Research group on Quality and Sustainability of horticulture production

LIFE AGREMSO3IL

LIFE 17 AGREMSO3IL ENV/ES/000203

Región de Murcia

The project LIFE AgRemSO$_3$il: Agrochemical remediation of farm soils by combining solarization and ozonation techniques

Conference Innovations to reduce and remediate farm soil pollution: a contribution to the EU Soil Strategy. Brussels, November 21st 2022

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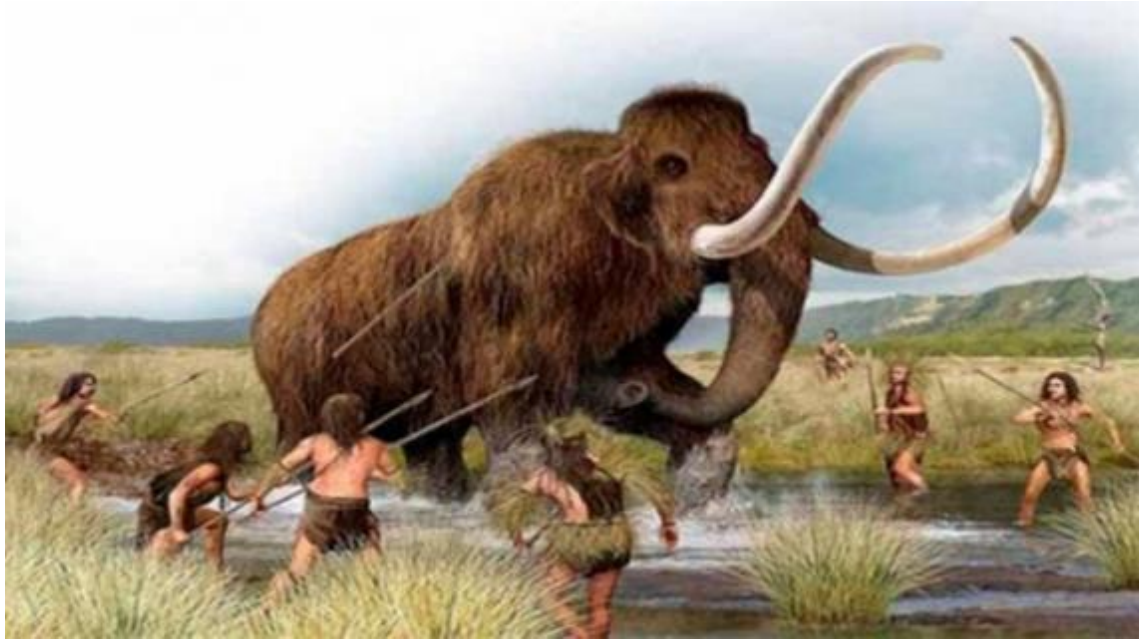
Facts at issue: Agriculture versus Environment



Agriculture: The Worst Mistake in the History of the Human Race

Jared Diamond (1997)

Agriculture versus Environment

For 12,000 years

Soil use change

For 100 years

Agrochems

*Rodríguez-Eugenio, N., McLaughlin, M. and Pennock, D. 2018. **Soil Pollution: a hidden reality**. Rome, FAO. 142 pp.*

The silent problem of soil pollution

The Status of the World's Soil Resources Report (SWSR) identified **soil pollution as one of the main soil threats** affecting global soils and the ecosystems services provided by them.

The **main anthropogenic sources** of soil pollution are the **chemicals** used in or produced as byproducts of industrial activities, domestic, livestock and municipal wastes (including wastewater), **agrochemicals**, and petroleum-derived products.

These chemicals are **released** to the environment accidentally, but also **intentionally**, as is the case with the use of fertilizers and pesticides, irrigation with untreated wastewater, or land application of sewage sludge.

Based on scientific evidence, soil pollution can severely **degrade the major ecosystem services** provided by soil. Soil pollution reduces food security by both reducing crop yields due to toxic levels of contaminants and by causing crops produced from polluted soils to be unsafe for consumption by animals and humans.

The results of scientific research demonstrate that soil pollution directly **affects human health**.

