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Exposure to Pesticides by Air and Respiratory Health in School Children in VALais, Switzerland (PARVAL)

Scientific Report

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Disclaimer

The views and ideas expressed herein are those of the author(s) and do not necessarily imply or reflect the opinion of the Institute.

Abbreviations

3H to 8H	3 HarmoS to 8 HarmoS: Swiss school system
	Assessment 1 to 3 (April-June 2024)
B	Baseline (January 2024)
BAFU	Bundesamt für Umwelt
BASEC	Business Administration System for Ethical Committees
BILD	Basel Infant Lung Development
BLV	Bundesamt für Lebensmittelsicherheit und Veterinärwesen
BOS-OH	Hydroxy Boscalid
CapSA	Child Health Agricultural Pesticide Cohort Study in South Africa
DAP	Dialkyl Phosphate
DDE	Dichlorodiphenyldichloroethylene
DE	Diethyl Phosphate
ETU	Ethylenethiourea
FarmCoSuisse	Farm Cohort Study Switzerland
FEF25-75	Forced Expiratory Mid Flow 25–75% of FEV_1 (L/s)
FEV_1	Forced Expiratory Volume in 1 second (L/s)
FEV_1/FVC	Ratio (%)
FVC	Forced Vital Capacity (L)
GLI	Global Lung Function Initiative
HBM4EU	Human Biomonitoring for Europe
ICC	Intraclass Correlation Coefficient
IDAWEB	Integrated Data Access Web
IQR	Interquartile Range
ISAAC	International Study of Asthma and Allergies in Childhood
LC	Liquid Chromatography
LOD	Limit of Detection
LOQ	Limit of Quantification
NHANES	National Health and Nutrition Examination Survey
OVS	Observatoire Valaisan de la Santé
PARVAL	Exposure to Pesticides by Air and Respiratory Health in School Children in VALais, Switzerland
PEF	Peak Expiratory Flow (L/s)
$PM_{2.5}$	Particulate Matter with a diameter of less than 2.5 micrometers
PPDB	Pesticide Properties Database
SAEDN	Swiss Agri-Environmental Data Network
SI	Supplementary Information
SOP	Standard operation procedure
Swiss TPH	Swiss Tropical and Public Health Institute
TEB-OH	Hydroxy Tebuconazole

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Summary

Introduction: Concerns about the potential adverse lung health risks of pesticide use in agricultural areas prompted this investigation. In 2023, the Valais Department of Health commissioned the Swiss Tropical and Public Health Institute (Swiss TPH) to design and conduct the PARVAL study with the aim to examine pesticide exposure and its short-term association with respiratory health (symptoms; lung function measures) in primary school children living near vineyards and orchards in Valais, Switzerland. The study allowed a distinction to be made between well-established respiratory health effects due to air pollution or pollen and those due to pesticides, which are less well understood.

What did the study do: The study involved 206 children aged 6 to 13 years from three schools in the Valais region, characterized by different agricultural activities (mainly vineyards in Salgesch and Chamoson and both vineyards and fruit orchards in Saxon). Over four assessments from January (non-spraying season) to April, May, and June 2024 (spraying season), the researchers collected pesticide exposure data (prioritizing common pesticides with hypothesized respiratory effects) by having children wear wristbands and provide urine samples to assess exposure to 83 different fungicides, insecticides, and herbicides (representing 60% of potentially respiratory irritant pesticides sold in Switzerland in 2020). Children performed lung function tests using a portable spirometer. Parents completed questionnaires about their children's respiratory health, household conditions, and other risk factors.

Key Findings: The findings revealed widespread exposure to single pesticides and pesticide mixtures among children. Of the 81 pesticides analyzed in wristbands, 36 were detected in wristbands, and both biomarkers which were analyzed in urine were detected. On average, children were exposed to 14 different pesticides across all four study assessments. The number of pesticides in wristbands was higher for most pesticides from April to June 2024 (when pesticides were sprayed) than in January 2024 (when no spraying occurred). This was especially true for children who lived closer to vineyards and fruit orchards. Children's exposure to pesticides was different between the three communities they lived in, likely depending on the different types of crops and the amount of pesticides used.

No associations were found between children's exposure to pesticides and respiratory symptoms, like coughing or breathing difficulties. There were small decreases in certain measurements of lung function related to single pesticides, but these links were very unstable and depended on the statistical method used.

Conclusion: Pesticides used in vineyards and fruit orchards near children's homes are a contributing factor to children's exposure to pesticides. The study did not provide evidence that pesticide exposure was associated with severe short-term respiratory health symptoms. To confirm the observed small short-term effects of specific pesticides on lung function, larger studies are needed, which should also investigate effects of pesticide mixtures and the long-term effects.

In a risk reduction strategy, the results underscore the importance of continued pesticide monitoring, health surveillance, and precautionary measures to safeguard children's health. Longer-term research, including larger groups of participants, is essential to better determine the degree of pesticide exposure and potential broad health effects in different populations. A long-term study of 100'000 children and adults living in Switzerland is currently being developed under the lead of the Federal Office of Public Health and the Swiss public health research community. This study would serve the purpose of a much-needed human chemical and health surveillance.

1. Background and Project Rationale

Pesticides and Respiratory Health Effects on Children

Toxicological and epidemiological evidence links pesticides to various acute and chronic health issues, often without a safe threshold of exposure (Ohlander et al., 2020; Slama et al., 2017). For instance, agricultural workers have reported reduced lung capacity, asthma, and respiratory symptoms (Tarmure et al., 2020). In Switzerland, agricultural work has been associated with higher rates of chronic bronchitis and phlegm compared to the general population (Danuser et al., 2001), though specific studies on pesticide exposure are lacking. However, there is international evidence providing insights: The U.S. Agricultural Health Study found that pyrethroid use was linked to allergic asthma in farmers and their spouses, and to non-allergic asthma in female spouses (Hoppin et al., 2006). Pyrethroid exposure among rural women in South Africa activated T-helper 2 cytokines, potentially contributing to asthma (Tarmure et al., 2020).

The impact of agricultural pesticide use on the respiratory health of children, as a particularly vulnerable group of the population, remains poorly understood (Van Horne et al., 2022). A recent review identified only 25 studies, mostly from the U.S., that examined pesticide exposure and respiratory health in children (Van Horne et al., 2022). Among these, nine focused on asthma, using varied methods such as self-reported questionnaires, biomarkers (e.g., uLTE4 or Th1/Th2 levels), and emergency admission records. Some positive associations were found, particularly for organophosphates and pyrethroids, which may contribute to asthma through mechanisms like acetylcholinesterase inhibition. However, the findings were inconsistent.

Another five studies have examined the impact of pesticide exposure on respiratory health in children (Van Horne et al., 2022). These studies consistently found that higher pesticide exposure was associated with reduced lung function, with lower forced expiratory volume in one second (FEV_1) being the most frequently reported significant outcome. Two studies used proximity to pesticide application as an exposure metric, while three relied on urinary metabolites. In California's agricultural communities, post-natal urinary diethyl phosphate (DE) and total dialkyl phosphate (DAP) levels were linked to reduced lung function at age seven, though dimethyl phosphate showed no association. Similarly, urinary 3-Phenoxybenzoic acid (3-PBA) levels in U.S. children aged 6–17 correlated with reduced FEV_1, forced vital capacity (FVC), and peak expiratory flow (PEF), but not other measures. In California, proximity to sulfur applications within 1000 m of homes, but not wind-adjusted fumigant use, was associated with lower FEV_1 and FVC. In rural France, ethylenethiourea (ETU), a marker for dithiocarbamate fungicides, was linked to asthma symptoms, but not to lung function.

In summary, there are **only a few, mostly cross-sectional, epidemiological studies having investigated the association between pesticide exposure and respiratory health outcomes, and they focused on a small number of pesticides, most of which are already banned in Switzerland.** In addition, most of these studies did not adjust for short-term associations between air pollution and pollen with respiratory health outcomes. The need for longitudinal epidemiological studies in children examining multiple and currently broadly applied pesticides and assessing respiratory health outcomes is undeniable. Such research can contribute to evidence-based discussions on the health effects of pesticides in Switzerland and globally.

Pesticide application in vineyards and respiratory health in children

Fungicides are likely to be the most common pesticides in the air around vineyards. Fungicides such as mancozeb, boscalid and tebuconazole have been detected in the air or urine samples of residents living near vineyards in France (Campbell et al., 2017, Soulard et al., 2022).

However, the respiratory health effects of most pesticides in general and pesticides applied in vineyards remain poorly understood, particularly in the context of other concurrently present air pollutants such as particulate matter ($PM_{2.5}$). Indeed, respiratory health problems (e.g. asthma) and allergies (e.g. rhinitis) are known to be affected by short-term exposure to a variety of inhaled irritants (e.g. active and passive smoking; ambient air pollution; pollen) (Chatkin et al., 2022; D'Amato et al., 2020; Pfeffer et al., 2021). Ambient air pollutants, particularly nitrogine dioxide (NO_2) (De Hoogh et al., 2019) and pollen (Luyten et al., 2024; Valipour Shokouhi et al., 2024), vary seasonally in level and composition, and the changes in part follow seasonal patterns also observed for pesticides in response to the spraying season. Accordingly, assessing the adverse respiratory health effects of pesticides in the context of other inhalants and pollen is important, but rarely done.

Pesticide exposure assessment in epidemiological studies

Pesticides are used for crop protection. There are hundreds of them, subdivided into three large groups: insecticides, herbicides, and fungicides. While environmental monitoring data from Switzerland—such as those concerning pesticide residues in water (BAFU, 2022), rain and air (Carbotech, 2021)—provide insights into the environmental presence of pesticides, current knowledge of actual pesticide application practices remains limited. Pesticide usage information in Switzerland is fragmented and based largely on non-representative, small-scale farmer surveys, with significant methodological limitations identified by Lutz (2023) in Agroscope's analyses and further underscored by Gilgen et al. (2023) in their critique of the Swiss Agri-Environmental Data Network (SAEDN), thereby underscoring the urgent need for more systematic, reliable, and spatially explicit pesticide use data (Gilgen et al., 2023; Lutz et al., 2023). In contrast, biomonitoring program data on human pesticide exposure are lacking (Probst-Hensch et al., 2022). Therefore, the contribution from different sources and the health risks associated with single pesticides and common mixtures have not yet been studied prospectively. Even though Switzerland participated in the European-wide HBM4EU science-to-policy program (https://www.hbm4eu.eu/). **The lack of data on human exposure to pesticides and related health risks is a concern for evidence-based decision-making on pesticide regulation. It also affects the development of the comprehensive "Swiss National Action Plan for Reducing Pesticide Risks" and the implementation of evidence-based occupational and non-occupational pesticide risk reduction measures** (BLW, 2017). In 2021, the political debates and citizens' initiatives as referendums on the future of synthetic pesticide use (e.g. "For a Switzerland without synthetic pesticides" or "Drinking water initiative") revealed widespread public concern about the potential health impacts on consumers and residents living near agricultural land (Finger, 2021; Kaiser, 2023).

People living near agricultural land are exposed to multiple pesticides via different exposure pathways (e.g., drift, take-home exposure or dietary intake) (Hyland & Laribi, 2017). These exposure pathways show high temporal variability (between and within seasons) and depend on specific area, family or household characteristics (e.g., occupation of adults, number of farm workers at home or type of crops grown in proximity). Most studies on pesticide exposure are however limited to cross-sectionally studied crude exposure markers, such as crop- or occupational-exposure matrices or self-reported data (Ohlander et al., 2020; Teysseire et al., 2020), rather than objectively measured pesticide exposures. It is indeed challenging to assess exposure to specific pesticides allowing to compare exposure estimates across studies. Pesticide exposure assessment methods are limited by: (i) the number of pesticides to investigate; (ii) the variable exposure windows due to differences in application timing; (iii) the possible self-reporting bias in the case of direct pesticide use (in farmers' studies), or the misclassification of pesticide use when reported by experts; and finally (iv) ignoring participants' individual behavior in environmental exposure modeling studies. These limitations are often cumulated by practical problems when performing studies in populations in remote areas. To overcome some of these limitations, objective tools such as **silicone wristbands - representing passive samplers - have been proposed to measure time-integrated airborne exposure to multiple chemicals** (Fuhrimann et al., 2021).

Another promising exposure method, **urinary biomarkers, could be used for a more holistic, physiologically relevant and pesticide-specific exposure estimation** (Norén et al., 2020).However, due to the high costs of the laboratory analysis, difficult sample logistics and ethics, studies assessing pesticide biomarkers remain primarily cross-sectional, small in size, and target a few biomarkers only. Further, multiple exposure measurements have to be taken in order to estimate a longer-term exposure, i.e. to account for the high temporal (often daily or weekly) variation due to the biomarker's short half-life (e.g. 2-3 days) or the seasonal use patterns (Veludo et al., 2022). Modeling average exposure (i.e. as a proxy for cumulative long-term exposure) is therefore important for epidemiological analysis. It has been successfully used to overcome situations where within-person variability is relatively high compared to between-person variability to minimize exposure misclassification (Kromhout & Heederik, 2005). Pesticide exposure is typical of the latter (Fuhrimann et al., 2020).

Finally, a major challenge in assessing the health relevance of specific pesticide sources is the fact that people are exposed to often the same pesticides from a multitude of different sources, e.g. nearby pesticide application, diet, beverages, household application of pesticides.

Pesticide use in Switzerland

In Switzerland, 248 different pesticides were sold for farming in 2023 (BLW, 2023). Between **2013 and 2019, a decreasing trend in pesticide sales was reported for all pesticide groups** (BLW, 2023)**.** The five most sold products in 2018 were sulfur (fungicide), paraffin oil (insecticide), folpet (fungicide), mancozeb (fungicide), and glyphosate (herbicide). Sulfur and paraffin oil are approved for both organic and conventional production (BLW, 2023). However, in spite of the reduction in the overall amount of agricultural pesticide use in high-income contexts (including Switzerland), the risks for the environment and human health are potentially increasing due to the introduction of pesticides that are less frequently applied, but more toxic (Schulz et al., 2021). Newly introduced pesticides may also be less well characterized for their long-term health effects in humans.

There were also several environmental monitoring programs which could establish that low concentrations of pesticides are present in different environmental matrices such as water (BAFU, 2022), rain, and air (Carbotech, 2021). Recently, official **pilot air quality measurements for 83 pesticides and their metabolites were conducted across different locations in Switzerland in 2020** (Carbotech, 2021). In the air, 26 pesticides were present. Among the herbicides, terbuthylazine and its metabolite terbuthylazine-desethyl, diuron und s-metolachlor exhibited the highest concentrations. The **sampling sites in Valais showed highest concentrations in spring between March and June**. Most prominently, fungicides (pyrimethanil, cyprodinil, metalaxyl (-M), fenhexamid, fenpropidin, and fludioxonil) were measured in higher concentrations. The risk of all individual substances measured in air was evaluated to be low compared to toxicological reference thresholds. However, **most of these evidenced pesticides have not been evaluated in epidemiological studies. Likewise, the exposure risks have not been accounted for potential pesticide co-occurrence and the possible cumulative effects of pesticide mixtures and pesticides accumulation from exposure to different sources.**

Considering the above arguments, we proposed to objectively assess concurrent pesticide exposure and study the related short-term respiratory health effects in primary schoolchildren living in proximity to typical agricultural activities of the canton Valais.

2. Purpose of the Study

Given the need for epidemiological studies in exposed populations, especially in vulnerable groups such as children, we proposed to study airborne pesticide exposure and the potential associated short-term health effects. We proposed to study short-term respiratory health, including lung function and respiratory symptoms, in primary school children who are likely to be exposed via air drift from agricultural pesticide applications.

2.1 Aims

The study aims to broadly and objectively evaluate pesticide exposure in primary school children attending schools near vineyards and fruit orchards, and to investigate the short-term association of pesticide exposure with respiratory health, accounting for other non-pesticide inhaled irritants, including exposure to pollen and/or air pollution.

2.2 Primary and Secondary Objectives

The study has two main objectives and was designed to answer four key research questions:

Primary objective: To measure the extent of pesticide exposure experienced by primary school children living near vineyards and orchards.

Key Questions:

1. Which pesticides are the children exposed to via air?
2. What determines children's airborne pesticide exposure near vineyards and orchards?

Secondary objective: To explore how pesticide exposure acutely affects children's respiratory health, including respiratory symptoms and lung function, during different seasons.

Key Questions:

3. Is there a short-term link between measured pesticide exposure and reported respiratory symptoms?
4. Is there a short-term link between measured pesticide exposure and changes in lung function?

Further, notably based on the results of this study, the Department of Health in Valais has mandated the Swiss Tropical and Public Health Institute (Swiss TPH) to **give recommendations** on how to decrease, if necessary, the exposure to pesticides of children living near vineyards and fruit orchards and how to mitigate their effect, if any evidenced, on the health of children.

3. METHODS

In the following section, we will present the methodologies used to collect our data and to answer our main objectives and specific research questions.

3.1 Ethical Approval

Ethical clearance was obtained by the regional ethical commission “Commission cantonale d'éthique de la recherche sur l'être humain” of the canton Vaud, Switzerland on November 16, 2023 (CER-VD) (BASEC No. 2023-01155).

The recruitment and written informed consent process involved contacting parents through their child's teacher with multilingual study information and consent forms. Parents returned completed forms via their child, or an empty envelope if they chose not to participate. Participants then registered online and completed a demographic questionnaire. Out of the targeted 785 children, 273 agreed to participate in the study and completed parent questionnaires, 206 children were randomly selected to participate in the measurements (99 from Saxon and 77 from Chamoson. Random selection was not possible for Salgesch due to the small number of participants (n = 30). The subset of 206 consenting participating children underwent in-depth assessments, complemented by age-appropriate assent and parental consent. Support for parents was provided through a hotline and email.

Access to person-identifying information was restricted to the study team and IT support, with usage logged. During analysis, data was de-identified. De-identified data was shared with partners using written specific data transfer agreements. Biological samples were managed by Swiss TPH, double-coded, and stored in secure dedicated infrastructure space. Urine samples were shipped frozen to Lund University (Applied Mass Spectrometry in Environmental Medicine | Lund University 2024) and stored at -80°C, while wristband extracts were sent to Wageningen University (Wageningen Food Safety Research 2019) for analysis. All procedures adhered to the declaration of Helsinki and the declaration of Taipei.

3.2 Study Participants and Sampling Procedure

The study investigated pesticide exposure and respiratory health in primary school children attending school levels 3H to 8H. The study took place in three primary schools in the municipalities of Chamoson, Saxon and Salgesch in the canton of Valais, Switzerland **(Figure 1)**. The school levels 3H to 8H represent the six years of primary school education, following two years of kindergarten. **Figure 1 in supplementary information 2 (SI2)** outlines the process for recruiting schools, and Figure 2 in SI2 detailing the criteria and stages for identifying eligible participants.

The study targeted all 785 children attending the three primary schools, with an estimated participation rate of 50%. Power simulations of our case-cross-over design indicated that a minimum sample size of 400 children was required for binary outcomes (parent-reported respiratory symptoms [yes/no]) and 200 children for continuous outcomes (lung function measurements). Details of the power calculations are provided in **SI1 section (3)**. Enrolment took place between November and December 2023. **Inclusion criteria (SI2 Figure 2)** required children to be enrolled in primary school grades 3H to 8H at one of the participating schools. To participate, children in grades 6H to 8H required both signed parental consent and child written assent, while children in grades 3H to 5H required signed parental consent and child verbal assent. **Children were excluded** from the study if they had an allergy to silicone or were unable to understand the study protocol. The final sample of participants was randomly selected using the sample() function in base R (version 4.4.1; RStudio version 2024.09.0, "Cranberry Hibiscus" release) to ensure a representative distribution across the schools. Specifically, 100 children were targeted at the two schools located near vineyards (Chamoson and Salgesch) and 100 children at the school near both vineyards and orchards (Saxon). This approach ensured representation of the diverse agricultural environments across the three participating schools.

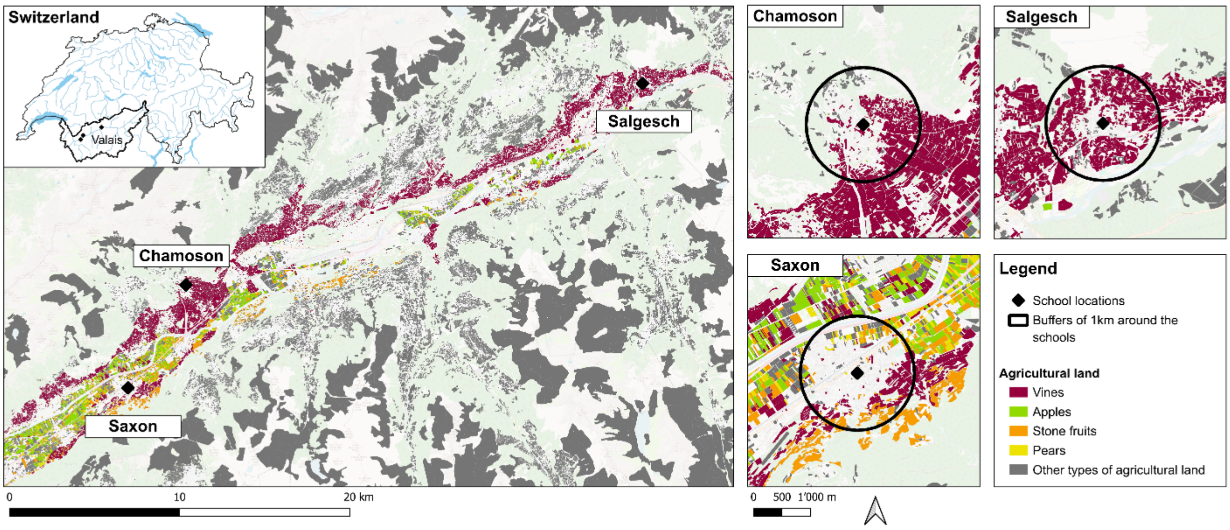

Figure 1: Map of the study site, showing the three villages of Saxon, Chamoson, and Salgesch, along with the selected schools and nearby agricultural land, including vineyards and fruit orchards.

The study involved four one-week assessments in two phases (off-spraying and spraying season) **(Figure 2a)**: (1) a baseline assessment during the off-spraying season (January 8 to February 9, 2024) and (2) three follow-up assessments during the pesticide spraying season (April 8 to June 21, 2024). Assessments were conducted during school periods, excluding school holidays.

At each of the four assessments **(Figure 2b)**, parents of the participating children filled out an online questionnaire. The survey asked about family background, where exact address of residency, any known pesticide exposure (nearby agricultural activities, parent-occupational exposure, children's behavior and food consumption) and their child's respiratory health. The health questions were based on the asthma and allergy study called International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire (Asher et al., 1995; Braun-Fahrländer et al., 1997).

From the random selection of 206 children, in-depth measurements were conducted during each assessment to measure pesticide exposure and respiratory function. Each assessment included the following **steps (Figure 2b and SI1 section (1))**:

- **Pesticide Exposure:** Children wore a silicone wristband during the assessment week to measure pesticide exposure (Fuhrimann et al., 2021). Additionally, a random subsample of 52 children placed stationary silicone wristbands at home. At the end of each week (day 8), urine samples were collected to test for targeted pesticide biomarkers (Norén et al., 2020).
- **Lung Function:** Children used a smartphone-connected spirometer device to measure their lung function (MIR, 2019). The measurements were performed under supervision of trained fieldworker at school on day 1 and 8, and with the help of their parents at home every evening on days 1 to 7 (between 6pm and 9pm).
- **Height and Weight:** Children's height and weight were measured on day 1.

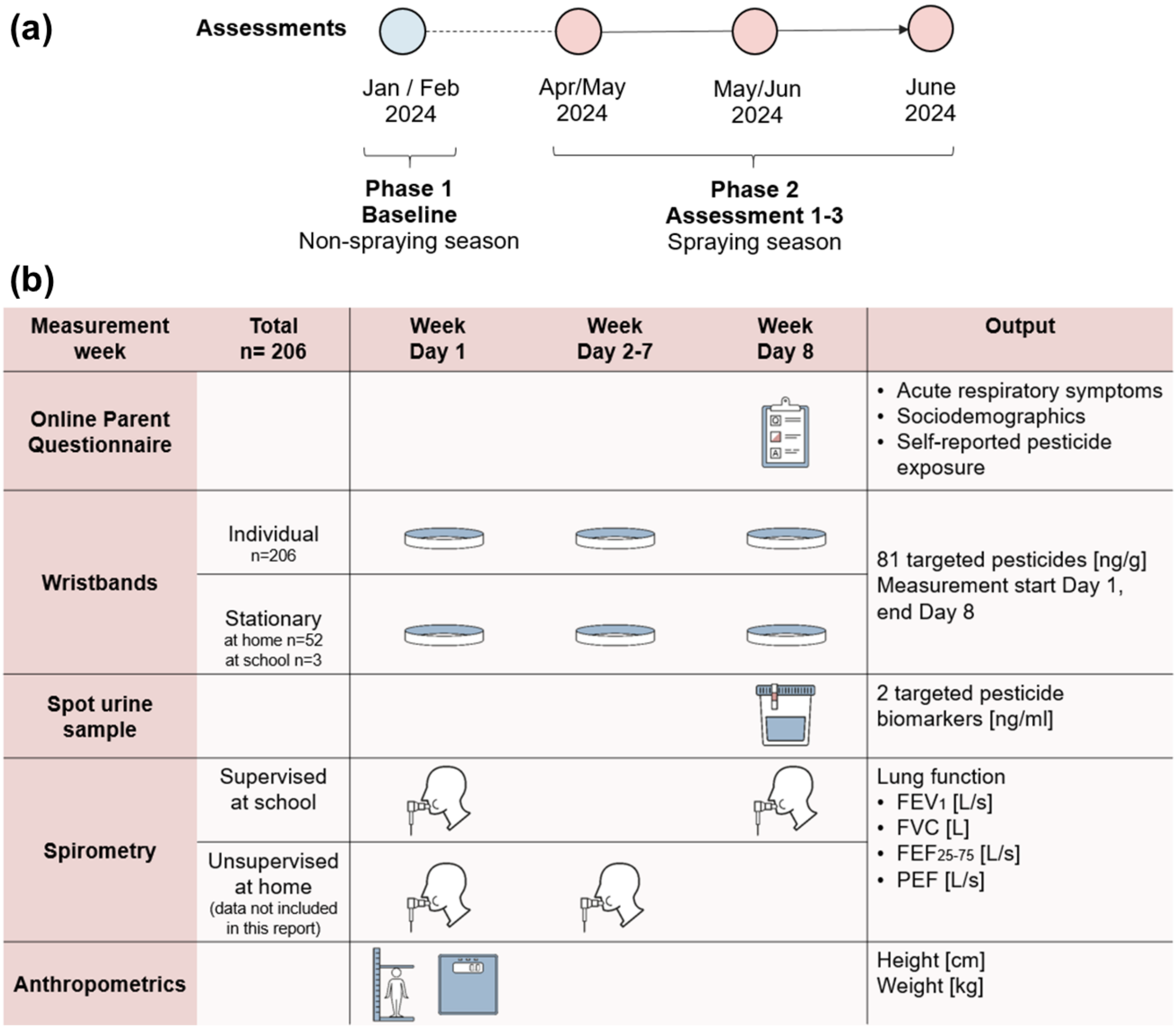

Figure 2: (a) Shows the overall plan for the study, including the total number of children included in the analysis (n = 206) and the two phases (non-spraying and spraying seasons) consisting of a total of four assessments periods. **(b)** Shows the measurements taken from the children during the in-depth measurements.

3.3 Selection of Target Pesticides

A total of 81 pesticides and two urinary biomarkers were selected for analysis in wristbands and urine samples. The selection process followed a stepwise approach based on the following criteria **(Figure 3)**:

- **Market availability:** Pesticides sold in Switzerland in 2020 (BLW, 2023).
- **Relevance to respiratory health:** Pesticides known or suspected to irritate the respiratory system, as well as those with missing toxicological data in the Pesticides Properties Database (Lewis et al., 2016).
- **Analytical feasibility:** Pesticides that could be reliably detected using the available analytical methods.

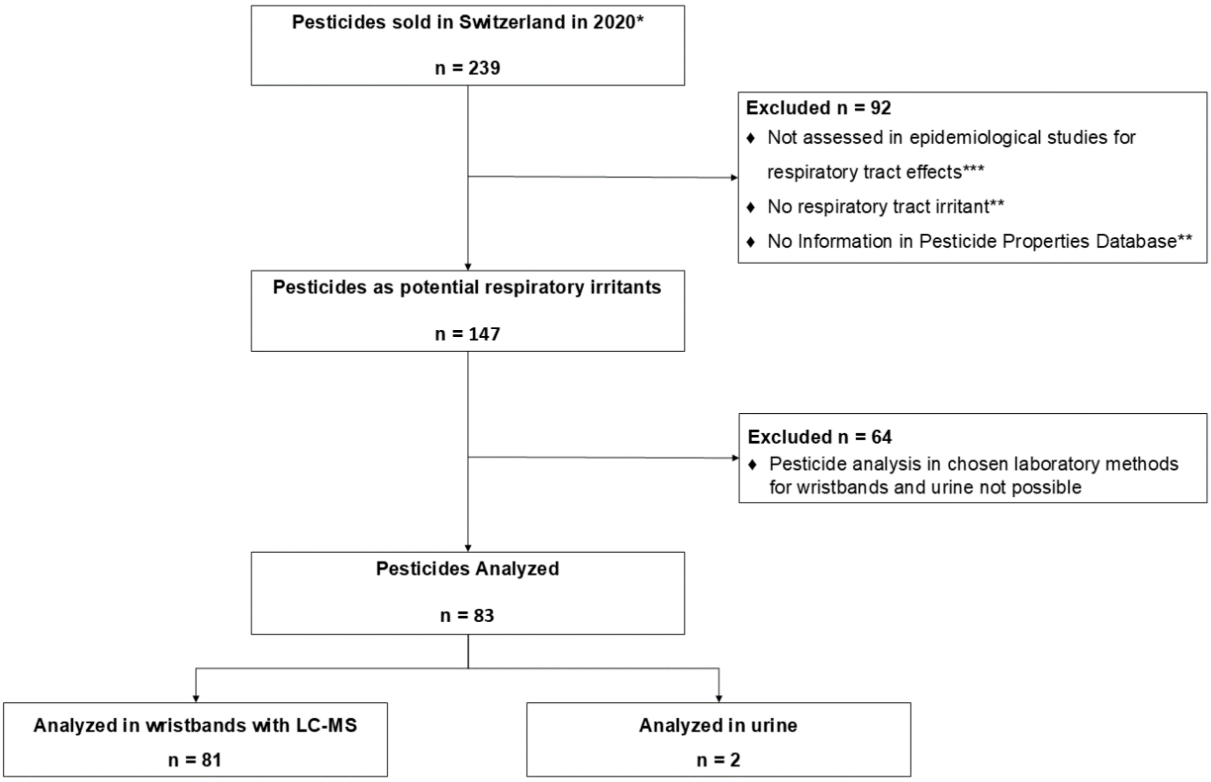

Figure 3: This flowchart illustrates the selection of targeted pesticides for the wristband and urine analysis, detailing the sequential steps and criteria applied at each stage. * The targeted pesticides were selected based on the most recent available data at the time (BLW, 2023). **Based on the Pesticides Properties Database (PPDB, Lewis et al., 2016). ***(Raherison et al., 2019; Yang et al., 2023, p. 20).

While our analysis covers nearly 60% of the potentially respiratory irritant pesticides sold in Switzerland in 2020, several key pesticides, such as pyrethroids (Arcury et al., 2021; Islam et al., 2023; Lee et al., 2022), sulfur (Raanan et al., 2017), copper, folpet, and captan (Galea et al., 2015; Lewis et al., 2016), were not included due to limitations in sampling materials or analytical methods. For example, wristbands and urine samples cannot effectively capture excess copper and sulfur exposure, while high detection limits in existing methods for folpet and captan make it difficult to measure the low levels expected from drift exposure in nearby populations. Pyrethroid exposure is measured in urine and will be presented in the near future.

3.4 Data Collection

The study gathered broad data to evaluate pesticide exposure, health outcomes, and potential confounding factors. **Table 1** highlights the methods used to quantify pesticide exposure, while **Table 2** details the tools and techniques for assessing health outcomes and related variables.

Table 1: Types of data and study tools used to measure or estimate pesticide exposure.

Pesticide exposure measures	Type of data (sample involved)	Tools	Metrics
Measured airborne 7-day cumulative exposure to selected pesticides	**Measurement (sub-sample)**	Individual silicone wristbands	One wristband per child, at each of the 3 schools and at 52 households (one in each assessment) were collected and screened for 81 pesticides which were registered in Switzerland in 2020 and are potential respiratory irritants (section 3.4.3).
Measured exposure to selected pesticide urinary biomarkers	**Measurement (sub-sample)**	Urinary biomarkers	Four urine samples per child were collected on day 8 of each assessment. Two urinary biomarkers were analyzed (section 3.4.3).
The distance of the residential address to the closest agricultural land	**Measurement**	Geocoded residential addresses and agricultural land use data	Closest distance [m] to any conventional and organic agricultural land, any vineyards, and any fruit orchards (section 3.4.2).
The surface of agricultural land around the residential address	**Measurement**	Geocoded residential addresses and agricultural land use data	The proportion of land of conventional and organic agricultural land, vineyards, and fruit orchards within 50 m, 250 m, 500 m, and 1000 m buffers around each household (section 3.4.2).
Pesticide use at home Parents' occupation Parents' occupational pesticide use	**Self-reported (total sample)**	Online questionnaire Source : BILD, CapSA, FarmCoSuisse,	Continuous or grouped into categories (section 3.4.1).

Table 2: Types of data and study tools used to measure respiratory health outcomes and potential confounding factors.

Health outcome	Type of Data (sample involved)	Tools	Metrics
Lung function	**Measurement (subsample)**	Spirobank Smart; MIR (Medical International Research, Rome, Italy)	Measured lung function parameters were done at schools, one at each assessment at day 1 and day 8 as well as at home in the evening. Lung function parameters include: forced expiratory volume at 1 second (FEV_1 [L]), forced vital capacity (FVC [L]), their ratio (FEV_1/FVC), and peak expiratory flow (PEF [L/s], and forced expiratory flow between 25% and 75% of FVC ($FEF_{25\text{-}75}$ [L/s]) (section 3.4.4).
Body height and weight	**Measurement (subsample)**	Scales, measuring tape	Height [cm] (section 3.4.5).
Self-reported asthma, rhinitis, and other respiratory symptoms	**Parent-reported (total sample)**	Study of Asthma and Allergies in Childhood (ISAAC) questionnaire	Score of self-reported respiratory symptoms (yes/no) for the measurement week and asthma (ever diagnosed) (section 3.4.4).
Other respiratory conditions and information	**Parent-reported (total sample)**	LuftiBus Study und BILD Study questionnaire for parents	Assessment of different respiratory diseases and confounding factors validated for Swiss school children (section 3.4.4).
Potential confounding factors	**Type of Data (sample involved)**	**Tools**	**Metrics**
Puberty stage	**Parent-reported (total sample)**	Online questionnaire	Assessment of onset of early puberty (section 3.4.1).
Socio-demographics	**Parent-reported (total sample)**	Online questionnaire Source: HBM4EU SOPHYA	Age, sex, parental education, household income, ethnicity (section 3.4.1).
Other respiratory risk factors	**Parent-reported (total sample)**	Online questionnaire Source: BILD	Smoking in the household (yes/no), furry pets (yes/no) (section 3.4.1).
Air pollution at the household and school level	**Measured (daily)**	Air pollution data. Including the residential history of children	Daily average of $PM_{2.5}$ concentration, during measurement weeks. Data were obtained from the official cantonal local measuring station in Sion (IDAWEB database), Switzerland (section 3.4.6).
Pollen exposure	**Measured (daily)**	Regional measurement station	Daily pollen levels during measurement weeks. Data were obtained from the official cantonal measuring station in Sion (IDAWEB database), Switzerland (section 3.4.6).

Parent Questionnaire

The questionnaire aimed to gather self-reported data on children's respiratory health and pesticide exposure, along with household socioeconomic status, demographics, puberty stage, residential history, and other respiratory risk factors **(Figure 2, Table 2)**.

The baseline questionnaire, validated and piloted beforehand, was administered to parents online after each assessment to minimize reporting bias, as many questions focused on the preceding seven days. If not completed within three days, parents received up to two reminder emails every two days. Paper questionnaires were available upon request, with responses manually entered in ODK or REDCap by the study team. Baseline questions covered the past 12 months and the last 7 days, while follow-up assessments focused on the past month and the last 7 days. Baseline data were collected using ODK, and follow-up questionnaires utilized REDCap, both hosted at Swiss TPH.

Distance to and area of agricultural land use around participants home addresses

Address geocoding: We successfully geocoded 205 out of 206 home addresses based on the information provided during registration. The x and y coordinates of the participants' current home addresses were manually retrieved from the Swiss Federal Office of Topography (map.geo.admin.ch).

Agricultural Land Use: We utilized agricultural land use data for 2023 from the Geoinformation Service of the Canton of Valais. This vector-based dataset includes geometric representations of farming plots at a 1:5'000 resolution, covering 83 crops. Our analysis focused on agricultural land, specifically vineyards, apples, pears, and stone fruits, with apples, pears, and stone fruits grouped as "fruits." Production modes were categorized as conventional or organic. We extracted and classified the relevant land use data into eight distinct categories **(Table 3)**. Using R (R Core Team, 2023) we computed (1) the shortest distance [m] between participant's residential address and each land use category and (2) the proportion of the area [%] of each land use category present around the participant's household in a buffer radius of 50 m, 250 m, 500 m and 1000 m, respectively.

Table 3: Overview of the agricultural land categories of interest considered for our analysis

Category number	Crop(s)	Production mode(s)
1	Agricultural land	Any (regardless of production mode, including grassland)
2	Vineyards	Any (regardless of production mode)
3		Conventional
4		Organic
5	Fruit orchards	Any (regardless of production mode)
6		Conventional
7		Organic
8	Vineyards or fruit orchards	Any (regardless of production mode)

Pesticide Exposure Measurements

Silicone Wristbands

Silicone wristbands were used to measure individual, household, and school airborne pesticide exposure. For each assessment, the children received a silicone wristband on day 1 and wore it until day 8. They were instructed to never take it off. On day 8, the fieldworkers collected the wristbands. The silicone wristbands passively absorbed pesticides in the air. For each school, one pre-packed wristband was taken along as a field blank to observe if there was cross-contamination during the packing and transportation of the samples **(SI1 section (1))** (Fuhrimann et al., 2021).

Wageningen University in the Netherlands analyzed the 81 pesticides in the silicone wristbands. (*Wageningen Food Safety Research*, 2019). The Laboratory used liquid chromatography (LC) to detect pesticides. LC separates pesticides in a liquid mobile phase based on their interactions with a stationary phase, allowing for detection and quantification using mass spectrometry or other detectors (Elmastas, 2024).

Airborne pesticide exposure was defined as the pesticide measured in the children's wristbands. A pesticide is detected when its concentration exceeds the machine's Limit of Detection (LOD). The LOD refers to the lowest concentration of a substance that can be reliably detected but not necessarily quantified. Azoxistrobin has a LOD of 2 ng/g of wristband. All other pesticides have a LOD of 0.7 ng/g of wristband. We focused on the pesticides with a detection frequency of 40% above LOD in at least one assessment. From here onwards, the LOD will be referred to as detection frequency.

A random sub-sample of 52 children (around 15 per community) received a stationary wristband for each assessment to be placed outside of their home. Please refer to **SI1 section (1)** for a detailed description of the instructions given to parents. The 52 children were stratified into two groups to establish a contrast in the households' proximity to the nearest vineyards or fruit orchards (category number eight in **Table 3**). One group was within 0-20 m of the closest vineyard or fruit orchard, and the other group was within 20-200 m of the closest vineyard or fruit orchard. The cut-off at 20 m was chosen according to instructions from the authorization service (BLV) concerning measures to reduce the risks associated with the application of pesticides (BLV, 2024a). The stationary wristbands were placed in the schools and distributed to the selected sub-sample of households along with the individual wristbands. A string was used to hang the wristbands about 1.5 m above the ground outside the house/school under a shelter protected from weather and direct sunlight.

Spot Urine Samples

On day 8, spot urine samples were collected from children at school using 100 mL sterile plastic containers (Sarsted, container with screw cap, 100 mL) (Veludo et al., 2024). The samples were then aliquoted into 4 mL sterile plastic test tubes (Sarsted, V-Monovette®) and stored at −20 °C in the laboratory of the Institute Central de l'Hôpital du Valais (OVS) in Sion, Switzerland. One aliquot was sent to Lund University, Sweden, for pesticide biomarker analysis, while another was stored at Swiss TPH at -80°C.

At Lund University, the urine samples were analyzed for pesticide biomarkers, specifically hydroxy boscalid (BOS-OH) and hydroxy tebuconazole (TEB-OH) (*Applied Mass Spectrometry in Environmental Medicine | Lund University*, 2024). Urine samples provide a comprehensive assessment of short-term pesticide exposure, encompassing multiple exposure routes such as inhalation, dermal contact, and dietary intake. A urinary biomarker was considered detected when its concentration exceeded the machine's LOD of 0.03 ng/mL for both urinary biomarkers.

Respiratory Health Measurements:

Self-Reported Respiratory Symptoms

Weekly acute respiratory symptoms (yes/no) were used as the outcome for objective 1. They were defined as having any of the five reported respiratory symptoms (chest wheezing, severe chest wheezing; wheezing after exercise, rhinitis, and dry cough without cold/bronchitis) during the course of the last week (Gunier et al., 2018; Raanan, 2021). Respiratory symptoms were assessed using questions adapted from the ISAAC questionnaire, which was developed to identify asthma, rhinitis, chronic bronchitis, and eczema (Asher et al., 1995). Additional questions from the LuftiBus (Mozun et al., 2021) and BILD (Fuchs et al., 2011) studies were included to address respiratory diseases in Swiss school children. Parents completed an online questionnaire after each assessment, reporting symptoms experienced ever, in the past month, and in the past week.

Lung Function Measurements

The five measured lung function parameters included forced expiratory volume in 1 second (FEV_1 [L/s]), forced vital capacity (FVC [L]), their ratio (FEV_1/FVC [%]), peak expiratory flow (PEF [L/s]), and mean forced expiratory flow during 25% and 75% of FVC (FEF_{25-75} [L/s]). An app-based, portable spirometer (Spirobank Smart, Medical International Research MIR, Rome, Italy) was used to measure lung function repeatedly (MIR, 2019).

Spirometry measurements were conducted on day 1 and day 8 under the supervision of a trained fieldworker. In addition, the children performed daily unsupervised spirometry measurements at home with their parents' support from day 1 to day 8 (between 6pm and 9pm). The fieldworker demonstrated proper use of the spirometer, emphasizing correct hand placement, sealing the lips around the tube, proper placement of the nose clip, and using relatable examples, such as blowing up a balloon or extinguishing birthday candles, to explain the breathing technique. Children were instructed to sit or stand upright, exhale forcefully and continuously, and maintain the effort as long as possible. The fieldworker monitored posture, provided real-time guidance, and ensured the tests were repeated up to five times for accuracy, motivating children throughout the process. Once the tests were completed, data were securely uploaded – via the dedicated and secured smartphone app data connection - to the Swiss TPH server for storage and analysis. For home measurements, parents received a written manual with instructions on how to use the Spirobank smart device and perform spirometry measurements. Families were instructed to complete daily tests between 6pm and 9pm and to send the results via the dedicated smartphone app to the secure study server at Swiss TPH. Finally on day 8, the fieldworkers returned to the school for an additional supervised spirometry measurement, during which children performed five spirometry tests (Richardson et al., 2022). A detailed description of the procedure can be found in the standard operation procedure document (SOP) **section (1) in SI1**.

Anthropometry

On day 1 of each assessment, the children's **height and weight** were measured twice to increase accuracy. Height was measured using a stadiometer Seca 213 and weight was measured using a scale Seca 803 (*Seca, Reinach, Switzerland*, 2023).

Pollen and Air Pollution

Daily pollen concentration data were obtained from the Integrated Data Access Web (IDAWEB) database. We downloaded data from Sion for the period from January 8, 2024, to October 21, 2024. The monitored pollen types included hazel, alder, birch, ash, grasses, mugwort, and ragweed, which are the seven most allergenic pollen types. No data was available for mugwort and ragweed for the months of January through June 2024. Pollen concentrations were measured in real time with hourly resolution and reported as the number of grains per cubic meter of air [No/m³]. For our analysis, we used the mean daily concentration values. To create a comprehensive measure of daily pollen exposure, we developed a composite pollen score, i.e. the average daily concentration of alder, birch, hazel, common ash and grasses per individual.

For air pollution, we focused on particulate matter with a diameter of 2.5 µm or smaller ($PM_{2.5}$), measured in micrograms per cubic meter [µg/m³], which were collected from the same monitoring station as the pollen data.

3.5 Statistical Analysis

Software and Significance Level

Our study utilized R statistical software (R version 4.4.1, RStudio version 2024.09.0 Build 375, "Cranberry Hibiscus" Release) for data management and analysis. The *censReg* package was used for left-censored linear regression models, the *lmerTest* package was used for linear mixed regression models, and the *lme4* package was used for logistic mixed regression models. Additional packages included *rspiro* for calculating lung function measurement z-scores, *anthroplus* for calculating BMI z-scores, *ggplot2* and *patchwork* for creating and organizing plots, *ICC* for calculating intraclass correlation coefficients (ICCs), *broom.mixed* for generating summary tables of model outputs, and *biostatUZH* for formatting p-values and 95% confidence intervals (Cis). We set the significance level at α = 0.05 for all statistical tests.

Data Preparation

The following variables were created after data collection.

Pesticide exposure variables:

- To address the research questions, the statistical analysis focused on pesticides with a detection frequency of at least 40% in at least one of the four assessments. This included eight pesticides: six detected in wristbands **–** ametoctradin, cyprodinil, dimethomorph, imazalil, metalaxyl, and propiconazole – and two pesticide biomarkers in urine samples; hydroxy boscalid and hydroxy tebuconazole.

Confounders and risk factors adapted from the original form:

- The **caregiver's highest education** was categorized as primary or lower / secondary / tertiary according to the Swiss education system, which is divided into three levels: primary (4-11 years), secondary (12-19 years) and tertiary (19-24 years) (EDA, 2024).
- **Body mass index z-scores** (BMI z-scores) were calculated using reference data from the Centers for Disease Control and Prevention (CDC, 2024), and categorized according to the World Health Organization (WHO, 2007) classification (Severe Thinness / Thinness / Normal / Overweight / Obesity) (WHO, 2007).
- **Agricultural land use** was computed for: (1) the shortest distance between participant's address and each land use category **(Table 3)** and (2) the total surface area of each land use category present around the participant's household in circular buffers of 50, 250, 500 and 1000 m. Eight different land use types were considered: (i) any agricultural land, (ii) any vineyards or fruit orchards, (iii) any vineyards, iv) organic vineyards, (v) conventional vineyards, (vi) any fruit orchards, (vii) organic fruit orchards, (viii) and conventional fruit orchards **(Table 3)**.

Potential confounders of associations between dependent and independent variables of interest were identified through a literature review and expert opinion in environmental and occupational health. They included assessments, spraying season, school, caregiver education, farm residency, child age, child sex, fieldworker, puberty onset, parental smoking, household income, categorized child physical activity compared to other children, cold-like symptoms (cough, cold, aching throat), daily $PM_{2.5}$ concentration, and allergenic pollen concentration.

