SETTLED DUST COLLECTION IN PROCESSING SHOPS OF ORE MINING ENTERPRISES

V.A. Shapovalov

PhD (Engineering), Assoc. Prof., Assoc. Prof. of the Department of Labor Protection and Civil Security, Kryvyi Rih National University, Ukraine

Aim. The research is aimed at solving the problem of dust collection inside processing shops of ore mining enterprises.

Methods. Methods of research and publication analysis and target natural investigation into industrial premises were used to study, systematize and generalize dust sources and techniques to collect it.

Findings. Dust accumulation on the surface of industrial structures and equipment does not occur in the same manner. The amount of dust and intensity of its settlement in the upper part of an industrial premise are much smaller than those next to dust emission sources. That is the reason why dust collection intervals in a separate premise will depend on intensity of dust precipitation and accumulation on elements of a given object. This will enable enterprises to keep industrial premises clean by using industrial mobile dust collectors that could be transported to another object after cleaning the previous one.

Scientific novelty. Intensity of dust precipitation on various surfaces inside processing shops of mining enterprises makes from 0.01680 kg/m^2 to 0.1440 kg/m^2 per day. During long periods, on surfaces of construction structures, pipelines, equipment, etc. a great amount of dust is accumulated making up to 20 kg/m^2 in some places. The thickness of dust layers reaches 10 mm. The most intensive dust settlement is observed next to crushers and screens as well as at ground level of the crusher house floor дробильного корпуса.

Practical relevance. There is developed a mobile dust collector that can move independently to a required object within an enterprise. The problem of dust collection can be solved at the lowest cost by removing stationary pipelines, installing the machine at the most convenient places along the perimeter of an industrial object, fast handling of pipelines and high capacity. It can be used together with current dust suppression and collection means to maintain dust level of working places within sanitary standards.

Keywords: dust emission, dust settling/precipitation, dust collection, industrial dust collector.

Introduction. Technological processes of rock processing are accompanied by intensive dust emission which increases allowable values of dust content in the air of working places. Available methods of dust suppression such as aspiration, ventilation, dust binding by moistening processed materials, capsulation of trans-loading units, etc. are unable to localize dust sources completely.

Emitted dust spreads all over industrial premises and settles on various surfaces (construction structures, pipelines, cable trunks, equipment elements, etc.) making layers of various thickness. Under the action of various factors (equipment operation and vibration, repair works, aeration flows, etc.), settled dust can repeatedly turn into aerosols. Due to this, dust content of the air increases that can provoke vocational diseases of processing shop employees.

At the same time, the dust having settled on various surfaces makes equipment maintenance and repair more complicated, expedites wear of certain assemblies and parts, reduces maintenance periods, and disrupts the operation of control and weighing equipment.

That is why, solution of dust collection problem is urgent for processing shops of mining enterprises, it allowing them to facilitate working conditions, reduce vocational disease rates and cut down equipment wear.

1. Analysis of dust emission sources and dust content in the air of working places

Transloading units of bulk materials, grizzly and unbalanced-throw screens, medium and fine crushers, belt conveyors are basic and primary dust emission sources in processing shops [1-6].

While loading ore or waste materials from one equipment type to another, dust is emitted into the air of an industrial premise because of diffusion of a dust-air flow, kinetic power of dust particles imposed by moving mechanical parts, excessive air pressure inside transloading units (chutes) and receiving bins as well as inside protective shields of grizzly and unbalanced-throw screens. Excessive pressure makes dust enter the premise atmosphere through loading mouths or slots. Without protective shields of screens the air dust level reaches 800-1000 mg/m^3, and it reduces five-tenfold if they are available [5]. Dust emissions through loading mouths of crushers make 8-60 m/sec [6]. The way screens, inlet and outlet mouths of chutes and crushers are compressed and covered affects dust content in the air of working places.

A conveyor belt is another dust source. Humidity of transported materials and operation of liquid atomizers to suppress dust enhance dust adhering to the belt surface [5, 6]. If conveyor belt cleaners do not operate properly, part of dust materials stick to supporting rollers. In this place, intensive abrasion of ore dust occurs between a roller and the belt accompanied by intensive dust emission. Dust adhesion to supporting rollers happens along the whole length of the conveyor. The maximum dust adhesion is observed in the head part of the conveyor just after unloading. As moving away from the conveyer head, adhesion decreases [5].

Irregularity of materials on the dumping tract and adhesion of hauled materials on supporting rollers cause vibrations of the conveyor belt and dust emission.

