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Methods for monitoring indoor air quality in schools

Report of a meeting

Bonn, Germany

4-5 April 2011

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The meeting was cosponsored by the
Joint Research Centre of the European Commission

ABSTRACT

A WHO consultation in November 2010 selected a set of environmental health indicators for monitoring the implementation of time bound commitments to reduce health effects of environmental hazards in children that were adopted by Member States at the Fifth Ministerial Conference on Environment and Health in Parma (2010). New indicators addressing exposure to selected indoor air pollutants in the school environment, moulds and dampness in school buildings, and insufficient ventilation in classrooms will require new data collection in Member States. This technical meeting co-sponsored by WHO and the Joint Research Centre of European Commission defined methodological approaches for national surveys in schools, set schedule for further methodology development, pilot testing and preparation of guidelines.

Keywords

AIR POLLUTION, INDOOR – prevention and control
SCHOOLS ENVIRONMENTAL MONITORING AIR
POLLUTANTS – adverse effects
CHILD

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Background and preparation of the meeting

The Fifth Ministerial Conference on Environment and Health (Parma, Italy, 2010) adopted the Declaration and the Commitment to Act containing the set of targets for the environment and health (EH) process under four Regional Priority Goals (RPGs): (1) Ensuring public health by improving access to safe water and sanitation; (2) Addressing obesity and injuries through safe environments, physical activity and healthy diets; (3) Preventing disease through improved indoor and outdoor air quality; and (4) Preventing disease arising from chemical, biological and physical environments. For the first time in history, it set time-bound targets for the implementation of specific commitments to act to protect children's health.

The 60th Session of the WHO Regional Committee for Europe, Moscow, September 2010, directed WHO Europe to support Member States in their efforts to implement Parma commitments. The resolution EUR/RC60/R7 of the Regional Committee urged Member States and WHO to pay particular attention to achieving the measurable targets set out in the Parma Declaration on Environment and Health.

On 24-25 November 2010, WHO hosted a meeting of international experts to select a minimum set of indicators for monitoring Parma commitments with a particular focus on the five time-bound commitments. The meeting selected 18 indicators for further development and implementation in the Environment and Health Information System (ENHIS) maintained by the WHO European Centre for Environment and Health in Bonn, Germany (see meeting report at http://www.euro.who.int/__data/assets/pdf_file/0019/134380/e94788.pdf).

The set of proposed indicators includes several indicators which will require new data collection in Member States in order to provide relevant and targeted information for Parma follow-up. The November 2010 meeting decided that WHO would coordinate the development of survey tools to enable Member States to collect comparable and consistent data using a standardized methodology. The WHO European Centre for Environment and Health, Bonn office established collaboration with the European Commission's Joint Research Centre (JRC) in order to jointly coordinate the development of methodologies for indicators of exposure to indoor air pollutants in schools (excluding tobacco smoke) under the RPG 3 Commitment iii:

- "We aim to provide each child by 2020 with healthy indoor environment in child care facilities, kindergartens, schools and public recreational settings, implementing WHO's indoor air quality guidelines…"

WHO and JRC jointly sponsored a technical meeting of experts in Bonn on April 4-5, 2011, which was the first step towards the preparation of guidelines for designing national surveys.

The focus of the April 2011 meeting was on the following indicators of exposure to indoor air pollutants in schools:

- Mould and dampness in school facilities
- Insufficient ventilation in schools (calculated from CO_2 concentrations)
- Exposure to selected indoor air pollutants in schools (NO_2 and formaldehyde as core pollutants, and benzene as an optional pollutant)

The mould/dampness indicator will require school inspections, while the indicators of ventilation and exposure to chemicals in indoor air will require air quality monitoring in schools.

The meeting included presentations on the existing national indoor air quality monitoring programs in schools and other public buildings. Based upon the experience from several Member States which have large scale surveillance programs involving hundreds of facilities and extensive sets of pollutants, and taking into account resource limitations and local capabilities in other countries, the meeting produced recommendations for a basic indoor air quality surveillance program in schools that can be realistically implemented in most countries across the Region.

In order to reduce the cost, the proposed survey of schools will also include data collection for the following proposed indicators:

- Smoking in schools and on school grounds, and exposure to second-hand tobacco smoke in schools (questionnaire survey of pupils)
- Access to improved and adequately operated and maintained sanitation facilities in schools and kindergartens (school inspection by trained technicians)
- Hygienic practices in schoolchildren (questionnaire survey of pupils)
- Proportion of children going to and from school by different transportation modes (questionnaire survey of pupils)

Methodologies for these indicators have not been discussed at this meeting. They will be developed separately by other groups of experts.

Summary of meeting discussions

Meeting objectives and organization

The experts who attended the meeting included all members of the RPG3 group of volunteer experts, which was formed after the November 2010 meeting, as well as selected experts who are or have been involved in national and international indoor air pollution surveys in Europe, a statistician, and experts from JRC and WHO (see List of Participants in Annex 1). The meeting was charged with developing recommendations on the following issues:

1. Methodology of monitoring exposure to formaldehyde and nitrogen dioxide (NO_2) in classrooms;
2. Methodology of indoor air exchange (ventilation) rate measurements based on the carbon dioxide (CO_2) equilibrium method or other suitable techniques;
3. Methodology for evaluating presence of mould and dampness in schools;
4. Survey design issues including school selection procedures, study power, and sample size.

The meeting aimed at identifying and selecting appropriate techniques for the proposed survey taking in account methodologies of the ongoing national and international indoor air pollution surveys. The meeting also specified further steps for the development of survey methodology including its pilot testing in selected Member States. The meeting discussed necessary measures to facilitate new data collection in Member States, identify national and international partner institutions and ensure synergies with ongoing and forthcoming international data collection and reporting mechanisms. The meeting included plenary sessions and four working groups to discuss each of the four issues listed above.

Overview of approaches and limitations

WHO European Region includes 53 countries with a wide range of climatic and socioeconomic conditions and building practices. Therefore, the objective is to develop a minimalistic survey design that can be applied in all countries of the Region. Individual countries will have an option of expanding the survey beyond the core set of parameters in order to address national priority issues.

It is important to note that the goal of the proposed survey is to assess exposure to specific factors in the school environment for which adverse health effects are well established. The survey is not intended to prove once again that exposure to these factors is associated with health risks. Therefore, the basic survey protocol will not involve collection of data on health outcomes.

The use of diffusive samplers for monitoring of chemical pollutants is recommended in order to minimise the cost of sampling, which is viewed as essential for a successful implementation of the survey in many countries. However, it was noted that the concentration averaging period for diffusion samplers (one school week/5 school days for all pollutants) does not match time periods specified in WHO Indoor Air Quality (IAQ) guidelines. Therefore, the proposed survey will not directly evaluate compliance with the WHO IAQ guidelines. However, the data will enable general characterization of a magnitude of IAQ problems, comparison of countries and characterization of temporal trends.

The survey is designed to address exposure in the school environment only. The results of this survey will be used to support policy actions targeting schools. While children can be exposed to the same harmful environmental factors outside the school, the survey will not include assessment of their total exposure levels. Personal exposure monitors or other measures to evaluate total exposure will not be used. Measurements will only be conducted in the school environment and they will be limited to time periods when pupils are present.

Presentations on existing indoor air pollution surveillance programs in schools

France

In the framework of the National EH Action Plan, France has developed an extensive programme of indoor air quality monitoring in schools and other public buildings. A pilot study is ongoing in schools and day-care centres (2009-2011). In each classroom, one passive sampler is used for each chemical pollutant (formaldehyde and benzene; 5 days in summer plus 5 days in winter). Additionally, air stuffiness is measured through CO_2 measurements every 10 minutes in occupied classrooms using an infrared sensor Lum'Air® (also 5 days in the warm and cold seasons). One to two classrooms are sampled on each floor of the school. The costs are approximately 2,000 Euros per school for sampling and 600 Euros for building inspection. A total of 320 voluntary schools and day care centres have participated in the pilot study. This will be followed by a mandatory baseline surveillance of IAQ in public building from 2013 to 2015, and follow-up surveys every 7 years.