Primary objective: To measure the extent of pesticide exposure experienced by primary school children living near vineyards and orchards.

1. Which pesticides are the children exposed to via air?

In our analysis of airborne pesticide exposure, we employed a range of descriptive statistics to provide a comprehensive overview. We utilized frequency counts and percentages to quantify pesticide detection, visualizing these through bar plots and heat maps. Co-occurrence patterns were illustrated using Upset plots, while correlation patterns were examined using Spearman correlation coefficients and displayed in heat maps. To compare individual and stationary wristband measurements, we created scatter plots and calculated correlation coefficients. The distribution of pesticide concentrations was represented using box plots, accompanied by ICC to evaluate measurement consistency. We also reported measures of central tendency (mean, median) and dispersion (standard deviation, interquartile range), along with descriptive summaries including minimum and maximum values. This diverse set of statistical tools allowed us to effectively characterize pesticide exposure patterns, correlations, and distributions across various statistical assessments and measurement methods.

2. What determines children's airborne pesticide exposure near vineyards and orchards?

The following three specific research questions were addressed:

1. How does the proximity of children's home addresses to agricultural land influence their level of pesticide exposure?

To evaluate the relationship between mean pesticide exposure and proximity to agricultural land, linear Tobit models were employed for the pesticides detected on wristbands **(equation 1a)**, and linear mixed models for the pesticides detected in urine **(equation 1b)**.

$$\frac{1}{J}\sum_{j}\log_{10}\left(c_{pesticide,ij}\right) \sim \beta_0 + \beta_1 * distance_i + \sum_{k=2}^{3}\beta_{2k} * school_{ik} + \sum_{k=2}^{3}\beta_{3k} * education_{ik} + \beta_4 * farm_i,$$

for $i = 1, \dots, n$, $j =$ {B, A1, A2, A3} and $k = k$th level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable; adjusting variables
(equation 1a)

$$\log_{10}(c_{pesticide,ij}) \sim \beta_0 + \beta_1 * distance_i + \sum_{k=2}^{3}\beta_{2k} * school_{ik} + \sum_{k=2}^{3}\beta_{3k} * education_{ik} + \beta_4 * farm_i + \beta_5 * spraying\ season_j + \alpha_{0ij} * child_{ij},$$

for $i = 1, \dots, n$, $j =$ {B, A1, A2, A3} and $k = k$th level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable; adjusting variables; random effects

(equation 1b)

The **outcome variable** was defined as the mean of the $\log_{10}$-transformed concentration of the pesticides [ng/g] measured in children's individual wristbands, and as the $\log_{10}$-transformed concentration of the pesticide biomarkers [ng/ml] measured in children's individual urine samples. For the pesticide biomarkers measured in urine, machine-read values below LOD were provided and used for the analysis. For the pesticides measured in biomarkers, values below LOD were replaced by 0.01, and censored at $\frac{1}{J}\sum_j \log_{10}(0.01) = -2$. The **exposure variable** was defined as the shortest distance [100 m] from a participant's home address to the eight different types of agricultural land use **(Table 3)**. A separate model was fitted for each combination of pesticide/pesticide biomarker and type of agricultural land use, resulting in 64 models. **Models were adjusted** for school (Chamoson, Saxon, Salgesch), the caregiver's highest education (primary or lower, secondary, tertiary) and whether the child lives on a farm (no, yes). The models for the urinary pesticide biomarkers were additionally adjusted for spraying season (no, yes).

2. **How does the total area of different land use types within different buffers around children's homes influence their pesticide exposure?**

To evaluate the relationship between pesticide exposure and the area of different agricultural land use types surrounding children's homes, linear Tobit models were employed for the pesticides measured on wristbands. The depicted equation represents the model structure without censoring **(equation 2a).** For the pesticide biomarkers measured in urine, linear mixed models were employed with child ID modeled as a random effect **(equation 2b)**.

$$\frac{1}{J}\sum_{j}\log_{10}\left(c_{pesticide,ij}\right) \sim \beta_0 + \beta_1 * area_i + \sum_{k=2}^{3}\beta_{2k} * school_{ik} + \sum_{k=2}^{3}\beta_{3k} * education_{ik} + \beta_4 * farm_i$$

for $i = 1, \dots, n$, $j =$ {B, A1, A2, A3} and $k = k$th level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable; adjusting variables
area: 50 m buffer, 250 m buffer, 500 m buffer, 1000 m buffer

.

(equation 2a)

$$\log_{10}\left(c_{pesticide,ij}\right) \sim \beta_0 + \beta_1 * area_i + \sum_{k=2}^{3}\beta_{2k} * school_{ik} + \sum_{k=2}^{3}\beta_{3k} * education_{ik} + \beta_4 * farm_i + \beta_5 * spraying\ season_j + \alpha_{0ij} * child_{ij}$$

for $i = 1, \dots, n$, $j =$ {B, A1, A2, A3} and $k = k$th level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable; adjusting variables; random effect
area: 50 m buffer, 250 m buffer, 500 m buffer, 1000 m buffer

(equation 2b)

The **outcome variable** was defined as the mean of the $\log_{10}$-transformed concentration of the pesticides [ng/g] measured in children's individual wristbands, and the $\log_{10}$-transformed concentration of the pesticide biomarkers [ng/ml] measured in children's individual urine samples. For urine measurements, machine-read values below LOD were provided and used for the analysis. For wristband measurements, values below LOD were replaced by 0.01, and censored at $\frac{1}{J}\sum_j \log_{10}(0.01) = -2$. The **exposure variable** was defined as the percentage of the area around children's homes within four buffers with a specific radius (50 m, 250 m, 500 m, 1000 m) that consists of the eight different agricultural land use types.

A separate model was fitted for each combination of pesticide, buffer size and agricultural land use type, resulting in 192 models (not 256, because there are no organic fruit orchards within a 50 m buffer around any child's residence). **Models were adjusted** for school (Chamoson, Saxon, Salgesch), the caregiver's highest education (primary or lower, secondary, tertiary), and whether the child lives on a farm (no, yes). For urine measurements, the models were additionally adjusted for spraying season (no, yes).

3. **What are the key spatiotemporal and behavioral factors predicting pesticide exposure in children?**

To identify spatiotemporal and behavioral factors associated with pesticide exposure in children, linear Tobit models were employed for wristband measurements. The depicted equation represents the model structure without censoring **(equation 5)**. For urine measurements, linear mixed models were employed **(equation 3b)**.

$$\frac{1}{J}\sum_{j}\log_{10}(c_{pesticide,ij}) \sim \beta_0 + \beta_1 * \frac{1}{J}\sum_{j} age_{ij} + \beta_2 * sex_i + \sum_{k=2}^{3}\beta_{3k} * education_{ik} + \sum_{k=2}^{3}\beta_{4k} * school_{ik} + \beta_5 * distance_i + \sum_{k=2}^{3}\beta_{6k} * school\ way_{ik} + \beta_7 * \frac{1}{J}\sum_{j} outside_{ij} + \sum_{k=2}^{3}\beta_{8k} * water\ source_{ik} + \beta_9 * farm\ work_i + \beta_{10} * \frac{1}{J}\sum_{j} bath_{ij} + \beta_{11} * fungicides_i + \sum_{k=2}^{4}\beta_{12k} * farm\ type_{ik}$$

for $i = 1, \ldots, n$, j = {B, A1, A2, A3} and k = kth level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variables

(equation 3a)

$$\log_{10}(c_{pesticide,ij}) \sim \beta_0 + \beta_1 * age_{ij} + \beta_2 * sex_i + \sum_{k=2}^{3}\beta_{3k} * education_{ik} + \sum_{k=2}^{3}\beta_{4k} * school_{ik} + \beta_5 * distance_i + \sum_{k=2}^{3}\beta_{6k} * school\ way_{ik} + \beta_7 * outside_{ij} + \sum_{k=2}^{3}\beta_{8k} * water\ source_{ik} + \beta_9 * farm\ work_i + \beta_{10} * bath_{ij} + \beta_{11} * fungicides_i + \sum_{k=2}^{4}\beta_{12k} * farm\ type_{ik} + \beta_{13} * spraying\ season_{ij} + \alpha_{0ij} * child_{ij}$$

for $i = 1, \ldots, n$, j = {B, A1, A2, A3} and k = kth level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variables; random effect

(equation 3b)

The **outcomes variables** were the mean of the $\log_{10}$-transformed concentration of the pesticides [ng/g] measured in children's individual wristbands, and the $\log_{10}$-transformed concentration of the pesticide biomarkers [ng/ml] measured in children's individual urine samples. For urine measurements, machine-read values below LOD were provided and used for the analysis. For wristband measurements, values below LOD were replaced by 0.01, and censored at $\frac{1}{J}\sum_j \log_{10}(0.01) = -2$. The **exposure variables** included the child's age [years], the child's sex (male, female), the caregiver's highest education (primary or lower, secondary, tertiary), school (Chamoson, Saxon, Salgesch), shortest distance of children's homes to any vineyards or fruit orchards (<20 m, ≥20 m), mode of school way (driving, biking, walking), weekly average hours a child spends outside, household water source (public, private, unknown), times the child takes a bath per week, whether the child helps on a farm (no, yes), use of fungicides in household or garden (no, yes), and the farm type a family member works at (none, conventional, IP, organic). For urine measurements, models were additionally adjusted for spraying season (no, yes). A separate model was fitted for each pesticide and pesticide biomarker, resulting in eight models.

Secondary objective: To explore how pesticide exposure is associated with children's respiratory health, including symptoms and lung function, during different seasons.

3. Is there an association between measured pesticide exposures and self-reported respiratory symptoms?

To investigate associations between pesticide exposure and self-reported **weekly acute respiratory symptoms**, mixed logistic regression models were employed with child ID modelled as a random effect **(equation 4a, 4b)**.

$$\log(odds\ of\ acute\ respiratory\ symptoms) = \beta_0 + \sum_{k=2}^{3} \beta_{1k} * c_{pesticide,ijk} + \sum_{k=2}^{3} \beta_{2k} * school_{ik} + \sum_{j=2}^{4} \beta_{3j} * assessment\ phase_j + \sum_{k=2}^{4} \beta_{4k} * income_{ik} + \beta_5 * pollen_{ij} + \beta_6 * PM_{2.5,ij} + \alpha_{0ij} * child_{ij}$$

for $i = 1, \dots, n$, $j =$ {B, A1, A2, A3} and $k = k$th level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(0, \sigma^2), \rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable, adjusting variables; random effect

(equation 4a)

$$\log(odds\ of\ acute\ respiratory\ symptoms) = \beta_0 + \beta_1 * c_{pesticide,ij} + \sum_{k=2}^{3} \beta_{2k} * school_{ik} + \sum_{j=2}^{4} \beta_{3j} * assessment\ phase_j + \sum_{k=2}^{4} \beta_{4k} * income_{ik} + \beta_5 * pollen_{ij} + \beta_6 * PM_{2.5,ij} + \alpha_{0ij} * child_{ij}$$

for $i = 1, \dots, n$, $j =$ {B, A1, A2, A3} and $k = k$th level of categorical variable, where $\alpha_{0ij} \sim \mathrm{N}(0, \sigma^2), \rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable, adjusting variables; random effect

(equation 4b)

The **outcome variable** was defined as the occurrence of at least one out of five parent-reported weekly acute respiratory symptoms (no / yes) **(Table 5)**. The **exposure variable** was defined as the categorized $\log_{10}$-transformed concentration of pesticides [ng/g] measured in children's individual wristbands (value < LOD, LOD ≤ value ≤ median, value > median), and as the $\log_{10}$-transformed concentration pesticide biomarkers [ng/ml] measured in children's individual urine samples. To avoid multicollinearity issues, a separate model was fitted for each pesticide and pesticide biomarker, resulting in eight models. This modelling choice assumes no confounding effect in-between pesticides. **Models were adjusted** for school (Chamoson, Saxon, Salgesch), assessment phase (B, A1, A2, A3), monthly household net income (<4500 CHF, 4500-9000 CHF, >9000 CHF, no answer), the mean of the mean daily ambient concentration of the five most allergenic pollen types **(see section 3.4.6)** and the mean daily ambient $PM_{2.5}$ concentration.

4. Is there a link between measured pesticide exposures and changes in lung function?

Three modeling approaches **(A-C, see SI2 Table 1)** were employed to investigate the association between measured pesticide exposure and lung function parameters.

The primary approach (A) used a linear mixed effects model with child as a random effect **(equation 5a, 5b)**.

$$\begin{aligned}
&Lung\ function\ parameter\ on\ day\ 8_{ij} \sim \beta_0 + \sum_{k=2}^{3} \beta_{1k} * c_{pesticide,ijk} + \beta_2 \\
&\quad * lung\ function\ parameter\ on\ day\ 1_{iB} + \sum_{j=2}^{4} \beta_{3j} * assessment\ phase_{ij} \\
&\quad + \sum_{k=2}^{3} \beta_{4k} * school_{ik} + \sum_{k=2}^{6} \beta_{5k} * fieldworker_{ijk} + \sum_{k=2}^{4} \beta_{6k} * income_{ik} + \beta_7 \\
&\quad * puberty\ onset_{ij} + \beta_8 * symptoms_{ij} + \sum_{k=2}^{5} \beta_{9k} * activity_{ijk} + \beta_{10} \\
&\quad * parental\ smoking_i + \beta_{11} * PM_{2.5ij} + \beta_{12} * pollen_{ij} + \alpha_{0ij} * child_{ij}
\end{aligned}$$

for $i = 1, \dots, n$, $j = \{$B, A1, A2, A3$\}$ and k = kth level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable, adjusting variables; random effect

(equation 5a)

$$\begin{aligned} Lung\ function\ parameter\ on\ day\ 8_{ij} \sim\ & \beta_0 + \beta_1 * c_{pesticide,ij} + \beta_2 \\ & * lung\ function\ parameter\ on\ day\ 1_{iB} + \sum_{j=2}^{4} \beta_{3j} * assessment\ phase_{ij} \\ & + \sum_{k=2}^{3} \beta_{4k} * school_{ik} + \sum_{k=2}^{6} \beta_{5k} * fieldworker_{ijk} + \sum_{k=2}^{4} \beta_{6k} * income_{ik} + \beta_7 \\ & * puberty\ onset_{ij} + \beta_8 * symptoms_{ij} + \sum_{k=2}^{5} \beta_{9k} * activity_{ijk} + \beta_{10} \\ & * parental\ smoking_i + \beta_{11} * PM_{2.5ij} + \beta_{12} * pollen_{ij} + \alpha_{0ij} * child_{ij} \end{aligned}$$

for $i = 1, \ldots, n$, $j =$ {B, A1, A2, A3} and k = kth level of categorical variable,

where $\alpha_{0ij} \sim \mathrm{N}(\mu, \sigma^2)$, $\rho_{within} > 0$ and $\rho_{between} = 0$.

outcome; exposure variable, adjusting variables; random effect

(equation 5b)

The **outcome variables** were defined as the five lung function parameters FEV_1, FVC, FEV_1/FVC, PEF, and $FEF_{25\text{-}75}$ that were measured on day 8 of each assessment. The lung function parameters were expressed as z-scores adjusted for sex, height, age and ethnicity, based on the Global Lung Function Initiative (GLI) equations (Quanjer et al., 2012). Since no GLI equations exist for PEF, equations from the NHANES III Cohort were employed instead (Hankinson et al., 1999). Z-scores represent the deviation, in standard deviations, of the measured value from the predicted value, accounting for age, height, sex, and ethnicity (Quanjer et al., 2012). Values which met the criteria for repeatability set out in the American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines were kept (Graham et al., 2019): The difference between the largest and second-largest FEV_1 and FVC values is ≤0.15 L. The largest PEF value was taken from the maneuvers that met the repeatability criteria for FEV1, while $FEF_{25\text{-}75}$ was reported from the maneuver with the largest sum of FEV_1 and FVC. The acceptability and usability criteria were not applicable in this setting, due to the citizen-science approach (Graham et al., 2019). The final model included the following numbers of observations: FVC: n = 487, FEV_1: n = 544, PEF: n = 544, $FEF_{25\text{-}75}$: n = 627, and FEV_1/FVC: n = 412.

The **exposure variable** was defined as the categorized $\log_{10}$-transformed concentration of the pesticides [ng/g] measured in children's individual wristbands (value < LOD, LOD ≤ value ≤ median, value > median), and as the log10-transformed concentration of the pesticide biomarkers [ng/ml] measured in children's individual urine samples. A separate model was fitted for each of the five lung function parameters and for each of the eight pesticide exposures, resulting in 48 models. The **models were adjusted** for the lung function outcome measured on day 1 during baseline, assessment (B, A1, A2, A3), school (Chamoson, Saxon, Salgesch), fieldworker, puberty onset (no, yes), monthly household net income (<4500 CHF, 4500-9000 CHF, >9000 CHF, no answer), child's physical activity level compared to other children (much lower, lower, average, higher, much higher), presence of cold-like symptoms (no, yes), parental smoking (no, yes), daily ambient $PM_{2.5}$ concentration, and the total daily ambient concentration of five allergenic pollen types (birch, alder, common ash, grasses, and hazel). Of note, the additional adjustment of the model compared to self-reported respiratory symptoms was possible due to the larger sample size.

A **sensitivity analysis** was performed to test the findings' robustness **(SI2 Figure 7)**: **Figure 7 in the SI2** provides a comparison of the final approach with and without adjustment for $PM_{2.5}$ and pollen.

Data Visualization

Boxplots (Figure 4) visualize how data are distributed by showing the median (red line) and a box representing the interquartile range (IQR), which is the range of values within which the middle 50% of the data lies. It is framed by the lower quartile Q1 (blue line), which is the value beneath which 25% of all data points lie, and the upper quartile Q3 (orange line), which is the value beneath which 75% of all data points lie. Points within the whiskers (green lines) represent data points with a value of at least Q1 – 1.5 * IQR (min) and at most Q3 + 1.5 * IQR (max). The proportion of IQR to whiskers is not accurate in the depicted figure. Points outside the whiskers are classified as outliers (grey points).

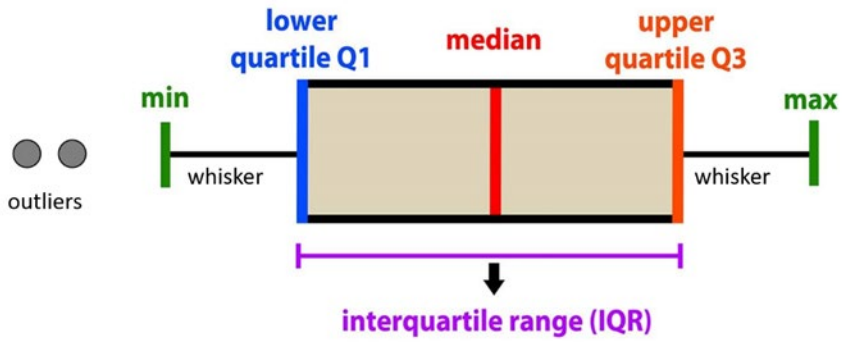

Figure 4: Boxplot interpretation adapted from www.simplypsychology.org. From left to right: *Minimum:* Minimal measured value within Q1 – 1.5 * IQR (end of left whisker); *Lower Quartile* (Q1): 25th percentile; *Median*: 50th percentile, divides box in half; Upper Quartile (Q3): 75th percentile; *Maximum*: Maximal measured value within Q3 +1.5 * IQR (end of right whisker); *Interquartile Range* (IQR): Middle 50% of scores (Q3 - Q1). The box represents the IQR, with whiskers extending to the minimum and maximum values within a pre-defined range, excluding outliers.

Forest plots (Figure 5) display regression outputs, highlighting the slopes (values of effect estimates β) of an independent variable (for example, **see subchapter 3.6.2 equation 1**). Each point represents the effect size with 95% confidence intervals (Cis) shown as error bars. Statistical significance, marked by a red star, occurs when the confidence interval does not cross the x-intercept at 0 or 1, for linear and logistic regression, respectively. This is equivalent to a p-value < 0.05.

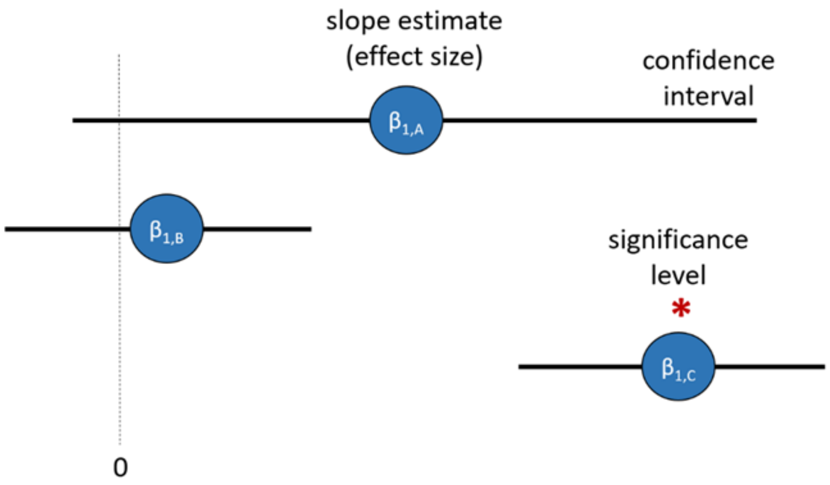

Figure 5: Forest Plot interpretation. *Regression Coefficient* (β): For a linear regression, it indicates how much the outcome measure of the dependent variable increases for a one-unit change in the independent variable. For a logistic regression, it indicates by how much the odds of the dependent variable are multiplied with for a one-unit change in the independent variable. *Confidence Interval (CI)*: A range that shows where the true value of the regression coefficient falls in 95% of cases, if the study was repeated n times with a different random draw from the population. It is usually expressed as [a; b]. It indicates the precision of the estimate. *The dashed line at 0 r*epresents no effect for linear regression. Equivalently, a dashed line at 1 would represent no effect for logistic regression. If the confidence interval does not cross this line, the result is statistically significant.

4. Results

In the following section, we present the results according to our main objectives and specific research questions.

4.1 Study Population and Socio-demographic Characteristics

Of the targeted 785 children, 273 agreed to participate in the study and completed parent questionnaires. From these, 206 children were randomly selected to participate in the measurements (99 from Saxon and 77 from Chamoson). Random selection was not possible for Salgesch due to the small number of participants (n = 30). This resulted in an overall participation rate of 35% **(Table 4 and SI2 Figure 2)**. To answer the study objectives, the report focuses on data from the 206 children participating in the measurements. We excluded the 67 children who were only interviewed by questionnaire because, particularly for research question 3 (respiratory symptoms), we would have needed a sample size of 400 children to predict their pesticide exposure and ultimately use these data in a meaningful way in the analysis.

The 206 children were aged between 6 and 13 years with a mean age of 9.5 years. More boys (58%) than girls (42%) participated in the study **(Table 4)**. The parents had a well-balanced educational background, with 47% having completed secondary education and 44% holding tertiary qualifications, reflecting the Swiss population, where over 44% attain tertiary education (EDA, 2024). The study population is broadly represented across income levels, with 49% reporting a monthly income between CHF 4’500 and CHF 9’000 per month, which is in line with the national average disposable household income in Switzerland of CHF 6’706 per month in 2021 **(Table 4)** (BFS, 2021). Seventeen children (8%) had previously been diagnosed with asthma by a doctor, aligning with the Swiss national average of approximately 10% (Delgrande

Jordan et al., 2022). A detailed summary of all socio-demographic characteristics and relevant confounding variables included in the statistical models can be found in **SI2 Table 2**.

Table 4: Socio-demographic population characteristics for the 206 children and their parents.

	Overall	Missing (%)
	n = 206	
School (n (%))		0.0
Chamoson	77 (37.4)	
Saxon	99 (48.1)	
Salgesch	30 (14.6)	
Child's sex = Female (n (%))	86 (41.7)	0.0
Child's age [y] (mean (SD))	9.5 (1.7)	0.0
Caregiver's education (n (%))		10.7
Primary or lower	17 (9.2)	
Secondary	87 (47.3)	
Tertiary	80 (43.5)	
Monthly net household income (n (%))		11.2
<4500 CHF	7 (3.8)	
4500-9000 CHF	89 (48.6)	
>9000 CHF	49 (26.8)	
No answer	38 (20.8)	
BMI standardized for age and sex (mean (SD))	3.20 (0.53)	1.0
Asthma ever diagnosed = Yes (n (%))	17 (8.3)	1.0
Shortest distance household [m]		0.5
to any agricultural land (median (IQR))	33.8 (43.4)	
to any vineyards (median (IQR))	64.2 (134.9)	
to any fruit orchards (median (IQR))	216.5 (421.5)	
Caregiver answering the questionnaire (n (%))		10.7
Mother	131 (71.2)	
Father	51 (27.7)	
Other	2 (1.1)	

Note: BMI=Body Mass Index

4.2 Agricultural land use around Children's Home Addresses

Agricultural Areas Surrounding Participants' Homes

The 206 children in the study lived at a [median (IQR) m] distance of [33.8 (43.4) m] from the nearest agricultural land. Children lived closer to any vineyards [64.2 (134.9) m] compared to any fruit orchards [216.5 (421.5) m] **(SI2 Table 18)**. The agricultural areas near participants' homes and the proximity of the closest agricultural land to each household is shown in **Figures 6 and 7**.

Composition of Agricultural Areas

Figure 6 and SI2 Table 4 present the distribution of the area as a percentage (%) of total area surrounding home given a specific radius. In Chamoson and Salgesch, vineyards dominate the agricultural landscape around participants' homes in all four buffer zones **(Figure 6, SI2 Table 4).** In Saxon, both fruit orchards and vineyards are present within the 250 m buffer [median = 7.9, (IQR = 10.5) %] and even tripling in percentage within the 1 km buffer [25.9 (9.8) %], reflecting a more diverse agricultural environment. Salgesch, however, is primarily surrounded by vineyards, with the highest proportion [18.8 (30.3) %] compared to the other two communities within a 50 m radius. Beyond 50 m, the proportion of vineyards increases significantly. Similarly, Chamoson exhibits extensive vineyard coverage across buffer zones, from 250 m to 1000 m [14.7 (31.0) % to 32.7 (46.0) %].

Organic vs. Conventional Agricultural Land

All three communities are in [median (IQR)] closer to conventional vineyards [65.5 m (134.8) m] and fruit orchards [214.9 (422.0) m] than to vineyards [245.1 (398.4 m] and organic fruit orchards [892.5 m (1823.9) m]; **(Figure 7, SI2 Table 18)**. Organic agricultural lands, which are less prevalent and typically located farther away than conventional agricultural lands, contributed less to overall pesticide exposure due to their limited use of chemical pesticides. Salgesch's proximity to conventional vineyards [21.2 (31.3) m] presents a higher exposure risk, while Saxon's comparable proximity to both conventional vineyards [136.72 (99.9) m] and conventional fruit orchards [136.72 m (118.5) m] is characterized by a combined exposure risk. Detailed results can be found in **SI2 Table 3**.

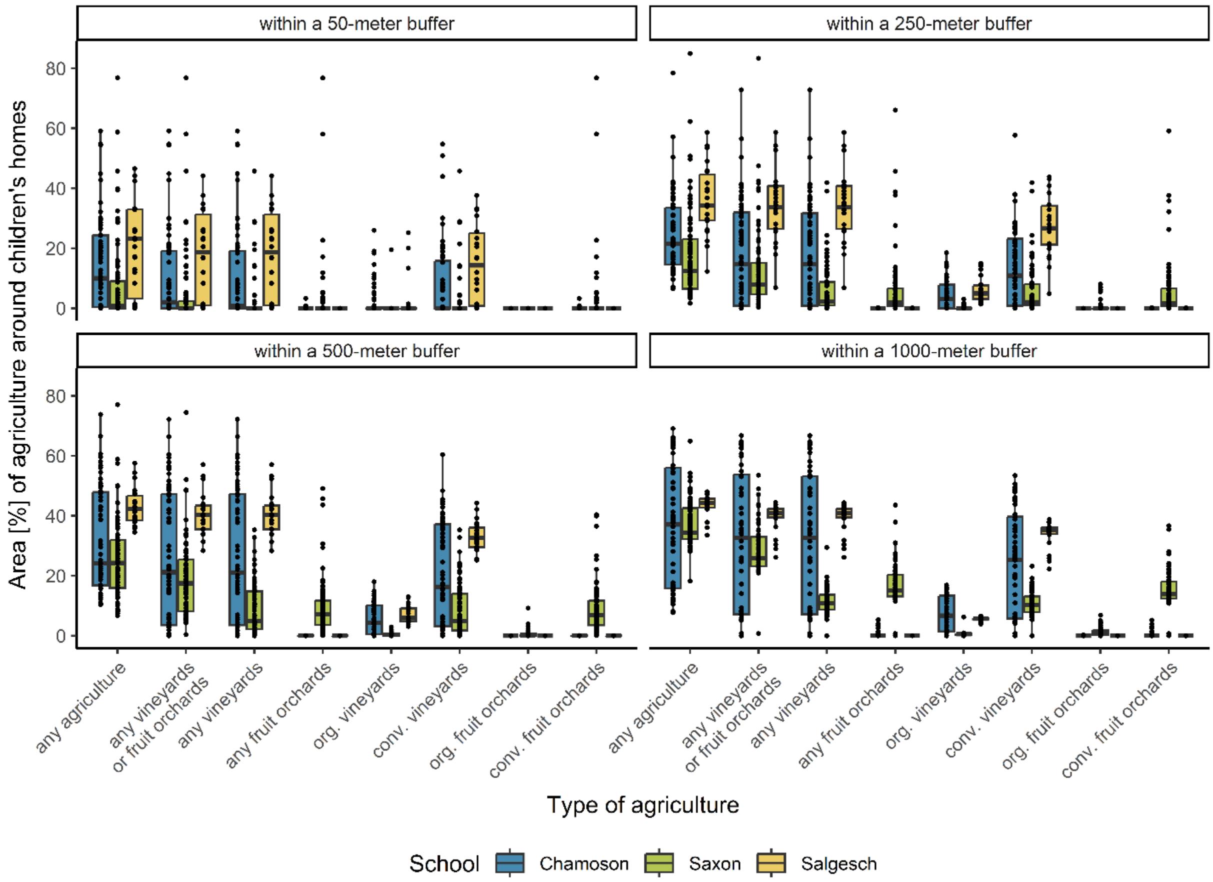

Figure 6: Boxplots showing the distribution of the area [% of total area surrounding home given specific radius] surrounding the home addresses of 203 of the 206 children indicating the eight different types of agricultural land use, stratified by village. Org. = organic; conv. = conventional.

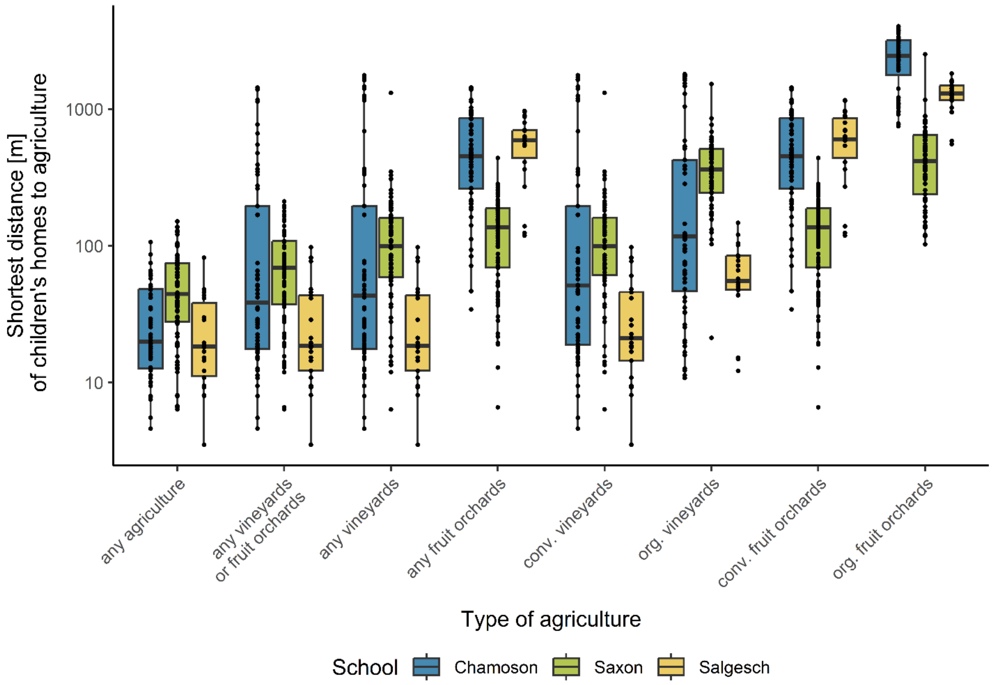

Figure 7: Boxplots showing the distribution of the closest distances [m, $\log_{10}$-scale] from the home addresses of 203 of the 206 children to the eight different types of agricultural land use, stratified by school. Org. = organic; conv. = conventional.

4.3 Primary objective: To measure the extent of pesticide exposure experienced by primary school children living near vineyards and orchards.

1. Which pesticides are the children exposed to via air?

Detection of Pesticides in Wristbands

A total of 778 wristbands from 204 children were collected. Of the 81 pesticides analyzed **(SI3)**, 36 were detected **(Figure 8)**. On average, 14 pesticides per child were detected across all four assessments **(B, A1–A3; Table 5)**. The number of pesticides increased from the baseline assessment (January/February) to the assessment 3 (June). Fungicides were the most frequently detected type of pesticide, with 25 identified, compared to 8 herbicides and 4 insecticides **(Figure 8 and 9, Table 5)**. Most pesticides showed high temporal variability (ICC close to 0), meaning that the children's exposure levels varied significantly across measurements. In contrast, propiconazole displayed moderate variability (ICC 0.69), indicating more consistent exposure levels across time points **(SI2, Table 6/7)**.

A sub-sample of 52 children placed stationary wristbands outside their homes alongside wearing their individual wristbands **(SI2 Table 5)**. More pesticides were detected in individual wristbands than in stationary ones **(36 vs. 15; Figure 8)**. Like the individual wristbands the number of pesticides increased from the baseline assessment (January/February) to the assessment 3 (June) for stationary wristbands. Fungicides were the most frequently type of pesticide detected, with 11 identified, compared to 2 herbicides and 2 insecticides **(Figure 8, SI2 Figure 7 and Table 5)**.Correlation between individual and stationary wristbands was generally low, except for cyflufenamide, cyprodinil, and metalaxyl (r = 0.54–0.69), which were moderately correlated, and proquinazid, showing strong correlation (up to r = 1) during specific assessments **(SI2 Figure 4 and Table 21)**. Moderate to strong correlations may suggest drift exposure from nearby applications.

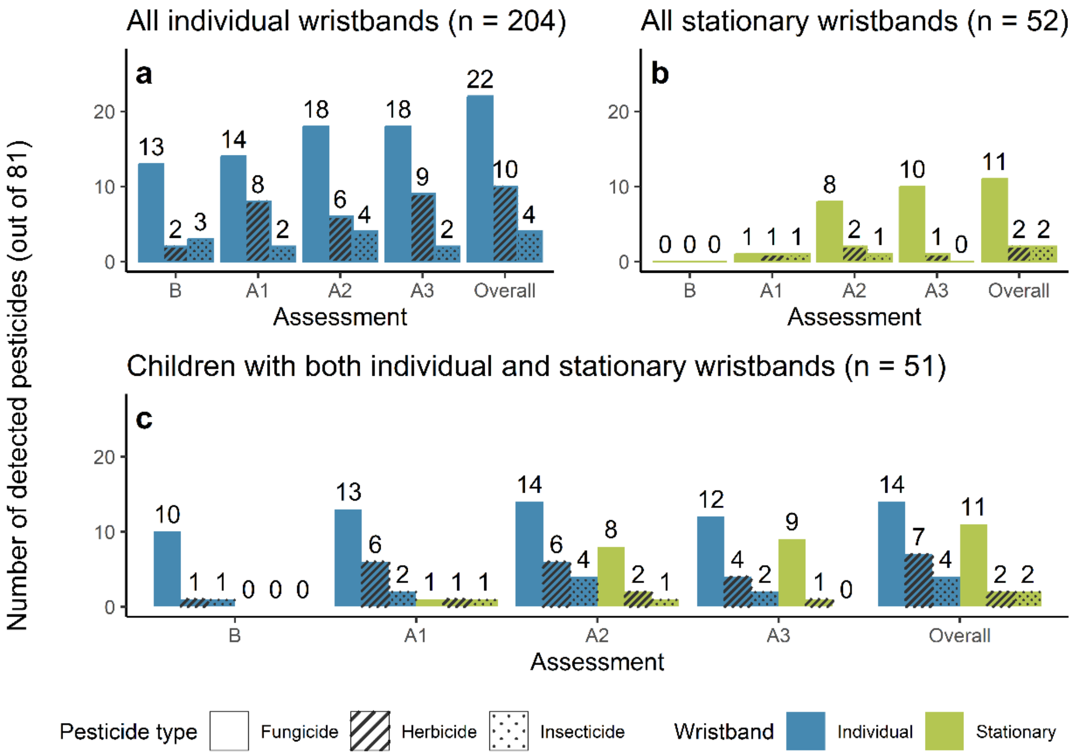

Figure 8: Number of pesticides detected in wristbands, stratified by pesticide type (fungicide, herbicide, insecticide) and assessment B = Baseline (January/February), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). **(a)** Children with individual wristbands (204 children, n = 778 wristbands) and **(b)** stationary wristbands at home (52 children, n = 176 wristbands), **(c)** children with both individual and stationary wristbands (51 children, n = 175 wristbands).

Table 5: The mean and standard deviation (SD) of the number of pesticides detected per child above the LOD on individual wristbands, stratified by pesticide type and assessment B = Baseline (January/February), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

Number of Pesticides detected	Assessment	Mean (SD)	Min.	Max.
Any	Overall	13.65 (5.85)	1	32
	B	1.49 (1.23)	0	7
	A1	2.90 (1.76)	0	9
	A2	4.53 (2.66)	0	14
	A3	5.41 (2.09)	0	12
Fungicide	Overall	11.09 (4.55)	1	25
	B	1.40 (1.17)	0	6
	A1	2.06 (1.22)	0	6
	A2	3.47 (2.04)	0	9
	A3	4.71 (1.72)	0	11
Herbicide	Overall	1.90 (1.71)	0	8
	B	0.07 (0.26)	0	1
	A1	0.72 (0.82)	0	3
	A2	0.60 (0.79)	0	3
	A3	0.60 (0.76)	0	3
Insecticide	Overall	0.67 (0.87)	0	4
	B	0.02 (0.14)	0	1
	A1	0.12 (0.33)	0	1
	A2	0.46 (0.57)	0	2
	A3	0.10 (0.30)	0	1

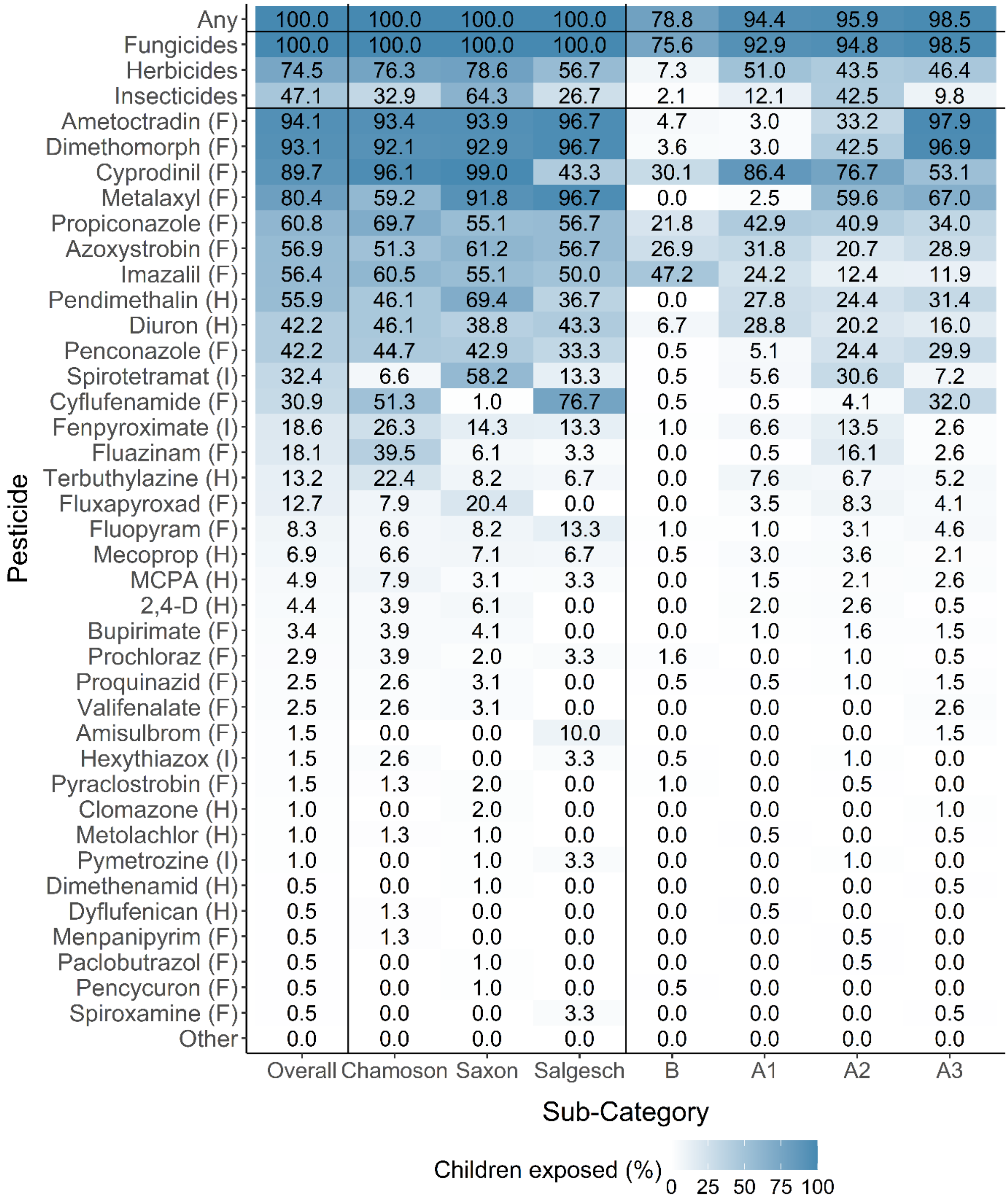

Figure 9: The percentages of children with the respective pesticides detected in their individual wristbands, categorized by school and assessment phase. The heatmap shows how often the 36 different pesticides were detected on the 778 wristbands worn by the 206 children. Percentages are shown in relation to the 206 children overall, stratified by the three schools and the four assessments: B = Baseline (January/February), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June), and the pesticides are classified as F (Fungicide), H (Herbicide), or I (Insecticide).

Detection Frequency and Patterns of Pesticides Detected in More than 40% of the Study Population

Six pesticides were detected in more than 40% of the study population in at least one assessment **(Figure 10 and SI2 Table 7)**: the fungicides ametoctradin, cyprodinil, dimethomorph, imazalil, propiconazole, and metalaxyl. The concentrations of these five fungicides increased from baseline assessment to assessment 2, except for imazalil. Imazalil concentrations were highest in the baseline assessment in winter **(SI2 Figure 5)** and decreased across the four assessments. **Figures 10 and 11** illustrate the combinations and the correlations of the six pesticides detected simultaneously in individual wristbands and their overall detection frequencies. Ametoctradin was highly correlated with dimethomorph (correlation coefficient r = 0.92). **Figure 12** displays a scatterplot of pesticide detections in individual vs. stationary wristbands, stratified by assessment. Cyprodinil was primarily detected in Chamoson and Saxon during assessment 1, while ametoctradin and dimethomorph were most frequently found across all three communities during assessment 2 and 3.

