Atmospheric pressure gas chromatography triple quadrupole mass spectrometry as a powerful tool for trace analysis of pesticides in epidemiological studies

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INTRODUCTION

Legacy pesticides are still of interest in the research and regulatory community due to their continued presence in the natural environment. Although most of these halogenated compounds are banned from the market worldwide, dichlorodiphenyltrichloroethane (DDT) use is still permitted in parts of the southern hemisphere and Asia for malaria control, creating current emissions sources. Other legacy pesticides (e.g., chlordanes, dieldrin, hexachlorobenzene, mirex, etc.) continued to be found in the natural environment and biomagnify through food chains years after regulations on production and use have been placed.
Analysis of DDTs and their metabolites is typically done by gas chromatography (GC) coupled to mass spectrometry (MS) using electron impact ionisation mode (EI). Enhanced sensitivity can be achieved for DDT and other legacy pesticides using negative chemical ionisation (NCI). Introductionof GC-tandem-mass spectrometers (GC-MS/MS) have helped enhance the analysis for environmental applications by minimizing background and matrix response on the analytical signal using multiple reaction monitoring (MRM). Novel innovation in analytical technology has combined atmospheric pressure ionisation (API) with GC-MS/MS. The APGC-MS/MS instrument offers the advantage of ionisation at atmospheric pressure conditions together with reduced fragmentation. API is a relative soft ionisation process compared to EI where ions can be generated through charge transfer or protonation processes. Mass spectra can be dominated by $M^{+\bullet}$, $[M+H]^+$ or $[M-H]^+$, offering extensive capabilities for selection of precursor ions for targeted quantification in MRM.

COMPOUNDS

Analytes:
- DDTs and metabolites
- Chlordanes
- HCHs
- Dieldrin, aldrin, endrin, isodrin
- Toxaphenes (Parlar 26, 32, 50, 62)
- Endosulfanes
- HCB, PeCB
- Mirex
- Trifluralin
- Octachlorostyrene

Internal standards: ^{13}C or D isotope labelled analytes

INSTRUMENTAL SET-UP

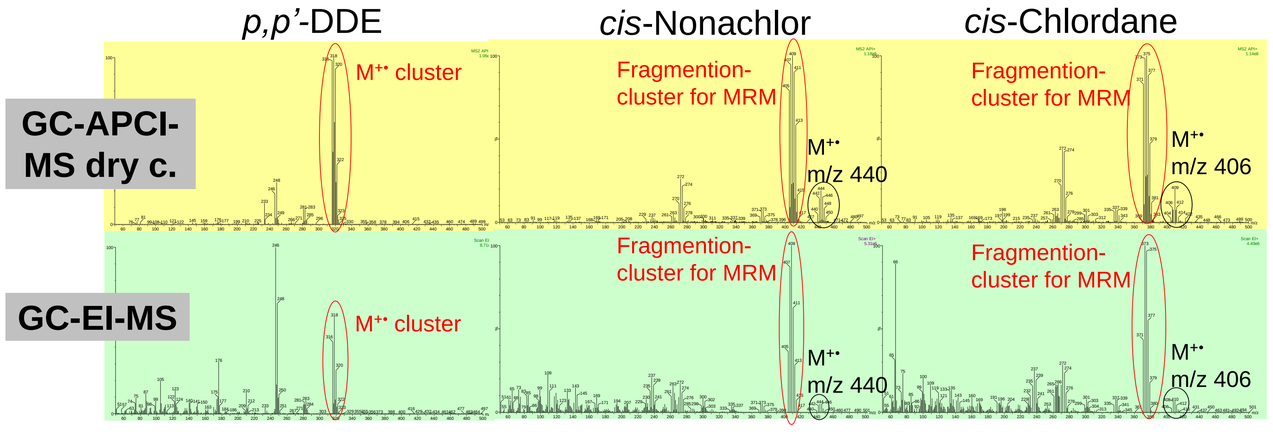
APGC-MS/MS: Waters APGC-Xevo TSQ
GC: Agilent 7890A with CTC PAL AS
Ionisation mode: AP (dry condition) and APCI with H_2Oas modifier (wet condition)
Column flow: 2 ml/min, constant flow