A research programme will be implemented by the French Observatory for IAQ to develop a national indoor air action plan. A sample of 300 schools (600 classrooms) will be randomly selected across the country; in each school, 2 classrooms will be sampled for one week. Parameters will include temperature, relative humidity and CO_2 (using Q-Trak devices), volatile organic compounds (VOCs) and aldehydes (active sampling), semi-volatile organic compounds (SVOCs), $PM_{2.5}$ (active sampling during occupation) and particle count in the 0.3 – 20 µm range using an optical particle counter. Assessment of exposure to mould will be based on measurements of characteristic chemical species in indoor air (microbial volatile organic compounds, MVOCs). Settled dust will be sampled for metals, allergens and SVOCs. Two pilot studies have been carried out in 2010 (in 45 schools, representing 140 classrooms in total). The national survey will start in September 2011.

Belgium

Two studies of indoor air pollution in schools were conducted in 2006 – 2009 in the Flanders region of Belgium. The Binnenlucht in Basisscholen (BiBa) study involved measurements of a large number of indoor and outdoor air pollutants at 30 elementary schools (90 classrooms total). The study included classroom inspections, assessment of exposure to chemicals ($PM_{2.5}$, PM_x, MTBE, benzene, toluene, tetrachlorethene, ethylbenzene, xylene isomers, 1,2,4-triethylbenzene, total VOC, formaldehyde, acetaldehyde, total other aldehydes, temperature, relative humidity and CO_2), visual inspection for moulds, measurements of ventilation rates in classrooms, and measurements of respiratory function in more than 1,500 children. It demonstrated that concentrations of many chemicals were much higher indoors than outdoors. It also showed a high variability in concentrations between classrooms. Seven out of 90 classrooms had visible mould. No association was found between ventilation rate and the presence of mould.

Another study used diffusion samplers to assess exposure of children to formaldehyde, NO_2, benzene and other pollutants in different microenvironments. It was demonstrated that the Flemish indoor environment guidelines were often exceeded for formaldehyde, benzene, total VOC, CO_2 and other parameters.

Italy

Monitoring of indoor air pollution in Italy is conducted in the framework of the Ultrafine Particles from Traffic Emissions and Children's Health (UPTECH) project. It involves monitoring of ultrafine particles with the size <0.1 µm (100 nm) originating mainly from transport sources. These particles have a high specific surface area, can catalyse chemical reactions, and adsorb high amounts of toxic substances, which they can carry deep into the lungs during inhalation. These particles can also enter the circulation and form complexes with serum proteins altering their functionality, induce oxidative stress and affect immunity. This cross-sectional study aims at assessing dose-response relationships between ultrafine particles and specific health effects in children aged 8 to 11 years. The sample size in Italy consists of six schools, 40 children in each school, of which two schools have already been examined. Air quality is monitored in 5 locations at each school (3 outdoor and 2 indoor) for two weeks. Parameters include particles count and size distribution, particle chemical composition, NO_x, CO and ions.

Schools INdoor Pollution and Health: Observatory Network In Europe (SINPHONIE)

The SINPHONIE study is funded by DG SANCO and coordinated by the Regional Environmental Centre (REC) for central and eastern Europe. Its partners include 38 institutions in 25 countries. The study aims at providing data for comprehensive assessment of health risks due to indoor air pollution in schools. The list of parameters to be monitored includes formaldehyde, benzene, trichloroethylene, tetrachloroethylene, pinene, limonene, NO_2, O_3, polycyclic aromatic hydrocarbons (PAH), radon, CO, CO_2, relative humidity, temperature, ventilation rate, as well as biological agents including bacteria, mould and allergens. Monitoring will be conducted in a total of 120 schools in Europe, in 3 classrooms and one representative outdoor site per school. It will be organized in four geographic clusters with different climatic conditions. The list of participating countries includes Norway, Sweden, Finland, Island, Denmark, Estonia, Latvia, Lithuania, United Kingdom, Ireland, Netherlands, Belgium, France, Luxembourg, Germany, Austria, Switzerland, Poland, Slovakia, Czech Republic, Hungary, Romania, Bulgaria, Serbia, Bosnia and Herzegovina, Portugal, Spain, the former Yugoslav Republic of Macedonia, Italy, Malta, Greece, Cyprus and Albania. Field data collection is expected to start in 2011-2012. The objectives of SINPHONIE and the proposed WHO survey overlap to a substantial extent. However, SINPHONIE will use a small sample size in each country but involve measurements of many indoor air quality parameters in each school. The SINPHONIE survey and the WHO-sponsored survey of schools can supplement each other and mutually benefit from re-using local expertise and infrastructure, such as trained interviewers. While it would be helpful to synchronize approaches of monitoring overlapping parameters, this is not a requirement since the two projects have different objectives.

Overview of application of indoor air quality monitoring methods in European surveillance programs

European Commission’s Joint Research Centre (JRC) in Ispra, Italy is coordinating efforts to synchronize indoor air quality monitoring in the EU countries. JRC is also running the JRC-INDOOR_MONIT program, which deals with indoor air quality complaints, clarifies the reasons for poor air quality, measures concentrations of pollutants and checks the efficiency of remedial actions.

While passive diffusion samplers are generally less accurate and sensitive than active samplers, JRC commonly uses diffusion samplers to monitor average indoor concentrations of chemical pollutants for practical reasons. They are small and cheap, and do not require a power source. JRC has developed brief manuals for monitoring indoor concentrations of formaldehyde, NO_2 and benzene using diffusion samplers (these manuals were made available to the meeting participants).

Different diffusion samplers have different diffusion rates and limits of detection dictating different duration of sampling. Typically, the duration of sampling ranges from 48 hours to one week. Temperature and humidity can affect the results of sampling. In principle, diffusion samplers also require a minimum air current at the interface. Sites for diffusion samplers within each classroom have to be selected to ensure that the sample is representative of air quality in the room. Minimum distance from the wall or floor is specified in order to ensure that the air flow is sufficient and that material emissions or absorption does not distort the results of monitoring. Information about conditions and activities during sampling needs to be collected to aid the interpretation of the results. More detailed guidance on the organization of indoor air quality monitoring can be found in ISO methodological documents.

Survey methods

Monitoring exposure to chemical indoor air pollutants

General considerations

Type of samplers

Chemical indoor air pollutants will be monitored using passive samplers, which provide data on average concentration during the sampling period. The diffusion samplers are exposed for a defined time period. The rate of sampling depends on the diffusion coefficient of the target chemical, which is directly associated with the cross-sectional area of the opening of the sampler and inversely associated with the length of the diffusion zone of the monitor. This rate is known as the diffusive uptake rate of the sampler. For each sampler model, the uptake rate is determined by the manufacturer using calibration in a standard atmosphere. The actual uptake rate during exposure is a function of temperature.

It is necessary to select samplers for different pollutants so that all pollutants will be monitored simultaneously and for the same amount of time. Sampling should be conducted during one school week. Because of the ventilation practices and activities within and outside of the school building, most indoor concentrations will be significantly different during the schooldays compared to the evenings, nights and weekends. Ideally, therefore, samplers would need to be capped at the end of each school day and uncapped at the beginning of the next school day in order to measure relevant concentrations during class hours. However, concerns were expressed that this approach might be problematic in practice. If technicians are to be present in each school every day in order to cap and uncap samplers, the survey may become too expensive. A potential solution is to train school employees or even older pupils to cap and uncap samplers. Final determination on the practicality and feasibility of monitoring during class hours only will be made based on the results of pilot surveys.

Sampling will need to be conducted indoors and outdoors. The meeting participants discussed the number of outdoor sampling sites per school. One approach would be to sample at the “clean” and “polluted” sides of the building. In the absence of preliminary sampling, this would require a subjective determination of polluted and clean sides, which may not always be reliable. A simpler approach is to collect only one outdoor sample per school, for example, at the facade side of the building.