When bulk materials move along unbalanced-throw screens, they make oscillatory movements vertically. It results in auxiliary dusting of materials that enhances fine-dispersed dust formation. When the material moves vertically, dust comes out of the flow and enters the premise atmosphere through slots of protective shields of the screen and the loading device. The dust level next to operating screens ranges from 20 to 150 mg/m^3 [4, 5].

When loading cone crushers of КСД-2200, КМД-2200m and КМДТ-2200 types, there is additional dusting of the rock mass flow moving along the cone towards the crushing bowl, this causing intensive emission of fine-dispersed dust. Because of excessive pressure in the loading space of the crusher, the dust comes out of the total flow and enters the air atmosphere of the shop. The most intensive dust emission is observed in case of using hammer mills with excessive pressure of 20-30 N/m^2 inside their housing [4, 5].

In hauling bulk materials from the receiving bin to the emergency storage, from one conveyor to another, there occurs adhesion of processed materials under screens. This causes production stoppages. These places are cleaned during inter-shift periods by means of pick hammers and compressed air. Such operations intensify dust content in the air that exceeds standard values by a factor of 15-20.

The dust settled on various surfaces is a source of secondary dusting. Some authors indicate that secondary dust sources are more difficult to eliminate than the primary ones [4, 5].

During their shifts, employees clean their working places by means of brooms, spades and scrapers. The floor surface is the main cleaning object, protective shields of equipment and construction structures are sometimes cleaned as well.

According to A.A. Kurnikov [7], while cleaning premises with brooms and scrapers, 40-50% of dust is left and about 10% rises into suspension. The residual concentration of dust is almost by 1.35 times bigger than background concentration.

Thus, both primary and secondary dust sources cause air pollution of industrial premises.

Table 1 presents the results of measuring the dust content in working places at the crushing and sizing plant of Rodina mine conducted by the industrial sanitary laboratory of the PJSC KZRK (Kryvyi Rih Iron Ore Works).

Table 1

Dust concentration in working places of the crushing and sizing plant of Rodina mine

Working place	Characteristics of a technological process	Dust concentration in the working place, mg/m^3
Belt runner	Monitoring and control	46,0
Screener	Screening	4,4
Crusher operator	Crushing	4,2
Bunkerman- signaler	Monitoring and control	5,4
Shift repairman	Monitoring and control	2,9-3,5

The maximum allowable concentration of dust containing from 10 to 90 % of crystalline silicon dioxide makes 2 mg/m3. The measurement results indicate that dust content in working places exceeds allowable values. Screens, crushers, transloading units and belt conveyors are the most intensive dust sources.

2. Numerical assessment of dust accumulation on various surfaces

The dust settled on various surfaces is characterized by different fraction composition. Fine-dispersed dust particles of 0-20 μm can be in suspension state for a long time. The most hazardous for health are dust particles of 0.2-5 μm causing acute respiratory diseases [5]. Particles of up to 200 μm enter the air atmosphere and precipitate on the surface of construction structures, cable trunks, equipment, etc. under gravity. Gradually dust accumulates on these surfaces. Part of dust becomes compressed while newly settled dust remains suspended for a while and from time to time is blown off the surface by air flows or leaks down under the action of different factors. Larger dust particles of 200 μm-1 mm fall onto the floor next to the dust source. The amount of settled dust decreases with distance from the dust source. Percentage of fine fractions in flying dust increases due to larger particles precipitating. If the dust source is high above the floor, emitted large-dispersed particles tend to reach the ground level. In most cases, dust settles on horizontal surfaces which happen to be on its way.

It is very difficult to get rid of settled dust completely using some simple cleaning means only. Application of brooms and brushes causes secondary intake of dust into the air creating increased dust content [7].

The most intensive dust precipitation on various surfaces results from crushing, grinding, screening and mechanical haulage of solid materials. Researches into intensity of dust accumulation at crushing and sizing plants enabled definition of the daily amount of settled dust.

There were selected places of maximum dust precipitation at the crushing and sizing plant of Rodina mine next to the most intensive dust emission sources. All the selected measurement points are on the floor next to the dust sources. The plant processes raw materials (iron ore) 18 hours a day and inter-shift stoppages and preventive repairs take 6 hours. It was noticed that dust precipitation occurs not only during plant operation, but also between shifts.

Observations were held within 24 hours. Samples of settled dust were weighed by means of analytical scales. Observation data are given in Table 2.

