SAY NO TO SULFLURAMID: REASONS FOR A WORLDWIDE BAN ON THIS AGROTOXIC CHEMICAL

Sulfluramid is a chemically-synthesized pesticide used as a formicide, which, as it breaks down, turns into perfluorooctane sulfonate (PFOS). PFOS is a toxic, extremely persistent and bioaccumulative pollutant, subject to worldwide restrictions pursuant to the Stockholm Convention on Persistent Organic Pollutants (POPs). This Convention, intended to protect human health and the environment, took effect in 2004, and has been signed by most governments, including countries in Latin America and the Caribbean.

Despite the hazards of PFOS, various exemptions have been granted for its use. One of the "acceptable uses" is the application of sulfluramid bait to control leaf-cutting ants of the *Atta* spp. and *Acromyrmex* spp. genera. The ninth meeting of the Conference of the Parties to the Stockholm Convention, to be held from April 29th to May 10th, 2019, in Geneva, Switzerland, will evaluate whether the exemptions and "acceptable uses" of PFOS are necessary. The Party governments will make a decision on whether to accept or modify the recommendation of the Persistent Organic Pollutants Review Committee to permit the use of sulfluramid for agricultural purposes.

This fact-sheet is to inform civil society and government representatives about the environmental and public health problems involved in the use of sulfluramid when it transforms into PFOS. It also illustrates the lack of control in its use, identifies the economic interests involved in its sale, provides some examples of alternatives, and explains how it is sold and used in Latin America in breach of the Stockholm Convention.

Farmer in Colombia applying sulfluramid.
Photo: Plácido Silva, COLNODO, 2019

Finally, this publication argues for urgent measures to restrict the use of sulfluramid, while progressively banning it altogether. Sulfluramid must be banned nationwide in gardening and agricultural use, where there are alternatives, and a deadline must be set for the banning of its use worldwide, with temporary exemptions for specific agricultural crops. It is important that government decisions are transparent, and the accounts are rendered to civil society to better protect health and the environment.

USES OF SULFLURAMID

Sulfluramid is an insecticide generally used in granulated baits to control leaf-cutting ants, and is used widely in industrial plantations of eucalyptus, pine, and oil palms in the region, as well as against termites and red ants in grazing pastures, fruit orchards, and other agricultural cropland. In some countries, its use is also authorized against domestic insects, like ants and bush cockroaches. Historically, it has also been used to control fire ants (*Solenopsis invicta*) and termites, and to protect cables.

In the European Union, sulfluramid and PFOS are no longer used in making bait or pesticides for control of beetles and ants. In the United States, the Environmental Protection Agency (EPA) canceled production and registry of sulfluramid in May 2008 and all products registered in 2012.[1] This includes the southern United States, where leaf-cutter ants of the *Atta* spp. and *Acromyrmex* spp. genera reside, just as they are present in much of Latin America and the Caribbean. China's Ministry for Agriculture and Foreign Relations, a major consumer of sulfluramid, proposed revoking all licenses for the production and use of sulfluramid starting in March 2019.[2] But sulfluramid is still produced, exported, imported, and used in Latin America and the Caribbean.

WHAT IS SULFLURAMID?

Sulfluramid is the common name of the chemical compound N-ethyl perfluorooctane sulfonamide (EtFOSA). Its chemical formula is $C_{10}H_6F_{17}NO_2S$ and it belongs to the chemical group of Fluoraliphatic Sulfonamides.

Sulfluramid is classified in numerous countries within toxicological category IV, considering only its acute toxicity, so on the surface it does not appear so toxic, as reflected in the blue or green band on the label; and in category III as hazardous to the environment. Some manufacturers even assert that it is not highly hazardous for persons or the environment, but the reality is very different for the compound into which it degrades.

The main environmental problem of sulfluramid is that it breaks down into PFOS, a compound that meets the Stockholm Convention criteria of persistence, bioaccumulation, adverse effects, and long-range environmental transport. For this reason, PFOS is considered a Persistent Organic Pollutant.