Remediation of polluted soils is essential, as well as the development of novel science-based remediation methods

Speaking about Agriculture: no practical remediation technology is available for soils despite scientific results

Agrochemical remediation of farm soils by combining solarization and ozonation techniques

Budget:

Total amount: 2,221,241 €

% EC co-funding: 60%

Duration: 01/07/2018 - 31/12/2022

Consortium:

CSIC

IMIDA

ID consortium

NOVAGRIC

OBJECTIVES

- To develop and tune at **farm scale** a new technology and its associated techniques for the **agrochemical remediation of farm soils** by combining solarization and ozonation *in situ*.
- To test and **demonstrate** the technical, economic, and ecological **feasibility** of the innovation -without any alternative available in the market- through a prototype in commercial farms at real running scale.

EFFECTS STUDIED

- **Pesticide** content in soil
- Soil **microbiota**
- **Nematode** population
- **Crop performance**
- **Economic and Life Cycle Analyses**

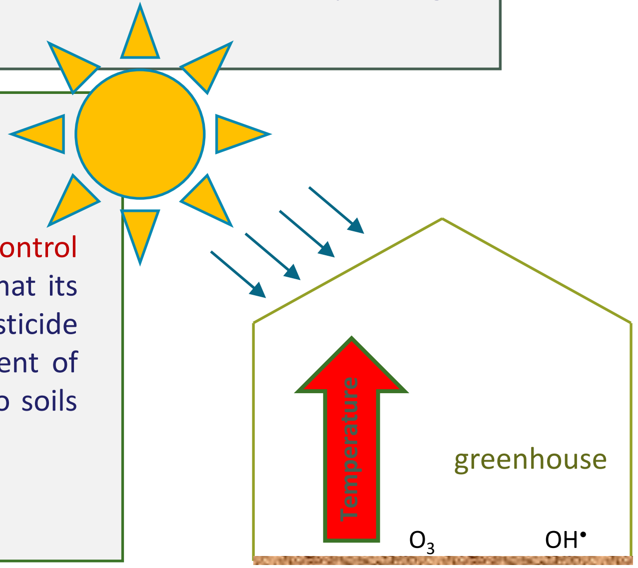
Technologies selected for soil remediation: ozone in gas mode + solarization by plastic ground cover

Ozonation

Ozone (O_3) is considered a **strong oxidant** agent with high reactivity able to attack and destroy easily organic compounds (transforming them into CO_2, H_2O and mineral salts). In addition, ozone can produce hydroxyl radicals, which are more powerful oxidizers than ozone. Both species are involved in pesticide degradation, either directly through molecular ozone or indirectly through HO• radicals produced in ozone decomposition.

Solarization

Solarization is a disinfection technique normally utilized to control soil-borne pathogens. At the same time, it has been found that its application could increase the natural attenuation of pesticide residues present in soil. Solarization is based on the increment of **temperature** that occurs after placing a clear plastic film onto soils and exposing them to solar irradiation during the hot season.



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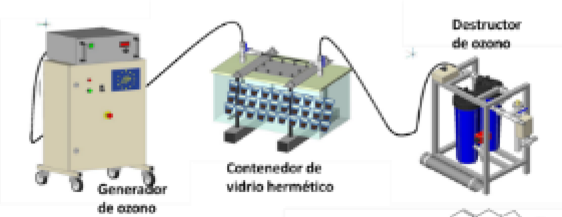
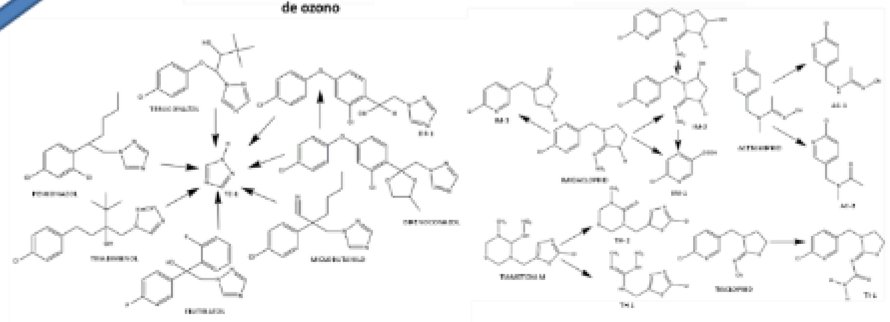
Upscaling approach