The meeting briefly discussed optional pollutants that can be added to national surveys. It was noted that for some important pollutants, such as $PM_{2.5}$ and PM_{10}, practical and relatively low cost methods of measurement are not available. Therefore, these pollutants can not be recommended for a Region-wide surveillance program. For benzene (which was recommended at the November 2010 WHO consultation as an optional pollutant), low cost diffusion samplers are available. Benzene and related compounds, toluene and xylenes (which can be monitored using the same passive samplers, and analysed with the same instrument in the laboratory) were not included in the list of core pollutants because the laboratory analysis requires more expensive equipment, which may not be available in some Member States.

At the 5th Ministerial Conference on Environment and Health, Member States committed themselves to implementing WHO guidelines for indoor air quality (Parma Declaration, Commitment RPG3 iii). The WHO guideline values for the two core pollutants and one optional pollutant are as follows:

- Formaldehyde: 100 $\mu g/m^3$ (30 min average)
- NO_2: 40 $\mu g/ m^3$ (annual average)

- Benzene: No safe limit of exposure to this carcinogenic compound can be recommended. Long-term exposure to 0.17 µg/m^3 is associated with 1/1,000,000 excess life time risk of cancer.

Compliance monitoring for formaldehyde would require samplers with 30 min or shorter averaging time. These would have to be active samplers since diffusion samplers require a much longer sampling duration at the typical formaldehyde levels in schools. Since a single 30-min sample would not be representative, a large number of measurements would have to be taken at each location to characterize the distribution of concentrations. This would make the cost of the survey prohibitively high. To reduce the cost, the survey will use diffusion samplers with one school week averaging time. This, however, will make it impossible to directly evaluate compliance with the WHO IAQ guidelines. The survey will only provide data to assess the magnitude of a problem. Similarly, monitoring NO_2 for an entire year at each sampling site or long-term monitoring of benzene levels would be prohibitively expensive. Thus, weekly average concentrations from diffusion samplers will be used to characterize the magnitude of the problem.

Duration of sampling

The sampling should last for one school week covering five days while children are present at school. One option is to always start sampling on Monday morning and finish at the end of the school day on Friday. In this case, however, the work load will be uneven during the week if technicians only need to come to each school twice, at the beginning and at the end of the monitoring period. Another option is to allow flexible schedules so that sampling can start on different days in different schools: for example, from Tuesday morning until the end of a school day on the following Monday. The latter option is preferable as it would reduce the number of technicians and make it easier to organize and run the survey. However, it can only be exercised if diffusion samplers are capped at the end of each school day and uncapped at the beginning of next school day so that samplers can be capped for a weekend.

Sampling time

Relevant measurement time is during class hours. Measuring non-stop for 24 hours per day can result in overestimation of exposure to formaldehyde, which may accumulate during the night when windows are closed or mechanical system turned off, and it can also produce biased estimates of exposure to NO_2 (the direction of bias would depend on contributions of indoor and outdoor sources of combustion). It may be advisable to cap samplers at the end of each school day and uncap the samplers next morning in order to measure concentrations during class hours only (final recommendation will be based on the results of pilot surveys).

Another issue is seasonal variability in concentrations of some pollutants. Concentrations of formaldehyde in indoor air may have a seasonal pattern due to different emission and ventilation rates in the winter and summer seasons. The peak seasonal concentrations have been reported in the winter in temperate climates due to poorer ventilation and increased emission from materials and products, such as paints and furniture, which are located near heating systems and are exposed to high temperature (however, summer peaks associated with higher temperature can also be observed in some buildings depending on ventilation and heating systems). Similarly, ambient concentrations of benzene peak in the winter (atmospheric inversion, incomplete combustion when starting cold engines). When indoor combustion sources are present, NO_2 also peaks in winter in the indoor environment. Thus, monitoring indoor air pollution in the winter would characterize peak exposure levels.

Another option is to conduct the survey continuously during a school year. This would enable characterization of seasonal patterns of exposure. However, the drawback is that resources will be spent on collecting data when indoor air pollutant concentrations are low. Also, it will increase the variance and decrease the precision of country level estimate as the variance will include a seasonal component. Most importantly, the interpretation of the results in terms of proportion of children exposed to an inacceptable high level of pollutants using data from low-exposure season will be problematic. Thus, conducting most of the sampling during the heating season is a preferable approach, for example, from November to March. To address the seasonal variability issue, monitoring during the warm season can be conducted on a smaller scale.

Indoor air sampling locations

In each school, at least three sampling locations in classrooms (one sampler per classroom) should be selected that are routinely occupied during school hours. Classrooms selected for monitoring have to be representative of the school building. Initial inspection should identify homogeneous blocs of classrooms. These are likely to be rooms on each floor, or rooms on the 1^{st} and top floors. Within each block, rooms that are continuously occupied by pupils should be selected randomly for monitoring.

An important factor for defining a sampling strategy is the effect of air flow velocity on sampling results. Diffusion samplers typically require a minimum air flow. Since the air flow is reduced near surfaces, meeting participants recommended that samplers should be placed at least 1 m from the wall and at least 1.5 m height from the floor. However, in reality, samplers will need to be placed in such a way as to make sure that they are not tampered with by pupils. This may be a higher elevation from the floor and a closer location to the wall. Requirements for placing samplers in the room need to be clarified. Photos of sampling locations demonstrated at the meeting showed samplers on top of closets or in a close proximity to the wall. The working group discussed the use of fans close to the samplers to ensure sufficient air velocity, or measurements of air velocity in the room prior to placing samplers. Specific requirements will be developed after the completion of pilot projects.

Outdoor air sampling

The survey will also assess outdoor concentrations of pollutants because children's exposure also occurs outside and because of the transfer of ambient pollutants into the indoor air. For NO_2 and benzene, simultaneous and co-located indoor and outdoor sampling is essential. At least one outdoor air sample should be collected at each school for each pollutant. For formaldehyde, outdoor measurements can be omitted if the budget is scarce because main sources of this chemical are usually in the indoor environment. Distance to traffic (and type of road) or industrial sources of emission should be recorded for each outdoor sampling site.

Information on activities and potential sources of emission

Factors affecting indoor air quality should be registered and reported (sources of combustion indoor and outdoor, cooking, etc). Outdoor environment including distance to a busy road, industrial sources of emissions, etc., should also be described. The start and end time of classes when pupils are present in the classroom and the time of school breaks should be recorded. Other factors affecting the results of sampling are temperature and relative humidity. (These factors will be collected for air exchange rate measurements.)

QA/QC procedures

An ideal way to ensure the consistency of results is to analyse all samples from the Region in one laboratory. Nevertheless, this may not be feasible, due to high transportation costs and the lack of centralized funding. Moreover, analysing national samples locally would enhance acceptance of the study and contribute to building local expertise and capacity. A reference laboratory would have to be designated in order to analyse control samples from each country. It is also advisable to conduct laboratory proficiency tests involving analysis of exposed samplers with known amounts of chemicals before the start of the survey in each country. Such control samples would need to be prepared by reference laboratories. The meeting recommended that national laboratories should be accredited prior to the beginning of survey implementation. Only accredited laboratories will analyse survey samples.

Certified reference materials will need to be used in round robin tests throughout the survey. Procedures will need to be specified for dealing with unsatisfactory or inconsistent results of control tests. Sufficient resources will need to be made available for activities of reference laboratories.

QA/QC procedures will also include components that will be implemented within each country. Sampling will have to include at least 10% replicate samples. At least one field blank (sampler that is placed in a classroom but not open) per school should also be collected (some sampler types include field blanks as part of their design). In addition, at least one laboratory blank should be analysed per batch of samples.

Reporting results to schools and national authorities

There are several options of reporting survey results back to participating schools or local school districts including national distribution, individual value, individual value in the context of national distribution, etc. If the results of monitoring are reported to individual schools, they will need to be comprehensively explained in relation to the existing standards or guidelines, and potential health effects.

Specific procedures for nitrogen dioxide

Detailed sampling protocol for NO_2 is available in the ISO document CEN TC 264 WG11 – ISO 16000-15.

Diffusion samplers

Several models of diffusion samplers for NO_2 are available on the market and general reference guidance for the selection and use of samplers. The meeting decided that samplers based on triethanolamine adsorbent should be used. These are commonly analysed by means of spectrophotometry following solvent desorption, but ion chromatography may also be applied.

