Risk Quotient (RQ) Analysis in Workers Exposed to Respirable Dust in Ceramic Industry

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Abstract

Ceramics are produced from mashed clay, made using high temperatures with long durability so that the clay powder becomes very dry, triggering the spread of dust in the work environment. The very small dust, when inhaled, is able to enter the lungs, causing health problems to workers. To identify health problems that can occur to the workers, risk analysis is needed to determine the level of risk in the workers. This study aims to analyze the risk of workers exposed to respirated dust in ceramics industry. This study was an observational study using a cross sectional approach. The population in this study were all workers who worked in the production sector in ceramics industry comprising 30 workers. The sample in this study was the study population, consisting of 30 workers. Exposure to respirable dust on the respondents was measured using total dust sampling, indicating that 53.3% of the respondents had values exceeding the threshold <2 mg/m3 according to Minister of Manpower and Transmigration Regulation No. 13 of 2011, concerning Threshold Value of Chemical Factors in Work Environment. The analysis showed that the RQ (realtime) values ranged from 0.13-1.06 mg/m3/year. Measurement of the level of risk based on RQ value showed that 13.3% of the workers had an RQ value of >1, which means that they had a risk of being unsafe against exposure to respirated dust, so that they were at risk of developing health problems. Actions that can be taken to minimize the adverse effects of dust in work environment are by controlling dust at the source, using Personal Protective Equipment (PPE) at work, and periodic physiological pulmonary health examination.

Keywords *: respirable dust, ceramic industry, risk characteristics, Risk Quotient (RQ)*

Introduction

Health of the workers is also a concern of public health. Air pollution is the entry of living beings, substances, energy, and/or other components into ambient air by human activities so that they exceed the prescribed air quality standards[1]

There are several stages of the process that must be done to make ceramic products, ie. processing raw materials, forming, drying, combusting, and grinding. Basically, ceramics are divided into two, the traditional ceramics, which are made using natural raw materials such as ceramics for glassware and other household furniture; and fine ceramics, which are made using metal or metal oxides. For example, metal oxides (Al_2O_3, ZrO_2, ThO_2, BeO, MgO, and $MgAl_2O_4$), nitrides and carbides (Si_3N_4, SiC, B_4C, and TiB).

According to WHO[2] harmful dust is as large as 0.1 to 5 microns or 10 microns. The Ministry of Health states that the size of harmful dust ranges from 0.1 to 10 microns. Threshold value is a standard of recommended work environment factors in the workplace so that workers can still receive it without causing health problems. Minister of Manpower Regulation Number 13 of 2011 concerning Threshold Values of the physical and chemical factors in the work environment set a threshold of 2 mg/m3.

Risk Analysis is a scientific process that is used to estimate the possible negative effects of health due to exposure to harmful chemicals.[3] The level of risk in workers can be determined by conducting exposure analysis in which risk agent intake that enters the body of the workers was calculated according to the workers' anthropometry and is assessed as the default.

Method

This study was an observational study with a cross-sectional approach. The population in this study was all workers in the production section, ranging from raw materials processing to packing, comprising 30 persons. The sample in this study was the study population of 30 workers. This study was conducted in the ceramic industry of PT. X in Gresik District, East Java, Indonesia. Data collection was carried out in November - December 2018.

In this study the primary data consisted of measurements of inhaled dust using a Total Dust Sample measuring instrument, and the measurement of lung function capacity using spirometry. Determination of individual characteristics and exposure factors was carried out using a questionnaire. Primary data collected in this study with using questionnaires were about self-identity, age, duration of exposure and the use of Personal Protective Equipment (PPE).

Results

Workers' age distribution

Table 1. Distribution of respondents based on the age of the workers in the production section of a ceramics industry in 2018

No.	Age	Total	Percentage (%)
1.	19-27	11	36.67
2.	28-36	12	40
3.	37-45	4	13.33
4.	46-54	3	10
Total		30	100

Table 1 shows that the majority of the workers are 28-36 years old (40%). They were the workers in the production section of the ceramics industry.