Year 1

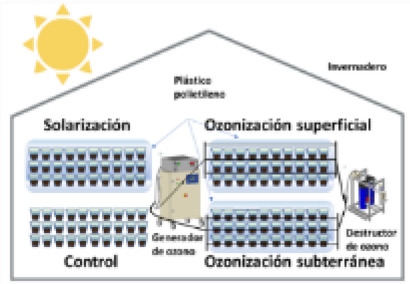
1 Laboratory





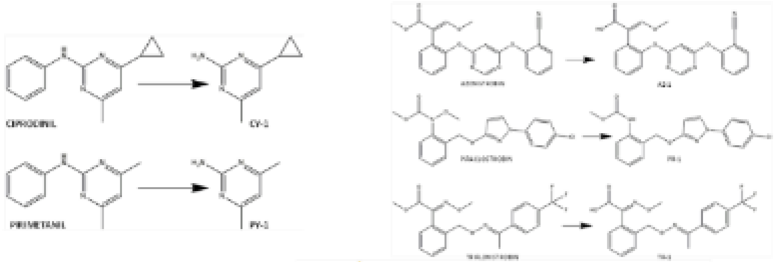
Variables under control:

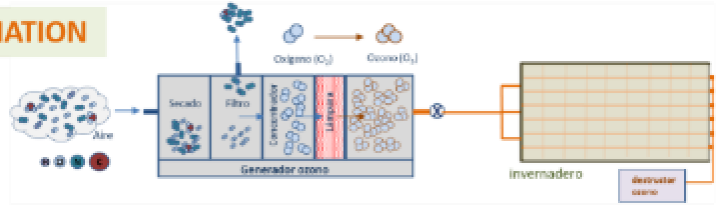
- **Soil type** (OM, texture…)
- **Ozone dose**
- **Ozone aplication** (Surface/subsurface)
- **Temperature**
- **Pesticide type and concentration**
- **Soil residence time of the pesticide**
- **Treatment time**



2 Experimental Greenhouse (Containers)

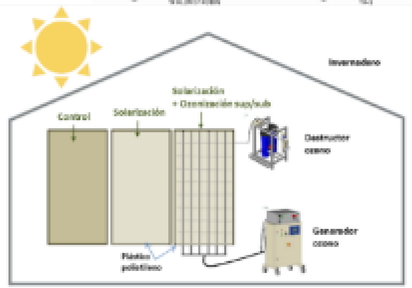
SOLARISATION + OZONATION FOR FARM SOIL REMEDIATION





4 Commercial Greenhouse

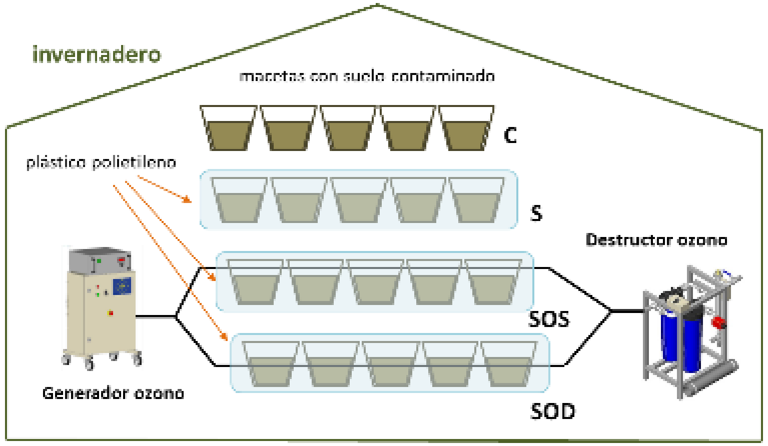
Years 3 and 4



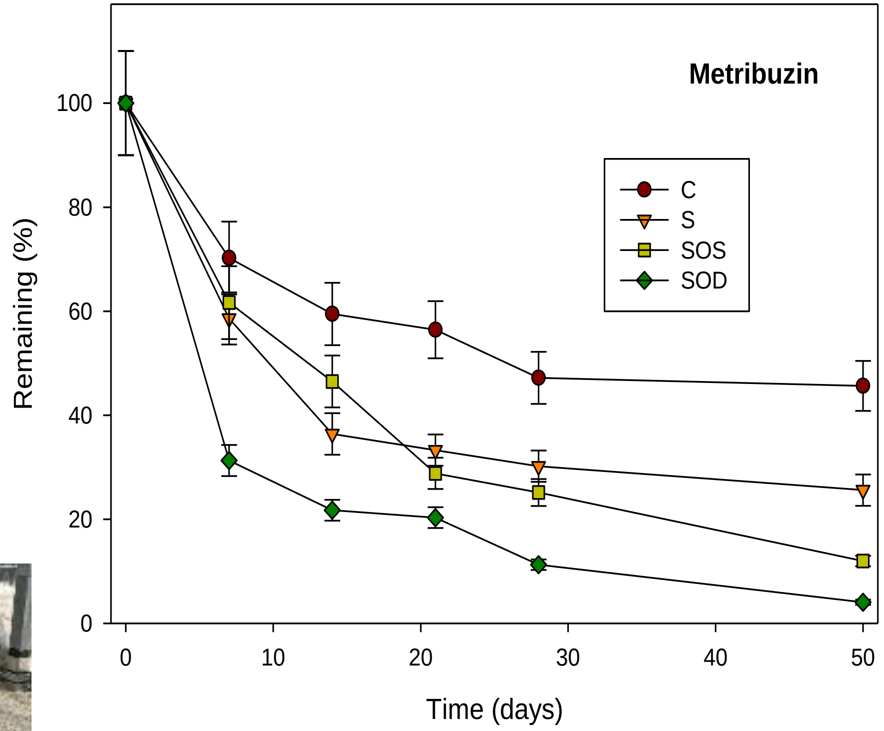
3 Experimental Greenhouse (Soil)