Placement of samplers

The sampling device should be placed at least 1 m (ideally 2 meters) from a wall and 1.50 m from the floor. One sampler of each type per room should be sufficient for most rooms (duplicate samples will be collected in a subset of rooms for QA/QC). All samplers should be placed to minimize interference with normal activities in the classroom, preferably out of reach of pupils. Outdoor sampler should be placed at least 5 m from the building. Samplers should be placed in a protective shelter, in order to avoid exposure to the direct sun light or precipitation. Indoor samplers should not be placed near heating systems or ventilation channels, or location with noticeable draught.

Sample handling and processing

After the completion of sampling, samplers should be placed in a sealed protective container and stored in a freezer until analysis. Analysis should ideally take place within two weeks from sample collection.

Laboratory analysis

UV-Vis Spectrophotometers should be used in laboratory analysis. More details are available in ISO 16000-15.

Specific procedures for formaldehyde

Detailed sampling protocols for formaldehyde are available in the ISO documents ISO 16000-4 and ISO 16000-2.

Diffusion samplers
The formaldehyde vapour migrates into the sampler by diffusion. It is collected, in the form of a stable hydrazone, on a strip of cellulose paper with silica gel coated with 2,4-dinitrophenylhydrazine (DNPH) and phosphoric acid.

Placement of samplers
The position of a sampler in a room can decisively influence the result. Sampling in the vicinity of a suspected emission source often result in higher concentrations than those obtained at other locations in the same room. For example, measuring formaldehyde in close proximity to a piece of new furniture made of particle board can produce an overestimate of formaldehyde exposure of individuals present in the room.

Information on activities and potential sources of emission
In addition to the occupancy of classroom and activities of pupils, potential sources of emission, such as new furniture, recent renovation of classrooms, use of chemicals, etc. need to be recorded.

Sample handling and processing
After the completion of sampling, samplers should be placed in a sealed protective container and stored in a freezer until analysis. Analysis should ideally take place within two weeks from sample collection.

Laboratory analysis
Hydrazone is desorbed from the sampler by acetonitrile and the solution analysed by means of a high performance liquid chromatograph (HPLC) equipped with an ultraviolet (UV) detector. Appropriate advice on safe laboratory procedures should be included in the survey protocol.

Benzene and related compounds

The meeting did not discuss specific procedures for benzene (optional pollutant). Detailed sampling protocol is available in the ISO document 16017-part 2.

Methodology of indoor air exchange rate monitoring

Insufficient ventilation in schools has been linked with respiratory and general symptoms, infectious diseases and impaired learning outcomes. Poor ventilation is also associated with higher levels of chemical pollutants, and problems with mould and dampness. The problem of insufficient ventilation in schools appears to be common. However, there are no representative and comparable ventilation data for schools across Europe and for many European countries. This will be the first comprehensive region-wide effort to characterize the magnitude of this problem.

While insufficient air exchange rate is associated with a generally poor indoor air quality, the goal is not necessarily to increase ventilation rate universally. Since greater air exchange rate during the heating season also results in greater energy consumption for heating and for mechanical ventilation, air exchange rates have to be optimized to balance the air quality and energy requirements.

Concentrations of ambient air pollutants with outdoor sources, such as $PM_{2.5}$, can also increase with an increased air exchange rate. Maintaining adequate air exchange rates also does not replace or reduce the need to control sources of emission of harmful chemicals indoor.

Air exchange rate in a room is not constant. Therefore, longer-term measurements covering an entire week are necessary to characterize prevailing conditions in each room. Using CO_2 exhaled by occupants as a tracer gas offers a number of advantages, such as the ease of measurements and well established methodologies. To assess the dynamic ventilation rate, continuous CO_2 data from inside and outside the school have to be collected.

It is preferable to procure portable CO_2 monitors with data logging capability. There are many types of automatic CO_2 loggers on the market. Some of these devices can also record temperature, relative humidity and concentration of CO. Depending on functionality, the price of these monitors ranges from $ 150 to $ 600. Models that can also record temperature and relative humidity, although more expensive, are preferable. A suitable device should be capable of measuring CO_2 concentrations in a wide range from the ambient air level (300 to 400 ppm) up to 5,000 to 6,000 ppm level, that can be found in poorly ventilated classrooms. The total number of monitors should be calculated taking in account the need to have some spare units, for example, for calibrations and repairs. Ideally, all equipment should be purchased centrally. This will reduce the cost, ensure that common procedures are used and make it easier to organize common training.

The interpretation of data requires recording room occupation (number, age and gender distribution, and physical activity levels of the occupants) during measurements. In addition, all actions on ventilation and heating will need to be recorded. Ventilation rate as a function of time should be determined using a dynamic model. The results of monitoring in each classroom should be presented initially as a distribution of ventilation rates reflecting temporal variability of this parameter. It should be noted that Member States use different target ventilation rates, such as 6 or 7 L/sec per pupil. Further analysis may involve dichotomization of data at selected cut-off values.

Ventilation rate measures in one classroom may not be representative of other classrooms in the building. Therefore, measurements will need to be conducted in several classrooms simultaneously (preferably, in the three classrooms where samplers for chemical pollutants are placed). Because natural gravimetric ventilation depends on the weather, collecting also local meteorological data (temperature, wind speed, humidity) is necessary.

The CO_2 method is applicable in schools with natural ventilation, mechanical exhaust ventilation and also for full mechanical ventilation systems if air is not re-circulated. In schools that use full mechanical ventilation with air re-circulated within the whole building, alternative classroom air exchange rate measurement techniques or calculations based on ventilation system parameters or actual room inflow and exhaust vent measurements should be used. Finland is a country where a large proportion of schools have mechanical ventilation. Similar situation may exist in other Nordic countries, while the use of mechanical ventilation outside of this subregion appears to be rare. The most modern mechanical ventilation system use heat exchangers and do not re-circulate the air. Only a subset of older systems employs this technique. Comparability of data obtained using different ventilation rate measurement techniques has to be determined. For example, simultaneous ventilation rate determination using CO_2, and other techniques, such as SF_6 tracer gas, in schools with natural ventilation can be conducted. There may be a possibility to compare air exchange rate measurements using CO_2 and SF_6 in Portugal, where activities are ongoing in this area. However, using SF_6 may be less acceptable as introducing tracer gas in the school environment may be problematic logistically and organizationally. Since the proportion of schools that use mechanical ventilation with air recirculation appears to be small, the meeting focused on the general CO_2 monitoring approach that can be used in a great majority of schools in the Region.

The problem of insufficient ventilation is likely to be more pronounced during the cold season, when the windows and doors often remain closed and possibly also sealed. On the other hand, the forces of natural ventilation tend to be stronger in the cold season due to a greater indoor/outdoor temperature difference. Monitoring during the warm season is, therefore, also recommended. Its objective will be to characterize seasonal variability in different regions. To reduce the cost, a smaller number of schools may be monitored during the warm season.

In each school, there will be at least four CO_2 monitors including one that will be used to measure CO_2 level outdoors. Two monitors may also be installed in one room for quality control. Based on experience from air exchange rate surveillance in Finland, two to four schools within 10 km distance can be monitored simultaneously by one technician. In total, 8 to 16 portable CO_2 monitors will need to be procured for each technician.

The raw CO_2, temperature and relative humidity monitoring data should be provided along with room occupancy and activity data for centralized data processing and analysis of air exchange rates.

Methodology for evaluating the presence of dampness and mould in schools

Dampness and mould in homes have been linked with asthma, respiratory symptoms and infections while remediation of dampness and mould problems has been associated with a decline in these symptoms. The presence of both factors, dampness and mould, has to be taken in account as they are both associated with health effects. A proportion of rooms affected in each school needs to be estimated using school inspections by trained technicians. For the purpose of this survey, a specific room is deemed affected if more than 1 m^2 is covered with visible mould or if there is severe moisture damage, leakage, moisture accumulation or mould odour.

The objective of the proposed survey is to assess the occurrence of dampness and mould problems in schools in the WHO European Region at the country level. Since this survey is not a research project, it will not include any measures of health effects in children. Also, the focus of this survey is on schools only. It will not include data collection on exposure to mould and dampness in homes, even if the home microenvironment may be more important. Also, the basic survey design will not include any measures of mould spores in indoor air or chemical indicators of mould contamination or bacterial growth. However, individual countries can include additional parameters in national surveys if warranted.