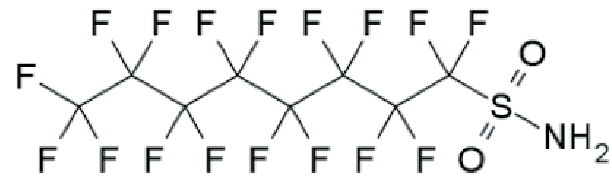


Figure 1: Structural formula for sulfluramid

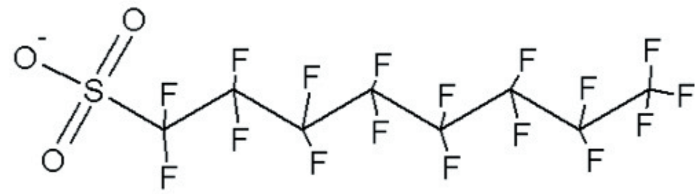


Figure 2: Structural formula of PFOS (UNEP/POPS/POPRC.2/1/Add.5.), where: F=fluorine, S=sulfur, O=oxygen

WHAT IS PFOS AND HOW IS IT USED?

PFOS is used in a wide range of applications, including the manufacture of Teflon cooking instruments, fire extinguishing foam, water and stain repellent for carpets and textiles, manufacture of semi-conductors, medical products, and other uses.[3]

One of the sources from which PFOS is released into the environment is sulfluramid, which, as it breaks down into the environment, transforms into PFOS[4] and another fluorinated compound, perfluorooctanesulfonyl fluoride (POSF), which is used as a raw material in the industrial manufacture of this pesticide. Both PFOS and POSF are subject to worldwide restriction in Annex B of the Stockholm Convention.

Fluorinated products like PFOS contain long chains of carbons completely saturated with fluorine. The strength of the carbon-fluorine bonds (C-F) is what contributes extreme chemical stability to perfluorinated compounds (PFC) and lends them their distinctive properties.[5]

Figure 2 shows the basic structure of PFOS, whose molecular formula is $C_8F_{17}SO_3$.

PFOS is extremely persistent. PFOS does not hydrolyze, meaning it does not react to water; it does not photolyze, which means it does not break down in sunlight; and it does not biodegrade under any tested environmental condition, so it can remain active and pollute for a long time—so much so that studies have not been able to establish precisely how many tens of decades it may remain in the environment. PFOS tends to be absorbed into sediment and sludge, or combine with particular matter in water columns.[6]

PFOS bioaccumulates and biomagnifies. Because of its capacity for bioaccumulation and biomagnification in food chains, high concentrations of PFOS have been found in the food chains of large predators, like polar bears, seals, bald eagles, and mink. Substances with PFOS do not follow the classic scheme of other chlorinated POPs which are lipophilic and partitioned into fatty tissues. Instead, PFOS substances join with proteins in the blood and in the liver of animals.[7]

PFOS also has a series of adverse effects on plants and soil. Between 2014 and 2018, various studies were carried out in which PFOS and other fluorinated compounds were found in corn, wheat, soy, tomato, carrots, and squash. PFOS was also found in soils and in earthworms. PFOS is accumulated in spring wheat, oats, potatoes, corn, and perennial ryegrass.[8]

PFOS is transported over long distances. According to the available data[9], PFOS meets the criteria for long-range environmental transport. This is obvious from the monitoring data, which show very high levels of PFOS in various parts of the northern hemisphere. It is particularly evident in the Arctic biome, far from anthropogenic sources. PFOS also meets the specific criteria for atmospheric half-life.

PFOS is toxic. Its toxicity to mammals has been proven in studies where repeated doses of low concentrations (sub-chronic) have been applied, as well as its reproductive toxicity in rats, with mortality of pups shortly after birth. PFOS is toxic for aquatic organisms.[10] Exposure to PFOS has been related to weight loss, disproportionate weight gain, reductions in blood cholesterol and thyroid hormone; it has also been shown to have hepatotoxic and carcinogenic effects in laboratory animals and humans.[11] Recent studies reveal a variety of adverse effects from PFOS on human beings including: association with liver function biomarkers disorder[12], development of genetic disorders of the bone (osteogenesis)[13], neurotoxicity[14], association with great risk of attention deficit disorder/ hyperactivity[15], alterations of estrogen homeostasis[16], association with obesity or increased girth[17], negative effects on renal function[18], reductions in vitamin D biomarkers[19], immunotoxicity[20], increased risk of asthma in adolescents[21], alteration of thyroid hormone[22] and increased cholesterol in children[23], among others.