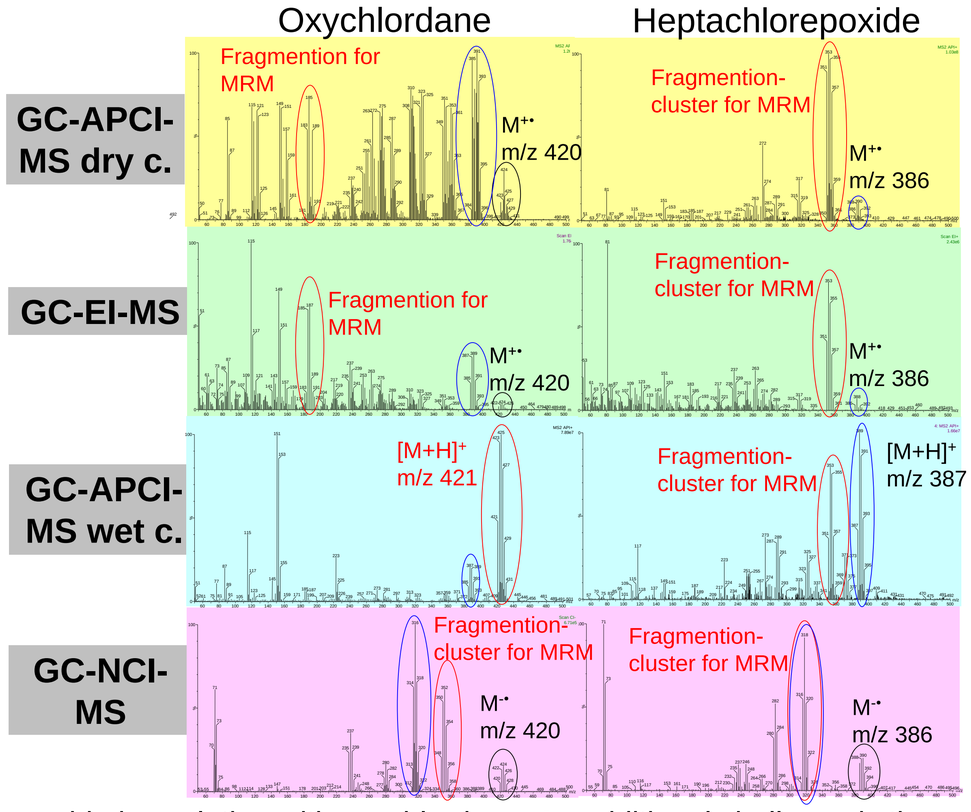
GC-EI/NCI-MS/MS: Waters quattro micro GC-MS
GC: Agilent 7890A with 7683B AS or Agilent 6890N with CTC PAL AS
Ionisation mode: EI and NCI with methane
Column flow: 1 ml/min, constant flow

Same conditions for both set-ups:

Injector: split/splitless, 250°C **Injection volume:** 1 µL **GC-transferline temperature:** 280°C
Column: Agilent DB-5 ms (30 m x 0.25 mm x 0.25 µm)
GC-temperature programme 1: initial 70ºC for 3 min, rate of 15°C/min to 180°C, 5°C /min to 280°C, hold for 6 min.
GC-temperature programme 2: initial 70ºC for 0.5 min, rate of 30°C/min to 200°C, 5°C /min to 240°C, 10°C /min to 280°C, hold for 5 min.