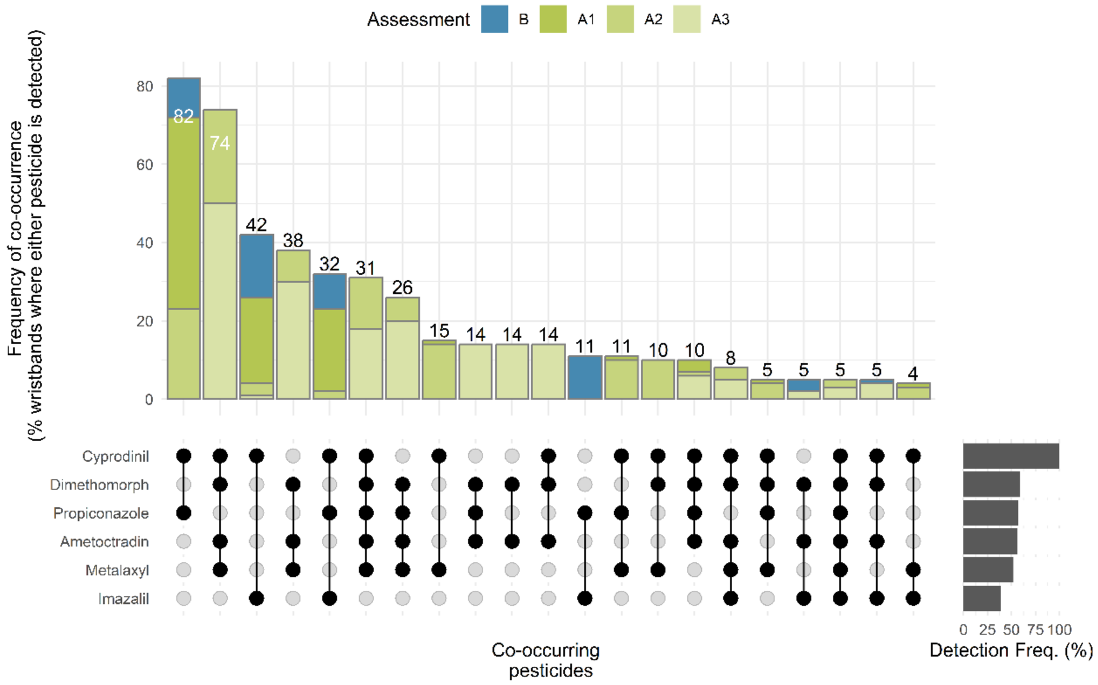

Figure 10: UpSet plot to help identify patterns of pesticide overlap and determine which combinations of pesticides were most frequently detected across the four assessment phases. It presents the combinations of six pesticides detected in 40% of the samples in at least one assessment phase. Right-side bars display the detection frequency of each pesticide individually across the 778 wristbands. The top bars represent the percentages of each respective pesticide combination among all wristbands in which at least one of the involved pesticides was detected, showing how often specific pesticides were detected together. The results are stratified by assessment: B = Baseline (January/February), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

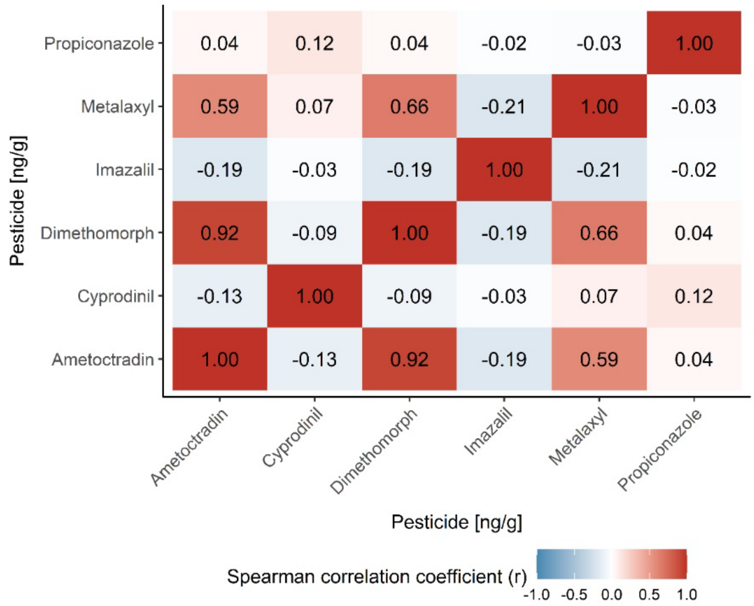

Figure 11: Spearman correlation between the six pesticides [ng/g] with a detection frequency of at least 40% in at least one assessment**.**

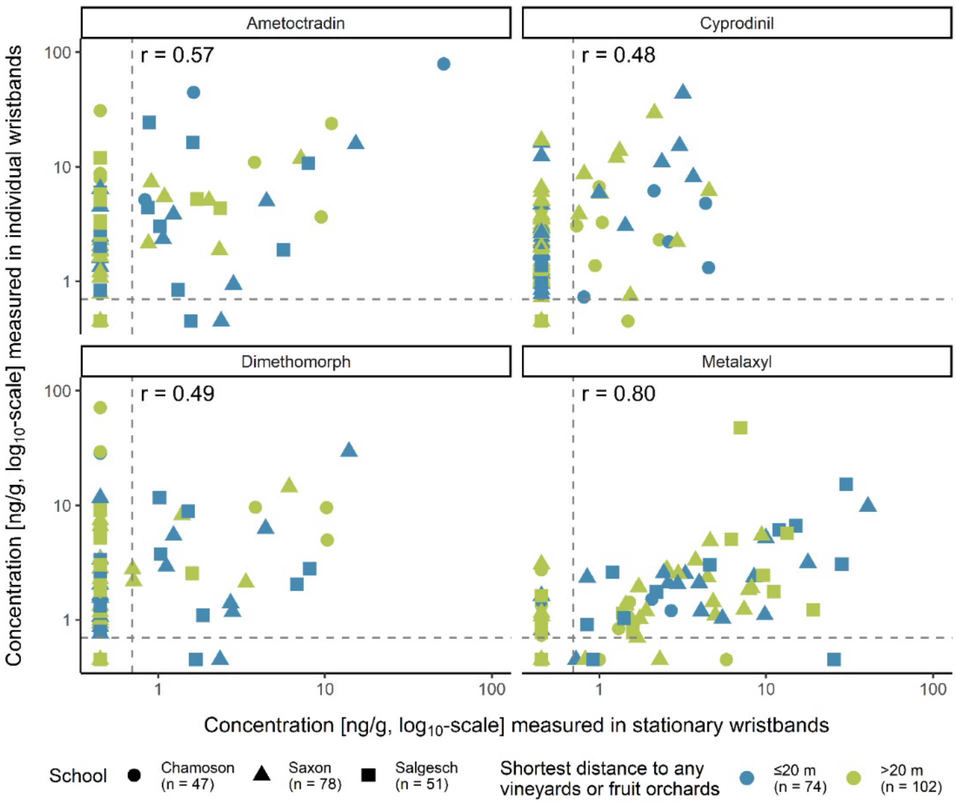

Figure 12: Scatterplot of pesticide concentrations [ng/g, $\log_{10}$-scale] measured in individual vs. stationary wristbands. Data includes 51 children with both individual and stationary wristbands (total of 176 samples) and pesticides detected in both wristband types with an LOD > 40% in at least one assessment. The dashed line indicates the LOD (0.7 ng/g). Points are colored by the shortest distance of a child's home to any vineyards or fruit orchards (≤20 m, >20 m), and shaped by the child's school (Chamoson, Saxon, Salgesch). Number of children in Chamoson (n = 16); Saxon (n = 20); Salgesch (n = 15). Total number of children in ≤20 m (n = 21) and >20 m (n = 30).

Pesticide Urinary Biomarkers

The two pesticide biomarkers, hydroxy boscalid and hydroxy tebuconazole, were consistently detected across all four assessments in 715 urine samples from 202 children **(SI2 Table 9)**. Detection frequencies remained consistently high, with hydroxy tebuconazole at 98.6% and hydroxy boscalid at 91.9%. Despite these high detection rates, low ICC values indicate significant temporal variability, meaning children's exposure levels differ across measurements. This pattern was similarly observed in the wristband measurements **(SI2 Table 9)**.

2. How does the proximity of children's home addresses to agricultural land influence their level of pesticide exposure?

Results presented in **Figure 13 and 14, and SI2 Tables 10 and 11** indicate the relationship between household distance from different agricultural land types and children's airborne pesticide exposure. The data can be interpreted for every 100-meter increase in distance from certain types of agricultural land, there is a corresponding change in pesticide concentration.

Specifically, for **imazalil**, the results show a slight decrease in mean concentration with increasing distance from any type of agricultural land [10^{β} = 0.17, 95% CI = 0.04 to 0.68]. The regression coefficient β = -0.77 for imazalil can be interpreted as follows: For each 100-meter increase in distance from organic orchards, the geometric mean of a child's imazalil concentration changed by a factor of $10^{-0.77}$ ≈ 0.17 **(Figure 13 and SI2 Table 10)**. This translates to a decrease in the geometric mean of a child's imazalil concentration by approximately 83% for each 100-meter increase in distance [(0.17 - 1) * 100% ≈ -83%].

For **metalaxyl**, a statistically significant negative association is observed for any vineyards by 6% [10^{β} = 0.94, 95% CI = 0.90 to 0.99], for conventional vineyards by 6% [10^{β} = 0.94, 95% CI = 0.90 to 0.99] and for organic vineyards by 5% [10^{β} = 0.95, 95% CI = 0.91 to 0.99].

The analysis of **propiconazole** exposure shows a relationship between pesticide concentration and proximity to orchards. For both any orchards [10^{β} = 0.97, 95% CI = 0.64 to 0.97] and conventional orchards [10^{β} = 0.76, 95% CI = 0.63 to 0.93], the data consistently show a subtle decrease in propiconazole concentrations with increasing distance. When examining exposure in relation to all orchards, the results show that for every 100-meter increase in distance, propiconazole concentration decreased by 3%. This subtle decrease suggests a gradual reduction in exposure with increasing distance between households and orchard areas. The pattern remains consistent when focusing specifically on conventional orchards. Here, propiconazole concentrations decreased by 37% for every 100-meter increase in distance, reinforcing the observation of a modest, but notable exposure gradient. For organic orchards, however, the results show a statistically significant positive association [10^{β} = 1.17, 95% CI = 1.08 to 1.26] between propiconazole concentration and increased distance. Additionally, statistically significant positive associations are found between propiconazole concentration and all types of vineyards. Propiconazole increases by 25% per 100-meter increase in distance to any vineyards [10^{β} = 1.25, 95% CI = 1.07 to 1.45], by 25% per 100-meter increase in distance to conventional vineyards [10^{β} = 1.25, 95% CI = 1.07 to 1.45], and by 26% per 100-meter increase in distance to organic vineyards [10^{β} = 1.26, 95% CI = 1.11 to 1.44]. These results highlight the importance of spatial considerations when assessing airborne pesticide exposure and show how even small changes in distance can incrementally affect potential pesticide concentrations in residential areas close to agricultural landscapes **(Figure 13 and SI2 Table 10).**

Analysis of the urinary biomarker **hydroxy boscalid** shows subtle relationships between exposure levels and proximity to different types of agricultural land **(Figure 14 SI2 Table 11)**. For any vineyards or fruit orchards, the concentration decreases by 7% per 100-meter increase in distance [10^{β} = 0.93, 95% CI = 0.88 to 0.97]. For any vineyards, the concentration decreases by 4% per 100-meter increase in distance [10^{β} = 0.96, 95% CI = 0.93 to 1.00]. The same pattern persists within both conventional vineyards with a decrease of 4% [10^{β} = 0.96, 95% CI = 0.93 to 0.99] as well as for organic vineyards with a decrease of 3% [10^{β} = 0.97, 95% CI = 0.94 to 1.00].

Interestingly, organic orchards also show a negative association, with a 2% decrease in concentration per 100-meter increase in distance [10^{β} = 0.98, 95% CI = 0.96 to 1.00]. Taken together, these results suggest that proximity to vineyards and organic orchards is associated with slightly higher levels of urinary hydroxy boscalid, with the strongest relationship observed for conventional vineyards. However, it's important to note that these effects are relatively small, suggesting subtle gradients in exposure based on residential proximity to these agricultural areas.

Analysis of the urinary biomarker **hydroxy tebuconazole** shows a subtle relationship with proximity to organic orchards [10^{β} = 0.98, 95% CI = 0.97 to 1.00]. For each 100-meter increase in distance from organic orchards, the concentration of hydroxy tebuconazole decreased by approximately 2%. This negative correlation suggests that closer proximity to organic orchards is associated with slightly higher levels of hydroxy tebuconazole in urine. However, it's important to note that this effect is very small, suggesting only a subtle gradient in exposure based on residential proximity to these agricultural areas **(Figure 14 SI2 Table 11)**.

No statistically significant associations were found between the concentrations of ametoctradin, cyprodinil, dimethomorph or imazalil and proximity to agricultural land **(Figure 13 SI2 Table 10)**. This suggests that for these specific pesticides, the distance from agricultural areas does not appear to be a determining factor in exposure levels, at least within the context and limitations of this study.

These findings highlight the complexity of pesticide exposure patterns, where some compounds may show slight associations with agricultural proximity while others do not demonstrate clear relationships. Such results underscore the importance of compound-specific analyses in environmental exposure assessments.

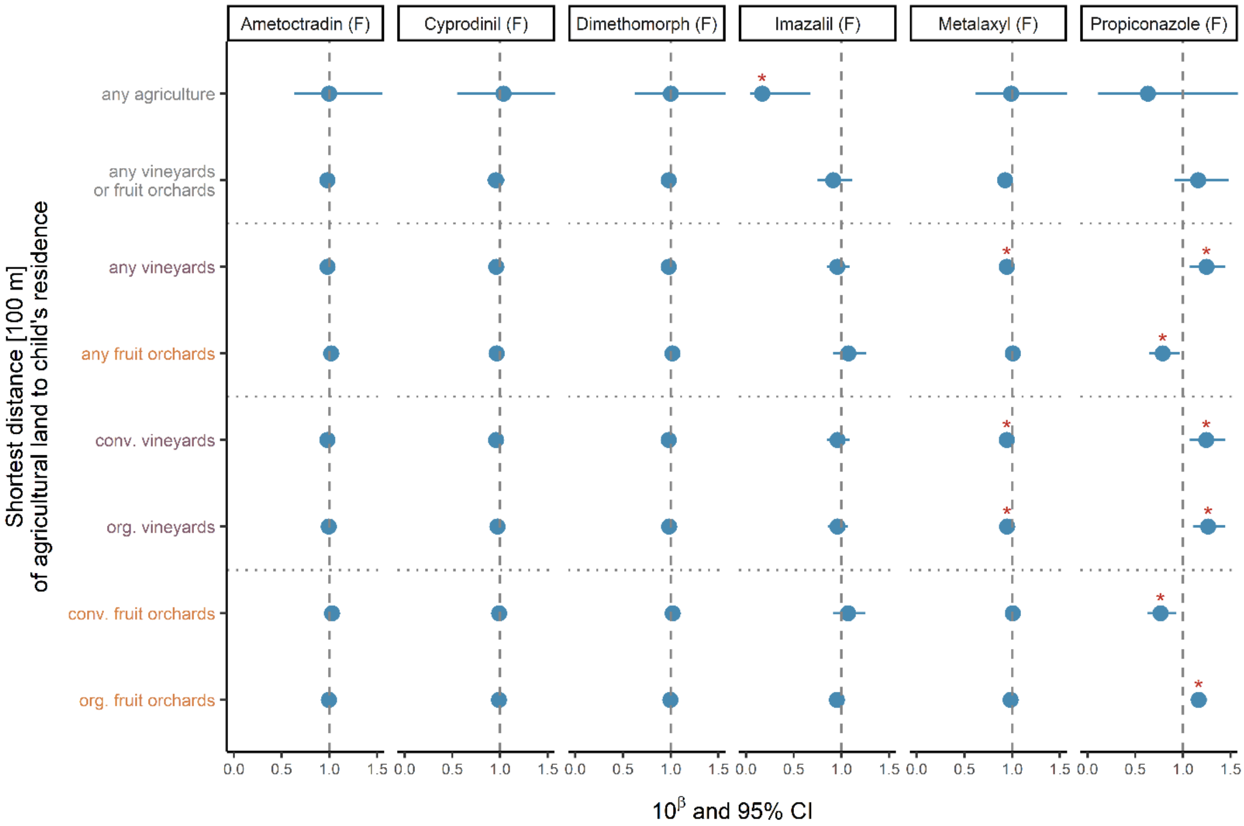

Figure 13: **Association between the six most detected pesticides in individual wristbands and shortest distance [100 m] to agricultural land,** presented as the anti-logarithm of the regression coefficients β and their corresponding 95% CIs. The value of 10^{β} indicates that the geometric mean of a child's pesticide concentration [ng/g] is to be multiplied by that value for each additional 100 m that a child lives further away from that agricultural land use type. Values > 1 indicate an increase in exposure with increased distance, values < 1 indicate a decrease in exposure with increased distance. The dashed vertical line at 1 indicates no effects. Models are adjusted for child living on a farm, school, and education. Red stars (*) indicate statistical significance ($p < 0.05$). An effect is statistically significant if the CI does not cross the line of no effect.

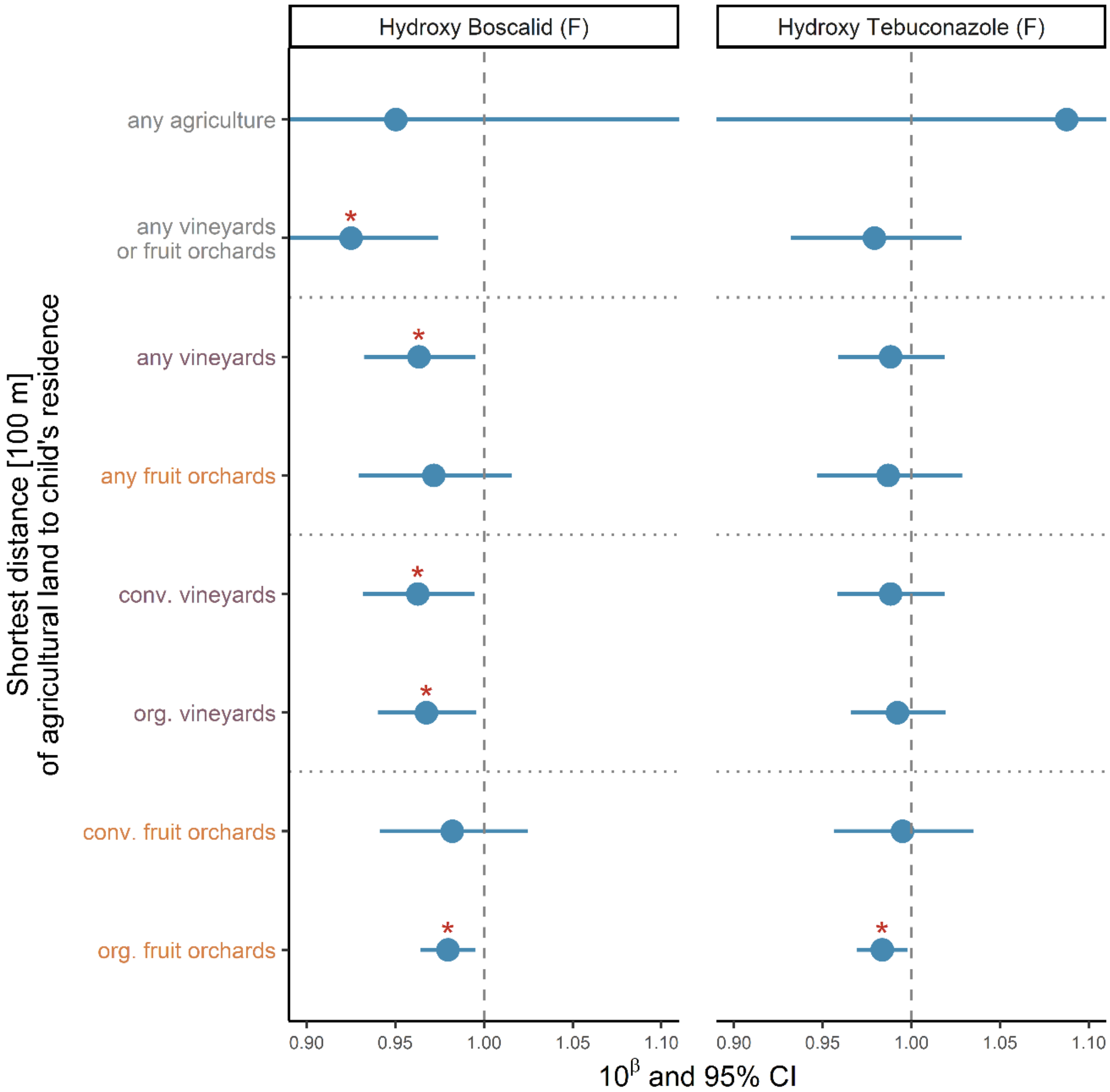

Figure 14: **Association between the two detected pesticide biomarkers in individual urine samples and shortest distance [100 m] to agricultural land,** presented as the anti-logarithm of the regression coefficients β and their corresponding 95% CIs. The value of 10^{β} indicates that the average pesticide concentration [ng/ml] is to be multiplied by that value for each additional 100 m that a child lives further away from that agricultural land use type. Values > 1 indicate an increase in exposure with increased distance, values < 1 indicate a decrease in exposure with increased distance. The dashed vertical line at 1 indicates no effects. Models are adjusted for child living on a farm, school, spraying season and education. Red stars (*) indicate statistical significance ($p < 0.05$). An effect is statistically significant if the CI does not cross the line of no effect.

3. How does the total area of different crops cultivated within different buffers around children's homes influence their level of pesticide exposure

Looking at the results presented in **Figures 15 and 16 and SI2 Tables 12 and 13**, we can interpret the relationship between measures of pesticide exposure and the percentage of different types of agricultural land within different buffer zones around the location of the children's homes. The data shows that within each buffer zone (50 m, 250 m, 500 m, and 1000 m), there is a corresponding percentage of agricultural land types surrounding the children's homes. This analysis allows us to understand how the composition of agricultural land changes as we increase the buffer size around the children's homes. For example, within a 50 m buffer we might see a certain percentage of orchards, whereas at 1000 m this percentage might be significantly different. This approach provides an insight into potential exposure patterns based on the proximity and prevalence of different agricultural activities around the children's homes.

Effect estimates 10^{β} are to be interpreted as follows: If 10^{β} is, e.g., 1.5, it means that the geometric mean of a child's measured concentration of the respective pesticide is multiplied by 1.5 (which corresponds to an increase by 50%), if the area of the respective agricultural land use type within the respective buffer increases by one percent, e.g. if within a 50 m buffer radius, the share of conventional vineyards increases from 20% to 21%.

For **ametoctradin**, statistically significant positive associations are found for any vineyards or fruit orchards within a 50 m [10^{β} = 1.01, 95% CI = 1.00 to 1.02] and 250 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.02], for any vineyards within a 50 m [10^{β} = 1.01, 95% CI = 1.00 to 1.02] and 250 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.02], for conventional vineyards within a 50 m [10^{β} = 1.02, 95% CI = 1.01 to 1.03], a 250 m [10^{β} = 1.02, 95% CI = 1.01 to 1.03] and a 500 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.03], and for organic fruit orchards within a 1000 m buffer [10^{β} = 1.23, 95% CI = 1.03 to 1.46]. Overall, these findings suggest a positive association between ametoctradin concentration and the area of vineyards surrounding a child's home.

For **cyprodinil**, statistically significant positive associations were found for any vineyards or fruit orchards within a 50 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.03], for any fruit orchards within a 50 m [10^{β} = 1.04, 95% CI = 1.02 to 1.07], a 250 m [10^{β} = 1.04, 95% CI = 1.01 to 1.06] and a 500 m [10^{β} = 1.05, 95% CI = 1.01 to 1.08] buffer, for organic fruit orchards within a 250 m [10^{β} = 1.24, 95% CI = 1.04 to 1.48], a 500 m [10^{β} = 1.39, 95% CI = 1.13 to 1.70] and a 1000 m buffer [10^{β} = 1.39, 95% CI = 1.09 to 1.76], and for conventional fruit orchards within a 50 m [10^{β} = 1.04, 95% CI = 1.02 to 1.07], a 250 m [10^{β} = 1.04, 95% CI = 1.01 to 1.07] and a 500 m buffer [10^{β} = 1.05, 95% CI = 1.01 to 1.09]. Overall, these findings suggest a positive association between cyprodinil concentration and the area of fruit orchards surrounding a child's home.

For **dimethomorph**, statistically significant positive associations were observed for any vineyards or fruit orchards within a 250 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.02], for any vineyards within a 250 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.02], for conventional vineyards within a 50 m [10^{β} = 1.02, 95% CI = 1.00 to 1.03], a 250 m [10^{β} = 1.02, 95% CI = 1.00 to 1.03] and a 500 m buffer [10^{β} = 1.01, 95% CI = 1.00 to 1.02], and for organic fruit orchards within a 1000 m buffer [10^{β} = 1.32, 95% CI = 1.10 to 1.57]. Overall, these findings suggest a positive association between dimethomorph concentration and the area of conventional vineyards surrounding a child's home.

For **imazalil**, statistically significant positive associations were found for any agricultural land within a 50 m buffer [10^{β} = 1.09, 95% CI = 1.01 to 1.18], for any vineyards within a 50 m buffer [10^{β} = 1.03, 95% CI = 1.00 to 1.07], and for organic vineyards within a 50 m [10^{β} = 1.01, 95% CI = 1.00 to 1.02], a 500 m [10^{β} = 1.13, 95% CI = 1.01 to 1.27] and a 1000 m buffer [10^{β} = 1.14, 95% CI = 1.02 to 1.26]. Overall, these findings suggest a positive associtation between imazalil concentration and the area of vineyards surrounding a child's home.

For **metalaxyl**, statistically significant positive associations were found for any agricultural land within a 500 m [10^{β} = 1.01, 95% CI = 1.00 to 1.02] and a 1000 m buffer [10^{β} = 1.01, 95% CI =

1.00 to 1.02], for any vineyards or fruit orchards within a 250 m [10^β = 1.01, 95% CI = 1.00 to 1.02], a 500 m [10^β = 1.02, 95% CI = 1.01 to 1.02] and a 1000 m buffer [10^β = 1.01, 95% CI = 1.00 to 1.02], for any vineyards within a 250 m [10^β = 1.02, 95% CI = 1.01 to 1.03], a 500 m [10^β = 1.02, 95% CI = 1.01 to 1.03] and a 1000 m buffer [10^β = 1.01, 95% CI = 1.00 to 1.02], for organic vineyards within a 250 m [10^β = 1.05, 95% CI = 1.00 to 1.09], a 500 m [10^β = 1.05, 95% CI = 1.00 to 1.09] and a 1000 m buffer [10^β = 1.04, 95% CI = 1.00 to 1.08], and for conventional vineyards within a 50 m [10^β = 1.01, 95% CI = 1.00 to 1.03], a 250 m [10^β = 1.02, 95% CI = 1.01 to 1.04], a 500 m [10^β = 1.02, 95% CI = 1.01 to 1.03] and a 1000 m buffer [10^β = 1.02, 95% CI = 1.00 to 1.03]. On the contrary, a statistically significant negative association was found for organic vineyards within a 50 m buffer [10^β = 0.95, 95% CI = 0.92 to 0.98]. Overall, these results suggest a positive associtation between metalaxyl concentration and the area of vineyards surrounding a child's home.

For **propiconazole**, statistically significant negative associations were found for any agricultural land within a 500 m [10^β = 0.96, 95% CI = 0.92 to 0.99] and 1000 m buffer [10^β = 0.95, 95% CI = 0.91 to 0.98], for any vineyards or fruit orchards within a 500 m [10^β = 0.96, 95% CI = 0.93 to 0.99] and 1000 m buffer [10^β = 0.95, 95% CI = 0.92 to 0.98], for any vineyards within a 50 m [10^β = 0.94, 95% CI = 0.91 to 0.98], a 250 m [10^β = 0.96, 95% CI = 0.92 to 1.00], a 500 m [10^β = 0.95, 95% CI = 0.92 to 0.98] and a 1000 m buffer [10^β = 0.95, 95% CI = 0.92 to 0.98], for organic vineyards within a 250 m [10^β = 0.82, 95% CI = 0.70 to 0.95], a 500 m [10^β = 0.76, 95% CI = 0.66 to 0.87] and a 1000 m buffer [10^β = 0.79, 95% CI = 0.70 to 0.90], and for conventional vineyards within a 50 m [10^β = 0.93, 95% CI = 0.89 to 0.98], a 500 m [10^β = 0.94, 95% CI = 0.90 to 0.98] and a 1000 m buffer [10^β = 0.93, 95% CI = 0.90 to 0.97]. Overall, these findings suggest a negative association between propiconazole concentration and the area of vineyards surrounding a child's home.

The analysis of urinary biomarker **hydroxy boscalid** reveals intriguing relationships with various agricultural buffer zones **(Figure 16 SI2 Table 13)**. Statistically significant positive associations were found for any agricultural land within a 1000 m buffer [10^β = 2.20, 95% CI = 1.04 to 4.65], for any vineyards or fruit orchards within a 50 m buffer [10^β = 1.01, 95% CI = 1.00 to 1.02], for any vineyards within a 50 m [10^β = 1.01, 95% CI = 1.00 to 1.02] and 500 m buffer [10^β = 1.05, 95% CI = 1.00 to 1.10], for conventional vineyards within a 50 m buffer [10^β = 1.01, 95% CI = 1.00 to 1.02], and for organic fruit orchards within a 500 m [10^β = 1.00, 95% CI = 1.00 to 1.00] and 1000 m buffer [10^β = 1.22, 95% CI = 1.01 to 1.47].

No associations were found between proximity to any type of agricultural land and the urinary biomarker hydroxy tebuconazole across all buffer zones **(Figure 16)**. The lack of clear associations for this pesticide highlights the importance of compound-specific analyses in environmental exposure assessments. It also underscores the need for comprehensive research approaches that consider multiple factors beyond just proximity when assessing pesticide exposure risks in residential areas near agricultural land.

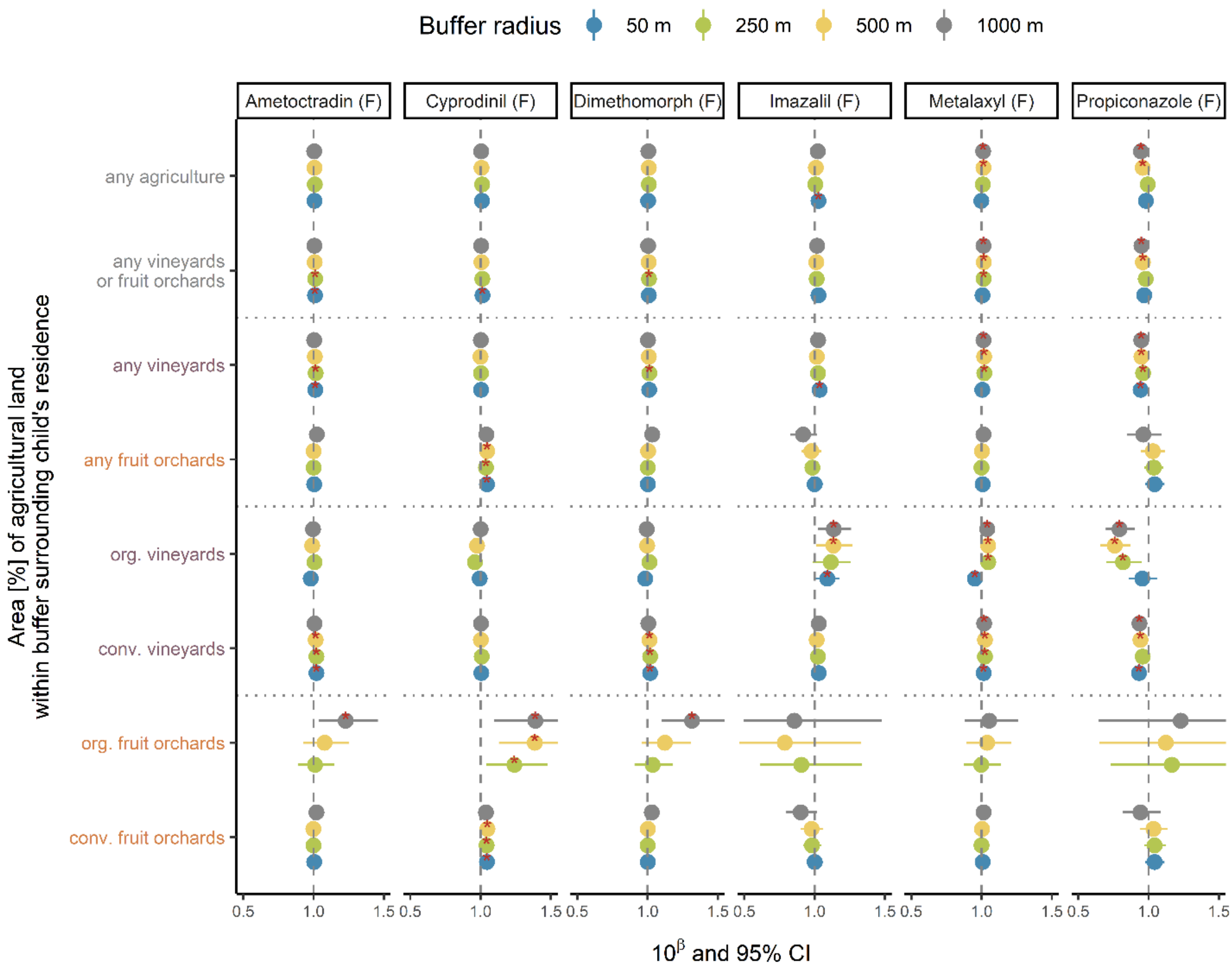

Figure 15: **Associations between different areas of agricultural land use [% of total area surrounding home given specific radius] around participants' homes and six pesticides detected in the individual wristband**, presented as the anti-logarithm of the regression coefficients β and their corresponding 95% CIs. The value of 10^{β} indicates that the geometric mean of a child's pesticide concentration [ng/g] is to be multiplied by that value for each additional percentage of the indicated agricultural land use type within the indicated buffer. Values > 1 indicate an increase in exposure with increased area, values < 1 indicate a decrease in exposure with increased area. The dashed vertical line at 1 indicates no effects. Models are adjusted for child living on a farm, school, and education. The red stars (*) indicate statistical significance ($p < 0.05$). An effect is statistically significant if the CI does not cross the line of no effect.

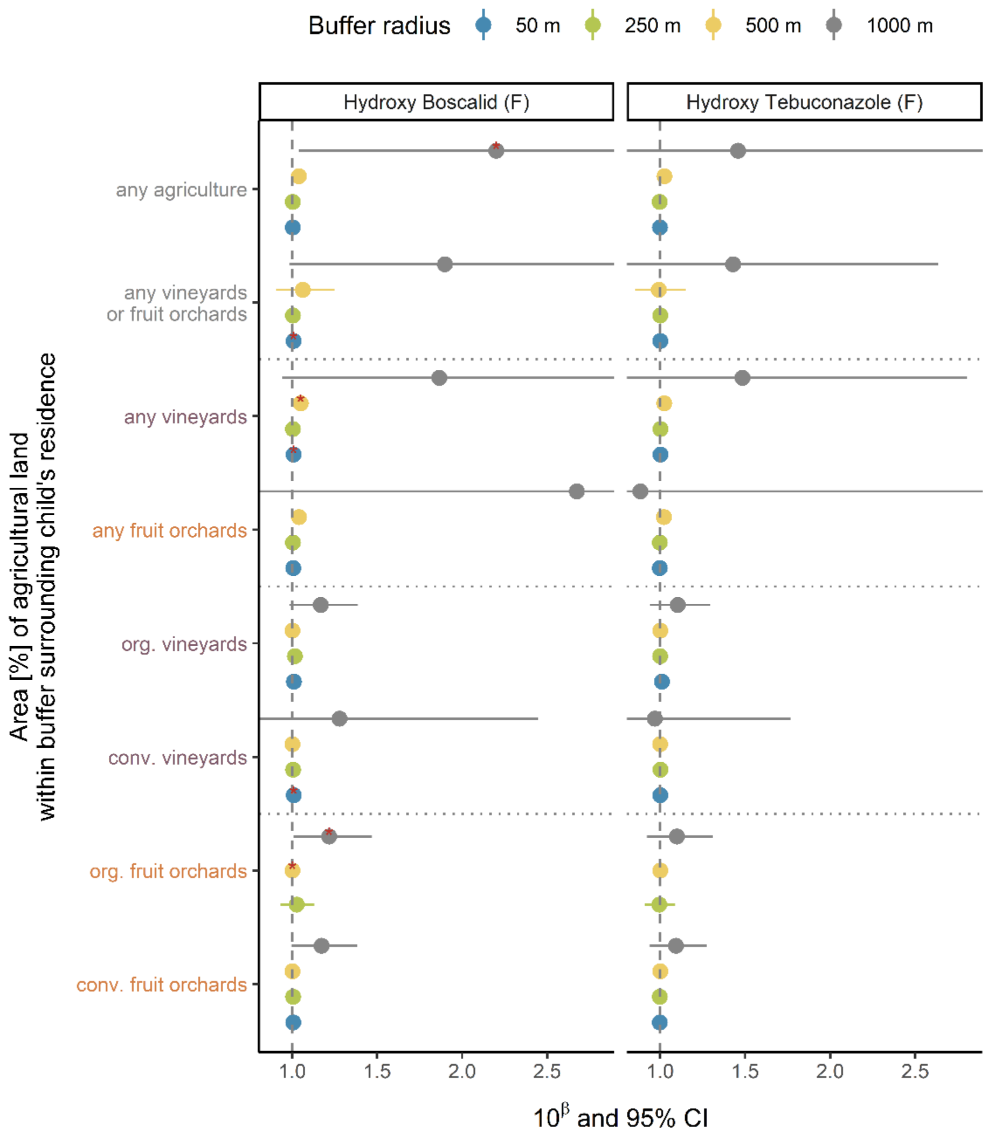

Figure 16: **Associations between different areas of agricultural land use [% of total area surrounding home given specific radius] around participants' homes and urinary pesticide biomarkers**, presented as the anti-logarithm of the regression coefficients β and their corresponding 95% CIs. The value of 10^{β} indicates that pesticide concentration [ng/g] is to be multiplied by that value for each additional percentage of the indicated agricultural land use type within the indicated buffer. Values > 1 indicate an increase in exposure with increased area, values < 1 indicate a decrease in exposure with increased area. The dashed vertical line at 1 indicates no effects. Models are adjusted for child living on a farm, school, and education. The red stars (*) indicate statistical significance ($p < 0.05$). An effect is statistically significant if the CI does not cross the line of no effect.

4. What are the key spatiotemporal and behavioral factors predicting pesticide exposure in children?

Examining the results presented in **Figure 17 and 18 and SI2 Tables 14 and 15**, we can interpret the relationship between various factors and pesticide exposure as measured by wristbands and urinary biomarkers. The data show the average change in pesticide levels associated with a one-unit increase in a particular factor.

Effect estimates 10^{β} are to be interpreted as follows: For continuous risk factors such as age, a value of 10^{β} = 1.5 means that for every additional year of age, e.g. for a seven year old compared to a six year old child, the expected geometric mean a child's measured concentration of the respective pesticide increases by 1.5-fold, or, in other words, by 50%. For categorical variables such as sex, a value of 10^{β} = 1.5 means that for the listed category (here: Female) compared to the reference category (here: Male), the expected geometric mean of a child's measured concentration of the respective pesticide increases by 1.5-fold or by 50%.

For **ametoctradin**, the results show a statistically significant negative association with age [10^{β} = 0.91, 95% CI = 0.84 to 0.98]. This means that the geometric mean of a child's urine sample ametoctradin concentration decreases by 9% for every additional year of age **(Figure 17 and SI2 Table 14)**.

The analysis of **cyprodinil** exposure reveals significant geographical and occupational patterns. Cyprodinil concentrations were approximately 86% (or by a 0.14-fold) lower in **Chamoson** [10^{β} = 0.14, 95%, CI = 0.09 to 0.23] compared to Saxon, while in **Salgesch**, [10^{β}= 0.01, 95% CI = 0.01 to 0.02] concentrations were about 99% lower than in Saxon. This indicates notable regional differences in exposure levels. Using a bike instead of driving to school results in an increase in cyprodinil concentration by 168% (or by a 2.68-fold) [10^{β} = 2.68, 95% CI = 1.16 to 6.21]. The parent-reported use of fungicide application in garden or household resulted in a decrease of cyprodinil concentration by 27% [10^{β} = 0.73, 95% CI = 0.08 to 0.90]. Additionally, **having a family member working on a farm in integrated production** compared to no family member working on a farm was associated with a 763% increase (or 8.63-fold) in cyprodinil concentrations [10^{β} = 8.63, 95% CI = 1.30 to 57.52]. These results highlight important factors influencing cyprodinil exposure, emphasizing the need to consider both geographical location and family occupational background when assessing pesticide exposure risks **(Figure 17 and SI2 Table 14)**.

The analysis of **dimethomorph** exposure showed decreased concentrations in Chamoson [10^{β} = 0.62, 95% CI = 0.43; 0.88] compared to Chamoson **(Figure 17 and SI2 Table 14)**.

The analysis of **imazalil** exposure showed that individuals whose **parents have secondary education** experienced approximately 70% lower exposure compared to those with tertiary education [10^{β}= 0.30, 95% CI = 0.13 to 0.72]. This finding highlights potential differences in exposure related to educational background. Additionally, statistical evidence was found for a decrease in imazalil concentration by 98% if a child was occasionally helping on a farm [10^{β} = 0.02, 95% CI = 0.00 to 0.85] compared to when it was not **(Figure 17 and SI2 Table 14)**.

The analysis of **metalaxyl** exposure showed a decrease in concentration by 33% for females compared to males [10^{β} = 0.67, 95% CI = 0.50 to 0.89], as well as a decrease in concentration by 8% per additional year of age [10^{β} = 0.92, 95% CI = 0.84 to 0.99]. Moreover, statistical evidence was found for a decrease in metalaxyl concentration by 79% in Chamoson [10^{β} = 0.21, 95% CI = 0.15 to 0.30] compared to Saxon **(Figure 17 and SI2 Table 14).**

The analysis of **propiconazole** exposure showed a decrease in concentration of 30% per additional year of age [10^{β} = 0.70, 95% CI = 0.52 to 0.94]. Moreover, it showed that individuals in **Chamoson** experienced approximately 714% (or by an 8.14-fold) higher airborne pesticide exposure compared to those in **Saxon** [10^{β} = 8.14, 95% CI = 2.30 to 28.83]. Statistical evidence was also found for an increase in propiconazole concentration by 243% (or a 3.43-fold) with increased distance to vineyards or fruit orchards [10^{β} = 3.43, 95% CI = 1.02 to 11.57], and for an increase in propiconazole concentration when individuals used a private water source rather than a public one [10^{β} = 5.52, 95% CI = 1.09 to 27.88] **(Figure 17 and SI2 Table 14)**.

Additionally, compared to children living in Saxon, levels of the biomarker **hydroxy boscalid** were 41% higher among children living in **Chamoson** [10^{β} = 1.41, 95% CI = 1.08 to 1.85], and 42% lower for the biomarker **hydroxy tebuconazole** among those in **Salgesch** [10^{β} = 0.58, 95% CI = 0.41 to 0.83, **(Figure 18 and SI2 Table 15).** No other associations were found between urinary pesticide biomarkers and potential predictors of pesticide exposure.

To summarize:

Demographics: Males had a tendency towards higher exposure concentrations compared to females **(Figure 17 and SI2 Table 14)**.

Geography: Children in Saxon had a tendency towards higher exposure concentrations compared to children in Chamoson, except for propiconazole and hydroxy boscalid, where concentrations were lower than in Chamoson. Children in Salgesch experienced higher concentrations in ametoctradin, dimethomorph and metalaxyl than children in Chamoson, but lower concentrations in cyprodinil, imazalil, propiconazole, hydroxy tebuconazole and hydroxy boscalid than children in Chamoson. These differences likely reflect variations in local farming practices, pest pressures, and environmental conditions.

Proximity to Vineyards and Fruit Orchards: For all the eight pesticides there was a relationship between measured pesticide concentration and either the distance to the closest field or the % of agricultural areas in the close surrounding which was depended on the specific crop (vine and fruit) or organic and conventional practice. For example, imazalil, proximity to vineyards and fruit orchards increased concentration, whereas for propiconazole, living closer distance to fruit farming area increases children’s exposure concentration.

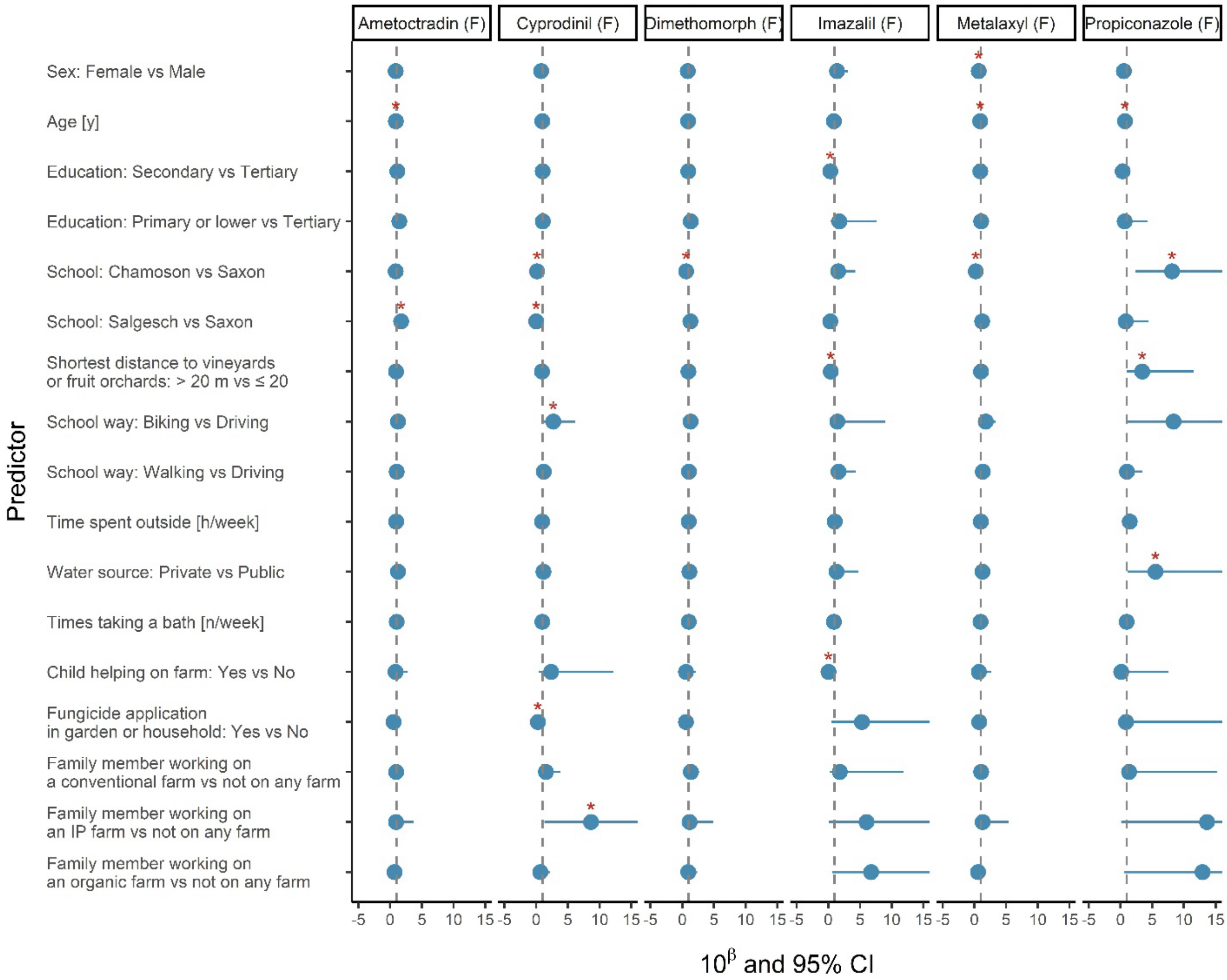

Figure 17: Potential predictors of pesticides concentrations [ng/g] detected in silicone wristbands. Depicted are the anti-logarithm of the regression coefficients β and their corresponding 95% CIs. The value for 10^{β} means that the geometric mean of a child's pesticide concentration is to be multiplied by that value if the indicated predictor increases by one unit (continuous variables) or for the indicated predictor level compared to its reference level (categorical variables). Values > 1 indicate an increase in exposure, values < 1 indicate a decrease in exposure. The dashed vertical line at 1 indicates no effect. Red stars (*) indicate statistical significance ($p < 0.05$).

