# Dust suppressant treatments. Quality control

## *Tratamientos supresores de polvo. Control de calidad*

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**Resumen**

La emisión de polvo por efecto del viento desde depósitos de residuos mineros o industriales y el paso de vehículos en vías no pavimentadas, es un problema que afecta las actividades productivas; el ambiente y la salud de las personas que permanecen en el área contaminada. En Chile, en los últimos años la sensibilidad social y las exigencias ambientales han aumentado, así como la oferta de diferentes supresores y tecnologías de aplicación. Se han revisado las causas que provocan emisión de polvo y las tecnologías disponibles en Chile para la supresión de polvo, además de las metodologías y normativa para evaluar el desempeño de los materiales tratados con diferentes supresores. En algunos casos no es posible comparar propiedades de desempeño, como durabilidad, dosis a aplicar y frecuencia de las aplicaciones, entre otros aspectos. Los procedimientos descritos en la norma NCh3266-2012 permiten evaluar la erosión eólica en depósitos de residuos, sitios eriazos y caminos no pavimentados, junto con evaluar el desempeño de diferentes tipos de supresores de polvo a partir de datos objetivos comparables. Esto permite seleccionar el supresor más adecuado, mejorar la eficiencia de los tratamientos, optimizar los costos y mejorar los procesos productivos.

**Palabras clave:** Erosión-eólica, supresor de polvo, residuos-mineros, caminos-no pavimentados.

**Abstract**

Dust emissions by wind effect from mining deposits or industrial waste and passing vehicles on unpaved roads, is a problem that affects the productive activities; the environment and the health of those who remain in the contaminated area. The social sensitivity and environmental requirements on this issue in Chile have increased, as well as offering different suppressors and application technologies. Have been reviewed the causes of dust emission and technologies available in Chile for dust suppression, plus methodologies and standards for assessing the performance of the treated materials with different suppressors. In some cases it is not possible to compare performance properties such as durability, application dose and frequency of applications, among others aspects. The procedures described in the NCh 3266-2012 standard allows the assessment of wind erosion in waste deposits, vacant lots and unpaved roads, among others, along with evaluating the performance of different types of dust suppressants from comparable objective data. This allows selecting the most suitable suppressor, improve efficiency of treatments, optimize costs and improve production processes.

**Keywords:** Wind-erosion, dust-suppressor, mining-waste, unpaved-roads

## Introduction

The problems created by particulate matter emissions originating in industrial residue deposits and/or mine tailings facilities, vacant land, and unpaved streets and roads located in the vicinity of populated areas and productive areas, greatly affect both the quality of life and the general health of people, and have negative effects on productive systems and on the environment.

A great variety of products is now available on the Chilean market for the suppression or abatement of uncontrolled emissions of particulate matter generated as a result of road traffic and the action of the wind. Many different solutions have been tried, and several of these are applied on streets and unpaved roads, and also on dumps or deposits of mine tailings and industrial residues. These products may be based on chlorides, silicates, enzymes, polymers, or other substances.

The technologies currently used in Chile to apply products intended to abate particulate matter emissions generated by traffic and/or wind action, include – on the one hand – direct spraying of the product onto the surface at the origin of the emission and, on the other, the method usually employed on unpaved roads, which consists of mixing a certain product with the soil in order to stabilize it and improve its mechanical properties, extend the road's service life, and control emissions.

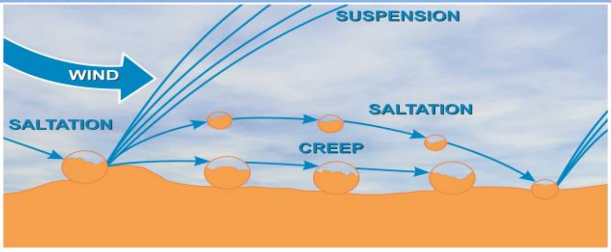
In spite of the availability of a broad and growing range of products and services aimed at abating uncontrolled emissions of particulate matter, the effectiveness and duration of the treatments are not always evaluated. This makes it difficult to improve the efficiency of these various technologies. Implementing a monitoring system aimed at evaluating the efficiency and effective duration of the treatments can provide objective data for decision-making and for improving the application procedures of products aimed at abating particulate matter emissions generated by road traffic, construction equipment, and/or the wind.

## Description of the Problem

### The process of soil erosion due to wind action

Wind erosion takes place when soil particles in the surface layer of the ground are put into motion by the action of a moving mass of air in contact with the soil. Depending on the ground surface conditions, a minimum wind velocity is needed to put the erodable soil particles into movement and, as the intensity and velocity of the wind increase, larger particles can be put into movement until a point is reached at which wind velocities are reached capable of moving all of the erodable particles, as illustrated in Figure 1. Wind erosion may be divided into three distinct stages: initiation of movement, transport, and deposition.