Year 2

Containers in experimental greenhouse: the example of metribuzin

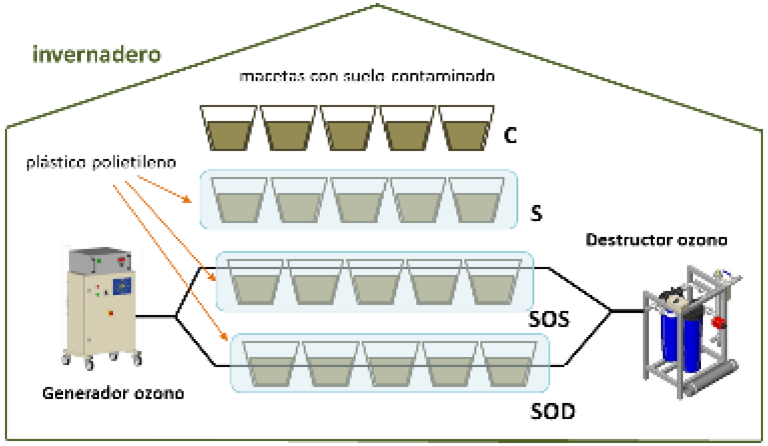


Soil polluted with 35 pesticides



Dinamic behaviour of metribuzin in different treatments under controlled conditions

Containers in experimental greenhouse: main conclusions



Soil polluted with 35 pesticides

<u>% degradation after 50 treatment days</u>

49% control
69% solarization
77 % solarization + O_3 superficial
82% solarization + O_3 subsuperficial

Selection of ozonation delivering O_3 gas on soil surface and 10 cm deep (dual treatment)

Solarisation + dual ozonation in experimental greenhouse


Soil polluted with 35 pesticides   Plots (12 m²)


Influence on pesticide content under adverse conditions: aged polluted soil and treatment in winter

Winter treatment

Despite adverse conditions (winter, when solarisation is less effective), **SOSD** degradation percentages (**81%**) are much higher than those obtained for the **control** (**23%**) after 38 days of treatment

The example of metribuzin (degradation rates)

C	9.2%
S	33.3%
SOSD	86.8%

The AGREMSO3IL system

Prototype

Ozone generator 60 g O_3 h^{-1}
Flow rate 28 L min^{-1}
Ozone concentration of 35 g m^{-3} measured in gas streams

Superficial and subsuperficial (dual) distribution pipes

Ozone destructor

Solarization cover

Demonstration at commercial farm scale

Pesticide	Concentration (t0) [a]	Remaining (t1) [b]
Triadimenol	297,3	51,7
Boscalid	1.486,8	55,3
Tebuconazole	945,8	52,7
Fluopyram	262,6	62,4
Difenoconazole	437,8	56,7
Pyraclostrobin	332,2	51,8
Indoxacarb	510,0	16,3
Fenpyroximate	140,9	25,7
Cyprodinil	150,3	52,1
Cymoxanil	133,1	0,5
Fludioxonil	649,2	46,1
Kresoxim-methyl	463,7	11,8
Imidacloprid	16,9	59,1
Acetamiprid	33,9	13,7
Chlorantraniliprole	48,6	28,8
Spirotetramat	12,6	0,7
Cyflufenamid	22,5	44,6
Metalaxyl	24,4	45,7
Cyproconazole	23,4	75,5
Diethofencarb	10,7	25,9
Iprodione	11,0	35,4
Benalaxyl	18,8	60,4
Azoxystrobin	59,8	48,1
Tebufenpyrad	48,6	55,1
Pymetrozine	6,4	51,7
Spinosad-A	7,2	17,1
Spinosad-D	8,0	20,1
Fenhexamid	4,3	21,0
Pyriproxyfen	0,3	40,4
Hexythiazox	0,8	25,6
Etofenprox	3,6	48,3