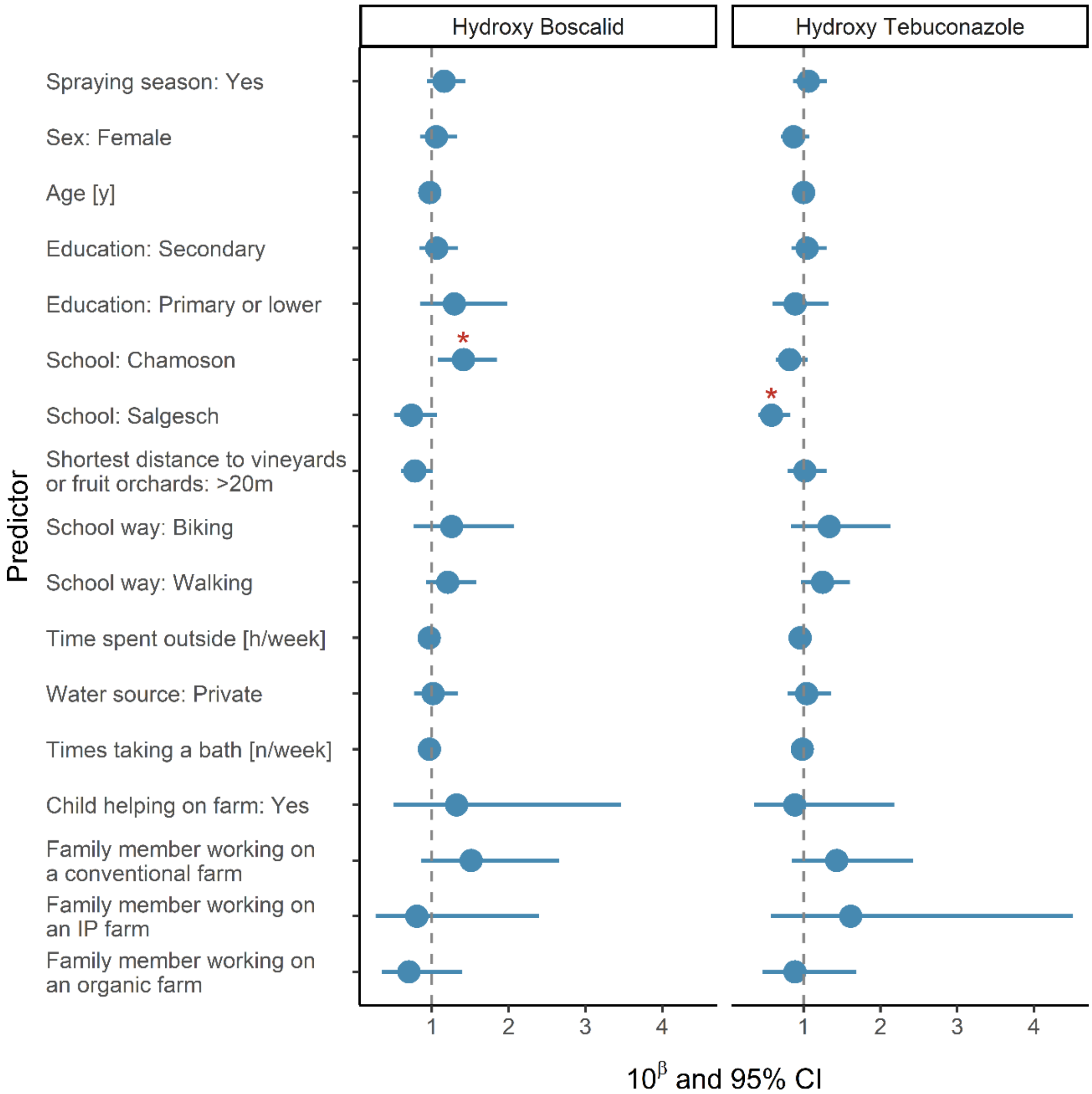

Figure 18: Potential predictors of pesticide biomarkers concentration [ng/ml] detected in urine samples. Depicted are the anti-logarithm of the regression coefficients β and their corresponding 95% CIs. The value for 10^{β} means that the average pesticide concentration is to be multiplied by that value if the indicated predictor increases by one unit (continuous variables) or for the indicated predictor level compared to its reference level (categorical variables). Values > 1 indicate an increase in exposure, values < 1 indicate a decrease in exposure. The dashed vertical line at 1 indicates no effect. Red stars (*) indicate statistical significance ($p < 0.05$).

4.4 Secondary Objective: Association between Pesticide Exposure and Respiratory Health

5. What is the association between pesticide exposures measured in wristbands and self-reported weekly acute respiratory symptoms?

Across all four assessments, the parents from 205 out of the 206 participating children had answered questions regarding weekly acute respiratory symptoms (defined as any of the five respiratory symptoms listed in **Table 6**). 40.5% of 205 children had at least one episode of respiratory acute symptoms in the preceding week. The prevalence of these symptoms was lower (9.2%) at baseline, (January/February) and increased to 20% during A1 to A3 (April/ May/June). The most reported symptoms were rhinitis and dry cough without cold/bronchitis (symptoms compatible with allergic reactions during spring season), with rates ranging from 2.2% to 16.2%.

Out of 17 children diagnosed with asthma, 16 reported experiencing weekly acute respiratory symptoms at least once during the study period, indicating a high prevalence of 94% among this group. However, it is noteworthy that the distribution of the symptom reports was random across the assessments, suggesting that not all children with asthma consistently reported respiratory symptoms throughout the evaluation periods. The variation in symptom reporting (across all assessments) suggests that children with an asthma diagnosis were not overrepresented among those reporting weekly acute respiratory symptoms, as children without asthma also reported these symptoms regularly.

In our regression models, no statistically significant associations were found between the six measured pesticides and weekly acute respiratory symptoms. **(Figure 19 and 20 and SI2 Table 16)**. Our data does not support a link between pesticide exposure and acute respiratory symptoms during the study period.

Effect estimates OR are to be interpreted as follows: For OR = 1.5, the odds of experiencing respiratory symptoms are 1.5-times (or 50%) higher in a child where the measured concentration of the respective pesticide lies within the indicated range (here: either between LOD and median or above median) compared to a child where the measured concentration of the respective pesticide lies within the reference range (here: below LOD).

Table 6: Binary weekly acute respiratory symptoms shown as n (%), stratified for each assessment. B = Baseline; A1-3 = Assessment 1-3.

n yes (%)	Total children	Total data points*	B	A1	A2	A3
n children/observations	205	736	184	192	175	185
Weekly Acute Respiratory Symptoms	83 (40.5%)	136 (18.5%)	17 (9.2%)	39 (20.3%)	39 (22.3%)	41 (22.2%)
Chest Wheeze**	7 (3.4%)	13 (1.8%)	4 (2.2%)	3 (1.6%)	3 (1.7%)	3 (1.6%)
Severe Chest Wheeze	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Wheeze after Sport	5 (2.4%)	7 (1%)	2 (1.1%)	0 (0%)	2 (1.1%)	3 (1.6%)
Rhinitis	51 (24.9%)	81 (11%)	4 (2.2%)	20 (10.4%)	27 (15.4%)	30 (16.2%)
Dry Cough without Cold/Bronchitis	49 (23.9%)	69 (9.4%)	12 (6.5%)	23 (12%)	18 (10.3%)	16 (8.6%)
Children diagnosed with asthma in total and who experienced weekly acute respiratory symptoms	16 (7.8%)	16 (2.2%)	3 (1.6%)	6 (3.1%)	3 (1.7%)	4 (2.2%)

*data points refer to affirmative answers in the parent questionnaires to the following symptoms within the last week: **Chest wheezing: if your child had wheezing noises in the chest; Severe chest wheezing: if the wheezing was so severe that the child had to breathe again already after speaking one or two words; Wheezing during or after sport: if your child had wheezing during or after exercise; Rhinitis: if your child has ever had a lot of sneezing or cold-like symptoms without having a cold; Dry cough at night without cold/bronchitis: if your child has had a dry cough at night without having a cold or bronchitis.

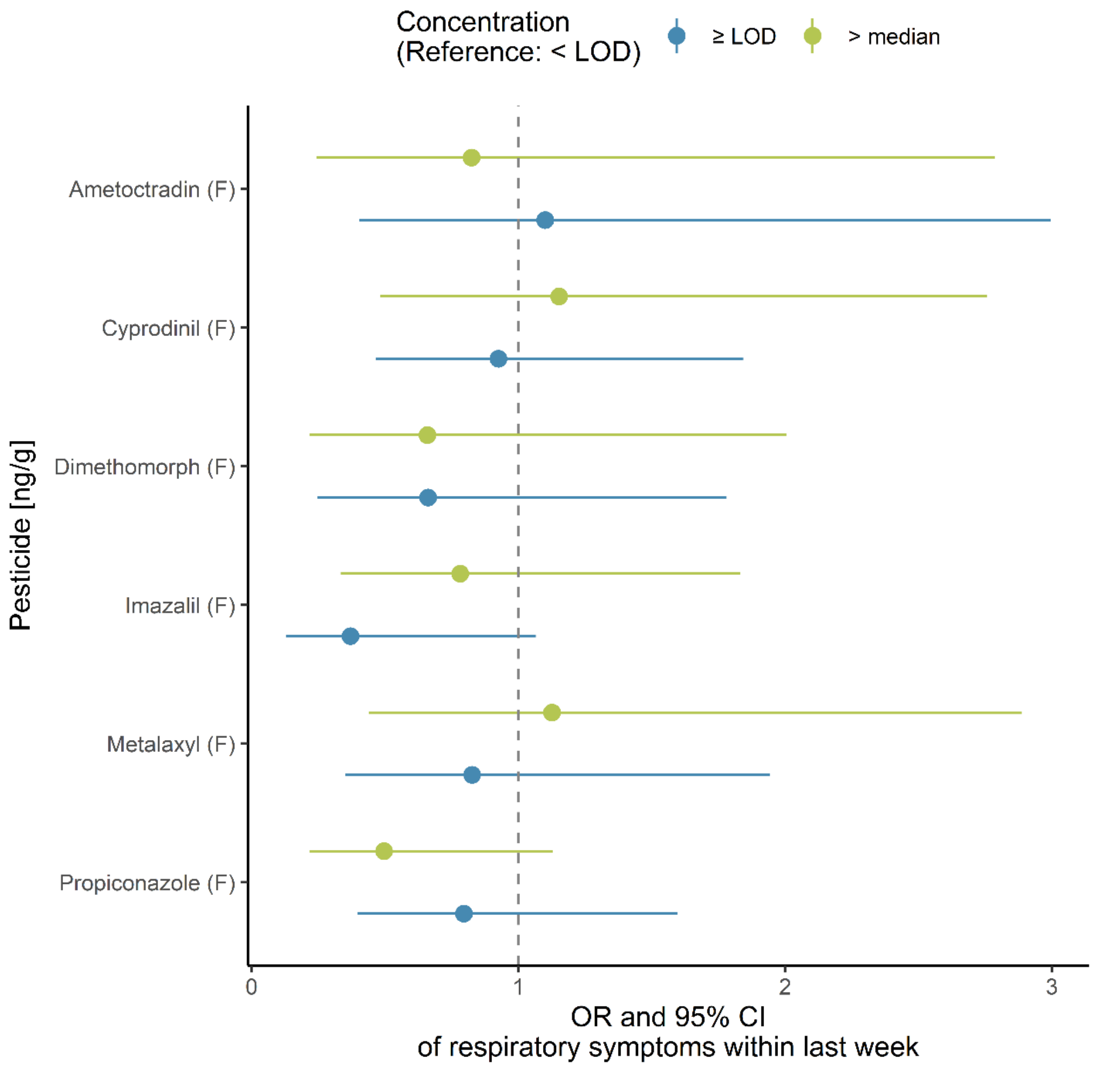

Figure 19: Association between pesticide exposure (wristbands) and self-reported respiratory symptoms. Odds ratio (OR) and 95% confidence intervals of the effect of principal components from specific pesticide exposures on respiratory symptoms during the last week. An OR of x means that the odds of experiencing respiratory symptoms are x-times higher for a child in the respective concentration category (≥ LOD, > median) compared to a child in the reference category (< LOD). Values > 1 indicate an increase in the odds for respiratory symptoms, values < 1 indicate a decrease in the odds for respiratory symptoms. The dashed vertical line at 1 indicates no effect. The models are adjusted for spraying season, school, income, $PM_{2.5}$ and pollen. Red stars (*) indicate statistical significance ($p < 0.05$).

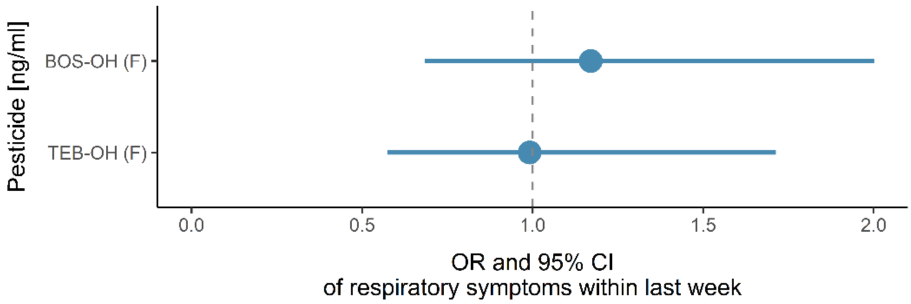

Figure 20: **Association between pesticide exposure (urine) and self-reported respiratory symptoms.** Odds ratio (OR) and 95% confidence intervals of the effect of principal components from specific pesticide exposures on respiratory symptoms during the last week. An OR of x means that for each 10-fold increase in pesticide exposure [ng/ml], there is an x-fold increase in the odds of having any respiratory symptoms, e.g. the odds of having any respiratory symptoms are x-times as high for a child with 10 ng/ml of a pesticide compared to a child with 1 ng/ml of the same pesticide. Values > 1 indicate an increase in the odds for respiratory symptoms, values < 1 indicate a decrease in the odds for respiratory symptoms. The dashed vertical line at 1 indicates no effect. The models are adjusted for spraying season, school, income, $PM_{2.5}$ and pollen. Red stars (*) indicate statistical significance ($p < 0.05$).

6. What is the association between measured pesticide exposure and measured lung function parameters?

Lung function is defined based on measurements taken by the fieldworker using the Spirobank Smart (MIR, 2019), an app-based portable spirometer. We defined the five main lung function outcome parameters from measurement obtained at day 8, namely forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), their ratio (FEV_1/FVC), peak expiratory flow (PEF), and forced expiratory mid flow (FEF_{25-75}) as outcome variables **(Table 7)**.

The results are reported as z-scores, which show how close a child's measurements are to what we would expect for their age, height, sex and ethnicity **(Table 7)**. A z-score of 0 means the value is exactly as expected. FEV_1 represents the volume of air that can be forcefully exhaled during the first second. The mean (SD) FEV_1 z-score was slightly below 0 (-0.13 (1.33)) at baseline but increased slightly above 0 (0.16 (1.33)) at A1. FVC, representing the maximum volume of one complete exhalation, had a mean z-score of approximately 0.50 across all assessments, ranging from 0.39 to 0.64. These changes in z-scores are minimal, with all values remaining close to 0, indicating that the children's average lung function was within the normal range. A z-score below -1.64 is considered below the lower limit of normal lung function and may indicate mild lung function impairment (Quanjer et al., 2012).

Table 7: Measured lung function parameters at day 8 presented as mean and SD stratified by assessment.

Supervised Data Day 8		Total	B	A1	A2	A3
FEV1 z-score	n (obs)	544	136	142	129	137
	n (children)	162	136	142	129	137
	Mean (SD)	0.11 (1.24)	-0.13 (1.33)	0.16 (1.33)	0.21 (1.03)	0.20 (1.21)
FVC z-score	n (obs)	487	119	128	114	126
	n (children)	151	119	128	114	126
	Mean (SD)	0.50 (1.33)	0.39 (1.44)	0.47 (1.35)	0.52 (1.27)	0.64 (1.24)
FEV1/FVC z-score	n (obs)	412	99	112	96	105
	n (children)	135	99	112	96	105
	Mean (SD)	-0.42 (1.16)	-0.54 (1.04)	-0.23 (1.28)	-0.38 (1.09)	-0.53 (1.18)
PEF z-score	n (obs)	544	136	142	129	137
	n (children)	162	136	142	129	137
	Mean (SD)	-0.15 (1.09)	-0.37 (1.16)	-0.20 (1.05)	0.05 (1.05)	-0.08 (1.05)
FEF25-75 z-score	n (obs)	627	157	160	149	161
	n (children)	178	157	160	149	161
	Mean (SD)	-0.63 (1.06)	-0.85 (1.08)	-0.55 (1.10)	-0.52 (0.95)	-0.59 (1.10)

Forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), peak expiratory flow (PEF), and forced expiratory flow at 25–75%). B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). Obs = Observations

Examining the results presented in **Figures 21, 22 and SI2 Table 17**, we find that most biomarkers were not associated with any lung function parameter. However, we observed a statistically significant negative association for propiconazole, imazalil and metalaxyl with lung function, and a statistically non-significant trend for a negative relationship between all lung function parameters and hydroxy tebunconazole concentration.

Effect estimates β are to be interpreted as follows: If β = 0.2, the expected mean z-score of the respective lung function parameter is increased by 0.2 (e.g. from 0.15 to 0.35) in a child where the measured concentration of the respective pesticide lies within the indicated concentration range (here: either between LOD and median or above median) compared to a child where the measured concentration of the respective pesticide lies within the reference range (here: below LOD).

Propiconazole showed a statistically significant negative association with FVC z-scores [β = -0.25, 95% CI = -0.49 to -0.01] for a concentration above median compared to a concentration below LOD. **Imazalil** showed a statistically significant negative association with FEV_1/FVC z-scores [β = -0.42, 95% CI = -0.77 to -0.07] for a concentration between LOD and median compared to a concentration below LOD. **Metalaxyl** showed a statistically significant negative association with FEF_{25-75} [β = -0.30, 95% CI = -0.55 to -0.05] for a concentration between LOD and median compared to a concentration below LOD.

Ametoctradin showed a statistically significant positive association with FVC z-scores [β = 0.50, 95% CI = 0.07 to 0.94] for a concentration between LOD and median compared to a concentration below LOD.

Propiconazole showed a statistically significant positive association with FEV_1/FVC z-scores [β = 0.43, 95% CI = 0.16 to 0.70] for a concentration between LOD and median compared to a concentration below LOD. In both cases, the change in FEV_1/FVC is a result of a change in FVC, not of a change in FEV_1.

Sensitivity analyses accounting for exposure to air pollution ($PM_{2.5}$) and pollen showed no material changes in the association results, regardless of their in- or exclusion **(SI2 Figure 11)**.

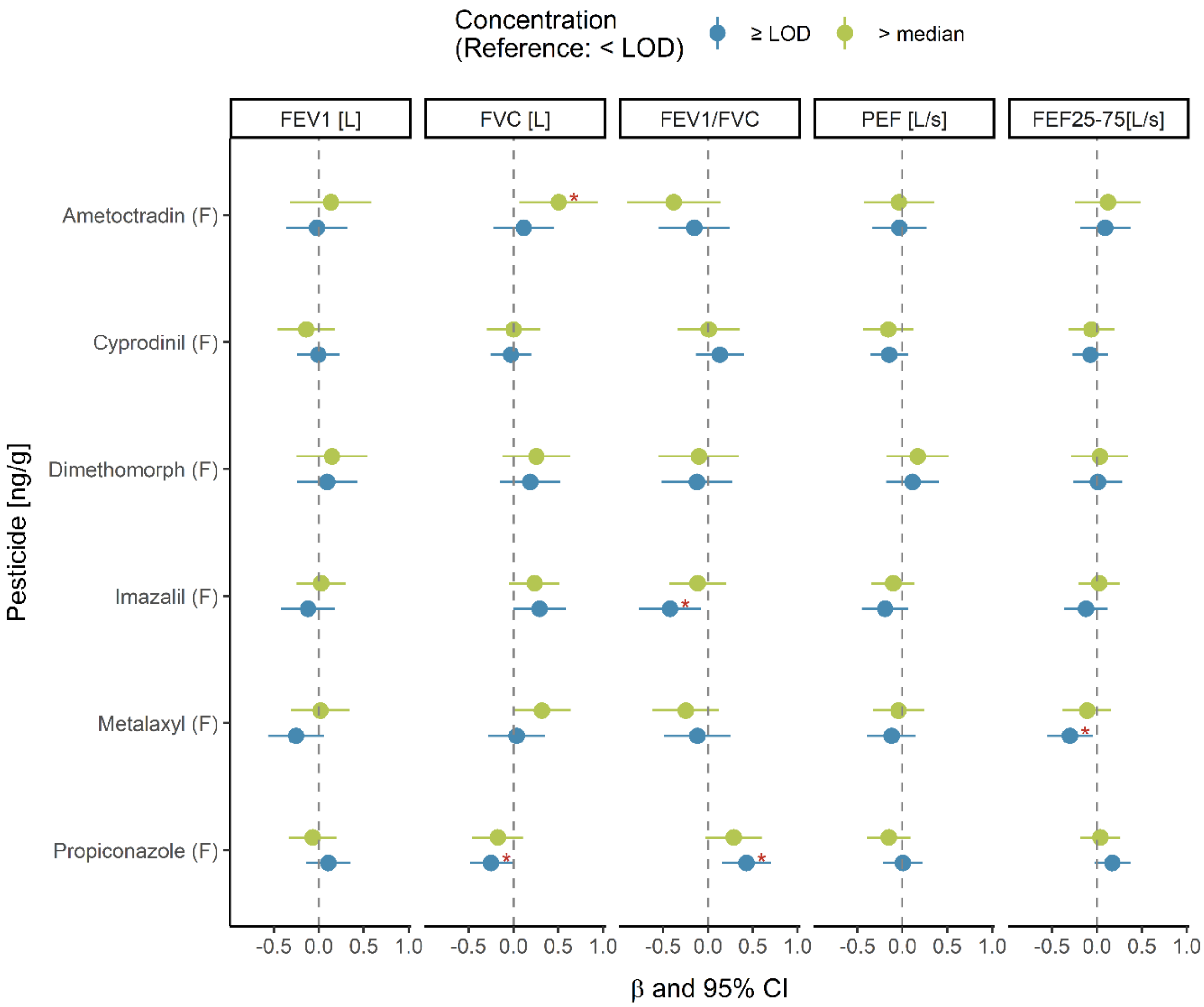

Figure 21: Association between measured pesticide exposure (wristbands) and lung function parameters. Presented as regression coefficients β and 95% CIs**.** The value for β indicates the change in lung function for children of the respective concentration category compared to children with a concentration below LOD. Values > 0 indicate an increase in lung function, values < 0 indicate a decrease in lung function. The dashed vertical line at 0 indicates no effect. All models are adjusted for the lung function value measured at day 1 baseline, assessment, school, puberty, fieldworker, physical activity, presence of cold-like symptoms, parental smoking, $PM_{2.5}$, and pollen concentration. Red stars (*) indicate statistical significance ($p < 0.05$).

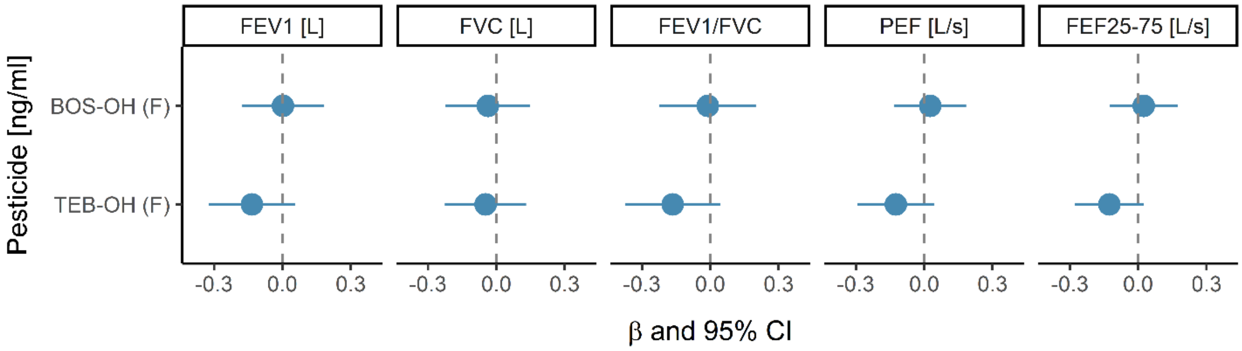

Figure 22: Association between measured pesticide exposure (urine) and lung function parameters. Presented as regression coefficients β and 95%CIs**.** The value for β indicates that for every 10-fold increase in pesticide concentration [ng/ml], that value is added to the lung function value. Values > 0 indicate an increase in lung function, values < 0 indicate a decrease in lung function. The dashed vertical line at 0 indicates no effect. All models are adjusted for the lung function value measured at day 1 baseline, assessment, school, puberty, fieldworker, physical activity, presence of cold-like symptoms, parental smoking, $PM_{2.5}$, and pollen concentration. Red stars (*) indicate statistical significance ($p < 0.05$).

5. DISCUSSION

The PARVAL study explored airborne pesticide exposure and its impacts on respiratory health in school children living near vineyards and fruit orchards in Valais, Switzerland. Conducted over six months in 2024, the study involved 206 children across four assessments, resulting in 778 wristband samples and 627 spirometry tests— to our knowledge the largest study of its kind globally. Notably, it is the first epidemiological study in Switzerland to investigate the link between pesticide exposure and potential health effects.

All children were exposed to at least one pesticide, with an average of 14 pesticides detected per child and 36 distinct pesticides identified overall out of the targeted 81 pesticides. Pesticide concentration exhibited strong seasonal and short-term variations, influenced by factors such as village location and nearby agricultural land use. The proximity to agricultural land was associated with a higher concentration of some pesticides. Other potential alternative sources of pesticide exposure like sports fields, household products, or food crops warrant further investigation.

There was no association between acute respiratory health symptoms and the intensity in pesticide exposure. However, an increased concentration of two pesticides was associated with a minor short-term decline in lung function, albeit not in a consistent manner across different modelling approaches. These findings emphasize the need for further research in larger epidemiological studies, particularly regarding exposure to pesticide mixtures and their potential health impacts.

To which pesticides are the children exposed via air?

In our study, most pesticides detected (23 out of 36 = 64 %), were fungicides. This aligns with the agricultural setting of the study areas, given that both vineyards and fruit orchards are highly susceptible to fungal diseases and require extensive fungicide use (BLW, 2024). 30 of the detected pesticides were registered for use in Switzerland in 2024. Notably, 12 of the pesticides were approved for aerial spraying via helicopter (e.g., cyprodinil, metalaxyl, and tebuconazole). Six detected pesticides (S-metolachlor, prochloraz, diuron, pencycuron, pymetrozine, and propiconazole) have been banned for use in Swiss agriculture since 2020, each with different phase-out periods. For instance, the last permitted usage date for products containing propiconazole was July 1, 2022 (BLV, 2024b). A detailed overview of chemical properties and comparison with detection in other studies in Switzerland for the targeted pesticides is shown in SI3.

Five pesticides detected in our study (ametoctradin, imazalil, cyprodinil, tebuconazole, and boscalid) have previously been identified in human biomonitoring studies of a random sample of 295 adults in Basel (EEA, 2023; Ottenbros et al., 2023). Similar to this study, short-term pesticide application and exposure events influence exposure levels, resulting in different pesticide mixes per sampling. Unlike the urban Basel study, which focused on food-borne exposure, we emphasize significant airborne pesticide exposure in agricultural areas. This underscores the need for high-resolution longitudinal monitoring using diverse methods, such as wristbands for airborne and urine sampling for food-borne exposure.

Beyond human biomonitoring, several of the pesticides have also been detected previously in environmental studies in Switzerland, highlighting their widespread presence in the environment (17 in rain, nine in air (Carbotech, 2021) and eight in water (BAFU, 2022)). Six of the pesticides are also discussed in the Swiss National Action Plan for Reducing Pesticide Risks in regard to limiting their use (BLW, 2017).

We did not compare pesticide concentrations in wristbands and urine to toxicological thresholds. However, notably, beyond their potential as respiratory irritants.

What are potential risk factors of being exposed to specific pesticides and at different intensities?

In addition to the clear seasonal patterns in exposure, proximity to agricultural land and the extent of surrounding agricultural land were linked to exposure to the two pesticides most frequently detected in the wristbands and the two pesticides analyzed in the urine samples, emphasizing the role of drift from nearby agricultural activities The fact that the associations between pesticide exposure and agricultural land use extended to 1 km buffer zones around children's homes in our study suggest that pesticide drift can extend over considerable distances. Community-level differences in pesticide occurrence and levels among Chamoson, Saxon and Salgesch further highlight the role of local land use (i.e. differences between vineyards and fruit orchards). These results, consistent with other studies, underscore the importance of considering crop-specific, distance-dependent, and area-related factors in assessing pesticide exposure risks in different parts of the world (Figueiredo et al., 2021; Fuhrimann et al., 2021; Teysseire et al., 2020). For example, elevated concentrations of cyprodinil, dimethomorph, ametoctradin, metalaxyl-M, boscalid, and tebuconazole likely reflect their current use in vineyards and fruit orchards. This association is further supported by a study in the US (Yang et al., 2023), which found that 23% of adults living within 2 km of commercial pesticide application sites were exposed to hydroxy boscalid and 21% to cyprodinil. This raises exposure risks, particularly for children spending time outdoors. These insights advocate for the implementation of tailored buffer zones to mitigate exposure, with adjustments based on specific pesticides and local land-use scenarios. In contrast, the association between propiconazole and vineyard areas may reflect historical applications or the use of older stock, despite its ban.

For most pesticides, we observed an increase in both the number of detected pesticides as well as in their concentration from January to June 2024, corresponding to the spraying season. This seasonal pattern is consistent with a French study (Raherison et al., 2019), which found higher airborne pesticide concentrations during vine-growing seasons compared to winter months, using both air monitoring and urine samples for measurement. Notably, the pesticides detected in the French study were similar to those in the PARVAL study, with fungicides being the most prevalent (e.g., dimethomorph, tebuconazole and cyprodinil were detected in both studies).

Interestingly, urinary biomarkers in our study showed no seasonal trends, indicating dietary intake to be a constant exposure source. This finding is supported by a study describing the probability of exposure to a set of pesticides in urine samples in five European countries (Ottenbros et al., 2023). First, hydroxy boscalid was also found in high concentrations in at least four of the five assessed countries. Second, their findings showed no consistent patterns when assessing predictors such as agricultural area or season of urine sampling.

Pesticide exposure in children in Valais is driven by agricultural land use and shaped by spatial, seasonal, demographic, and community-specific factors. Exposure is influenced by local land, pesticide use, and children's movements most probably beyond a 1 km radius of their homes. The high temporal variability observed underscores the need for long-term, cumulative exposure assessments—an approach rarely used in previous research. These results call for comprehensive strategies to monitor and reduce pesticide exposure, especially for vulnerable populations near agricultural areas.

Is there a link between measured pesticides and reported acute respiratory symptoms?

The prevalence of doctor-diagnosed asthma in our study population was consistent with the Swiss national average for children of approximately 10% (Delgrande Jordan et al., 2022). The weekly incidence of acute respiratory symptoms increased significantly, rising from 10% during the non-spraying season to 20% in the spraying season. However, no short-term associations were identified with the eight measured pesticides' concentrations, consistent with findings from previous studies, such as those conducted in the Netherlands (Wijga et al., 2014). It is worth noting that several pesticides, such as sulfur (Raanan et al., 2017) and pyrethroids (Islam et al., 2023), which are used in considerable amounts and have shown associations with respiratory symptoms in other studies, were not included in our analysis due to limited resources. Other pesticides, such as mancozeb, which previously showed effects (Mora et al., 2020a), are no longer in use in Switzerland and were therefore not included in this study.

The absence of associations between acute respiratory health and pesticide exposure should be interpreted with caution, as the low number of reported respiratory symptoms limited the statistical power to detect potential effects. Furthermore, studies have found associations between pesticide exposure and potential long-term respiratory health (Keleb et al., 2024; Yang et al., 2023). Findings based on self-reported respiratory symptoms may be influenced by parental reporting bias, potentially underestimating or overestimating the true prevalence of symptoms.

Is there a link between measured pesticides and changes in lung function?

Overall, our findings reveal no or small associations between pesticide concentration and lower lung function levels across the eight pesticides and five lung function parameters examined. The small yet statistically significant negative associations were found for propiconazole, and metalaxyl. Even though the observed reductions in lung function are modest, they may indicate subtle airway changes or early signs of respiratory stress. This underscores the need for further research into the long-term health implications of pesticide exposure, similar to concerns raised in air pollution studies (Obaseki et al. 2014, Kwon et al. 2020).

Other studies generally report minimal or no effects of airborne pesticide exposure on lung function (Mamane et al., 2015). Compared to previous studies, we assessed a substantially larger set of pesticides—81 in total—with a focus on those with potential respiratory irritant effects currently used in Switzerland. Notably, previous epidemiological research has highlighted the effects of certain pesticides, such as organophosphates (Hansen et al., 2021) and mancozeb (Islam et al., 2023), both of which are already banned and no longer in use in our study region. Of note, other potentially relevant pesticides, such as sulfur and pyrethroids, which have demonstrated effects in earlier research, were not examined in this study and should be focused on in future investigations.

Our study advances knowledge by employing direct pesticide exposure measurements and human biomonitoring (HBM) methods, rather than relying on indirect proxies like residential proximity. By using wristbands and urine samples, we provided a more accurate assessment of airborne pesticide exposure, compared for example to the Dutch PIAMA birth cohort (Bukalasa et al., 2017). By measuring pesticide exposure in both wristbands and urine samples, this study reveals the complexity of exposure pathways through a multi-matrix approach. This highlights the importance of integrating multiple sampling techniques for a comprehensive evaluation of environmental chemical exposures in children (Mora et al., 2020b; Probst-Hensch et al., 2022).

Our findings provide valuable insights for guiding the design of future research globally and particularly in Switzerland. While most pesticides showed no measurable effects, small reductions in lung function associated with a few pesticides could have long-term implications, particularly for populations with prolonged exposure (Iyanna et al., 2023; Mehta et al., 2012). Vulnerable groups, such as children with asthma, the elderly, and individuals with pre-existing conditions, may be at heightened risk. Future, larger studies investigating the underlying mechanisms of these effects should also account for cumulative and synergistic impacts, as an average of 14 pesticides per child was detected across the four assessments. This highlights the critical need to examine potential mixture effects in future research.

5.5 Strength and Limitations

Sample Size: This longitudinal study, involving 206 children across four sampling rounds, encompasses over 800 weeks of combined pesticide exposure and lung function assessments, making it the largest of its kind globally. While its scale is well-suited for analyzing continuous pesticide exposure and lung function outcomes, the sample size was insufficient to robustly assess rare binary acute respiratory symptoms. A larger sample of 400 children, as originally planned, would have provided more reliable results and allowed for more comprehensive adjustment of confounding factors.

Pesticide Exposure Assessment: From January to June 2024, the study conducted four one-week assessment phases, representing one of the most comprehensive global samplings of children to date. However, the exposure assessment had key limitations:

- While 83 pesticides were measured in wristbands and urine samples, approximately 80 additional highly used respiratory irritant pesticides — such as sulfur, copper, folpet, captan, and pyrethroids — were excluded due to technical and budgetary constraints.
- Pesticides are often applied in short windows of a few days, and the sampling design, with 20 to 30 children assessed daily, captured only a fraction of these exposures.
- Another limitation was that the urinary samples measured were not adjusted for dilution, potentially affecting the interpretation of pesticide concentrations.

Future studies should include cumulative exposure assessments over entire spraying seasons, supported by detailed farmer spray records to improve temporal accuracy and coverage.

Spirometry Measurements: The low number of eligible FVC values indicates that the children frequently didn’t exhale completely during the performance of spirometry measurements. This limitation may affect the reliability and completeness of the lung function data in our study.

Recall Bias: Parent-reported data on pesticide exposure and respiratory health may have introduced recall bias, as parents might not accurately recall or report their children's behavior and respiratory symptoms.

Model Sensitivity: Different choices of variables to be included as confounders would only marginally affect the resulting effect estimates. Further analysis of the spirometry data collected each evening will be conducted by Swiss TPH, but this falls outside the scope of the current project report.

In summary, while this study provided valuable insights into pesticide exposure and its potential effects on respiratory health, key limitations—such as sample size, recall bias, and the scope of pesticide measurements—highlight the need for more comprehensive future research.

6. Overall Conclusion

Children living in agricultural areas are exposed to a wide range of pesticides. In our study, we detected 38 out of the 83 targeted pesticides in wristbands and urine samples, with a mean of 14 pesticides detected per child over all four assessments between January and June 2024.

Seasonality and complexity of exposure sources: A clear seasonal pattern was observed, with higher levels and detections in the spring compared to winter. For certain pesticides, the variability in exposure patterns suggests alternative sources, such as pesticides sprayed on sports fields, in forest or at home, should be investigated.

Limited respiratory effects: The observed effects on lung function and respiratory health were weak and mostly lacked statistical significance, indicating minimal immediate concern. However, the potential long-term health impacts of chronic low-level exposure remain unclear.

Future research needs: There is a critical need for longitudinal studies examining exposure to multiple currently used pesticides, considering cumulative and mixture effects. Research should also integrate other inhaled irritants, such as air pollution and pollen, to understand the broader context of respiratory health impacts. Further research should also investigate additional potential health impacts of these pesticides, as some of the pesticides have neurotoxic and endocrine-disrupting properties.

Policy implications: Findings suggest the importance of monitoring airborne pesticide exposure, particularly in vulnerable populations such as children, and developing strategies to mitigate potential risks. This evidence can contribute to informed discussions on pesticide regulation in Switzerland and globally.

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8. Publication

Anonymized data can be shared with research partners in the context of data transfer agreements for specific scientific projects in case it was agreed on in the informed consent signed by the child's parent. Swiss TPH will report the results to the cantonal authorities. Additionally, the study results will be published in peer-reviewed journals, and co-authors will not have access to the data unless authorized.

9. Declaration of Interest

The authors declare no conflict of interest.

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11. Supplementary Information

6.1 Supplementary Information (1)

06032025_SI_01_PARVAL_v20.docx

2.2 Supplementary Information (2)

01042025_SI_02_PARVAL_v20.docx

2.2.1 Table of Figures

2.2.2 Table of Tables

2.3 Supplementary Information (3)

Excel Table indicating investigated 147 pesticide with possible respiratory irritant hazard potential, showcasing chemical characteristics, use in Switzerland and detection frequencies in the PARVAL study

06032025_SI_03_PARVAL_v20.xlsx

Final, 28.4.2025, for the Department of Health Canton of Valais

Exposure to Pesticides by Air and Respiratory Health in School Children in VALais, Switzerland (PARVAL)

Supplementary Information 1

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CONTENTS

(1) STANDARD OPERATION PROCEDURE (SOP)

Overall Plan of Weekly Measurements

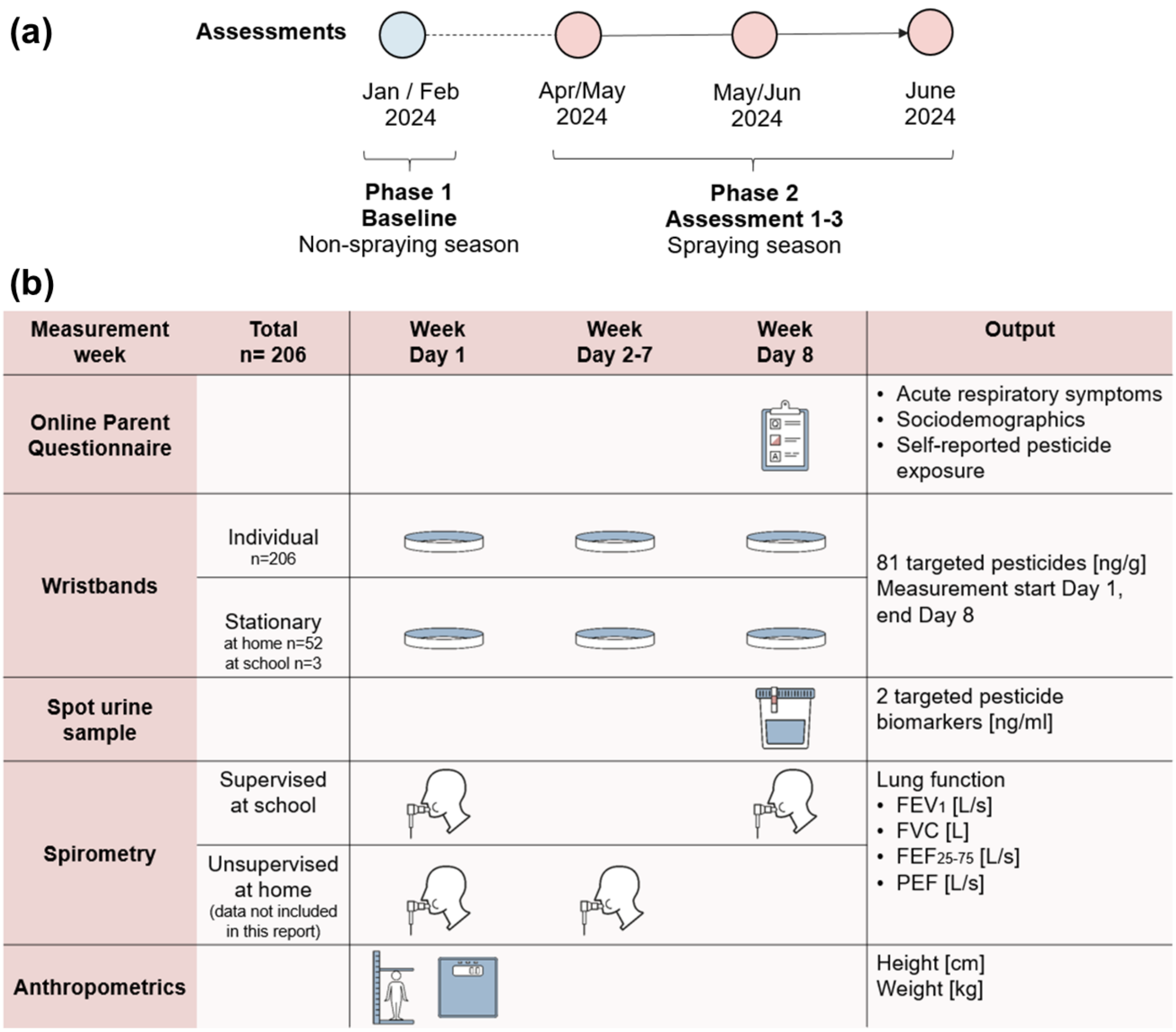


Figure 1: (a) Shows the adapted overall plan for the study, including the total number of children included in the analysis (n = 206) and the two phases and four assessments of data collection. **(b)** Shows the measurements taken from the children during the in-depth measurements.

Table 1: **Weekly resolution Assessment plan.** The Assessment will start on the 08.01.2024.2023 and end on the 02.02.2024. Included are the holidays and special free days. Salgesch has a free day on the 27.11.2023, Chamoson on the 30.11.2023 and all of the communities have a free day on the 08.12.2023 (this is why we can only have 4 assessment days in week 3 and 4). During the first two weeks (week 1&2) it is planned to do measurements with 24 children per day (12 children per researcher), on week 3&4, measurements with 20 children are planned per day.

Total of 200 children		Week 45							Week 46							Week 47						
PARVAL Project		1.1	2.1	3.1	4.1	5.1	6.1	7.1	8.1	9.1	10.1	11.1	12.1	13.1	14.1	15.1	16.1	17.1	18.1	19.1	20.1	21.1
Preperation Week 0		Mo.	Di.	Mi.	Do.	Fr.	Sa.	So.	Mo.	Di.	Mi.	Do.	Fr.	Sa.	So.	Mo	Di.	Mi.	Do	Fr.	Sa.	So.
1. Prepare urine kits, Spirometry and Wristbands																						
2. ODK																						
3. Wristbands --> Stationary, make sure they are placed																						
4. Prepare Documents (Spirometry guide)																						
5. Sending of Questionnaire (400)																						
6. Preperation Spirometry study team																						
Assessment week 1																						
School 1 - 24 children: wristband start + anthropometrics +spirometry	B 1.1																					
School 2 - 24 children: wristband start + anthropometrics +spirometry	B 1.2																					
School 3 - 24 children: wristband start + anthropometrics +spirometry	B 1.3																					
School 4 - 24 children: wristband start + anthropometrics +spirometry	B 1.4																					
School 5 - 24 children: wristband start + anthropometrics +spirometry	B 1.5																					
Preperation Spirometry study team																						
Assessment week 2																						
School 1 - 24 children: wristband start + anthropometrics +spirometry	E1.1																					
School 2 - 24 children: wristband start + anthropometrics +spirometry	E1.2																					
School 3 - 24 children: wristband start + anthropometrics +spirometry	E1.3																					
School 4 - 24 children: wristband start + anthropometrics +spirometry	E1.4																					
School 5 - 24 children: wristband start + anthropometrics +spirometry	E1.5																					
Preperation Spirometry study team																						
School 1-3 Saxon, Chamonson School 4-5 Salgesch																						

		Week 48							Week 49						
		22.1	23.1	24.1	25.1	26.1	27.1	28.1	29.1	30.1	1.2	2.2	3.2	4.2	5.2
		Mo.	Di.	Mi.	Do.	Fr.	Sa.	So.	Mo	Di.	Mi.	Do	Fr.	Sa.	So.
Assessment week 3															
School 1 - 24 children: wristband start + anthropometrics +spirometry	B 2.1														
School 2 - 20 children: wristband start + anthropometrics +spirometry	B 2.2														
School 3 - 20 children: wristband start + anthropometrics +spirometry	B 2.3														
School 4 - 20 children: wristband start + anthropometrics +spirometry	B 2.4														
School 5 - 20 children: wristband start + anthropometrics +spirometry	B 2.5														
Preperation Spirometry study team															
Assessment week 4															
School 1 - 24 children: wristband end + spirometry + urine sample	E 2.1														
School 2 - 20 children: wristband end + spirometry + urine sample	E 2.2														
School 3 - 20 children: wristband end + spirometry + urine sample	E 2.3														
School 4 - 20 children: wristband start + spirometry + urine sample	E 2.4														
School 5 - 20 children: wristband start + spirometry + urine sample	E 2.5														
FINISHED															

B = Baseline (day 1 of Assessment); E = endline (day 8 of Assessment)

School 1-3 will be either Saxon or Chamoson or mixed (morning, afternoon); School 4 and 5 will be Salgesch

Table 3: Timetable for each task during day 1 and day 8 of assessment.

	PARVAL Project example of chamonson	**Minutes:**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Tasks	**Time total**																				
Day 1	**0. Preperation**	60 min																				
	Measurement devices																					
	Tablet																					
	1. Information (all together)	30 min																				
	Collect and Inform 12 children and explain to them the plan for this morning																					
	Walk to designated room																					
	2. Measurements (wristband, anthropometric and spirometry)	20 min/child																				
	Assent	2 min																				
	Spirometry (go through the guide together and take 3 measurements)	10 min																				
	Wristband (explain on how to wear)	2 min																				
	Take height and wieght measurements (2x)?	5 min																				
	Give them the envelope with the spirometry instructions	1 min																				
	3. Qaulity control	5 min																				
	Prepare next participant ODK																					
Day 8	**0. Preperation**	60 min																				
	Measurement devices																					
	Tablet																					
	1. Information(alltogether)	30 min																				
	Collect and Inform 12 children and explain to them the plan for this morning																					
	Walk to designated room																					
	2. Measurements (wristband, anthropometric and spirometry)	20 min																				
	Spirometry (take 3 measurements and observe child)	8 min																				
	Questionnaire	2 min																				
	Urine sample (explain and wait for the child to bring)	8 min																				
	Aliquote Urine Sample	2 min																				
	3. Quality control	5 min																				
	Prepare next participant ODK																					

The tasks take less time as the fieldworker gains experience and the child becomes better informed. The duration of the follow-up measurements is about 2 times faster than the baseline measurements.

Overall Workflow

1. Discuss workflow and time table with school principal (how many blocks per day, how many children per day, from which class). Planned Teacher meetings end of September.
2. Ask for a separate room.
3. Recruitment of Participants (22.11.2023)
4. After signing the ICF the participant is asked to register online. Residential information, (address, email and phone number)
5. Send detailed time table to each school (1 week before start of assessment)
6. Prepare Equipment
7. Place stationary wristbands on selected houses (1 day before assessments starts)
8. Assessment start: Collect Data (Day 1 and Day 8)

Recruitment

Material List

- Print ICF x 1762 (German French)
- Print Invitation letter x 881 (German French)
- Print Non-respondent Questionnaire x 881 (German French)
- **Print Overview x 881** (German French)
- B5 envelopes x 881
- B4 envelopes x 38 (Addressed to Swiss TPH and Stamped!

The documents will also be available via the directors who have them electronically. The documents are translated in English, Portuguese, French and German.