The meeting discussed two main approaches. A cheaper but less reliable approach is administering a questionnaire on issues of moisture damage/dampness/mould in the school to the school administration (self evaluation). A more expensive approach that, however, produces more reliable data involves school inspections by trained inspectors. A combination approach was also discussed using a nested design where a larger number (300 to 500) of schools would conduct a self-administered survey and a subset of these schools would be inspected for quality control and estimation of error rates in the self-evaluation. It was noted that the level of awareness of the mould/dampness problem varies across the Region, which would likely affect approaches to self-evaluation and survey results. Also, schools may intentionally over- or underreport problems. It was concluded that the survey based on inspections by trained technicians is necessary in order to produce comparable data across the region.

School inspections will involve non-destructive, mainly visual evaluation of the school building using standardised checklists. The evaluation will include general school description, evaluation of heating, ventilation and air conditioning (HVAC) systems, condition and maintenance of the building, visible moisture damage observations, surface moisture recording, and assessment of the presence of dampness and mould. Inspections will require trained personnel. While individuals with building technology background would be ideal for this task, persons without such background can be employed providing that they complete standardized training. Training for inspection personnel will need to be centralized in order to ensure a common understanding of the definition of dampness and mould. Subjective observations can lead to bias and lack of data comparability. A small core group of technicians from each country will need to be trained at a central training site (to be identified), in English language (and also in Russian, if necessary). They then return to their home country with training materials and provide training to the rest of the study personnel in local language. For small countries, training may be conducted in English.

Equipment to perform inspections include temperature/relative humidity monitor (these may be available in CO_2 loggers), surface moisture recorder (the practicality of using surface moisture monitor vs. visual inspection will need to be evaluated in pilot surveys), digital camera, measurement tape, flashlight, gloves, etc. The recommended background information to be collected from school includes classroom occupancy, activities in the building (including maintenance), year of construction, type of the structure, history of water damage, information on dampness and mould reported by the school administration, indoor air quality complaints, related investigations by authorities, and remediation actions. A trained survey technician will conduct a walk-through inspection utilizing a standardized checklist translated into the local language (standard English version will be developed based on checklists from previously conducted projects, such as the Health effects of Indoor pollutants integrating microbial, Toxicological and Epidemiological Approaches (HITEA) survey, taking digital pictures and assessment of dampness, mould, and moisture/water damage. They will also use surface moisture recorders for non-destructive measure of excess moisture in the building structures. Based on experience from previously conducted studies, an average time for a walk-through inspection of one school by a single technician can take an entire day. Actual time depends on the school size, building type, and conditions. The approach will need to be tested in pilot projects where time expenditures of technicians will be recorded. Detailed recommendations on dampness/mould inspections enabling technicians to reduce inspection time while ensuring adequate data quality will need to be developed after completion of pilot projects.

Data from checklists and surface moisture measurements will be entered into standardized computer databases using standard data entry forms (databases and data entry forms will need to be developed for this survey and pilot tested). Data management will be conducted at the country level using standardized procedures including quality assurance and quality control. It needs to be determined if data analysis is to be conducted at the national or international level. With a national analysis, WHO will receive only statistical data summaries. Specific requirements for summary data will need to be developed, including the list of statistical measures.

The HITEA survey (www.hitea.eu) data can be used for an initial estimate of the prevalence of moisture damage/dampness in schools. This survey was conducted in three countries (Finland, Spain, The Netherlands). The HITEA survey used a nested approach: at the first stage, a screening questionnaire was sent to schools to assess the prevalence of moisture damage/dampness and mould in each country. At the second stage, detailed building inspections were conducted in a subset of schools to evaluate the damage status of the building. From 24% to 48% of schools were found to have mould or dampness problems in different countries.

A working group of volunteers will continue developing a checklist, training materials and recommendations, walk-through protocol, data analysis, and other issues. A draft methodological document will need to be pilot-tested in selected countries. The working group should include an expert who has been involved in the development of the WHO mould guidelines to ensure a coherent approach as well as experts from different European areas/climatic regions with knowledge on the region-specific dampness/mould issues. The issue of surface moisture measurements will also need to be addressed and specific equipment parameters specified for the standard survey protocol.

Survey design and sample size

General considerations

The objective of the proposed survey is to characterize the magnitude of a specific problem and monitor temporal trends within each country. Therefore, data summarized at the country level will be used in ENHIS indicators, and also in baseline assessment and progress assessment reports that will be prepared for policy-makers. The survey shall have an adequate power to demonstrate meaningful temporal changes in each indicator at the conventional level of statistical significance ($\alpha = 0.05$). The meeting suggested that the survey needs to be able to demonstrate 10% to 20% change in a specific parameter compared to the baseline level.

Guidelines for the development of national surveys need to specify minimum sample sizes in terms of the number of schools for specified categories of countries (e.g. small vs. large countries). Individual countries can use a larger sample size in order to characterize spatial variability within the country or temporal trends within subnational regions. Minimum samples size estimates are affected by study design parameters such as the variability of the specific pollutant within and between schools, clusters and strata.

The baseline survey in 2012 – 2013 will produce data to compare countries and assess the magnitude of specific problems. At least one more round of survey will be conducted prior to the 6^{th} Ministerial Conference in 2016. Thus, the assessment of temporal changes within each country will be based on the minimum of two surveys. The minimum sample size has to be sufficient for all core pollutants (formaldehyde, NO_2, ventilation rate, dampness/mould).

Clustered stratified sampling design

Conducting a survey in each school would be too expensive and time consuming for most countries. Therefore, surveillance will have to be conducted in a random sample of schools. A random sample selected from the list of all schools would be a feasible solution for small countries only. In medium-size or large countries, this approach would be logistically difficult and expensive due to large distances between schools and high transportation and labour costs. In such countries, a two-stage randomized cluster sampling will need to be conducted. Geographically compact clusters (e.g. towns or counties) will be selected using a random selection process with stratification. Stratification will involve classifying clusters into groups, and then performing random sampling of clusters in each group. Urbanicity (urban vs. rural clusters) will be an obligatory stratifying factor. In biggest countries, different climatic zones and/or historic, cultural or geographic regions will be selected by local experts to define an additional stratifying factor. Thus, in a hypothetic big country with two defined geographic regions (e.g. east/west), the selection of clusters will be performed independently in each of the four strata (east-urban, east-rural, west-urban, west-rural). This will be followed by a random selection of schools within each selected cluster.

Stratification leads to gains in efficiency of the survey if strata-specific means are substantially different. For example, a study in Spain demonstrated that NO_2 concentrations were substantially higher in urban schools (median 22.2 μg/m^3) compared to rural schools (median 10.7 μg/m^3) (Esplugues et al. 2010 Indoor and outdoor concentrations and determinants of NO_2 in a cohort of 1-year-old children in Valencia, Spain. Indoor Air 20: 213–223). The degree of efficiency improvement due to stratified design will be evaluated at a later stage using Monte Carlo simulations based on the results of pilot projects in selected countries.

Meeting participants also discussed the use of further stratification factors for schools within selected clusters, for example, by the building type (single storey, two storey, multistorey buildings), school size, school category (elementary vs. secondary, public vs. private) or the type of ventilation system (mechanical vs. natural gravimetric). A reliable list of schools with their associated characteristics (size, building type, etc.) would be needed at the design stage to implement such stratification. Such data may not be readily available in many countries of the region. Moreover, additional stratification does not guarantee significant improvements in efficiency. Therefore, the simpler stratification scheme described above is preferred.

While clustered design will reduce transportation costs and improve the feasibility of data collection, it may also be associated with certain inefficiencies. When variability in classroom air quality between schools within a compact cluster is smaller than in the entire country, clustered design requires a larger sample size in order to provide the same study power. In contrast, stratification can result in a greater efficiency compared to simple random sampling. The key difference between stratification and clustering is that, in stratified sampling, a random sample is drawn from each of the strata, whereas in cluster sampling only the selected clusters are studied. These effects can be quantified using assumptions on the ratio of variances in specific pollutants across the country and within clusters and strata, and statistical simulations.