Units: [a] $\mu g\ kg^{-1}$; [b] %

Dual distribution

Ozone destructor

Solarization cover

Variables **Soil type** (OM, texture…), **Ozone dose, Ozone aplication** (Surface/subsurface), **Temperature, Pesticide type and concentration, Soil residence time of the pesticide, Treatment time**

The application of AGREMSOIL produces 57 - 63% average degradation of total pesticide residues in soil, when the elimination of these pollutants in the control soil (without any remediation treatment) was insignificant. The remediation effect of AGREMSOIL is mainly due to the high oxidative power of ozone together with the high temperatures reached under the plastic film.

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Soil microbiota

Soil is an ecosystem that harbours a great variety of microorganisms, which constitute a fundamental component for the maintenance of ecosystem services, preserving its fertility and sustainability. Moreover, they play a crucial role in the regulation of biogeochemical cycles, so the maintenance of soil microbial diversity must be ensured in any action carried out on the soil.

The influence of AGREMSOIL technology on soil microbiota was measured by measuring the main physico-chemical (pH, electrical conductivity, total nitrogen and organic carbon content, etc.), biochemical (dehydrogenase activity, urease, alkaline phosphatase and β-glucosidase) and microbiological (microbial biomass and diversity) parameters of the soil. The results indicated that ozonisation does not modify the activity of micro-organisms, which are essential for plant development and a key component of soil fertility.

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Soil microbiota

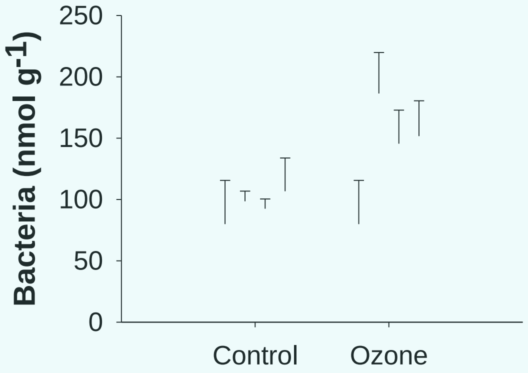
Microbial biodiversity

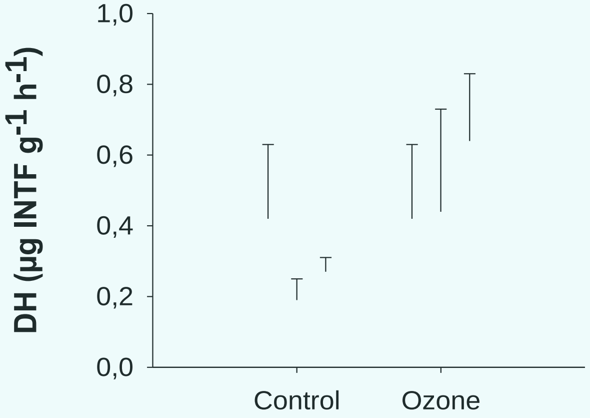
Ecosystem services

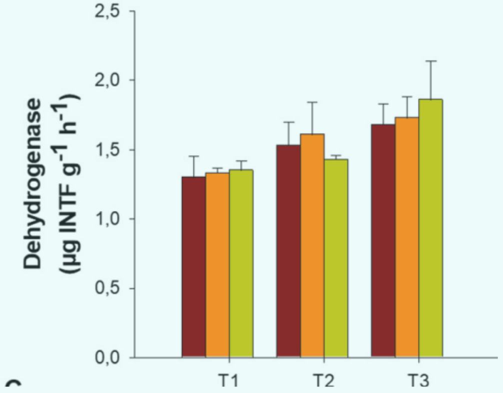
Soil fertility
Nutrient cycles
C sequestration
Pollutants degradation

Ozone applications in soil and irrigation water provided positive effects on edaphic microbiota, e.g. bacterial biomass and general activity of microorganisms (dehydrogenase).

This ozone use can contribute to improve soil functions mediated by microbiota.