***Figure 1.*** *Movement of particles due to the action of the wind. Source: Jaramillo, I., Miranda, A., 2003.*




The initial movement is due to the direct pressure of the wind mobilizing the soil particles, and also to the impact of the moving particles which advance in small leaps over the ground surface.

The particles are transported in one or more of the following manners: Movement in suspension (Soil particles whose diameter is smaller than 0.05 mm are classified as fine material and dust. These particles are transported suspended in the air, along paths more or less parallel to the direction of the wind). Movement by saltation (advancement by leaps or discontinuous movement, this type of movement is caused by the pressure of the wind against soil particles, and the ensuing collision between different particles). Movement by surface creep (This type of movement is caused by smaller grains, which have been put in motion by saltation, striking larger grains when they descend to the surface).

The particles moved by the wind through suspension, saltation, and surface creep may be deposited in different places when the velocity of the wind decreases. This is a continuous process of selection and deposition of different-size particles, and the velocity of the wind plays a key role in this process.

## Dust emissions from tailings and industrial residue deposits

Wind erosion of large deposits of mine waste rock, tailings and other industrial residue deposits may be characterized as a loss of particulate matter from the surface, as a result of wind action which creates gullies in slopes and flat areas. Due to their physical characteristics and the size of the grains, particulate matter residues such as tailings and flying ash are susceptible to be eroded by the action of the wind.

In many cases, wind erosion in mining and industrial residue deposits in the North of Chile occurs in an uncontrolled manner, because of the configuration of the facilities and/or their location in the open desert or in semi-desert areas, in the absence of vegetation and other barriers that might mitigate the force of the wind. Furthermore, during spring and summer the general aridity and other climate conditions of this area lead to high atmospheric pressures that reinforce the action of the wind, eroding the slopes and flat areas of the different deposits, and also leading to environmental damage in adjacent areas which might be intended for residential, productive or recreational use, as illustrated in Figure 2.

The mobilization of particulate matter from the flat areas of a residues deposit may lead to environmental impact in the facility's area of influence and may even affect the facility's operating conditions due to the presence of suspended dust and fine particles. Furthermore, if wind erosion affects the main body of the facility, its physical stability may be compromised through the loss of material (by saltation and surface creep, mostly).

Most studies of the effects of wind erosion on land have been conducted in agricultural land or on dunes in deserts. There are some similarities between said sites and the deposits of mining and industrial residues, since these deposits hold materials similar to natural soils, as is the case with mine tailings or coal fly ash. Therefore, the conditions described by Ciccone, et. al. (1987) will apply, in the sense that particles having diameters from 0.1 mm to 1.0 mm are mainly transported by saltation, while particles having diameters smaller than 0.1 mm are transported mainly by suspension along the turbulence paths of the wind, thus creating the typical dust clouds visible at great distances from these facilities. Gillete (1977) points out that there can be interaction between the saltation, surface creep, and suspension mechanisms when the process of cascade saltation causes fine particles of sand to "sprinkle" particles of dust when falling on silty surfaces, causing these latter particles to enter a state of suspension.

***Figure 2.*** *Erosive effect of wind on a tailings dam. Source: Self-elaboration, 2006.*

The effects of climate are associated with the frequency and severity of wind storms, and problems related to dust from mine tailings have been reported in many different types of climate: the extremely hot; the dry conditions of the western United States; and the cold and humid conditions of Ireland.

Apparently, the proximity of tailings dams to population centers, and the degree of social awareness and sensitivity to dust contamination are important factors in determining how the problem of dust from mine tailings is perceived by the population. (Burgos, 2013).

The capacity to resist the erosive effect of the wind decreases considerably in tailings, coal ash, and other mining or industrial residues that have low-cohesion characteristics, thus preventing the formation of a crust or of stable layers on the surface.

***Figure 3.*** *Particulate matter emissions from unpaved roads. Source: Vial Corp S.A., 2012.*

## Emission of dust from unpaved roads

The loss of particulate matter from the surface of a street or unpaved road gradually affects the roadway's structural characteristics as a result of the loss of fine soil from the spaces between the larger particles that support the traffic loads. The fine soil helps to maintain a road structure having higher density and lower deformability. It is desirable that the fine soil remain in the road layers, so that the larger-grain particles may maintain their consolidated condition. The loss of fine material decreases the cohesion of the larger particles, leading to their gradual disintegration which in turns creates dust emissions, pot holes, a rough road surface, and ever-greater quantities of loose material on the road surface.