Clusters can be defined as administrative units of appropriate size. Using administrative units is advantageous because the survey will rely on cooperation and assistance from the local administration. An alternative approach is to use census blocks as clusters. Since the sizes of administrative units and census blocks are different in different counties, cluster definitions and selection procedures will need to be specified in each country at the stage of the development of national survey protocol.

From a sampling precision point of view, a design with many clusters and a small number of schools selected from each cluster is preferable compared to a design with few large clusters and many schools in each cluster. However, logistically, it is easier to organize data collection when each cluster includes many schools so that a group of field technicians can share an organizational infrastructure and work under an oversight of a local coordinator. In addition, it would be easier to obtain all necessary permissions to work in a small number of big clusters. Thus, the actual size of clusters in terms of the number of schools will have to be determined taking in account specific conditions in each country. In population-based surveys, using 30 households per clusters has become popularized, although there is no statistical justification for 30 as an ideal number. Similarly, approximately 30 schools per cluster may be used as a target value.

To select clusters for the survey, study coordinators in a specific country would have to prepare a full list of geographic and climatic regions (in big countries), and list of clusters within each region or entire country. The clusters would then need to be classified as urban or rural. Since geographic clusters will have different population sizes and numbers of schools, it needs to be determined if clusters should be selected with equal probability or the probability of selection should be proportional to the cluster size. The latter method would produce lower standard errors but would require more complicated formulas and methods. Within each cluster, schools should be selected randomly. A constant number of schools should be selected in each cluster to ensure roughly the same work load in each cluster.

The probability of selecting a specific school within a cluster can be proportional to the number of pupils in the school. The data on the number of pupils in each school will need to be collected and national level exposure will need to be estimated as a weighted average taking in account actual sizes of participating schools, as well as the total sizes of rural and urban schools populations, and populations of each geographic/climatic region (for big countries). Alternatively, a constant selection probability independent of the school size can be used. This approach may be easier logistically.

Within each school, classrooms would need to be selected using stratified random sampling procedure. A list of classrooms including stratification factor(s) will need to be prepared for each school. Stratification variables may include floor (at least one classroom on each floor), proximity to outdoor pollution sources ("polluted" side of the building vs. "clean" side) or presence of indoor sources of pollution. Potential problems with stratification by exposure level are its subjectivity and the fact that the survey needs to assess exposures to multiple factors. Therefore, a random selection of classrooms on each floor, or only on the ground floor and top floor is preferable.

Another design issue that needs to be settled is sampling during the warm and cold seasons. It seems that in the southern countries where forced ventilation is uncommon, indoor air quality during the warm season is likely to be similar to the outdoor air quality as windows are kept open most of the time. It was suggested that the main survey should be conducted during the cold season. In pilot projects, a smaller number of schools would need to be sampled during the warm season to determine if limited scale surveillance during the warm season is warranted.

Repetitive surveys in the same schools vs. independent selection of schools for each round of survey

An important issue affecting the required sample size is whether follow-up surveys will be conducted in the same set of schools, or in different sets of randomly selected schools. The repetitive sampling design (same schools) is substantially more efficient (requires a smaller sample size). However, it can produce biased data if the results are reported back to schools, and administration of schools with severe air quality problems takes measures to improve the situation. In this case, an observed improvement would only characterize the set of schools participating in the survey and it will not be representative of the situation in the entire country.

The meeting decided that each round of survey will use a new independent random sample of schools. If clusters are sufficiently large so that only a small fraction of schools from each cluster is selected to participate in each round, a new set of schools can be selected from the same clusters. Otherwise, selection of new clusters will be necessary. The former option may be cheaper and easier to organize. Also, if variability within clusters is smaller than variability between clusters, repeated sampling from the same clusters would be a more efficient design.

An important issue to be addressed in the guidelines is feedback to the schools involved. The survey protocol would have to specify if feedback is provided at the school level, city level and/or country level. Specific recommendations on feedback to the schools will be included in methodological guidelines. To ensure that schools with severe indoor air quality problems (heavily polluted or insufficiently ventilated classrooms, presence of mould and dampness) take measures to improve the situation, such schools should also be included in a follow-up survey, as a separate set. The results from a follow-up survey in these "problematic" schools will only be used to provide feedback to school administration and local authorities and help them to make sure that the air quality problems uncovered at the previous round of survey have been addressed. These schools will not be included in the estimate of the country average and temporal trend.

Preliminary estimates of sample size

Sample size estimates for evaluating exposure to chemical indoor air pollutants

For the purpose of estimating sample size, the available data on NO_2 and formaldehyde concentrations were log-transformed because the distributions are skewed to the right and are approximately log-normal. Since no analytical formulas are available for the complex sampling including several stratification factors and clustering, final sample size estimates will need to be based on simulations. The analysis presented in Table 1 is based on the following sample size formula for characterizing concentrations of indoor air pollutants in a specific country with specified precision levels:

$$n = Deff \cdot \frac{1.96^2}{e^2} CV^2$$

Where e is the precision of the estimate, 1.96 is the z statistic for the conventional 95% confidence level (we want to be 95% sure that the population mean lies between the sample mean $\pm e\%$). CV is the coefficient of variation of the variable, defined as the standard deviation of the log-transformed variable divided by its mean, $CV = sd/mean$. $Deff$ is the design effect that provides a correction for the loss of sampling efficiency resulting from the use of cluster sampling instead of simple random sampling. $Deff$ is influenced by the degree of similarity of the pollution levels in schools from the same cluster and by the target number of schools per cluster. Variation between strata also has an effect on $Deff$. Based on analysis of literature, the value of 2 is assumed for a clustered design that will be used in large countries and the value of 1 is used for small countries where simple random sampling without clustering will be used.

The data in Table 1 show that CV varies substantially among cities and countries, which has a strong effect on the sample size estimate. The CV values for NO_2 and formaldehyde (CH_2O) overlap substantially suggesting that variability in school design and ventilation systems determines the sample size. It should also be noted that CV values for individual cities from the Expolis survey which did not include rural schools may underestimate potential variability in pollutant concentration at the country level. In addition, the data on between-school variability in pollution levels are available only for western Europe and Australia. The level of variability in school designs, sources of emission and other relevant conditions may be different in the eastern part of the European Region. To estimate the sample size for a hypothetical high CV scenario, Table 1 includes a row for $CV = 0.4$.

The sample size estimates show that approximately 100 to 150 schools will be needed in a small country with study design without clustering ($Deff = 1$) and twice as many in a big country ($Deff = 2$) to characterize the concentrations of NO_2 and formaldehyde with 4% precision if CV falls within the range of data from previously conducted surveys. For a high CV scenario, similar sample size would provide an 8% precision.

The following sample size formula for comparing two group means using a *t* test for independent samples was used to estimate sample size for detecting a specified temporal change in pollutant concentration at the country level:

$$n = Deff * \left[1 + 2C\left(\frac{s}{d}\right)^2\right]$$

Where *s* is standard deviation, *d* is the difference to be detected, and *C* is a constant depending on the statistical significance level α and the β error probability (1 – study power):

$$C = (z_{\alpha/2} + z_{\beta})^2$$

Where *z* values are obtained from the standard normal distribution. For the conventional significance level, $\alpha = 0.05$ and two-sided test of null hypothesis, $z_{\alpha/2} = 1.96$; the values of β vary depending of study power. For example, for 80% power, $\beta = 0.2$ and $z_{\beta} = 0.84$.

Samples size estimates for demonstrating temporal changes between two rounds of survey are included in Table 1. These estimates are produced for two effect sizes, 15% change and 10% change in pollutant levels, two study power levels, 80% and 90%, and two categories of country size, small (*Deff* = 1) and big (*Deff* = 2). These data show that *CV* has a strong effect on sample size estimates. Sample sizes between 100 and 150 schools for small countries, and between 200 and 300 schools for big countries will be sufficient to provide 80% to 90% power to demonstrate a 10% change in the level of pollutant at the 0.05 significance level. For a high *CV* scenario, same sample sizes would be sufficient to provide 80% to 90% power to demonstrate a 15% change in indoor air pollution.