Table 2

Amount of dust settled on the floor next to the dust sources at the crushing and sizing plant

Measuring points	Amount of settled dust, kg/m^2 per day
1	2
Crusher КСД-2200 Б # 1	0,1152
Belt conveyor ЛК-3, ЛК-4 (drive)	0,0456
Crusher КСД-2200 Б No 2	0,1248
Belt conveyor ЛК-10	0,0696
Unbalanced-throw screens ГИТ-71 #1, 2	0,1416
Grizzly screen	0,1272
Belt conveyor ЛК-5	0,0168
Ground level of the crusher house	0,1440
Belt conveyor ЛК-2	0,0552
Gallery of Conveyors 8, 9 (tail)	0,0312
Gallery of Conveyors 8, 9 (head)	0,0408

The observation results indicate that if aspiration systems function properly, dust precipitation on the floor next to the selected dust sources make 0,0168-0,1440 kg/m^2 per day. The most intensive dust precipitation is next to crushers and screens and at the ground level of the crusher house making 0,1152-0,1440 kg/m^2 per day.

Part of the dust settled on the floor next to dust sources during the shift is cleaned by employees by means of scrapers and brooms. The rest of the dust in suspended state gradually precipitate on the surface of equipment, construction structures, pipelines, etc. As time goes by, dust accumulates on these surfaces making a layer of considerable thickness. This dust is not cleaned by conventional brooms and scrapers as this greatly increases the dust content in the air.

To determine the weight of settled dust on various surfaces of the crushing and sizing plant, there were chosen sites of 1 dm^2 on different heights on horizontal and spherical surfaces. A year later, the dust was collected there. The samples from each site were weighed and areal density of the settled dust was determined by re-computation. While sampling, dust layer thickness was determined as well. The results are given in Table 3.

Table 3

Results of determining dust density and thickness on various surfaces of the crushing and sizing plant of Rodina mine

Sampling places	Areal density of dust, kg/m^2	Thickness of the dust layer, mm	Height from the floor, m
1	2	3	4
The drive of the КСД-2200 crusher	3,88	1,5	1,5
The guard of the crusher charging chute	15,46	4,0	4,6
Column ties L75×75 of the crusher house	10,59	3,0	1,0
The repair platform near the КСД-2200 crusher (floor)	3,23	0,8	0
Drive guard of Conveyor 3	1,47	0,5	1,2
Metal structures of the ventilation installation	4,23	1,2	2,5
АТУ 2 pipeline	4,29	1,2	3,0
The floor under АТУ 2	41,23	10,8	0
The beam of the bridge crane of the crusher house	11,84	3,2	6

Continuation of table. 3

1	2	3	4
The frame of the laminal feeder	5,23	1,4	1,2
The guard of the charging chute of Conveyor 9 (tail)	18,01	4,7	1,2
Guard of charging chute of Conveyor 8 (tail)	22,67	5,9	1,2
The frame of Conveyor 9	7,74	2,6	0,7
The frame of Conveyor 8	5,46	1,4	0,7
Metal structures of the gallery of Conveyors 8 and 9	19,73	5,2	3,2
Cable runs of Conveyors 8 and 9	4,54	1,2	1,8
Metal structures of the gallery (ties)	11,22	4,3	1,8
Metal structures of the transloading unit	9,55	4,0	4,0
Metal structures of АТУ 4	22,51	6,0	3,0
The fire pipeline of ∅ 100 mm	3,12	0,8	1,2
The drive enclosure of Conveyor 9	17,33	4,6	1,5
The drive enclosure of Conveyor 8	21,98	5,5	1,5
The drive bottom of Conveyors 8 and 9	5,52	1,8	0
The cable runs along the gallery of Conveyors 8 and 9	8,89	2,3	1,8
The air duct of ∅ 108 mm (at EL of the storage hopper)	3,30	0,9	1,0
The window frame (at the same place)	0,30	0,1	0,8
Metal structures L100×100 (column ties)	12,34	2,6	5,2
The air inlet case of the storage hopper	22,14	5,6	4,8
Metal structures of the charging slot of the storage hopper	22,0	5,5	1,1
The pipeline of ∅ 159 mm	18,63	4,9	1,2
The cable run above the ГИТ-71 screen	6,05	1,6	1,8
The cable run at EL +4000 m	8,37	2,2	1,8
Metal structures at EL of the ГИТ-71 screens	11,51	3,0	4,1
Metal structures (column ties) L90×90	7,88	2,0	2,2