On exposed soil surfaces such as areas without vegetation, vacant lots and unpaved roads, the action of the wind - along with vehicle traffic – creates mechanical loads and stresses on the soil particles, usually leading to dust emissions into the atmosphere, as illustrated in Figure 3.

Bellolio (2005) reports that emission of particulate matter occurs when: the shear stresses caused by the wind or by vehicle tires create forces between the particles which exceed the forces working to maintain the particles united; and a considerable amount of loose fine material (less than 0.075 mm diameter) is present on the road surface.

Apart from the above conditions, the emission of particulate matter is determined by factors associated with the following: a) Velocity of surficial air currents, which depends on the velocity of traffic (the emission of particulate matter is proportional to the velocity of the vehicle), the aerodynamic shape of the vehicle (vehicles that are lower mobilize more particulate matter), and wind velocity. b) Traffic volume, because the volume of particulate matter put into motion is proportional to the number of vehicles passing. c) Soil granulometry: smaller particles (fines) are put into motion and transported as suspended matter, while larger particles are mobilized and transported by processes of saltation and surface creep.

Climate conditions in the area, such as relative humidity, rate of precipitation and rate of evaporation may work to increase or reduce the emission of particulate matter. Unpaved roads in arid zones or during the dry season in temperate zones, tend to generate more particulate matter emissions.

The dust emitted from these open sources is called "fugitive emissions". Studies conducted in the U.S. indicate that 34% of particulate matter in the atmosphere originates in unpaved roads (Bellolio, 2005). It is estimated that a light vehicle that is driven a distance of 1,600 m daily is capable of putting one ton of dust into suspension annually (Rada and Cruz, 2013).

## Suppression Technologies - Particulate Matter Emissions

Environmental control of particulate matter emitted from sources such as vacant land, deposits of mining / industrial residues, and unpaved streets and roads, as a result of wind action, construction equipment activity, and road traffic may be achieved by means of mechanical barriers that prevent the mobilization of particles by the action of the wind, or by means of treatments containing additives that modify the physico-chemical characteristics of particulate matter, allowing it to resist the forces originating in the movement of vehicles, operation of machinery, as well as the erosive effect of the wind.

Treatments containing additives consist of adding (to the soil, to tailings, or to the industrial residues) a chemical product or organic compound that modifies the soil's geotechnical properties and controls the emission of particulate matter. Table 1 presents a summary of some of the additives commonly used.

When the additives become mixed with the soil material (through the use of some type of mechanical equipment) in a layer of sufficient thickness, the treatment is called soil stabilization. This type of treatment is capable of modifying the geotechnical properties of the soil, for example, by increasing its mechanical strength, and/or by reducing both deformability and permeability as a result of changes in surficial electrical properties and/or in the physical agglomeration of the grains. Stabilization treatments are used mainly on unpaved streets and roads. Modification of geotechnical characteristics can have positive effects on the soil such as improving workability, optimizing the thickness of the top layers and extending their lifespan, as well as reducing emissions of particulate matter (Pradena et al, 2010). The present article does not cover this type of treatment, nor the most commonly used stabilizers, such as lime, Portland cement and asphalt.

The treatments involving application of additives by spraying the emitting surface (in order to control particulate matter emissions), are called dust suppression treatments. This type of treatment may be applied at jobsites where minerals or soil are being loaded, vacant lots, large deposits of mining and industrial residues, unpaved streets and roads, and other sources of dust emissions. The technologies and processes used for spraying particulate matter suppression products involve different types of equipment and procedures.

In material stockpile areas and deposits of mining or industrial residues, where there is difficulty of access, or when conditions are not suitable for heavy equipment and/or haul truck traffic, the implementation of a dust suppression treatment will usually involve previous mixing or preparation of the particulate matter abatement additive and prior surface irrigation or spraying.

***Figure 4.*** *Applying particulate matter abatement product in areas with low bearing capacity. Source: Aguasin Ltd.*

The preparation of the particulate matter abatement additive may be done on-site or in dedicated, specially-equipped facilities. In general, the additives are mixed with water, in proportions indicated by the manufacturer's instructions. They are then transferred to tanks installed on the equipment that is to perform the application/spraying onto the surface to be treated. In other cases, the additive is added directly to a quantity of water stored in the tank of the spraying equipment.