Associations between *CV* and sample size are presented on Fig. 1. This analysis shows that a sample size of 100 schools will result in a study power of 0.8 to demonstrate a 15% change for *CV* = 0.38. Big countries with clustered design will need twice bigger sample sizes to demonstrate the same temporal change in exposure.

Sample size for evaluating exposure to mould and dampness

These preliminary estimates assume that the data will be dichotomized at the school level. Using the normal approximation to the binomial distribution, the precision of the estimate of the proportion of schools with mould/dampness problems at the 95% confidence level in cross-sectional analysis are presented on Fig. 2A. For the sample size of 100 schools, the 95% confidence interval for 20% prevalence will be $\pm$ 7.8% or (12.2%, 27.8%); for 50% prevalence, the 95% confidence interval will be $\pm$ 9.8%.

The required samples sizes were also estimated for specified values of percentage decline or increase in the prevalence of mould/dampness problem between two rounds of survey and study power levels (Fig. 2B) using the following formula for a two-sided test:

$$n = Deff * (z_{\alpha/2} + z_{\beta})^2 * \left[\frac{p_0(1-p_0) + p_1(1-p_1)}{(p_1 - p_0)^2}\right]$$

Where *n* is sample size, p_0 is the baseline prevalence of mould/dampness problems in the source population of schools and p_1 is the prevalence at a follow-up survey. For this analysis, the value of *Deff* was set to 1. The statistical significance level is set constant at $\alpha = 0.05$.

Fig. 2B shows that sample size estimates depend on the baseline prevalence (being the biggest for approximately 50% prevalence). If the baseline prevalence is 20%, the sample size estimate for an 80%

power to demonstrate a 12% decline in prevalence (from 20% to 8%) is 127 schools. For a constant effect size and study power, sample size estimates peak at approximately 50% baseline prevalence.

For bigger countries that will use clustered design, the sample size estimates are twice bigger (*Deff* = 2) at the same study power and effect size. In this group of countries, the sample size of 300 schools will provide an 80% power to demonstrate a 15% decline from a baseline prevalence of 40%.

It should be noted that bringing about a substantial reduction in the occurrence of mould and dampness in school buildings will require concerted actions at the national level and will likely take more than two years. Thus, assessing a trend in exposure will require more than two surveys. The surveillance will need to continue at least until the deadline for the implementation of the related Parma commitment in the year 2020.

Sample size recommendations

Based on this preliminary analysis, tentative recommendations for sample size are from 100 schools for small countries with homogenous conditions to 300 schools with large countries with substantial variability in climatic conditions and building practices. These recommendations will be finalized based on the results of pilot surveys and statistical simulations taking in account clustered stratified study design. It is possible that a large sample size will be required for the evaluation of exposure to mould and dampness than for chemical air pollutants. In this case, a subset of schools will only be inspected for mould and dampness.

Table 1. Required sample size for demonstrating, at the conventional level of statistical significance, a specified change in pollution levels between two consecutive rounds of survey in a country.

City/country and pollutant	*CV*	Sample size for cross-sectional analysis				Sample size for analysis of temporal changes (2 rounds of survey)							
		4% precision		8% precision		15% change, 80% power		15% change, 90% power		10% change, 80% power		10% change, 90% power	
		Deff=1	*Deff*=2	*Deff*=1	*Deff*=2	*Deff*=1	*Deff*=2	*Deff*=1	*Deff*=2	*Deff*=1	*Deff*=2	*Deff*=1	*Deff*=2
NO_2, Basel[1]	0.25	150	300	38	76	45	90	59	118	99	198	132	264
NO_2, Helsinki[1]	0.21	106	212	26	52	32	64	42	84	70	140	94	188
NO_2, Oxford[1]	0.23	127	254	32	64	38	76	50	100	84	168	112	224
NO_2, Prague[1]	0.14	47	94	12	24	15	30	19	38	32	64	42	84
NO_2, Australia[2]	0.27	175	350	44	88	52	104	69	138	115	230	154	308
Average for NO_2	0.22	116	232	29	58	35	70	46	92	77	154	103	206
CH_2O, Finland[3]	0.14	47	94	12	24	15	30	19	38	32	64	42	84
CH_2O, France[3]	0.19	87	174	22	44	26	52	35	70	58	116	77	154
CH_2O, Italy[3]	0.18	78	156	19	38	24	48	31	62	52	104	69	138
CH_2O, Netherlands[3]	0.23	127	254	32	64	38	76	50	100	84	168	112	224
Average for CH_2O	0.185	82	164	21	42	25	50	33	66	55	110	73	146
Hypothetical country/pollutant	0.4	384	768	96	192	113	226	150	300	252	504	337	674

[1] Expolis data, courtesy of Otto Hanninen.

[2] Data abstracted from *Pilotto et al., 1997. Respiratory effects associated with indoor nitrogen dioxide exposure in children. Int J Epidemiol. 26(4):788-96.*

[3] EBoDE data, courtesy of Otto Hanninen.

Fig. 1. Associations between the Coefficient of Variation (*CV*) and the required sample size (number of schools) for demonstrating 10% or 15% change in pollution levels between two consecutive rounds of survey in a small country (*Deff* = 1) at the conventional level of statistical significance (α = 0.05) with study power (P) levels 0.8 or 0.9.

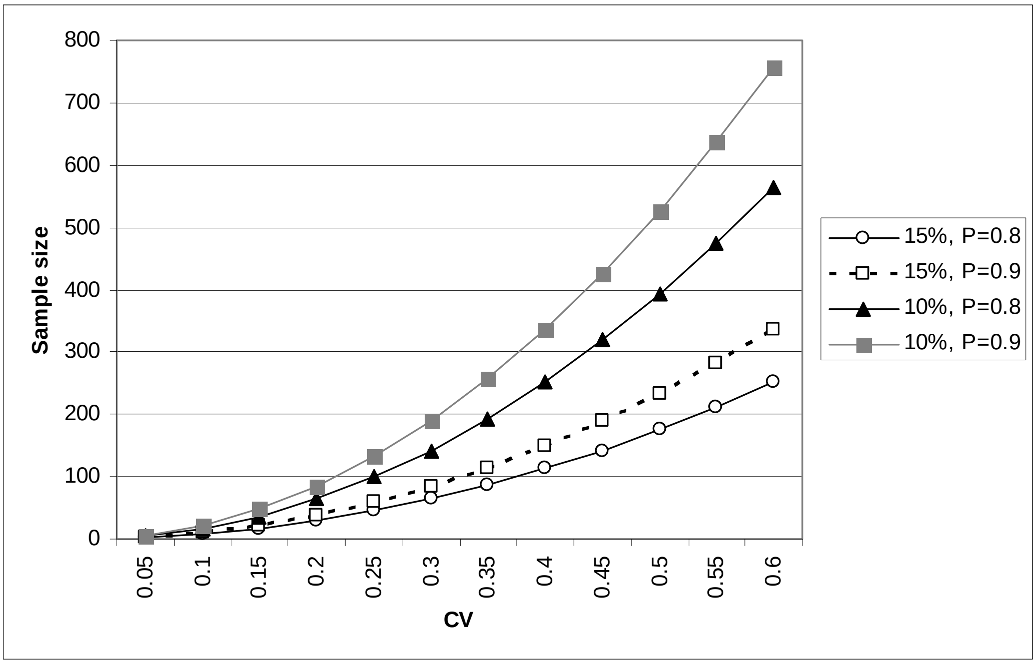
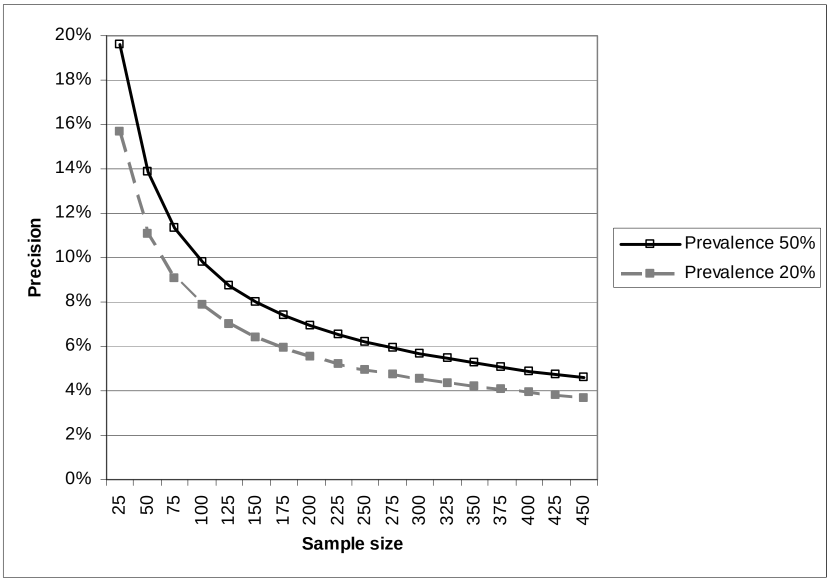
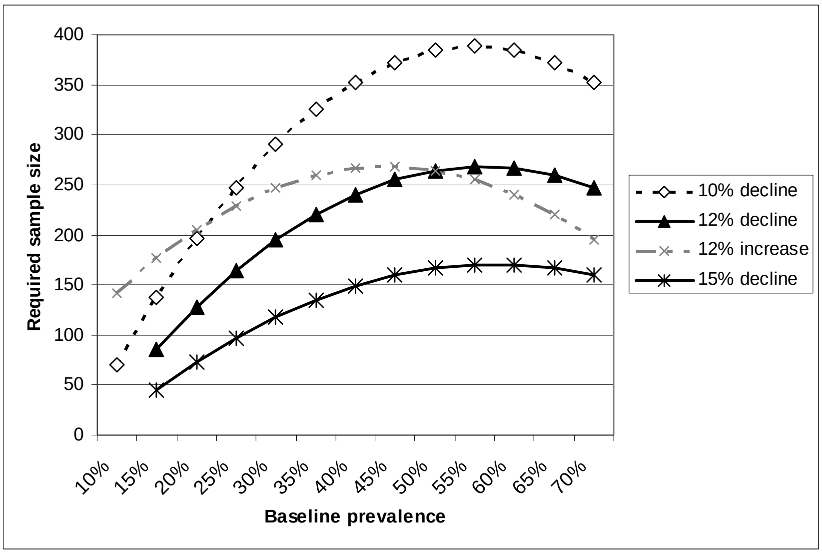


