

Occupational Exposure to Chalk Dust in Classrooms: A Breathometer-Based Analytical Study

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Abstract: Teachers exposed to chalk dust in classrooms face significant health risks primarily due to the inhalation of fine particulate matter, such as calcium carbonate particles from traditional blackboard chalk, which can penetrate deep into the respiratory system. Prolonged exposure, often spanning years for educators writing on boards for several hours daily, leads to a range of respiratory ailments including chronic cough, throat irritation, asthma-like symptoms, sneezing, chest tightness, and reduced lung function. Studies have documented these effects through subjective questionnaires and objective pulmonary function tests, revealing higher incidences of bronchitis, interstitial pneumonia, and allergic reactions among teachers compared to non-exposed individuals. For instance, autopsies of long-term educators have shown chalk particle deposition in lung tissues, contributing to inflammation and scarring over time. Additional symptoms extend beyond respiration, encompassing eye irritation, skin itching, redness, nausea, headaches, and general weakness, particularly in those teaching more than five hours per day. To assess these impacts, researchers employ various diagnostic tools, with peak expiratory flow rate (PEFR) measurements via spirometry serving as a key indicator of airway obstruction—a method akin to what might be referenced as a "breathometer" for monitoring breath-related metrics. In one study on school teachers, exposed groups exhibited lower mean PEFR values alongside elevated COPD Assessment Test (CAT) scores, indicating impaired breathing capacity, though statistical significance varied. Dust levels are quantified using particle counters that detect elevated PM_{2.5} concentrations near chalkboards, often exceeding safe thresholds during active writing sessions. Questionnaires further capture daily symptoms like breathlessness and productivity loss, correlating exposure duration with severity. While no study explicitly uses a "breathometer" (a term more commonly associated with alcohol detection devices), spirometers and peak flow meters effectively fulfill this role by providing quantifiable data on expiratory force and volume, helping differentiate chalk-induced obstruction from other factors.

Keywords: PEFR-Peak Expiratory Flow Rate, Chalk Dust Particles, Breathometer, COPD- Chronic Obstructive Pulmonary Disease, Dyspnoea, Asthma.

Introduction

In many parts of the world, chalk and slate boards are still used in classrooms; exposing teachers to dust that can irritate the airways and pose a long-term occupational health risk. While studies have confirmed that chalk dust exposure can lead to respiratory issues, a new approach involving a breathometer apparatus promises a more direct, personalized, and objective assessment of a teacher's respiratory health. This portable device uses a combination of exhaled gas analysis and spirometry to provide a comprehensive picture of a teacher's pulmonary function, potentially leading to earlier intervention and improved health outcomes.

The silent hazard of chalk dust: Research has long established that prolonged exposure to fine particulate matter, including that from chalk dust, can negatively impact respiratory health.

Key findings from multiple studies reveal the following impacts on teachers: Increased symptoms: Teachers who use chalk frequently report a higher prevalence of respiratory symptoms like coughing, wheezing, and chest tightness.

Reduced lung function: Studies show a measurable decline in forced expiratory values, such as peak expiratory flow rate (PEFR), in teachers with long-term exposure to chalk dust.

Increased risk of disease: The inhalation of chalk particles can lead to or exacerbate conditions like asthma and obstructive bronchitis, with one study finding that chronic respiratory symptoms were a risk factor for chalk users.

Correlation with years of exposure: A longer teaching career involving chalk and talk is linked to an increase in respiratory problems. These traditional studies often rely on questionnaires or clinical spirometry conducted in a healthcare setting. While valuable, these methods may not capture the day-to-day fluctuations in a teacher's lung function that are directly triggered by classroom activities.