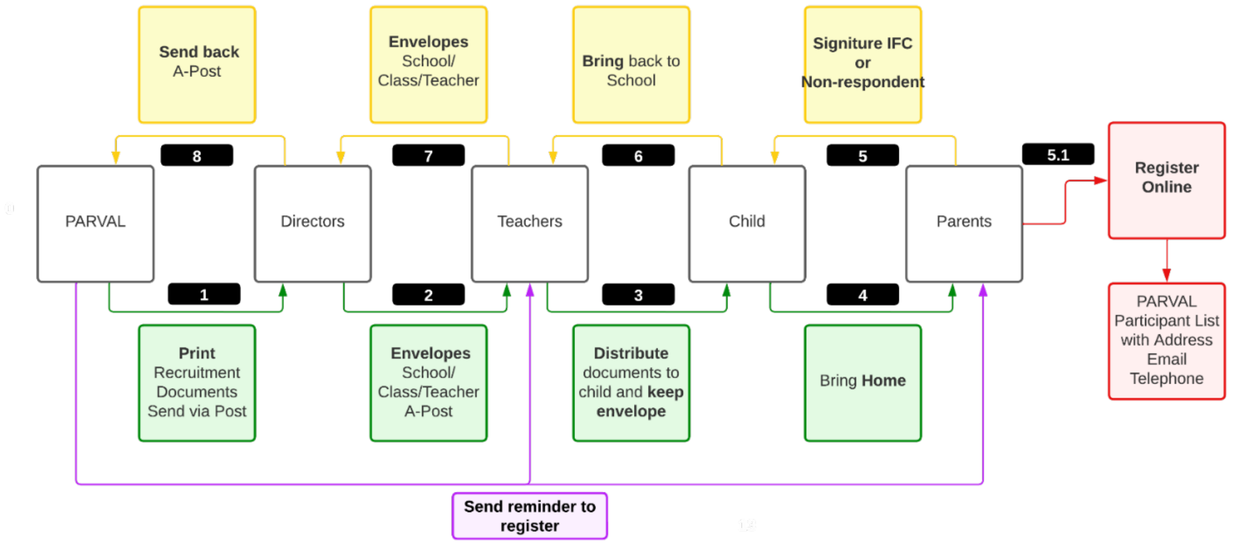


Figure 2: Overview of the workflow for the Recruitment.

1. Documents will be printed with WBZ company. in French (Chamonson and Saxon) and German (Salgesch) plus 10 in Portuguese. The documents will be sorted per class and put into an envelope marked with the name of the school, teacher and class. Documents are sent via Kurierzentrale.
    - The envelopes are already addressed to the Swiss TPH and stamped A-post.
2. The School director will distribute the envelopes to the designated teachers.
3. The Teachers will distribute the documents to each child.
    - The envelope, which contained the documents, is kept by the teacher.
4. The children will be asked to put the documents into an envelope and bring home to their parents.
5. The parents will sign the ICF or fill out the non-respondent questionnaire depending on whether they want their child to take part in the study. The non-respondent Questionnaire is voluntary.
    - **5.1 After signing the ICF the parents are asked to register online via a QR code presented on the information document.**
    - They will put the respective documents into the designated envelope and give it to their child to bring back to school.
    - In case of non-participation the envelope can also be empty.
6. Child brings the envelope back to school.
7. The teachers will collect the ICFs and non-respondent questionnaire in the respective envelope (addressed to the Swiss TPH and stamped A-post).
8. Either the director collects all envelopes and send them all together via post or the teachers separately send the envelopes via post.

A reminder to the teachers will be sent via email (to the directors) to remind the parents on their chosen communication pathway. We will see online via the registration the number of participants and the teachers will let us know how many children have not brought back an envelope.

Comments: Sending of Documents worked great. Distribution as well. Parents forget to register online. We wrote an extra email to all directors to inform the teacher to remind the parents to online register.

Preparation of Assessment

The following activities are realized before the Assessment starts as listed in Table 4.

Materials:

- 400x Printed Assent (children)
- 200x Printed Instructions for parents at home (French and German) and Portuguese.
- 200x Envelopes (Assent and Instructions)
- 200x Spirometry instructions for parents
- Labels (Stickers)
- 200x Urine sample tool kit
    - 200 x 100 ml collection cups,
- 200 x 4 ml v-monovette tubes1-2x glove boxes size M
- 1 Cool box
- 6x cooling elements
- 200 Wristbands
- 1 scale

- 1 Stadiometer
- 2 barcode scanner
- 3 big Boxes for (wristband, urine kits and spirometry)
- 200x Gym bag
- Printed Checklist for packing
- 200 Small airtight bags
- Place stationary wristbands on selected houses
- Send Questionnaires to parents via email (after day 8)
- String for stationary wristbands

Child Assessment

1. Anthropometric measurements (Day 1)
2. Silicone wristbands (1 week)
3. Spirometry (Day 1 and Day 8 with field worker, day 2-7 with parents at home)
4. Urine sample (Day 8)

First Day of Assessment

The following activities are realized on Day 1 as listed in Figure 4.

Materials:

- 400x Printed Assent (children) (1 copy for the children to keep)
- 200x Printed Instructions for parents at home
- Extra spirometer books
- 200x Envelopes
- 1x Scale and Stadiometer
- 2x barcode scanners
- 3x Bag/Box for Spirometers and Wristbands
- 200x Gym bag for children bags
- 200x nose clips
- 200x (+ extra for each child) Silicone Wristbands (already in plastic bag and labelled)
- 200 Small plastic bags reusable and airtight
- 200x Spirometry devices
- 28x Zip lock bags for the wristband package
- Some snacks (banana, chocolate (Branchli) and Water)
- Pens to color the Gym bag
- Stationary wristbands
- Stationary instructions

Informed Assent

Procedure to follow.

1. Provide a copy of a blank informed assent form to the participant.
2. Read the informed consent together and make sure to answer all the questions that the participant has.
3. Tick the sub-parts of the study the participants agree to participate in.
4. Sign the consent if the participant agrees to participate in the study. (Verbal (6-10 years) or written (11-12 years) depending on age)

Measurements

Up to three measuring stations were set up. Each station was equipped with all the materials to perform all the measurements. The field worker followed the measurement procedure using the ODK form on the laptop.

Wristbands (2 min)

At day 1, in each study site the child will receive one silicone wristband to put on his wrist. The participant will be asked to keep it on and to never take it off (even during the shower or when taking a bath or doing sports) for the following 7 days.

Three different sizes:

- Size S (160x12x2), ages 6-8 years
- Size M (180x12x2), ages 10-12 years
- Size L (202x12x2), adults

Child ID, Teacher ID, date and time of handing out the wristband will be recorded → scan barcode for wristband ID

- on the label on the plastic bag
- In the study logbook.

1. Ask the child to try on the Size S or M, check which fits better and ask the child how it feels on the wrist.
2. Choose, correct size (Size M tends to be very large)
3. Ask the child to take the wristband out of the silver bag and put the wristband (left side)
4. We keep the silver wristband package in envelopes (per class)

IMPORTANT: at the end of day 1 the study supervisor must cross-check if the id’s recorded on the plastic bag label and the study logbook match the participant list

In each study area, one silicone wristband will be taken into the field as a control (blank). Important to keep it always in sealed in the plastic bag.

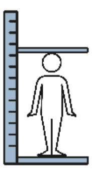
Stationary Wristband

Size M was used as a stationary wristband. It is indicated on the fieldwork list if the child receives a stationary wristband to take home or not.

Tell the child about the materials he or she has received. This includes the paper instructions, the wristband (still in the aluminum zip lock, labeled), a small rope, and a sticker (for attachment). Put it in the envelope together with the general instructions for parents and the spirometer manual (all in 1 envelope).

Scan the barcode for the label (input in ODK).

Height (2.5 min)



1. Ask the participant to remove the shoes: "Can you remove the shoes please?"
2. Show the participant how to place oneself in front of the stadiometer.
    a. With the rod in the center of the back and head
    b. Feet together, hands hanging next to body and head.
    c. Shoulders, buttocks, calves, and heels touching to the stadiometer.

3. Then say, "Please lower your chin." (eyes should be in a line with the top of the ears)
4. Take the carpenter square and place it in the center of the stadiometer, support one side of the squad 5 cm above the participant's head, and then lower the squad until it touches the participant's head at a right angle.
5. Hold the squad in place and do not move it, ask the participant to withdraw ("Now you can move") to observe the size data.
6. Record the size of the participant with one decimal on the sheet.
7. Repeat the measurement 1 more time and record the sizes (total of measurements: 2).

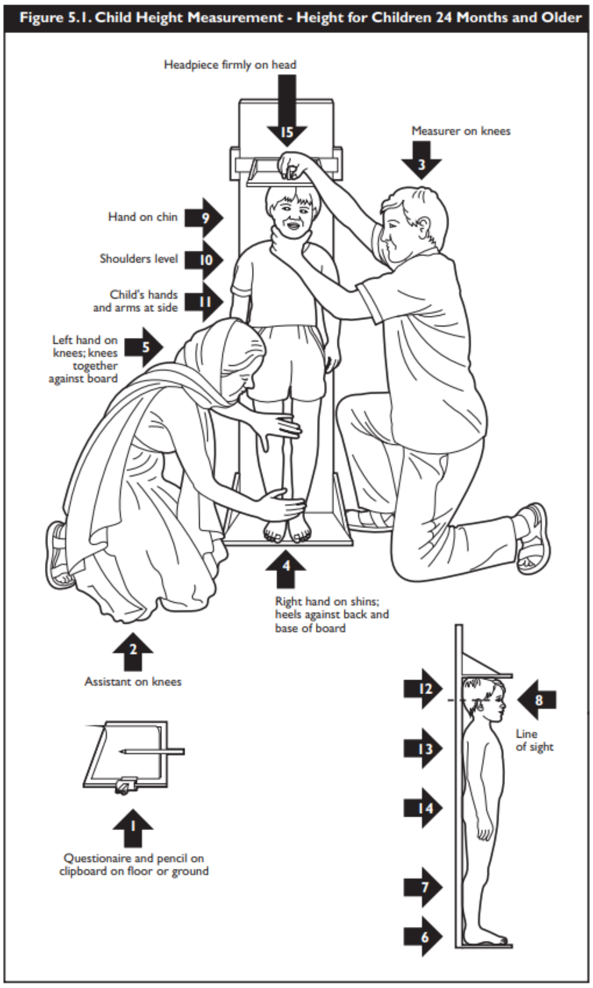
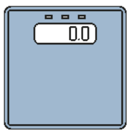


Figure 5.1. Child Height Measurement - Height for Children 24 Months and Older

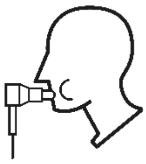
Source: How to Weigh and Measure Children: Assessing the Nutritional Status of Young Children, UN 1986.

Weight (2.5 min)



1. Switch on the scale
2. Perform the measurement 2 times and record the data with a decimal on the tablet. (total of 2 measurements)

Spirometry (5-7 min)



The following activities will be done according to the spirometry manual.

https://usa.spirometry.com/videos

1. Insert participant ID and spirometer serial number in ODK → scan barcode
2. Connect to mobile Tablet
3. Read the Spirometry Manual with the participant.
4. Explain what we are measuring now.

5. Show how to hold the spirometer: both hands,
6. Show how the mouth is placed around the tube: put mouth around the tube and seal lips around it.
7. Show breathing technique: long fast and hard breathing → “inflating a balloon until it feels like it is bursting and then let the air out. For the duration of how long to exhale we use the example of “imagine you want to blow out all the candles on birthday cake”.
8. Ask the participant if they understood how to do it
9. Ask the participant to stand or sit up straight
10. The lips are sealed around the tube.
11. Do a first try.
12. Encourage the child to blow strong and fast!
13. Hold the phone in front of the child on the same height as the child’s phase (this will help prevent the child from leaning forward)
14. Observe the child on how well it performs the test.
15. Do a second try.
16. Do a third try. Until 5 tries are completed
17. Encourage the child to blow strong and fast!
18. Send results to PARVAL Study server

Day 8 of Assessment

The following activities are realized on Day 8 as listed in Figure 4.

Materials:

- 3x Bag/Box for Spirometers and Wristbands and Urine Kits
- Urine Sample kit
    - 200x Urine containers (100ml)
    - 400x v-monovettes (4 ml)
    - 3x Cryo Boxes (for 7x7 tubes)
    - Two tube holders (yellow) → bring to ICH
    - Labels for the urine v-monovettes
    - Urine tracking sheet
- 1x Cool box for urine samples
- 6x Ice elements
- 3x Pack of gloves, size M
- 1x disinfectant for hands
- 1x disinfectant for surfaces
- 1x roll of trash bags
- 3 barcode scanners
- Big envelopes or Plastic bag to collect wristbands
- Permanent marker (ID and max line for urine samples)
- Paper questionnaire
- Envelopes for the questionnaire
- Stamps
- Tags to group the bags
- Empty box to collect the bags
- Empty silver bags (or L wristband bags) in case we can't find the original silver bag
- Extra spirometer for the children who forgot it + tubes

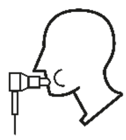
Measurements/ Samples

The following measurements/samples will be collected.

Wristbands

1. After 7 days, the wristband will be removed and packed again in an airproof plastic bag, seal tight → scan barcode
2. IMPORTANT: At the end of day 8, the study supervisor must crosscheck if the ID's recorded on the plastic bag label and the study logbook match the participant list and are complete.
3. Will be shipped in a bigger bag to the lab (uncooled). Silicone wristband will be sent to Wageningen University.

Spirometry

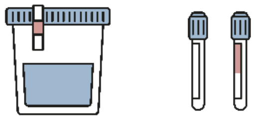


The following activities will be done according to the spirometry manual.

1. Insert participant ID and spirometer serial number in ODK → scan barcode
2. Connect to mobile Phone.
3. Read the Spirometry Manual with the participant.
4. Explain what we are measuring now.

5. Show how to hold the spirometer: both hands,
6. Show how the mouth is placed around the tube: put mouth around the tube and seal lips around it.
7. Show breathing technique: long fast and hard breathing → "blowing out candles on birthday cake"; "imagine blowing away a Ping-Pong ball" (min. six seconds)
8. Ask the participant if they understood how to do it
9. Do a first try. (Observe the child on how well it performs the test.)
10. Do two more tries (total of 5 tries)
11. Send pdf to PARVAL Study server

Urine Sample (5-7 min)



1. Distribute urine sample collection tube.
2. Explain to the participant how to take a spot urine sample.
3. The participant will be asked to wash their hands first.
4. Then it will receive a 100 mL container with personal ID and toilet paper and will be asked to pee into the tube on the toilet
5. Child collects urine sample on toilet
6. Collect urine sample, fil two monovetts (4mL) → scan barcode
7. Afterwards, the urine will be poured into four smaller tubes of 2ml by the study staff.
8. These smaller tubes will then be stored in a storage box in a freezer box at the apartment.
9. Every end of the week we will bring the urine samples to a storage freezer at the OVS in Sion. (-20°C)

Quality Control

1. Record the participant's name, ID and comments in the contact.
2. Upload the ODK questionnaires to the server every night.
3. Review the informed consent photos and participant identification and transfer it to an external disk.
4. Data Monitoring: record all handed out items in the study log book with assigned Study ID

Open Data Kit (ODK) is an open source tool which helps to facilitate mobile data collection. With the help of ODK Collect, an open source Android app, we can replace paper forms used in survey-based data gathering. Benefit of ODK is that it supports a wide range of question and answer types, and can be utilized without network connectivity.

Data collection will occur off-line on password protected android devices. Data connectivity will only be used to send data collected in the field. We will have 3 different user profiles that can be configured on ODK Central:

1. Admin (full access to data, to forms and able to create users)
2. Form Manager (full access to data and able to upload or delete forms)
3. Data Viewer (only view the data submitted)

Data storage will be on a local secured server at Swiss TPH using the ODK Central server and secured via SSL. Once the data is uploaded on the server, it can be accessed through the web interface of ODK Central. Access to data is restricted to a number of people.

More detailed procedure on how to handle data during the four assessments:

a. Day 1: assign Study ID to each participant
b. Record on tablet: informed assent
c. Double check if wristband and spirometry device have same ID as assigned study ID. → record on tablet
d. Distribute the wristband and spirometry device to the assigned participant ID.
e. Record all measurements taken into the table (age, sex, height, weight,
f. Day 8: Collect wristband and Spirometry device and again check for study ID on each device plus questionnaire. → Record tablet
g. Record Spirometry measurements
h. Distribute urine sample kit with same Study ID. → record tablet
i. Collect Sample Kit and immediately aliquot urine sample.
j. Label aliquots according to the study ID. → record in study log book
k. Upload data at the end of the day to ODKCheck variables, height, weight, ID etc.

(2) STATIONARY WRISTBAND: INSTRUCTIONS FOR PARENTS

PARVAL-Studie: Anleitung für das stationäre Armband

Liebe Teilnehmerinnen und Teilnehmer,

Wir danken Ihnen für Ihre Teilnahme an dieser Studie.
Sie haben sich bereit erklärt, ein stationäres Armband bei Ihnen zu Hause anzubringen. Ihr Kind hat eine Stoff Tasche mit einem Spirometriegerät, einem Spirometrie Handbuch und einer Anleitung für Sie mit nach Hause genommen. **Außerdem haben wir ein zusätzliches Armband beigelegt, das bei Ihnen zu Hause platziert werden soll.** Hier einige wichtige Hinweise zur Handhabung des Armbands:

Wir bitten Sie, die folgenden Anweisungen zu beachten:

1. **Reinigen Sie Ihre Hände:** Bevor Sie das Armband anfassen, vergewissern Sie sich, dass Ihre Hände sauber sind.
2. **Bewahren Sie die silberne Reißverschlusstasche auf, um das Armband am Ende der Woche wieder hineinzulegen!**
3. **Standort: Das Armband sollte Draussen in der Nähe Ihres Hauses angebracht werden (idealerweise am Fenster oder auf dem Balkon). Achten Sie darauf, dass das Armband nichts berührt (wie auf dem Foto).** Wenn Sie im Erdgeschoss wohnen, bringen Sie das Armband bitte in einer Höhe von etwa **1,5 Metern über dem Boden an**. Wählen Sie einen Ort, an dem es leicht zu sehen und zu erreichen ist.
4. **Verwenden Sie die Schnur:** Wir haben eine Schnur beigelegt. Bitte binden Sie sie fest um das Armband. Achten Sie darauf, dass Sie das Armband nicht beschädigen.

Beispiel für die Platzierung des Armbands

Rückgabe des Materials: An diesem Datum: __________________, schicken Sie bitte das Armband in der vorgesehenen Verpackung (silberner Verschlussbeutel) zusammen mit den restlichen Studienmaterialien zurück. Achten Sie darauf, dass der Beutel mit dem Verschluss gut verschlossen ist. Ihr Kind kann das gesamte Material bequem in der bereitgestellten Tasche zurückbringen.

Überblick: Zeitplan der Studie:

Bewertung :	**Wo**	**Datum**
Tag 1	Platzieren Sie das stationäre Armband zu Hause	
Tag 8	Das Armband an die Schule zurückgeben	
Nächste Bewertung		April 2024

Wenn Sie weitere Fragen haben, wenden Sie sich bitte an das Studienteam (Telefon: +41 61 284 87 80, E-Mail: parval@swisstph.ch).
Öffnungszeiten: Montag bis Freitag von 18.00 bis 21.00 Uhr

(3) SAMPLE SIZE CALCULATION

Power simulations

Power simulations indicated a sample size of 400 children for binary outcomes (self-reported respiratory symptoms prevalence (yes/no)) and 200 children for continuous outcomes (lung function measurements).The details of the power calculation is explained below.

Power simulations for binary outcomes

Here, data were generated according to the following equation:

$$logit\left(P\left(Y_{i,t}\right)\right) = logit(p_0) + \beta x_{i,t} + e_i$$

with

p_0 = hypothesized median prevalence of the outcome for $x_{i,t} = 0$, $x_{i,t} = u_i + v_{i,t}$ for t > 1, and $x_{i,t} = 0$ for t = 1, where
$u_i \sim \sqrt{ICCx}\, Chi^2(df)$,
$v_{i,t} \sim \sqrt{1 - ICCx}\, Chi^2(df)$,
$e_i \sim N(0, \sigma^2)$,

$\beta = \log(OR)\,/IQR(x_i)$,

where OR is the hypothesized odds ratio associated with an increase in $Chi^2(df)$ from the first to the third quartile. Again, we considered df=2 and df=4.
The parameter σ^2 defines the degree of correlation of Y within subjects. Table of power estimates

a) Results from 1000 simulations for N = 400 and an odds ratio of 1.5 per IQR of exposure

Prevalence of outcome at exposure = 0	**Standard deviation of individual prevalence logits at exposure = 0**	**P95 of individual prevalences**	**Exposure intra-class correlation coefficient**	**Power**
0.02	0.5	0.044	0.3	0.84
0.02	0.5	0.044	0.5	0.84
0.02	0.5	0.044	0.7	0.84
0.02	0.75	0.065	0.3	0.84
0.02	0.75	0.065	0.5	0.83
0.02	0.75	0.065	0.7	0.82
0.03	0.5	0.066	0.3	0.94
0.03	0.5	0.066	0.5	0.95
0.03	0.5	0.066	0.7	0.93
0.03	0.75	0.096	0.3	0.94
0.03	0.75	0.096	0.5	0.94
0.03	0.75	0.096	0.7	0.93

b) Results from 1000 simulations for N = 400 and an odds ratio of 2 per IQR of exposure

Prevalence of outcome at exposure = 0	**Standard deviation of individual prevalence logits at exposure = 0**	**P95 of individual prevalences**	**Exposure intra-class correlation coefficient**	**Power**
0.01	0.5	0.022	0.3	>0.99
0.01	0.5	0.022	0.5	>0.99
0.01	0.5	0.022	0.7	>0.99
0.01	0.75	0.034	0.3	>0.99
0.01	0.75	0.034	0.5	>0.99
0.01	0.75	0.034	0.7	>0.99
0.02	0.5	0.044	0.3	>0.99
0.02	0.5	0.044	0.5	>0.99
0.02	0.5	0.044	0.7	>0.99
0.02	0.75	0.065	0.3	>0.99
0.02	0.75	0.065	0.5	>0.99
0.02	0.75	0.065	0.7	>0.99
0.03	0.5	0.066	0.3	>0.99
0.03	0.5	0.066	0.5	>0.99
0.03	0.5	0.066	0.7	>0.99
0.03	0.75	0.096	0.3	>0.99
0.03	0.75	0.096	0.5	>0.99
0.03	0.75	0.096	0.7	>0.99

Power simulations for continuous outcomes

Let x denote exposure on its original scale and β the effect on the mean of the outcome Y per unit increase in x. We used the re-scaled exposure variable

$$x' = \beta x$$

for which the regression coefficient becomes 1. As we hypothesize that $\beta < 0$, we have x' < 0.

The effect of x' was simulated using scaled Chi2-distributions with four degrees of freedom for the time points 2 to 4 and with a value of 0 for time point 1 (i.e., in late 2023). This was to take into account that the skewed nature of the exposure distributions.

For continuous outcomes Y the following data model was used

$$y_{i,t} = x'_{i,t} + e_i + f_{i,t}$$

with i denoting the subject and t the time point (t = 1,2,3,4).

Without loss of generality, we assume the variance of Y to be 1. The proportion of variance explained by x' is denoted by R^2.

If ICC denotes the intra-class correlation coefficient of the part of Y unexplained by x', we have

$e_i \sim N(0, (1 - R^2)ICC)$, for all i, and

$f_{i,t} \sim N(0, (1 - R^2)(1 - ICC))$, for all i and t.

We assumed the variable $x'_{i,t}$ to be composed of a part u_i being constant within subjects and a part $v_{i,t}$ varying within subjects

$$x'_{i,t} = u_i + v_{i,t} \ .$$

The two parts were simulated as follows

$$u_i \sim -\frac{\sqrt{R^2 ICCx}}{\sqrt{2df}} Chi^2(df)$$
$$v_{i,t} \sim -\frac{\sqrt{R^2(1 - ICCx)}}{\sqrt{2df}} Chi^2(df)$$

where ICCx denotes the intra-class correlation coefficient of x'.

Clearly, the power increases with the sample size n, with ICC and with R^2 .

For each simulated data set, the outcome Y was then regressed against x', adjusting for autocorrelation of residuals within subjects. If the number of subjects was N, the number of observations of each simulated data set was 4N. The proportion of simulated data sets in which the estimated effect of x' reached statistical significance at the 5%-level was then taken as an estimate of the statistical power.

A paper by Scalco et al. (Scalco, 2017) suggests an ICC of about 0.7 for repeated daily measurements, However, if children measure their lung function at a daily basis and daily measurements are averaged by week, the ICC of the part of the outcome, which is unexplained by exposure, will increase. In the following, we therefore assume that ICC=0.8.

Table of power estimates
(Results from 1000 simulations)

Number of subjects	**ICC of part of outcome unexplained by exposure**	**R-squared of exposure**	**ICC of exposure**	**Power estimate**
200		0.003	0.7	0.93
			0.5	0.96
			0.3	0.97
			0.1	0.96
			0.0	0.91

The hypothesized effects can be expressed in terms of a comparison of the median outcome (e.g., FEV1) between children with a medium exposure in the season of pesticide spraying and children without exposure (i.e., in the control period).

R-squared of exposure	**ICC of exposure**	**Mean outcome in children with a median exposure during the pesticide spraying season expressed as percentile of the outcome distribution in children without exposure**
0.003	0.7	48.2nd percentile
	0.5	48.2nd percentile
	0.3	48.3rd percentile
	0.1	48.4th percentile
	0.0	48.8th percentile

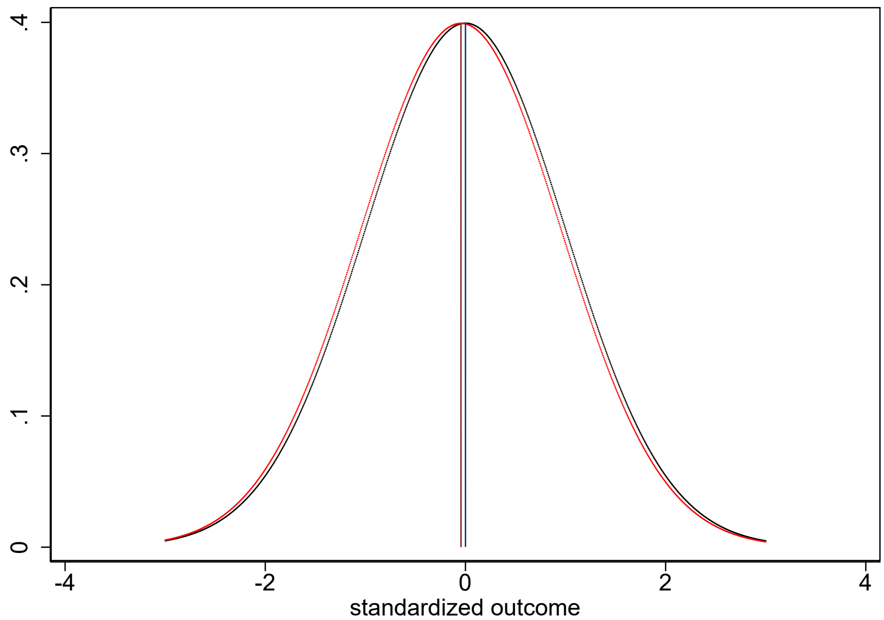


Figure: The two curves illustrate the hypothesized shift of the distribution of the standardized outcome associated with an increase in exposure from 0 (black curve) to the median of the spray season (red curve).

Final, 28.04.2025 for the Department of Health Canton of Valais

Exposure to Pesticides by Air and Respiratory Health in School Children in VALais, Switzerland (PARVAL)

Supplementary Information 2

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Swiss TPH
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Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse
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Supplementary Information 2

Figures

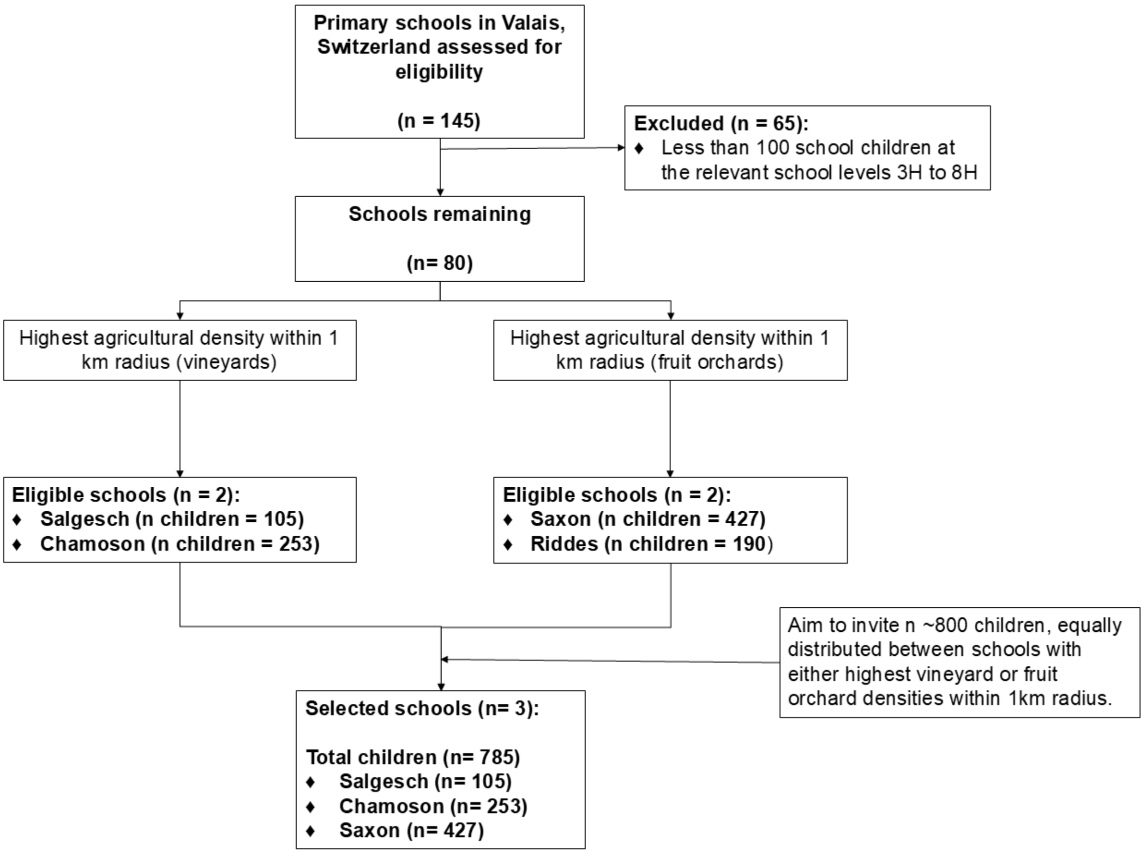

Figure 1: Selection process of the three schools. Criteria and stages involved in identifying and including eligible schools in the study**.**

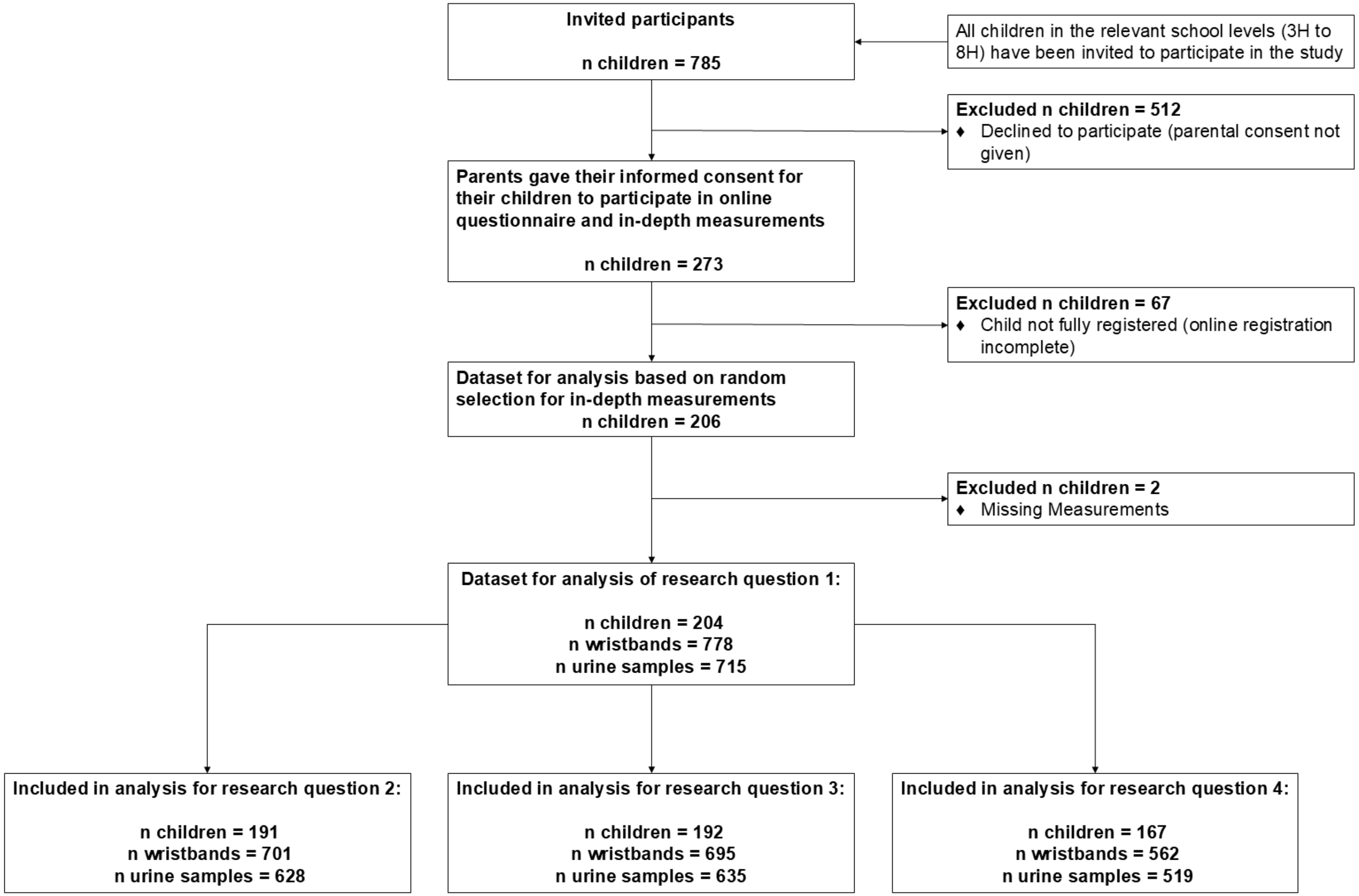

Figure 2: Enrollment process of the study population.

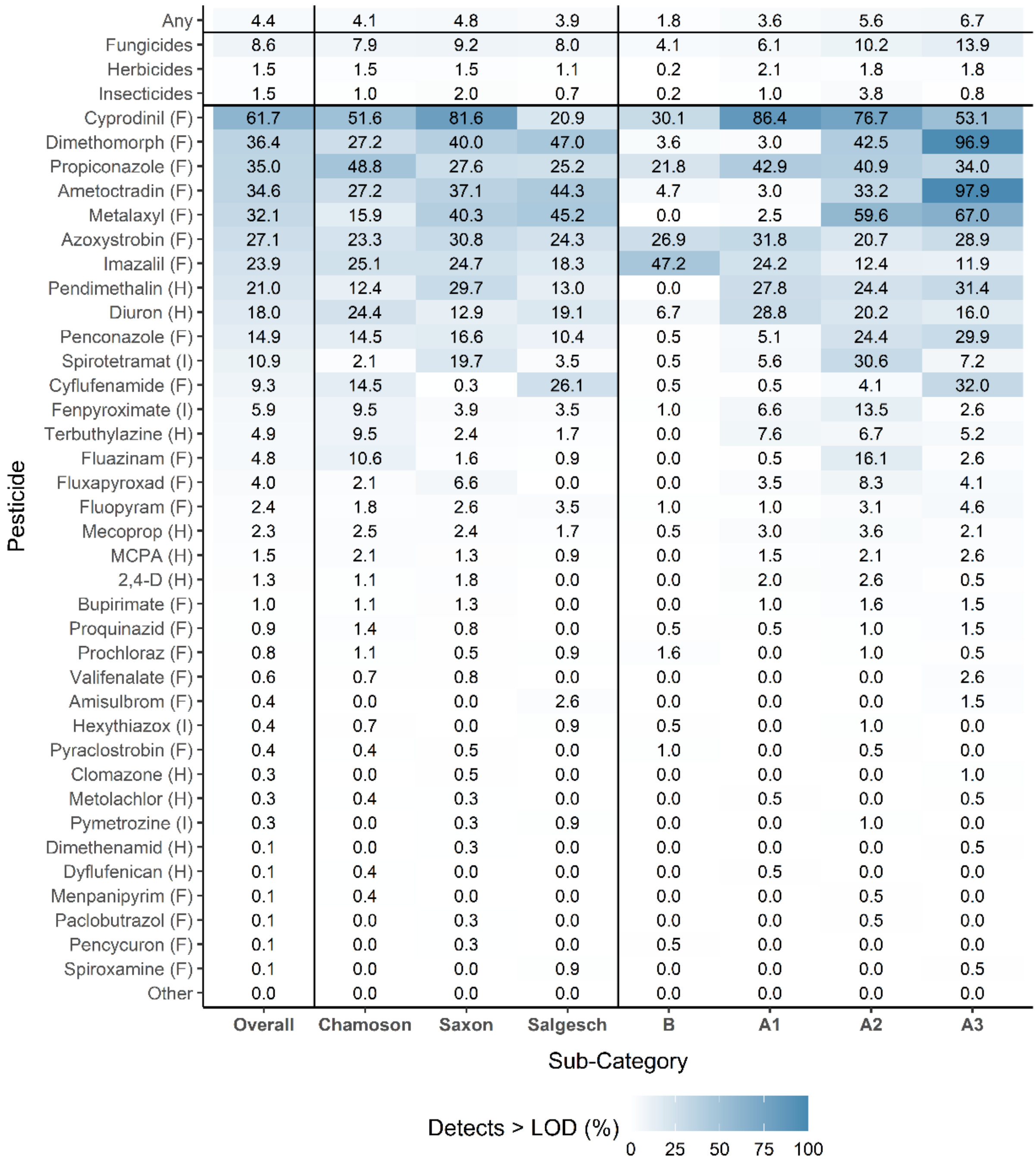

Figure 3: Detection Frequency (%) of the 36 detected pesticides in the individual wristbands. In total, 778 wristbands were detected from 204 children. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). LOD = Limit of Detection.

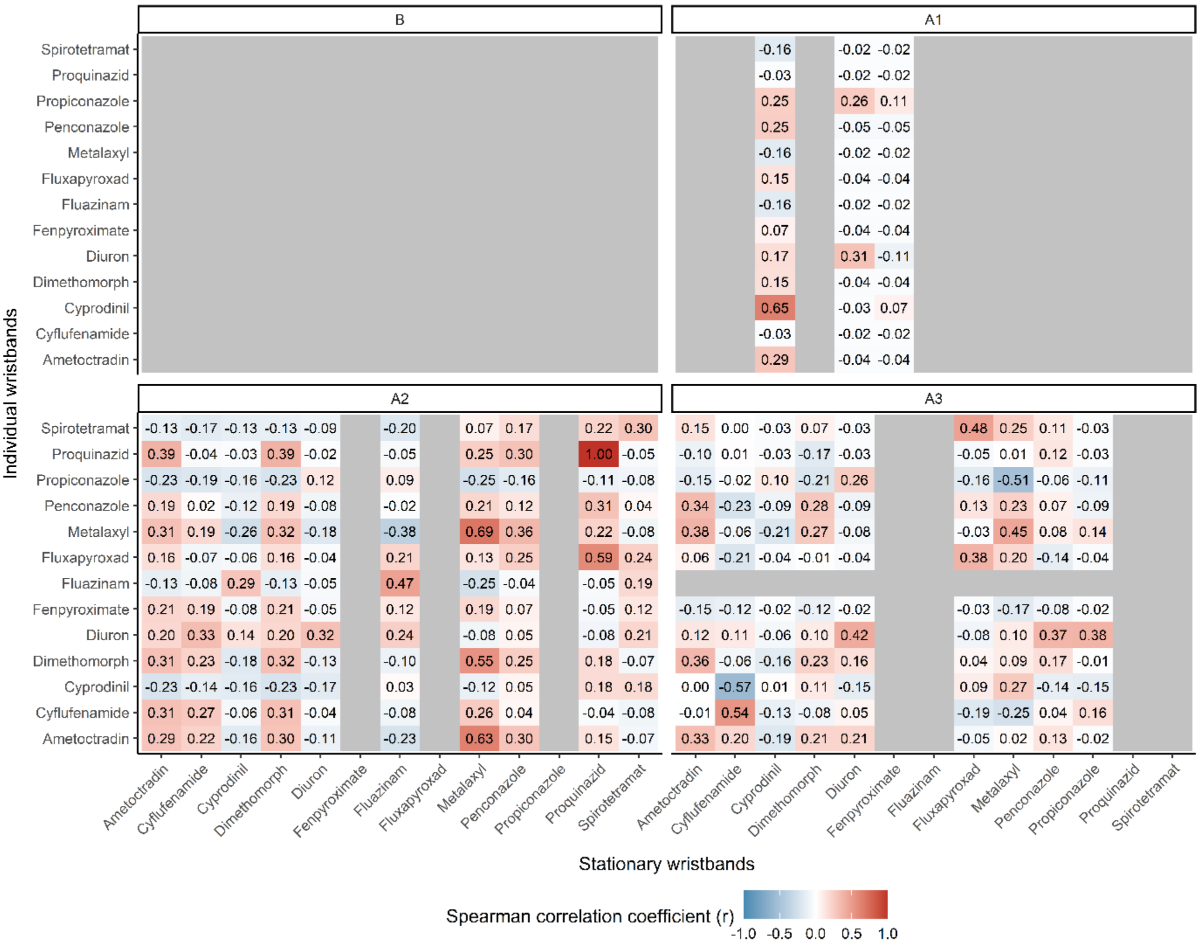

Figure 4: Spearman correlation between individual and stationary wristband pesticide concentrations [ng/g] for children with both an individual and a stationary wristband, and for pesticides detected in both wristband types in at least one assessment phase. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). In total, 176 individual and stationary wristbands were collected from 51 children (45 in B and A2, 43 in A1 and A3). Grey rows and columns indicate pesticides that were not detected in either individual or stationary wristbands within the respective assessment phase.

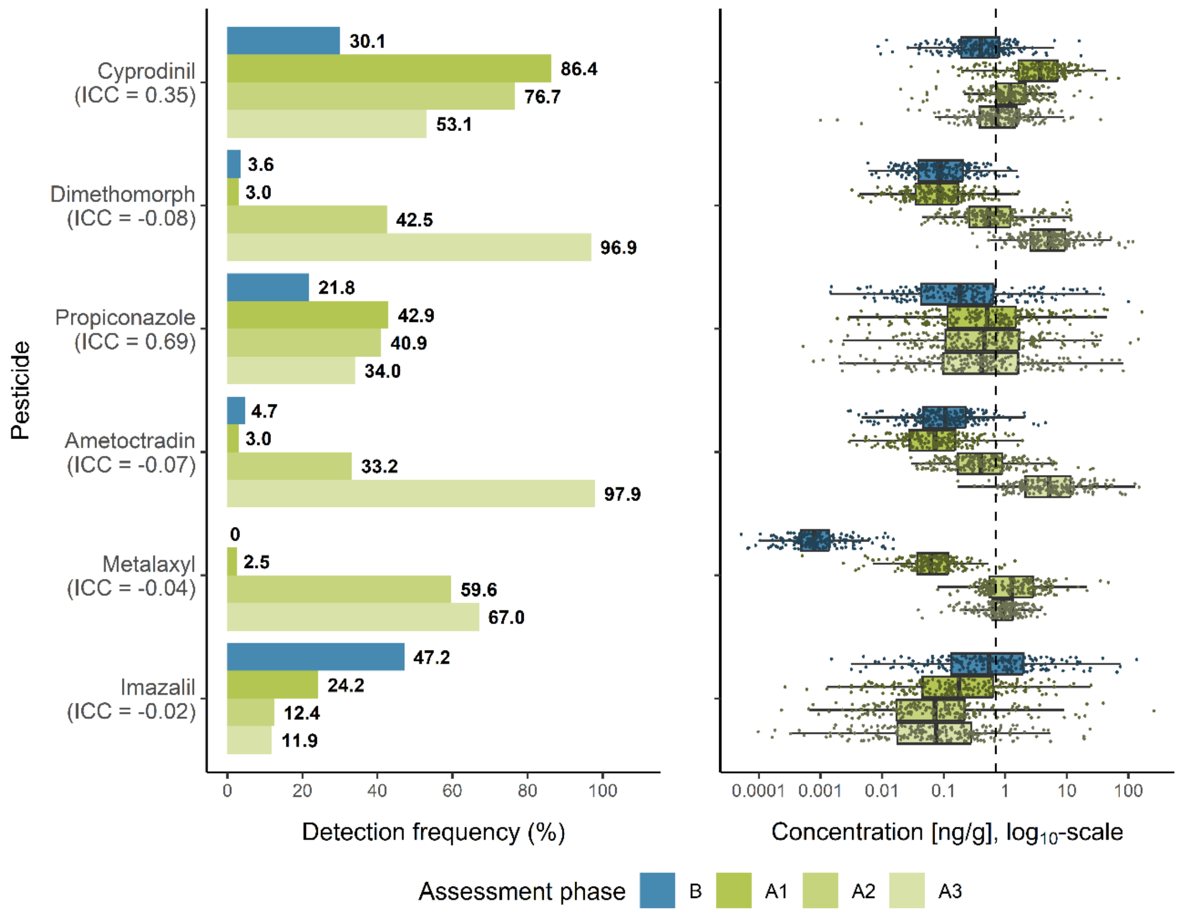

Figure 5: The six active pesticides with a detection frequency of at least 40% in at least one assessment phase in children's individual wristbands, stratified by assessment phase. **(a)** Bar chart showing the percentage of detected pesticides above limit of detection (LOD); **(b)** Boxplots showing the pesticides' concentrations [ng/g] after imputation. The dashed line represents the LOD (0.7 ng/g). Values below LOD were imputed. In total, 778 wristbands were collected from 204 children. ICC = Intraclass Correlation Coefficient. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

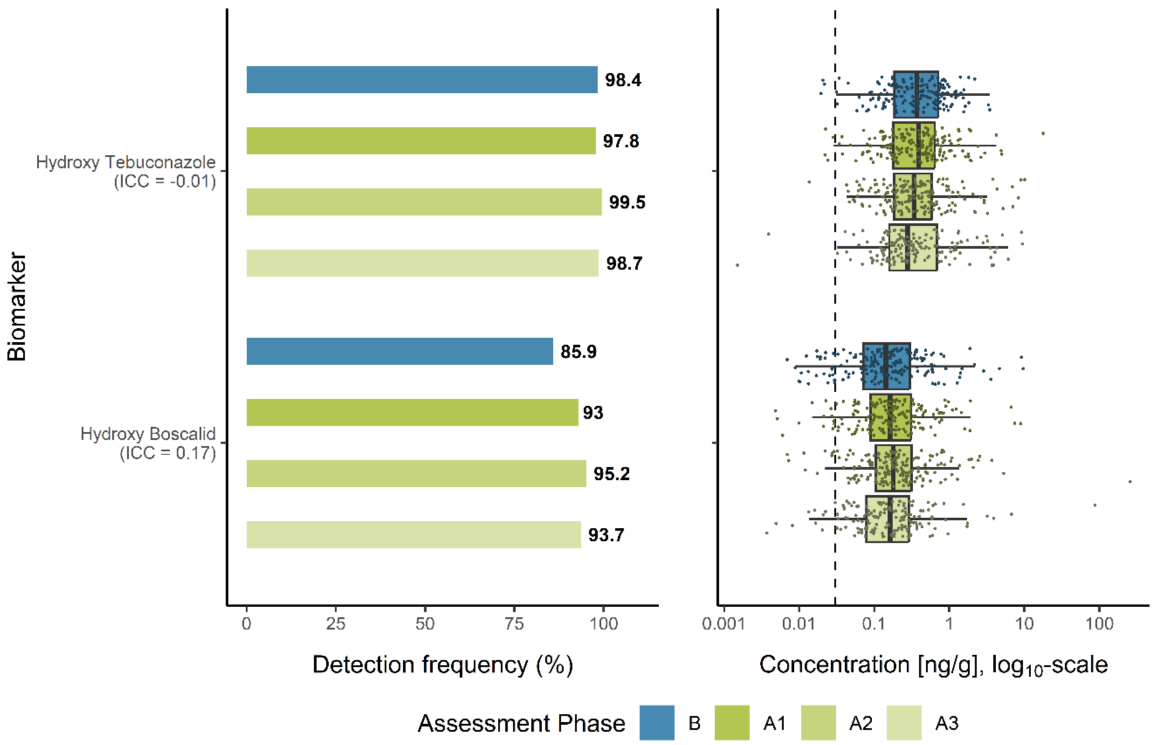

Figure 6: Detection frequency (%) (bar chart) and the concentrations [ng/ml] (boxplots) of the two targeted pesticide biomarkers hydroxy boscalid and hydroxy tebuconazole (ng/ml), stratified by assessment phase. The dashed line represents the limit of detection (LOD; 0.03 ng/ml). In total, 715 urine samples were collected from 202 children. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). ICC = Intraclass Correlation Coefficient.