During the surficial application stage, if the tailings / industrial residues deposit has flat areas with sufficient bearing capacity, as in the crest of a tailing dam, the usual practice is to have tanks mounted on spray trucks or on trailers fitted with nozzles and spray devices, or capable of applying the product through irrigation by gravity or by means of pump-driven pressurized systems that provide more efficient distribution, and greater soil penetration. If the flat areas of the waste deposit do not offer sufficient bearing capacity for the conventional spraying/irrigation equipment, as in the case of an operating tailings deposit, vehicles such as tractors may be fitted out, so they can move over the surface, carrying the tank containing the product and the irrigation system, as illustrated in Figure 4.

In the case of steeper slopes on the sides of residue deposits or stockpiles of dust-emitting materials, and in other limited-access spaces, such as ore/soils loading areas, vacant land, or large deposits of mining and industrial residues that cannot be accessed by the irrigation trucks, the application of particulate matter abatement additives is usually done using fire-fighting equipment such as hoses (2.5 cm to 5.0 cm in diameter) fitted with special nozzles that can deliver different types of water jet (a water mister is the type most commonly used). It is also possible to use water sprinklers, especially adapted for use with different particulate matter abatement additives, as illustrated in Figure 5. When applying the spray, the tank loaded with the particulate matter abatement product, must be located either higher or lower than the surface to be treated, so that the pump - which may be located within the tank or on the truck - can drive the water/additive mixture to the spraying system

***Figure 5.*** *Applying particulate matter abatement product on slopes. Source: Self-elaboration, 2010.*

On unpaved roads and flat land offering sufficient bearing capacity for the equipment and trucks, the dust suppression treatment will usually require some prior preparatory work of the surface, prior preparation of the particulate matter abatement additive/water mixture, and prior surficial irrigation.

The preparation of the surface to be treated begins with scarification. The depth of scarification may vary from 5 cm to 20 cm, depending on the conditions and humidity of the soil. In some cases, and depending on the type of additive being used, the soil may have to be pre-moistened in order to achieve good results, followed by scarification and subsequent smoothing over with compacting equipment such as smooth rollers or pneumatic rollers, taking care to ensure that slopes are adequate for surficial drainage.

The preparation of the particulate matter abatement additive may be done on-site or in dedicated facilities. In general – except for asphalts, emulsions, and cutback asphalt - the additives are mixed with water in the proportions indicated by the supplier, and are then transferred to tanks from which they are applied to the prepared surface. In other cases, the additive is directly added to the water tank on the irrigation equipment.

For surficial irrigation, irrigation trucks fitted with nozzles and sprayers are used, that can either apply the product through gravity irrigation or pressurized pump-driven systems that provide more efficient irrigation and deeper penetration of the soil, as illustrated in Figure 6. The asphalt-based additives such as emulsions and cutback asphalts are loaded onto irrigation trucks or on trailers fitted with pumps, circulation systems that keep the additive in the liquid state, spray bars, and control systems to adjust the volume of asphalt leaving the spray bar. In some cases - depending on the type of product being applied - it is advisable to subsequently compact the treated surface with a vibratory roller or other type of compacting equipment suitable to the soil being treated, in order to seal the surface.

***Figure 6.*** *Applying particulate matter abatement product on unpaved roads. Source: Vial Corp S.A., 2012.*

## Methodologies for Evaluating Particulate matter Suppression Treatments

In Chile, the issues relating to particulate matter emissions from tailing and industrial residue deposits, vacant land, dust-emitting materials stockpiles, unpaved roads, and other sources, are a growing concern for most engineering, mining, energy, and road projects. This growing concern springs from the need to improve the efficiency of productive processes, respond to civil society's environmental awareness, and comply with more stringent environmental standards.

A great variety of particulate matter abatement products is now available on the national and international markets. These products are of different types, and they offer different characteristics and properties as indicated in Table 1. There are particulate matter abatement additives that modify the soil's characteristics in different ways, including changes to the mechanical strength and the durability characteristics of the treated soil material. The treated soil will behave differently under different climatic conditions such as wind velocity and wind persistence; rates of precipitation; aridity; intensity of solar radiation, etc. The treated areas will also present differences in behavior under operational conditions such as the type of vehicles and equipment in operation; magnitude of the applied loads; and traffic density.