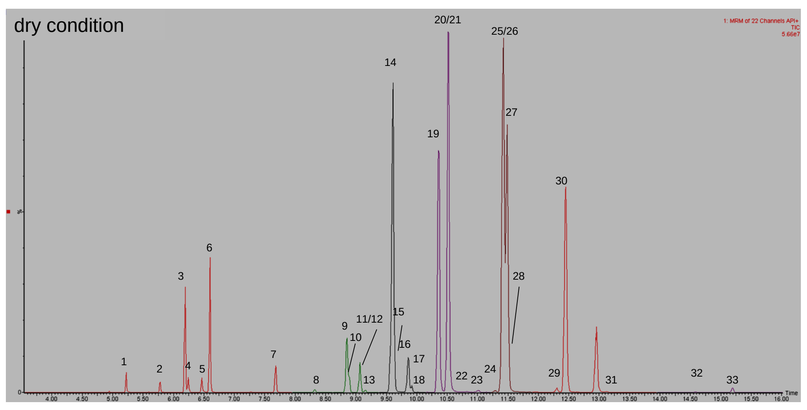
FULL SCAN SPECTRUM CHARACTERISTICS OF SELECTED COMPOUNDS



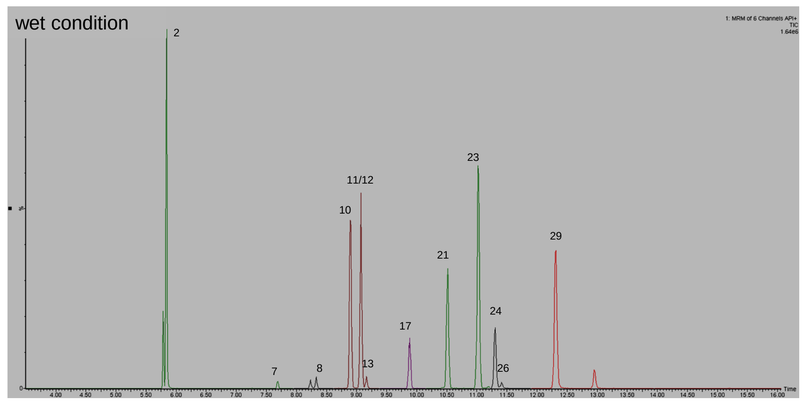


➡ **high abundance of $M^{+\bullet}$ ions and/or higher m/z fragment ions with GC-APCI-MS**

MRM-CHROMATOGRAMS



GC-APCI-MS/MS chromatogram, measurement under charge- transfer condition (dry condition)



GC-APCI-MS/MS chromatogram, measurement under proton-transfer condition (wet condition)

Analytes
1 Pentachlorbenzene
2 Trifluralin
3 α-HCH
4 Hexachlorbenzene
5 β-HCH
6 γ-HCH
7 Heptachlor
8 Aldrin
9 Octachlorostyrene
10 Isodrin
11 cis-Heptachlorepoxide
12 Oxychlordane
13 trans-Heptachlorepoxide
14 trans-Chlordane
15 o,p'-DDE
16 cis-Chlordane
17 Endosulfan I
18 cis-Nonachlor
19 p,p'-DDE
20 o,p'-DDD
21 Dieldrin
22 Toxafen Parlar 26
23 Endrin
24 Endosulfan II
25 p,p'-DDD
26 trans-Nonachlor
27 Toxafen Parlar 32
28 o,p'-DDT
29 Endosulfan sulfate
30 p,p'-DDT
31 Toxafen Parlar 50
32 Toxafen Parlar 62
33 Mirex

Heptachlorepoxide is coeluting with oxychlordane. An additional challenge is the presence of similar ions and fragment ion clusters in their spectra. The APCI application shows, compared to AP, EI and NCI, a better sensitivity and selectivity with regard to the $[M+H]^+$ and fragment ion clusters.

FIRST RESULTS FROM MRM EXPERIMENTS

➢**APGC-MS/MS vs GC-MS/MS:** Signal enhancement resulting in better sensitivity as e.g. factor 160 – 600 for DDTs and metabolites, ~20 for Chlordanes and 120 for Nonachlors (GC-progr.1 and same transitions)

➢**Charge-transfer vs proton-transfer condition:** compound specific results; proton-transfer condition gives enhanced sensitivity for trifluralin, dieldrin, aldrin, endrin, isodrin and endosulfanes and better selectivity for oxychlordane and heptachlorepoxides. (GC-progr. 2 and adapted transitions)

CONCLUSIONS

The soft ionisation processes in the API source generate reduced fragmentation patterns with higher abundance of $M^{+\bullet}$ or $[M+H]^+$ ions and high m/z fragmention clusters, resulting in better sensitivity on the APGC system compared to a GC-MS/MS system. Faster scan rates associated with new generation instrumentation further enhances the sensitivity on the APGC-MS/MS system. These results demonstrate that APGC-MS/MS is a powerful tool for trace analytical work on legacy pesticides in human matrices.

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