plain with high levels. Indeed, highly toxic, persistent and bio-accumulating pesticides such as DDT have been replaced by less persistent in the environment and less toxic to non-target organisms such as ON pesticides.

Table 21 **Contamination Levels of OC pesticides in Akkar groundwater (µg/L) (n.d: not detected : <0.0005 µg/L)**

	Individual concentration in each sampling sites in µg/L (the corresponding names are given below the table*)														
Molecules	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
α-HCH	1.30	0.02	0.02	1.42	5.76	0.04	2.36	0.52	2.21	1.60	2.85	1.46	2.16	1.62	3.28
β-HCH	0.16	0.03	0.06	0.22	0.04	0.36	0.21	0.16	0.14	0.19	0.24	0.15	0.18	0.22	0.04
γ-HCH	1.91	0.1	0.19	0.53	0.72	1.63	1.61	3.16	1.33	1.33	1.17	1.14	1.91	2.27	0.56
δ-HCH	0.07	n.d	0.02	n.d	0.01	0.01	0.02	0.03	0.01	0.02	0.01	0.01	0.02	0.03	n.d
α-/ γ-HCH	0.68	0.18	0.11	2.69	7.98	0.02	1.46	0.16	1.67	1.21	2.44	1.28	1.13	0.71	5.88
∑ HCHs	**3.44**	**0.15**	**0.29**	**2.17**	**6.53**	**2.04**	**4.20**	**3.87**	**3.69**	**3.14**	**4.27**	**2.76**	**4.27**	**4.14**	**3.88**
2,4'-DDD	15.77	n.d	0.06	9.45	12.48	n.d	19.17	0.74	15.77	18.26	16.11	16.79	14.44	12.64	15.01
4,4'-DDE	0.07	0.01	0.01	0.06	0.08	0.03	0.077	0	0.03	0.01	0.05	0.02	0.02	0.02	0.01
4,4'-DDT	0.39	0.27	0.31	0.28	0.28	0.28	0.29	0.42	0.27	0.28	0.29	0.28	0.27	0.27	0.37
2,4'-DDT	0.90	0.33	0.33	0.47	0.33	0.33	0.44	0.34	0.38	0.33	0.39	0.33	0.33	0.33	0.33
4,4'-DDD	0.25	0.09	0.10	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
p,p'-DDE+p,p'-DDD)/DDTs	0.02	0.23	0.21	0.01	0.01	0.08	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	0.96
4,4'DDE/4,4'DDT	0.18	0.04	0.03	0.21	0.29	0.1	0.27	0	0.11	0.04	0.17	0.07	0.07	0.07	0.02
2,4'-DDT/4,4'-DDT	2.31	1.22	1.06	1.68	1.18	1.18	1.52	0.81	1.41	1.18	1.34	1.18	1.22	1.22	0.90
∑DDTs	**17.13**	**0.61**	**0.71**	**10.26**	**13.17**	**0.64**	**19.98**	**1.5**	**16.45**	**18.88**	**16.84**	**17.42**	**15.06**	**13.26**	**15.72**
Aldrin	9.33	0.04	0.07	2.57	3.52	1.00	2.04	1.08	2.11	1.25	2.32	2.06	3.79	1.96	1.43
Heptachlor Epoxide	7.04	1.39	4.2	14.66	25.12	2.96	7.48	24.63	7.27	5.82	5.84	6.66	4.01	2.50	15.50
Dieldrin	0.72	0.08	0.05	9.56	4.46	0.22	4.09	0.17	3.19	2.76	3.96	2.85	4.37	2.54	1.80
Endosulfan	0.07	0.02	n.d	0.04	0.07	0.03	0.07	0.05	0.05	0.04	0.04	0.08	0.07	0.06	0.03
Endrin	0.02	0.02	0.02	0.41	0.29	0.02	0.4	0.07	0.41	0.52	0.64	0.53	0.47	0.18	0.22
Endrin aldehyde	0.05	0.06	0.02	0.14	0.19	0.02	0.07	0.09	0.07	0.03	0.05	0.02	n.d	n.d	0.02
Endosulfan sulfate	0.56	0.15	0.19	0.45	0.89	0.47	0.85	n.d	0.64	0.54	0.25	0.72	0.81	0.71	1.65
Endrin ketone	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Metoxychlor	0.11	n.d	n.d	0.06	0.12	n.d	0.25	0.15	n.d	0.06	n.d	n.d	n.d	n.d	n.d
Heptachlor	6.13	n.d	n.d	5.83	4.51	n.d	5.70	0.41	4.74	4.13	2.55	4.28	4.84	3.87	3.63
∑ Heptachlors	13.17	1.39	4.2	20.49	29.63	2.96	13.18	25.04	12.01	9.95	8.39	10.94	8.85	6.37	19.13
heptachlor/heptachlor Epoxide	0.87	n.d	n.d	0.40	0.18	n.d	0.762	0.02	0.65	0.71	0.44	0.64	1.21	1.54	0.23
∑ cyclodienes	**24.03**	**1.76**	**4.55**	**33.72**	**39.17**	**4.72**	**20.95**	**26.65**	**18.48**	**15.15**	**15.65**	**17.2**	**18.36**	**11.82**	**24.28**
∑ *OCP* µg/L	**44.85**	**2.61**	**5.65**	**46.15**	**58.87**	**7.40**	**45.13**	**32.02**	**38.62**	**37.17**	**36.76**	**37.38**	**37.69**	**29.22**	**43.88**

** 1: Koubet Al Choumra, 2: Mqaitaa, 3: Qaabarine, 4: Qlaiaat, 5: Tall Mehyen, 6: Ballaneh Al Hissa, 7: Hissa, 8: Masaoudieh, 9: Tal Andi, 10: Al Chaykh Ayach, 11: Tal Biri, 12: Tal Abbas El Gharbi, 13: Kouikhat, 14: Tal Abbas El Charqi, 15: Al Mahmra.*

A. Organochlorine pesticides (OCPs)

OCs pesticides are highly resistant to biological and chemical degradation. For this reason, they have been banned under the Stockholm Convention on POPs (Jones and De Voogt, 1999). Even though toxic and restricted, in the present study, OC pesticides were quantified in 95-100% of the Akkar groundwater samples with values exceeding the limits set by the European Union.

i. DDT and its degradation products

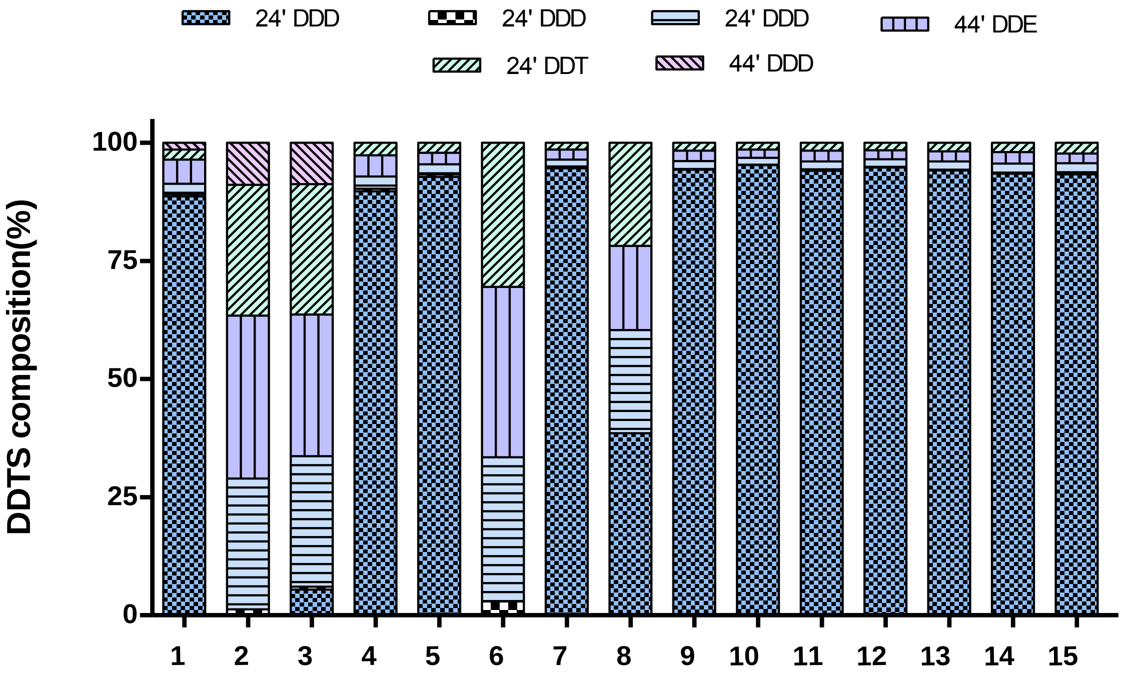
DDTs and its metabolite products were detected at levels ranging from 0.61 to 19.98 µg/L with an average of 11.84 µg/L (Table 21). Current and historical uses (Zhou et al., 2006) can be differentiated using the (DDDs+DDEs)/DDTs ratio (Eqani et al., 2011). A (DDE+DDD)/DDTs ratio higher than 0.5 indicates long-term biotransformation of DDT to DDE and DDD; and hence indicate the historical use of DDT. While the ratio lower than 0.5 indicates recent inputs of DDT (Hitch and Day, 1992). In our case, (DDD+DDE)/DDT ratios were lower than 0.5 except at Al Mhamra (0.96; Table 21).

In addition, the ratios of 4,4'-DDE/4,4′-DDT were varied from 0 to 0.29 with an average value of 0.11 (Table 21), indicating that DDTs in this area come from local deposition, not long rage transport (Dai et al., 2011). In the present case, the average compositions of DDTs in the Akkar groundwater were 2,4'-DDD > 2,4'-DDT > 4,4'-DDT > 4,4'-DDD > 4,4'-DDE accounting for an average percentage of 73.44%, 12.81%, 11.34, 1.78 and 0.6% of ΣDDTs, respectively (Fig. 26A). It was due to the transformation of DDTs to DDD in the soil under anaerobic environmental conditions (Zheng et al., 2009). 4,4'-DDT was detected at higher level compared to which reported for the same sites 2 years earlier by El-Osmani et al. (2014). In 2013, they were 0.31; 0.35; 0.23; 0.25; 0.35; <0.06 µg/L in Kobbet Al Choumra, Qaabarine, Tal Mehyen, Tal Abbas Gharbi, Masoudieh respectively (El-Osmani et al., 2014).

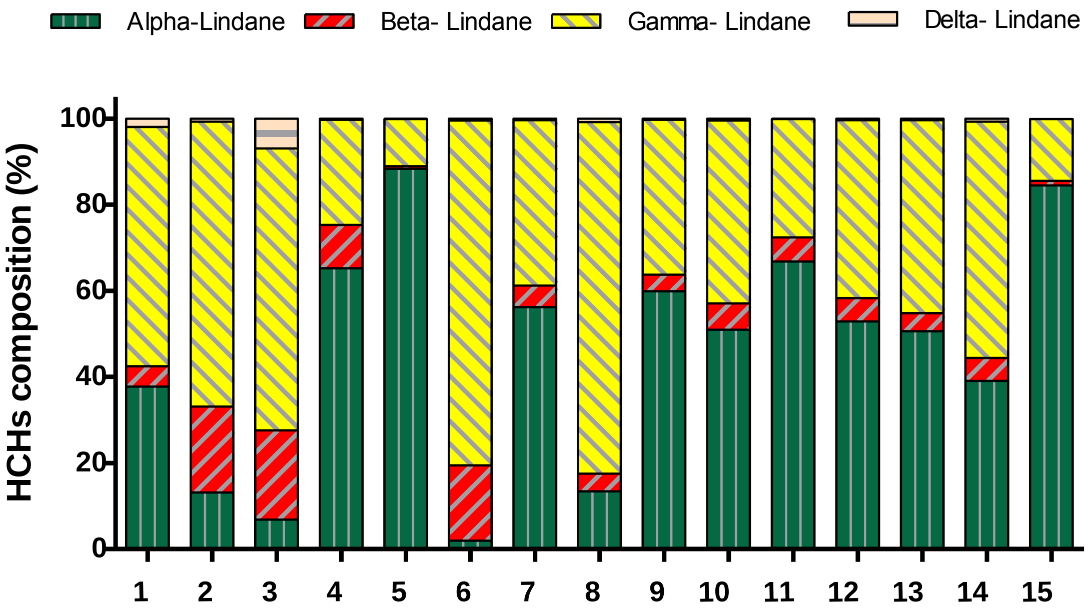
Moreover, the 2,4'-DDT/4,4'-DDT ratio can be also used to identify the origin of DDT. The 2,4'-DDT/4,4'-DDT ratio between 0.2 and 0.3 indicate that the DDT originates from the use of Technical DDT, while the 2,4'-DDT/4,4'-DDT ratio between 1.3 and 9.3 indicates that the DDT is originated from the use of dicofol (Qiu et al, 2005). Technical DDT refers to be a mixture of 75% of 4,4'-DDT, 15% of 2,4'-DDD, 5% of 4,4'-DDE, and 5% other specie (Li et al., 2008) and dicofol refers to be similar in structure to DDT with a replacement of the Hydrogen on C-1position by OH; manufacturing used dicofol products contain a number of DDT analogs impurities. In our study, the 2,4'-DDT/4,4'-DDT ratios were ranging from 0.81 to 2.31, which together with the other ratio information rather suggests the main source of DDTs in the groundwater of the Akkar plain is from the current use of dicofol containing DDTs as impurity.

ii. HCH and its isomers

Lindane (γ-hexachlorocyclohexane; γ-HCH) has been used as an agricultural insecticide for many years. The concentrations of total HCHs (ΣHCH) in the samples ranged from 0.15 µg/L in Mqaitaa to 6.53 µg/L in Tal Mehyen with an average of 3.26 µg/L (Table 21). α-HCH and γ-HCH were the most commonly detected isomers, their concentrations ranged from 0.02 to 5.76 µg/L for α-HCH and 0.1 to 3.16 µg/L for γ-HCH (Table 21). δ-HCH was almost non-existent in all sites, and its mean value was 0.017 µg/L (Table 3). Related to the persistence of HCHs in the environment and their bioaccumulation, the isomers recorded in Kobbet Al Choumra (3.44) µg/L), Tal Mehyen (6.53 µg/L), Masoudieh (3.87), Tal Abbas Gharbi (2.76 µg/L) were higher than those detected in 2013 (0.23, 7.86, n.d, and 0.4 µg/L respectively).



A



B

1: Koubet Al Choumra, 2: Mqaitaa, 3: Qaabarine, 4: Qlaiaat, 5: Tall Mehyen, 6: Ballaneh Al Hissa, 7: Hissa, 8: Masaoudieh, 9: Tal Andi, 10: Al Chaykh Ayach, 11: Tal Biri, 12: Tal Abbas El Gharbi, 13: Kouikhat, 14: Tal Abbas El Charqi, 15: Al Mahmra.

Figure 26 Composition of OC pesticides in groundwater of Akkar plain (A) for DDTs and (B) for HCHs

The ratio of α-HCH to γ-HCH is 4–7 for technical HCH and nearly zero for lindane (Zhao et al., 2009). The α-HCH/γ-HCH ratio in the majority of sites varied from 0.11 to 5.58 (Table 21), indicating the continuous use of lindane and technical HCH. The predominance of α-HCH isomer (Fig.26B) reflects the biological degradation of γ-HCH and isomerization to α-HCH under anaerobic conditions in the soils (Li et al., 2006; Yang et al., 2010). It is well known that the technical HCH contains a mixture of α-HCH (60-70%), γ-HCH (10-15%), β-HCH (5-12%) and δ-HCH (6-10%) (Zhao et al., 2009; Li et al., 2006). The concentrations of ∑DDTs and HCHs in our study are higher than the levels detected in groundwater in Chine (0.19–35.25 ng/L for ∑DDTs; Yang et al., 2016), India (4.187 µg/L for ∑HCHs; Singh et al., 2005) and lower than detected in Syria (10.6 – 13.6 and 20.2 – 53.7 µg/L for α-HCH and γ-HCH respectively; Hajjar and Mouna, 2011).

iii. *Cyclodiene insecticides*

Cyclodiene insecticides include endouslfans, heptachlors, aldrin, dieldrin, isomers of endrin and chlordane. They have been used extensively in worldwide scale in agriculture and for vector control since

World War II. The total cyclodiene concentrations in groundwater of Akkar plain were from 1.76 µg/L at Mqaitaa to 39.17 µg/L at Tal Mehyen with an average of 18.43 µg/L (Table 21). The results showed the dominance of cyclodiene among the OCs which represents 57% of ΣOCs.

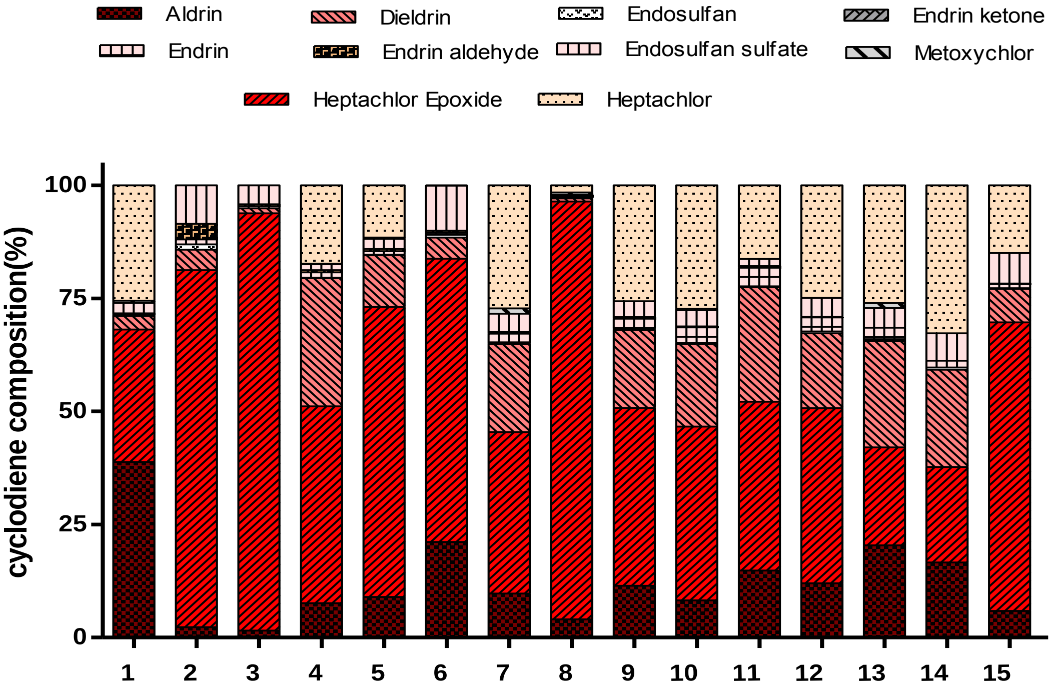


Figure 27 Composition of cyclodiene insecticides in Akkar groundwater

Commercial endosulfan is a mixture of two isomers, alpha and beta endosulfan with a ratio of 7:3 (Bhalerao and Puranik, 2007). Endosulfan sulfate is the major metabolite concern of endosulfan (Awasthi et al., 2000). These compounds can be persistent in water with a half-live of 60 and 200 days for α-endosulfan and β-endosulfan respectively (Kuranchie-Mensah et al., 2012).

This metabolite is more toxic and persists longer time in soils (Fujii et al., 2012). It is also the most frequent form of endosulfan detected in groundwater. The highest concentrations of endosulfan (sum of α- and β-endosulfan) were detected at Tal Abbas El Gharbi (0.08 µg/L), Kobbet Al Choumra, Al Hisa, Kowikhat (0.07 µg/L). While Endosulfan sulfate concentrations varied from <LOQ at Masaoudieh to 1.65 µg/L in Al Mahmra (Table 21, Fig.27). Endosulfan sulfate concentrations were higher than endosulfan. However, these concentrations were lower than those reported previously for the sample collected in 2013 (El-Osmani et al., 2014). In this study, endrin aldehyde and endrin were found at low levels ranging from <LOQ at Kouikhat and Tal Abbas El Charqi to 0.19 µg/L at Tall Mehyen and from

0.02 at Koubet Al Choumra, Mqaitaa, Qaabarine and Ballaneh Al Hissa to 0.64 μg/L at Tal Biri respectively. This is consistent with the fact that aldrin and dieldrin evaporate slowly in the air, and aldrin can readily change into dieldrin once it enters either the environment. The concentration of endrin were higher than its degradation products (endrin aldehyde and endrin ketone) indicating its fresh inputs in the water body (Rissato et al., 2006). The presence of both dieldrin and endrin in water samples reflects their historical uses, their concentrations were lower than those observed in Akkar groundwater reported for 2013 (El-Osmani et al., 2014).