Composition of Chalk:

Chalk dust is a fine powder produced when chalk is used to write on blackboards or other rough surfaces. It is commonly found in schools, colleges, and art studios where chalk is frequently used for teaching or drawing. Although chalk looks like a simple white stick, it has a complex chemical and physical composition. The particles released when writing, erasing, or cleaning are very fine and can float in the air for a long time. This dust is more than just a nuisance—it can affect air quality, breathing, and cleanliness in classrooms. The makeup of chalk dust varies depending on whether it is natural chalk, which comes from limestone, or manufactured chalk, which is made from purified chemicals. However, in both cases, the main ingredient is calcium carbonate (CaCO₃), with smaller amounts of magnesium carbonate (MgCO₃), silica (SiO₂), alumina (Al₂O₃), and other minerals or additives.

Understanding the components of chalk dust is important not only for knowing how it works but also for assessing its impact on the environment and health.

Chemical Composition of Chalk Dust:

1. Calcium Carbonate (CaCO₃):

Calcium carbonate is the main part of chalk, making up about 70% to 95% of its weight. It is a natural mineral found in limestone, marble, and the shells of marine animals like oysters and corals. Chemically, calcium carbonate contains calcium (Ca²⁺), carbon (C), and oxygen (O₂) arranged in a crystal structure. It can appear in two crystal forms—calcite or aragonite. Its softness (with a Mohs hardness of around 3) allows chalk to write easily on surfaces without scratching them. When chalk is rubbed on a blackboard, tiny pieces of calcium carbonate are scraped off and stick to the board. However, a lot of this becomes dust that floats in the air. Calcium carbonate reacts with acids like hydrochloric acid (HCl), producing carbon dioxide gas (CO₂), water, and calcium chloride (CaCl₂). This reaction causes the fizzing seen when chalk is exposed to acidic substances.

2. Magnesium Carbonate (MgCO₃):

Magnesium carbonate is present in smaller amounts, usually between 1% and 10%. It affects the texture and feel of chalk, making it smoother and easier to use. In some man-made chalks, a mix of calcium and magnesium carbonates is used to balance smoothness and brittleness. This type is called dolomitic chalk, derived from a mineral called dolomite (CaMg(CO₃)₂). Magnesium carbonate is softer and less dense than calcium carbonate and helps chalk absorb moisture, improving how well it grips the board during writing. However, because it is light and porous, it contributes to more dust when chalk is used vigorously.

3. Silica (SiO₂):

Silica is another minor component in chalk dust, either naturally present in limestone or added during manufacturing to make chalk stronger. It exists in different crystal forms, such as quartz, cristobalite, and tridymite. In chalk, the silica content is usually below 5%. While it improves durability, the presence of silica dust can cause slight irritation when inhaled. Prolonged exposure to high levels may lead to lung problems, but the amount in typical classroom chalk is unlikely to cause serious harm. It may, however, cause discomfort for people with sensitive respiratory systems.

4. Alumina and Clay Minerals:

Chalk may also include small amounts of alumina (Al₂O₃) and hydrated silicates, which are often from clay. These act as natural binders, holding the chalk particles together. The clay helps improve the chalk's consistency, reduces brittleness, and makes writing marks on the board more uniform. In synthetic chalk, these materials are sometimes added intentionally to enhance hardness, reduce particle breakage, and control dust. They also influence the color, giving chalk a slightly off-white or creamy appearance.

5. Additives and Binders:

Modern chalk, especially dustless varieties, often includes various additives to reduce dust.

Examples include:

- Gum arabic or starch to bind particles together and reduce breakage.
- Casein (a milk protein) as a natural binder for better cohesion.
- Stearic acid or talc to prevent chalk from sticking to fingers.
- Coloring agents such as iron oxide for red, chromium oxide for green, and titanium dioxide for white.

These ingredients alter how chalk behaves, making it less dusty and more user-friendly.

Dustless chalk is not completely dust-free but releases larger, heavier particles that settle quickly rather than remaining suspended in the air.

Physical Characteristics of Chalk Dust:

1. Particle Size:

The particles from chalk are very small, typically ranging from 0.5 μm to 10 μm in diameter. These sizes classify them as either fine inhalable particles (PM₁₀) or even smaller respirable particles (PM_{2.5}), which can reach deep into the lungs. Because of their size, these particles can float in the air for extended periods, especially in closed classrooms with poor ventilation.