In Brazil, there has been evidence of water and sediment contamination from PFOS and other compounds due to the possible use of sulfluramid. In a study by Nascimento and other authors on the agricultural region of Bahía state, a zone characterized by low levels of industrial activity and urbanization and large eucalyptus plantations, PFOS and PFOA were detected in all river water samples and sulfluramid was indicated as a possible source of river water pollution. Ground water was also found to be contaminated with perfluorinated alkyl substances (PFAS), probably from the use of sulfluramid. In general, these data support the hypothesis that the use of sulfluramid contributes to the presence of PFAS in the Brazilian environment. This is the first analysis of PFAS in groundwater, sediment, and eucalyptus leaves carried out in South America.[24]

There is also evidence in Brazil of PFOS bioaccumulation from the application of sulfluramid in agricultural crops. Zabaleta *et al.*[25] carried out the first study evaluating uptake, leaching, biodegradation, and distribution of sulfluramid (EtFOSA) and its transformation products over 81 days in the soil–carrot mesocosm (*Daucus carota* ssp. *sativus*). In assays with the carrot, PFOS levels of up to 34% were found using the standard EtFOSA technique, and up to 277% using Grão Forte, a chemical bait that contains 0.0024% sulfluramid. In the carrot, the most hydrophilic transformation products (PFOS, for example) appeared primarily in the leaves, while the most hydrophobic products (e.g. FOSA, FOSAA and EtFOSA) were found in the peel and core of the carrot. Taken together, the data show that the application of sulfluramid bait may lead to the appearance of PFOS in crops and in the surrounding environment in levels considerably higher than was previously thought.

SULFLURAMID WAS A FALSE ALTERNATIVE TO MIREX, ANOTHER POP

For many years, sulfluramid was considered as an alternative to mirex, an organochlorine pesticide used against ants and termites, included on the original list of a dozen POPs produced by the Stockholm Convention, which took effect May 17, 2004. Many countries in the region saw sulfluramid and fipronil as an alternative to mirex, but the shift was misleading, because they not only failed to resolve the problem, but also generated environmental pollution and new health problems for producers, workers, and the exposed population. As we will see later on, some manufacturers sell sulfluramid under the commercial brand Mirex (in some cases with other letters or words added, as in Mirex-S or Mirex SD), although it no longer includes this active ingredient.

THE RECOMMENDATION OF THE PERSISTENT ORGANIC POLLUTANTS REVIEW COMMITTEE ON PFOS AND SULFLURAMID

The Persistent Organic Pollutants Review Committee (POPRC) is a subsidiary body of the Stockholm Convention and is made up of government-designated experts. The Committee examines the chemical products proposed for inclusion in the Convention and makes recommendations to the Conference of the Parties. This Committee is also open to participation by industry observers and non-governmental groups.

In 2009, the Parties to the Convention included PFOS and its salts, as well as perfluorooctanesulfonyl fluoride (POSF) in Annex B for worldwide restriction, but many of their uses were exempted, and permitted to continue.

In a meeting of the Committee in September 2018, after a second review of alternatives to PFOS, its salts and PFOSF, the Committee once again recommended that the ninth Conference of Parties explicitly mention "insect bait with sulfluramide (CAS No. 4151-50-2) as an active ingredient for the control of *Atta* spp. and *Acromyrmex* spp., leaf-cutting ants, for agricultural use only" in the list of substances with an acceptable purpose. It also recommended that the parties to the Convention that use it for this accepted purpose be urged to advise the Secretariat, in accordance with Annex B of the Convention[26], because most countries in Latin America that continue using it have not done so.

The POP Review Committee recognizes that the review process "showed dissenting views on the need to use sulfluramid for combating leaf-cutting ants, the availability of alternatives, and the technical and economic feasibility and operational effectiveness of those alternatives." The Committee further "encourages Parties to consider monitoring activities for sulfluramid, PFOS and other relevant degradation products in the different environmental compartments (soil, groundwater, surface water) of the application sites."[27]

Experts from IPEN and Pesticide Action Network (PAN) have participated in discussions of the POP Review Committee, contributing critical information on its alternatives and communicating concern about the indiscriminate use of sulfluramid.[28] But the Brazilian Association of Insecticide Bait Manufacturers (ABRAISCA), which groups together the three largest manufacturers of sulfluramid, along with officials of the Brazilian Ministry of Agriculture and academics in the field of agronomy, have also participated, and all insist that there are no alternatives as effective as sulfluramid in agricultural crops like livestock pastures and large-scale tree plantations[29], and that, according to ABRAISCA, sulfluramid is indispensable for Brazilian agribusiness.[30]