Heptachlor is a constituent of technical chlordane CHLs. It has been used as a termicide (Prado et al., 2009; Fujii et al., 2012). Heptachlor was detected in all groundwater samples except for Mqaitaa and Qaabarine. The highest concentration was recorded at Kobbet Al Choumra and followed by Qlaiaat and Al Hisa with a mean concentration of 6.13, 5.83 and 5.70 μg/L respectively. A Heptachlor/heptachlor epoxide ratio is an indicator of heptachlor history and degradation. In this study the ration was less than 1.55 thus reflecting the recent exposure to parent heptachlor (Salem et al., 2014).

B. Organophosphorus and Organonitrogen pesticides

The withdrawn OCPs was replaced by OPPs and ONP pesticides. OPPs and ONPs pesticides are extensively applied owing to their low cost, ready availability, wide range of efficacy, ability to combat a large number of pest species and insects, and being less stable in the environment than OCPs (Li et al., 2007). In this study, OP pesticides were found in groundwater ranging from 18.2 μg/L in Massoudieh to 98.29 μg/L in Qaabarine (Table 22). Among the various OPPs selected in this work, only sulfotep residues were not found in the water samples (Fig 28). Methylparathion and famphur were predominant among this class of insecticides with the mean values were 27.72 and 5.34 μg/L respectively. For the other OPPs, the highest concentrations were 12.91 μg/L for dimethoate, 5.19 μg/L for disulfon, 4.17 μg/L for parathion, 3.62 μg/L for thionazin, and 1.21 μg/L for O,O,O-triethylphosphate.

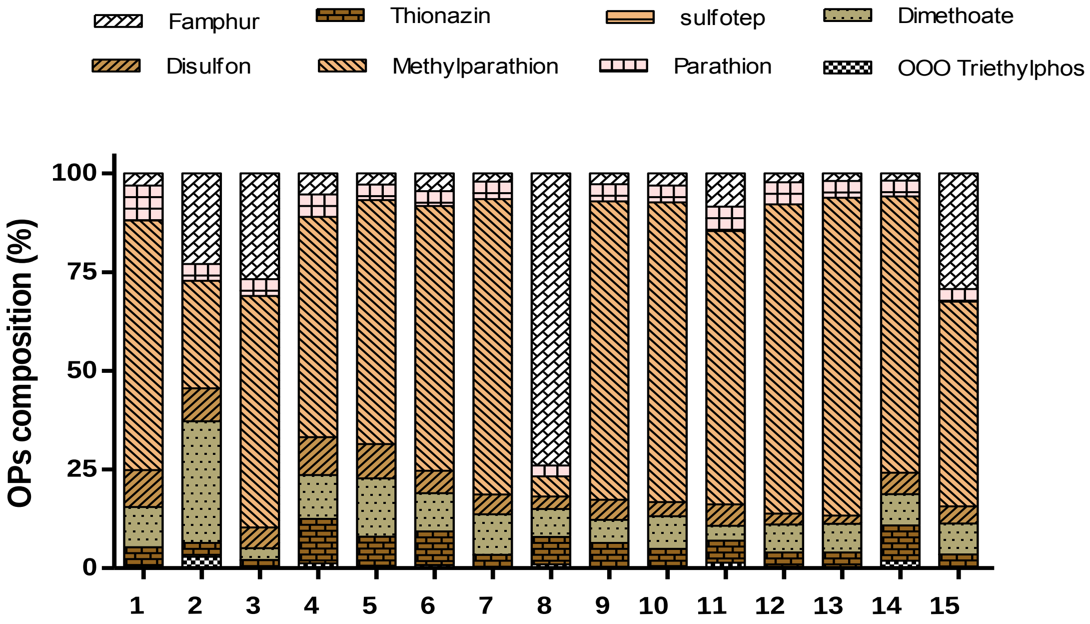


Figure 28 Concentrations of OPPs in groundwater of Akkar.

Chloroacetanilide herbicides including alachlor, acetochlor and metolachlor have been shown to degrade more rapidly in soil than other herbicides, with half-lives of 15-30 days, while triazines half-lives are typically 30-60 days (Hostetler and Thurman, 2000). Among them, the concentration of alachlor was the highest followed by acetolachlor. Their concentrations varied from <LOQ at almost of sites to 6.31 µg/L at Koubet Al Choumra, and from 0.19 µg/L at Kouikhat to 6.23 µg/L at Koubet Al Choumra respectively. These two products are classified as probable human carcinogen “class B2” by the USEPA, whereas metolachlor is viewed as a class C (USEPA, 1995, 1998, 2006). The concentration of metolachlor varied from <LOQ at Al Chaykh Ayach, Tal Biri, Tal Abbas El Gharbi to 0.72 µg/L at Koubet Al Choumra.

A maximum concentration of butachlor was detected at 2.17 µg/L in Kwoikhat. Molinate is a pre-emergent thiocarbamate herbicide. Atrazine is one of the most commonly used herbicides and it has been frequently detected in all Akkar groundwater with a high concentration that can reach 4.88 µg/L at Tal Abbas El Charki (Table 22, Fig. 29).

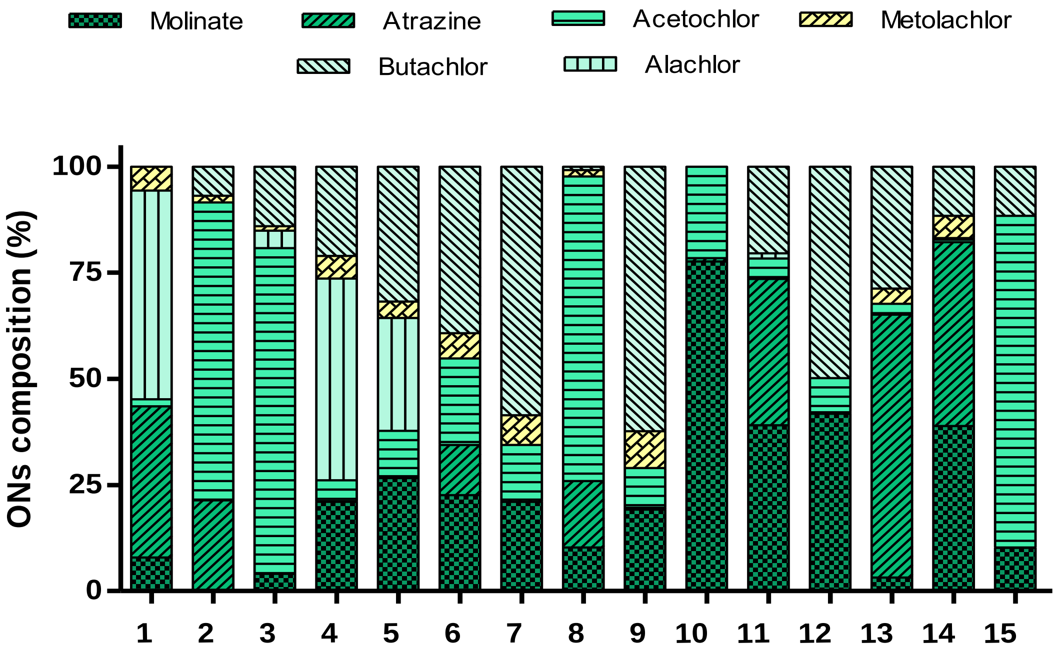


Figure 29 Concentrations of ON pesticides in Akkar groundwater

Table 22 Contamination levels of OPs and ONs in underground water in Akkar (µg/L)

	Concentration in each sampling sites in µg/L (the corresponding names are given below the table*)														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
OOO-Triethylphos	0.12	1.21	0.17	0.35	0.10	0.27	0.05	0.18	0.17	0.26	0.90	0.20	0.08	0.70	0.18
Thionazin	2.14	1.47	1.88	3.25	1.21	2.82	1.2	1.26	2.63	1.98	3.62	1.77	1.91	3.29	1.52
Sulfotep	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dimethoate	4.32	12.91	2.94	3.2	2.43	3.18	3.79	1.29	2.54	3.76	2.38	3.57	3.63	2.90	3.90
Disulfoton	3.93	3.51	5.19	2.77	1.43	1.88	1.83	0.58	2.23	1.63	3.54	1.39	1.05	2.01	2.12
Methylparathion	26.8	11.41	57.6	16.06	10.17	22.18	27.61	0.93	32.92	34.54	44.64	39.25	40.36	25.76	25.63
Parathion	3.75	1.8	4.17	1.64	0.65	1.25	1.63	0.49	1.89	1.96	4.03	2.78	2.12	1.48	1.57
Famphur	1.30	9.62	26.34	1.53	0.46	1.48	0.77	13.47	1.20	1.38	5.40	1.12	0.96	0.66	14.46
∑OPs	**42.36**	**41.93**	**98.29**	**28.8**	**16.45**	**33.06**	**36.88**	**18.2**	**43.58**	**45.51**	**64.51**	**50.08**	**50.11**	**36.8**	**49.38**
Molinate	1.02	n.d.	0.23	1.38	0.62	0.61	0.54	0.86	0.49	1.08	1.86	1.04	0.24	4.39	0.81
Atrazine	4.56	1.06	0.01	0.01	0.01	0.32	0.012	1.31	0.01	0.01	1.64	0.01	4.68	4.88	0.01
Acetochlor	0.22	3.48	4.36	0.32	0.25	0.55	0.33	6.00	0.24	0.30	0.23	0.20	0.19	0.07	6.23
Alachlor	6.31	n.d.	0.23	3.11	0.62	n.d.	n.d.	n.d.	n.d.	n.d.	0.06	n.d.	n.d.	0.04	n.d.
Metolachlor	0.72	0.08	0.06	0.35	0.09	0.16	0.18	0.12	0.22	n.d.	n.d.	n.d.	0.27	0.59	n.d.
Butachlor	n.d.	0.34	0.80	1.38	0.74	1.06	1.50	0.07	1.59	n.d.	0.97	1.24	2.17	1.31	0.92
∑ONs	**12.83**	**4.96**	**5.69**	**6.55**	**2.33**	**2.7**	**2.562**	**8.36**	**2.55**	**1.39**	**4.76**	**2.49**	**7.55**	**11.28**	**7.97**

** 1: Koubet Al Choumra, 2: Mqaitaa, 3: Qaabarine, 4: Qlaiaat, 5: Tall Mehyen, 6: Ballaneh Al Hissa, 7: Hissa, 8: Masaoudieh, 9: Tal Andi, 10: Al Chaykh Ayach, 11: Tal Biri, 12: Tal Abbas El Gharbi, 13: Kouikhat, 14: Tal Abbas El Charqi, 15: Al Mahmra.*

Conclusion

This work presents the current status of Akkar groundwater contamination by pesticides related to the inputs of several pesticides used in agricultural activity. Due to the intensive use and their persistent characteristics in the environment, restricted pesticides are still present in the groundwater in Akkar. Groundwater collected from the closed wells of fifteen agricultural areas is highly contaminated by 31 OCPs, OPPs and ONP pesticides. Cyclodiene group was the predominant among the OCs in most groundwater (wells samples) with concentration that can be up to 39.2 µg/L detected at Tal Mehyen.

Several diagnostic ratios have been used to differentiate the current and historical use of some pesticides. The diagnostic ratio based on DDTs isomers indicates a recent input of these compounds resulting from the use of dicofol containing DDTs as impurities. Moreover, the presence of the γ-isomer HCH, followed by the α-isomer, was detected in all the samples collected from Akkar plain indicating that technical lindane was the main HCH source. Anaerobic transformation of α-HCH to γ-HCH on the soil can be presented. OPs pesticides were found at very high levels in groundwater (wells waters) with a mean value of 43.7 µg/L suggesting a recent intensive use of these insecticides and herbicides in Akkar. ONs presented at high level but much more moderate than OPs with an average of 5.6 µg/L. Above all, in most cases, the concentrations detected in wells waters of Akkar plain were higher than the limits set by the European Union, especially for those toxic OPPs and OCPs molecules which were banned by Stockholm convention such as DDTs and HCHs, chlordane, aldrin, endrin, dieldrin, heptachlor, methylparathion.

The obtained results can be used to design an Integrated Management Program to control the concentration of pesticides and their metabolites in ground water and assessing the potential risk of these products to consumer's health. And there is an urgent need that the ministry of Environment and the NGOs should focus more efforts to training and educating farmers about the use and application of pesticides, and the dangers posed by their residues.

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Chapter 2.

Distribution of Organochlorine pesticides and trace metals in Lebanese agricultural soil (Case study-plain of Akkar)

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Abstract

Soil contamination by heavy metals (HMs) and persistent organic pollutant such as organochlorine pesticides is a worldwide global concern. These pollutants can introduce to the soil through human activities including mining, smelting, industry and agriculture. They alter soil properties, and affect all living beings. The present work was focused on the contamination level of organochlorine pesticides (OCPs) and HMs in soils originated from six villages located in an agricultural area northern Lebanon-Akkar. Determination of OCPs was established by accelerated solvent extraction followed by GC-MS analysis, and investigation of heavy metals was performed by total extraction occupied with ICP-AES.OCPs have been found at high levels. Concentrations of DDTs, HCHs and cyclodiene insecticides were as following 29.4 ng/g, 10.1 ng/g and 37.3 ng/g. A high concentration of OCPs was found in cultivated area and a huge difference was observed between the same region and tillage land. Furthermore, variation of concentration was determined also among depth and soil category. Predominance of DDE has been presented and a historical application of dicofol has been identified by 2,4'DDT/4,4'DDT and DDE+DDD/DDTs values. An unbroken and recent use of HCHs, chlordane and heptachlor has been manifested based on values of α-HCH/γ-HCH, *Cis/trans* chlordane and heptachlor / heptachlor epoxide ratios respectively. Nickel was the mostly metal detected at all sites and a moderate pollution by cd (Enrichment factor >25) has been provided probably due to the use of pesticides comprising certain trace of this metal during agricultural practices. As conclusion, soil of Akkar is not only contaminated by pesticides but also with trace metals which necessities an effort to protect people living around this region from their risk.

Keywords: Organochlorine pesticides, agricultural soil, contamination, ASE, GC/MS, ICP/AES, trace metals.

1. Introduction

Soil is considered as the major terrestrial reservoir of a variety of environmental pollutants both organic and inorganic compounds (Marchand et al., 2011). Soil contamination is a great global concern. Pollution deduce the fertility of soil; it alters natural, chemical and biological properties, and affect negatively affecting all living beings. Soil constitute an important sink of pollution. However, it is not a permanent sink because its retention capacity is limited and can re-emit contaminants such as pesticides and metallic trace elements (ETM) into the environment as secondary source (Zheng et al., 2009). The soil-air exchange (Meijer et al., 2003) can transport these pollutants to the atmosphere on regional and global scales (Degrendele et al., 2016) which indirectly resulted in water and atmospheric contamination (Bidleman and Leone, 2004).

Pesticides have been currently used in agriculture to enhance crop yields. Their significant amounts accumulate in soil. Organochlorine pesticides are classified as persistent organic pollutants (POPs) with a high environmental concern because of their wide spread use, their persistent and their potential impacts on human health. OCPs are chemically very stable, lipophilic, highly persistent in the environment, and have the capacity of a long-range atmospheric transport (Prado et al., 2009); they are highly toxic, strongly bound to soils and sediments and resistant to microbial, photochemical, chemical, and thermal degradation **(**Feng et al., 2011). They are environmentally ubiquitous compound found in various environmental matrices such as soils, sediments, water, air and biota and in food (Quinete et al., 2011; Mazurek et al., 2017; Sajid et al., 2016).

ETM are natural metallic elements, metals or metalloids characterized with relatively high densities (>5 g/cm^3) and high atomic numbers (Z >11) (Miquel, 2001). Sources of HMs in the environment can be from natural or anthropogenic (Rivera et al., 2015). Natural origins are related to lithogenic and pedogenic processes (Kabata-Pendias, 2011); while most of their anthropogenic sources are mines, industrial, petroleum contamination, agricultural activities, sewage disposal (Santos et al., 2005) and wastewater treatment plants. HMs have generally high toxicity with low concentration thresholds, long residence times, and persistent bioavailability (Alloway, 2013). They could be hazardous to human health and ecosystems at a trace level due to their ubiquity, toxicity, and persistence (Burges et al., 2015).

Organochlorine pesticides and ETM in soils can easily enter to human and animal bodies by inhalation, dermal absorption or ingestion (Sun et al., 2010). Moreover, accumulate in their blood and fatty tissues (El Nemr et al., 2012).

Furthermore, the exposure to these compounds at a long term can cause adverse health effects in humans and aquatic organisms (WHO, 2004; Villanneau et al., 2011). For this purpose, the United States Environmental Protection Agency by their regulatory jurisdictions seek to address the health concerns of soil direct contact with Regulatory Guidance Values (RGVs) that establish the Maximum Contaminant Levels (MCLs) for several pollutant including OCPs and Heavy metals. Cadmium (cd), lead (Pb), Nickel (Ni), Mercury (Hg), chromium (Cr), Arsenic (As), Zinc (Zn) are classified as priority control pollutants (USEPA, 2014), which may be present in the soil without prompting a regulatory response (Jennings, 2013).

Comportment of OCPs and ETM in soil matrices depend on the soil type, topography of the land and soil conditions (Carabias-Martínez et al., 2003).; the nature of the individual metal (Kabata-Pendias, 2011); the type and characteristics of pesticides such as the main ingredients and the intensity of application; the physical–chemical properties of pollutants and the weather conditions including the amount of precipitation and the wind power (Gu et al., 2016).

Lebanon has a Mediterranean climate characterized by long, hot, dry summers and short, cool, rainy winter with a precipitation ranging from 200 to 1400 mm/year (Ministry of environment/UNDP 2011). It has also individualized by various types of soils namely red and brown Mediterranean soils, calcareous soils, sandy soils, and heavily weathered fersialitic soils of volcanic origin (Chalak and Sabra, 2007).

Our study has been focused in the plain of Akkar which is a traditional agricultural region characterized by intensive Tabaco, vegetables and fruit crops farming. In the same time, surface and groundwater resources can be tabbed for irrigation and human consumption. Several researches have interested in the study of the groundwater contamination of this region by pesticides and in the assessment of their risk on human health especially for nervous disorders (Chbib et al., 2017). The present paper aimed to assess the contamination levels of organochlorine pesticides and heavy metals along the plain in order to discover their background historical pollution in the agricultural soil in Akkar.

2. Materials and methods

2.1.Study Area and samples collection

1-Kobet Al Choumra, 2-Mqaitaa, 3-Qaabarine, 4-Qlaiaat, 5-Tal Mehyen, 6-Al Mhamra

Figure 30 Location of the soil sampling sites in Akkar

Plain of Akkar is situated in the coastal plain of Lebanon, reaching a maximum of 9km to the sea with a land slope gradient ranging between 0 and 8% and are generally used mainly for citrus, bananas and vegetables crops with frequent urban sprawl (FAO, 2017) (Fig. 30). Precipitation in Akkar starts to occur around October and continue until April, with a minimum level in the east region that is protected by mountains. In addition, the effects of high levels of precipitation in Akkar are dependent on soil properties, which is permeable in the western region and theasaltic impermeable soil in the eastern region. More particularly, in November the average of precipitation in the plain of Akkar was between 101 and 150 mm **(**UNHCR, 2014).

The soil of Akkar is characterized a neutral pH at 7.5, and rich of organic matter at 15.8% which is higher than other area in Lebanon such as koura (6%), Nabatiyeh (6.8%) and baalbeck (8%). In addition, this soil contains high proportion of clay comparing to the three cited zones. The clay fraction values were 529.6; 281.4; 335.4 and 346.0 g/kg for Akkar, Koura, Nabatiye and Baalbeck respectively (Saad et al., 2006). The geological map of Akkar varied widely from quaternary colluvial, sand and lake deposits to fluvial deposits; volcanic rocks and non-clastic mesozoic sedimentary rocks (Darwish et al., 2012).

A total of 30 soil samples has been collected in November 2015 from 6 villages, namely Kobbet Choumra, Tal Mehyen, Mqaitaa, Al Mhamra, Qlaiaat and Qaabarine, located in the plain of Akkar (Figure 30). The soil map of Lebanon showed that the Vertic Cambisols was found at Kobbet Al choumra, Mqaitaa, Qaabarine and Qlaiaat, terric anthrosols at Al Mhamra , and Gleyic Andosols at Tal Mehyen (FAO, 2017). At each site, five samples covering different depth (0-5 cm; 25 cm; 50 cm; 75cm; 1m) have been taken using a spade in stainless steel by digging a V-shaped hole from different depth. Description of land characteristics and location were summarized in the table 23. Soil samples were kept in stainless steel for pesticides analysis and were kept in plastic grab for ETM analysis. All the samples were then packed into poly- ethylene bags and freeze until analysis.