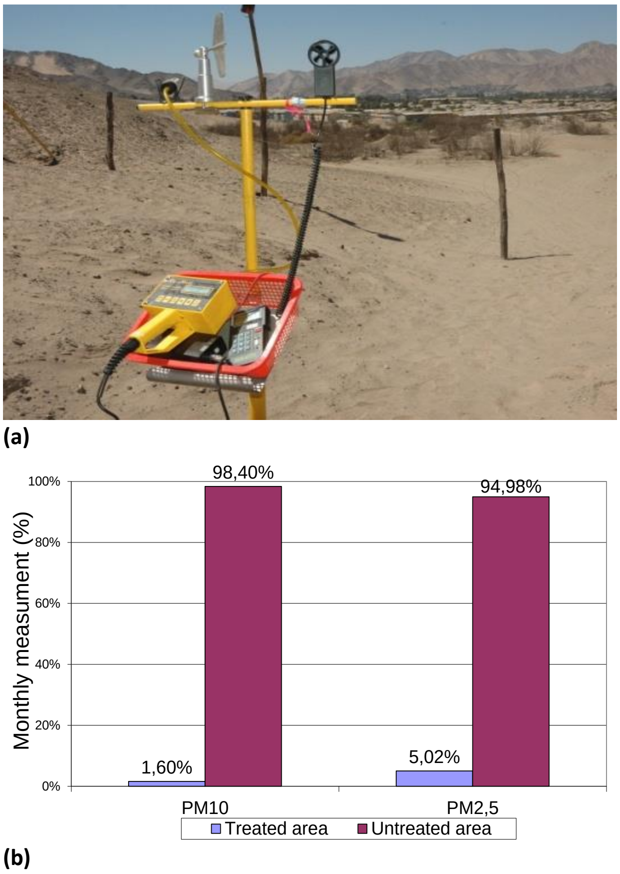
Procedures and systems are needed for measuring and monitoring the wind-driven particulate matter emissions originating in sources such as mining/industrial residue deposits, materials stockpiles, and unpaved roads, etc, and also to measure and monitor the abatement treatments that are implemented. These measurements make it possible to quantify wind-driven emissions and also to evaluate the effectiveness and duration of the treatments applied. The results of the emissions measurements and of the abatement monitoring activities serve as decision-making tools for selecting the abatement process to be implemented, and to increase the efficiency of processes such as materials loading and transport, to determine the degree of contamination of areas in the vicinity of residue deposits and unpaved roads, and to prevent health and environmental effects due to particulate matter emissions.

There may be different reasons for having to mitigate particulate matter emissions from tailings deposits and industrial residue deposits. However, in order to ensure the efficiency of the process and to achieve the desired results, certain activities must be carried out both before and after the application of the abatement product. This is especially important in large-scale initiatives involving large investments or when certain regulatory emissions thresholds must be met and demonstrated by means of objective indicators. For this purpose, the Geotechnical Group at Pontificia Universidad Católica de Valparaíso conducted studies (with the participation of the authors of the present article), over a period of more than 10 years, through FONDEF project D00I1101, which was conducted from 2001 to 2004, and through FONDEF projects D06I1097, and INNOVA Project 08CM01-13 "Draft Technical Standards for Quality Control of Operational Processes in Tailing Dams", conducted from 2007 to 2011, which resulted in the elaboration and approval of Chilean Standard NCh 3266-2012 "Tailings Deposits - Characterization of Particulate Matter Abatement Products - Evaluation of Performance Properties of Tailings Treated with Particulate Matter Abatement Products".

This Standard establishes the procedures to be followed for the evaluation of tailings treated with particulate matter abatement products in situ and in the laboratory. Based on this treatment effectiveness evaluation standard, operational guidelines and recommendations can be established, and the application process for particulate matter emission abatement treatments/systems can be optimized in operating tailings dams and/or in abandoned tailings dams. The application of this standard may be extensible to other types of deposits having similar characteristics, such as mine waste rock dumps or industrial residues such as fly ash and coal slag, where there are also reasons for minimizing environmental impact and optimizing costs, both during operations and in post-abandonment. Summarized below are the most relevant aspects of the proposed methodologies and the procedures considered in our research and in Standard NCh 3266-2012.

The methodology involves three stages: evaluation of the problem; the application as such; and evaluation of the effectiveness of the treatment using a particulate matter abatement product.

***Figure 7.*** *Measurement of direction, wind speed and breathable particulate matter (a) equipment (b) evaluation (PM10 and PM2.5). Source: Self-elaboration, 2010.*




a) Evaluation of the problem, or characterization of the site. This stage involves all activities needed to characterize the site in question, including the following: geotechnical characterization of the tailing/residue; topographical survey of the site; determining the direction and velocity of prevailing winds at the deposit location; and taking measurements of the amounts of particulate matter. These measurements must be taken prior to the application of the stabilizing product, and they must cover not only the area to be stabilized, but surrounding areas as well. The execution of this phase can be optimized if relevant information is already available. If adequate data have been obtained, it will be easier to delimit the area to be treated, and to select the most suitable type of abatement product to achieve the desired results. If this preliminary stage cannot be implemented, special care must be taken during the evaluation stage in terms of defining a control area that is to remain untreated, and that will serve for evaluating the effectiveness of the treatment.

b) Application of the particulate matter abatement product. Based on the supplier's specifications, sufficient resources must be available, and adequate procedures followed, to ensure correct application of the product, and to achieve the expected results.

c) Evaluation of the dust abatement treatment. To evaluate the efficiency of the particulate matter abatement product, a set of points must be defined at which measurements will be taken, both in the treated zone and in the untreated zone. These points will allow comparisons to be made, and also to determine the efficiency of the treatment.

