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Do COVID-19 preventive measures and ventilation types affect indoor air quality at secondary schools?

Objective: Little is known on the impact of national COVID-19 preventive measures and ventilation regimes on potential SARS-CoV-2 or other infectious exposure in school environments. Since quantitative SARS-CoV-2 exposure information is not available, 16S rRNA total bacterial load (16S) was considered as a generic microbial indoor air quality marker. We explored whether 16S levels in airborne settling dust was associated with a range of national COVID-19 preventive measures, ventilation regimes and pupil occupancy in secondary schools.
Methods: Airborne settling dust was collected longitudinally using Electrostatic Dust Collectors (EDCs). EDCs were placed in classrooms, canteens and teacher's offices of 18 secondary schools. EDCs were 4-5 times repeatedly sampled for approximately 4 weeks between October 2020 until June 2021. Four ventilation regimes were identified in the classrooms: natural ventilation, mechanical exhaust, mechanical supply, and mechanical supply and exhaust ventilation. During the study, three phases with national COVID-19 measures were in place. At the beginning of the study (pre-lockdown), schools had limited COVID-19 measures implemented. This was followed by a lockdown period during which schools were almost completely closed. During post-lockdown, schools partially re-opened with stricter COVID-19 measures implemented, e.g 1.5 meter distance between pupils, face mask mandates and stricter quarantine rules. 16S levels in EDCs was assessed through DNA extraction followed by 16S rRNA v3-v4 qPCR. Ventilation regimes in each classroom were determined based on observation and technical construction drawings. Pupil occupancy per classroom per EDC sampling period was determined based on scheduled average lessons per week and the average number of attending pupils in each lesson provided by the schools. A Bayesian mixed effects censored regression model was used to account for repeated measurements and measurements below the limit of detection (LOD). 16S levels were first analysed in an univariate model with only COVID-19 preventive measures, ventilation regimes or pupil occupancy. Subsequently, 16S levels were analysed in a multivariate model including all parameters.
Results: A total of 480 airborne settling dust samples were collected (335 samples in 84 classrooms, 70 samples in canteens and 75 samples in teacher offices). In univariate models, 16S levels were significantly associated with pupil occupancy and COVID-19 preventive measures. Ventilation regimes did not affect 16S levels in classrooms. In the multivariate model 16S levels were only significantly and independently associated with pupil occupancy. 16S levels in classrooms increased with 7% with every doubling of pupil occupancy. The effect of COVID-19 preventive measures almost completely disappeared after adjustment for pupil occupancy.
Conclusion: Airborne 16S levels were significantly lower when pupil occupancy in classrooms were reduced, which suggests that reduced pupil occupancy may improve school indoor air quality through reducing microbial air exposure. No distinct effect of different ventilation systems was observed. This might have been caused by the additional natural ventilation implemented in the classrooms, as teachers were advised to open classroom windows during the COVID19 pandemic. This study shows that total bacterial 16S may be useful as a marker of indoor air quality in schools. Further studies need to assess whether this proxy is a better candidate for indoor air quality than other proxy measures like CO2 levels to predict infection risks.

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