PRODUCTION AND SALE OF SULFLURAMID IN LATIN AMERICA

Brazil is currently one of the world's leading producers of sulfluramid, a product that is made from perfluorooctanesulfonyl fluoride (POSF), which is imported from China, who is also a major producer and exporter of sulfluramid. Industrial manufacture of sulfluramid in Brazil grew from 30 to 60 metric tons a year between 2003 and 2013, and Brazil uses it domestically and exports it to other Latin American countries. Between 2004 and 2015, it was exported mainly to Argentina (7.2 t), Colombia (2.07 t), Costa Rica (1.13 t), Ecuador (2.16 t) and Venezuela (2.4 t).[31] Brazil also reports having exported sulfluramid to Bolivia, El Salvador, Guatemala, Honduras, Panama, Paraguay, Peru, and Uruguay.

Eucalyptus plantation in Matto Grosso do Sul, Brazil. *Photo: WRM, 2018*

Brazil, a major world agricultural producer, used approximately 30 metric tons a year of sulfluramid active ingredient between 2004 and 2015. Between 2003 and 2008, Brazil was the third largest consumer of PFOS- and POSF-related compounds due to the use of sulfluramid.[32]

Among the main consumers of sulfluramid are industrial tree plantations that cultivate forest species (like eucalyptus for making pulp) and palm oil for export; they also use other dangerous agrotoxins like herbicides. In Brazil, the forestry industry occupied 7.84 million hectares of land in 2017[33], making it the country with the most land used for this purpose in Latin America. The expansion of tree monoculture has not only generated environmental problems but has given rise to a number of highly troubling social conflicts.[34] Although the Forest Stewardship Council (FSC) has excluded sulfluramid from certification because of its bioaccumulative nature[35], in November 2007, forestry companies in Uruguay, Brazil, Argentina, Paraguay, Colombia, and Venezuela requested an exemption so as to continue using it, and today are authorized to use it massively and extensively.[36]

SULFLURAMID IS SOLD AND USED WITHOUT STRICT CONTROLS AND WITHOUT NOTIFYING THE STOCKHOLM CONVENTION SECRETARIAT

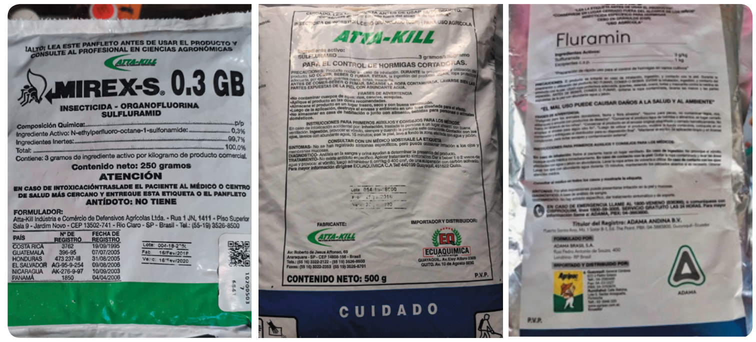
According to UN documents, sulfluramid is registered for use in Argentina, Belize, Bolivia, Brazil, Mexico, Nicaragua, Panama, Peru, and Santa Lucia[37], but it is also authorized for use in Uruguay.

The main commercial brands of sulfluramid used in the region for agricultural purposes, including forestry application, are: MIREX-S 0.3. GB, exported from Brazil by the company Atta Kill Industria e Comercio de Defensivos Agricolas, and the brand FLUORAMIN produced by Adama Brasil, formulated by other companies in that country[38], and distributed and/or formulated by various companies in other parts of the region such as Argentina, Paraguay, Ecuador, Bolivia, and Central America. Other commercial brands in the region used for agricultural purposes are: FORISK AG, CITROMAX S, DINAGRO-S, ATTA MEX-S, GRAO VERDE in Brazil[39]; MIX HOR-TAL Cebo, MIREX-GLEX, FLURIMEX, SULFA-MIREX-S, HORMIFAV-S, MIREX ESPACIAL, and DELENTE MIREX in Argentina[40]; ATTA-KILL in Colombia; P-MIREX in Peru[41]; MART DRIM 0.3 GB in Honduras; and AGRIMEX-S in Uruguay.[42] In Mexico, the FMC-registered brand is sulfluramid, for exclusive use in pesticide-making plants.[43] There are other sulfluramid brands for use in gardening in the region.