Level of respirated dust

Dust measurement used Total Dust Sampling that had been installed in each respondent, which aimed to determine the distribution of respiratory dust exposure to each respondent. Measurement of dust levels was carried out in the work environment of the respondents.

Table 2. Total dust exposure distribution to workers in the ceramics industry production section in 2018

Respondents	Dust Level (mg/m³)	Respondents	Dust Level (mg/m³)	Respondents	Dust Level (mg/m³)
1	5.8	11	5.8	21	1.2
2	1.2	12	1.2	22	5.8
3	1.2	13	5.8	23	5.8
4	1.2	14	1.2	24	1.2
5	5.8	15	1.2	25	1.2
6	5.8	16	0.95	26	5.8
7	5.8	17	5.8	27	5.8
8	0.95	18	1.2	28	5.8
9	0.95	19	1.2	29	5.8
10	5.8	20	5.8	30	5.8

Dust measurement using total dust sampling that had been installed in each respondent showed dust levels of 0.95-5.8 mg/m3. Minister of Manpower and Transmigration Regulation Number 13 of 2011 concerning the Threshold Value of Chemical Factors in Work Environment on particulate respirable dust determines the threshold of <2 mg/m3. Thus, in this study as many as 16 (53.3%) workers had Total Dust Sampling higher than the predetermined threshold value.

Exposure analysis

This study was to determine the intake value of the risk agents that entered the body of the workers in accordance with the workers' anthropometry and the existing default values. The variables in exposure analysis in this study were concentration, inhalation rate, exposure time, exposure frequency, duration of exposure, body weight and time of average exposure. Table 3 shows the results of exposure analysis to workers in the ceramics industry:

Table 3. Distribution of exposure analysis for respondents in the ceramics industry in 2018

Respondents	C	R (inhalation rate)	T_E (h/day)	f_E (effective days/year)	D_t	W_b	T_{avg} (h/y)	$I_{(realtime)}$
1	5.8	0.589	7	250	2	53	365	0.020612
2	1.2	0.624	7	250	2	62	365	0.003859
3	1.2	0.563	7	250	2	47	365	0.004592
4	1.2	0.597	7	250	2	55	365	0.004166
5	5.8	0.576	7	250	2	50	365	0.021371
6	5.8	0.593	7	250	2	54	365	0.020372
7	5.8	0.627	7	250	2	63	365	0.018463
8	0.95	0.62	7	250	2	61	365	0.003087
9	0.95	0.677	7	250	2	79	365	0.002603
10	5.8	0.597	7	250	2	55	365	0.020138
11	5.8	0.68	7	250	2	80	365	0.015762
12	1.2	0.553	7	250	2	45	365	0.004714
13	5.8	0.617	7	250	2	60	365	0.019053
14	1.2	0.563	7	250	2	47	365	0.004592
15	1.2	0.663	7	250	2	74	365	0.003436
16	0.95	0.593	7	250	2	54	365	0.003336
17	5.8	0.617	7	250	2	60	365	0.019053
18	1.2	0.657	7	250	2	72	365	0.003499
19	1.2	0.609	7	250	2	58	365	0.004028
20	5.8	0.613	7	250	2	59	365	0.019260
21	1.2	0.613	7	250	2	59	365	0.003984
22	5.8	0.686	7	250	2	82	365	0.015501
23	5.8	0.624	7	250	2	62	365	0.018655
24	1.2	0.666	7	250	2	75	365	0.003405
25	1.2	0.648	7	250	2	69	365	0.003599
26	5.8	0.617	7	250	2	60	365	0.019053
27	5.8	0.644	7	250	2	68	365	0.017565
28	5.8	0.634	7	250	2	65	365	0.018092
29	5.8	0.624	7	250	2	62	365	0.018655
30	5.8	0.617	7	250	2	60	365	0.019053

Realtime exposure analysis was calculated based on years of work ranging from being accepted as a worker for the first time until the implementation of this study. The value of realtime intake was the intake value until this study was carried out, while the estimated intake value was the cumulative estimated intake value. The results of calculating realtime intake were used to determine the value of RQ risk level of the respondents. The intake value was also used to determine the estimated value that will be calculated within 5 years, 10 years, 15 years, 20 years, 25 years, and 30 years.