2. Density and Structure:

Calcium carbonate-based chalk has a density of about 2.7 g/cm³, but chalk dust has a much lower bulk density due to the porous nature of the particles. The irregular, rough shape of the dust particles helps them stay suspended in the air and stick to surfaces, including the lining of the respiratory tract.

3. Hygroscopic Nature:

Chalk dust has a slight hygroscopic trait, meaning it can absorb moisture from the air. This helps reduce static electricity and prevents clumping, but in humid conditions, it can cause the chalk to soften or leave sticky residues on the board.

Formation and airborne behaviour:

When chalk is used on a blackboard, mechanical friction causes the chalk stick to break into fine particles. The physical process involves:

1. Writing: Pressure applied by the chalk stick against the board generates friction, releasing tiny CaCO₃ and MgCO₃ fragments.

2. Erasing: Wiping the board with a duster or cloth dislodges settled particles, reintroducing them into the air.
3. Cleaning: Brushing or tapping the eraser further disperses dust throughout the classroom. Once airborne, these particles are light enough to remain suspended for several minutes to hours, depending on air circulation. In poorly ventilated classrooms, dust can accumulate over time on surfaces, books, and electronic devices.

Health Implications of Chalk Dust Composition:

Although chalk is chemically classified as non-toxic, its fine particulate nature makes it a respiratory irritant. The health effects are influenced by the chemical makeup and particle size:

1. Calcium Carbonate: Generally considered safe, but when inhaled in large amounts, it can cause nasal irritation, throat dryness, and persistent coughing.
2. Magnesium Carbonate: Mildly irritant to mucous membranes; can cause sneezing and temporary breathing discomfort.
3. Silica: The most concerning component, as crystalline silica is known to cause lung irritation and, with chronic exposure, could contribute to conditions like silicosis in industrial settings (though classroom exposure levels are much lower).
4. Binders and Pigments: Usually non-toxic, but some synthetic dyes may trigger allergic reactions or skin irritation in sensitive individuals.

Teachers and students continuously exposed to chalk dust may experience:

1. Persistent sore throat or cough
2. Watery eyes or sneezing
3. Worsening of asthma or bronchitis
4. Headaches and nasal congestion
5. These symptoms arise primarily from mechanical irritation rather than chemical toxicity.
6. The respirable particles can deposit deep into the lungs, potentially affecting lung capacity over long-term exposure.

Environmental and Air Quality Considerations:

In closed classrooms, chalk dust can act as a fine particulate pollutant, affecting indoor air quality. The accumulation of calcium carbonate dust on surfaces can interfere with electronic devices, especially projectors, fans, and air conditioners. Studies using breathometer and particle counters have shown that airborne particulate concentration significantly increases during and immediately after blackboard writing or erasing. However, proper ventilation, use of dustless chalk, and regular cleaning can dramatically reduce these levels.

Chalk dust, though seemingly harmless, is a complex mixture of mineral particles dominated by calcium carbonate (CaCO_3), accompanied by magnesium carbonate (MgCO_3), silica (SiO_2), and trace amounts of alumina, clays, and organic binders. These fine particles, typically less than $10\ \mu\text{m}$ in size, become airborne during writing and erasing activities and can remain suspended for extended periods, contributing to indoor air pollution.

From a chemical standpoint, the main components of chalk are non-toxic and environmentally benign. However, their physical form as fine respirable dust poses potential health risks, especially for individuals with pre-existing respiratory conditions. Prolonged exposure can lead to throat irritation, coughing, and aggravation of asthma symptoms.

Efforts to mitigate these effects have led to the development of dustless chalks, which use binding agents to minimize airborne dust formation. Additionally, improving ventilation systems, using air purifiers, and adopting whiteboard technologies are effective strategies for maintaining healthier classroom environments.