Table 23 GPS coordinates, Altitude, geology and land's characteristics of studied villages.

Name of village	**GPs coordinates**		**Altitude (m)**	**Geological characteristics (Darwish, 2012)**	**Description of land's characteristics**
	Latitude	**Longitude**			
Tal Mehyen	34^{0} 35' 27''N	36^{0} 02' 25'' E	58	Volcanic rocks	Tillage land (in progress)
Kobbet Al choumra	34^{0} 32' 37''N	36^{0} 00' 06'' E	54	Quaternary deposits	Cultivated land (Vegetable ; lettuce)
Qlaiaat	34^{0} 35' 13''N	36^{0} 01' 03'' E	39	Quaternary deposits	Non cultivated zone (tillage land)
Al Mhamra	34^{0} 30 '29'' N	35^{0} 57' 58'' E	70	Mixture of fluvial and quaternary deposits	Soil collected from Greenhouses
Qaabarine	34^{0} 34' 25''N	36^{0} 00' 54'' E	24	Quaternary deposits	Sandy soil

2.2. Reagents and glassware

The standards mixture solutions of 21 chlorinated pesticides (α-HCH; β-HCH; γ-HCH; δ-HCH; 2,4′-DDD; 4,4′-DDD; 4,4′-DDE; 2,4′-DDT; 4,4′-DDT; Aldrin; dieldrin, endosulfan I and II; chlordane; cis-chlordane; endrin; endrin aldehyde; endrin ketone; endosulfan sulfate; metoxychlor; heptachlor and heptachlor epoxide) were purchased from Sigma-Aldrich (France) with the purity of 98.89% (table 24). Pentachloronitrobenzene used as the internal standard with the purity of 94% was purchased from Sigma-Aldrich (Saint-Louis, USA). Stock solutions were prepared at concentrations ranging from 0.1 ng/mL to 10 µg/mL in hexane and stored at −10 °C. All solvents used in this study were of pesticide grade. Ultra-pure water with resistivity <18.2 MΩ cm was obtained from a Milli-Q Ultrapure Water Purification System apparatus (Merck Millipore). Whatman GF/A filter used in ASE extraction were purchased from Whatman (England). In order to reduce sample contamination, glassware was systematically washed before each use with detergent (Decon, East Sussex, UK), rinsed with ultrapure water and acetone, and finally dried at 120 °C. Hydrochloric acid (HCl, 37%) and potassium Hydroxide (KOH, 0.5 mol/L) used in ETM analysis were purchased from Sigma Aldrich. Standard solution multi element (ASTASOL - Mix) was purchased from sigma Aldrich and was used for the calibration of the ICP-AES. Reference standards material (HISS 1 and MESS3) were provided by the National Research Council of Canada for QC.

Table 24 Molecular weight, identification ions, limit of detection and the recovery of studied OCPs.

Molecule	MW (g/mol)	m/z	LOD (ng/g)	Recovery (%)
α-HCH	290.83	145-146	0.05	98.1
β-HCH	290.83	145-146	0.1	73.7
γ-HCH	290.83	145-146	0.1	78.8
δ-HCH	290.83	145-146	0.1	94.8
2,4′-DDD	320.04	165,199	0.005	68.4
4,4′-DDD	320.04	165,199	0.01	67.3
4,4′-DDE	318.02	246-248	0.01	82.2
2,4′-DDT	354.48	235-	0.005	66.7
4,4′-DDT	354.48	165,199	0.01	44.5
Aldrin	364.9	261	0.05	97.7
Dieldrin	380.91	78-79	0.05	92.8
Molecules	**MW (g/mol)**	**m/z**	**LOD (ng/g)**	**Recovery (%)**
Endosulfan I	406.93	315-318	0.5	93.2
Endosulfan II	406.93	192,159	0.2	94.3
Trans-Chlordane	409.758	264-266	0.1	92.8
Cis-chlordane	409.758	299-301	0.1	98.4
Endrin	380.91	81-82	0.005	94.0
Endrin Aldehyde	380.91	207-208	0.2	94.7
Endrin ketone	380.91	279-281	0.2	87.7
Endosulfan sulfate	422.92	235-237	0.5	65.3
Heptachlor	373.32	270-272	0.01	96.6
Heptachlor epoxide	389.32	261-263	0.005	95.0

2.3. Sample preparation and analytical procedure

2.3.1. Mineralogical analysis of studied soil (RDX)

Dried soil samples were micro-crushed until obtaining cohesive powder, and then a pellet was made by pressure (Total fraction). Samples were analyzed using one of a

The fraction with particle size less than 2 µm has been extracted before a treatment with hydrochloric acid diluted to N / 5, and centrifugation at 3500 rpm for 45 min. The diffractometric investigation of this clay fraction was carried out on three preparations: (1) Natural test: air-dried sample, (2) Glycol test: saturated sample with ethylene glycol for 12 hours under vacuum, (3) Heated test: sample heated at 490 ° C for 2 hours to kaolinite destruction and dehydration of smectic minerals. Samples of total fraction and clay fraction were analyzed using BRUKER D4 Endeavor diffractometer equipped with a copper anticathode coupled to a Lynxeye fast detector (with a voltage of 30 kV, an intensity of 35 mA and angular scan extends from 1.49 to 32.5 °C). The identification of clay minerals has been performed according to Brindley & Brown study (1980), and the semi-quantitative analysis was achieved using the MacDiff software (Method used by Biscaye,1965). The reproducibility of the analysis has been established by 3 measurements by X-ray diffraction from 5 aliquots of the same preparation.

2.3.2. Pesticides analysis

ASE Extraction and clean up

Samples were dried and sieved at 224 µm prior to extraction. Pesticides in soil samples are difficult to extract because they present at trace level and can be strongly bound to the sorbent matrix of soil. Organic substances in soil interact with the matrix components such as sand, clay, and organic matter (Hubert et al., 2000). Accuracy of soil sample analysis depends on the efficiency and the robustness of the extraction step. In this study, pesticides residues in soil were extracted using ASE (ASE 200, Dionex Corp., USA). Approximately 15~20 g of soil sample was firstly spiked with internal standard then extracted with ASE under 2 successive processes. Firstly, the sample was extract with Hexane/acetone (1/1 v/v) according to the method developed by (Zhoa et al, 2010). The extraction conditions were as follow: 10 min of preheating, temperature 100 °C, static solvent extraction time 10 min with 4 static cycles, pressure 103.45 bars and purge 3 min with a volume of 60 %. Secondly, the extraction was performed with DCM according to the method developed by Tronczynski et al. (2005). The condition of the conditions of the extraction were as follow: heat time 5 min, temperature 100 °C, static solvent extraction time 5 min with 2 static cycles, pressure 138 bars and purge 3 min with a volume of 35 %. High purity nitrogen was used as the purge gas. The two extracts were combined together.

The activated copper was added into the extract to remove elemental sulfur. The extract was concentrated and solvent-exchanged to hexane and purified on silica column. In the top of silica column, 2g of Na_2SO_4 to eliminate eventual trace of water. Targeted compounds were recovered by successive elution with 20 mL of hexane, 15 mL of hexane/DCM mixtures (3/1 v/v) followed by 15 mL of hexane/DCM mixture (1/1 v/v), 15 mL DCM and then 15 mL of ACN. For each sample, all the fractions were combined, and the mixture was concentrated to 2 ml using rotary evaporator then to 500 µl with a gentle nitrogen stream. The final extract was analyzed directly with GC-MS. The repeatability and reproducibility of ASE extraction method were checked by using standard and blank samples. The validation and the recovery of this technic were verified by triplicate extraction of a 5 g mixture of the different soil types spiked with a known volume of OCs.

GC/MS Analysis

The determination of OCs residues was performed on a Varian 3900 gas chromatograph (GC) equipped with a deactivated fused-silica guard column (5 m, 0.53 mm i.d.) and coupled to a Varian Saturn 2000 Ion Trap Mass Spectrometer (MS) detector, the fused-silica capillary 5-MS (60 m length, 0.25 mm i.d., 0.25 µm film thickness) was used. The carrier gas was Helium at a constant flow rate of 1 mL/min. one µL of each sample was injected in the split less mode at 290 °C and the injector was purged with helium after 1 min. Temperature of the GC oven was programmed as follows: the initial temperature of 80 °C (hold 1 min), increased to 160 °C at 10 °C/min (hold 1 min) then increased to 230 °C at 3 °C/min (hold 1 min) and finally increased to 290 °C at 12 °C/min (hold for 2min), with a total acquisition time of 42.83 min.

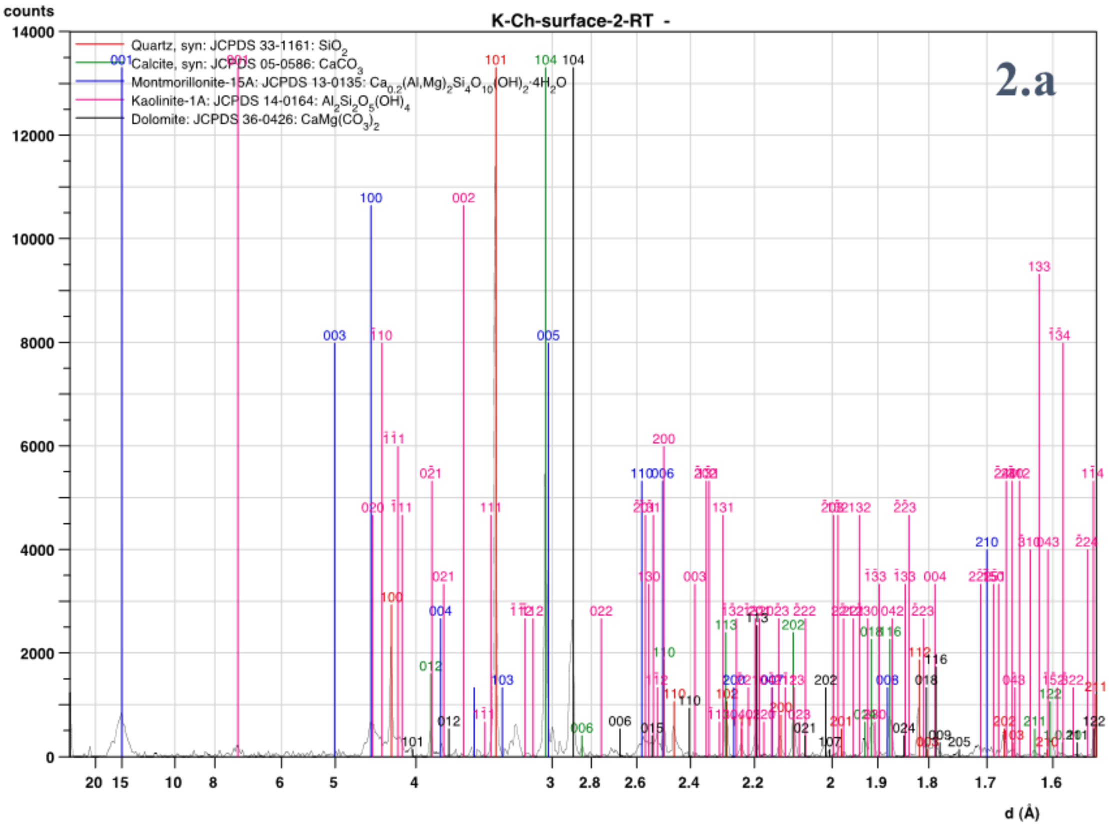
Identification of detected molecules was firstly based on the retention time and the standards ions on the full scan of the standard solution (m/Z from 40 to 450), and the Tandem mass spectrometry (MS/MS) mode was performed on the ion parent to prepare quantification methods. Quantification was performed by five-point calibration method (from 0.5 to 10 µg/mL with $r^2 > 0.992$). For quality control (QC) and quality assurance (QA), limits of quantification (LOQ) and limits of detection (LOD) have been determined and their values were presented in Table 24.

2.3.3. ETM analysis

For ETM analysis, the soil sample was sieved at < 63 µm prior to the total mineralization. Indeed, previous work has reported that this fraction lower than 63 µm has the affinity and ability to retain the largest trace metals (Hamzeh et al; 2012). The total mineralization procedure was used according to the protocol developed by Ouddane (1990) and modified by (Billon 2001). Briefly, approximately 200 mg of sieved soil sample was introduced into a reactor. Samples have been digested with a concentrated mixture acid (HCl and HNO_3 (3:1 v/v) by adding 3 ml of hydrochloric acid 37% and 1 ml of nitric acid 65%. The mineralization was realized in a heating block to 100-105°C for 24 hours. At the end of the neutralization, 10 ml of milli-Q water has been added, filtered and then ETM were analyzed by ICP-AES. Therefore, for quality control (QC) and quality assurance (QA) and blank control, 2 standards reference material (HISS 1 and MESS3) have been used for verification and validation of the procedure (QC). The calibration range was ranging from 25 to 100 µg/L.

3. Results

3.1. Soil Characteristics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12000
10000
8000
6000
4000
2000
0
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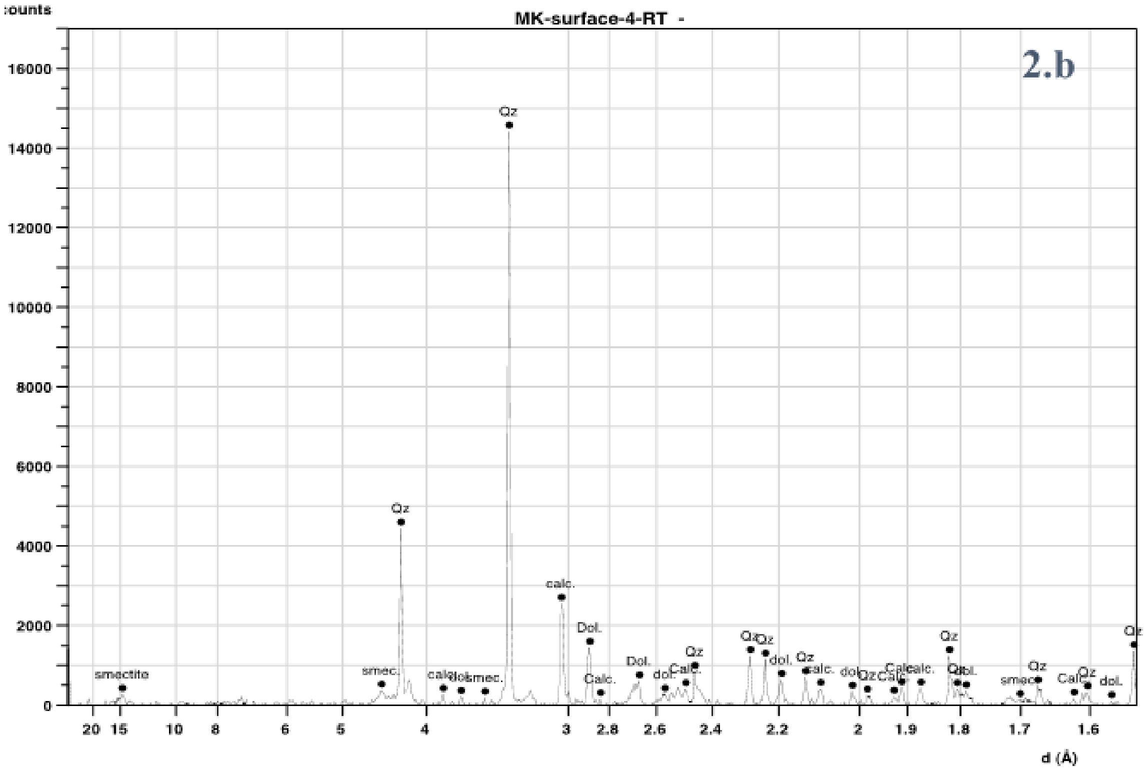
Calcite, syn: JCPDS 05-0586: CaCO3
Montmorillonite-15A: JCPDS 13-0135: Ca0.2(Al,Mg)2Si4O10(OH)2·4H2O
Kaolinite-1A: JCPDS 14-0164: Al2Si2O5(OH)4
Dolomite: JCPDS 36-0426: CaMg(CO3)2
001
001
101
104
104
100
002
003
110
005
200
133
134
20
15
10
8
6
5
4
3
2.8
2.6
2.4
2.2
2
1.9
1.8
1.7
1.6
d (Å)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Qz
calc.
Dol.
Calc.
Dol.
smectite
smec.
smec.
calc.
dol.
20
15
10
8
6
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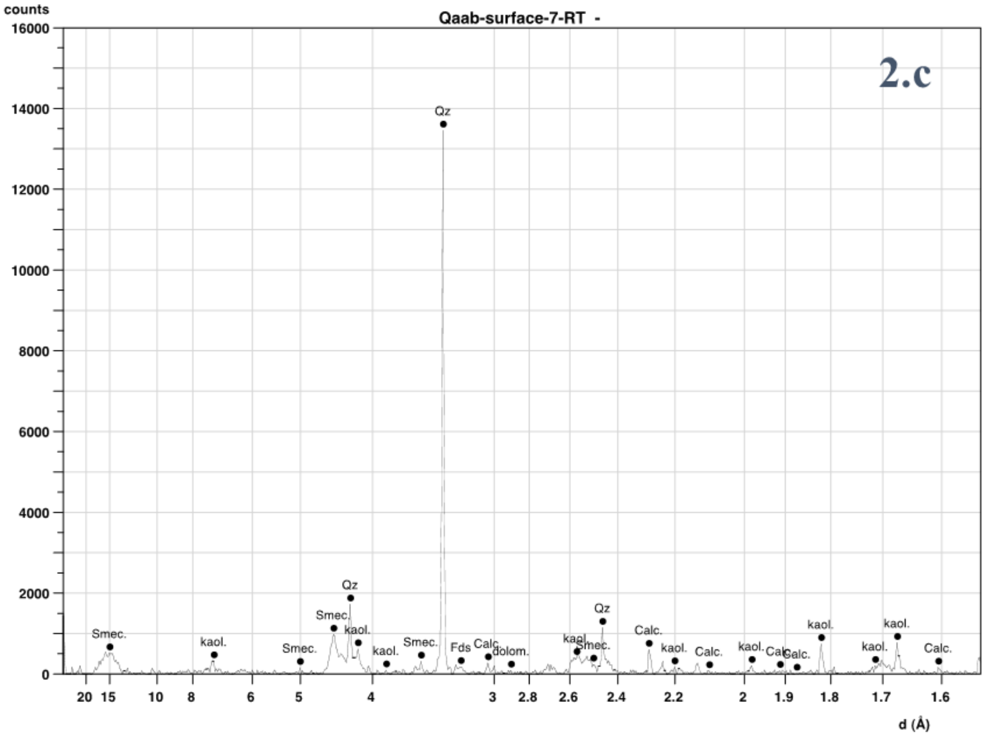
2
1.9
1.8
1.7
1.6
d (Å)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2000
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Qz
Qz
Smec.
Smec.
kaol.
Smec.
kaol.
kaol.
Smec.
Fds
Calc
dolom.
kaol.
Smec.
Qz
Calc.
kaol.
Calc.
kaol.
Calc.
Calc.
kaol.
kaol.
kaol.
Calc.
20
15
10
8
6
5
4
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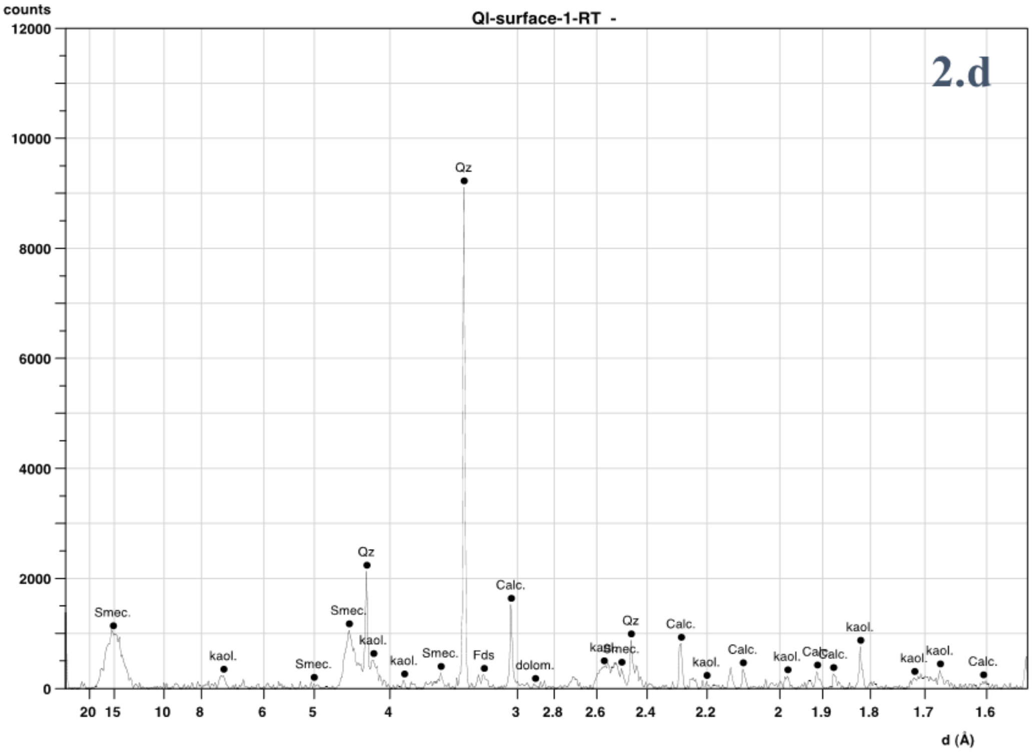
2.8
2.6
2.4
2.2
2
1.9
1.8
1.7
1.6
d (Å)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8000
6000
4000
2000
0
Qz
Qz
Calc.
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kaol.
kaol.
Smec.
kaol.
Smec.
Fds
dolom.
kaol.
Smec.
Qz
Calc.
kaol.
Calc.
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20
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1.6
d (Å)