Fig. 2. Sample size analysis for mould and dampness survey in schools for *Deff* = 1. A) The effect of samples size on the precision of prevalence estimates in cross-sectional analysis (95% confidence level); B) The effects of baseline prevalence rate on the required samples size for analysis of temporal changes in prevalence for specified temporal changes in the prevalence of exposure and 80% study power 80%.

A)



B)



Conclusions, recommendations and way forward

The objectives of the proposed survey are as follows:

- Provide cross-sectional information on the prevalence of exposure to harmful factors in the school environment
- Monitor trend and provide feedback on the effect of policy measures under the Parma commitments on reducing exposures to indoor air pollutants in schools
- Produce information that can be used for health risk assessment

The meeting affirmed the need to maintain and further develop collaboration between WHO and JRC, and to establish collaborations with other national and international partners. The final product of this effort will be methodological guidelines for national studies. This document will be developed jointly by WHO and JRC with contributions from national experts and institutions.

Meeting participants discussed issues rising from the different capabilities, needs and technical solutions in different Member States. The meeting concluded that the same basic protocol has to be applied consistently and uniformly across the Region in order to ensure comparability of data.

The meeting decided that this survey will employ clustered stratified sampling design. Preliminary sample size recommendations are from 100 schools for small countries with homogenous conditions to 300 schools for large countries with diverse conditions and climates.

Trained technicians will perform school inspections to assess exposure to dampness/mould, administer questionnaires to pupils (to assess smoking, mode of transportation and hygiene), measure carbon dioxide levels in classrooms and collect samples for indoor air pollutants using passive diffusion samplers. In each school, sampling will be conducted for 5 days (one school week) in 3 classrooms using passive diffusion samplers for NO_2 and formaldehyde (and, optionally, for benzene and related compounds), and automatic data loggers for CO_2. Specific number of technicians for the proposed survey will depend on the total work load including school inspection for dampness/mould and quality of sanitary facilities, administration of questionnaires and air sampling. A maximum number of schools that can be served by one technician will be determined during pilot surveys in selected countries.

The meeting strongly recommended that there should be central funding for project management for the entire European Region. It is needed for the development of study materials and protocols, centralized training, technical assistance and quality control, procurement of monitoring equipment and training of survey personnel. Training of field technicians will need to be centralized or semi-centralized. For some small countries, training may be provided in English only (or Russian, if preferred). For larger countries, selected technicians proficient in English will be trained centrally. They will then train other local technicians in their domestic language.

The meeting identified main tasks that remain to be completed and main items that will need to be included in guidelines for national survey. These will have to be tested in pilot studies and finalized based on the results and feedback. The meeting confirmed the need to identify at least two countries for pilot projects. Working groups of volunteer experts will continue to work on the development of specific methods and protocols listed below.

- Tasks for the monitoring of indoor air pollutants:
    - Formulate technical specifications for diffusion samplers to be procured for national surveys.

  - Identify reference laboratory(-ies) for indoor air pollutants and specification of procedures for accreditation of national laboratories and continuous performance evaluation.
  - Develop detailed guidelines on air sampling, sampler processing, laboratory analysis, data entry and processing
- Tasks for monitoring air exchange rates:
  - Formulate detailed technical specification for CO_2 data loggers.
  - Develop time activity diaries and forms for collecting data on classroom usage and ventilation
  - Specify dynamic models and data analysis protocols for estimating air exchange rates using CO_2 data, and procedures for analysis and reporting of ventilation rate data.
- Tasks for evaluating exposure to mould and dampness:
  - Prepare school evaluation checklists, questionnaires and protocols for evaluating exposure to mould and dampness.
  - Prepare training materials for survey technicians, selection of training sites, organization of training for measurements of pollutants and detection of mould and dampness.
- Other tasks:
  - Develop information materials for school system managers, teachers, pupils and their families
  - As a separate issue, other groups of experts will have to develop methodologies for mode of transportation to school, quality and maintenance of sanitary facilities, hygiene practices and smoking in schools. These will be included in the unified survey protocol.
  - Finalize sample size estimates using data from pilot projects and applying Monte Carlo simulations to account for the complex clustered and stratified study design, and variability in pollutant concentrations.
  - Develop data entry forms and integrated survey database.
  - Develop procedures for data submission to WHO, data QA/QC checks, data cleaning, statistical analysis and presentation of results in ENHIS.
  - Develop policy guidelines on reporting and disseminating survey results pertaining to individual schools.

The meeting affirmed the need to conduct pilot projects in selected countries in order to finalize the survey methodology. WHO will have an opportunity to conduct a pilot study in Albania in 2011 using funding from the United Nations Coherence Programme. The survey in Albania will utilize experience and expertise from the SINPHONIE study, which will also be conducted in this country. At least one more country, preferably with different climatic and socioeconomic conditions needs to be identified for another pilot project. All meeting participants are requested to explore potential opportunities and funding sources in their home countries for a pilot project.

Preliminary survey methodology and protocol will be discussed at the WHO consultation in Bonn at the end of September 2011. A technical summary of survey methodology will be presented to the 1st session of the European Environment and Health Task Force (EHTF) in October 2011. Pilot projects will employ a version of the survey methodology incorporating comments from the September 2011 meeting and from the EHTF.

After the completion of pilot surveys at the beginning of 2012, final adjustments will be made to the guidelines for national surveys. It is expected that the baseline round of main survey should take place during the 2012/2013 heating season. In most countries, a follow-up survey round should take place two years later, during 2014/2015 heating season. The results of two rounds of survey and analysis of temporal changes will be presented in the progress assessment report that will be prepared for the 6th Ministerial Conference in 2016.

Annex 1. List of participants

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