Ultimately, understanding the composition and behaviour of chalk dust is crucial not only for improving classroom hygiene but also for safeguarding the health of teachers and students exposed to it on a daily basis.

Health Effects on Teachers:

1. Respiratory System Effects:

a. Short-term (Immediate) Effects

Teachers exposed to chalk dust frequently experience:

- Nasal irritation, dryness, and sneezing due to mucous membrane inflammation.
- Coughing and throat irritation, as the dust particles irritate the pharynx and larynx.
- Chest tightness and mild breathlessness after prolonged teaching sessions.
- These effects are often temporary but can worsen in poorly ventilated classrooms where dust levels remain high.

b. Long-term Effects

Continuous exposure leads to more serious respiratory disorders:

- Chronic Bronchitis: Persistent coughing and mucus formation due to irritation of bronchial linings.
- Asthma and Wheezing: Chalk dust can act as a trigger or aggravating factor for asthma, especially in sensitive individuals.
- Decreased Lung Function: Studies have shown that long-term exposure reduces the Peak Expiratory Flow Rate (PEFR) and overall lung capacity in teachers.
- Pulmonary Fibrosis (rare): Prolonged inhalation of calcium-based or silica-containing dust may cause scarring of lung tissues, reducing oxygen exchange.

- Teachers with pre-existing respiratory problems (like asthma, allergies, or sinusitis) are at higher risk of developing severe symptoms.

2. Skin and Eye Irritation

a. Skin Effects

- Direct contact with chalk dust can cause:
- Dryness and irritation of the skin, especially on hands and forearms.
- Allergic dermatitis in sensitive individuals due to repeated exposure to additives or dyes used in colored chalks.
- Micro-abrasions from fine particles that damage the skin barrier, leading to itching and redness.
- Using damp cloths or washing hands frequently may worsen irritation if proper moisturizing is not practiced.

b. Eye Effects

Fine chalk particles that become airborne can easily enter the eyes and cause:

- Redness, itching, and watering of eyes.
- Conjunctivitis-like symptoms due to irritation of the conjunctiva.
- Foreign body sensation and blurred vision after long exposure.
- Teachers using contact lenses may experience more discomfort, as the dust can accumulate under the lenses, causing friction and inflammation.

3. Allergic Reactions and Immune System Response

Chalk dust can act as an allergen. Repeated exposure may lead to hypersensitivity reactions, especially in individuals prone to allergies. The immune system identifies chalk particles as foreign bodies, leading to the release of histamines and inflammatory mediators, which cause:

- Sneezing
- Nasal congestion
- Itchy or watery eyes
- Coughing fits

Over time, chronic allergic reactions may evolve into occupational asthma—a serious condition that can limit a teacher’s ability to work effectively.

4. Impact on the Vocal and Throat Health

Teachers rely heavily on their voice for communication. Continuous exposure to chalk dust irritates the mucous membranes of the throat and vocal cords, leading to:

- Hoarseness of voice
- Sore throat
- Pharyngitis (throat inflammation)
- Vocal cord strain due to persistent coughing or throat clearing

These conditions may force teachers to take frequent breaks, reducing teaching efficiency and increasing absenteeism.

5. Effects on the Nervous and Cardiovascular Systems (Indirect)

While chalk dust is primarily a respiratory irritant, chronic stress from coughing, sleep disturbances, and reduced oxygen intake may indirectly affect the nervous and cardiovascular systems. Teachers may experience:

- Fatigue and headaches due to reduced oxygenation.
- Anxiety and stress, especially if respiratory -discomfort interferes with teaching performance.
- Though rare, studies have suggested that continuous low-level exposure to airborne particulates can have systemic inflammatory effects, contributing to long-term health decline.