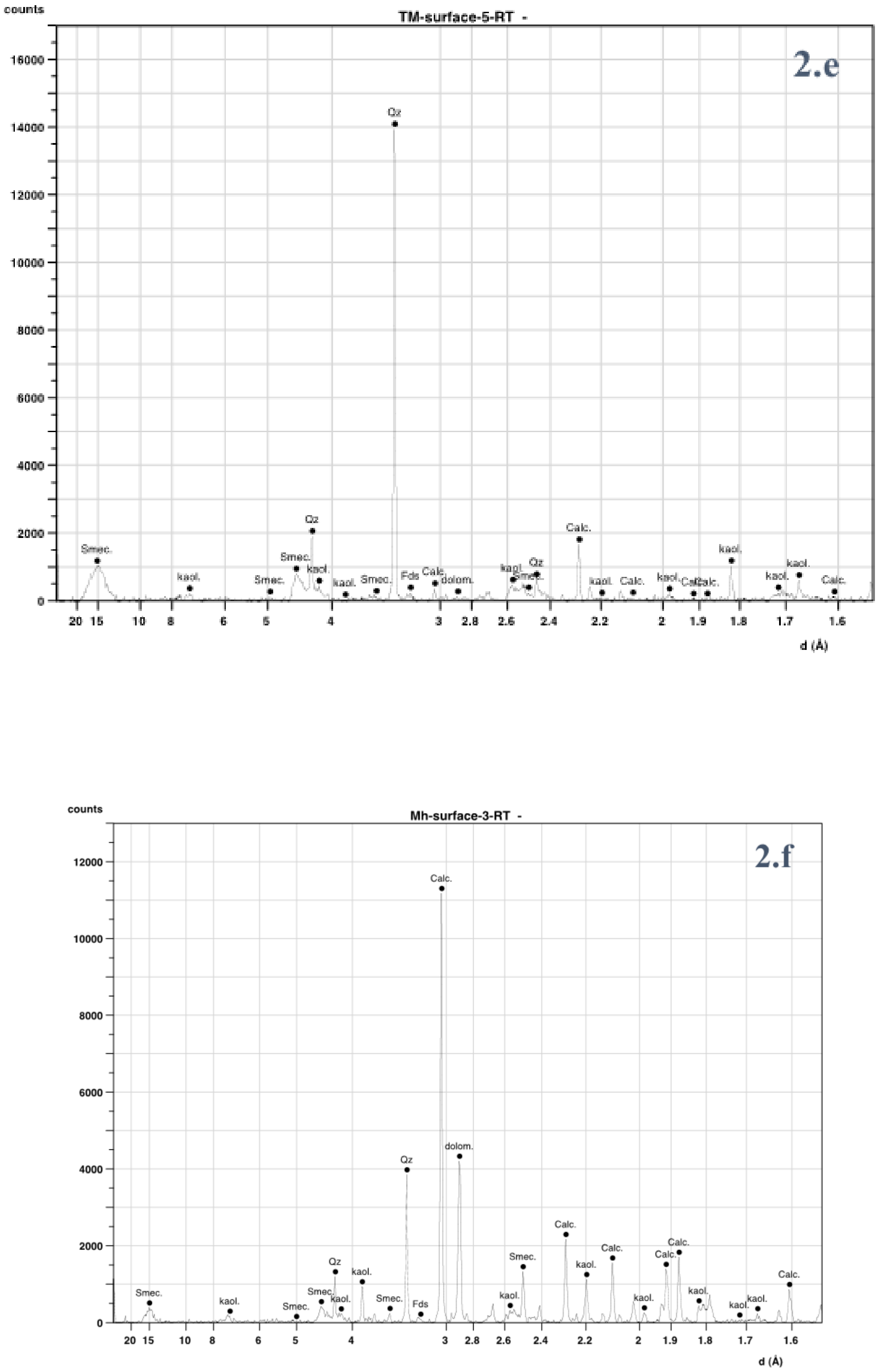

Figure 31 Diffractometer of the total fraction of studied soils (2a. Kobbet Al choumra; 2b.Mkayteh; 2c.Qaabarine; 2d.Qlaiaat; 2e.Tal Mehyen; 2f.Al Mhamra)

As shown in figure 31 (a, b, c, d, e, f). The composition of the total fraction of the rock in the 6 villages of Akkar was the same. The samples are mainly composed of quartz (SiO_2) which is an important rock-forming mineral more stable than most other minerals under conditions and assumes a mostly passive role in the geological environment; Calcite ($CaCO_3$), Montmorillonite ($Ca_{0,2}(Al, Mg)_2Si_4O_{10}(OH)_2 \cdot 4 H_2O$). There is also less dolomite ($CaMg(CO_3)_2$) and Kaolinite $Al_2Si_2O_5(OH)_4$. In addition, Smectite is also present, as well as the association of kaolinite-chlorite.

The semi-quantitative results of the mineralogical analyze have been accurate to ± 5%. and have been present in table 25.

Table 25 composition of the clay fraction of surface soil samples (percentage of the four major minerals: Smectite, Illinite, Koalonite, Chlorite)

Site samples	Smectite	Ilinite	Koalonite	Chlorite	Other minerals	Total percentage
Kobbet Al choumra *(0-5cm)*	79%	2%	14%	5%	-	100%
Mkayteh *(0-5cm)*	67%	3%	21%	9%	-	100%
Qaabarine *(0-5cm)*	81%	1%	12%	6%	-	100%
Qlaiaat *(0-5cm)*	89%	1%	7%	3%	-	100%
Tal Mehyen *(0-5cm)*	94%	-	4%	2%	-	100%
Tal Mehyen *(1m)*	93%	-	4%	3%	-	100%
Al Mhamra *(0-5cm)*	77%	2%	15%	6%	-	100%

Minerals in clay fraction have been found in the succeeding order: Smectite (67-94%), Koalonite (4-21%), Chlorite (2-9%), Illinite (0-2%). The composition of soils has varied widely between sites. For example, Kobbet Al choumra and Al Mhamra soil samples have similar compositions: 77 and 79% smectite associated with 15 and 14% kaolinite and 6 and 5% chlorite.

Mkayteh soil samples was the least rich in smectite with 67%, but the richest in kaolinite and chlorite (21% and 9%, respectively); Qaabarine samples have 81% smectite associated with 12% kaolinite and 6% chlorite in its composition.

Although, Qlaiaat and Tal Mehyen were a similar composition; They were very rich in smectite (89% and >93% respectively) associated with kaolinite (7% and 4% respectively) and chlorite (3% for Qlaiaat and <3% for Tal Mehyen). In addition, soils had conserve the same composition for the different depth (e.g. Tal Mehyen, Table 25).

Furthermore, Smectite- the most dominant mineral- regrouped many phyllosilicate mineral species including montmorillonite, beidellite, nontronite, saponite and hectorite. Due to the fact that Smectite has a large chemically active surface area, a high cation exchange capacity, hydration characteristics and the ability to modify the flow behavior of liquids (Odom, 1984); the impressive difference among the soil composition (especially in the percentage of Smectite) can affect the adsorption of environmental contaminants and their transportation via organic matter and soil particles.

3.2.Organochlorine pesticides

The results showed that OCPs levels varied between sampling sites, depth and type of soil (Table 27). The highest average of ∑OCPs were detected at 47.6 ng/g at Kobbet Al Choumra and followed by 41.1 ng/g at Qaabarine. The other villages showed the concentration 2 or 3 times lower; they were detected at 21.3 ng/g at Qlaiaat; 17.1 ng/g at Mkayeh; 16.9 ng/g at Al Mhamra and 14.4 ng/g at Tal Mehyen. Compared to agricultural soil in Wuhan in China, our results are much lower. Zhou et al. (2013) have reported the ∑OCPs detected in Wuhan at 196.6 ng/g.

For the surface soil, the ∑OCPs at cultivated zone of Kobbet Al Choumra were the highest with a mean value of 78 ng/g. In addition, a huge difference has been shown between this area (cultivated land) and tillage land (Tal Mehyen). Isomers of DDTs were the most OCPs detected. Endosulfan I, II, Endrin ketone and aldehyde were not detected in any sites. Concentrations of some pesticides such as Aldrin, chlordane, DDTs, Dieldrin and Heptachlor found in the agricultural soil of Akkar were lower than the levels fixed by RGVs on the original Stockholm convention- POPs (table 26)

Table 26 Concentration of some pesticides fixed by Stockholm convention for POP.

	Aldrin	Chlordane	DDT	Dieldrin	Endrin	Heptachlor
Arithmetic Mean of all RGVs (mg/kg)	11.3	41.3	93.2	276.0	42.3	15.9
Arithmetic Mean of U.S.-related RGVs (mg/kg)	17.8	51.3	40.9	589.0	67.5	21.8

DDT and its analogs

Mean ΣDDTs in the present study was 29.42 ng/g. This value is lower than those values in agricultural soil of Wouhan in China detected at 151.56 ng/g and in Mexico detected at in the range of 31-47 ng/g. However, in our work, ΣDDTs detected in Akkar agricultural soil was higher than those detected in Shanghai-China at 21.41 ng/g (Sánchez-Osorio et al., 2017; Jiang et al., 2009). DDT and its degradation products can remain in soil for more than 30 years (Ortiz et al., 2002). In Akkar plain soil, DDT and its degradation products were detected in 85% of soil samples. The soil of Akkar is rich on organic matter, which contribute to the permeability, the aeration of the soil and the water retention capacity; in addition, DDT can be biodegraded to DDE under aerobic condition and to DDD under anaerobic condition. As shown in figure 31, the average percentage of 4,4'DDE was the highest which represented at 36.37%) of ΣDDTs followed by 2,4'DDE (30.01%), 2,4'DDT (18.40%) 4,4'DDT (9.88%) and 4,4'DDD (4.97%). High level of DDE is possibly due to a long-term biotransformation of DDT to DDE and suggest that soils undergo a permanent weathering process (Eqani et al., 2011).

The concentration of 4,4'DDE was ranged from a minimum of 0.58 ng/g to a maximum concentration of 37.9 ng/g at Qlaia at -25cm of depth with a mean value of 10.8 ng/g (Table 27). The relative proportion of the parent DDT compound and its metabolites DDD and DDE can be used to assess the possible pollution sources (Hitch and Day, 1992). The (DDE + DDD) /DDTs ratio in surface soil samples lower than 0.5 indicate a recent inputs of DDT and the ratio higher than 0.5 indicating the historical use of DDTs. Our results showed then value lower than 0.5 at Tal Mehyen and Mkayteh (0.47 and 0.29 respectively), which indicate a recent inputs of DDT in these regions. However, the ratios calculated in the other sites were higher than 0.5, which indicate the historical use of DDTs. DDTs was detected for all depth in our study (table 28). This is probably due to the persistence of DDTs. However, the 4,4'DDT was not detected for all depth. Consequently, the 2,4'DDT/4,4'DDT ratio has been calculating only for soil samples collected at

75cm of depth. The ratio ranges from 0.2 to 0.3 indicate their origin from technical DDT and when the ratio is ranging from 1.3 to 9.3 or higher indicate their origin form dicofol. Our results showed that this ratio ranged from 1.25 to 5.84 (Table 28) which suggest the application of dicofol containing impurities of DDT as an insecticide (Qiu et al., 2005).

HCH and its isomers

The ∑HCHs were detected at high level; the average of ∑HCHs were detected at 10.09 ng/g. This value is higher than those reported at 2.41 ng/g for agricultural soil of Shanghai in China and at 0.49-2 ng/g for agricultural soil of Yaqui and Mexicali valley in Mexico (Sánchez-Osorio et al., 2017). However, our results were lower than those reported in Wuhan soil in China at 15.39 ng/g. α-HCH was the isomer the most detected with the concentrations varied from 0.41 ng/g at Al Mhamra-50cm to 15.08 ng/g at Qaabarine-75cm and a mean value of 3.28 ng/g (Table 27).

The figure 32 and figure 33 show the compositions of DDTs and HCHs in soil. The figure 32 shows that the concentration of α-HCH, β-HCH, δ-HCH, γ-HCH represented 32.46, 31.41, 18.52 and 17.60 % of HCHs respectively. Generally, the technical HCH which contains usually a mixture of α-HCH (60–70%), γ-HCH (10–15%), β-HCH (5–12%), and δ-HCH (6–10%) (Zhao et al. 2009; Chbib et al., 2017). This difference is overdue reasonably to the continuous application of Lindane, and in view that β-HCH is easily adsorbed to the soil organic matter more than the other isomers and it is more difficult to be evaporate from the soil than other HCH isomers. In addition, α-HCH and γ-HCH can be transformed into β HCH in the environment (Walker et al., 1999).

The ratio of α-HCH to γ-HCH could be used to monitor whether the source of lindane. A value of this ratio among 4–7 indicates that the main source is technical HCH and a value nearly zero, reveals that lindane is the source (Zhao et al., 2009). The α-HCH/γ- HCH ratio in the studied surface soil varied from 0.87 (Mkayteh) to 3.35 (Qaabarine) indicating the use of technical HCH (table 28).

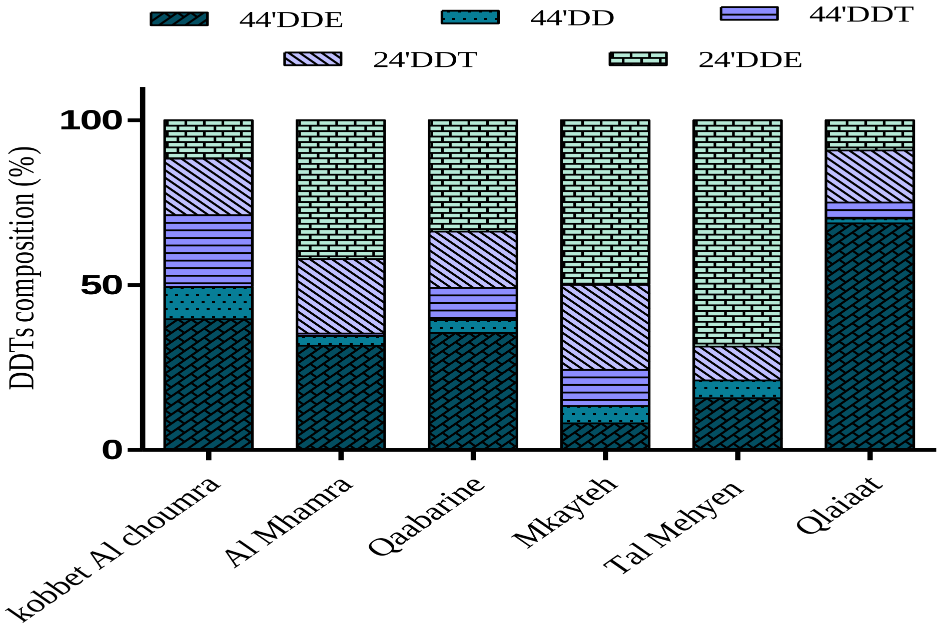

Figure 32 Composition of OCPs in soil of Akkar plain for DDTs

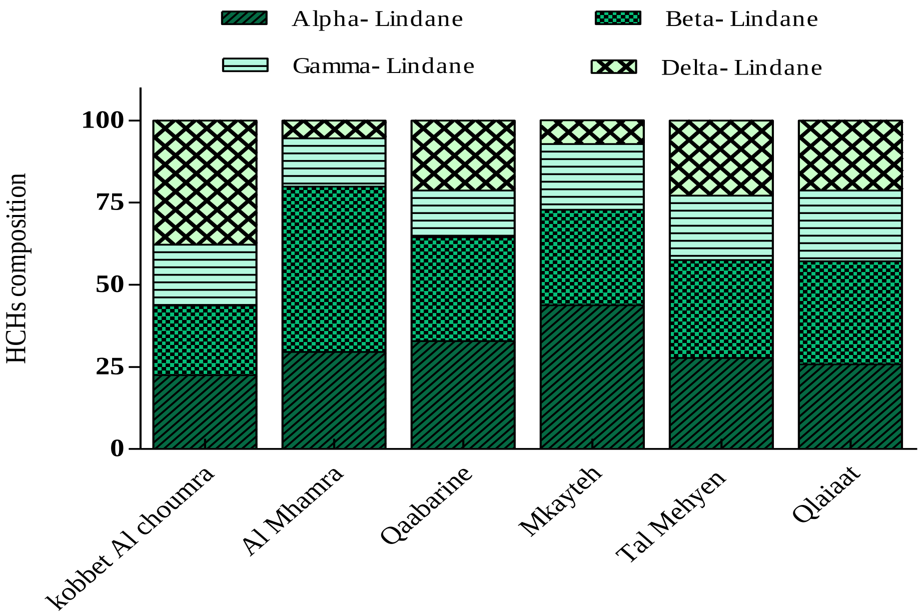

Figure 33 Composition of OCPs in soil of Akkar plain for HCHs

Cyclodiene pesticides.

Cyclodiene insecticides including endosulfans, heptachlors, aldrin, dieldrin, isomers of endrin, and chlordane were studied. The two isomers of Endosulfan (I and II) were detected only in Kobbet Al choumra surface soil. Their concentrations were determined at 0.72 and 3.54 ng/g respectively for Endosulfan I and II (Table 27). And, their metabolite endosulfan sulfate was observed in surface soil of Kobbet Al choumra (18.47 ng/g). For endrin, it was detected only at surface soil of Kobbet Al Choumra at the concentration of 1.11 ng/g and it could be due to its fresh inputs. Its degradation products such as endrin aldehyde was also found in Kobbet Al Choumra. Endrin Ketone was not detected in any sites (Table 27). Concentrations of aldrin varied from <LOD to 9.41 ng/g at Mkayteh at -1m dept. In addition, dieldrin which is the main epoxide of aldrin in the environment has been found in surface soil samples of Kobbet Al choumra (4.73 ng/g), Qaabarine (3.86 ng/g) and Tal Mehyen (22.7 ng/g) (Table 27).

Trans-chlordane and *cis*-chlordane have been only found in a few soil samples of Akkar plain at low levels ranging from <LOD to a maximum of 2.34 ng/g. Mean concentration of *cis*-chlordane was 0.25 ng/g. It was in the same other of *trans*-chlordane detected at 0.26 ng/g (Table 5b). This low concentration may be due to the easier degradation of cis-chlordane in the environment (Eitzer et al., 2001). The *cis*-chlordane/ *Trans*-chlordane ratios in Akkar plain were presented in the table 28. The ratio *cis*-chlordane/ *Trans*-chlordane indicate the origin of chlordane. Indeed, when its ratio <1 indicate that chlordane residues is originated from recent application of chlordane (Bidleman et al., 2002).

For heptachlor, it was detected at high level ranging from 7.79 at Al Mhamra to 39.42 ng/g at Qaabarine. It was higher than that of heptachlor epoxide. The concentration of heptachlor epoxide was in the range of <LOD to 5.41 ng/g at Mkayteh. The heptachlor/heptachlor epoxide ratio values were > 1.5 which indicate the recent introduction of heptachlor in farmland of Akkar plain.