Some commercial brands of sulfluramid for controlling domestic leaf-cutting and garden ants that we have discovered are: in Brazil, MIREX-SD, GrãoVerde (mixed with fipronil) and ATRATEX, FORMIFIRE-S[44]; in Argentina we found MIX HOR-TAL, MANCHESTER CEBO MIREX, MIREX GEL, FLUMIREX SH, SULFA MIREX, HORMIFAV, MAMBORETA MIREX S, MIREX SUL GREHSA, DELENTE MIREX, and EL BUITRE MATA, according to government sources.[45] In Mexico, SULFLURAMIDA is registered by Full Finishing as a domestic insecticide for controlling termites, and permitted only for export.[46] In Colombia, we found BELL Gel cockroach poison.[47]

Most imports of sulfluramid to Latin America have been carried out without reporting to the Stockholm Convention Secretariat, in violation of Article 3 which stipulates notification of use of substances listed as banned (Annex A) or restricted (Annex B), as in the case of PFOS.[48]

Most sulfluramid importing countries not only violate Article 3 of the Convention by failing to notify the Stockholm Convention Secretariat of agricultural uses, but also because they allow it to be sold for gardening use, which is not permitted under the international agreement signed by these countries. And the main exporting country, Brazil, which under the Convention is allowed to use sulfluramid for agricultural purposes, also allows it to be used in gardening, in violation of the Convention. Sulfluramid is sold in both importing and exporting countries without any restriction whatsoever.



Commercial brands of sulfluramid in Costa Rica, Bolivia and Ecuador. *Photos: Fernando Ramírez, CODAPMA and Angel Llerena, 2019*

Commercial brands of sulfluramid for gardening use in Porto Alegre, Brasil and Uruguay (imported from Argentina) 2019. *Photos: Leonardo Melgarejo and María Cárcamo*

ALTERNATIVES TO THE USE OF SULFLURAMID

Leaf-cutting ants of the *Atta* spp. and *Acromyrmex* spp. genera are among the most damaging insects for ground crops, fruit trees, pastures, and forest plantations. They are known in Latin America and the Caribbean by names such as *hormigas arrieras*, *zompopas*, *cepe*, *hormiga minera*, *bibijagua*, *hormigas limón*, *hormigas cabeza de vidrio*, and others.

Despite the damage they cause, it is important to consider the importance of their role in ecosystem services: they guarantee the flow of nutrients and energy by carrying organic material in their nests from one place to another, enriching the soil[49], which is important in soil protection. These ants favor drainage and the penetration of roots because of their deep soil removal, by building nests that form an extensive network of galleries. These benefits should also be taken into consideration when deciding on practices for managing them in sustainable farming contexts, as recognized by the United Nations report.[50]

Leaf-cutting ants have a high degree of social organization: they live in colonies, cultivate a fungus that is used to feed the larvae and the queen, the worker ants forage for food, their nests have a complex structure, and they carry out cleaning and sanitizing activities. These characteristics make it more difficult to control them.[51]

To manage leaf-cutting ants, it should be taken into account that they live in a symbiotic community of three organisms that live in cooperation: the ants, the fungus that serves as their food (*Leucocoprinus gongylophorus*), and the fungus that serves as protection (*Pseudonocardia* sp); the latter grows on the cuticle of all the ants in the colony and protects them from entomopathogenic bacteria and fungi, and it also protects the *L. gongylophorus* from possible micoparasites.[52] This symbiotic community complicates efforts to control the ants. An agroecological system of management should be based on an understanding of the relationships between these three organizations, which have so far been little studied.

A review of the literature on possible alternatives to the use of sulfluramid reveals that most work focuses narrowly on a single solution: replacing one product (sulfluramid) with another product of similar characteristics (except those that make it a highly hazardous pesticide). With such a focus, finding a solution is not easy, and a different approach must be taken. It is necessary to further document the evidence and results of agroecological pest control programs, taking into account the effect on ant populations of various practices and methods. This includes, for example, re-designing the vast monoculture of tree plantations, which are the main cause of the explosion of leaf-cutting ant populations.