Nematodes

Nematodes of the genus Meloidogyne are obligate endoparasites of more than 5500 plant species. Some species are responsible for large economic losses due to their high multiplication rate as they have several generations per year in warm and temperate climates. Meloidogyne incognita is considered the main phytoparasitic nematode worldwide and is, together with M. javanica and M. arenaria, the predominant species in Spain. They damage the root system of the plants with the appearance of nodules due to the bites of the juveniles. This damage to the roots results in yellowing of the aerial part, reduction of vegetative development, reduction of production and, in extreme cases, death of the plants.

The nematode population was controlled by bioassays to estimate the viability of juveniles and egg masses (capable of infesting plant roots). The treatment achieved 100% elimination of juveniles and non-viability of eggs.

Cost-benefit and Life Cycle Analyses

Scenario 1: Decontamination of agricultural soils in greenhouse and change of use so that no new residues are expected. Amortization based on greenhouse life, 25 years

Scenario 2: Decontamination of greenhouse soil by treating with the equipment every 5 years, keeping pesticide use

Scenario 3: Decontamination every 2 years (one year biosolarisation, one year AGREMSOIL, alternatively), and ozone application in irrigation water , keeping pesticide use

Tomato greenhouse

Scenario 1 (once)	862.32 €/ha year	(0.006 €/kg)
Scenario 2 (once every 5 years)	4,311.60 €/ha year	(0.028 €/kg)
Scenario 3 (once every 2 years)	25,820 €/ha year	(0.17 €/kg)

For **Scenario 1**, the total cost of the decontamination treatment represents an **increase of 1.2% of the total annual cost** of a hectare of tomatoes under plastic.

The additional cost per kilo produced would be around 0.5 euro cents depending on the size of the equipment used.

The environmental cost from a life cycle perspective represents a low increase of 1.17%.

The best scenarios for the application of AGREMSOIL are those in which one treatment is applied after a crop cycle and no new pesticide residues are expected, such as a change from conventional to organic production or a process of land use change

Main figures

Demonstration on
2 commercial farms
dedicated to tomato cultivation under greenhouse and under net.

2000 m2 of decontaminated soil

Waste from
34 active substances
detected in soil have been degraded

9 mg kg-1
of pesticides found in soil

Eliminated
57-63%
of pesticide residues in soil

CONCLUSIONS

The AGREMSOIL system shows a high performance for pesticide degradation at commercial scale

The AGREMSOIL system shows a low impact on soil microbiota

The effects of AGREMSOIL on nematode population need further studies

Comparative advantages with other remediation systems are its application in situ, effectiveness in depth and short time of treatment (soil availability)

The adaptation of the system on a wider soil surface and to other pollutants should be developed

AGREMSOIL ought to be applied in protected environments such as greenhouse soils to avoid eventual atmospheric interference in open spaces

The use of AGREMSOIL is recommended as a service hired by farmers

Implementation barrier for further discussion

The use of ozone in agriculture is not allowed as it is not in the list of pesticides

A legal gap? Its use as a remediation system between two crop cycles

Potential uses of AGREMSOIL are soil use change and speeding change from conventional to organic farming at an assumable cost

Soil remediation is not obligatory for farmers, although many have expressed interest either for environmental awareness or to prevent risks of pesticide residues in their production (even organic)

More Info: **http://agremso3il.eu**

Remediation of triazole, anilinopyrimidine, strobilurin and neonicotinoid pesticides in polluted soil using ozonation and solarization. Journal of Environmental Management 310 (2022) 114781.
https://doi.org/10.1016/j.jenvman.2022.114781

Ozonation for remediation of pesticide-contaminated soils at field scale. Chemical Engineering Journal 446 (2022) 137182.
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Combined ozonation and solarization for the removal of pesticides from soil: Effects on soil microbial communities. Science of the Total Environment 758 (2021) 143950.
https://doi.org/10.1016/j.scitotenv.2020.143950

The effects of ozone treatments on the agro-physiological parameters of tomato plants and the soil microbial community. Science of the Total Environment 812 (2022) 151429.
https://doi.org/10.1016/j.scitotenv.2021.151429

PhD thesis Aplicación de solarización y ozonización para la eliminación de residuos de plaguicidas en suelos agrícolas
https://digitum.um.es/digitum/bitstream/10201/122670/1/Tesis%20Carmen%20Mar%C3%ADa%20Mart%C3%ADnez%20Escudero%20impresi%C3%B3n_1%20TAPA%20DURA%20OFICIAL_.pdf

Eager to your questions and comments

Thank you

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