Table 27 **Concentration of OCPs in soil samples of Akkar plain on ng/g d.w**

Site	Depth	α-HCH	β-HCH	γ-HCH	δ-HCH	Aldrin	4,4' DDE	4,4'DDT	4,4'DDD	2,4'DDE	2,4'DDT
Kobbet Al Choumra	0-5cm	0.90±0.12	0.85±0.43	1.03±0.17	2.55±0.17	n.d	20.17±0.03	9.95±1.23	2.67±0.70	0.7±0.20	4.73±1.20
	25cm	0.59±0.1	1.16±0.5	1.04±0.8	n.d	n.d	20.87±3.31	8.33±0.18	4.61±0.80	3.90±0.90	7.58±1.07
	50cm	2.59±0.2	4.00±0.12	2.39±0.03	13.64±0.40	n.d	31.07±0.81	4.67±0.67	10.82±0.10	19.56±0.74	12.86±2.97
	75cm	1.96±0.5	1.22±0.20	0.39±0.11	n.d	n.d	5.89±0.82	0.78±0.29	2.22±0.78	n.d	4.58±0.35
	1m	4.07±0.66	2.24±0.61	3.46±0.77	0.74±0.05	0.66±0.10	4.34±1.98	21.34±4.50	n.d	n.d	5.80±1.50
Al Mhamra	0-5cm	1.66±0.1	0.58±0.08	0.91±0.01	n.d	n.d	14.32±1.50	0.68±0.09	1.26±0.25	7.75±0.39	5.44±1.82
	25cm	1.11±0.1	0.48±0.1	n.d	1.64±0.25	n.d	21.37±2.7	n.d	1.75±0.53	9.38±1.75	7.12±2.04
	50cm	0.41±0.02	1.08±0.02	0.38±0.09	0.25±0.04	2.59±0.50	2.00±0.41	n.d	0.55±0.18	n.d	2.38±1.13
	75cm	0.52±0.12	0.42±0.15	0.13±0.04	n.d	1.62±0.63	1.12±0.70	0.46±0.10	0.04±0.02	48.87±0.25	1.01±0.09
	1m	6.61±0.06	5.03±0.70	3.72±0.07	n.d	n.d	10.87±1.77	n.d	0.94±0.20	n.d	19.37±2.73
Qaabarine	0-5cm	4.56±0.41	9.28±0.90	3.35±0.30	n.d	1.13±0.40	27.56±7.60	5.16±1.00	2.58±0.12	n.d	9.39±1.23
	25cm	2.51±0.25	3.19±0.36	0.65±0.10	n.d	n.d	9.27±3.24	n.d	n.d	13.34±0.85	4.40±3.80
	50cm	3.68±0.21	8.90±1.77	1.72±0.20	8.98±1.10	0.19±0.07	18.64±5.15	6.41±0.89	2.50±0.28	22.34±1.01	11.02±1.97
	75cm	15.08±0.67	4.64±0.30	5.60±0.13	9.75±2.07	n.d	33.46±2.45	10.67±1.14	4.59±1.95	37.23±1.55	13.37±2.77
	1m	3.08±0.42	1.85±0.13	1.14±0.60	n.d	n.d	n.d	2.34±0.20	n.d	11.66±1.06	5.30±2.70
Mkayteh	0-5cm	1.33±0.28	1.17±0.26	0.47±0.22	n.d	n.d	0.92±0.24	n.d	0.98±0.10	4.74±0.12	n.d
	25cm	4.72±0.84	3.34±1.31	1.28±0.50	n.d	9.28±1.25	1.61±0.51	n.d	0.86±0.09	9.27±0.23	n.d
	50cm	4.14±0.50	1.45±0.18	0.55±0.06	0.59±0.12	3.76±0.93	0.58±0.04	0.72±0.29	n.d	6.09±0.90	n.d
	75cm	13.09±0.80	11.95±0.61	9.30±0.03	n.d	8.37±0.36	2.06±1.21	6.91±2.07	0.98±0.30	26.23±1.07	19.09±3.45
	1m	9.81±0.12	4.02±0.13	3.47±0.18	4.87±0.19	9.41±0.24	2.35±0.78	2.60±1.10	2.05±0.80	n.d	4.88±1.90
Tal Mehyen	0-5cm	1.13±0.16	0.77±0.17	1.08±0.21	0.83±0.24	0.22±0.07	2.14±0.65	n.d	n.d	2.14±0.10	0.52±0.17
	25cm	1.48±0.13	2.95±0.16	0.66±0.03	0.89±0.04	n.d	1.14±0.10	n.d	n.d	6.02±0.90	1.48±0.46
	50cm	1.72±0.18	1.07±0.12	0.97±0.09	0.90±0.20	n.d	0.90±0.52	n.d	0.79±0.24	10.26±0.70	2.79±0.78
	75cm	0.82±0.12	1.04±0.07	0.44±0.28	n.d	0.53±0.30	1.03±0.60	n.d	0.49±0.10	6.05±0.67	n.d
	1m	2.01±0.31	1.85±0.004	1.93±0.50	3.28±0.50	0.61±0.20	2.07±0.54	n.d	n.d	7.33±0.96	n.d
Qlaiaat	0-5cm	1.76±0.15	2.72±0.05	1.08±0.06	2.20±0.60	n.d	17.31±2.64	n.d	n.d	n.d	4.84±1.20
	25cm	1.02±0.17	0.80±0.03	0.20±0.09	0.62±0.05	n.d	13.32±3.25	n.d	n.d	n.d	2.11±0.25
	50cm	0.87±0.19	1.24±0.16	0.89±0.04	2.35±0.39	1.04±0.35	37.96±6.50	1.38±0.19	1.22±0.60	n.d	2.72±0.30
	75cm	3.63±0.23	4.11±0.40	3.65±0.08	0.90±0.02	n.d	13.52±4.64	4.81±1.30	0.18±0.09	n.d	8.35±2.10
	1m	1.41±0.44	1.68±0.20	1.41±0.13	1.10±0.39	n.d	6.30±1.67	n.d	0.55±0.06	11.90±2.60	2.24±1.50

Site	Depth	Heptachlor	Heptachlor Epoxide	Trans-Chlordane	Endosulfan II	Cis-Cholrdane	Dieldrin	Endrin	Endosulfan I	Endrin aldehyde	Endosulfan sulfate	Endrin ketone
Kobbet Al Choumra	0-5cm	11.96±0.40	0.23±0.04	0.21±0.08	11.12±0.59	0.11±0.02	4.73±1.50	1.11±0.60	3.54±0.12	8.57±0.50	18.47±6.14	n.d
	25cm	9.78±0.90	n.d	0.59±0.10	n.d	0.74±0.20	75.75±5.20	n.d	n.d	n.d	n.d	n.d
	50cm	10.20±2.20	n.d	0.38±0.06	n.d	0.56±0.09	45.94±5.30	n.d	n.d	n.d	n.d	n.d
	75cm	9.79±1.09	0.12±0.07	0.32±0.07	n.d	0.36±0.12	n.d	n.d	n.d	n.d	n.d	n.d
	1m	13.38±1.08	1.10±0.30	1.07±0.6	n.d	0.89±0.10	99.10±8.9	n.d	n.d	n.d	n.d	n.d
Al Mhamra	0-5cm	11.12±0.50	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	25cm	7.79±0.40	n.d	0.18±0.05	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	50cm	10.04±0.40	n.d	0.26±0.16	n.d	n.d	32.99	n.d	n.d	n.d	n.d	n.d
	75cm	8.23±0.30	n.d	n.d	n.d	n.d	19.03	n.d	n.d	n.d	n.d	n.d
	1m	31.73±2.30	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Qaabarine	0-5cm	39.42±1.17	0.31±0.07	1.42±0.21	n.d	0.77±0.20	3.86±0.06	n.d	n.d	n.d	n.d	n.d
	25cm	22.21±0.90	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	50cm	27.48±2.02	0.08±0.03	0.20±0.09	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	75cm	33.48±0.60	0.93±0.20	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	1m	27.10±0.70	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Mkayteh	0-5cm	8.60±0.10	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	25cm	18.16±0.70	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	50cm	8.11±0.11	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	75cm	25.88±1.01	5.41±0.28	1.17±0.02	n.d	0.85±0.32	9.62±1.30	n.d	n.d	n.d	n.d	n.d
	1m	14.48±0.40	n.d	0.83±0.10	n.d	n.d	62.34±5.30	n.d	n.d	n.d	n.d	n.d
Tal Mehyen	0-5cm	12.70±0.71	n.d	n.d	n.d	n.d	22.72±1.75	n.d	n.d	33.14±4.50	n.d	n.d
	25cm	13.67±1.10	n.d	n.d	n.d	n.d	26.40±2.69	n.d	n.d	9.39±1.20	n.d	n.d
	50cm	12.50±0.57	n.d	n.d	n.d	n.d	n.d	n.d	n.d	11.62±2.20	n.d	n.d
	75cm	47.49±1.10	0.23±0.08	0.59±0.13	n.d	0.42±0.07	4.81±0.72	n.d	n.d	n.d	n.d	n.d
	1m	34.78±0.57	0.40±0.09	0.56±0.09	n.d	0.58±0.10	n.d	n.d	n.d	n.d	n.d	n.d
Qlaiaat	0-5cm	16.53±0.35	n.d	n.d	n.d	2.34±0.43	n.d	n.d	n.d	n.d	n.d	n.d
	25cm	14.04±4.04	n.d	n.d	n.d	n.d	13.59±2.14	n.d	n.d	n.d	n.d	n.d
	50cm	12.82±0.73	0.10±0.03	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	75cm	17.56±1.10	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
	1m	16.72±1.20	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d

n.d: not detected, concentrations < LOD

Table 28 ΣOCPs, ΣHCHs, ΣDDTs, α-HCH/γ-HCH, 4,4'DDE+4,4'DD/DDTs, 2,4'DDT/4,4'DDT, Cis/Trans-chlordane values in each studied sites

Site	Depth	ΣOCPs (ng/g)	ΣHCHs (ng/g)	ΣDDTs (ng/g)	α-HCH/γ-HCH	4,4'DDE+4,4'DD/DDTs	2,4'DDT/4,4'DDT	Cis/Trans-chlordane
Kobbet Al Choumra	0-5cm	93.27	5.33	38.30	0.87	0.60	0.48	0.52
	25cm	134.95	2.79	45.29	0.57	0.56	0.91	1.26
	50cm	158.67	22.61	78.98	1.08	0.53	2.75	1.45
	75cm	27.62	3.57	13.48	5.06	0.60	5.84	1.11
	1m	158.19	10.51	31.47	1.18	0.14	0.27	0.83
Al Mhamra	0-5cm	43.73	3.15	29.46	1.81	0.53	7.96	n.d
	25cm	50.84	3.23	39.63	n.d	0.58	n.d	0
	50cm	62.92	12.11	4.93	1.10	0.52	n.d	0
	75cm	81.46	1.07	51.54	3.96	0.02	2.19	n.d
	1m	78.28	15.37	31.18	1.78	0.38	n.d	n.d
Qaabarine	0-5cm	107.78	17.19	43.69	1.36	0.69	1.63	0.54
	25cm	55.56	6.35	27.00	3.86	0.34	n.d	n.d
	50cm	112.14	23.29	60.91	2.14	0.35	1.72	0
	75cm	168.80	35.07	99.32	2.69	0.38	1.25	n.d
	1m	52.47	6.07	19.30	2.71	0	2.27	n.d
Mkayteh	0-5cm	18.22	2.97	6.65	2.82	0.29	n.d	n.d
	25cm	48.54	9.35	11.75	3.68	0.21	n.d	n.d
	50cm	25.99	6.72	7.39	7.58	0.08	0	n.d
	75cm	140.90	34.33	55.27	1.41	0.06	2.76	0.72
	1m	121.11	22.18	11.88	2.83	0.37	1.88	0
Tal Mehyen	0-5cm	77.61	3.81	5.02	1.05	0.47	n.d	n.d
	25cm	64.09	5.98	8.65	2.26	0.13	n.d	n.d
	50cm	43.52	4.66	14.73	1.77	0.11	n.d	n.d
	75cm	64.25	2.30	7.57	1.89	0.20	n.d	0.72
	1m	56.38	9.07	10.39	1.04	0.29	n.d	1.04
Qlaiaat	0-5cm	48.78	7.76	22.15	1.63	0.78	n.d	n.d
	25cm	45.71	2.64	15.44	5.00	0.86	n.d	n.d
	50cm	62.59	5.35	43.28	0.98	0.91	1.97	n.d
	75cm	56.71	12.29	26.86	0.99	0.51	1.73	n.d
	1m	43.30	5.60	20.99	1.00	0.33	n.d	n.d

n.d: not determinate

Table 29 Concentration of Heavy metals (As, Pb, Cr, Cu, Zn and cdCd) detected in soil samples of Akkar plain and Enrichment factor

		Concentration (mg/kg d.w) ; Enrichment factor of Heavy metals											
Name of site	**Depth**	**As**		**Cd**		**Cu**		**Ni**		**Pb**		**Zn**	
		Conc	EF	Conc	EF	Conc	EF	Conc	EF	Conc	EF	Conc	EF
Kobbet bchamra	**0-25 cm**	5.5	0.54	7.0;	23.46	29.5 ;	0.656	74.1 ;	1.48	35.8 ;	1.79	94.4 ;	0.99
	25 cm	7.1 ;	0.71	7.3;	24.45	31.2 ;	0.692	78.6 ;	1.57	36.0 ;	1.80	97.5 ;	1.03
	50 cm	6.8 ;	0.67	7.2;	24.01	29.3 ;	0.652	77.4 ;	1.55	35.5 ;	1.78	83.2 ;	0.88
	75 cm	4.0 ;	0.40	6.6;	21.96	26.7 ;	0.594	75.3 ;	1.51	23.2 ;	1.16	65.7 ;	0.69
	1m	3.7 ;	0.37	7.3;	24.21	28.4 ;	0.632	79.9 ;	1.60	30.2 ;	1.51	69.6 ;	0.73
Tal Mehyen	**0-25 cm**	1.3 ;	0.13	10.0;	33.20	47.0 ;	1.045	94.3 ;	1.89	42.2 ;	2.11	78.6 ;	0.83
	25 cm	4.4 ;	0.44	10.0;	33.36	47.9 ;	1.064	95.7 ;	1.91	37.3 ;	1.87	83.5 ;	0.88
	50 cm	< LOD ;	< LOD	9.5;	31.80	46.8 ;	1.041	92.8 ;	1.86	44.6 ;	2.23	80.8 ;	0.85
	75 cm	2.8 ;	0.28	10.2;	33.84	47.4 ;	1.053	95.6 ;	1.91	42.0 ;	2.10	80.3 ;	0.84
	1 m	< LOD ;	< LOD	9.7;	32.27	45.3 ;	1.006	95.6 ;	1.91	38.3 ;	1.92	74.7 ;	0.79
	1.5 m	< LOD ;	< LOD	10.0;	33.40	45.1 ;	1.003	94.6 ;	1.89	40.3 ;	2.02	73.2 ;	0.77
	2 m	< LOD ;	< LOD	10.3;	34.33	45.2 ;	1.005	94.3 ;	1.89	41.9 ;	2.09	74.5 ;	0.78
Mkayteh	**0-25 cm**	6.2 ;	0.61	8.8;	29.25	35.0 ;	0.779	83.5 ;	1.67	47.5 ;	2.38	88.7 ;	0.93
	25 cm	7.6 ;	0.75	7.5;	25.11	27.7 ;	0.616	83.2 ;	1.66	36.2 ;	1.81	69.4 ;	0.73
	50 cm	5.8 ;	0.58	7.0;	23.32	25.0 ;	0.555	78.2 ;	1.56	28.6 ;	1.43	63.7 ;	0.67
	75 cm	2.5 ;	0.25	4.7;	15.74	19.4 ;	0.431	61.5 ;	1.23	26.4 ;	1.32	50.0 ;	0.53
	1 m	2.0 ;	0.20	3.8;	12.71	17.5 ;	0.388	54.6 ;	1.09	25.8 ;	1.29	44.9 ;	0.47
Qaabrine	**0-25 cm**	6.5 ;	0.64	9.2;	30.82	39.4 ;	0.875	107.2 ;	2.14	47.7 ;	2.38	85.8 ;	0.90
	25 cm	6.3 ;	0.62	9.5;	31.53	40.3 ;	0.895	107.3 ;	2.15	47.6 ;	2.38	86.1 ;	0.91
	50 cm	5.4 ;	0.54	9.2;	30.83	38.0 ;	0.845	103.4 ;	2.07	43.2 ;	2.16	82.7 ;	0.87
	75 cm	6.5 ;	0.65	9.5;	31.59	38.6 ;	0.859	107.8 ;	2.16	41.6 ;	2.08	83.8 ;	0.88
	1 m	5.7 ;	0.57	9.9;	33.04	39.5 ;	0.878	105.5 ;	2.11	49.1 ;	2.45	81.9 ;	0.86
Qlaiaat	**0-25 cm**	5.7 ;	0.57	10.2;	33.98	45.0 ;	0.999	111.1 ;	2.22	42.9 ;	2.14	87.2 ;	0.92
	25 cm	4.9 ;	0.48	9.3;	30.94	42.6 ;	0.947	104.2 ;	2.08	37.3 ;	1.87	82.3 ;	0.87
	50 cm	3.1 ;	0.31	9.0;	30.06	40.6 ;	0.902	100.3 ;	2.01	40.7 ;	2.04	80.6 ;	0.85
	75 cm	5.1 ;	0.51	9.6;	31.88	42.0 ;	0.933	104.0 ;	2.08	37.7 ;	1.89	80.1 ;	0.84
	1 m	4.4 ;	0.43	9.5;	31.58	40.1 ;	0.891	101.9 ;	2.04	39.7 ;	1.99	76.3 ;	0.80
Al Mhamra	**0-25 cm**	2.9 ;	0.29	3.3;	10.88	25.8 ;	0.574	49.2 ;	0.98	24.2 ;	1.21	95.7 ;	1.01
	25 cm	3.3 ;	0.33	3.4;	11.22	25.7 ;	0.571	50.0 ;	1.00	30.2 ;	1.51	89.6 ;	0.94
	50 cm	3.9 ;	0.39	3.8;	12.79	21.9 ;	0.486	54.3 ;	1.09	24.1 ;	1.21	55.4 ;	0.58
	75 cm	3.7 ;	0.36	3.5;	11.57	20.6 ;	0.459	53.0 ;	1.06	22.2 ;	1.11	47.1 ;	0.50
	1 m	4.3 ;	0.43	3.8;	12.59	20.2 ;	0.449	53.9 ;	1.08	25.3 ;	1.27	53.2 ;	0.56

3.3. Trace metal (ETM)

Akkar plain is an agricultural area where there is the absence of any exposure of anthropogenic and industrial trace metals activities. The individual concentrations for each ETM in the soil of Akkar have been summarized in table 29. The concentration of As, Cd, Cu, Ni, Pb and Zn were found in the soils with averages of 4.1, 7.8, 34.8, 85.51, 36.4, 76.3 mg/kg, respectively. High concentration of some ETM including Pb and Zn in soils may be due to the influence of traffic routes and agricultural activities. Indeed, the Cd, Cu, Ni can present in pesticides (Wallace, 2015). Cd can be found in many farm fertilizers, in cigarette smoke, rechargeable batteries, certain cosmetics, bread and other cereals, potatoes, root crops, and vegetables. It was also used in manufacturing of batteries, and other consumer products (Wallace, 2015). Cd is highly toxic and numerous studies have demonstrated that cadmium may induce kidney damages, lung fibrosis, cardiovascular and may facilitate the development of a variety of cancers such as breast cancer (Godt et al., 2006; Denkhaus and Salnikow, 2002). Its levels in the soil of Akkar varied from 10.8 to 33.84 mg/kg d.w. Tal Mehyen soil is the largely contaminated with a mean concentration exceeding 30 mg/kg d.w.

Ni is a naturally present in the earth's crust and widely used in modern industry and it was the mostly detected with a concentration varied between 49.2 and 107.8 mg/kg d.w (Table 29). While As is a toxic metalloid to plants and animals. It can come from anthropogenic activities such as contaminated irrigation water by mining and smelting industries, agricultural practice like the historical use of arsenic-based pesticides and the application of fertilizers and sludge containing arsenic (Khan et al., 2010). Concentration of As in Akkar soils ranged from < LOD to 7.6 mg/kg d.w at Mkayteh at -25cm depth (Table 29).