The specific types of measurements that may be made, both during the problem evaluation stage and during the treatment-effectiveness evaluation, will depend on the availability of technologies and equipment. Standard NCh 3266-2012 sets out some evaluation procedures, including the following:

• Wind Direction. A wind vane is placed on a tripod (minimum height: 1.3 m). Wind direction is determined by means of a compass. Measurements of wind direction are made and recorded every time that wind velocity is measured.

• Wind velocity. A portable anemometer is placed on a tripod next to the compass, in order to take measurements of wind velocity and ambient temperature. The device must be correctly oriented (facing the wind). These measurements should be taken at least once every month, for a period of 5 minutes each.

• Breathable particulate matter emissions. A portable apparatus is used to measure and record PM10 and PM2.5 emissions (particles less than 10 and 2.5 micrometers in diameter, respectively). The apparatus is placed on the tripod, next to the compass, on the side opposite to the anemometer, and it must also be pointed in the direction of the wind shown by the compass. The measurements provide a continuous record of emissions (during 5 minutes), which must be taken simultaneously to the measurements of wind direction and velocity, as illustrated in Figure 7.

• Settleable particle emissions. This can be evaluated by means of a passive method. It consists of capturing settleable particulate matter in a standardized container. The procedure is established in Standard ASTM D 1739 – 98, the standard test method for collection and measurement of dustfall (settleable particulate matter). It is recommended that the collector be placed at a height of 1.5 m above ground level, and that the test last for 30 days, as illustrated in Figure 8.

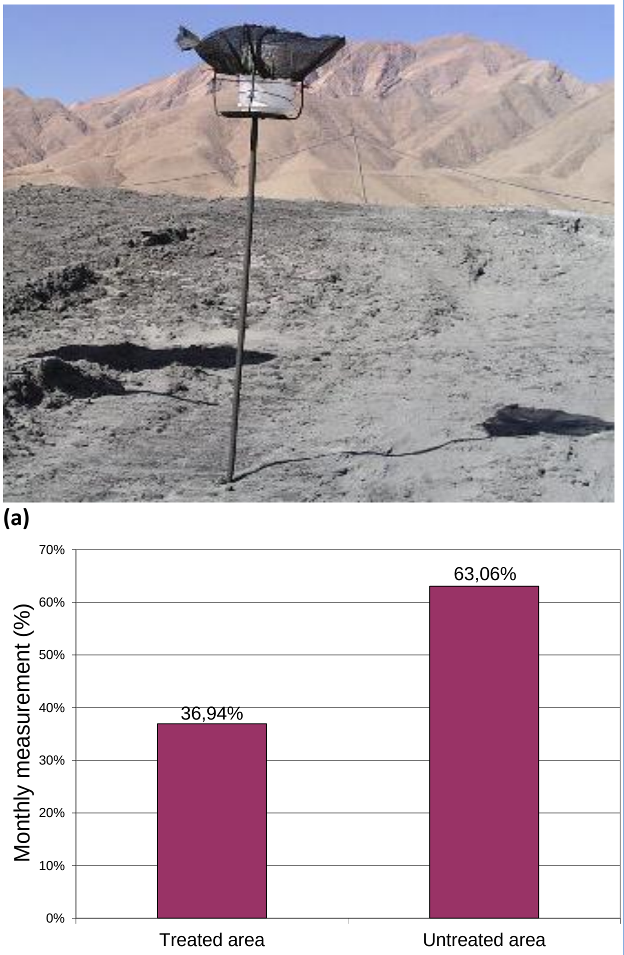
• Determining the quantity of material in saltation. The quantity of particles mobilized by the wind through saltation is determined through the use of Leatherman traps. This test was developed by Leatherman (1978) at the Imperial College of London, and has been used ever since for the study of wind erosion in soils. The trap must remain in the tailings dam for a period of at least a month, as illustrated in Figure 9.