One of the possible alternatives to the use of sulfluramid is applied biological control. So far, the most promising method has been using entomopathogenic bacteria to control ants, and the antagonistic fungus Trichoderma to attack the fungus they cultivate (*L. gongylophorus*).[53] Among the most widely used entomopathogens are *Beauveria bassiana* (see photo) and *Metarhizium anisopliae*.[54] As an example, since the mid-2000s, the Cuban Ministry of Agriculture[55] registered the product Bibisav to control *Atta* and *Acromyrmex* in various crops[56]; this is produced in Centers for Reproduction of Entomophages and Entomopathogens.[57] In Argentina, a bait was registered that is based on *B. bassiana*, a substitute for fipronil, which was banned in that country in 2018 because of its classification as a highly hazardous pesticide.

In Brazil, comprehensive pest control programs have used the fungi *B. bassiana*, *M. anisopliae* and *Paecilomyces farinosus*, the bacteria *Bacillus thuringiensis*, and the nematodes *Steinernema* and *Heterorhabditis* which are associated with symbiotic bacteria *Xenorhabdus* and *Photorhabdus* (Zanetti et al. 2014), among other measures.[58]

In Mexico, as well, there are registered microbial insecticides produced with *B. bassiana* mixed with extract of *Sophora* sp. and *Ricinus* sp. for bait in pellets. Another registered brand is Biodie, a product made with Argemonina, Berberina, Ricinina and α-Terthienyl; and *Metarhizium anisopliae*, used as a microbial insecticide to infect foraging ants and contaminate their nests, provided they are infected through food or the insects themselves, with various brands like Spectrum Meta and others.[59]

In Latin America and the Caribbean, there are technologies available for the production of these biological control agents and vegetable extracts, which range from artisanal to industrial production. Brazil is the country that has made most progress on this front. Today, there is sufficient scientific evidence of the potential to control leaf-cutting ants with these entomopathogens. What is necessary now is to continue research into their integration with other control methods: signaling populations of ants (monitoring) and their natural enemies, such as: cultural control, for example, borders of tree monoculture alternating with borders of native forest; the planting of repellent plants like *Canavalia* spp. and Vetiver; and the application of botanical extracts like *Tephrosia*, used in making the Brazilian commercial product Bioisca.

Ant of the genus* Atta*, Brazil.

***Dead ant (*Atta insularis*) killed by the fungus* Beauveria bassiana.** *Photo: Anabel Ibarra Mederos, Grupo Manejo Biológico de Plagas, Universidad Agraria de La Habana, 2018*

Bioisca is made with saponins and flavonoids extracted from the leguminous plant *Tephrosia candida*. It was registered by the Brazilian Ministry of Agriculture in 2014 for controlling ants of the *Atta* species, and is recommended for use in organic agriculture, and also in conventional crops for both small-scale and commercial scale farming. This product was registered by a cooperative of coffee growers in Francia, in the state of Sao Paolo, which has patent rights to the formula. It is currently sold in 11 states of Brazil and will be exported to 16 countries.[60, 61]

Researchers should also take into account the experience of producers and communities that practice organic agriculture and livestock farming, and sustainable forestry, in investigating uses where it is currently argued that there are not alternatives to sulfluramid in the region.

RECOMMENDATIONS

To National Governments

- Revoke permits for the use of sulfluramid in gardening and agricultural crops, and support strategies and inputs for pest control using agroecological techniques.
- Strictly control the sale of sulfluramid, set deadlines for its use in industrial tree plantations and other agricultural crops, and open a public discussion on the sustainability of these systems of large-scale monoculture farming, taking into account the environmental and social costs it entails, including water and soil pollution from the use of insecticide and other agrotoxins.
- Inform the public of the health and environmental effects associated with the use of sulfluramid and other highly hazardous pesticides.
- Develop government programs to support agroecological forms of controlling leaf-cutting ants, with the participation not just of experts in agroecology, but producers' organizations themselves, particularly those which are practicing strategies of transition toward organic agriculture and sustainable livestock farming, and the emerging sector of companies that specialize in making biopesticides, to find the best alternatives.
- Improve inter-institutional coordination in managing and registering pesticides to better protect public health and the environment and transition toward less hazardous pesticides.

To the Conference of the Parties to the Stockholm Convention

- Explicitly mention sulfluramid in Annex B on PFOS and change "acceptable uses" to "specific exemptions" for controlling leaf-cutting ants of the *Atta* and *Acromyrmex* genera, in order to set deadlines for their use in agriculture around the world. Exemptions should be strictly limited to specific agricultural uses.

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