Continuation of table. 3

1	2	3	4
Metal structures of the industrial building (the ceiling beam I 30)	6,36	1,8	3,3
Metal structures (column ties) L75×75	25,52	6,6	2,4
Metal structures (the ceiling beam I30)	6,50	1,8	3,5
The air duct of ∅ 108 mm at EL +4.000 м	6,83	1,8	1,0
The air duct of ∅ 300 mm	21,93	5,8	1,8
The equipment at the repair platform at EL +4000 m	1,85	0,2	0
The ventilation pipeline of ∅ 450 мм	20,81	5,5	2,2
Cable runs of Conveyor 50	9,85	2,5	1,8
Cable runs inside the drive building of Conveyor 50	5,42	1,4	1,8
The fire main of ∅ 108 mm	10,28	2,7	1,8
The frame of Conveyor 50 (gallery)	2,97	0,9	0,7
The frame of Conveyor 50 (tail)	7,64	2,0	0,7
The frame of Conveyor 12	7,11	1,9	0,7
The frame of Conveyor 50	7,39	1,9	0,7
Ties of load-bearing columns (L90×90, left)	13,21	3,5	2,8
Ties of load-bearing columns (L90×90, right)	16,91	4,4	2,8
The repair platform	19,44	5,1	0
The air inlet of the charging slot of Conveyor 12	16,91	4,4	2,5
The air inlet of the charging slot of Conveyor 50	22,20	5,8	1,5
The air inlet of the transloading unit (the drive of Conveyor 12)	7,19	1,9	1,6
The air inlet of the transloading unit (the drive of Conveyor 50)	7,39	1,9	1,6
The air duct of ∅ 150 mm	15,73	4,1	1,5
The trans-loading unit from Conveyor 50 to Conveyor 12	3,64	1,0	1,1
Metal structures of the gallery of Conveyors 12 and 50	8,30	2,2	2,6
The same building of the trans-loading unit	6,45	1,7	2,6

Analysis of the results of determining areal density indicates quite a great amount of dust (up to 20 kg/m^2 per year) and in some places - over 40 kg/m^2 per year - accumulated during a long period of time on the surface of structures, pipelines, and cable trunks. On all flat surfaces, dust settles in equal layers with the exception of cylindrical and spherical surfaces of cable communications, air ducts and some other equipment. There, dust layers copy these objects outlines with the highest thickness in the central part of the surface. The amount of dust and intensity of its precipitation on the surfaces in the upper parts of a premise is much smaller than next to the dust sources. Therefore, intervals of dust collection in a separate premise will depend on intensity of dust precipitation and accumulation on elements of a given object.

3. Dust collection

Technologies of rock processing are noted for a variety of sources of intensive dust emission and great areas of its precipitation to be cleaned. Centralized industrial dust collectors can be applied to different surfaces in processing shops of mining enterprises [8-15].

Yet, these machines are stationary and applicable to just one premise. The stationary pipeline system when in long service tends to be polluted and requires either cleaning or demounting. Dust precipitation reduces the amount of air exhausted through dust-cleaning nozzles and changes aerodynamic indices and efficiency of the vacuum system as a whole.

The length of pipelines of stationary vacuum systems is conditioned by large areas to be cleaned and a great amount of equipment there. This requires highly efficient traction activators consuming much power.

Thus, a long stationary system of pipelines is the most significant disadvantage of all modifications of centralized industrial dust collectors. It should also be noted that one machine is applicable to one premise only. For large-scale enterprises, there should be several single-types machines, each of them having a stationary system of pipelines. It makes control over pipe blockage more complicated and is associated with higher maintenance costs of such a long system within one enterprise.

Dust accumulation on surfaces of industrial structures and equipment does not occur uniformly. It enables an enterprise to keep its industrial premises clean by using a mobile dust collector that is transported to another object after cleaning the previous one. Basic equipment of a mobile dust collector is in the body of a van outside a premise to be cleaned (Fig. 1).

Before starting the machine, some assembling operations are required to install vertical and horizontal sections of a pipeline.