As for quantification of particulate matter emissions and evaluation of the effectiveness and duration of abatement treatments applied on unpaved streets and roads, as well as in productive activities involving earth movement and construction of roadways in mining, forestry and/or agriculture, etc, Chilean and foreign researchers have developed and adapted a variety of procedures to evaluate dust emissions from unpaved roads.

One such example is the methodology for quantifying dust emissions from unpaved roads (MPC-1), developed by DICTUC at Pontificia Universidad Católica de Chile, based on the use of Turnkey Instrument's "Dust Mate" portable equipment (Bellolio, 2005). This procedure directly quantifies the dust produced by the interaction between vehicle tires and road surface, and employs standardized parameters such as measuring interval, location of the air sampling point, measurement parameters, type of vehicle, and test vehicle velocity.

The suggested measuring interval is one second, which gives greater measuring accuracy. The height of the air-sample intake is equal to the height of the rear axle of the vehicle being used. The air-sample intake should be in line with the transversal axis of the vehicle's tire. This methodology quantifies the concentration of PM2.5 particles (2.5 micrometers in diameter), because this is the completely breathable fraction that remains suspended for the longest time due to its small size.

***Figure 8.*** *Measurement of settleable particles (ASTM D 1739-98), (a) collector, (b) evaluation. Source: Self-elaboration, 2010.*

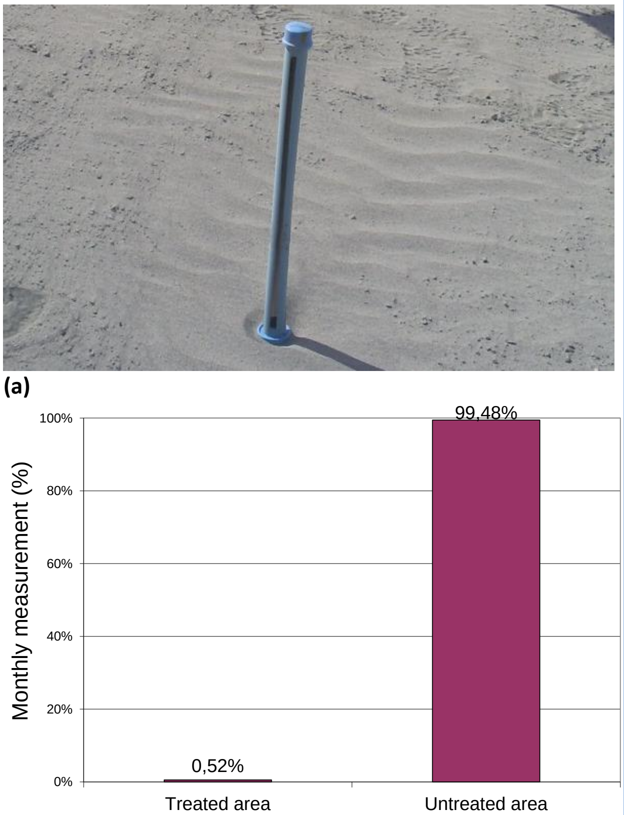



**(b)**

It is recommended that all measurements be taken using the same vehicle and at the same velocity. It is suggested that a pickup truck be used, at velocities from 40 km/hr to 45 km/hr in the case of unpaved roads, and 50 km/h in the case of roads treated with the dust abatement product. The stretch of road to be evaluated should consist of two sub-stretches (250m each), one of which has been treated with the dust abatement product and the other has been left untreated (this will serve as a control or baseline condition), making it possible to determine - by comparison - the efficiency of the abatement product. It is recommended that five consecutive measurements be taken in each stretch, so as to minimize the variability of the measurements.

Another methodology used to evaluate dust emissions is the one employed by researchers at Colombia's Universidad del Valle to evaluate calcium chloride as a dust abatement product on unpaved roads (Orobio et al 2007). This methodology is based on Standard ASTM-D1739-98 which, like the previous methodology, requires treated and untreated stretches of road (one immediately after the other, so as to minimize possible differences in road conditions, etc.). Dust collectors are placed every two meters at a height of about five centimeters from the ground surface, and at a distance of six meters from the side of the road. The dust emissions (and the corresponding amounts of eroded soil) are estimated on the basis of the collected material, which is then weighed. This process also makes it possible to estimate the quantity of accumulated material resulting from erosion, and also indicates the locations where the highest percentages of eroded material tend to accumulate. Monthly measurements are suggested, along with visual inspections made by an expert, as well as keeping photographic and video records of the tests.