Risk characterization was carried out to identify the level of risk to determine the level of dust at certain concentrations which had a risk to create health effects on the workers. Risk characteristization was carried out by comparing or dividing the intake with the dose or concentration of respirable dust. The value of the risk level was stated without units and was regarded as safe if the intake ≤ Rfc or expressed by RQ ≤ 1. The level of risk was regarded as unsafe when the intake > Rfc or expressed by RQ > 1. Table 4 shows the results of calculated RQ value of workers in the ceramics industry.

Risk characterization

Table 4. Distribution of risk level values (RQ) of realtime exposure and estimatedly 30 years later among the workers in the ceramics industry in 2018

Respondents	Risk Level Value (RQ)						
	Realtime	5 years	10 years	15 years	20 years	25 years	30 years
1	1.030605	3.60711	6.18363	8.76014	11.33666	13.9131	16.4896
2	0.19299	0.67546	1.15793	1.64041	2.122889	2.60536	3.08783
3	0.229623	0.80368	1.37773	1.95179	2.525856	3.09991	3.67397
4	0.208327	0.72914	1.24996	1.77078	2.2916	2.81241	3.33323
5	1.068587	3.74005	6.41151	9.08298	11.75445	14.4259	17.0973
6	1.018606	3.56512	6.11163	8.65815	11.20466	13.7511	16.2976
7	0.923177	3.23112	5.53906	7.84700	10.15495	12.4628	14.7708
8	0.154395	0.54038	0.92636	1.31235	1.69834	2.08432	2.47031
9	0.13019	0.45566	0.78114	1.10661	1.432092	1.75756	2.08304
10	1.006915	3.52420	6.04148	8.55877	11.07606	13.5933	16.1106
11	0.788128	2.75845	4.72877	6.69909	8.669413	10.6397	12.6100
12	0.235736	0.82507	1.41441	2.00375	2.593097	3.18243	3.77177
13	0.952691	3.33441	5.71614	8.09787	10.4796	12.8613	15.2430
14	0.229623	0.80368	1.37773	1.95179	2.525856	3.09991	3.67397
15	0.17182	0.60137	1.03092	1.46047	1.890024	2.31957	2.74912
16	0.166841	0.58394	1.00104	1.41814	1.835247	2.25234	2.66944
17	0.952691	3.33441	5.71614	8.09787	10.4796	12.8613	15.2430
18	0.174981	0.61243	1.04988	1.48734	1.924796	2.36225	2.79970
19	0.20143	0.70500	1.20857	1.71215	2.215727	2.71930	3.22287
20	0.963007	3.37052	5.77804	8.18555	10.59307	13.0005	15.4081
21	0.199243	0.69735	1.19545	1.69356	2.191671	2.68977	3.18788
22	0.77507	2.71274	4.65041	6.58809	8.525769	10.4634	12.4011
23	0.932785	3.26474	5.59670	7.92866	10.26063	12.5925	14.9245
24	0.170287	0.59600	1.02172	1.44744	1.873161	2.29888	2.72459
25	0.179977	0.62992	1.07986	1.52980	1.979748	2.42969	2.87963
26	0.952691	3.33441	5.71614	8.09787	10.4796	12.8613	15.2430
27	0.878287	3.07400	5.26972	7.46544	9.661158	11.8568	14.0525
28	0.904614	3.16614	5.42768	7.68921	9.950754	12.2122	14.4738
29	0.932785	3.26474	5.59670	7.92866	10.26063	12.5925	14.9245
30	0.952691	3.33441	5.71614	8.09787	10.4796	12.8613	15.2430
Minimum	0.13019	0.45566	0.78114	1.10661	1.432092	1.75756	2.08304
Maximum	1.068587	3.74005	6.41151	9.08298	11.75445	14.4259	17.0973
Average	0.589293	2.06252	3.53575	5.00899	6.482224	7.95545	9.42868

Discussion

Dust is a solid chemical substance produced by natural and mechanical forces, such as processing, destruction, softening, rapid packing, blasting, etc., from organic and inorganic objects.[4] In this study, the production process in ceramics industry was carried out in the same building with closed conditions so that the respirable dust was evenly distributed throughout the production room. Respirable dust source in the production part comes from raw materials in the form of clay and several other types of materials. Firing in the production process carried out to temperatures reaching 1200 degrees C will form another fraction of respirable dust that is more reactive and more hazardous. Measured dust levels had a uniform distribution throughout the workplace with an average level of 3.6 mg/m3.