Pesticide	Overall	Chamoson	Saxon	Salgesch	B	A1	A2	A3
Any	88.5	70.6	100.0	93.3	0.0	54.5	80.9	77.3
Fungicides	88.5	70.6	100.0	93.3	0.0	54.5	78.7	77.3
Insecticides	7.7	5.9	15.0	0.0	0.0	2.3	8.5	0.0
Herbicides	3.8	5.9	5.0	0.0	0.0	2.3	4.3	2.3
Metalaxyl (F)	73.1	35.3	95.0	86.7	0.0	0.0	68.1	63.6
Cyprodinil (F)	50.0	64.7	75.0	0.0	0.0	54.5	4.3	2.3
Ametoctradin (F)	48.1	41.2	55.0	46.7	0.0	0.0	14.9	52.3
Dimethomorph (F)	40.4	29.4	50.0	40.0	0.0	0.0	14.9	40.9
Penconazole (F)	36.5	35.3	35.0	40.0	0.0	0.0	27.7	22.7
Cyflufenamide (F)	32.7	29.4	5.0	73.3	0.0	0.0	6.4	38.6
Fluazinam (F)	7.7	23.5	0.0	0.0	0.0	0.0	8.5	0.0
Spirotetramat (I)	7.7	5.9	15.0	0.0	0.0	0.0	8.5	0.0
Fluxapyroxad (F)	3.8	5.9	5.0	0.0	0.0	0.0	0.0	4.5
Proquinazid (F)	3.8	5.9	5.0	0.0	0.0	0.0	2.1	2.3
Amisulbrom (F)	1.9	0.0	5.0	0.0	0.0	0.0	0.0	2.3
Diuron (H)	1.9	5.9	0.0	0.0	0.0	2.3	2.1	2.3
Fenpyroximate (I)	1.9	5.9	0.0	0.0	0.0	2.3	0.0	0.0
Propiconazole (F)	1.9	0.0	0.0	6.7	0.0	0.0	0.0	2.3
Prosulfocarb (H)	1.9	0.0	5.0	0.0	0.0	0.0	2.1	0.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 7: The percentages of children with the respective pesticides detected in their stationary wristbands, categorized by school and assessment phase. The heatmap shows how often the 15 different pesticides were detected on the 176 wristbands worn by the 205 children. Percentages are shown in relation to the 205 children overall, stratified by the three schools and the four assessments: B = Baseline (January/February), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June), and the pesticides are classified as F (Fungicide), H (Herbicide), or I (Insecticide).

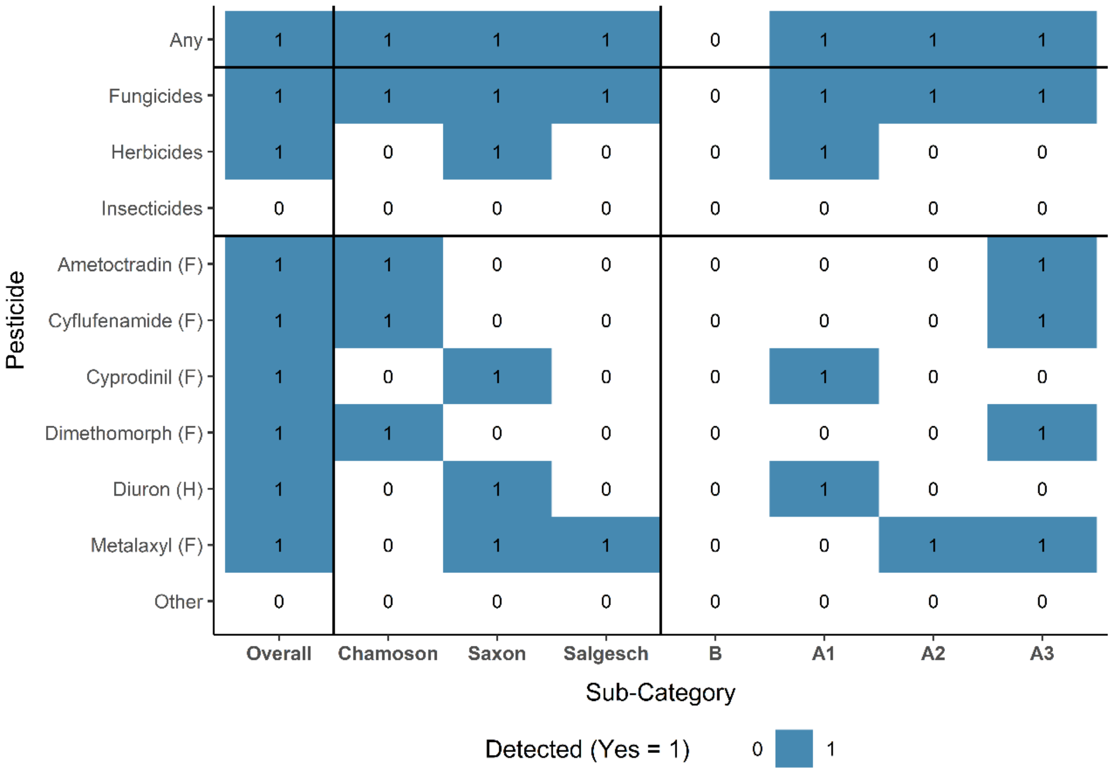

Figure 8: Detected pesticides in wristbands placed at each school, stratified by school and assessment phase (detected yes/no). Data includes 11 wristbands total (Chamoson (n = 4), Saxon (n = 4) and Salgesch (n = 3)). B = B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

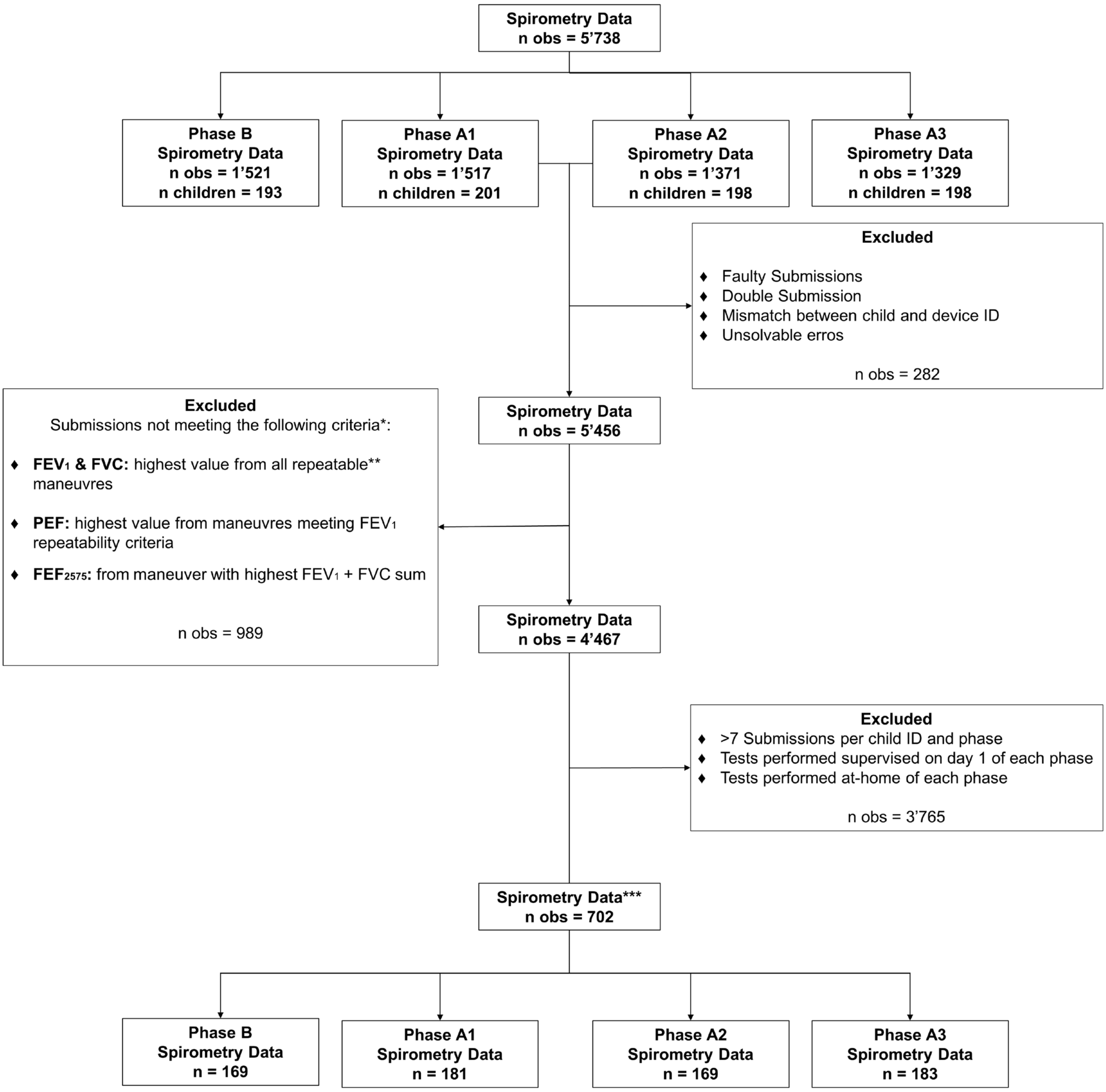

Figure 9: Data cleaning process of spirometry data. *From American Thoracic Society (Graham et al., 2019). **The difference between the two largest values must be ≤ 0.15 L. *** The data is based on measurements from day 8, meaning each child has one final observation per phase. Therefore, **n** represents both the number of children and the number of observations. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

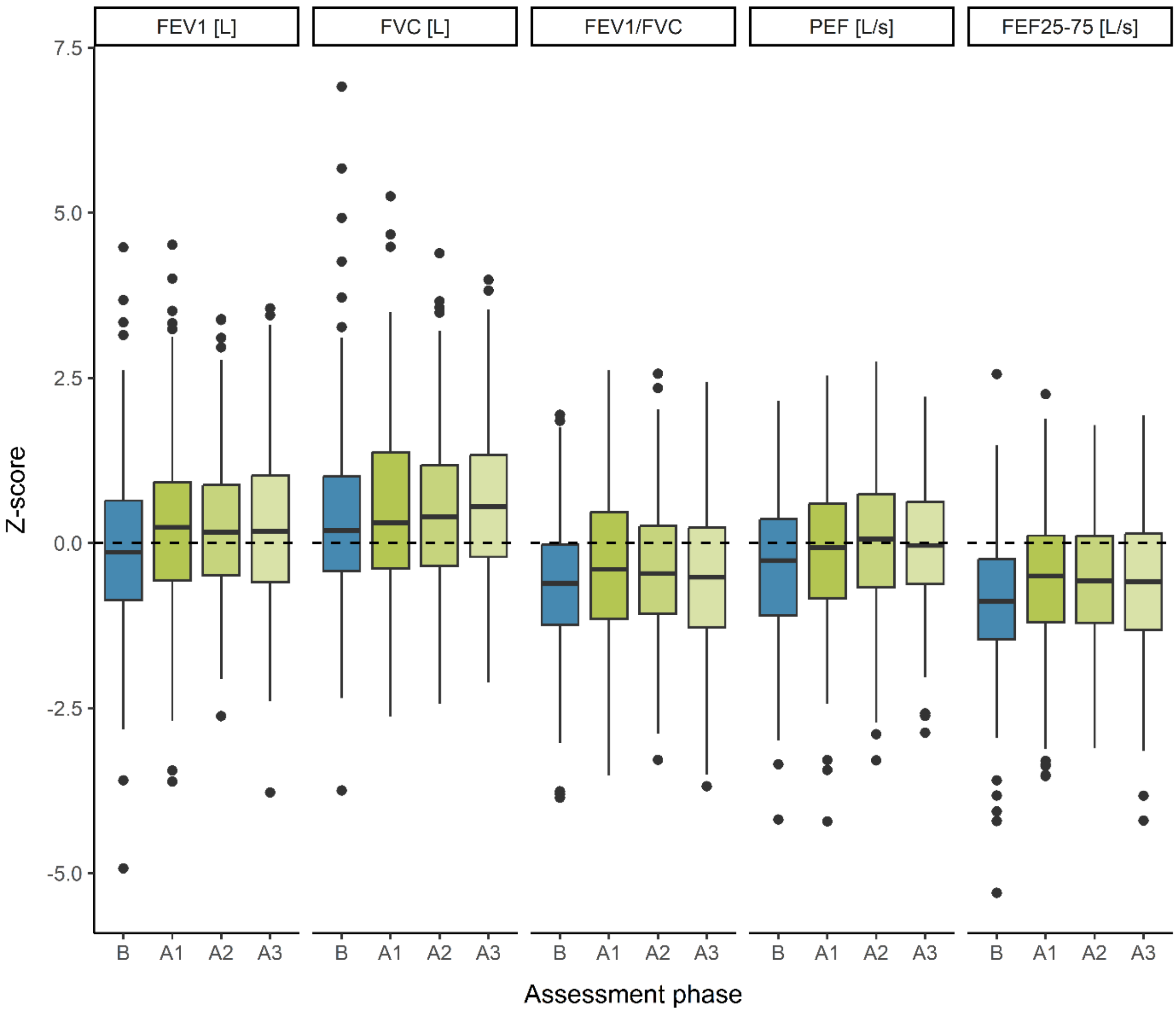

Figure 10: Boxplots showing the distribution of each lung function parameter across the four assessment phases. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

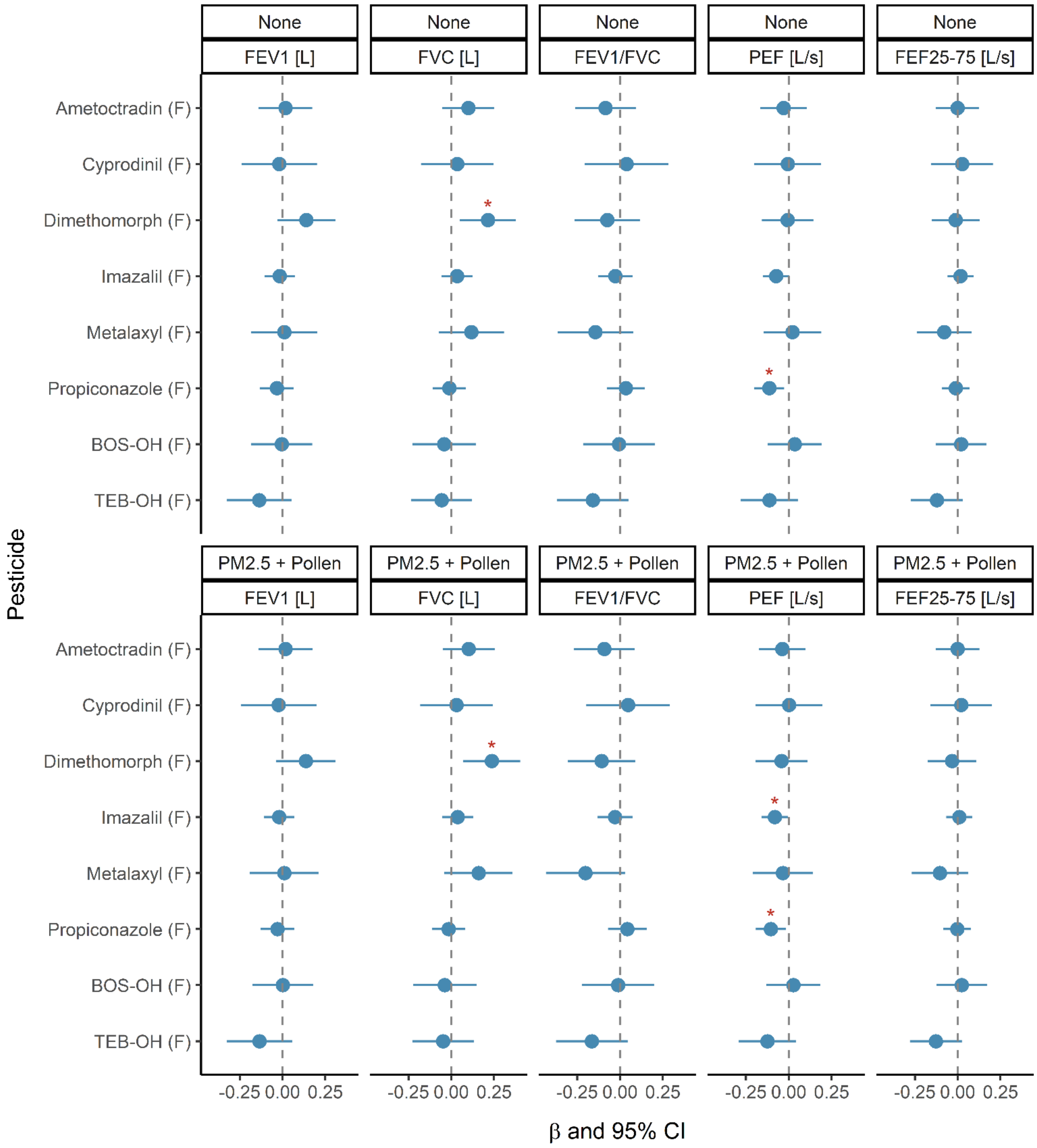

Figure 11: Comparison of the final model approach with and without adjustment for $PM_{2.5}$ and pollen. Models investigate the association between pesticide exposure and lung function values. The number of observations and children in the model are reported in **Table 1**.

Tables

Table 1: Approach for analyzing the association between pesticide exposure and lung function parameters.

Outcome	**Exposure and Confounders**	**n obs**	**Pros**
DayX8 X = {B, A1, A2, A3}	Exposure: B, A1, A2, A3 Confounders: Day B1	FVC: 487 FEV1: 544 PEF: 544 FEF2575: 627 FEV1/FVC: 412	Controls bias introduced by lung function correlated over time. Children serve as their own control => control unknown sources of bias.

Table 2: Population Characteristics for the 206 children and stratified for each assessment phase. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

Variable	B	A1	A2	A3	Missing (%)
n	195	204	200	199	
Demographics					
School (%)					0.0
Chamoson	71 (36.4)	75 (36.8)	75 (37.5)	75 (37.7)	
Saxon	95 (48.7)	99 (48.5)	96 (48.0)	96 (48.2)	
Salgesch	29 (14.9)	30 (14.7)	29 (14.5)	28 (14.1)	
Child's sex = Female (%)	78 (40.0)	86 (42.2)	85 (42.5)	85 (42.7)	0.0
Child's age [y] (mean (SD))	9.36 (1.75)	9.57 (1.74)	9.65 (1.75)	9.71 (1.75)	0.0
Household Information					
Caregiver's education (%)					9.4
Primary or lower	17 (9.2)	17 (9.3)	17 (9.5)	17 (9.6)	
Secondary	87 (47.3)	86 (47.3)	83 (46.4)	82 (46.1)	
Tertiary	80 (43.5)	79 (43.4)	79 (44.1)	79 (44.4)	
Monthly net household income (%)					9.9
<4500 CHF	7 (3.8)	7 (3.9)	7 (3.9)	7 (4.0)	
4500-9000 CHF	89 (48.6)	88 (48.6)	87 (48.9)	86 (48.6)	
>9000 CHF	49 (26.8)	48 (26.5)	48 (27.0)	48 (27.1)	
No answer	38 (20.8)	38 (21.0)	36 (20.2)	36 (20.3)	
Household farming practice (%)					5.5
None	163 (88.6)				
Organic	7 (3.8)				
IP	3 (1.6)				
Conventional	8 (4.3)				
Other	1 (0.5)				
Unknown	2 (1.1)				
Private fungicide use = Yes (%)	24 (13.0)	12 (6.0)	5 (2.8)	9 (4.7)	5.5
Household pets (%)					5.5
No pets	83 (45.1)	90 (44.8)	81 (45.3)	85 (44.7)	
Non-furry pets	2 (1.1)	1 (0.5)	1 (0.6)	1 (0.5)	
Furry pets	99 (53.8)	110 (54.7)	97 (54.2)	104 (54.7)	
Water source (%)					7.6
Public	140 (76.1)	152 (78.4)	147 (84.0)	154 (83.7)	
Private	41 (22.3)	34 (17.5)	26 (14.9)	24 (13.0)	
Unknown	3 (1.6)	8 (4.1)	2 (1.1)	6 (3.3)	
Child living on a farm = Yes (%)	6 (3.3)	0 (0.0)	0 (0.0)	0 (0.0)	5.5
Child Health History					
Puberty onset = Yes (%)	35 (19.0)	40 (20.5)	40 (22.7)	38 (20.4)	7.1
Height [cm] (mean (SD))	135.43 (11.44)	137.21 (11.64)	141.96 (62.48)	137.93 (11.65)	1.1
BMI standardized for age and sex (%)					1.1
Severe thinness	0 (0.0)	0 (0.0)	1 (0.5)	0 (0.0)	
Thinness	2 (1.0)	2 (1.0)	2 (1.0)	2 (1.0)	
Normal	155 (79.9)	160 (80.0)	160 (81.2)	164 (82.8)	
Overweight	27 (13.9)	29 (14.5)	27 (13.7)	24 (12.1)	
Obesity	10 (5.2)	9 (4.5)	7 (3.6)	8 (4.0)	
Asthma ever experienced (self-reported) (%)					9.4
No	168 (91.3)	166 (91.2)	164 (91.6)	163 (91.6)	
Yes	14 (7.6)	14 (7.7)	13 (7.3)	13 (7.3)	
Unknown	2 (1.1)	2 (1.1)	2 (1.1)	2 (1.1)	
Asthma ever diagnosed = Yes (%)	13 (7.1)	14 (7.2)	11 (6.3)	14 (7.6)	7.5

Continued table 2: Population Characteristics for the 206 children and stratified for each assessment phase. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

Variable	B	A1	A2	A3	Missing (%)
n	195	204	200	199	
Child Activity					
Activity compared to other children (%)					7.3
A lot more active	30 (16.4)	28 (14.4)	18 (10.2)	25 (13.4)	
A bit more active	67 (36.6)	73 (37.4)	74 (42.0)	84 (45.2)	
Average	78 (42.6)	85 (43.6)	77 (43.8)	70 (37.6)	
A bit less active	7 (3.8)	9 (4.6)	6 (3.4)	7 (3.8)	
A lot less active	1 (0.5)	0 (0.0)	1 (0.6)	0 (0.0)	
Child working with pesticides (%)					30.7
No	0 (0.0)	180 (92.8)	162 (92.6)	166 (90.2)	
Yes	0 (0.0)	12 (6.2)	10 (5.7)	14 (7.6)	
Unknown	0 (0.0)	2 (1.0)	3 (1.7)	4 (2.2)	
Child playing within pesticides (%)	0				30.7
No	0 (0.0)	180 (92.8)	162 (92.6)	166 (90.2)	
Yes	0 (0.0)	12 (6.2)	10 (5.7)	14 (7.6)	
Unknown	0 (0.0)	2 (1.0)	3 (1.7)	4 (2.2)	
Mode of school way (%)					9.4
Driving	54 (29.3)	53 (29.1)	53 (29.6)	53 (29.8)	
Biking	15 (8.2)	15 (8.2)	15 (8.4)	14 (7.9)	
Walking	115 (62.5)	114 (62.6)	111 (62.0)	111 (62.4)	
Times taking a bath per week (mean (SD))	3.83 (1.82)	4.10 (1.91)	4.27 (1.91)	4.29 (1.88)	7.6
Environmental Exposure					
Shortest distance [m] to any agriculture (mean (SD))	41.41 (32.30)	41.56 (32.10)	41.25 (31.73)	41.04 (31.68)	0.5
Shortest distance [m] to any vineyards (mean (SD))	166.37 (327.39)	168.56 (328.36)	170.19 (331.36)	170.64 (332.14)	0.5
Shortest distance [m] to any fruit orchards (mean (SD))	342.35 (312.74)	349.52 (318.07)	350.60 (319.84)	350.54 (320.65)	0.5
PM2.5 (mean (SD))	15.32 (5.13)	7.84 (7.02)	4.47 (1.21)	4.46 (0.85)	8.3
Sum of allergenic pollen (mean (SD))	245.54 (66.03)	292.84 (69.94)	335.27 (13.60)	340.76 (12.59)	0.0
Study Context					
Fieldworker (%)					0.0
1	24 (12.3)	11 (5.4)	16 (8.0)	0 (0.0)	
2	95 (48.7)	37 (18.1)	49 (24.5)	60 (30.2)	
3	76 (39.0)	0 (0.0)	0 (0.0)	0 (0.0)	
4	0 (0.0)	74 (36.3)	71 (35.5)	70 (35.2)	
5	0 (0.0)	68 (33.3)	63 (31.5)	69 (34.7)	
Other	0 (0.0)	14 (6.9)	1 (0.5)	0 (0.0)	
Caregiver answering the questionnaire (%)					9.4
Mother	131 (71.2)	130 (71.4)	128 (71.5)	128 (71.9)	
Father	51 (27.7)	50 (27.5)	49 (27.4)	48 (27.0)	
Other	2 (1.1)	2 (1.1)	2 (1.1)	2 (1.1)	

Table 3: The shortest distance [m, log_{10}-scale] from participants' home address to the eight different agricultural land use types, stratified by school. Org = organic; conv = conventional agricultural practices. Chamoson (n = 76), Saxon (n = 97), Salgesch (n = 30). In total, 203 out of 204 children with pesticide measurements were included, since one had reported an invalid address.

Shortest distance [m] to	School	Median	IQR	Min.	Max.
any agriculture	Chamoson	19.9	35.7	4.6	106.6
	Saxon	44.5	46.8	6.4	151.3
	Salgesch	18.4	27.4	3.5	82.1
any vineyards or fruit orchards	Chamoson	38.7	178.3	4.6	1440.0
	Saxon	69.2	70.9	6.4	211.8
	Salgesch	18.6	31.3	3.5	97.8
any vineyards	Chamoson	43.4	178.3	4.6	1772.3
	Saxon	99.6	101.0	6.4	1317.0
	Salgesch	18.6	31.3	3.5	97.8
any fruit orchards	Chamoson	451.4	598.3	34.3	1440.0
	Saxon	136.7	118.5	6.6	439.5
	Salgesch	590.1	258.7	118.9	971.3
conv. vineyards	Chamoson	51.3	176.9	4.6	1772.3
	Saxon	99.6	99.6	6.4	1317.0
	Salgesch	21.2	31.3	3.5	97.8
org. vineyards	Chamoson	117.0	378.8	10.8	1806.0
	Saxon	362.0	267.3	21.2	1529.2
	Salgesch	55.6	37.2	12.2	147.5
conv. fruit orchards	Chamoson	451.4	598.3	34.3	1440.0
	Saxon	136.7	118.5	6.6	439.5
	Salgesch	603.8	414.5	118.9	1161.7
org. fruit orchards	Chamoson	2448.0	1392.2	749.6	4040.5
	Saxon	415.8	408.4	102.7	2520.0
	Salgesch	1298.6	327.9	555.0	1823.6

Table 4: The percentage of the four buffers (50 m, 250 m, 500 m, and 1000 m) [% of total area surrounding home given specific radius] surrounding participants' home addresses indicating the eight different agricultural land use types, stratified by village. Org = organic; conv = conventional agricultural practices. Chamoson (n = 76), Saxon (n = 97), Salgesch (n = 30). In total, 203 out of 204 children with pesticide measurements were included, since one had reported an invalid address.

Area [%] consisting of		School	Median	IQR	Min.	Max.
any agricultural land	within a 50-meter buffer	Chamoson	10.0	23.9	0.0	59.1
		Saxon	0.7	9.0	0.0	76.9
		Salgesch	23.2	29.8	0.0	46.5
	within a 250-meter buffer	Chamoson	21.6	19.0	6.5	78.5
		Saxon	12.4	16.5	1.6	84.9
		Salgesch	34.2	15.3	12.3	58.7
	within a 500-meter buffer	Chamoson	24.1	31.1	10.4	73.8
		Saxon	24.3	16.0	6.7	77.1
		Salgesch	42.3	8.2	34.5	57.6
	within a 1000-meter buffer	Chamoson	37.1	40.2	7.7	69.1
		Saxon	34.5	10.4	18.2	64.9
		Salgesch	44.3	3.0	33.6	48.0
any vineyards or fruit orchards	within a 50-meter buffer	Chamoson	2.0	19.1	0.0	59.1
		Saxon	0.0	2.3	0.0	76.9
		Salgesch	18.8	30.3	0.0	44.2
	within a 250-meter buffer	Chamoson	14.7	31.1	0.0	72.9
		Saxon	7.9	10.5	0.3	83.4
		Salgesch	33.8	14.4	6.9	58.7
	within a 500-meter buffer	Chamoson	21.2	43.7	0.0	72.2
		Saxon	17.5	17.2	0.4	74.5
		Salgesch	40.3	7.9	28.4	57.1
	within a 1000-meter buffer	Chamoson	32.8	46.6	0.0	66.8
		Saxon	25.9	9.8	0.7	53.5
		Salgesch	40.9	2.8	26.2	44.4
any vineyards	within a 50-meter buffer	Chamoson	0.8	19.1	0.0	59.1
		Saxon	0.0	0.0	0.0	45.7
		Salgesch	18.8	30.3	0.0	44.2
	within a 250-meter buffer	Chamoson	14.7	31.0	0.0	72.9
		Saxon	2.2	7.8	0.0	41.9
		Salgesch	33.7	14.4	6.9	58.7
	within a 500-meter buffer	Chamoson	21.2	43.7	0.0	72.2
		Saxon	5.0	12.6	0.0	35.3
		Salgesch	40.2	7.9	28.3	57.1
	within a 1000-meter buffer	Chamoson	32.7	46.0	0.0	66.8
		Saxon	10.9	4.9	0.0	29.4
		Salgesch	40.8	2.9	26.2	44.4
any fruit orchards	within a 50-meter buffer	Chamoson	0.0	0.0	0.0	3.3
		Saxon	0.0	0.0	0.0	76.9
		Salgesch	0.0	0.0	0.0	0.0
	within a 250-meter buffer	Chamoson	0.0	0.0	0.0	0.3
		Saxon	2.0	5.7	0.0	66.1

Area [%] consisting of		School	Median	IQR	Min.	Max.
		Salgesch	0.0	0.0	0.0	0.2
	within a 500-meter buffer	Chamoson	0.0	0.1	0.0	0.1
		Saxon	7.1	8.2	0.1	49.1
		Salgesch	0.0	0.0	0.0	0.0
	within a 1000-meter buffer	Chamoson	0.0	0.0	0.0	5.3
		Saxon	15.1	7.2	0.0	43.6
		Salgesch	0.0	0.0	0.0	0.0
org. vineyards	within a 50-meter buffer	Chamoson	0.0	0.3	0.0	26.0
		Saxon	0.0	0.0	0.0	19.5
		Salgesch	0.0	0.1	0.0	25.2
	within a 250-meter buffer	Chamoson	3.1	7.8	0.0	18.5
		Saxon	0.0	0.0	0.0	3.1
		Salgesch	5.0	4.6	1.4	14.9
	within a 500-meter buffer	Chamoson	4.3	9.7	0.0	18.0
		Saxon	0.3	0.8	0.0	2.9
		Salgesch	5.9	4.4	3.1	13.0
	within a 1000-meter buffer	Chamoson	6.7	11.9	0.0	16.9
		Saxon	0.5	0.4	0.0	6.2
		Salgesch	5.6	0.4	3.9	6.6
conv. vineyards	within a 50-meter buffer	Chamoson	0.0	15.8	0.0	54.7
		Saxon	0.0	0.0	0.0	45.7
		Salgesch	14.3	24.3	0.0	37.6
	within a 250-meter buffer	Chamoson	10.9	22.4	0.0	57.7
		Saxon	2.1	7.1	0.0	41.9
		Salgesch	26.7	12.9	4.9	43.8
	within a 500-meter buffer	Chamoson	16.3	34.1	0.0	60.4
		Saxon	4.9	12.2	0.0	35.3
		Salgesch	32.7	6.5	25.2	44.3
	within a 1000-meter buffer	Chamoson	25.3	33.9	0.0	53.5
		Saxon	10.2	5.3	0.0	23.2
		Salgesch	35.2	2.2	22.3	38.8
org. fruit orchards	within a 50-meter buffer	Chamoson	0.0	0.0	0.0	0.0
		Saxon	0.0	0.0	0.0	0.0
		Salgesch	0.0	0.0	0.0	0.0
	within a 250-meter buffer	Chamoson	0.0	0.0	0.0	0.0
		Saxon	0.0	0.1	0.0	8.0
		Salgesch	0.0	0.0	0.0	0.0
	within a 500-meter buffer	Chamoson	0.0	0.0	0.0	0.0
		Saxon	0.1	0.6	0.0	9.2
		Salgesch	0.0	0.0	0.0	0.0
	within a 1000-meter buffer	Chamoson	0.0	0.0	0.0	0.4
		Saxon	1.3	1.4	0.0	6.9
		Salgesch	0.0	0.0	0.0	0.0
conv. fruit orchards	within a 50-meter buffer	Chamoson	0.0	0.0	0.0	3.3
		Saxon	0.0	0.0	0.0	76.9
		Salgesch	0.0	0.0	0.0	0.0
		Chamoson	0.0	0.0	0.0	0.3

Area [%] consisting of		School	Median	IQR	Min.	Max.
	within a 250-meter buffer	Saxon	1.6	5.7	0.0	59.1
		Salgesch	0.0	0.0	0.0	0.2
	within a 500-meter buffer	Chamoson	0.0	0.1	0.0	0.1
		Saxon	6.8	8.2	0.1	40.4
		Salgesch	0.0	0.0	0.0	0.0
	within a 1000-meter buffer	Chamoson	0.0	0.0	0.0	5.2
		Saxon	13.9	5.7	0.0	36.7
		Salgesch	0.0	0.0	0.0	0.0

Table 5: The mean and standard deviation (SD) of the type of pesticide detected per child above the detection frequency (%) on stationary wristbands, overall and stratified by pesticide type and assessment phase. In total, 176 wristbands were collected from 52 children, and targeted for 81 pesticides. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

Pesticide	Assessment phase	Mean (SD)	Min.	Max.
Any	Overall	3.92 (2.94)	0	11
	B	0.00 (0.00)	0	0
	A1	0.59 (0.58)	0	2
	A2	1.60 (1.44)	0	5
	A3	2.34 (1.88)	0	6
Fungicide	Overall	3.75 (2.80)	0	11
	B	0.00 (0.00)	0	0
	A1	0.55 (0.50)	0	1
	A2	1.47 (1.40)	0	5
	A3	2.32 (1.84)	0	6
Herbicide	Overall	0.08 (0.44)	0	3
	B	0.00 (0.00)	0	0
	A1	0.02 (0.15)	0	1
	A2	0.04 (0.20)	0	1
	A3	0.02 (0.15)	0	1
Insecticide	Overall	0.10 (0.36)	0	2
	B	0.00 (0.00)	0	0
	A1	0.02 (0.15)	0	1
	A2	0.09 (0.28)	0	1
	A3	0.00 (0.00)	0	0

Table 6: The 36 pesticides detected (from 81 targeted) across 778 wristbands from 204 children. The pesticides are listed by their overall detection frequency, and summary statistics are shown overall, as well as stratified by assessment phase: B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). LOD = Limit of Detection. ICC = Intraclass Correlation Coefficient.

Pesticide	Phase	> LOD (%)	Median	IQR	P90	Max.
Cyprodinil	B	30.1	0.00	0.79	1.35	17.00
	A1	86.4	3.65	5.37	11.02	69.45
	A2	76.7	1.19	1.40	3.56	25.07
	A3	53.1	0.75	1.50	2.79	35.32
	Overall	61.7	1.00	2.44	5.92	69.45
Dimethomorph	B	3.6	0.00	0.00	0.00	1.57
	A1	3.0	0.00	0.00	0.00	10.10
	A2	42.5	0.00	1.21	3.00	11.81
	A3	96.9	5.19	6.85	16.55	118.56
	Overall	36.4	0.00	1.83	7.12	118.56
Propiconazole	B	21.8	0.00	0.00	3.40	100.61
	A1	42.9	0.00	1.49	5.16	165.69
	A2	40.9	0.00	1.67	4.71	145.74
	A3	34.0	0.00	1.62	5.63	82.49
	Overall	35.0	0.00	1.29	4.32	165.69
Ametoctradin	B	4.7	0.00	0.00	0.00	4.53
	A1	3.0	0.00	0.00	0.00	1.90
	A2	33.2	0.00	0.89	2.21	26.75
	A3	97.9	5.17	9.49	25.79	149.41
	Overall	34.6	0.00	1.74	7.13	149.41
Metalaxyl	B	0.0	0.00	0.00	0.00	0.00
	A1	2.5	0.00	0.00	0.00	1.44
	A2	59.6	1.28	2.86	5.18	47.30
	A3	67.0	0.91	1.33	1.95	4.42
	Overall	32.1	0.00	1.03	2.36	47.30
Azoxystrobin	B	26.9	0.00	2.77	8.48	103.71
	A1	31.8	0.00	3.32	8.95	99.19
	A2	20.7	0.00	0.00	6.91	59.94
	A3	28.9	0.00	3.07	6.60	94.31
	Overall	27.1	0.00	2.77	7.77	103.71
Imazalil	B	47.2	0.00	1.98	5.75	136.40
	A1	24.2	0.00	0.00	1.87	24.74
	A2	12.4	0.00	0.00	1.24	260.08
	A3	11.9	0.00	0.00	0.84	23.83
	Overall	23.9	0.00	0.00	2.17	260.08
Pendimethalin	B	0.0	0.00	0.00	0.00	0.00
	A1	27.8	0.00	0.74	1.15	1.86
	A2	24.4	0.00	0.00	1.06	2.06
	A3	31.4	0.00	0.84	1.05	2.95
	Overall	21.0	0.00	0.00	1.00	2.95
Diuron	B	6.7	0.00	0.00	0.00	8.71
	A1	28.8	0.00	0.78	1.65	95.61

Pesticide	Phase	> LOD (%)	Median	IQR	P90	Max.
	A2	20.2	0.00	0.00	1.32	4.95
	A3	16.0	0.00	0.00	0.80	4.18
	Overall	18.0	0.00	0.00	1.10	95.61
Penconazole	B	0.5	0.00	0.00	0.00	1.41
	A1	5.1	0.00	0.00	0.00	2.83
	A2	24.4	0.00	0.00	1.18	17.57
	A3	29.9	0.00	0.82	1.13	3.97
	Overall	14.9	0.00	0.00	0.91	17.57
Spirotetramat	B	0.5	0.00	0.00	0.00	1.02
	A1	5.6	0.00	0.00	0.00	3.19
	A2	30.6	0.00	0.90	2.19	24.10
	A3	7.2	0.00	0.00	0.00	3.25
	Overall	10.9	0.00	0.00	0.84	24.10
Cyflufenamide	B	0.5	0.00	0.00	0.00	2.57
	A1	0.5	0.00	0.00	0.00	2.60
	A2	4.1	0.00	0.00	0.00	3.73
	A3	32.0	0.00	0.92	1.47	16.12
	Overall	9.3	0.00	0.00	0.00	16.12
Fenpyroximate	B	1.0	0.00	0.00	0.00	1.46
	A1	6.6	0.00	0.00	0.00	7.14
	A2	13.5	0.00	0.00	1.05	19.47
	A3	2.6	0.00	0.00	0.00	2.10
	Overall	5.9	0.00	0.00	0.00	19.47
Terbuthylazine	B	0.0	0.00	0.00	0.00	0.00
	A1	7.6	0.00	0.00	0.00	257.79
	A2	6.7	0.00	0.00	0.00	4.93
	A3	5.2	0.00	0.00	0.00	6.91
	Overall	4.9	0.00	0.00	0.00	257.79
Fluazinam	B	0.0	0.00	0.00	0.00	0.00
	A1	0.5	0.00	0.00	0.00	3.09
	A2	16.1	0.00	0.00	0.92	4.96
	A3	2.6	0.00	0.00	0.00	2.48
	Overall	4.8	0.00	0.00	0.00	4.96
Fluxapyroxad	B	0.0	0.00	0.00	0.00	0.00
	A1	3.5	0.00	0.00	0.00	3.38
	A2	8.3	0.00	0.00	0.00	3.54
	A3	4.1	0.00	0.00	0.00	33.06
	Overall	4.0	0.00	0.00	0.00	33.06
Fluopyram	B	1.0	0.00	0.00	0.00	1.59
	A1	1.0	0.00	0.00	0.00	1.31
	A2	3.1	0.00	0.00	0.00	99.83
	A3	4.6	0.00	0.00	0.00	4.39
	Overall	2.4	0.00	0.00	0.00	99.83
Mecoprop	B	0.5	0.00	0.00	0.00	0.78
	A1	3.0	0.00	0.00	0.00	3.55
	A2	3.6	0.00	0.00	0.00	203.49
	A3	2.1	0.00	0.00	0.00	5.39

Pesticide	Phase	> LOD (%)	Median	IQR	P90	Max.
	Overall	2.3	0.00	0.00	0.00	203.49
MCPA	B	0.0	0.00	0.00	0.00	0.00
	A1	1.5	0.00	0.00	0.00	4.65
	A2	2.1	0.00	0.00	0.00	96.57
	A3	2.6	0.00	0.00	0.00	3.71
	Overall	1.5	0.00	0.00	0.00	96.57
2,4-D	B	0.0	0.00	0.00	0.00	0.00
	A1	2.0	0.00	0.00	0.00	4.09
	A2	2.6	0.00	0.00	0.00	80.52
	A3	0.5	0.00	0.00	0.00	3.53
	Overall	1.3	0.00	0.00	0.00	80.52
Bupirimate	B	0.0	0.00	0.00	0.00	0.00
	A1	1.0	0.00	0.00	0.00	2.20
	A2	1.6	0.00	0.00	0.00	1.66
	A3	1.5	0.00	0.00	0.00	1.83
	Overall	1.0	0.00	0.00	0.00	2.20
Proquinazid	B	0.5	0.00	0.00	0.00	2.21
	A1	0.5	0.00	0.00	0.00	1.43
	A2	1.0	0.00	0.00	0.00	1.00
	A3	1.5	0.00	0.00	0.00	3.43
	Overall	0.9	0.00	0.00	0.00	3.43
Prochloraz	B	1.6	0.00	0.00	0.00	12.27
	A1	0.0	0.00	0.00	0.00	0.00
	A2	1.0	0.00	0.00	0.00	44.30
	A3	0.5	0.00	0.00	0.00	8.39
	Overall	0.8	0.00	0.00	0.00	44.30
Valifenalate	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.0	0.00	0.00	0.00	0.00
	A3	2.6	0.00	0.00	0.00	11.05
	Overall	0.6	0.00	0.00	0.00	11.05
Amisulbrom	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.0	0.00	0.00	0.00	0.00
	A3	1.5	0.00	0.00	0.00	20.32
	Overall	0.4	0.00	0.00	0.00	20.32
Hexythiazox	B	0.5	0.00	0.00	0.00	1.29
	A1	0.0	0.00	0.00	0.00	0.00
	A2	1.0	0.00	0.00	0.00	2.32
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.4	0.00	0.00	0.00	2.32
Pyraclostrobin	B	1.0	0.00	0.00	0.00	1.17
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.5	0.00	0.00	0.00	0.85
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.4	0.00	0.00	0.00	1.17
Clomazone	B	0.0	0.00	0.00	0.00	0.00

Pesticide	Phase	> LOD (%)	Median	IQR	P90	Max.
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.0	0.00	0.00	0.00	0.00
	A3	1.0	0.00	0.00	0.00	260.00
	Overall	0.3	0.00	0.00	0.00	260.00
Metolachlor	B	0.0	0.00	0.00	0.00	0.00
	A1	0.5	0.00	0.00	0.00	1.51
	A2	0.0	0.00	0.00	0.00	0.00
	A3	0.5	0.00	0.00	0.00	4.19
	Overall	0.3	0.00	0.00	0.00	4.19
Pymetrozine	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	1.0	0.00	0.00	0.00	20.62
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.3	0.00	0.00	0.00	20.62
Dimethenamid	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.0	0.00	0.00	0.00	0.00
	A3	0.5	0.00	0.00	0.00	1.99
	Overall	0.1	0.00	0.00	0.00	1.99
Dyflufenican	B	0.0	0.00	0.00	0.00	0.00
	A1	0.5	0.00	0.00	0.00	0.96
	A2	0.0	0.00	0.00	0.00	0.00
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.1	0.00	0.00	0.00	0.96
Menpanipyrim	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.5	0.00	0.00	0.00	6.75
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.1	0.00	0.00	0.00	6.75
Paclobutrazol	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.5	0.00	0.00	0.00	8.05
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.1	0.00	0.00	0.00	8.05
Pencycuron	B	0.5	0.00	0.00	0.00	1.09
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.0	0.00	0.00	0.00	0.00
	A3	0.0	0.00	0.00	0.00	0.00
	Overall	0.1	0.00	0.00	0.00	1.09
Spiroxamine	B	0.0	0.00	0.00	0.00	0.00
	A1	0.0	0.00	0.00	0.00	0.00
	A2	0.0	0.00	0.00	0.00	0.00
	A3	0.5	0.00	0.00	0.00	4.41
	Overall	0.1	0.00	0.00	0.00	4.41

Table 7: The six pesticides [µg/kg] with a detection frequency of at least 40% in at least one assessment phase in the individual wristbands. Summary statistics are stratified by assessment phase. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June)). LOD = Limit of Detection. ICC = Intraclass Correlation Coefficient.