6. Effects on Classroom Environment and Students

While the focus is on teachers, chalk dust also affects the indoor air quality (IAQ) of classrooms, impacting students as well. The dust settles on desks, books, electronic equipment, and surfaces, causing:

- Contamination of classroom air
- Increased cleaning frequency

Potential respiratory irritation in children, who are more vulnerable due to developing lungs.

Role of the Breathometer in Respiratory Assessment of Chalk Dust Exposure



Breathometer Device

A breathometer, also known as a breath analyser or portable spirometry device, is an important diagnostic tool used to evaluate pulmonary function in individuals exposed to airborne pollutants. In educational settings, teachers are frequently exposed to chalk dust generated during writing, erasing, and cleaning of chalkboards. Continuous inhalation of fine chalk particles may adversely affect the respiratory system over time. The breathometer provides a reliable, non-invasive, and quantitative method to assess these effects and to identify early respiratory impairment.

Principle and Function of a Breathometer - The breathometer works on the principle of measuring airflow and lung volumes during forced inhalation and exhalation. When an individual exhales forcefully into the device, sensors detect the flow rate and volume of air, which are then converted into measurable respiratory parameters. These parameters reflect the mechanical functioning of the lungs, airways, and respiratory muscles. Because the test is simple, quick, and reproducible, it is particularly suitable for occupational health screening and large population studies.

Key Respiratory Parameters Measured

1. Peak Expiratory Flow Rate (PEFR): PEFR represents the maximum speed of expiration achieved during a forceful breath out. It is primarily used to assess the degree of airway obstruction. In teachers exposed to chalk dust, a reduced PEFR may indicate narrowing of the airways due to irritation, inflammation, or accumulation of dust particles. PEFR is especially useful for detecting early functional changes before the onset of clinically apparent respiratory disease.

2. Forced Vital Capacity (FVC): FVC measures the total volume of air that can be forcibly exhaled after a full inspiration. A decrease in FVC suggests restrictive or obstructive lung conditions. Chronic inhalation of chalk dust may reduce lung compliance or cause inflammation of lung tissues, leading to a decrease in this parameter.

3. Forced Expiratory Volume in One Second (FEV₁): FEV₁ indicates the volume of air expelled in the first second of forced expiration. It is one of the most sensitive indicators of airway resistance and obstruction. Lower FEV₁ values in chalk-exposed teachers may reflect compromised airway function due to prolonged dust exposure.

Role in Occupational Exposure Assessment

The breathometer plays a crucial role in comparing respiratory function between exposed teachers and non-exposed individuals. Such comparative analysis helps establish a relationship between chalk dust exposure and respiratory impairment. Consistently lower PEFR, FVC, and FEV₁ values in exposed groups provide objective evidence of the adverse effects of chalk dust on lung function.

Additionally, periodic breathometer assessments allow monitoring of respiratory health over time. This is particularly valuable for early detection of occupational lung disorders, enabling timely medical intervention and implementation of preventive strategies.