Risk characteristics can be determined from the ratio of intake and the reference dose value (Rfc), where the higher the intake, the higher the risk. In this study, the value of dust RfC (TSP) used a reference dose value from the Environmental Health Risk analysis study conducted by Rahman et al.[5] which was equal to 0.02 mg/kg/day because the value of RfC dust (TSP) in the IRIS list was not yet available. Table 6 shows that the value of RQ in realtime exposure indicates that 13.3% of the workers have an RQ value > 1, which means that they have an unsafe risk of respirable dust exposure. In other words, 13.3% of the workers exposed to resirable dust to date have a risk of experiencing health problems.

According to Wallaert[6] there are two main causes of obstructive pulmonary funcion disorder in groups of people who are always exposed to dust. The first cause is that the exposure to dust concentration lasts more than ten years. The second cause is that the level of dust exposing an individual exceed the Threshold Value.

Calculation of risk management strategies resulted in a median of safe concentrations, safe frequencies and safe times, which were, respectively, 5.62 mg/m3, 243 days/year and 6 hours/day. Safe duration could not be determined because the results of realtime calculations of dust exposure based on the working period of workers have shown a level of risk that is not safe. The safest risk management strategy that is most likely and feasible to do is to reduce the concentration of risk agents, namely the concentration of respirable dust in the work environment, to the safe limit according to the

calculation of the risk management strategy. The safe limit for respirable dust concentration was calculated from each worker, then the median value of the safe concentration was taken as 6.08 mg/m3.

After risk analysis, the next step was to run risk management if the obtained one was the unsafe level of risk, either current risks or future risks. After conducting a risk analysis, we obtained a safe limit value in accordance with anthropometric conditions and current environmental conditions, which was equal to 6.188 mg/m3. This safe concentration value was chosen because it was the most logical value and most likely to be fulfilled. To achieve this value, the company must make efforts to control the respirable dust.

Control can be done by using a hierarchy of controls, ie. technical, administrative, and the use of personal protective equipment. Technical control can be carried out, among others, by installing local vents on biscuit printing machines as well as on kilns or on machines that have the potential to remove dust to be sucked and stored in dust collector. Wet process can also be done to minimize the spread of dust in the work environment. Administrative control can be done by rotating workers in the production section whose working period is more than 20 years, especially in the processing of raw materials. Health examination in preventive efforts need to be carried out, especially special health examination for workers in production department by prioritizing routine anatomical and physiological examinations. Personal protective equipment that can be used is a mask for reducing dust, especially those measuring under 5 micrograms. Personal protective equipment is the last alternative choice if technical and administrative controls are no longer possible. Types of masks that can be used to reduce dust entering the lungs include the masks of N-95 or N-100 type.

Conclusion

Respiratory dust levels were measured using the NIOSH 7500 method. The measurement was performed using total dust samplers on the workers and it was found that 53.3% of the total respondents exceeded the Threshold Value for respirable dust (NAB=2 mg/m3) with a concentration between 0.95 - 5.8 mg/m3. The assessment of the level of risk in realtime exposure on each worker showed an unsafe level of risk (RQ> 1) due to exposure to respirable dust by 13.3% of the total

respondents. These figures indicate the need for dust control by identifying the limits of safe duration, safe concentration, safe frequency, and safe time through the assessment of risk management strategies. The assessment of risk management strategy results in safe duration, safe concentration, safe frequency and safe time. From these assessment, the most logical and most feasible alternative to reduce the level of risk to be safe is to reduce the concentration of respirable dust in work environment until ≤ 2 mg/m3.

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Ethical Clearance: Received from the Ethics Committee of the Faculty of Public Health, Airlangga University, Indonesia.

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