Another trace metallic element is lead (Pb). In Akkar plain, the concentrations of Pb was in the range of 1.11 -2.38 mg/kg d.w. It can be found in leaded gasoline, industrial processes, lead-based paints, lead-based solder in water supply systems, batteries, grids, bearings and others (Flora et al., 2012). Pb can affect the central nervous, hematopoietic, hepatic and renal system producing serious disorders (Kalia and Flora, 2005). For Zn and Cu, they are essential trace metal for the biological system of soils and relatively non-toxic to humans and biota at low levels (Plum et al., 2010). Deficiency of these 2 metals in human body reduced the immune function, cause normocytic, hypochromic anemia, leucopenia and neuropenia, and inclusive osteoporosis in children (Kanumakala et al., 2002). Furthermore, Cu can lead to gastro-intestinal effects and liver damages. (Fraga, 2005; Goldhaber, 2003). In Akkar plain, the concentrations of Zn and Cu were in the range of 47.1 - 97.5 and 17.4 - 47.9 respectively (Table 29).

The accumulation of heavy metals on soils pose adverse negative effects including deterioration of soil quality, and reduction of resources capacity (Dudzik et al., 2010). The intensity of pollution with heavy metals in soils depends primarily on physic-chemical properties and characteristics of the terrain (Pająk et al., 2015); the nature and amount of individual trace metals, their geoavailability (Rivera et al., 2015) and their stability in the environment. In the present study, the enrichment factors (EFs) of trace metals in soils have been calculated to determine if they are originated from human activities or from natural source. Consequently, EFs allow to assess the degree of anthropogenic influence (Jiang et al., 2017). EF was calculated according to the following formula (SEF= Ci/CAS). Where, Ci is the concentration of individual trace metal in each sample (µg/g d.w.) and CAS is the world average concentration of individual trace metals reported for the shale by Turekian and Wedepohl, (1961). Furthermore, according to EFs values, the pollution can be classified into five major classes: EF< 1 indicates no enrichment; <3 is minor; 3–5 is moderate; 5–10 is moderately severe; 10–25 is severe; 25–50 is very severe; and >50 is extremely severe (Acevedo-Figueroa et al., 2006).

Our results showed that the average EF values for As, Cd, Cu, Ni, Pb and Zn were 0.43, 25.51, 0.76, 1.69, 1.81 respectively with the ranges of 0.12-0.54, 11.81-33.17, 0.51-1.03, 1.04-2.13, 1.26-2.29 respectively (Table 29). EF values of As and Ni were < 1, indicating a natural origin of the metal. The values for Pb, Zn and Cd were > 1 suggesting that the sources are more likely to be anthropogenic (Diop et al., 2015). And, EF of Cd was very high varied from 25 to 50 with an average of 25.51 which correspond to a very severe enrichment. This value indicate that the studied area was affected by human activities such as the use of pesticides containing impurities of Cd.

To indicate the degree of pollution, the total enrichment factor was calculated as the average of EF for all analyzed metals. The site is highly polluted if TR >3, moderately polluted if

TR value is between 3 and 2, weakly polluted for TR value between 2 and 1, and unpolluted for TR < 1 (Adamo et al., 2005). Kobbet al Choumra, Tal Mehyen, Mkayteh, Qaabarine, Qlaiaat were highly polluted by trace metals originate from cadmium pollution; their TR were 4.80, 6.51, 4.34, 6.39, 6.34 respectively. While Al Mhamra was moderately polluted by HM (TR= 2.62).

4. Conclusion

The agricultural soil of Akkar was a victim of human activities. Indeed, soil is one the final receptacle of environmental pollutants of organic or inorganic compounds. The contamination levels of Akkar plain soil by organochlorine pesticides and ETM have been evaluated. The results have shown that most of studied OCPs were presents in soil samples at all depth. Sum of OCPs were found at high level and ranging from 14.36 to 47.56 ng/g. Soil of Kobbet Al Choumra, which is under vegetable cultivation, was the mostly contaminated by OCPs. DDTs were detected at high levels and their ratios indicate the historical application of dicofol containing some traces of DDTs. Concentrations of HCHs exceeded those levels in other regions and α-HCH/γ- HCH ratio values lower than 4 have demonstrated a continuous use of technical HCH. In addition, a recent application of chlordane and heptachlor in Akkar region was established. A significant absence of soil contamination in the Akkar plain by some heavy metals (As, Zn, Cu, Pb, Ni) has been notify except a high pollution by Cd where high enrichment factor was observed at different sites. Ancient anthropogenic pollution or the application of pesticides containing Cd can be the main source of cd in the soil of Akkar. This study indicate that is necessary to determinate the levels of these contaminants in vegetables and fruits of the plain in order to estimate their human risk.

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Chapter 3

Relationship between the consumption of contaminated water by pesticides and the risk of nervous disorders (Alzheimer and Parkinson) in Akkar - Lebanon

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Abstract

Long-term occupational to pesticides can harm human life and disturb the function of different organs in the body. Published studies in the second largest agricultural zone in Lebanon showed that the wells water is highly contaminated by pesticides. Nervous system is theoretically affected by these pollutants. Very few studies discussed the impact of pesticides in the water on human being health.

A Cross-sectional was performed in this region to investigate the presence of chronic diseases including Alzheimer (AD) and Parkinson disease (PD). It was carried out from July 2015 to November 2015 in the plain of Akkar. A questionnaire was filled face to face with a random sample of 2833 inhabitants aged from 25 to 91 years obtained from 1264 surveys. Descriptive statistics are presented as percentages and means ± SD; prevalence of each disease was calculated. Chi-square X^2, T-test, Anova tests were used. Significance level was established for a value $p<0.05$.

The prevalence of AD and PD of people aged ≥65 years was respectively 10.30% and 10.91% which exceed percentages in other regions. The prevalence rate of both diseases increases as age group increases and their presence in females were higher than males.

Symptoms and signs to AD and PD are higher in inhabitants consuming wells water comparing to those that don’t consume this water (p-values<0.0001).

AD and PD were detected with high prevalence and a significant correlation has been associated between wells water consumption and AD; PD appearance. Future studies could be taken to identify pesticide’s levels in human blood, serum or urine.

Keywords: Alzheimer, Parkinson, prevalence, pesticides contamination, ground water.

1. Introduction

Pesticides regrouped a large number of organic compounds belonging to different chemical families; they are used for removing weeds, fungi and insects and increasing agricultural productivity (Blasco et al., 2002). However, these products are environmental hazards due to their stability, persistence and toxicity (Carvalho et al., 2008; Jiménez and Pastor, 2012). Humans became into contact with the residues of pesticides, through multiple pathways and routes either orally, inhalation, or skin absorption (European Food Safety Authority, 20008).

Long-term exposure to pesticides can induce harmful health effects including neurodegenerative diseases such as Parkinson and Alzheimer diseases, human reproductive problems, immune system dysfunction, cancer, respiratory and other chronic diseases (Alavanja et al., 2013; Andreotti et al., 2009; Band et al., 2011; Dennis et al., 2010; Hoppin et al., 2008; Lee et al., 2016; Mostafalou and Abdollahi., 2013; Multigner et al., 2010; Ortega Jacome et al., 2010; Purdue et al., 2007; Rull et al., 2009; Salam et al., 2004; Shirangi et al., 2011; Tiemann ,2008 ; Zhu et al., 2015. However, the World Health Organization currently estimates that around a billion people worldwide are affected by a neurodegenerative disease (Bongaarts, 2006). Furthermore, many studies showed that people exposed to pesticides had an elevated risk of Alzheimer's and Parkinson’s disease (Ascherio etal., 2006; Baldi et al., 2003; Bonetta ,2002; Chou et al., 2008; Dutheil et al., 2010; Freire and Koifman , 2012; Gatto et al., 2009; Hayden et al., 2010; Lim et al., 2011; Nandipati and Litvan, 2016 ; Parrón et al., 2011; Sánchez-Santed et al., 2016; Tanner et al., 2011; Van Maele-Fabry et al., 2012; Wang et al., 2011).

Approximately 90 % of the total contaminants are from oral exposure including food and wells water (Li et al., 2008). Direct contamination of drinking wells water by pesticides in north Lebanon (Akkar valley) has been documented in the literature (Hu et al., 2011; Júnior and Re-Poppi, 2007; Toccalino et al., 2014). In Akkar, many studies had shown an intensive use of pesticides and a high contamination of analyzed groundwater samples by numerous herbicides and insecticides like Organochlorine (OCPs), Organonitrogen (ONPs) and Organophosphate pesticides (OPPs). This area is vulnerable to long-term pesticides exposure with many publications reporting that the concentrations of OPPs, OCPs, and ONPs exceeded the limits fixed by the European Union Drinking Water Directive (Chbib et al., 2017; El-Osmani et al., 2014). Published studies had shown that the exposure to pesticides was associated with chronic respiratory symptoms and disease among Lebanese children (Salameh et al., 2003). However, little is known about the prevalence of nervous disorders and no modeling efforts exist in estimating the potential human health from exposure to pesticides posed by water or food consumption.

Based on this background, the aim of the present study was to assess the prevalence of two nervous disorders: Alzheimer (AD) and Parkinson disease (PD) in north area of Lebanon namely Akkar valley, and to reveal association between the consumption of wells water and the occurrence of these diseases.

2. Methods

This was a community-based, cross-sectional study, which carried out from July 2015 to November 2015 in fifteen villages located in the valley of Akkar, north Lebanon. The selected area is nearly a square (10X10 Km) in the northern part of Lebanon, limited by the Lebanese Syrian border from the north, and the Mediterranean sea shore from the west. Divided into three zones (Fig. 34). (*Kobbet Al Choumra, Mqaitaa, Qaabarine, Qlaiaat, Tall Mehyen, Ballaneh Al Hissa, Hissa, Masaoudieh, Tal Andi, Al Chaykh Ayach, Tal Biri, Tal Abbas El Gharbi, Kouikhat, Tal Abbas El Charqi, Al Mhamra).*

Face to face interviews with all individuals living in the selected villages. Adults aged ≥ 25 years old living in these villages were included in the survey, with a total sample of 2833 inhabitants. Non Lebanese inhabitants (Syrians and Palestinians) were excluded. The survey was conducted by the Lebanese University, Faculty of Public Health III. Research committee for PhD degree’s at the Lebanese university and the university of Lille - France approved the study. Verbal consent form was obtained from all interviewed families.

2.1.Questionnaire

A provisional version of the questionnaire was created after a literature review concerning the toxicity of pesticides and their effects on human health. The questionnaire went through content validity through a meeting with specialized physicians the different fields related to the subject doctors in various specialties has taken place in the syndicate of doctors in Tripoli-Lebanon, and approved the questionnaire.

The first draft of the questionnaire has been tested on a sample of 20 individuals. The final version resulted from the pre-test was ready for the survey with maximum possible clarity, easiness and understandable form of questions with minimum confusion and bias.

The questionnaire included basic demographic characteristics for each adult member in the family such as: age, sex and civil State disease history in addition to information concerning water consumption such as: source, quantity …

The Alzheimer's disease (AD) has been identified by its symptoms such as gradually worsening ability to remember new information, disturbances in language and other cognitive functions, confusion with time or place, problems with words in speaking or writing. These occur because the first neurons to malfunction and die are usually neurons in brain regions involved in forming new memories. Furthermore, changes in behaviors and personality including anxiety, depression and impairments in activities of daily living such as bathing, dressing, eating, loss of ability to communicate can be other symptoms of AD (Qiu et al., 2009).

Parkinson's disease (PD) has been manifested by cardinal signs like bradykinesia or slow movements, chronic resting tremor, cogwheel rigidity and posture instability. In progress stages, the cardinal motor symptoms of PD like cognitive decline, neuropsychological problems, and autonomic failure will reduce the patient's activities of daily living, and health-related quality of life and sleep disturbances (Chen et al., 2010).

2.2.Statistical analysis

Descriptive statistics are presented as number (%) and means ± standard deviation (SD).

Chi-square test is performed to for nominal variables, T-test and ANOVA test were used for comparison for scale variables. Significance level was established for a p-value <0.05.

Data analysis was performed using the "IBM SPSS statistics version 21" software package.

Prevalence is defined and calculated as the total number of persons with an AD and PD within the total number of given population at a fixed point in time. According to the equation below:

$$\frac{Number\ of\ people\ with\ AD\ \ or\ PD}{Number\ of\ people\ measured} * 100$$

3. Results

A total of 2883 adult aged ≥ 25 years old were included in the final analysis of this study. The participants' demographic characteristics in the three zones are presented in Table 30. The male to female ratio was nearly equal (1:1) with no significant differences in sex ratios or mean age between the three zones. The OCs concentrations µg/L, OPPs concentrations µg/L and the total pesticides concentration is not significantly different between the three Zones, and they are all higher than the recommended international standards (table 30). The prevalence of the different AD and PD symptoms are similar in the three zones (all p-values >0.05) (table 31). The results of this study reveal that the prevalence of AD is between 4.74% and 6.86% in the three zones, and the prevalence of PD is between 3.73% and 5.9% (table 31).

The prevalence of AD and PD symptoms varied widely between males and females, and with age groups. The prevalence of PD symptoms increased significantly (p-value < 0.0001) as age increases starting from 2.77% up to 10.91% for age groups [25-39] and +65 years old respectively . Similarly, the prevalence of AD symptoms increased significantly (p-value = 0.008) as age increases starting from 4.92% up to 10.30% for age groups [25-39] and +65 years old respectively (Table 32). Females were found significantly with higher prevalence of AD and PD symptoms compared to males (P<0.0001) (Table 32).

Most people with Alzheimer and Parkinson's diseases are diagnosed at age 65 or older, in our study, 17 persons (10.30 %) aged +65 years had AD symptoms and 18 persons (10.91 %) had PD symptoms (Table 32).

The results of the study reveal that 86% of total inhabitants consume wells water as drinking and cooking water without any treatment. The presence of PD symptoms is significantly associated with the average duration and intake quantity for both drinking and cooking (table 33). The mean duration of drinking water was 27.83 years for patients with PD symptoms significantly higher (p-value = 0.018) than patients without PD symptoms with mean duration of 23.70 years. The mean duration of cooking water was 25.52 years for patients with PD symptoms significantly higher (p-value = 0.024) than patients without PD symptoms with mean duration of 22.21 years. However, the results of this study did not reveal an association between the presence of AD symptoms and water consumption (Table 33).

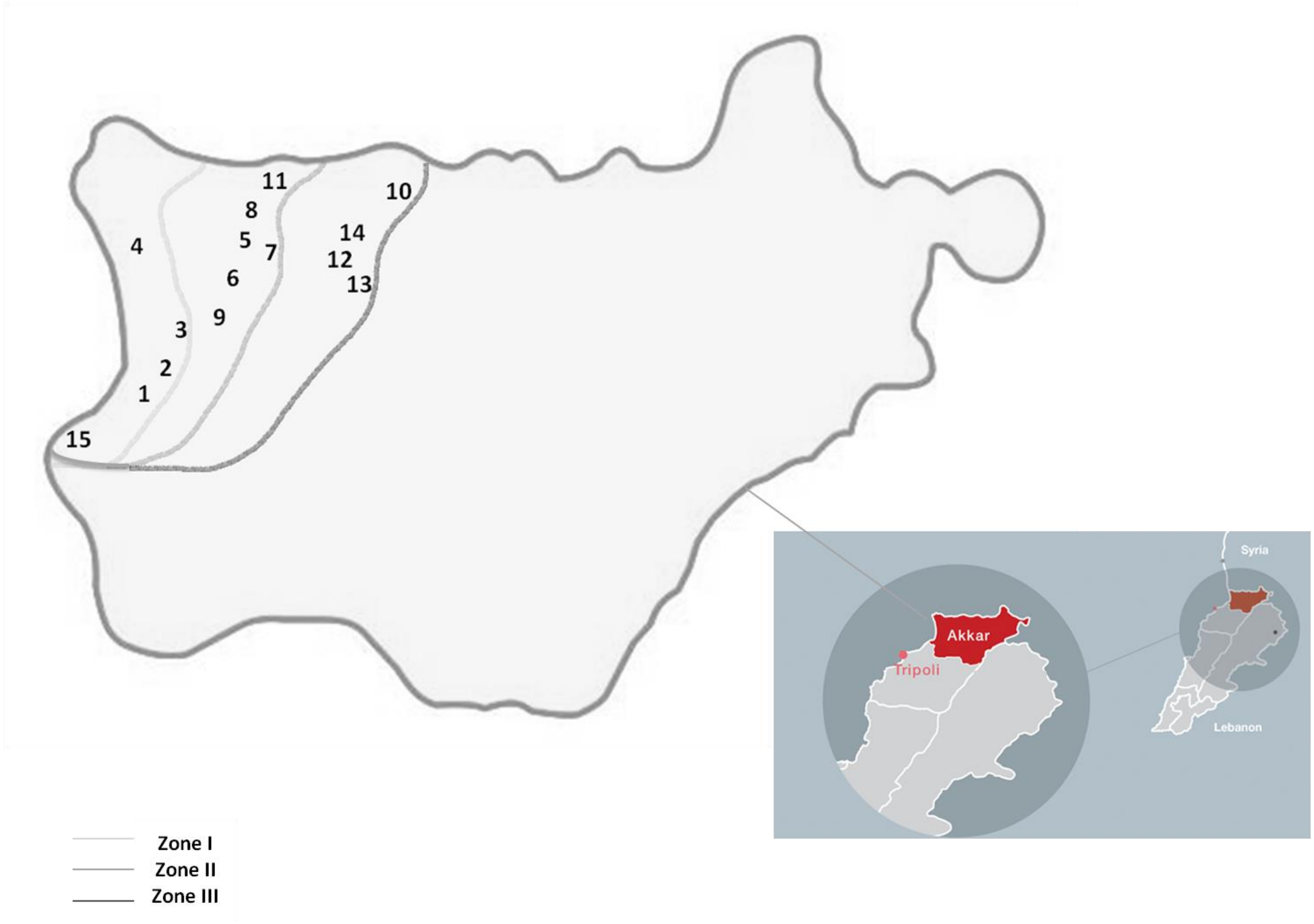

Figure 34 Location of survey area (Akkar and the 15 studied villages)

Table 30 Characteristics of studied villages, total number of participants by sex and age, and pesticides concentration in wells water in the three zones, Akkar 2015.

	Zone I	Zone II	Zone III	P-value
Number of Villages in the area	11	12	10	
Sampled villages	5	6	4	
Altitude	[0-70] m	[55-150] m	[120-230] m	
Distance from sea shore	[0-6] Km	[6-12] Km	[12-18] Km	
Sampled villages inhabitants	1426	2215	717	
Total sampled individuals	908 (63.7%)	1501 (67.8%)	424 (59.1%)	
Sex				
Female	449(49.4%)	734(48.9%)	204(48.1%)	0.899
Male	459(50.6%)	767(51.1%)	220(51.9%)	
Age				
[25-40]	480(52.9%)	759(50.6%)	204(48.1%)	
[40-65]	382(42.1%)	649(43.2%)	194(45.8%)	0.464
>= 65	46(5.1%)	93(6.2%)	26(6.1%)	
OCs concentrations µg/L	28.63±12.40	36.47±17.01	35.37±4.10	0.604
OPs concentrations µg/L	52.15±16.84	35.45±17.76	45.63±6.27	0.235
Total pesticides µg/L	80.78±22.81	69.92±22.54	81.00±10.25	0.526

Table 31 Prevalence of AD and PD symptoms for participants aged ≥25 in the sampled villages, Akkar plain 2015.

	Zone I		**Zone II**		**Zone III**		**P-value**
	N	%	N	%	n	%	
Total participants age ≥ 25	908		1501		424		
Alzheimer Symptoms							
Confusion with time and place	26	2.86%	58	3.86%	18	4.25%	0.328
Difficulties in remembering	39	4.3%	97	6.46%	23	5.42%	0.080
Anxiety	33	3.63%	55	3.66%	18	4.25%	0.838
Depression	42	4.63%	84	5.6%	32	7.55%	0.096
Participants with Alzheimer	43	4.74%	103	6.86%	25	5.90%	0.104
Parkinson Symptoms							
Arthralgia	159	17.51%	257	17.13%	89	21.0%	0.177
chronic resting tremor	47	5.18%	67	4.46%	28	6.60%	0.222
Tingling of articulations	69	7.60%	57	3.80%	30	7.08 %	0.201
cogwheel rigidity	31	3.41%	39	2.60%	20	4.72%	0.507
Slow motion	32	3.52%	44	2.93%	17	4.01%	0.483
Difficulty with talking, walking	27	2.97%	30	1.20%	12	2.83%	0.274
Participants with Parkinson	38	4.19%	56	3.73%	25	5.90%	0.479

Table 32 Prevalence of PD and AD symptoms by age and sex, Akkar plain 2015.