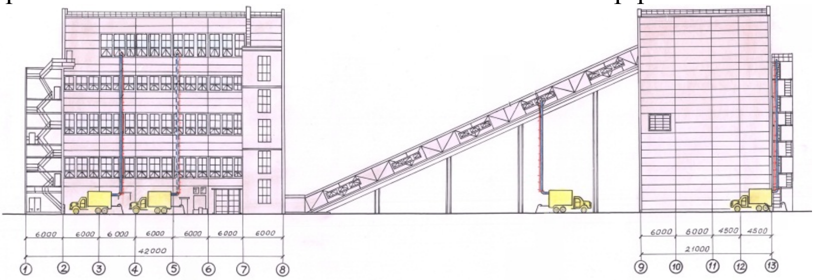

Fig. 1. Location of the mobile dust collector while assembling the vertical section of pipelines

As the industrial dust collector is mobile, assembly operations are conducted permanently when it is transported to another place. Before mounting the vertical section of a pipeline, the van is next to the premise where the pipeline system is to be installed at the set elevation (Fig. 1).

When the required elevation of the vertical section is reached, horizontal pipeline branching is mounted (Fig. 2).

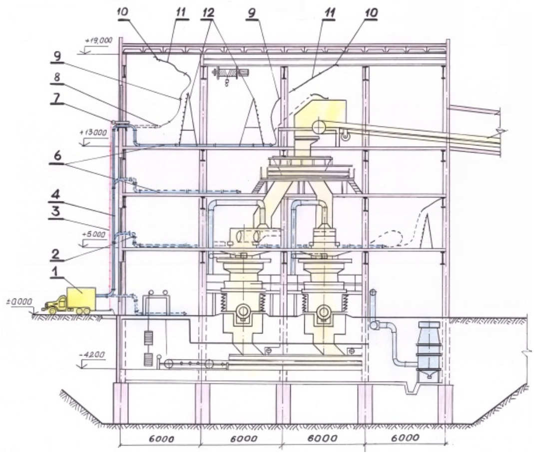

Fig. 2 Layout of pipelines inside a premise: *1* - mobile dust collector; *2* – pipeline elements (elbows, tees, etc.); *3* - winch cable; *4* - vertical pipeline; 5 - loading conveyors; *6* - horizontal pipeline; *7* - block-clamp; *8* - cone adapter; *9* - flexible hose; *10* - nozzle; *11* - lever; *12* - step-ladders

The mobile industrial dust collector is serviced by three people, one of them is a driver and the rest are dust-collecting operators. The driver controls basic equipment, while operators clean a premise. Both operators also deal with high-up surfaces and hard-to-reach places. One of them cleans the surface using a step-ladder, while the other watches out for him, switches a flexible hose from one pipe union to another, gives required nozzles, etc.

A mobile industrial dust collector is able to move independently to a required object of cleaning within a given enterprise as a traction activator and dust catching devices are inside a mobile van, while detachable pipelines and nozzles are mounted from separate sections during cleaning. It reduces the total length of the vacuum system and helps avoid blockage of pipelines in the long run. There is also an opportunity of cleaning hard-to-reach surfaces. As the van is located outside the cleaned object, the air does not re-circulate in heavily polluted premises.

Mobile dust collectors are applicable to shops with any appliance saturation. The machines are able to collect great amounts of dust and transport it to unloading points without intermediate loading-unloading operations. Dust unloading is performed outside the industrial premise to avoid its secondary dust pollution.

Conclusions

The most intensive dust sources in processing shops of ore mining enterprises are screens, crushers, transloading units and belt conveyors. Settled dust becomes a source of secondary dust emission. Both primary and secondary dust sources cause dust pollution of industrial premises with dust content in the air exceeding allowable standards in working places.

Intensity of dust precipitation on various surfaces in processing shops of ore mining enterprises makes from 0,0168 kg/m^2 to 0,1440 kg/m^2 per day. Over the course of a long period, a great amount of dust (up to 20 kg/m^2 in some places) precipitates on the surfaces of construction structures, pipelines, equipment, etc. Layers of settled dust can reach 10 mm. The most intensive dust precipitation is observed next to crushers and screens as well as at the ground level of the crusher house floor.

Dust accumulation on the surface of premise structures and equipment is not uniform. Dust quantity and intensity of its precipitation in the upper parts of a premise are much smaller than next to dust sources. Dust collection intervals in a separate premise will depend on intensity of dust precipitation and accumulation on elements of a given object. It will enable an enterprise to keep its industrial premises clean by using mobile industrial dust collectors transported to another object after cleaning the previous one.

A mobile industrial dust collector can independently move towards a required object within a given enterprise. Absence of a stationary pipeline system, an opportunity to be used in the most convenient points along the perimeter of a premise, quick mounting and demounting of pipelines, and high efficiency enables solution of the dust collection issue at minimal costs. If combined with current means of dust suppression and collection, the machine allows keeping dust content in working places within sanitary standards.

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