Active ingredient	Phase	> LOD (%)	Median	IQR	P90	Max.	ICC
Ametoctradin	B	4.7	0.00	0.00	0.00	4.53	-0.07204
	A1	3.0	0.00	0.00	0.00	1.90	
	A2	33.2	0.00	0.89	2.21	26.75	
	A3	97.9	5.17	9.49	25.79	149.41	
	Overall	34.6	0.00	1.74	7.13	149.41	
Cyprodinil	B	30.1	0.00	0.79	1.35	17.00	0.35018
	A1	86.4	3.65	5.37	11.02	69.45	
	A2	76.7	1.19	1.40	3.56	25.07	
	A3	53.1	0.75	1.50	2.79	35.32	
	Overall	61.7	1.00	2.44	5.92	69.45	
Dimethomorph	B	3.6	0.00	0.00	0.00	1.57	-0.08107
	A1	3.0	0.00	0.00	0.00	10.10	
	A2	42.5	0.00	1.21	3.00	11.81	
	A3	96.9	5.19	6.85	16.55	118.56	
	Overall	36.4	0.00	1.83	7.12	118.56	
Imazalil	B	47.2	0.00	1.98	5.75	136.40	-0.01646
	A1	24.2	0.00	0.00	1.87	24.74	
	A2	12.4	0.00	0.00	1.24	260.08	
	A3	11.9	0.00	0.00	0.84	23.83	
	Overall	23.9	0.00	0.00	2.17	260.08	
Metalaxyl	B	0.0	0.00	0.00	0.00	0.00	-0.03028
	A1	2.5	0.00	0.00	0.00	1.44	
	A2	59.6	1.28	2.86	5.18	47.30	
	A3	67.0	0.91	1.33	1.95	4.42	
	Overall	32.1	0.00	1.03	2.36	47.30	
Propiconazole	B	21.8	0.00	0.00	3.40	100.61	0.69368
	A1	42.9	0.00	1.49	5.16	165.69	
	A2	40.9	0.00	1.67	4.71	145.74	
	A3	34.0	0.00	1.62	5.63	82.49	
	Overall	35.0	0.00	1.29	4.32	165.69	

Table 8: The pesticides [µg/kg] with a detection frequency of at least 40% in at least one assessment phase in the stationary wristbands. Summary statistics are stratified by assessment phase. In total, 178 stationary wristbands from 52 children were collected. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June)). LOD = Limit of Detection. ICC = Intraclass Correlation Coefficient.

Pesticide	Phase	> LOD (%)	Median	IQR	P90	Max.
Metalaxyl	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	68.1	4.58	9.71	21.72	144.99
	A3	63.6	1.22	2.10	3.54	17.80
	Overall	33.7	0	1.66	7.52	144.99
Ametoctradin	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	14.9	0	0.00	1.14	5.64
	A3	52.3	0.85	2.34	7.71	51.53
	Overall	16.9	0	0.00	1.62	51.53
Cyprodinil	B	0.0	0	0.00	0.00	0.00
	A1	57.1	0.88	2.14	3.16	4.54
	A2	4.3	0	0.00	0.00	1.49
	A3	2.3	0	0.00	0.00	1.53
	Overall	15.2	0	0.00	1.11	4.54
Dimethomorph	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	14.9	0	0.00	1.30	6.78
	A3	40.9	0	1.90	7.68	53.46
	Overall	14.0	0	0.00	1.43	53.46
Penconazole	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	27.7	0	0.78	1.14	2.94
	A3	22.7	0	0.00	0.90	2.88
	Overall	12.9	0	0.00	0.85	2.94
Cyflufenamide	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	6.4	0	0.00	0.00	1.67
	A3	38.6	0	1.04	2.40	10.21
	Overall	11.2	0	0.00	0.75	10.21
Fluazinam	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	8.5	0	0.00	0.00	51.35
	A3	0.0	0	0.00	0.00	0.00
	Overall	2.2	0	0.00	0.00	51.35
Spirotetramat	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	8.5	0	0.00	0.00	1.40
	A3	0.0	0	0.00	0.00	0.00
	Overall	2.2	0	0.00	0.00	1.40

Pesticide	Phase	> LOD (%)	Median	IQR	P90	Max.
Diuron	B	0.0	0	0.00	0.00	0.00
	A1	2.4	0	0.00	0.00	2.13
	A2	2.1	0	0.00	0.00	1.09
	A3	2.3	0	0.00	0.00	2.41
	Overall	1.7	0	0.00	0.00	2.41
Fluxapyroxad	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	0.0	0	0.00	0.00	0.00
	A3	4.5	0	0.00	0.00	2.15
	Overall	1.1	0	0.00	0.00	2.15
Proquinazid	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	2.1	0	0.00	0.00	2.76
	A3	2.3	0	0.00	0.00	7.30
	Overall	1.1	0	0.00	0.00	7.30
Amisulbrom	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	0.0	0	0.00	0.00	0.00
	A3	2.3	0	0.00	0.00	1.21
	Overall	0.6	0	0.00	0.00	1.21
Fenpyroximate	B	0.0	0	0.00	0.00	0.00
	A1	2.4	0	0.00	0.00	1.11
	A2	0.0	0	0.00	0.00	0.00
	A3	0.0	0	0.00	0.00	0.00
	Overall	0.6	0	0.00	0.00	1.11
Propiconazole	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	0.0	0	0.00	0.00	0.00
	A3	2.3	0	0.00	0.00	1.22
	Overall	0.6	0	0.00	0.00	1.22
Prosulfocarb	B	0.0	0	0.00	0.00	0.00
	A1	0.0	0	0.00	0.00	0.00
	A2	2.1	0	0.00	0.00	1.01
	A3	0.0	0	0.00	0.00	0.00
	Overall	0.6	0	0.00	0.00	1.01

Table 9: Two biomarkers hydroxy boscalid (BOS-OH) and hydroxy tebuconazole (TEB-OH) [ng/ml] measured in spot urine samples. Summary statistics are stratified by assessment phase. In total, 715 urinary samples have been collected from 202 children. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June). LOD = Limit of Detection. ICC = Intraclass Correlation Coefficient.

Biomarker	Phase	> LOD (%)	Median	IQR	P90	Max.	ICC
BOS-OH	B	85.9	0.14	0.23	0.61	9.61	0.17
	A1	93.0	0.16	0.22	0.67	8.92	
	A2	95.2	0.18	0.21	0.77	257.68	
	A3	93.7	0.16	0.21	0.56	87.58	
	Overall	91.9	0.16	0.22	0.64	257.68	
TEB-OH	B	98.4	0.37	0.53	1.03	3.45	-0.01
	A1	97.8	0.39	0.46	1.32	17.83	
	A2	99.5	0.34	0.40	1.33	10.14	
	A3	98.7	0.28	0.53	1.54	9.41	
	Overall	98.6	0.34	0.49	1.31	17.83	

Table 10: Association between pesticides [ng/g] and shortest distance [100 m] to agricultural land, presented as β-estimates and 95% confidence intervals (CI**).** Models are adjusted for child living on farm, school, spraying season and education. (*) = $p<0.05$. Observations (n = 701), children (n = 191).

Source and Unit	Shortest distance [100 m] of child's residence to	Pesticide	10^{β}	95% CI	p-value
Wristbands [ng/g]	any agricultural land	Ametoctradin (F)	1.00	[0.64, 1.56]	0.99
		Cyprodinil (F)	1.03	[0.55, 1.95]	0.92
		Dimethomorph (F)	1.00	[0.62, 1.60]	1.00
		Imazalil (F)	0.17	[0.04, 0.68]	0.012
		Metalaxyl (F)	0.99	[0.62, 1.58]	0.96
		Propiconazole (F)	0.63	[0.11, 3.59]	0.61
	any vineyards or fruit orchards	Ametoctradin (F)	0.98	[0.92, 1.05]	0.54
		Cyprodinil (F)	0.95	[0.87, 1.05]	0.33
		Dimethomorph (F)	0.98	[0.91, 1.05]	0.52
		Imazalil (F)	0.91	[0.75, 1.11]	0.37
		Metalaxyl (F)	0.93	[0.86, 1.00]	0.054
		Propiconazole (F)	1.16	[0.91, 1.48]	0.23
	any vineyards	Ametoctradin (F)	0.98	[0.94, 1.02]	0.37
		Cyprodinil (F)	0.96	[0.90, 1.02]	0.19
		Dimethomorph (F)	0.98	[0.93, 1.02]	0.33
		Imazalil (F)	0.96	[0.84, 1.08]	0.47
		Metalaxyl (F)	0.94	[0.90, 0.99]	0.018
		Propiconazole (F)	1.25	[1.07, 1.45]	0.004
	any fruit orchards	Ametoctradin (F)	1.02	[0.96, 1.08]	0.51
		Cyprodinil (F)	0.96	[0.89, 1.04]	0.35
		Dimethomorph (F)	1.02	[0.96, 1.08]	0.55
		Imazalil (F)	1.07	[0.91, 1.26]	0.40
		Metalaxyl (F)	1.01	[0.95, 1.07]	0.84
		Propiconazole (F)	0.79	[0.64, 0.97]	0.022
	conv. vineyards	Ametoctradin (F)	0.98	[0.94, 1.02]	0.36
		Cyprodinil (F)	0.96	[0.90, 1.02]	0.17
		Dimethomorph (F)	0.98	[0.94, 1.02]	0.34
		Imazalil (F)	0.96	[0.85, 1.08]	0.49
		Metalaxyl (F)	0.94	[0.90, 0.99]	0.018
		Propiconazole (F)	1.25	[1.07, 1.45]	0.004
	org. vineyards	Ametoctradin (F)	0.99	[0.96, 1.03]	0.75
		Cyprodinil (F)	0.97	[0.92, 1.03]	0.31
		Dimethomorph (F)	0.98	[0.95, 1.02]	0.40
		Imazalil (F)	0.96	[0.86, 1.07]	0.45
		Metalaxyl (F)	0.95	[0.91, 0.99]	0.011
		Propiconazole (F)	1.26	[1.11, 1.44]	0.0004
	conv. fruit orchards	Ametoctradin (F)	1.03	[0.97, 1.08]	0.31
		Cyprodinil (F)	0.99	[0.92, 1.07]	0.80
		Dimethomorph (F)	1.02	[0.96, 1.08]	0.48
		Imazalil (F)	1.07	[0.92, 1.25]	0.40
		Metalaxyl (F)	1.01	[0.95, 1.07]	0.84
		Propiconazole (F)	0.76	[0.63, 0.93]	0.008
	org. fruit orchards	Ametoctradin (F)	0.99	[0.97, 1.02]	0.61
		Cyprodinil (F)	0.99	[0.96, 1.02]	0.44
		Dimethomorph (F)	1.00	[0.97, 1.02]	0.68
		Imazalil (F)	0.95	[0.89, 1.01]	0.10
		Metalaxyl (F)	0.98	[0.96, 1.00]	0.12
		Propiconazole (F)	1.17	[1.08, 1.26]	< 0.0001

Table 11: Association between the two urinary biomarkers hydroxy boscalid (BOS-OH) and hydroxy tebucunazole (TEB-OH) [ng/ml], and shortest distance [10m] to agricultural land, presented as β-estimates and 95% confidence intervals (CI). Org = organic; conv = conventional agricultural practices. Models adjusted for child living on a farm, school, spraying season and education. (*) = p<0.05. Observations (n = 628), children (n = 189)

Source and Unit	Shortest distance [100 m] of child's residence to	Pesticide	10^{β}	95% CI	p-value
Urine [ng/ml]	any agricultural land	Hydroxy Boscalid (F)	0.95	[0.66, 1.36]	0.78
		Hydroxy Tebuconazole (F)	1.09	[0.78, 1.52]	0.62
	any vineyards or fruit orchards	Hydroxy Boscalid (F)	0.93	[0.88, 0.97]	0.004
		Hydroxy Tebuconazole (F)	0.98	[0.93, 1.03]	0.40
	any vineyards	Hydroxy Boscalid (F)	0.96	[0.93, 1.00]	0.025
		Hydroxy Tebuconazole (F)	0.99	[0.96, 1.02]	0.45
	any fruit orchards	Hydroxy Boscalid (F)	0.97	[0.93, 1.02]	0.21
		Hydroxy Tebuconazole (F)	0.99	[0.95, 1.03]	0.53
	conv. vineyards	Hydroxy Boscalid (F)	0.96	[0.93, 0.99]	0.024
		Hydroxy Tebuconazole (F)	0.99	[0.96, 1.02]	0.45
	org. vineyards	Hydroxy Boscalid (F)	0.97	[0.94, 1.00]	0.025
		Hydroxy Tebuconazole (F)	0.99	[0.97, 1.02]	0.57
	conv. fruit orchards	Hydroxy Boscalid (F)	0.98	[0.94, 1.02]	0.40
		Hydroxy Tebuconazole (F)	1.00	[0.96, 1.04]	0.80
	org. fruit orchards	Hydroxy Boscalid (F)	0.98	[0.96, 1.00]	0.011
		Hydroxy Tebuconazole (F)	0.98	[0.97, 1.00]	0.027

Table 12: Associations between different areas of agricultural land use [%] around participants' homes and detected pesticides, presented as β-estimates and 95% confidence intervals (CI). Org = organic; conv = conventional agricultural practices. Models were adjusted for child living on a farm, school, spraying season and education. (*) = p<0.05. Observations (n = 701), children (n = 191).

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
Wristbands [ng/g]	any agricultural land	50 m	Ametoctradin (F)	1.01	[1.00, 1.01]	0.23
		250 m		1.01	[1.00, 1.02]	0.10
		500 m		1.01	[1.00, 1.02]	0.24
		1000 m		1.00	[0.99, 1.01]	0.52
		50 m	Cyprodinil (F)	1.01	[1.00, 1.02]	0.15
		250 m		1.01	[1.00, 1.02]	0.13
		500 m		1.01	[0.99, 1.02]	0.41
		1000 m		1.00	[0.99, 1.02]	0.58
		50 m	Dimethomorph (F)	1.00	[0.99, 1.01]	0.42
		250 m		1.01	[1.00, 1.02]	0.10
		500 m		1.01	[1.00, 1.02]	0.12
		1000 m		1.00	[0.99, 1.01]	0.40
		50 m	Imazalil (F)	1.03	[1.00, 1.05]	0.046
		250 m		1.00	[0.98, 1.03]	0.75
		500 m		1.01	[0.98, 1.04]	0.57
		1000 m		1.02	[0.99, 1.05]	0.14
		50 m	Metalaxyl (F)	1.00	[0.99, 1.01]	0.57
		250 m		1.01	[1.00, 1.02]	0.11
		500 m		1.01	[1.00, 1.02]	0.017
		1000 m		1.01	[1.00, 1.02]	0.048
		50 m	Propiconazole (F)	0.98	[0.95, 1.01]	0.24
		250 m		0.99	[0.96, 1.03]	0.73
		500 m		0.96	[0.92, 0.99]	0.019
		1000 m		0.95	[0.91, 0.98]	0.002

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
	any vineyards or fruit orchards	50 m	Ametoctradin (F)	1.01	[1.00, 1.02]	0.037
		250 m		1.01	[1.00, 1.02]	0.02
		500 m		1.01	[1.00, 1.02]	0.075
		1000 m		1.00	[1.00, 1.01]	0.29
		50 m	Cyprodinil (F)	1.01	[1.00, 1.03]	0.048
		250 m		1.01	[1.00, 1.02]	0.08
		500 m		1.01	[0.99, 1.02]	0.37
		1000 m		1.00	[0.99, 1.02]	0.51
		50 m	Dimethomorph (F)	1.01	[1.00, 1.02]	0.091
		250 m		1.01	[1.00, 1.02]	0.046
		500 m		1.01	[1.00, 1.02]	0.096
		1000 m		1.00	[1.00, 1.01]	0.36
		50 m	Imazalil (F)	1.03	[1.00, 1.06]	0.056
		250 m		1.01	[0.99, 1.04]	0.31
		500 m		1.01	[0.99, 1.04]	0.37
		1000 m		1.02	[0.99, 1.04]	0.16
		50 m	Metalaxyl (F)	1.01	[1.00, 1.02]	0.29
		250 m		1.01	[1.00, 1.02]	0.004
		500 m		1.02	[1.01, 1.02]	0.0008
		1000 m		1.01	[1.00, 1.02]	0.008
		50 m	Propiconazole (F)	0.97	[0.94, 1.00]	0.07
		250 m		0.98	[0.95, 1.01]	0.21
		500 m		0.96	[0.93, 0.99]	0.006
		1000 m		0.95	[0.92, 0.98]	0.0007
	any vineyards	50 m	Ametoctradin (F)	1.01	[1.00, 1.02]	0.027
		250 m		1.01	[1.00, 1.02]	0.007
		500 m		1.01	[1.00, 1.02]	0.059

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
		1000 m		1.00	[0.99, 1.01]	0.46
		50 m	Cyprodinil (F)	1.00	[0.99, 1.02]	0.78
		250 m		1.00	[0.99, 1.02]	0.78
		500 m		1.00	[0.99, 1.01]	0.91
		1000 m		1.00	[0.99, 1.01]	0.80
		50 m	Dimethomorph (F)	1.01	[1.00, 1.02]	0.064
		250 m		1.01	[1.00, 1.02]	0.026
		500 m		1.01	[1.00, 1.02]	0.094
		1000 m		1.00	[0.99, 1.01]	0.64
		50 m	Imazalil (F)	1.03	[1.00, 1.07]	0.032
		250 m		1.02	[0.99, 1.05]	0.14
		500 m		1.02	[0.99, 1.04]	0.24
		1000 m		1.02	[1.00, 1.05]	0.064
		50 m	Metalaxyl (F)	1.00	[0.99, 1.02]	0.43
		250 m		1.02	[1.01, 1.03]	0.0006
		500 m		1.02	[1.01, 1.03]	0.0004
		1000 m		1.01	[1.00, 1.02]	0.01
		50 m	Propiconazole (F)	0.94	[0.91, 0.98]	0.004
		250 m		0.96	[0.92, 1.00]	0.036
		500 m		0.95	[0.92, 0.98]	0.001
		1000 m		0.95	[0.92, 0.98]	0.0009
	any fruit orchards	50 m	Ametoctradin (F)	1.00	[0.98, 1.02]	0.75
		250 m		1.00	[0.98, 1.02]	0.97
		500 m		1.00	[0.98, 1.02]	0.98
		1000 m		1.02	[0.99, 1.06]	0.19
		50 m	Cyprodinil (F)	1.04	[1.02, 1.07]	0.0006
		250 m		1.04	[1.01, 1.06]	0.003

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^β	95% CI	p-value
		500 m		1.05	[1.01, 1.08]	0.005
		1000 m		1.04	[0.99, 1.09]	0.092
		50 m	Dimethomorph (F)	1.00	[0.98, 1.02]	0.89
		250 m		1.00	[0.98, 1.02]	0.92
		500 m		1.00	[0.98, 1.03]	0.79
		1000 m		1.03	[1.00, 1.07]	0.067
		50 m	Imazalil (F)	1.00	[0.94, 1.06]	0.98
		250 m		0.98	[0.93, 1.04]	0.57
		500 m		0.98	[0.91, 1.05]	0.53
		1000 m		0.92	[0.82, 1.02]	0.11
		50 m	Metalaxyl (F)	1.01	[0.99, 1.03]	0.47
		250 m		1.00	[0.98, 1.02]	0.91
		500 m		1.00	[0.98, 1.03]	0.84
		1000 m		1.01	[0.98, 1.05]	0.49
		50 m	Propiconazole (F)	1.04	[0.98, 1.11]	0.21
		250 m		1.04	[0.97, 1.10]	0.28
		500 m		1.03	[0.95, 1.12]	0.51
		1000 m		0.96	[0.85, 1.09]	0.54
	org. vineyards	50 m	Ametoctradin (F)	0.98	[0.95, 1.01]	0.14
		250 m		1.01	[0.97, 1.05]	0.76
		500 m		0.99	[0.95, 1.03]	0.60
		1000 m		0.99	[0.96, 1.03]	0.77
		50 m	Cyprodinil (F)	0.99	[0.95, 1.03]	0.71
		250 m		0.96	[0.90, 1.02]	0.17
		500 m		0.97	[0.92, 1.03]	0.36
		1000 m		1.00	[0.95, 1.05]	0.99
		50 m	Dimethomorph (F)	0.98	[0.95, 1.01]	0.25

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
		250 m		1.01	[0.97, 1.06]	0.57
		500 m		1.00	[0.96, 1.04]	0.88
		1000 m		0.99	[0.96, 1.03]	0.73
		50 m	Imazalil (F)	1.09	[1.01, 1.18]	0.03
		250 m		1.11	[0.99, 1.26]	0.077
		500 m		1.13	[1.01, 1.27]	0.029
		1000 m		1.14	[1.02, 1.26]	0.016
		50 m	Metalaxyl (F)	0.95	[0.92, 0.98]	0.003
		250 m		1.05	[1.00, 1.09]	0.041
		500 m		1.05	[1.00, 1.09]	0.033
		1000 m		1.04	[1.00, 1.08]	0.049
		50 m	Propiconazole (F)	0.95	[0.86, 1.06]	0.38
		250 m		0.82	[0.70, 0.95]	0.01
		500 m		0.76	[0.66, 0.87]	0.0001
		1000 m		0.79	[0.70, 0.90]	0.0005
	conv. vineyards	50 m	Ametoctradin (F)	1.02	[1.01, 1.03]	0.001
		250 m		1.02	[1.01, 1.03]	0.001
		500 m		1.01	[1.00, 1.03]	0.011
		1000 m		1.01	[0.99, 1.02]	0.29
		50 m	Cyprodinil (F)	1.00	[0.99, 1.02]	0.63
		250 m		1.01	[0.99, 1.03]	0.45
		500 m		1.00	[0.99, 1.02]	0.91
		1000 m		1.00	[0.99, 1.02]	0.74
		50 m	Dimethomorph (F)	1.02	[1.00, 1.03]	0.007
		250 m		1.02	[1.00, 1.03]	0.011
		500 m		1.01	[1.00, 1.02]	0.031
		1000 m		1.00	[0.99, 1.02]	0.47

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
		50 m	Imazalil (F)	1.03	[0.99, 1.07]	0.13
		250 m		1.02	[0.99, 1.06]	0.22
		500 m		1.01	[0.98, 1.05]	0.40
		1000 m		1.03	[0.99, 1.06]	0.099
		50 m	Metalaxyl (F)	1.01	[1.00, 1.03]	0.031
		250 m		1.02	[1.01, 1.04]	0.0004
		500 m		1.02	[1.01, 1.03]	0.0001
		1000 m		1.02	[1.00, 1.03]	0.006
		50 m	Propiconazole (F)	0.93	[0.89, 0.98]	0.003
		250 m		0.96	[0.91, 1.00]	0.078
		500 m		0.94	[0.90, 0.98]	0.004
		1000 m		0.93	[0.90, 0.97]	0.001
	org. fruit orchards	250 m	Ametoctradin (F)	1.01	[0.89, 1.15]	0.88
		500 m		1.08	[0.93, 1.25]	0.32
		1000 m		1.23	[1.03, 1.46]	0.019
		250 m	Cyprodinil (F)	1.24	[1.04, 1.48]	0.016
		500 m		1.39	[1.13, 1.70]	0.002
		1000 m		1.39	[1.09, 1.76]	0.007
		250 m	Dimethomorph (F)	1.03	[0.91, 1.18]	0.62
		500 m		1.12	[0.96, 1.31]	0.15
		1000 m		1.32	[1.10, 1.57]	0.003
		250 m	Imazalil (F)	0.90	[0.61, 1.34]	0.62
		500 m		0.79	[0.47, 1.33]	0.37
		1000 m		0.86	[0.50, 1.48]	0.57
		250 m	Metalaxyl (F)	1.00	[0.88, 1.14]	0.97
		500 m		1.04	[0.89, 1.21]	0.63
		1000 m		1.05	[0.88, 1.26]	0.56

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
		250 m	Propiconazole (F)	1.16	[0.73, 1.86]	0.52
		500 m		1.12	[0.65, 1.93]	0.68
		1000 m		1.23	[0.64, 2.35]	0.53
	conv. fruit orchards	50 m	Ametoctradin (F)	1.00	[0.98, 1.02]	0.75
		250 m		1.00	[0.98, 1.02]	0.95
		500 m		1.00	[0.97, 1.02]	0.89
		1000 m		1.02	[0.98, 1.06]	0.33
		50 m	Cyprodinil (F)	1.04	[1.02, 1.07]	0.0006
		250 m		1.04	[1.01, 1.07]	0.003
		500 m		1.05	[1.01, 1.09]	0.009
		1000 m		1.04	[0.98, 1.09]	0.18
		50 m	Dimethomorph (F)	1.00	[0.98, 1.02]	0.89
		250 m		1.00	[0.98, 1.02]	0.97
		500 m		1.00	[0.97, 1.03]	0.96
		1000 m		1.03	[0.99, 1.07]	0.15
		50 m	Imazalil (F)	1.00	[0.94, 1.06]	0.98
		250 m		0.98	[0.92, 1.05]	0.58
		500 m		0.98	[0.90, 1.06]	0.58
		1000 m		0.90	[0.80, 1.02]	0.088
		50 m	Metalaxyl (F)	1.01	[0.99, 1.03]	0.47
		250 m		1.00	[0.98, 1.02]	0.90
		500 m		1.00	[0.98, 1.03]	0.89
		1000 m		1.01	[0.97, 1.05]	0.51
		50 m	Propiconazole (F)	1.04	[0.98, 1.11]	0.21
		250 m		1.04	[0.97, 1.12]	0.27
		500 m		1.03	[0.94, 1.14]	0.49
		1000 m		0.94	[0.82, 1.09]	0.40

Table 13: Associations between different areas [%] of agricultural land use around participants' homes and urinary pesticide biomarkers hydroxy boscalid (BOS-OH) and hydroxy tebucunazole (TEB-OH) [ng/ml], presented as β-estimates and 95% confidence intervals (CI). Models adjusted for child living on a farm, school, spraying season and education. Observations (n = 628), children (n = 189).

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
Urine [ng/ml]	any agricultural land	50 m	Hydroxy Boscalid (F)	1.00	[1.00, 1.01]	0.28
		250 m		1.00	[1.00, 1.01]	0.27
		500 m		1.04	[1.00, 1.09]	0.075
		1000 m		2.20	[1.04, 4.65]	0.04
		50 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.85
		250 m		1.00	[0.99, 1.00]	0.49
		500 m		1.02	[0.99, 1.07]	0.23
		1000 m		1.46	[0.72, 2.94]	0.29
	any vineyards or fruit orchards	50 m	Hydroxy Boscalid (F)	1.01	[1.00, 1.02]	0.023
		250 m		1.01	[1.00, 1.01]	0.14
		500 m		1.06	[0.90, 1.25]	0.46
		1000 m		1.90	[0.99, 3.66]	0.057
		50 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.69
		250 m		1.00	[0.99, 1.01]	0.85
		500 m		0.99	[0.85, 1.15]	0.92
		1000 m		1.43	[0.77, 2.64]	0.25
	any vineyards	50 m	Hydroxy Boscalid (F)	1.01	[1.00, 1.02]	0.041
		250 m		1.01	[1.00, 1.01]	0.21
		500 m		1.05	[1.00, 1.10]	0.04
		1000 m		1.87	[0.94, 3.69]	0.075
		50 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.55
		250 m		1.00	[0.99, 1.01]	0.69
		500 m		1.02	[0.98, 1.07]	0.29
		1000 m		1.48	[0.79, 2.81]	0.23
	any fruit orchards	50 m	Hydroxy Boscalid (F)	1.01	[0.99, 1.02]	0.34
		250 m		1.00	[0.99, 1.02]	0.47

Source and Unit	Area [%] of agricultural land within buffer surrounding child's residence	Buffer radius	Pesticide	10^{β}	95% CI	p-value
		500 m		1.04	[1.00, 1.08]	0.057
		1000 m		2.67	[0.20, 35.81]	0.46
		50 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.82
		250 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.77
		500 m	Hydroxy Tebuconazole (F)	1.02	[0.98, 1.06]	0.25
		1000 m	Hydroxy Tebuconazole (F)	0.88	[0.08, 9.79]	0.92
	org. vineyards	50 m	Hydroxy Boscalid (F)	1.01	[0.99, 1.03]	0.39
		250 m	Hydroxy Boscalid (F)	1.02	[0.98, 1.05]	0.34
		500 m	Hydroxy Boscalid (F)	1.00	[1.00, 1.00]	0.075
		1000 m	Hydroxy Boscalid (F)	1.17	[0.99, 1.39]	0.075
		50 m	Hydroxy Tebuconazole (F)	1.01	[0.99, 1.03]	0.34
		250 m	Hydroxy Tebuconazole (F)	1.00	[0.97, 1.03]	0.99
		500 m	Hydroxy Tebuconazole (F)	1.00	[1.00, 1.00]	0.23
		1000 m	Hydroxy Tebuconazole (F)	1.10	[0.94, 1.29]	0.23
	conv. vineyards	50 m	Hydroxy Boscalid (F)	1.01	[1.00, 1.02]	0.047
		250 m	Hydroxy Boscalid (F)	1.01	[1.00, 1.02]	0.21
		500 m	Hydroxy Boscalid (F)	1.00	[1.00, 1.01]	0.46
		1000 m	Hydroxy Boscalid (F)	1.28	[0.67, 2.45]	0.46
		50 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.77
		250 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.63
		500 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.92
		1000 m	Hydroxy Tebuconazole (F)	0.97	[0.53, 1.77]	0.92
	org. fruit orchards	250 m	Hydroxy Boscalid (F)	1.03	[0.93, 1.13]	0.59
		500 m	Hydroxy Boscalid (F)	1.00	[1.00, 1.00]	0.04
		1000 m	Hydroxy Boscalid (F)	1.22	[1.01, 1.47]	0.04
		250 m	Hydroxy Tebuconazole (F)	1.00	[0.91, 1.09]	0.92
		500 m	Hydroxy Tebuconazole (F)	1.00	[1.00, 1.00]	0.29
		1000 m	Hydroxy Tebuconazole (F)	1.10	[0.92, 1.31]	0.29
	conv. fruit orchards	50 m	Hydroxy Boscalid (F)	1.01	[0.99, 1.02]	0.34
		250 m	Hydroxy Boscalid (F)	1.01	[0.99, 1.02]	0.47

Source and Unit	**Area [%] of agricultural land within buffer surrounding child's residence**	**Buffer radius**	**Pesticide**	**10^{β}**	**95% CI**	**p-value**
		500 m		1.00	[1.00, 1.00]	0.057
		1000 m		1.17	[1.00, 1.38]	0.057
		50 m	Hydroxy Tebuconazole (F)	1.00	[0.99, 1.01]	0.82
		250 m		1.00	[0.98, 1.01]	0.75
		500 m		1.00	[1.00, 1.00]	0.25
		1000 m		1.09	[0.94, 1.27]	0.25

Table 14: Predictors of pesticides [ng/g] detected in silicone wristbands. In blue are effect-estimates β and their 95% confidence intervals (CI). Observations (n = 678), children (n=191).

Source and Unit	Predictor	Pesticide	10^{β}	95% CI	p-value
Wristbands [ng/g]	Sex: Female vs Male	Ametoctradin (F)	0.87	[0.66, 1.14]	0.31
		Cyprodinil (F)	0.78	[0.53, 1.15]	0.20
		Dimethomorph (F)	0.86	[0.64, 1.15]	0.32
		Imazalil (F)	1.36	[0.60, 3.09]	0.46
		Metalaxyl (F)	0.67	[0.50, 0.89]	0.006
		Propiconazole (F)	0.53	[0.19, 1.49]	0.23
	Age [y]	Ametoctradin (F)	0.91	[0.84, 0.98]	0.018
		Cyprodinil (F)	0.97	[0.87, 1.08]	0.61
		Dimethomorph (F)	0.92	[0.85, 1.00]	0.056
		Imazalil (F)	0.86	[0.68, 1.09]	0.21
		Metalaxyl (F)	0.92	[0.84, 0.99]	0.033
		Propiconazole (F)	0.70	[0.52, 0.94]	0.018
	Education: Secondary vs Tertiary	Ametoctradin (F)	1.13	[0.85, 1.52]	0.40
		Cyprodinil (F)	1.01	[0.68, 1.52]	0.95
		Dimethomorph (F)	0.95	[0.69, 1.29]	0.72
		Imazalil (F)	0.30	[0.13, 0.72]	0.007
		Metalaxyl (F)	0.93	[0.69, 1.26]	0.63
		Propiconazole (F)	0.35	[0.12, 1.05]	0.062
	Education: Primary or lower vs Tertiary	Ametoctradin (F)	1.44	[0.86, 2.39]	0.16
		Cyprodinil (F)	1.03	[0.51, 2.08]	0.93
		Dimethomorph (F)	1.32	[0.77, 2.27]	0.31
		Imazalil (F)	1.73	[0.40, 7.59]	0.46
		Metalaxyl (F)	1.05	[0.63, 1.77]	0.85
		Propiconazole (F)	0.65	[0.10, 4.25]	0.65
	School: Chamoson vs Saxon	Ametoctradin (F)	0.89	[0.63, 1.24]	0.48
		Cyprodinil (F)	0.14	[0.09, 0.23]	< 0.0001
		Dimethomorph (F)	0.62	[0.43, 0.88]	0.008
		Imazalil (F)	1.55	[0.57, 4.25]	0.39
		Metalaxyl (F)	0.21	[0.15, 0.30]	< 0.0001
		Propiconazole (F)	8.14	[2.30, 28.83]	0.001
	School: Salgesch vs Saxon	Ametoctradin (F)	1.72	[1.11, 2.68]	0.016
		Cyprodinil (F)	0.01	[0.01, 0.02]	< 0.0001
		Dimethomorph (F)	1.27	[0.79, 2.03]	0.32
		Imazalil (F)	0.29	[0.07, 1.14]	0.077
		Metalaxyl (F)	1.21	[0.77, 1.89]	0.41
		Propiconazole (F)	0.82	[0.15, 4.40]	0.81
	Shortest distance to vineyards or fruit orchards: > 20 m vs ≤ 20	Ametoctradin (F)	0.92	[0.67, 1.26]	0.59
		Cyprodinil (F)	0.91	[0.58, 1.42]	0.66
		Dimethomorph (F)	0.97	[0.69, 1.36]	0.87
		Imazalil (F)	0.38	[0.14, 0.97]	0.044
		Metalaxyl (F)	1.04	[0.75, 1.45]	0.82
		Propiconazole (F)	3.43	[1.02, 11.57]	0.046

Source and Unit	Predictor	Pesticide	10^{β}	95% CI	p-value
	School way: Biking vs Driving	Ametoctradin (F)	1.24	[0.67, 2.28]	0.49
		Cyprodinil (F)	2.68	[1.16, 6.21]	0.021
		Dimethomorph (F)	1.32	[0.69, 2.51]	0.40
		Imazalil (F)	1.41	[0.22, 8.94]	0.71
		Metalaxyl (F)	1.79	[0.96, 3.32]	0.066
		Propiconazole (F)	8.36	[0.93, 75.25]	0.058
	School way: Walking vs Driving	Ametoctradin (F)	1.02	[0.73, 1.43]	0.90
		Cyprodinil (F)	1.20	[0.76, 1.91]	0.44
		Dimethomorph (F)	1.05	[0.74, 1.50]	0.78
		Imazalil (F)	1.59	[0.59, 4.29]	0.36
		Metalaxyl (F)	1.32	[0.93, 1.88]	0.12
		Propiconazole (F)	1.02	[0.30, 3.46]	0.98
	Time spent outside [h/week]	Ametoctradin (F)	0.96	[0.82, 1.12]	0.58
		Cyprodinil (F)	0.94	[0.76, 1.16]	0.56
		Dimethomorph (F)	1.03	[0.87, 1.21]	0.73
		Imazalil (F)	1.01	[0.64, 1.60]	0.96
		Metalaxyl (F)	1.02	[0.87, 1.19]	0.85
		Propiconazole (F)	1.46	[0.82, 2.59]	0.20
	Water source: Private vs Public	Ametoctradin (F)	1.24	[0.79, 1.94]	0.34
		Cyprodinil (F)	1.14	[0.61, 2.14]	0.69
		Dimethomorph (F)	1.11	[0.70, 1.78]	0.65
		Imazalil (F)	1.28	[0.34, 4.77]	0.72
		Metalaxyl (F)	1.27	[0.81, 2.00]	0.29
		Propiconazole (F)	5.52	[1.09, 27.88]	0.039
	Times taking a bath [n/week]	Ametoctradin (F)	1.04	[0.96, 1.13]	0.33
		Cyprodinil (F)	0.96	[0.86, 1.07]	0.48
		Dimethomorph (F)	1.02	[0.94, 1.11]	0.62
		Imazalil (F)	0.87	[0.68, 1.11]	0.27
		Metalaxyl (F)	0.96	[0.88, 1.04]	0.31
		Propiconazole (F)	0.98	[0.72, 1.32]	0.87
	Child helping on farm: Yes vs No	Ametoctradin (F)	0.84	[0.25, 2.82]	0.78
		Cyprodinil (F)	2.35	[0.45, 12.17]	0.31
		Dimethomorph (F)	0.59	[0.16, 2.11]	0.41
		Imazalil (F)	0.02	[0.00, 0.85]	0.041
		Metalaxyl (F)	0.69	[0.18, 2.60]	0.58
		Propiconazole (F)	0.10	[0.00, 7.57]	0.30
	Fungicide application in garden or household: Yes vs No	Ametoctradin (F)	0.54	[0.22, 1.29]	0.16
		Cyprodinil (F)	0.27	[0.08, 0.90]	0.033
		Dimethomorph (F)	0.58	[0.23, 1.48]	0.25
		Imazalil (F)	5.30	[0.46, 61.44]	0.18
		Metalaxyl (F)	0.76	[0.31, 1.86]	0.55
		Propiconazole (F)	0.87	[0.03, 22.79]	0.93
	Family member working on a conventional farm vs not on any farm	Ametoctradin (F)	0.95	[0.49, 1.83]	0.88
		Cyprodinil (F)	1.52	[0.60, 3.85]	0.37
		Dimethomorph (F)	1.34	[0.67, 2.68]	0.40
		Imazalil (F)	1.80	[0.27, 11.86]	0.54

Source and Unit	Predictor	Pesticide	10^{β}	95% CI	p-value
		Metalaxyl (F)	1.05	[0.54, 2.03]	0.89
		Propiconazole (F)	1.36	[0.12, 15.19]	0.80
	Family member working on an IP farm vs not on any farm	Ametoctradin (F)	0.94	[0.24, 3.71]	0.92
		Cyprodinil (F)	8.63	[1.30, 57.52]	0.026
		Dimethomorph (F)	1.15	[0.27, 4.95]	0.85
		Imazalil (F)	6.01	[0.12, 298.74]	0.37
		Metalaxyl (F)	1.29	[0.31, 5.36]	0.72
		Propiconazole (F)	13.63	[0.11, 1761.63]	0.29
	Family member working on an organic farm vs not on any farm	Ametoctradin (F)	0.70	[0.29, 1.66]	0.42
		Cyprodinil (F)	0.66	[0.20, 2.19]	0.50
		Dimethomorph (F)	0.94	[0.37, 2.36]	0.90
		Imazalil (F)	6.73	[0.58, 78.14]	0.13
		Metalaxyl (F)	0.58	[0.24, 1.43]	0.24
		Propiconazole (F)	12.95	[0.56, 299.24]	0.11

Table 15: Predictors of pesticide exposure of two biomarkers hydroxy boscalid (BOS-OH) and hydroxy tebuconazole (TEB-OH) [ng/ml] measured in urine samples. In blue are effect estimates β and their 95% confidence intervals (CI). Observations (n = 607), children (n = 189).

Source and Unit	Predictor	Pesticide	10^{β}	95% CI	p-value
Urine [ng/ml]	Spraying season: Yes	Hydroxy Boscalid (F)	1.16	[0.94, 1.43]	0.18
		Hydroxy Tebuconazole (F)	1.06	[0.86, 1.31]	0.58
	Sex: Female	Hydroxy Boscalid (F)	1.06	[0.85, 1.33]	0.61
		Hydroxy Tebuconazole (F)	0.87	[0.71, 1.08]	0.20
	Age [y]	Hydroxy Boscalid (F)	0.97	[0.91, 1.03]	0.37
		Hydroxy Tebuconazole (F)	1.00	[0.94, 1.06]	1.00
	Education: Secondary	Hydroxy Boscalid (F)	1.06	[0.84, 1.34]	0.61
		Hydroxy Tebuconazole (F)	1.05	[0.84, 1.30]	0.69
	Education: Primary or lower	Hydroxy Boscalid (F)	1.29	[0.85, 1.98]	0.24
		Hydroxy Tebuconazole (F)	0.89	[0.60, 1.32]	0.56
	School: Chamoson	Hydroxy Boscalid (F)	1.41	[1.08, 1.85]	0.01
		Hydroxy Tebuconazole (F)	0.82	[0.64, 1.05]	0.12
	School: Salgesch	Hydroxy Boscalid (F)	0.74	[0.51, 1.07]	0.11
		Hydroxy Tebuconazole (F)	0.58	[0.41, 0.83]	0.003
	Shortest distance to vineyards or fruit orchards: >20m	Hydroxy Boscalid (F)	0.78	[0.60, 1.01]	0.06
		Hydroxy Tebuconazole (F)	1.02	[0.79, 1.30]	0.90
	School way: Biking	Hydroxy Boscalid (F)	1.26	[0.76, 2.07]	0.37
		Hydroxy Tebuconazole (F)	1.33	[0.84, 2.13]	0.23
	School way: Walking	Hydroxy Boscalid (F)	1.21	[0.92, 1.58]	0.17
		Hydroxy Tebuconazole (F)	1.25	[0.97, 1.60]	0.09
	Time spent outside [h/week]	Hydroxy Boscalid (F)	0.96	[0.88, 1.06]	0.44
		Hydroxy Tebuconazole (F)	0.95	[0.87, 1.04]	0.28
	Water source: Private	Hydroxy Boscalid (F)	1.02	[0.77, 1.34]	0.91
		Hydroxy Tebuconazole (F)	1.04	[0.80, 1.36]	0.78
	Times taking a bath [n/week]	Hydroxy Boscalid (F)	0.97	[0.91, 1.03]	0.29
		Hydroxy Tebuconazole (F)	0.98	[0.93, 1.04]	0.55
	Child helping on farm: Yes	Hydroxy Boscalid (F)	1.32	[0.50, 3.46]	0.57
		Hydroxy Tebuconazole (F)	0.88	[0.36, 2.18]	0.79
	Family member working on a conventional farm	Hydroxy Boscalid (F)	1.51	[0.86, 2.66]	0.15
		Hydroxy Tebuconazole (F)	1.43	[0.84, 2.43]	0.19
	Family member working on an IP farm	Hydroxy Boscalid (F)	0.80	[0.27, 2.40]	0.70
		Hydroxy Tebuconazole (F)	1.61	[0.58, 4.50]	0.36
	Family member working on an organic farm	Hydroxy Boscalid (F)	0.70	[0.35, 1.40]	0.32
		Hydroxy Tebuconazole (F)	0.89	[0.46, 1.69]	0.71

Table 16: Association between (a) pesticide exposure [ng/g] and (b) urinary biomarkers hydroxy boscalid (BOS-OH) and hydroxy tebuconazole (TEB-OH) [ng/ml], with self-reported respiratory symptoms. Odds ratio and 95% confidence intervals of the effect of principal components from pesticide exposures on respiratory symptoms either last week. The models were adjusted for school, assessment phase, income, $PM_{2.5}$ and pollen. Observations pesticides (n = 695), children (n = 191); Observations biomarkers (n = 635), children (n = 189). LOD = Limit of Detection.

Source and Unit	Pesticide	Concentration	OR	95% CI	p-value
Wristbands [ng/g]	Ametoctradin (F)	≥ LOD	1.10	[0.40, 3.00]	0.85
		> Median	0.82	[0.24, 2.79]	0.76
	Cyprodinil (F)	≥ LOD	0.93	[0.46, 1.84]	0.83
		> Median	1.15	[0.48, 2.76]	0.75
	Dimethomorph (F)	≥ LOD	0.66	[0.25, 1.78]	0.41
		> Median	0.66	[0.22, 2.01]	0.46
	Imazalil (F)	≥ LOD	0.37	[0.13, 1.07]	0.065
		> Median	0.78	[0.33, 1.83]	0.57
	Metalaxyl (F)	≥ LOD	0.83	[0.35, 1.94]	0.66
		> Median	1.13	[0.44, 2.89]	0.81
	Propiconazole (F)	≥ LOD	0.80	[0.40, 1.60]	0.52
		> Median	0.50	[0.22, 1.13]	0.094

(a) Pesticides measured in wristbands

Source and Unit	Pesticide	OR	95% CI	p-value
Urine [ng/ml]	BOS-OH (F)	1.17	[0.68, 2.00]	0.57
	TEB-OH (F)	0.99	[0.57, 1.71]	0.98

(b) Pesticide biomarkers measured in urine

Table 17: Association between (a) pesticide exposure [ng/g] and (b) urinary biomarkers hydroxy boscalid (BOS-OH) and hydroxy tebuconazole (TEB-OH) [ng/ml], and lung function parameters. Presented as β-estimates and 95% confidence intervals (CI)**.** All models were corrected for lung function value measured at day 1 baseline, assessment phase, school, puberty, fieldworker, and physical activity, presence of cold-like symptoms, parental smoking, $PM_{2.5}$, and pollen concentration.