Importance in Preventive and Public Health Measures

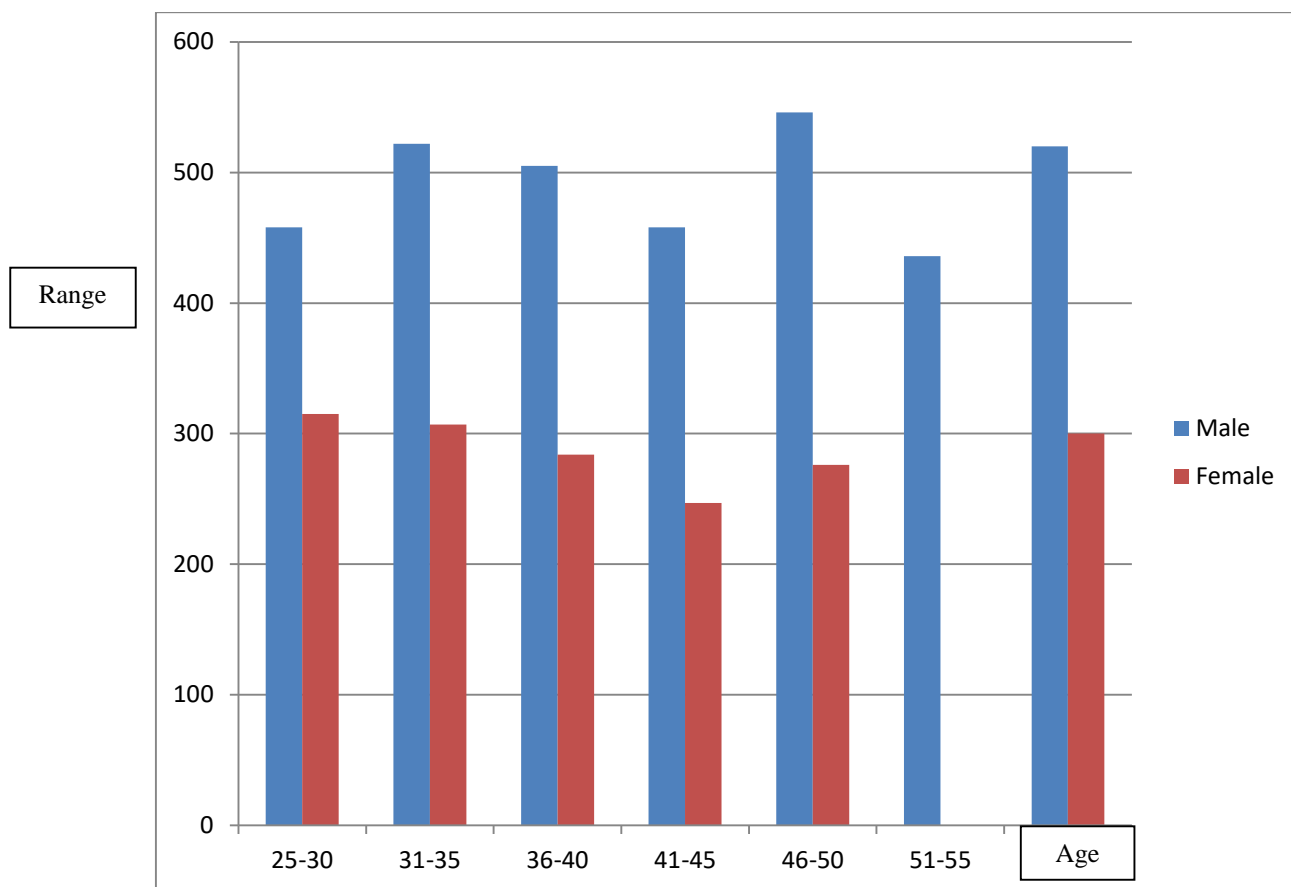
Data obtained from breathometer studies can guide the formulation of preventive measures, such as improving classroom ventilation, promoting the use of dust-free or low-dust chalk, and encouraging the adoption of alternative teaching aids like whiteboards or digital boards. From a public health perspective, breathometer-based screening supports awareness of occupational respiratory risks and emphasizes the need for regular health surveillance among teachers.

In summary, the breathometer is an essential tool for assessing the respiratory effects of chalk dust exposure among teachers. By measuring key lung function parameters such as PEFR, FVC, and FEV₁, it provides objective and quantifiable data on pulmonary health. Comparative evaluation between exposed and non-exposed individuals helps establish the occupational impact of chalk dust and underscores the importance of preventive strategies to protect respiratory health in educational environments.

Procedure Using Breathometer

- Teachers are asked to breathe normally, then exhale forcefully into the breathometer.
- The device measures airflow and lung capacity.
- Repeated tests over time can show decline in lung performance due to dust exposure.
- Data collected can be used for occupational health studies.