	Age [25-39]		**Age [40-64]**		**Age ≥65**		**Total**		**p-value****
Total participants	**1443**		**1225**		**165**		**2833**		
Female	757		558		72		1387		
Male	686		667		93		1446		
Parkinson									
Female	33	4.36%	47	8.42%	13	18.06%	93	6.71%	**<0.0001**
Male	7	1.02%	14	2.10%	5	5.38%	26	1.80%	**0.009**
Total	**40**	**2.77%**	**61**	**4.98%**	**18**	**10.91%**	**119**	**4.20%**	**<0.0001**
p-value*		**<0.0001**		**<0.0001**		**<0.0001**		**<0.0001**	
Alzheimer									
Female	59	7.80%	59	10.57%	13	18.06%	131	9.44%	**0.008**
Male	12	1.75%	24	3.60%	4	4.30%	40	2.77%	**0.075**
Total	**71**	**4.92%**	**83**	**6.78%**	**17**	**10.30%**	**171**	**6.04%**	**<0.0001**
p-value*		**<0.0001**		**<0.0001**		**<0.0001**		**<0.0001**	

p-value* comparison between males and females

p-value** comparison between age groups

Table 33 Prevalence of PD and AD by water consumption and duration, Akkar plain 2015

	Participants without symptoms	Participants with symptoms	P-value
Parkinson			
Wells water consumption			
Yes	2340 (95.39%)	113 (4.61%)	0.006
No	374 (98.42%)	6 (1.58%)	
Drinking water			
Duration (year)	23.70±18.51	27.83±20.39	0.018
Quantity (L/day)	12.90±8.61	15.20±9.11	0.005
Cooking water			
Duration (year)	22.21±15.54	25.52±15.83	0.024
Quantity (L/day)	9.09±9.45	11.34±8.18	0.010
Alzheimer			
Wells water consumption			
Yes	2299 (93.72%)	154 (6.27%)	0.1695
No	363 (95.30%)	17(4.47%)	
Drinking water			
Duration (year)	23.80±18.76	25.47±17.12	0.27
Quantity (L/day)	12.94±8.62	14.14±8.99	0.10
Cooking water			
Duration (year)	22.22±15.59	24.44±15.27	0.08
Quantity (L/day)	9.14±9.41	10.17±9.17	0.18

Data is presented as mean ± SD or n (%) as appropriate.

4. Discussion

In this survey, we study the two frequent adult neurodegenerative disorders (Alzheimer and Parkinson diseases) among the inhabitants of the plain of Akkar. To our knowledge, this is the first study to educate the relation between water consumption, contamination status of pesticides in nervous disorders in Lebanon.

4.1.Alzheimer's disease:

Alzheimer's disease (AD) -the most frequent cause of dementia- is a progressive chronic neurodegenerative disease that progress through three stages preclinical Alzheimer's disease, mild cognitive impairment (MCI), and dementia related to the criteria and guidelines classification**.** Research on its symptoms, causes, risk factors and treatment have not been treated that since the last 30 years (Alves et al., 2008; Chen et al., 2010; Tanner et al., 2011).

The greatest risk factor for Alzheimer's disease is advanced age. Most people with Alzheimer's disease are diagnosed at age 65 or older. The present survey has shown that the prevalence of AD (10.30%) was higher than in other countries (1.94; 4.4% in Europe) (Kalaria et al., 2008) People younger than 65 had also developed the disease but with a low rate (table 32). Furthermore, with the exception of the rare cases of Alzheimer's caused by known genetic mutations, the strong association of AD with increasing age for both female and male (Table 32) may reflect that advanced age alone is not sufficient to cause the disease. Other cumulative effect of multiple risks, including biological and psychosocial factors, and exposure to environmental pollutants. In addition, other diseases such as Cardiovascular Disease and diabetes increase the Risk Factor for AD.

The prevalence of AD varied widely between genders, it was 3 times higher in female from male especially for the oldest-old age groups which are similar to the results shown in Fratiglioni et al study on 2000.

Exposure to numerous classes of pesticides during consumption of wells water for many years of life was also evaluated. A significant association (p-value<0.049) has been reported (table 33) the appearance of AD has not been dependent neither by quantity nor by duration. For drinking and cooking water, the p-values were >0.05.

4.2.Parkinson's disease

Parkinson's disease (PD) - the most common movement disorder besides essential tremor and the second most common neurodegenerative disease progress slowly with age into 6 stages which means that development may last for 20 years. PD is basically disease of ageing, with a peak age between 60 and 65 years, approximately 1–2% or 1-7% of the population in the world over 65 years suffers from PD. In the present study, the prevalence was higher with a value of 10.91%. Furthermore, PD has been recorded in young adults (prevalence was 4.98% and 2.77% for people aging [40-65] and [25-40] years old respectively.

It's so difficult to establish the main causes of PD, identified genetic risk factors are rare and account for only 5% of PD cases. Since the prevalence is very high in our survey, this can be assumed that exposure to environmental factors including neurotoxic pesticide such as organophosphates, carbamates, organochlorines, pyrethroids and some other insecticides interfere with neurotransmission and function of ion channels in the nervous system and contribute to increasing the risk of PD (Costa et al., 2008).

Furthermore, several factors can be associated with PD including cigarette smoking, coffee/caffeine intake, high uric acid levels, cholesterol levels and anti-inflammatory drug use (De Lau and Breteler,2006; Liu et al.,2017; Noyce et al.,2016). A Gender differences in the risk of developing PD have been shown with an overall ratio (F: M) female / male ratio of 4.

This ratio has been reversed in almost of studied cases all over the world (Alves et al., 2008).

Highly significant association has been reported between water consumption and the prevalence of PD (p-value<0.05) (table 33). Human is the final accumulator of pesticides exposure. For both drinking and cooking water consumption, a relation of dose-effect has been reported, even the quantity of contaminated wells water consumption has been increased, the dose of ingested pesticides increased, and the risk of PD has been increased (p-value<0.05); it was the same for the duration (p-value<0.05).

The limited knowledge about the amount and the temporal change of crops patterns near their homes, the average quantity of pesticides in food intake may also influence the survey results.

5. Conclusion

In the region of Akkar, water wells constitute the main source of drinking water. The nervous system was particularly sensitive to toxic pesticides; which may play a role in the occurrence of neurodegenerative defects on people aging more than 25 years old. This screening survey proved higher prevalence of AD and PD in the people more exposed to pesticide then others less exposed our study. Results have shown that a significant association exists among exposure to pesticides and the development of Alzheimer Disease is less than that of the Parkinson. Prevalence differences among population are difficult to interpret because it may arise from differences in underlying incidence, exposition routes or duration. It is clear that more research on the prevalence, incidence and impact of water consumption on human health is needed. More studies could be established in order to identify pesticide's level on serum, blood, urine, hair in the inhabitants of this region or the breast milk. Evaluation of vegetables pesticides contamination in the plain of Akkar could be realized.

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Chapter 4

A cross-sectional study on pesticides use in agriculture and the risk assessment on inhabitants (Case study of Akkar-Lebanon)

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Abstract

Living in agricultural areas such as Akkar expose humans to toxic chemicals such as divers type of pesticides. A cross-sectional in the plain of Akkar was carried out to determinate the association of the consumption of contaminated wells and chronic diseases and health disorders in children. High prevalence of birth defects, mental, and growth retardation has been found in Akkar. Children were very sensitive to pesticides exposure, a big difference in the risk of congenital anomalies has been shown between maternal occupational exposure to pesticides and those less exposed. Chronic diseases that have a range of potential risk on person's lifestyle and quality have no identified special cause. Results of allergic rhinitis, Asthma, Chronic Obstructive Pulmonary Disease and cancer have been difficult to be interpreted and correlated with water consumption.

1. Introduction

In the last decades, pesticides were extensively used in the control of pests in agriculture and farm workers. Their residues may be transported for a long distance, persist in the different environmental matrices (soil, sediment, aquatic system, air, surface and groundwater) and accumulate in the fatty tissues of organisms (Falandysz et al., 2004; Mishra, & Sharma, 2011). In addition, they present a risk for humans living near rural regions especially for sensitive population including pregnant women, children, fetuses, malnourished and the immune-compromised. Moreover, the individual chemical category of each pesticide, its toxicity, the way, the dose, the duration of exposure and the exposure route (Hernández et al., 2013; EFSA, 2008) identify the severity of their effects on humans. Organophosphorus and organochlorine pesticides are known by their high toxicity and their role in the occurrence of reproductive problems, congenital abnormalities (Charlier and Foidart, 2005; Levario-Carrillo et al., 2004a, b; Sanchez-Pena et al., 2004; Brucker-Davis et al., 2008) ,cancer, respiratory effects and nervous disorders) has been suggested by public health researchers. **(**Mostafalou & Abdollahi, 2013; Band et al., 2011; Baldi et al., 2003; Costa et al., 2008 ; Alavanja, Ross, & Bonner, 2013; Shirangi et al., 2011; Abdollahi et al., 2004; Baltazar et al., 2014 ; Kim et al., 2017)

Humans can be exposed to pesticides more often than with any other chemical compound, even industrial pollutants (Margni et al., 2002; Tankiewicz et al., 2010; Li et al., 2008; Gerber et al., 2016). This contact cannot be only caused by occupational exposure to these chemicals during agricultural activities, but also by inhalation of polluted air and ingestion of water and food cha chemicals. In order to reduce their risk, several directives regulated the pesticides levels in the environment by setting maximum values. The most popular reglementation are WHO, European directives, United States standards (WHO, 2010; DCE, 2017; EPA, 2017). Agriculture is the major pesticide consuming sector (Ali et al., 2014). In Lebanon, 11% of the land in Lebanon is used for agricultural activities with extensive use of pesticides (World Bank, 2016) where the Agriculture sector is the third most important sector in the country (Haydamous & El Hajj; 2016). Our previous studies have demonstrated a high pollution of groundwater in a biggest agricultural zone "Akkar" by several type of pesticides including OCs, OPs and ONs due to their unrestricted and illegal use for crop protection and household disinfection in the area (Chbib et al., 2017a). And a positive correlation between nervous disorders in the same region and the wells water consumption has been established (Chbib et al., 2017b). In this overview, to assess the risk in the plain of Akkar, our present study has been aimed to get a full screening about the characteristics of the population (their activities, way of living) and to discuss the association of pesticide's exposure with the different types of chronic diseases.

1.1.a, population and data collection

The present study was a part of a thesis project and was approved by the Lebanese university and the university of Lille - France. It was focused in the plain of Akkar which is one of the largest littoral plains in the Northern Lebanon. Due to geographical characteristics and to the climate in this region (precipitation levels, temperature…); Cereals, potatoes, grapes, citrus and vegetables crops can be found in Akkar accompanied with intensive application of pesticides. Our cross-sectional study conducted during summer 2016, and covered 15 villages situated in this plain (*Kobbet Al Choumra, Mqaitaa, Qaabarine, Qlaiaat, Tall Mehyen, Ballaneh Al Hissa, Hissa, Masaoudieh, Tal Andi, Al Chaykh Ayach, Tal Biri, Tal Abbas El Gharbi, Kouikhat, Tal Abbas El Charqi, Al Mhamra).* The study population (8128 persons) consisted of the totality of general Lebanese population living in these villages. In addition, Syrian and Palestinian person were excluded from our study. Interviews were done with a group of volunteer students of the Lebanese University, Faculty of Public Health III and an informed verbal consent form has been signe by participants before the beginning of interviews.

Before data collection, the questionnaire has been tested on 60 individuals, validated and adjusted when necessary by doctors from various specialties in order to obtain a final version with a maximum possible clarity, easiness and understandable form of questions with minimum confusion and bias.

The dataset included age, sex, and socioeconomic status such as civil states and job, disease history in addition to information concerning water consumption such as: source, quantity …

1.2.Statistical analysis

The possible confounders as age, smoking, years of farming and educational level were considered. Alcohol can be another confounding factor, but in this study, data of alcohol use was not included due to remarkable absence of alcohol consumption limited by the economic and traditional reasons in this area. All data were entered and analyzed by the "IBM SPSS statistics version 21" software package**.**

Frequencies (%) and means ± standard deviation, cross tabulations, and graphical displayed were presented in the results. In addition, prevalence of each disease has been calculated and the results were compared with other regions. Chi-square test,T-test, for the comparison of two means univariate test of proportion and ANOVA test were used in the analysis with a significance level established for a p-value <0.05.

2. Results and discussion

2.1.Sample characteristics

Table 34 Statistical Data- General Information and characteristics of studied villages

	Total		Male		Female		P-value
	N	%	n	%	N	%	
Number of inhabitants (n=8345)			4202	50.35%	4143	49.65%	
Age group							
[0-18[years	2882	35.46%	1443	35.54%	1439	35.37%	
[18-65[years	5075	62.44%	2523	62.14%	2552	62.73%	0.396
≥65 years old	171	2.10%	94	2.32%	77	1.89%	
Total	8128	100%	4060	100%	4068	100%	
Educational level							
None	1418	18.14%	704	17.86%	714	18.42%	
Primary	3483	44.54%	1828	46.37%	1655	42.69%	
College	1949	24.93%	972	24.66%	977	25.20%	0.0004
Secondary	494	6.32%	238	6.04%	256	6.60%	
University/college	475	6.07%	200	5.07%	275	7.09%	
Total	7819	100%	3942	100%	3877	100%	
Smoking Age≥13							
No	4290	65.76%	2050	63.37%	2240	70.75%	
Yes	2111	34.24%	1185	36.63%	926	29.25%	
Total	6401	100%	3235	100%	3166	100%	<0.0001
Job of father and mother							
Farmer	422	17.32%	359	30.24%	63	5.04%	
Other	2015	82.68%	828	69.76%	1187	94.96%	
Total	2437	100%	1187	100%	1250	100%	<0.0001

The study sample included a total of 8345 participants aging from < 1 to 91 years' old which 4202 were males and 4143 were females. Participants were comprised of 2882 children (0 to 17 years), 5075 young and middle older adults "adults" (18 to 64 years old), and 171 older adults (≥ 65 years old). The mean age was of 32 years (32±38.30 for male; and 32±35.52 for female). The total ratio M/F was approximately near 1 and no significate difference (P=0.0396) has been shown between age group (Table 34).

Approximately, 88.89% and 86.31% of male and female respectively were below secondary and a high school diploma. Furthermore, 30.24% of father's and 5.04% of mother's work as farmer in their private land (Table 34). More than 51% of them work without using personal protective equipment (PPE) such as goggles, Powder Air Purifying Respirators (PAPR) or air purifying disposable particulate masks with exhalation valve, nitrile protective gloves or long rubber gloves, nitrile rubber footwear, chemical-resistant coveralls and aprons and waterproof hat). While 49% of them use sometimes this PPE. Furthermore, as known, in Lebanon, Conversely, occupational use of pesticides is as common as agricultural working, according to the report of Central Statistics Administration (1998), 10% of the Lebanese population). So farmworkers can be exposed to a high risk of pesticides during pest control operation (Yang et al., 2014).

According to World health organization, the minimum age for smoking was between 13-14 years old. In the present study, 36.63% and of male and 29.25% of female aging >13 years old were smokers (cigarette and/or Shisha smoking) (Table 34).

2.2.Diseases.

Birth defects and children developmental

During the first 5 years of life, child development is dynamic and involves the maturation of interrelated functioning such as cognitive, physical and socio-emotional capabilities. It is the period of neurological and physical development (Chilton et al., 2007). Early exposure to multiple risks, including toxics, malnutrition, poor health or infections during prenatal or during the first years can contribute to developmental problems or malformations affecting their life quality, their cognitive, motor, and their social-emotional development. (Grantham-McGregor et al., 2007). In Lebanon 0.83% of children< 5 years die on 2015 (Save the children, 2017). Prevalence of some children developmental problems in Akkar has been presented in the table below (Table 35)

Table 35 Prevalence of congenital disorders, intrauterine growth retardation, mental retardation and delayed growth in Children (Akkar).

Diseases	Number	Percentage	95% CI	P-value	Other studies
Children: age ≤ 1-year-old (n=204)					
Congenital disorders or birth defects	5	2.45 %	[0.80 - 5.63]	0.173 0.258; 0.646	2.4% (Francine et al., 2014) 1.35% (Zahed.P, et al., 2017) 1.49% ; 2% (Biri et al., 2005)
Intrauterine growth restriction	27	13.24 %	[8.91-18.67]	< 0.0001 0.011 0.494 0.895	5.13% (Romo et al., 2009) 8.3% (Takimoto et al., 2005) 11.7% (Djadou et al., 2005) 12.93%(Jdeidi et al ., 2006)
Children: age]1-5] years old(n=682)					
Delayed Growth	11	1.61%	[0.81- 2.86]	0.007 < 0.0001	7% (Victora et al., 2011) 9.5% ;10.1% (Save the children, 2017)
Children: age [3-10] years old(n=1256)					
Mental retardation or mental disability	30	2.39%	[1.62- 3.39]	< 0.0001	0.72% (Raina et al., 2012)

Congenital anomalies (CA) can be one of these problems. It is defined as the congenital anomalies as structural or functional anomalies including metabolic disorders, present at birth (WHO, 2017a). These defects of prenatal are classified as structural (e.g. orofacial clefts) or as functional (e.g., metabolic disorders) abnormalities or syndromes. They result in seriously damaging effects on children's health and life (Zahed. P, et al., 2017) causing elevated morbidity and mortality rates (Agha et al., 2006). According to a report by the World Health Organization (WHO) in 2017, globally, congenital anomalies were identified as causes of death in about 303,000 new borns below 1 month of age every year. Although approximately 50% of all birth defects have not been linked to an exact cause, there are some known genetic (30-40%), environmental (5-10%) and other causes or risk factors. Furthermore, maternal exposure to certain pesticides and other chemicals during pregnancy may increase the risk of having a fetus or neonate affected by congenital malformations (WHO, 2017a).

In Akkar, the prevalence of major CA (2.45%) (Table 35) was approximately the same value finding in in Lebanon on 2014, but higher than those values discovered in Iran (1.35%), in South Africa (1.49%) and in England (2%). The variation in rates may be explained by socio-economical, racial and ecological influences (Biri et al., 2005). Furthermore, significantly higher incidence of malformations in offspring of intra-family marriage (5.79%) has been shown comparing to other babies coming from parents without intra-family marriage (3.4%) with a p-value of 0.0502. While the percentage increase with smoking during pregnancy (percentage were 4.22% and 3.55% for smoker pregnant and non-smoker pregnant respectively) but a non-significate association has been found between the presence of CA and smoking during pregnancy (p-value=0.682).

Intra-Uterine growth restriction (IUGR) was referred by WHO to infants born at a weight less than 2500 g (WHO, 1990). In this study the prevalence of IUGR was 13.24% (Table 35). It was significantly higher than those observed in Japan, (8.3%), and no signifcantly higher than those reported in Togo (11.7%), Tunisia (12.93%) (Takimoto et al., 2005; Djadou et al., 2005; Jdeidi et al., 2006). The difference between the different countries of the world is explained by disparities concerning ethnicity, race, social status Economic, eating habits ... (Reime et al., 2006). In addition, other maternal factors such as maternal age, poor nutrition, uterine or cervical anomalies multiple gestation, Intrauterine infection, placental insufficiency, smoking, alcohol or drug usage were related to both prematurity and IUGR (Romo et al., 2009).

Delayed growth is a poor or abnormally growing rate (slow height or weight gains) of children younger than age 5 compared to the norm of an appropriate growth chart for their age (Rogol et al., 2000).

The determination of low growth is not well understood and are probably due to the numerous factors that play an important role in growth failure such as endocrine and/or metabolic dysfunction, foetal haematological status, and nutritional status genetics factors, specific nutrient deficiencies, and environmental factors may play an important role in growth failure (Iughetti et al., 2016; Habara & Steinberg, 2016)

In the last decades, growth failure was a great concern due to elevated rate (>20% of the population in developing countries) Many countries were forced to reduce the prevalence of DG; WHO lead by its projects to reduce by 40% the number of children under-fives who have a growth failure. For example, in Brazil, the prevalence of DG was decreased from 37% in 1974-1975 to 7% in 2006-2007 (WHO, 2012)

Delayed growth (DG) was appearing in 1.61% of children aged < 5years (Table 35) significantly comparing to 7% in Brazil, Tunisia (10.1%), Turkey (9.5%) (save the children, 2017)

Mental disorder is defined as a particular state of intellectual functioning that begins in childhood and is characterized by decreased intelligence level and limited adaptive skills (Bhagya, 2013; WHO, 2017b) such as communication (language), self-care, home living, cognitive, motor and social abilities, community use, self-direction, health and safety functional academics, leisure and work manifested “before age 18”. WHO estimates that 10% of the world's population has some form of disability. Intellectual disability (ID) or Mental retardation (MR) is one form of disability and affects 1-3% of human population. In general, the severity can be identified according to the International Classification of Diseases – Tenth revision (ICD-10) by the Intelligence quotient (IQ) levels. The cause of mental retardation in one-third to one-half of all affected individuals is unknown; MR can be from genetic causes or chromosomal abnormalities (~10% of MR in most cases) (Van Karnebeek et al., 2005), heterogeneous environmental (2.02%) and from Addictions, accidents or infections during prenatal or postnatal developments (Bhagya, 2013)

In the present study, for children aging 3 and 10 years, MR prevalence has been observed at 2.39% (Table 35). And it was highly significant than values reported by Raina et al., (2012) in two villages

(Kammun and Kashmir) of India (0.72%) **(**Raina et al., 2012). Furthermore, 2.3% of mental disability has been found in Karnataka (Kumar et al., 2008).