Source [Unit]	Pesticide	Lung function parameter	Concentration	β	95% CI	p-value
Wristbands [ng/g]	Ametoctradin (F)	FEV1 [L]	≥ LOD	-0.02	[-0.37;0.32]	0.89
			> Median	0.13	[-0.32;0.58]	0.56
		FVC [L]	≥ LOD	0.11	[-0.22;0.45]	0.51
			> Median	0.50	[0.07;0.94]	0.02
		FEV1/FVC	≥ LOD	-0.15	[-0.55;0.25]	0.46
			> Median	-0.38	[-0.90;0.14]	0.15
		PEF [L/s]	≥ LOD	-0.03	[-0.33;0.27]	0.83
			> Median	-0.04	[-0.43;0.35]	0.85
		FEF25-75 [L/s]	≥ LOD	0.09	[-0.19;0.37]	0.52
			> Median	0.12	[-0.24;0.49]	0.51
	Cyprodinil (F)	FEV1 [L]	≥ LOD	-0.01	[-0.24;0.23]	0.96
			> Median	-0.14	[-0.46;0.18]	0.38
		FVC [L]	≥ LOD	-0.03	[-0.26;0.20]	0.81
			> Median	0.00	[-0.29;0.30]	0.99
		FEV1/FVC	≥ LOD	0.13	[-0.14;0.40]	0.33
			> Median	0.01	[-0.34;0.36]	0.96
		PEF [L/s]	≥ LOD	-0.15	[-0.36;0.06]	0.17
			> Median	-0.16	[-0.43;0.12]	0.27
		FEF25-75 [L/s]	≥ LOD	-0.07	[-0.27;0.12]	0.45
			> Median	-0.06	[-0.32;0.20]	0.64
	Dimethomorph (F)	FEV1 [L]	≥ LOD	0.09	[-0.25;0.43]	0.60
			> Median	0.15	[-0.25;0.54]	0.47
		FVC [L]	≥ LOD	0.19	[-0.15;0.53]	0.28
			> Median	0.26	[-0.12;0.63]	0.18
		FEV1/FVC	≥ LOD	-0.12	[-0.52;0.27]	0.54
			> Median	-0.10	[-0.55;0.35]	0.66
		PEF [L/s]	≥ LOD	0.11	[-0.18;0.41]	0.45
			> Median	0.17	[-0.17;0.51]	0.33
		FEF25-75 [L/s]	≥ LOD	0.01	[-0.26;0.29]	0.94
			> Median	0.03	[-0.29;0.35]	0.84
	Imazalil (F)	FEV1 [L]	≥ LOD	-0.12	[-0.42;0.18]	0.43
			> Median	0.03	[-0.25;0.30]	0.86
		FVC [L]	≥ LOD	0.29	[-0.00;0.59]	0.05
			> Median	0.23	[-0.04;0.51]	0.10
		FEV1/FVC	≥ LOD	-0.42	[-0.77;-0.07]	0.02
			> Median	-0.11	[-0.43;0.20]	0.48
		PEF [L/s]	≥ LOD	-0.19	[-0.45;0.07]	0.15
			> Median	-0.10	[-0.34;0.14]	0.39
		FEF25-75 [L/s]	≥ LOD	-0.12	[-0.36;0.12]	0.32
			> Median	0.02	[-0.20;0.25]	0.83
	Metalaxyl (F)	FEV1 [L]	≥ LOD	-0.25	[-0.57;0.06]	0.11
			> Median	0.02	[-0.31;0.35]	0.91
		FVC [L]	≥ LOD	0.04	[-0.28;0.35]	0.82
			> Median	0.32	[-0.00;0.64]	0.05
		FEV1/FVC	≥ LOD	-0.12	[-0.49;0.26]	0.54
			> Median	-0.25	[-0.62;0.12]	0.19
		PEF [L/s]	≥ LOD	-0.12	[-0.39;0.15]	0.38
			> Median	-0.04	[-0.33;0.24]	0.76

Source [Unit]	Pesticide	Lung function parameter	Concentration	β	95% CI	p-value
		FEF25-75 [L/s]	≥ LOD	-0.30	[-0.55;-0.05]	0.02
			> Median	-0.11	[-0.38;0.16]	0.43
	Propiconazole (F)	FEV1 [L]	≥ LOD	0.10	[-0.14;0.35]	0.41
			> Median	-0.07	[-0.34;0.20]	0.61
		FVC [L]	≥ LOD	-0.25	[-0.49;-0.01]	0.04
			> Median	-0.18	[-0.46;0.11]	0.22
		FEV1/FVC	≥ LOD	0.43	[0.16;0.70]	0.0022
			> Median	0.29	[-0.03;0.60]	0.07
		PEF [L/s]	≥ LOD	0.01	[-0.21;0.22]	0.96
			> Median	-0.15	[-0.39;0.09]	0.22
		FEF25-75 [L/s]	≥ LOD	0.17	[-0.03;0.37]	0.09
			> Median	0.04	[-0.19;0.26]	0.75

(a) Pesticides measured in wristbands

Source [Unit]	Pesticide	Lung function value	β	95% CI	p-value
Urine [ng/ml]	BOS-OH (F)	FEV1 [L]	0.00	[-0.18;0.18]	0.98
		FVC [L]	-0.04	[-0.22;0.15]	0.69
		FEV1/FVC	-0.01	[-0.22;0.20]	0.91
		PEF [L/s]	0.03	[-0.13;0.18]	0.74
		FEF25-75 [L/s]	0.02	[-0.13;0.17]	0.75
	TEB-OH (F)	FEV1 [L]	-0.13	[-0.32;0.06]	0.17
		FVC [L]	-0.05	[-0.23;0.13]	0.60
		FEV1/FVC	-0.17	[-0.37;0.04]	0.12
		PEF [L/s]	-0.13	[-0.29;0.04]	0.14
		FEF25-75 [L/s]	-0.13	[-0.28;0.02]	0.10

(c) Pesticide biomarkers measured in urine

FEV1: Observations pesticides (n=488), children (n=153); Observations biomarker (n=450), children (n=152)

FVC: Observations pesticides (n=429), children (n=139); Observations biomarker (n=396), children (n=136)

FEV1/FVC: Observations pesticides (n=363), children (n=125); Observations biomarker (n=333), children (n=122)

PEF: Observations pesticides (n=488), children (n=153); Observations biomarker (n=450), children (n=152)

FEF: Observations pesticides (n=562), children (n=167); Observations biomarker (n=519), children (n=166)

Table 18: Overall median and IQR summary statistics for shortest distance and proportion of the total area across all buffer zones for each type of land use.

Variable		median (IQR)
n children		205
Shortest distance [m] to	any agriculture	33.8 (43.4)
	any vineyard or fruit orchard	45.8 (80.1)
	any vineyards	64.2 (134.9)
	any fruit orchards	216.5 (421.5)
	conventional vineyards	69.9 (130.5)
	organic vineyards	243.5 (404.0)
	conventional fruit orchards	216.5 (421.5)
	organic fruit orchards	892.5 (1692.7)
Area [%] of any agricultural land in	a 50 m buffer	5.4 (21.5)
	a 250 m buffer	20.4 (22.6)
	a 500 m buffer	27.2 (24.3)
	a 1000 m buffer	37.8 (14.6)
Area [%] of any vineyard or fruit orchard in	a 50 m buffer	0.3 (14.2)
	a 250 m buffer	13.0 (25.9)
	a 500 m buffer	21.7 (30.5)
	a 1000 m buffer	30.4 (17.7)
Area [%] of any vineyards in	a 50 m buffer	0.0 (9.4)
	a 250 m buffer	8.1 (24.7)
	a 500 m buffer	14.7 (32.1)
	a 1000 m buffer	13.7 (30.5)
Area [%] of any fruit orchards in	a 50 m buffer	0.0 (0.0)
	a 250 m buffer	0.2 (2.0)
	a 500 m buffer	0.1 (6.8)
	a 1000 m buffer	1.4 (14.6)
Area [%] of conventional vineyards in	a 50 m buffer	0.0 (8.2)
	a 250 m buffer	7.9 (20.6)
	a 500 m buffer	12.8 (26.9)
	a 1000 m buffer	13.2 (23.2)
Area [%] of organic vineyards in	a 50 m buffer	0.0 (0.0)
	a 250 m buffer	0.0 (4.1)
	a 500 m buffer	0.8 (5.3)
	a 1000 m buffer	0.8 (5.5)
Area [%] of conventional fruit orchards in	a 50 m buffer	0.0 (0.0)
	a 250 m buffer	0.2 (1.6)
	a 500 m buffer	0.1 (6.8)
	a 1000 m buffer	1.4 (13.6)
Area [%] of organic fruit orchards in	a 50 m buffer	0.0 (0.0)
	a 250 m buffer	0.0 (0.0)
	a 500 m buffer	0.0 (0.0)
	a 1000 m buffer	0.0 (1.2)

Table 19: Overall median and IQR summary statistics for pesticides detected in stationary wristband placed at the schools stratified by assessment. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

Pesticide	Phase	> LOD (%)	Median	IQR	Max.
Ametoctradin	B	0.0	< LOD	0.00	0.00
	A1	0.0	< LOD	0.00	0.00
	A2	0.0	< LOD	0.00	0.00
	A3	50.0	3.30	3.30	6.59
	Overall	9.1	< LOD	0.00	6.59
Cyflufenamide	B	0.0	< LOD	0.00	0.00
	A1	0.0	< LOD	0.00	0.00
	A2	0.0	< LOD	0.00	0.00
	A3	50.0	0.52	0.52	1.04
	Overall	9.1	< LOD	0.00	1.04
Cyprodinil	B	0.0	< LOD	0.00	0.00
	A1	33.3	< LOD	2.93	5.85
	A2	0.0	< LOD	0.00	0.00
	A3	0.0	< LOD	0.00	0.00
	Overall	9.1	< LOD	0.00	5.85
Dimethomorph	B	0.0	< LOD	0.00	0.00
	A1	0.0	< LOD	0.00	0.00
	A2	0.0	< LOD	0.00	0.00
	A3	50.0	2.51	2.51	5.03
	Overall	9.1	< LOD	0.00	5.03
Diuron	B	0.0	< LOD	0.00	0.00
	A1	33.3	< LOD	2.37	4.75
	A2	0.0	< LOD	0.00	0.00
	A3	0.0	< LOD	0.00	0.00
	Overall	9.1	< LOD	0.00	4.75
Metalaxyl	B	0.0	< LOD	0.00	0.00
	A1	0.0	< LOD	0.00	0.00
	A2	66.7	5.44	3.79	7.58
	A3	50.0	0.99	0.99	1.99
	Overall	27.3	< LOD	0.99	7.58
Other	Overall	0.0	< LOD	0.00	0.00

Table 20: Fungicides included in the further analysis to study reasons for airborne pesticide exposure and possible associations with acute respiratory outcomes. W = measured in children's and stationary wristbands, u = measured in urine.

Fungicides further analysis is focusing on	Allowed in vineyards	Allowed in fruit orchards	Remarks
Ametoctradin (w)	yes	no	Usually combined with **Dimethomorph** against mildew.
Dimethomorph (w)	yes	no	Usually combined with **Ametoctradin** against mildew. Scheduled to be banned in Switzerland starting January 2025.
Cyprodinil (w)	yes	yes	It is effective against diseases like scab in fruit trees and Botrytis in vines.
Metalaxyl (w)	yes	no	Against powdery mildew and botrytis.
Imazalil (w)	no	no	Registered for use in potatoes and greenhouse tomatoes in Switzerland. Commonly used to preserve citrus fruits abroad.
Propiconazole (w)	banned in CH	banned in CH	Removed from the market in 2020, use allowed until 2022. Residues may still remain in the environment, and leftover stock might still be in use, such as on sport fields
Hydroxy boscalid (u)	yes	yes	Commonly used to combat fungal diseases such as powdery mildew and downy mildew
Hydroxy tebuconazole (u)	yes	yes	Commonly used to combat fungal diseases such as powdery mildew and botrytis

Table 21: The mean and standard deviation (SD) of the type of pesticide detected per child above the detection frequency (%) on individual compared to stationary wristbands, overall and stratified by pesticide type and assessment phase. In total, 372 wristbands (individual 195, and stationary 177) were collected from 51 children, and targeted for 81 pesticides. B = Baseline (January), A1 = Assessment 1 (April/May), A2 = Assessment 2 (May/June) and A3 = Assessment 3 (June).

Pesticide	Assessment phase	Mean (SD)		Min.		Max.	
		Ind.	Stat.	Ind.	Stat.	Ind.	Stat.
Any	A1	2.63 (2.09)	0.59 (0.58)	0	0	9	2
	A2	4.59 (2.83)	1.60 (1.44)	0	0	14	5
	A3	5.44 (2.13)	2.34 (1.88)	0	0	10	6
	B	1.47 (1.44)	0.00 (0.00)	0	0	7	0
	Overall	13.47 (6.54)	4.00 (2.91)	1	0	32	11
Fungicide	A1	1.84 (1.37)	0.55 (0.50)	0	0	6	1
	A2	3.49 (2.03)	1.47 (1.40)	0	0	9	5
	A3	4.88 (1.79)	2.32 (1.84)	0	0	9	6
	B	1.41 (1.34)	0.00 (0.00)	0	0	6	0
	Overall	11.06 (4.99)	3.82 (2.78)	1	0	25	11
Herbicide	A1	0.73 (0.86)	0.02 (0.15)	0	0	3	1
	A2	0.67 (0.77)	0.04 (0.20)	0	0	3	1
	A3	0.50 (0.65)	0.02 (0.15)	0	0	2	1
	B	0.04 (0.20)	0.00 (0.00)	0	0	1	0
	Overall	1.86 (1.63)	0.08 (0.44)	0	0	7	3
Insecticide	A1	0.06 (0.24)	0.02 (0.15)	0	0	1	1
	A2	0.43 (0.65)	0.09 (0.28)	0	0	2	1
	A3	0.06 (0.24)	0.00 (0.00)	0	0	1	0
	B	0.02 (0.14)	0.00 (0.00)	0	0	1	0
	Overall	0.55 (0.86)	0.10 (0.36)	0	0	4	2

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Exposure to Pesticides by Air and Respiratory Health in School Children in VALais, Switzerland (PARVAL)

Supplementary Information 3

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Variable Names	Specification	Description	Reference
Pesticides targeted in the PARVAL study		Out of 147 pesticides with potential respiratory-irritating effects, 83 were targeted using wristband and urine (yes) analyses, and 38 were detected in the samples.	
Pesticides detected in the PARVAL study		38 pesticides were detected in the wristband and urine samples (yes).	
Pesticide		Name of Pesticides according to PPDB-Database[1]	Lewis et al.
Pesticide Type		Type of Pesticide (eg Insecticide, Fungicide, Herbicide) according to PPDB-Database	Lewis et al.
Chemical Formula		Chemical Formula of Pesticide according to PPDB-Database	Lewis et al.
Pesticide Chemical Class		Chemical Class of Pesticide according to PPBD-Database	Lewis et al.
Origin (Natural/Synthetic)		Is the Pesticide of Natural or Synthetic Origin according to PPDB-Database	Lewis et al.
EU Approved		Is the Pesticide approved for use in EU under EC1107-2009	Lewis et al.
Sales CH 2020 (tons)		Sales Volume per Pesticide in Switzerland in 2020, in tons	BLW Switzerland 1
Sales CH 2023 (tons)		Sales Volume per Pesticide in Switzerland in 2023, in tons	BLW Switzerland 1
is the pesticide classified as organic		Is the pesticide classified as "organic" according to FiBL	Betriebsmittelliste FIBL, 2024
Detected in Rain		Was the pesticide detected in rain samples?. n.t. refers to not detected The unit represents the amount of pesticide (in nanograms) detected in the number of samples (n) analyzed.	Carbotech AG, Basel
Detected in Air		Was the pesticide detected in air samples?. n.t. refers to not detected. The unit represents the amount of pesticide (in nanograms) detected in the number of samples (n) analyzed.	Carbotech AG, Basel
Detected in HBM4EU		Was the pesticide detected in Swiss participants of the Human Biomonitoring study (HBM4EU)	Ottenbros & Amman et al.
Action Plan		Is the pesticide classified as a plant protection product with special risk potential according to Annex 9 of the Plant Protection Products Action Plan (updated 01.01.2025)	BLW Switzerland 2
NAWA		Was the pesticide detected in the National monitoring of surface water qualiy program (NAWA) in Switzerland.	BAFU Switzerland
Respiratory Tract irritant		Is the Pesticide classified as a Respiratory Tract Irritant, according to PPDB-Database	Lewis et al.
Neurotoxicant		Is the Pesticide classified as a Neurotoxicant, according to PPDB-Database	Lewis et al.
Endocrine disruptor		Is the Pesticide classified as an Endocrine Disruptor, according to PPDB-Database	Lewis et al.
Allowed on vineyards in 2023		Is the Pesticide allowed to be applied on Vineyards in Switzerland, in 2023	Index des Produits Phytosanitaires, OSAV
Allowed on fruit trees in 2023		Is the Pesticide allowed to be applied on Fruit Orchards in Switzerland, in 2023	Index des Produits Phytosanitaires, OSAV
Allowed to be applied by Helicopter		Is the Pesticide allowed to be sprayed by Helicopter in Switzerland	Agroscope 2022
Pesticides included in Wristband Analysis		Pesticides marked as 'yes' in this category represent the finalized list of pesticides that have been analyzed in the wristbands.	-
Method for Pesticides included in Wristband Analysis (LC or GC)		This category indicates whether the pesticides have been or will be analyzed using LC-MS.	-
Pesticides included in Urine Analysis: status of analyis		Pesticides in this category represent the finalized list of targeted pesticides for analysis in urine. The information shows the status of the analysis (yes = analyzed)	-
Wristbands Children ≥ LOD[2] (%))	Overall Phase B Phase A1 Phase A2 Phase A3	Amount of children's wristbands in which the specific pesticide was detected above the LOD[2], along with the percentage of all wristbands (n (%)). The 'Overall' category includes all assessment phases, and Phase B, A1-A3 refer to the Baseline Phase (January/February 2024), Assessment 1 (April/May 2024), Assessment 2 (April/May 2024), and Assessment 3 (June 2024).	-
Wristbands Stationary ≥ LOD[2] (%))	Overall Phase A1 Phase A2 Phase A3	Amount of stationary wristbands in which the specific pesticide was detected above the LOD[2], along with the percentage of all stationary wristbands (n (%)). The 'Overall' category includes all assessment phases, and Phase B, A1-A3 refer to the Baseline Phase (January/February 2024), Assessment 1 (April/May 2024), Assessment 2 (April/May 2024), and Assessment 3 (June 2024).	-
Urine Children ≥ LOD[2] (%))	Overall Phase A1 Phase A2 Phase A3	Amount of urine samples in which the specific pesticide was detected above the LOD[2], along with the percentage of all urine samples (n (%)). The 'Overall' category includes all assessment phases, and Phase B, A1-A3 refer to the Baseline Phase (January/February 2024), Assessment 1 (April/May 2024), Assessment 2 (April/May 2024), and Assessment 3 (June 2024).	-

[1] PPDB = Pesticide Properties Database
[2] LOD = Limit of Detection

Inclusion		Pesticide Characteristics						Use in agriculture						Detected in Other Studies					Possible Health Effects			Measurements																
																								Wristbands Children ≥ LOD (%)					Wristbands Stationary ≥ LOD (%)					Urine Children ≥ LOD (%)				
Pesticides targeted in the PARVAL study	Pesticides detected in the PARVAL study	Pesticide	Pesticide Type	Pesticide Chemical Class	Origin (Natural/Synthetic)	organic	Half Life in Soil [d]	EU Approved	Sales CH 2020 (t)	Sales CH 2023 (t)	Allowed on vineyards in 2023	Allowed on fruit trees in 2023	Allowed to be applied by Helicopter	Detected in Rain	Detected in Air	Detected in HBM 4EU	Swiss Action Plan	NAWA	Respiratory tract irritant	Neurotoxicant	Endocrine distrupter	Method for Pesticides included in Wristband Analysis (LC or GC)	Pesticides included in Urine Analysis: status of analysis	Overall	Phase B	Phase A1	Phase A2	Phase A3	Overall	Phase B	Phase A1	Phase A2	Phase A3	Overall	Phase B	Phase A1	Phase A2	Phase A3
yes	yes	cyprodinil	Fungicide	Anilinopyrimidine : Aminopyrimidine	Synthetic		37	Approved	4.57	4.54	yes	yes	yes	1300	4200	x	x	x	Yes	No	No data	LC		61.7	30	86	77	53	15	0	57	4	2					
yes	yes	dimethomorph	Fungicide	Morpholine	Synthetic		73	Approved	1.62	3.01	yes	no		170	n.t.				Yes	No	No data	LC		36.4	4	3	43	97	14	0	0	15	41					
yes	yes	propiconazole	Fungicide	Triazole : Conazole	Synthetic		72	Not approved	0.65	lowed anymore				660	n.t.				Yes	No data	Yes	LC		35.0	22	43	41	34	1	0	0	0	2					
yes	yes	ametoctradin	Fungicide	Triazolopyrimidine	Synthetic		2	Approved	1.09	2.40	yes	no		n.t.	n.t.	x			No data	No	No	LC		34.6	5	3	33	98	17	0	0	15	52					
yes	yes	metalaxyl-M	Fungicide	Anilide : Acylamino acid	Synthetic		7	Approved	2.31	1.73	yes	no	yes	600	2200				No data	No	No data	LC		32.1	0	3	60	67	34	0	0	68	64					
yes	yes	azoxystrobin	Fungicide	Strobilurin	Synthetic		78	Approved	5.56	5.21	yes	yes	yes	140	n.t.			x	No data	No	No data	LC		27.1	27	32	21	29	0	0	0	0	0					
yes	yes	imazalil	Fungicide, Veterinary substa	Imidazole : Conazole	Synthetic		76	Approved	0.00	0.00				n.t.	n.t.	x			Yes	No	Yes	LC		23.9	47	24	12	12	0	0	0	0	0					
yes	yes	pendimethalin	Herbicide	Dinitroaniline	Synthetic		182	Approved	24.85	41.26	no	no		150	n.t.		x		Yes	No	Possible	LC		21.0	0	28	24	31	0	0	0	0	0					
yes	yes	diuron	Herbicide	Phenylurea : Urea	Synthetic		147	Not approved	1.36	lowed anymore				480	410				Yes	No	Yes	LC		18.0	7	29	20	16	2	0	2	2	2					
yes	yes	penconazole	Fungicide	Triazole : Conazole	Synthetic		117	Approved	0.69	0.48	yes	yes	yes	220	120	x			No data	No	Yes	LC		14.9	1	5	24	30	13	0	0	28	23					
yes	yes	spirotetramat	Insecticide	Tetramic acid	Synthetic		0	Approved	1.01	1.05	yes	yes		n.t.	n.t.				Possible	No	No	LC		10.9	1	6	31	7	2	0	0	9	0					
yes	yes	cyflufenamid	Fungicide	Amide	Synthetic		34	Approved	0.25	0.39	yes	yes	yes	n.t.	n.t.				No data	No data	No data	LC		9.3	1	1	4	32	11	0	0	6	39					
yes	yes	fenpyroximate	Acaricide, Insecticide	Pyrazolium	Synthetic			Approved	0.09	0.08	yes	yes		n.t.	n.t.				No data	No	No data	LC		5.9	1	7	14	3	1	0	2	0	0					
yes	yes	terbuthylazine	Herbicide, Microbiocide, Alg	Triazine : Methoxytriazine	Synthetic		72	Approved	13.99	0.49				930	2700				Yes	No data	No data	LC		4.9	0	8	7	5	0	0	0	0	0					
yes	yes	fluazinam	Fungicide, Acaricide	Chloropyridine	Synthetic		124	Approved	5.11	7.03	yes	no		n.t.	n.t.				No data	No	Possible	LC		4.8	0	1	16	3	2	0	0	9	0					
yes	yes	fluxapyroxad	Fungicide	Pyrazolecarboximide	Synthetic		183	Approved	2.41	2.98	yes	yes	yes	n.t.	n.t.		x		No data	No	No data	LC		4.0	0	4	8	4	1	0	0	0	5					
yes	yes	fluopyram	Fungicide, Nematicide	nematicide	Synthetic		309	Approved	1.95	2.92	yes	yes	yes	n.t.	n.t.				No data	Possible	No data	LC		2.4	1	1	3	5	0	0	0	0	0					
yes	yes	mecoprop-P	Herbicide	Phenoxypropionic	Synthetic		5	Approved	13.19	5.70	no	yes		51	78				Yes	No	No	LC		2.3	1	3	4	2	0	0	0	0	0					
yes	yes	MCPA	Herbicide, Metabolite	Aryloxyalkanoic acid : Phenoxyacetic	Synthetic		12	Approved	7.53	6.80	no	no		no	no			x	Possible	No	No	LC		1.5	0	2	2	3	0	0	0	0	0					
yes	yes	2,4-D	Herbicide, Plant growth regu	Phenoxyacetic : Auxin PGR	Synthetic		4	Approved	8.57	5.79	no	yes		n.t.	23	x			Yes	Yes	Yes	LC		1.3	0	2	3	1	0	0	0	0	0					
yes	yes	bupirimate	Fungicide	Pyrimidine	Synthetic		79	Approved	0.51	1.42	yes	yes	yes	1	n.t.				No data	No	Yes	LC		1.0	0	1	2	2	0	0	0	0	0					
yes	yes	proquinazid	Fungicide	Organoiodide compound	Synthetic		45	Approved	0.36	0.46	yes	no	yes	n.t.	n.t.				No data	No data	No data	LC		0.9	1	1	1	2	1	0	0	2	2					
yes	yes	prochloraz	Fungicide	Amide : Conazole	Synthetic		120	Not approved	1.50	0				n.t.	n.t.				No data	Possible	Yes	LC		0.8	2	0	1	1	0	0	0	0	0					
yes	yes	valifenalate	Fungicide	Acylamino acid	Synthetic		0	Approved	0.05	0.04	yes	no	yes	n.t.	n.t.				No data	No	No	LC		0.6	0	0	0	3	0	0	0	0	0					
yes	yes	amisulbrom	Fungicide	Sulfonamide : Triazole	Synthetic		143	Approved	0.17	0.26	yes	no	yes	n.t.	n.t.				No data	No	No data	LC		0.4	0	0	0	2	1	0	0	0	2					
yes	yes	hexythiazox	Acaricide, Insecticide	: Thiazolidine acaricide: Thiazolidine	Synthetic		30	Approved	0.03	0.13	yes	yes		n.t.	n.t.				Yes	No	No data	LC		0.4	1	0	1	0	0	0	0	0	0					
yes	yes	pyraclostrobin	Fungicide	Phenylpyrazole	Synthetic		42	Approved	0.37	0.48	no	yes		n.t.	n.t.				Yes	No	No	LC		0.4	1	0	1	0	0	0	0	0	0					
yes	yes	clomazone	Herbicide	Oxazole	Synthetic		23	Approved	2.66	4.30				n.t.	n.t.				No data	No	No data	LC		0.3	0	0	0	1	0	0	0	0	0					
yes	yes	pymetrozine	Insecticide	Pyridine : Azomethine	Synthetic		5	Not approved	1.00	lowed anymore				n.t.	n.t.				Yes	No	No data	LC		0.3	0	0	1	0	0	0	0	0	0					
yes	yes	S-metolachlor	Herbicide	Chloroacetamide : Acetamide	Synthetic		52	Not approved	16.83	1.20				2500	810				Possible	No data	Yes	LC		0.3	0	1	0	1	0	0	0	0	0					
yes	yes	diflufenican	Herbicide	Carboxamide : Anilide : Pyridine	Synthetic		95	Approved	2.99	4.54	no	yes		n.t.	n.t.		x	x	Possible	No	No data	LC		0.1	0	1	0	0	0	0	0	0	0					
yes	yes	dimethenamid-P	Herbicide	Chloroacetamide : Amide	Synthetic		11	Approved	22.18	55.14				280	n.t.			x	Possible	No	No data	LC		0.1	0	0	0	1	0	0	0	0	0					
yes	yes	mepanipyrim	Fungicide, Other substance	Anilinopyrimidine	Synthetic		142	Approved	0.15	0.26	yes	yes		n.t.	n.t.				No data	No	Possible	LC		0.1	0	0	1	0	0	0	0	0	0					
yes	yes	paclobutrazol	Plant growth regulator; Fung	Triazole	Synthetic		112	Approved	0.32	0.33	no	no		n.t.	n.t.		x		Yes	No	No data	LC		0.13	0	0	1	0	0	0	0	0	0					
yes	yes	pencycuron	Fungicide	Phenylurea : Urea	Synthetic		82	Not approved	1.81	lowed anymore				n.t.	n.t.				Yes	No	No data	LC		0.1	1	0	0	0	0	0	0	0	0					
yes	yes	spiroxamine	Fungicide	Morpholine : Spiroketalamine	Synthetic		25	Approved	5.64	7.49	yes	no	yes	150	190			x	Yes	No	No data	LC		0.1	0	0	0	1	0	0	0	0	0					
yes	yes	prosulfocarb	Herbicide	Thiocarbamate : Carbamate	Synthetic		12	Approved	20.60	22.55				660	n.t.				Yes	No data	No data	LC		0.0	0	0	0	0	1	0	0	2	0					
yes		aminopyralid	Herbicide	Pyridine : Picolinic acid	Synthetic		35	Approved	0.13	0.14				n.t.	n.t.				Possible	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		asulam	Herbicide	Carbamate : Sulphonamide	Synthetic		3	Not approved	12.16	6.69	no	yes		n.t.	n.t.				Yes	No data	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		benzovindiflupyr	Fungicide	Amide : Pyrolecarboxamide	Synthetic		908	Approved	1.44	0.97				n.t.	n.t.		x		No data	No	No	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		bifenazate	Insecticide, Acaricide	Carbazate : Carbazate acaricide	Synthetic		1	Approved	0.05	0.05	no	no		n.t.	n.t.				No data	Possible	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		bixafen	Fungicide	Pyrazolecarboximide	Synthetic		500	Approved	1.72	1.61				n.t.	n.t.		x		No data	No data	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		clopyralid	Herbicide	Pyridine : Picolinic acid	Synthetic		23	Approved	1.21	1.21	no	no		n.t.	n.t.				Yes	No	No	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		cyproconazole	Fungicide	Conazole : Triazole	Synthetic		142	Not approved	0.70	lowed anymore				n.t.	n.t.				Yes	No	Yes	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		dazomet	Insecticide, Fungicide, Herbi	Dithiocarbamate : Carbamate :	Synthetic		1	Approved	10.13	2.59				n.t.	n.t.				Possible	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		dodine	Fungicide	Guanidine : Aliphatic nitrogen	Synthetic		5	Approved	0.09	1.09	no	yes		n.t.	n.t.				No data	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		ethofumesate	Herbicide	Benzofuranyl alkylsulfonate	Synthetic		22	Approved	6.07	2.23				39	n.t.			x	Possible	No	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		etofenprox	Insecticide	Pyrethroid : Pyrethrid ether	Synthetic		11	Approved	0.18	0.24				n.t.	n.t.				No data	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		fenamidone	Fungicide	Imidazole	Synthetic		7	Not approved	2.36	lowed anymore				n.t.	n.t.				No data	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		fenpropidin	Fungicide	Unclassified	Synthetic		90	Approved	6.92	4.04	yes	no		37	270				Possible	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		florasulam	Herbicide	Triazolopyrimidine : Sulfonanilide	Synthetic		2	Approved	0.18	0.20				n.t.	n.t.				Yes	No	No	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		fluazifop-P-butyl	Herbicide	Aryloxyphenoxypropionate	Synthetic		1	Approved	2.16	5.35	yes	yes		n.t.	n.t.	x			Possible	No	No	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		flufenacet	Herbicide	Anilide	Synthetic		20	Approved	7.89	7.40				110	17				Possible	No	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		flumioxazin	Herbicide	Dicarboximide	Synthetic		22	Approved	0.23	0.46	yes	no		n.t.	n.t.				Possible	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		flutolanil	Fungicide	Benzanilide	Synthetic		400	Approved	0.17	0.19				n.t.	n.t.				Possible	No data	No	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		foramsulfuron	Herbicide	Sulfonylurea	Synthetic		25	Approved	1.30	2.47				n.t.	n.t.			x	Yes	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		haloxyfop-P-methyl	Herbicide	Aryloxyphenoxypropionate	Synthetic		1	Not approved	0.33	lowed anymore				n.t.	n.t.				Possible	No	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		kresoxim-methyl	Fungicide, Bactericide	strobilurin	Synthetic		16	Approved	1.78	0.46	yes	yes	yes	250	n.t.				Yes	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		lenacil	Herbicide	Uracil	Synthetic		50	Approved	3.04	1.92				n.t.	n.t.		x		Yes	No	No	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		lufenuron	Insecticide, Acaricide, Veteri	Benzoylurea : Benzoylphenylurea	Synthetic		16	Not approved	0.00	lowed anymore				n.t.	n.t.				Yes	No	No	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		MCPB	Herbicide	Aryloxyalkanoic acid : Phenoxyacetic	Synthetic		4	Approved	10.44	8.80	no	no		n.t.	n.t.				Yes	No	No	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		metconazole	Fungicide	Triazole : Conazole	Synthetic		142	Approved	0.48	1.08				n.t.	n.t.		x		Yes	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		methomyl	Insecticide, Acaricide, Metab	Carbamate acaricide: Oxime	Synthetic		7	Not approved	0.05	lowed anymore				n.t.	n.t.			x	Yes	Possible	Yes	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		methoxyfenozide	Insecticide	Monomethoxybenzene compound	Synthetic		456	Approved	0.26	lowed anymore				83	n.t.		x	x	No data	No	Possible	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		metobromuron	Herbicide	compound	Synthetic		34	Approved	0.82	1.50				n.t.	n.t.				Yes	No data	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		metsulfuron-methyl	Herbicide	Sulfonylurea : Triazinylsulfonylurea	Synthetic		10	Approved	0.11	0.10				n.t.	n.t.		x		Yes	No	No	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		napropamide	Herbicide	Amide	Synthetic		70	Approved	16.00	9.62	no	no		36	n.t.				Yes	No	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		nicosulfuron	Herbicide	Pyrimidinylsulfonylurea	Synthetic		26	Approved	1.02	0.01				n.t.	n.t.		x	x	Yes	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		phenmedipham	Herbicide	Carbanilate	Synthetic		12	Approved	4.54	2.35				n.t.	n.t.				No data	No	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		propamocarb	Fungicide	Carbamate	Synthetic		14	Approved	1.15	1.01	no	no		340	no	x			No data	Possible	Yes	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		propaquizafop	Herbicide	Aryloxyphenoxypropionate	Synthetic		2	Approved	0.23	0.38	no	yes		n.t.	n.t.				No data	No	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		pyridate	Herbicide	Pyridazine	Synthetic		1	Approved	0.60	1.42				n.t.	n.t.				No data	Possible	Yes	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		quinmerac	Herbicide	Quinolinecarboxylic acid	Synthetic		30	Approved	1.05	4.42				no	no				No data	No data	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		quinoxyfen	Fungicide	Quinoline	Synthetic		308	Not approved	0.14	lowed anymore				n.t.	n.t.				No data	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		quizalofop-P-ethyl	Herbicide	Aryloxyphenoxypropionate	Synthetic		2	Approved	0.20	0.23	no	yes		n.t.	n.t.				No data	No data	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		spinetoram	Insecticide	Spinosyn	Synthetic		16	Approved	0.17	0.17	no	yes		n.t.	n.t.				No data	No	No	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		spirodiclofen	Acaricide, Insecticide	acid	Synthetic		7	Not approved	0.11	lowed anymore				n.t.	n.t.				No data	Possible	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
yes		tebufenozide	Insecticide	Carbohydrazide compound	Synthetic		400	Approved	0.58	0.03				n.t.	n.t.		x		No data	No data	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		tembotrione	Herbicide	Aroylcyclohexanedione	Synthetic		15	Approved	1.12	1.06				n.t.	n.t.		x		No data	No data	No data	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		thiophanate-methyl	Fungicide	Carbamate	Synthetic		1	Not approved	1.90	lowed anymore				n.t.	n.t.				Yes	No data	No	LC		0.00	0	0	0	0	0	0	0	0	0					
yes		triclopyr	Herbicide	Pyridine	Synthetic		19	Approved	3.26	2.45	no	no		n.t.	n.t.				No data	No	No data	LC		0.0	0	0	0	0	0	0	0	0	0					
no		1-decanol	Plant growth regulator, Woo	Unclassified pesticide	Natural			Approved	1.98	2.96				n.t.	n.t.				Possible	No	No																	
no		1-naphthylacetic acid	Plant growth regulator	Auxin PGR: Naphthalene compound	Synthetic		42	Approved	0.06	0.05	no	yes		n.t.	n.t.				Yes	No data	No																	
no		acibenzolar-S-methyl	Fungicide, Plant activator	activator	Synthetic		0	Approved	0.07	0.07	no	yes		n.t.	n.t.				Yes	No	No data																	
no		alpha-cypermethrin	Insecticide, Veterinary subst	Pyrethroid	Synthetic		23	Not approved	0.04	lowed anymore				n.t.	n.t.				Yes	Possible	Yes																	
no		aluminium phosphide	Insecticide, Rodenticide	Inorganic compound	Natural		0	Approved	1.99	1.89	yes	no		n.t.	n.t.				Possible	Possible	No data																	
no		aluminium sulphate	Molluscicide, Bactericide	Inorganic compound	Synthetic		1,000	Approved	29.89	20.69	yes	yes							Yes	Possible	No data																	
no		benzoic acid	Insecticide, Fungicide, Antim	Aromatic carboxylic acid pesticide	Synthetic		1	Approved	0.86	2.52				n.t.	n.t.				Yes	No	No																	
no		bifenthrin	Insecticide, Acaricide	Pyrethroid ester	Synthetic		26	Not approved	0.12	lowed anymore				n.t.	n.t.				No data	Yes	Yes																	
yes	yes	boscalid	Fungicide	Carboxamide : Anilide : Pyridine	Synthetic		484	Approved	1.95	2.01	yes	yes		94		x		x	No	No	No		yes											91.89	85.9	93	95.2	93.7
no		calcium carbonate	Herbicide, Fungicide, Microb	Inorganic compound	Natural	yes		Approved	4.47	3.92	no			n.t.	n.t.				Yes	No	No																	
no		calcium phosphide	Rodenticide	emitter: Fumigant rodenticide	Synthetic		0	Not approved	0.62	lowed anymore				n.t.	n.t.				Yes	No data	No data																	
no		captan	Fungicide, Bactericide	Phthalimide	Synthetic		1	Approved	43.66	26.06	no	yes	yes	n.t.	n.t.				Yes	No	Yes																	
no		chlormequat	Plant growth regulator	Quaternary ammonium compound	Synthetic		27	Approved	9.10	6.16	no	yes		n.t.	n.t.				Yes	Possible	No data																	
no		cloquintocet-mexyl	Other substance	Unclassified pesticide	Synthetic		5	thorised at n	0.68	0.55				n.t.	n.t.				No data	No	No data																	
no		copper (II) hydroxide	Fungicide, Bactericide	Inorganic compound	Natural (but	yes	10,000	Approved	24.28	14.51	yes	yes	yes	n.t.	n.t.				Yes	No	No																	
no		copper oxychloride	Fungicide, Repellent	Inorganic compound	Natural	yes	10,000	Approved	22.59	13.01	yes	yes	yes	n.t.	n.t.				Possible	No data	Possible																	
no		copper sulphate	Fungicide, Algicide, Bacteric	Inorganic compound	Natural	yes	10,000	Approved	4.65	4.66	yes	yes	yes	n.t.	n.t.				Possible	No	No																	
no		cypermethrin	Insecticide, Acaricide, Veteri	Pyrethroid ester : Pyrethroid ester	Synthetic		22	Approved	0.62	0.20	no	no		n.t.	n.t.	x	x		Yes	Possible	Yes																	
no		daminozide	Plant growth regulator	Unclassified pesticide	Synthetic		0	Approved	0.37	0.29				n.t.	n.t.				Yes	Possible	No																	
no		dicamba	Herbicide, Plant growth regu	Benzoic acid : Benzoic acid PGR	Synthetic		10	Approved	8.10	6.07	no	no		n.t.	n.t.			x	Possible	No data	No data																	
no		dimethachlor	Herbicide	Chloroacetamide	Synthetic		7	Approved	6.87	0				98	63		x	x	Yes	No	No																	
no		diquat	Herbicide	Quaternary ammonium	Synthetic		2,345	Not approved	12.12	lowed anymore				n.t.	n.t.				Yes	No	No data																	
no		dithianon	Fungicide	Quinone	Synthetic		11	Approved	11.19	11.63	yes	yes		n.t.	n.t.				No data	No	No data																	
no		ethephon	Plant growth regulator	Ethylene emitter	Synthetic		13	Approved	7.10	7.75	no	yes		n.t.	n.t.				Yes	Yes	No data																	
no		fatty acids (generic)	Herbicide, Insecticide, Fungi	derived pesticide	Natural	yes	3	Not approved	48.53	59.52	no	no		n.t.	n.t.				Yes	No	No																	
no		fenoxaprop-P-ethyl	Herbicide	Aryloxyphenoxypropionate	Synthetic		0	Approved	0.64	0.22				n.t.	n.t.				Yes	Possible	No																	
no		fenpyrazamine	Fungicide	Pyrazolium	Synthetic		100	Approved	0.47	0.63	yes	yes	yes	n.t.	n.t.				No data	Possible	No																	
no		ferric phosphate	Molluscicide	Inorganic compound	Synthetic		5	Approved	1.61	1.50	yes	no		n.t.	n.t.				No data	No	No data																	
no		flazasulfuron	Herbicide	Sulfonylurea : Pyrimidinylsulfonylurea	Synthetic		41	Approved	0.07	0.16	yes	no		n.t.	n.t.				Yes	No	No data																	
no		flurochloridone	Herbicide	Organofluoride	Synthetic		53	Approved	0.04	lowed anymore				n.t.	n.t.		x		Yes	No data	Yes																	
no		folpet	Fungicide	Phthalimide	Synthetic		5	Approved	78.34	68.18	yes	yes	yes	n.t.	n.t.				Possible	No	No																	
no		fosetyl	Fungicide	Organophosphate	Synthetic		0	Approved	23.51	23.07	yes	yes	yes	n.t.	n.t.				Yes	Possible	No data																	
no		imazamox	Herbicide	Imidazolinone	Synthetic		200	Approved	0.14	0.20				n.t.	n.t.		x		No data	Possible	No data																	
no		iodosulfuron-methyl-sodium	Herbicide	Triazinylsulfonylurea : Sulfonylurea	Synthetic		3	Approved	0.24	0.20				n.t.	n.t.				Yes	Yes	No data																	
no		isoxadifen ethyl	Other substance	Unclassified	Synthetic			Not approved	0.60	1.11				n.t.	n.t.				No data	No	No data																	
no		kaolin	Insecticide, Repellent, Other	Inorganic compound	Natural	yes	1,000	Approved	17.69	15.18	yes	yes		n.t.	n.t.				Possible	No	No																	
no		lambda-cyhalothrin	Insecticide	Pyrethroid : Pyrethroid ester	Synthetic		175	Approved	0.83	1.33	yes	yes		n.t.	n.t.		x	x	Yes	Possible	No																	
no		magnesium phosphide	Insecticide, Rodenticide	Inorganic compound	Synthetic		0	Approved	0.07	0.04				n.t.	n.t.				Yes	No	No data																	
no		maleic hydrazide	Plant growth regulator, Herb	Pyridazine PGR	Synthetic		1	Approved	5.68	3.80	no	no		n.t.	n.t.				Yes	Yes	No																	
no		maltodextrin	Insecticide, Other substance	Polysaccharide	Synthetic		5	Approved	5.04	9.74	no	yes		n.t.	n.t.				Yes	No	No																	
no		mancozeb	Fungicide, Insecticide	Organometal : Organozinc	Synthetic		0	Not approved	89.00	0.01				n.t.	n.t.				Yes	No	Yes																	
no		mefenpyr diethyl	Other substance	Unclassified	Synthetic		18	thorised at n	1.19	0.99				n.t.	n.t.				Yes	No	No																	
no		mepiquat	Plant growth regulator, Herb	Quaternary ammonium PGR	Synthetic			Approved	3.40	3.82				n.t.	n.t.				Possible	No	No data																	
no		mesosulfuron-methyl	Herbicide	Sulfonylurea : Pirimidinylsulfonylurea	Synthetic		44	Approved	0.30	0.27				n.t.	n.t.				Yes	Possible	No																	
no		mesotrione	Herbicide	Aroylcyclohexanedione	Synthetic		20	Approved	1.70	2.25				n.t.	n.t.				No data	Yes	No																	
no		pelargonic acid	Herbicide, Plant growth regu	Plant derived substance	Natural		1	Approved	29.74	38.28	yes	yes		n.t.	n.t.				No data	No data	No data																	
no		pethoxamid	Herbicide	Chloroacetamide : Amide	Synthetic		6	Approved	6.52	9.19				n.t.	n.t.				No data	No	No																	
no		picloram	Herbicide	Pyridine : Picolinic acid	Synthetic		83	Approved	0.01	0.02				n.t.	n.t.				Yes	No	Yes																	
no		pinoxaden	Herbicide	Phenylpyrazole	Synthetic		1	Approved	0.72	0.96				n.t.	n.t.				Yes	No	Yes																	
no		potassium bicarbonate	Fungicide	Inorganic compound	Natural			Approved	30.41	73.20	yes	yes	yes	n.t.	n.t.				Possible	No data	No data																	
no		potassium phosphonates	Fungicide	Inorganic compound	Synthetic		142	Approved	21.30	10.25	yes	yes	yes	n.t.	n.t.				No data	No data	No data																	
no		prohexadione-calcium	Plant growth regulator	Unclassified pesticide	Synthetic		1	Approved	0.48	0.66	yes	yes		n.t.	n.t.				No data	No	No																	
no		propamocarb hydrochloride	Fungicide	Carbamate	Synthetic		39	Approved	15.71	1.82				n.t.	n.t.				No data	Possible	Yes																	
no		pyroxsulam	Herbicide; Graminicide	Triazolopyrimidine	Synthetic		3	Approved	0.36	0.30				n.t.	n.t.				No data	No	No																	
no		quartz sand	Mammal repellent	Inorganic compound	Natural		730	Approved	0.18	0				n.t.	n.t.				Possible	No	No data																	
no		quinoclamine	Herbicide, Algicide	Unclassified pesticide	Synthetic		22	Not approved	0.09	lowed anymore				n.t.	n.t.				Yes	Possible	No data																	
no		silica	Insecticide, Fungicide, Other	Inorganic compound	Natural		730	thorised at n	1.56	1.96				n.t.	n.t.				Yes	No	No																	
no		sulphur	Fungicide, Acaricide, Other	Inorganic compound	Natural	yes	30	Approved	####	102.28	yes	yes	yes	n.t.	n.t.				Yes	No	No																	
yes	yes	tebuconazole	Fungicide, Plant growth regu	Triazole : Conazole	Synthetic		63	Approved	6.06	3.11	yes	yes	yes	100		x	x	x	No	No	Yes		yes											98.6	98.4	97.8	99.5	98.7
no		thifensulfuron-methyl	Herbicide	Sulfonylurea : Triazinylsulfonylurea	Synthetic		1	Approved	0.53	0.18				n.t.	n.t.				Yes	Yes	No																	
no		thiram	Fungicide, Repellent, Metab	Carbamate : Dithiocarbamate	Synthetic		5	Not approved	1.92	lowed anymore				n.t.	n.t.				Possible	Possible	Possible																	
no		tribenuron-methyl	Herbicide	Sulfonylurea : Triazinylsulfonylurea	Synthetic		9	Approved	0.10	0.12				n.t.	n.t.				Yes	No	Yes																	
no		triflusulfuron-methyl	Herbicide	Sulfonylurea : Triazinylsulfonylurea	Synthetic		15	Approved	0.20	0.09				n.t.	n.t.				Yes	No	No																	
no		tritosulfuron	Herbicide	Sulfonylurea : Triazinylsulfonylurea	Synthetic		18	Approved	0.20	0.40				n.t.	n.t.				Yes	No	No																	
no		zeta-cypermethrin	Insecticide	Pyrethroid : Pyrethroid ester	Synthetic		49	Not approved	0.05	lowed anymore				n.t.	n.t.				Yes	Possible	Yes																	
no		ziram	Fungicide, Repellent	Organozinc : Dithiocarbamate	Synthetic		2	Approved	0.84	0.42				n.t.	n.t.				Yes	No data	Possible																	

REF	Link
Lewis et al.	https://sitem.herts.ac.uk/aeru/ppdb/
BLW Switzerland 1	https://www.blw.admin.ch/de/verkaufsmengen-der-pflanzenschutzmittel-wirkstoffe
Carbotech AG, Basel	https://carbotech.ch/projekte/pflanzenschutzmitteln-in-luft-und-regen/
Index de Produits Phytosanitaires, OSAV	https://www.psm.admin.ch/de/produkte
Agroscope 2022	https://www.air-glaciers.ch/images/spray/2023_Produits_autoriss_pour_les_applications_par_voie_arienne_hlicoptre.pdf
Betriebsmittelliste FIBL	https://www.betriebsmittelliste.ch/fileadmin/bml-ch/documents/archiv/Betriebsmittelliste_2024.pdf
Ottenbros & Amman et al.	https://pubmed.ncbi.nlm.nih.gov/37805179/
BLW Switzerland 2	https://www.blw.admin.ch/de/aktionsplan-pflanzenschutzmittel / https://backend.blw.admin.ch/fileservice/sdweb-docs-prod-blwch-files/files/2025/01/30/5e544b99-9d9c-45ea-8979-a6d1c99b256a.pdf
BAFU Switzerland	https://www.bafu.admin.ch/bafu/de/home/themen/wasser/publikationen-studien/publikationen-wasser/gewaesserbericht.html