Survey Analysis of Lung Function among Teacher's Exposed to Chalk Dust



- Graph showing age wise distribution of male and female analysis of breathometer ranges.
- Data collected from school teachers using chalk board.
- X axis represents age of teachers and Y axis represents shows the range of their lung capacity detected using breathometer instrument.
- The general conclusion from above comparative studies on this topic is that females often exhibit a more pronounced percentage decrease in lung function readings compared to males when exposed to the same concentration of chalk dust particles.

Preventive Measures for Teachers Using Chalkboards

Chalkboards remain a common teaching aid in many schools, especially in developing regions. Although effective and economical, prolonged use of chalkboards exposes teachers to fine chalk dust particles, which can pose occupational health risks. Chalk dust primarily contains calcium carbonate and other additives that become airborne during writing, erasing, or cleaning the board. Continuous inhalation of these particles may lead to respiratory problems, skin irritation, and eye discomfort among teachers. Therefore, adopting preventive measures is essential to protect teachers' health and ensure a safer teaching environment.

One of the most important preventive strategies is the use of personal protective measures. Teachers are advised to wear face masks, particularly while cleaning chalkboards, to reduce inhalation of dust particles. Regular hand washing after classroom sessions helps prevent the transfer of chalk dust to the eyes, nose, or mouth. Avoiding direct contact with the face during teaching hours can further minimize irritation and allergic reactions.

Classroom environmental control also plays a vital role in reducing chalk dust exposure. Adequate ventilation through open windows, doors, or exhaust fans helps disperse airborne particles and improves air quality. The use of ceiling fans or air circulation systems can further limit dust accumulation in closed classrooms. Cleaning practices should emphasize wet mopping of floors and surfaces instead of dry sweeping, as dry methods tend to resuspend chalk dust into the air.

The selection of safer teaching materials significantly contributes to prevention. Dustless or low-dust chalk should be preferred, as it produces fewer airborne particles compared to traditional chalk. Using chalk holders can reduce direct hand contact and minimize chalk breakage, thereby lowering dust generation. Where resources permit, replacing traditional chalkboards with whiteboards or digital smart boards offers a long-term solution to completely eliminate chalk dust exposure.

Proper chalkboard maintenance is another crucial preventive measure. Boards should be cleaned using damp cloths or wet dusters rather than dry erasers. Cleaning should be carried out at specific times, preferably after class hours, to avoid continuous exposure during teaching. Proper disposal of broken chalk pieces prevents unnecessary dust formation in the classroom.

Regular health monitoring and awareness are essential for early detection of chalk dust-related health issues. Teachers suffering from asthma, allergies, or chronic respiratory conditions should be especially cautious and limit prolonged chalkboard use. Periodic assessment of respiratory function using tools such as peak flow meters or breathometer can help identify early signs of lung

impairment. Educational institutions should organize awareness programs to inform teachers about occupational hazards and preventive practices.

In conclusion, while chalkboards continue to be widely used in educational settings, the health risks associated with chalk dust cannot be overlooked. By adopting personal protective measures, improving classroom ventilation, using safer materials, maintaining proper cleaning practices, and promoting institutional support, the adverse effects of chalk dust exposure can be significantly reduced. Ensuring the health and well-being of teachers ultimately contributes to a more effective and sustainable learning environment.

Conclusion

Teachers suffer notable respiratory harm from chalk dust, including reduced lung capacity, asthma, cough, and irritation, due to inhaling fine particles over time. While spirometry effectively measures these effects by tracking lung function metrics like FEV1 and PEFr, no direct evidence supports using a breathometer for chalk dust checks. Overall, switching to dustless alternatives and better ventilation remains essential to safeguard teacher health. Teachers experience chronic respiratory damage from chalk dust, manifesting as diminished lung function, persistent cough, asthma exacerbations, and throat irritation from inhaling respirable particles during prolonged classroom use. Spirometry provides reliable assessment of these impacts through metrics like FEV1 and PEFr, though breathometers lack specific validation for chalk dust monitoring. Adopting low-dust alternatives, enhancing classroom airflow, and routine health screenings offer the strongest defense against long-term health decline.

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