***Figure 9.*** *Measurement matter transported by saltation (a) Leatherman trap, (b) evaluation. Source: Self-elaboration, 2010.*




**(b)**

Selecting the procedures that will be used to evaluate the effectiveness of particulate matter abatement products in mining or industrial residue deposits or on unpaved roads, should be done as a function of local conditions, type of activities conducted at the site, climatic conditions, availability of technologies and resources, time frame for the execution of the tests, etc. In order to select the best evaluation procedure and decide which aspects need evaluation, the emissions problem that needs to be mitigated or eliminated must be clearly characterized in advance.

## Conclusions

Dust control is an issue that is considered in engineering projects, mineral and industrial waste deposits, material stockpiles and unpaved roads. The environmental impact assessment of engineering projects must include solutions for controlling particulate matter emissions that ensure they do not affect the health of people or the environment, and that optimize the use of water.

In some cases the problems of wind erosion are generated by the material removed by saltation and creep, while in other cases, the settleable suspended material, which affects visibility and vegetation, and in others, the breathable particulate matter that affects the health of people. Currently there are a number of products with different characteristics available to adequately solve the problem of dust emissions. However, it is often not possible to compare them in terms of their performance properties, such as durability, the dose to be applied and frequency of applications, among other aspects.

The development of standards, such as NCh3266-2012 Tailings deposits, the characterization of products which suppress particulate material – evaluation of the performance properties of tailings treated with particulate material suppressors, which provides processes for evaluating the performance of particulate matter suppressor treatments, certainly contribute towards the characterization and evaluation of wind erosion problems in mining waste deposits. The methods described in the paper are useful in assessing wind erosion on waste deposits, vacant land, and unpaved roads, among others, along with evaluating the performance of different types of particulate matter suppressors using objective comparable data. They also help to select the most appropriate suppressor, improve treatment efficiency, optimize costs and improve production processes, environmental protection and people's health.

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***Table 1.*** *Commonly-used chemical and organic additives for soil stabilization and dust suppression treatments. Source: Self-elaboration, 2014.*

| **Type of Suppressor** | **Available products** | **Principle** |
|---|---|---|
| Chemical | Magnesium chloride | Hygroscopic. Capable of absorbing humidity from the air and adjacent materials, maintains the soil layer at high humidity content, increases surface tension and resists evaporation from clayey soils. It also has an electro-chemical effect, reducing the thickness of the double layer, meaning that density and mechanical strength will be higher. It also reduces deformability and permeability. |
| | Sodium chloride | |
| | Calcium chloride | |
| | Sodium silicate | Adhesive and bonding agent. Creates improved bonds between the soil particles. In road applications, the best results have been obtained on sandy soils in moderate climates, provided only sodium silicate is used, because, in other types of soil, additional chemicals are required. In some soils, there is improved cohesion of particles, reduced loss of compacting water, lower plasticity index and lower expansion factor. |
| | Ammonium chloride | Electrochemical (Ionic). The product ionizes the water in the soil, raising its electrical conductivity by acting on the cationic exchange capacity. It facilitates the elimination of adsorbed water and reduces the affinity for water of the clay particles (electrically-charged, laminar-shaped mineral crystals that attract water molecules). This modifies the soil's plasticity and expansiveness properties, increases the soil's density and mechanical strength, and also reduces the soil's deformability and permeability. |
| Organic | sulphonated oils | |
| | Sodium lignosulphonates | |
| | Calcium lignosulphonates | |
| | Ammonium lignosulphonates | |
| | Enzymes | Electrochemical (Ionic). The product ionizes the water in the soil, raising its electrical conductivity, by acting on cationic exchange capacity. A process of biocatalysis or biotransformation is triggered, that results in the conversion of one chemical compound into another by means of an enzyme or independent enzymatic system. It facilitates the elimination of adsorbed water and reduces the affinity for water of the clay particles (electrically-charged, laminar-shaped mineral crystals that attract water molecules). This modifies the soil's plasticity and expansiveness properties, increases the soil's density, bonding strength and mechanical strength, and also reduces the soil's deformability and permeability. |
| | Asphalt emulsions | Adhesive binder. Covers the soil particles with a fine layer that bonds the particles, making compaction easier, and forming a more resistant surface layer. |
| | Cutback asphalt | |
| | Molasses | Adhesive binder. Covers the soil particles with a fine layer that bonds the particles, forming a smooth surface layer. |
| | Vegetable oils | |
| | Polymers | Adhesive binder. The molecules form strongly-bound reticular structures. This is a suitable binder for soils having low clay content. When the solution mixes with the soil, the polymer covers the surface of the particles, making compaction easier and lowering water requirements for compaction. The components act on the free ions of the soil to form polymers. |