Several studies have been established on mental disability, which reported the causal factors that still unknown for 50% of the cases, and showed the difference among children and adolescent adults, male and female in both rural and urban areas (Maulik et al., 2011).

Chronic diseases.

Chronic diseases such as cancer, heart disease, chronic respiratory diseases and diabetes are characterized by their generally slow progression and long term duration, which are considered as the leading cause of mortality in the new world, representing over 60% of all deaths. In low and middle income countries this percentage increase to be 80% (WHO, 2017a). These illnesses cannot be cured; they alter the quality of life but an appropriate management can be a sufficient controller.

Cancer

Table 36 Prevalence of cancer by age and sex, Akkar plain 2015.

	Male	Female	Total	Other studies
	n (%)	n (%)	n (%)	
Age [18-65[	28(1.11%)	12(0.47%)	40(0.79%)	
Age 65	6 (6.38%)	1 (1.30%)	7 (4.09%)	12.5% (Maddams J et al, 2009)
Total	34(1.30%)	13(0.49%)	47(0.90%)	
P-value	0.735*		0.895 ;0.85; 0.735	1.1% ; 1.2% ; 1.5% (Pisani.P et al, 2002)
			0.398 **	3% (Maddams J et al, 2009)

* : p-value between age and sex groups

* : p-value between the results of the present study and other studies

Cancer is resulted from abnormal cell division. It starts when cells grow out of control and crowd out normal cells. Many types of cancer can be identified concerning rectum, lung, breast, brain….

In Lebanon, Cancer risk are rarely reported in the published literature; due to the increasing of cancer incidence, the impact of this disease is beginning to be a priority for the ministry of health incidence of cancer has increased (Zein, 2007). And until now, any project was reported for its incidence in Akkar. In this study, Cancer in male was nearly 3 times higher than in female. e.g, in total population, 0.49% of female was cancer compared to 1.30% for male (Table 36), Prevalence proportions for all cancers combined increased dramatically with age. The prevalence of Cancer was in the present project 0.599% for the total adult population which is lower than those values reported in industrial countries including UK (3%)Western Europe and Australia and New Zealand (from 1.1 to 1.5%) (Maddams et al, 2009; Pisani et al, 2002)

Moreover, as shown in fig 35, the most common incident form of cancer in Akkar was lung cancer (18 % of all incident cases), succeeded by liver cancer (12%) and prostate cancer (12%). It was similar to the study of Boyle, P. and Ferlay, J. (2005). While in Canada, prevalence for the leading cancers was at the following order: female breast: 20.6%, prostate: 18.7%, colorectal: 12.9% and lung cancer (Ellison, L. F., & Wilkins, 2009).

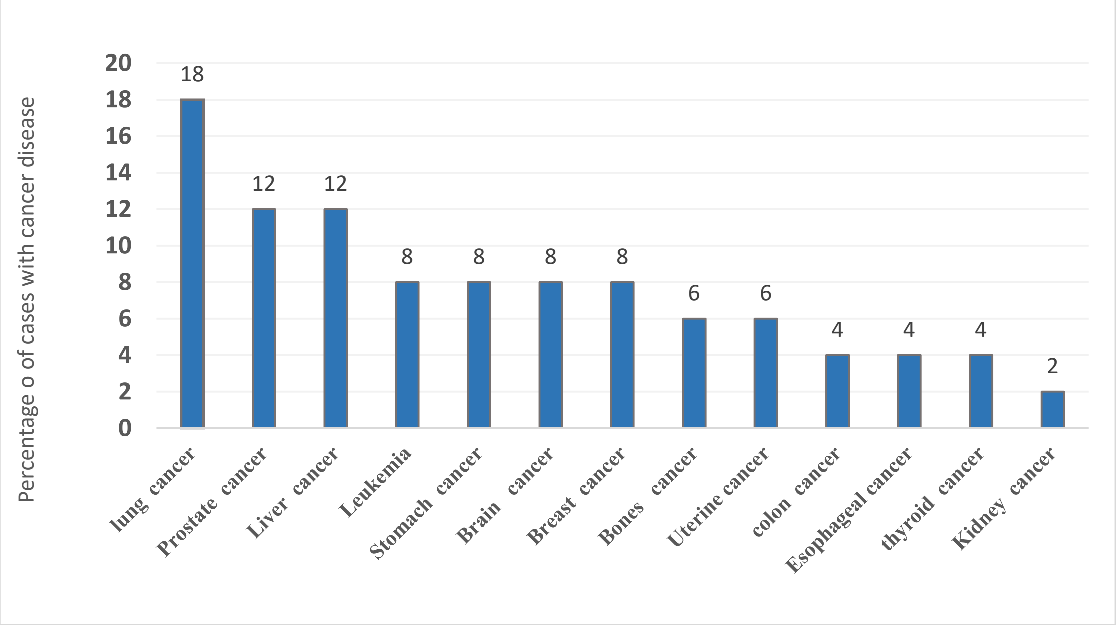

Figure 35 . Percentage of different type of cancer cases reported

Chronic respiratory disease.

Table 37 Prevalence of Allergic Rhinitis, Asthma and COPD by age and sex in Akkar.

	Male n (%)	Female n (%)	Total n(%)	Other studies	P-values**
Allergic rhinits					
Children [0-18 years old[(n=2882, M=1443, F=1439)	73 (5.06%)	74 (5.14%)	147 (5.10%)		
Adults ≥18 years old (n=5463)	164 (6.27%)	229 (8.71%)	393 (7.19%)		
Total (n=8345)	237 (5.84%)	303 (7.45%)	540 (6.47%)		
P-value*	0.98			10-25 % (Lundbäck, 1998)	0.006 <0.0001
				17-29 % (Bauchau et al, 2005)	<0.0001
				(9-42 %) (Settipane & Charnock, 2006)	0.039-<0.0001
Asthma					
Children [0-18 years old [(n=2882, M=1443, F=1439)	15 (1.039)	15(1.04%)	30 (1.04%)	10% (American Academy of Allergy Asthma and Immunology, 2017)	0.102
Adults ≥18 years old	62 (2.37%)	57 (2.17%)	119 (2.18%)	4.3% (To et al., 2012)	0.08
Total	77 (1.90%)	72 (1.77%)	102 (1.22%)	8% (AAAAI, 2017)	0.012
P-value*	0.839				
COPD					
Adults [18-45 years old[(n= 4041, M=1945, F=2096)	6 (0.31%)	7 (0.33%)	13 (0.32%)	1.5% (Roche et al., 2008)	0.73

Adults ≥45 years' old (n= 1171, M=657, F=514)	11(1.67%)	5 (0.97%)	16 (1.37%)	5-10% (Fuhrman & Delmas, 2010)	0.51
Total (n=5212)	17 (0.65%)	12 (0.46%)	29 (0.56%)		
P-value*	0.22				

* P-value between age and sex groups.

** P-value between the results of the preent study and other prevalences

Chronic respiratory diseases (CRDs) regrouped diseases of the airways and structures of the lung including Allergic rhinitis, Asthma, COPD, pulmonary hypertension… The prevalence of allergic diseases and asthma are increasing worldwide, particularly in low and middle income countries. Their main cause is not completely understood.

i. Allergic rhinitis (AR) is caused by inhalation (breathing) of an outdoor allergen such as trees, grass and weed pollens, or an indoor allergen including animal dander, indoor mould, or house dust mites (WHO, 2017c). Intensity of symptoms and the prevalence of AR increase when age increases. The prevalence was 5.01% in children and 7.19% in children (Table 37). No significant difference has been established between sex. Comparing to other countries especially industrialized one (9-42%) (Bauchau et al, 2005; Settipane & Charnock, 2006), Akkar had low prevalence of AR (6.47% of the total population in Akkar)

ii. Asthma is considered as the most common disorder among chronic respiratory dysfunctions affecting both children and adults. It is a chronic disease characterized by recurrent attacks of breathlessness and wheezing causing by the lining of the bronchial tubes swells; severity and frequency of the attack can vary widely from person to person. (WHO,2017d) According to WHO estimates, 300 million people suffer from asthma and with the rising trends, it is expected to increase to 400 million, by 2025. In general, the prevalence of asthma can vary widely between countries and between age groups: from 4.1% to 32.1% in young children and from 2.6% to 32.2% among adolescents (Puddu et al., 2003)

In Akkar, 1.04% of children (Male and female aging less than 18 years old) and 2.18% of adults (aged higher than or 18 years) (2.37% for male and 2.17% for female) had asthma symptoms (Table 37). Male to female ratio was nearly 1 for Asthma in both children and adults. A significant difference has been shown between ages. With the absence of industrial activities in Akkar's region, Asthma may be due to the long-term inhalation of several pollutants such as allergens, tobacco smoke and chemical irritants including some pesticides which can be a risk for developing Asthma. For all age groups, the prevalence of Asthma in Akkar was lower than values reported in the population of US on 2009. For example, for the total population, the percentage was 1.22% comparing to 8% in U.S (American Academy of Allergy Asthma and Immunology, 2017).

iii. While Chronic Obstructive Pulmonary Disease (COPD), which is known as chronic lung diseases causing limitations in lung airflow (WHO, 2017e), was mostly found in older adults aged 45 years old (1.37%); with a prevalence of 1.67% and 0.97% for male and female respectively and a male to female ratio of 1.72.

In addition, in almost of studies, COPD has been appeared and calculated on adults aging 45 years old. However, in our cases "Akkar region", a small number (0.32%) of young adult inhabitants in Akkar (0.32%; 0.31 and 0.33% for male and female respectively) suffer of COPD (Table 37).

The increased percentage in older male adults comparing to the female can maybe be due to the exposure to Tabaco smoking (percentage of smoking was 9% and 22% for male and female respectively), to air pollutants or to occupational chemicals during agriculture that are considered as the main risk factor of COPDs.

COPD can be manifested by breathlessness, excessive sputum production, and a chronic cough that may progressively lead to death.

Furthermore, prevalence of COPDs in our studied region was lower than those in France (5% for older adults and 1.5% for young adults) (Fuhrman and & Delmas, 2010; Roche et al., 2008)

2.3.Diseases and wells water consumption

Table 38 Prevalence of PD and AD per family by water consumption.

Disorders	Non-contaminated water	Contaminated water	Total per family	% per family	P-value
Congenital disorders or birth defects (number of family=1258)					
No	181	1072			
Yes	0	5	5	0.40%	0.358
Intra-uterine growth retardation (number of family=1258)					
No	181	1050			
Yes	0	27	27	2.17%	0/031
Mental retardation (number of family=1258)					
No	181	1047			
Yes	0	30	30	2.38%	0.023
Delayed Growth (number of family=1258)					
No	181	1066			
Yes	0	11	11	00.87%	0.172
Allergic Rhinitis (number of family=1262)					
No	125	688			
Yes	56	393	449 and 540 persons	35.58%	0.159
Asthma (number of family=1262)					
No	164	970			
Yes	17	111	128 and 237 persons	10.14%	0.718
COPD (number of family=1262)					
No	179	1072			

Yes	2	10	12 and 29 persons	0.91%	0.816
Cancer (number of family=1264)					
No	177	1037			
Yes	4	46	50	3.955%	0.193

As shown in table (38). The number of children with congenital disorders, intra-uterine growth retardation, mental retardation and delayed growth who were coming from family that they mother not consume wells water is 0, and it was found that those disease appears only in family consuming contaminated water. In this case, P-value was impossible to be calculated (% of family that have these diseases and not consume the wells water is zero) And maybe a positive correlation can be existed between wells water consumption and the apparition of those diseases. Cary et al, showed that women living near agricultural areas with high use of pesticides revealed increased risks of congenital anomalies, low birth weight, miscarriage (Gracía et al., 2017; Carmichael et al., 2014; Ueker et al., 2016; Trejo & Perry, 2017)

Concerning chronic disease, they have been several reports on increased rate of asthma in people occupationally exposed to pesticides (Hernandez et al.,2011) and an increased risk of chronic obstructive pulmonary disease (COPD) in farmers (Hoppin et al., 2007). A non-significant correlation has been established between those diseases and wells water consumption due to that the main causes of respiratory illnesses is the inhalation and not the ingestion one. Furthermore, numerous factors like the diversity of allergens that can induce asthma and COPD.

several studies conducted by the International Agency for Research on Cancer (IARC) have confirmed that the exposure to toxic chemicals such as pesticides can induce cancer by affecting genetic material directly (via induction of structural or functional damage to chromosomes, DNA, and Histone proteins), or indirectly disrupting the profile of gene expression through impairment of cellular organelles (George & Shukla, 2011; Baldi & Lebailly, 2007). In the present study, a non-significant correlation was being established between cancer and water consumption. This is can be due to the presence of numerous factors including age, sex, individual susceptibility, amount and duration of exposure, and simultaneous contacts with other cancer causing chemicals that can disturb the carcinogenic capacity of pesticides.

3. Conclusion

In Akkar, the prevalence of congenital disorders, intrauterine growth restriction, delayed growth, mental retardation was significantly higher than other values reported in other regions. Most of diseases were age and sex dependent. Maternal exposure to pesticides can contribute to increase the risk of those anomalies.

For respiratory chronic diseases, the complexity and severity of allergic diseases, including asthma, continue to increase especially for children and young adults. In addition, Chronic Obstructive Pulmonary Disease was found in male higher than those female for the same range of age (+65 years). In addition, the prevalence was lower than values in industrialized regions.

Cancer was found at low percentage; lung, liver and prostate cancer were the mostly type detected. Correlation between chronic diseases and contaminated water consumption is difficult to be interpreted due to their multiple sources. More information on pesticides, way of exposure levels should be important to estimate the risk of exposure to these chemical. Forced studies on reproductive disorders could be also realized.

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Conclusion and prospects

During their application, massive amounts of pesticides may be volatilizing from their target area to the atmosphere and transport for a long distance. According to their physic-chemical properties such as their persistence, solubility and stability, pesticide residues and metabolites are omnipresent contributing to local or regional contamination in the environment. These compounds can deposit into soil and sediments, contaminate the surface waters via runoff and drainage, and achieve the groundwater by infiltration especially in agricultural areas. Furthermore, production and use of pesticides exposed formulators, sprayers, mixers, loaders and agricultural farm workers to a high risk of various toxic chemicals including heavy metals, OCs, OPs, ONs, triazines.

In the last decades, the use of diverse type of pesticides in agricultural and human activities has been increased. These hazardous chemicals are highly toxic to the environment, animals and humans, and canbe accumulated in the organisms through the food chain. Many studies have revealed that direct or indirect long-term exposition of chemical substances including pesticides via dermal, inhalation and ingestion pose adverse effects on human health like congenital disorders, nervous troubles (depression, Alzheimer disease, Parkinson disease), respiratory diseases (Asthma and Chronic Obstructive Pulmonary Disease), reproductive problems (infertility and sterility). Due to their toxicity, and their persistent characteristics, Stockholm convention has banned the use of some toxic pesticides (DDTs, HCHs…). Nowadays, a particular concern is to reduce the pesticides levels in the environment; for this purpose, several regulations have been regulated their levels in groundwater and soil such as DCE, WHO and USEPA.

In Lebanon, the agricultural sector is an important economic sector, which is altered by climate changes and this last modifies in temperature and rainfall. Agricultural activities in Lebanon are characterized by an intensive and irregular use of pesticides, with a high production and high exportation intensity of fruits and vegetables to the Middle East.

This thesis was conducted in collaboration between the laboratory “LASIR” of University Lille 1 and Laboratory “Science of water and environment” of the Lebanese University. It was financed by the association AZM & SAADE in Lebanon and the PHC CEDRE project.

The work conducted in this thesis has contributed to the publication and diffusion in form of scientific articles and the participation in a numerous national and international conferences concerning pesticides, water resources, and environmental pollution.

The present project has been focused in an important agricultural zone namely Akkar in Lebanon where the wells water was consumed by local citizen as drinking water. The research has been composed of 2 major parts which are an analytical study accompanied by an epidemiological study. The first one presents the current contamination levels of groundwater and soil of the plain Akkar by the pesticides and heavy metals. While the second part was the first assessment which conduct to determinate the prevalence of some diseases in inhabitants of Akkar and to discover the relation between water contamination and these illnesses in the same region. In each part, it was necessary to minimize most of errors during sampling, collection of samples and the statistical data and the analysis in order to have representative and reliable results.

In this study, a significant quantity of currently-used OCs, OPs, and ON pesticides has been detected in closed wells of fifteen villages in Akkar at high levels exceeded the limits settled by European Unionand more particular, some restricted toxic pesticides are still present in this water such as DDTs and HCHs, chlordane, aldrin, endrin, dieldrin, heptachlor, methylparathion. Organophosphorus pesticides were the largely used; for organochlorines, DDTs detected in this area came from recent local deposition of the dicofol; while HCHs came from the application of technical HCH.

Furthermore, in fact that soil is a final reservoir of pollutants and a second source of pollution, determination of organochlorine pesticides and ETM levels from 0cm to 1m of depth allow to give some notes about their historical use because this pollutants canDeteriorate the of soil quality, and reduce the resources capacity. At all depth, soils of Akkar was polluted by most of studied OCPs principally in soils that were under vegetable cultivation. Aldrin and endrin ketone were not detected in any sites; while, Endrin, Endosulfan (I and II) and Endosulfan sulfate were only found in the surface soil of cultivated land. The historical use of dicofol containing some traces of DDTs and the continuous use of technical HCH could be the cause of the presence of

DDTs and HCHs in this region. Further, a recent application of chlordane and heptachlor was established and an ancient anthropogenic pollution or the application of pesticides containing Cd can be the main source of the severe pollution by Cd in the soil of Akkar. The enrichement factor values was demonstrated the natural origin of Pb, Zn and Cd, and the anthropogenic source of As and Ni.

In addition, discovering of the type of soil was important to better understand the behaviors of these contaminants. Soils of different villages of Akkar had the same composition. The total fraction has been composed of quartz, Calcite, Montmorillonite, Dolomite, Kaolinite and a less of Smectite. But the mineral composition in clay fraction has varied widely between the studied sites. In most cases, smectite was the predominant mineral followed by kaolinite, Chlorite and Illinite.

Based on the analysis of the collected surveys in the current study, an important percentage of parents were farmers that work with pesticides especially insecticides and herbicides permanently without using personal protective equipment (PPE). And more than 80% of the inhabitants consume their private wells water.

Nervous system in Akkar was particularly sensitive to toxic pesticides; the occurrence of the neurodegenerative defects (AD and PD) was greatly observed on people aging more than 25 years old, and increased significantly with age ; where for people aging higher than 65; the prevalence of these two diseases were considered very high congenital malformations, intra-uterine growth retardation , mental and physical children development problems were exclusively found in family consuming contaminated water with prevalence highest than other regions in the world.

Chronic diseases were less affected by this contamination and generally, diseases were appeared in people more exposed to pesticides who consumes contaminated wells water more than other less exposed. A significant association could be existed among exposure to pesticides and some human diseases. In addition, it was remarquably that the risk posed by pesticides for children is much higher than that for adults.

Our work was present the current status of Akkar groundwater and soil contaminated by pesticides related to the inputs of several pesticides used in agricultural activity. It could be used as a report about human health diseases in this region. The results should be taken in consideration to stimulate the governance for designing an Integrated Management Program to control the concentration of pesticides and their metabolites in the environment (water, air and soil) and to assess the potential risk of these products to consumer's health. Moreover, these existent data can be useful for the NGOs for training and educating farmers about the application of pesticides and their toxicity.

Furthermore, to confirm the results, more studies could be realized in order to identify pesticide's level on serum, blood, urine, hair or the breast milk in the inhabitants of this region. And the questionnaire could be applied on another non agricultural area in Lebanon to discover the prevalence of diseases and compare them with the present results. Indeed, the pesticides contamination in Akkar affects not only the inhabitants of this region but also the customer of its fruits and vegetables. Determination of crops quality and their contamination by pesticides in the plain of Akkar become a necessity to evaluate their contamination levels and to investigate the risk for human consumption. In addition, a continuous monitoring of soil and water quality should be recommended at studied sites and all the villages of Akkar. All these analyses could be a baseline information to determinate the daily intake of each molecules and the toxicological effects on humans.