

## 국내 업종별 결정형 유리규산 노출 평가

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## Evaluation of Crystalline Silica Exposure Level by Industries in Korea

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### ABSTRACT

**Objectives:** The major aim of this study is to construct the database of retrospective exposure assessment for crystalline silica through reviews of literatures in South Korea.

**Methods:** Airborne concentrations of crystalline silica were collected using an academic information search engine, Research Information Service System(RISS), operated by the Korea Education & Research Information Service(KERIS). The key words used for the literature search were 'silica', 'crystalline silica', 'cristobalite', 'quartz' and 'tridymite'. A total number of 18 published documents with the information of crystalline silica level in air or bulk samples were selected and used to estimate retrospective exposures to crystalline silica. Weighted arithmetic mean(WAM) calculated across studies was summarized by industry type. Industries were classified according to Korea Standard Industrial Classification(KSIC) using information provided in the literature.

**Results:** A total of 2,131 individual air sampling data measured from 1987 to 2012 were compiled. Compiled individual measurement data consisted of 827 respirable crystalline silica (RCS), 31 total crystalline silica(TCS), 24 crystalline silica(CS), 778 respirable dust(RD) and 471 total dust(TD). Most of RCS measurements(68.9%) were collected from 'cast of metals(KSIC 243)'. Comparing industry types, 'mining coal and lignite(KSIC 051)' showed the highest WAM concentration of RCS, 0.14 mg/m<sup>3</sup>, followed by 0.11 mg/m<sup>3</sup> of 'manufacture of other non-metallic mineral products(KSIC 239)', 0.108 mg/m<sup>3</sup> of 'manufacture of ceramic ware(KSIC 232)', 0.098 mg/m<sup>3</sup> of 'heavy construction(KSIC 412)' and 0.062 mg/m<sup>3</sup> of 'cast of metals(KSIC 243)'. In terms of crystalline silica contents in airborne dust, 'manufacture of other non-metallic mineral products(KSIC 239)' showed the highest value of 7.3%(wt/wt), followed by 6.8% of 'manufacture of ceramic ware(KSIC 232)', 5.8% of 'mining of iron ores(KSIC 061)', 4.9% of 'cast of metals(KSIC 243)' and 4.5% of 'heavy construction(KSIC 412)'. WAM concentrations of RCS had no consistent trends over time from 1994 (0.26 mg/m<sup>3</sup>) to 2012 (0.12 mg/m<sup>3</sup>).

**Conclusion:** The data set related RCS exposure level by industries can be used to determine not only the possibility of retrospective exposure to RCS, but also to evaluate the level of quantitative retrospective exposure to RCS.

**Key words:** crystalline silica, Korea Standard Industrial Classification, retrospective exposure estimation

### I. 서 론

직업성폐질환연구소에서 1999년부터 2005년까지 역학조사를 통해 직업성 폐암으로 판단된 사례 분석 결과에서 업무관련성이 높다고 판단된 직업성 폐암 53례 중 결정형 유리규산으로 인한 폐암 사례가 14

례로 석면, 다핵방향족탄화수소, 6가 크롬 다음으로 높은 비율을 차지하고 있다(Lim et al., 2010).

보통 유리규산은 비결정형, 결정형과 규산염으로 나눌 수 있으며 결정형 유리규산의 일반적인 형태로는 석영(quartz)과 트리디마이트(tridymite), 크리스토티알라이트(cristobalite)가 있다. 산업분야에서 석영은

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유리제조, 주물, 연마제, 수압파쇄작업 등에서 사용되며 화강암 등이 포함된 채광작업에서 노출이 이루어진다. 석영의 제조는 주물사 건조납품, 석영유리 제조 등에서 나타나 국내에서는 200여개 사업장 5만여명의 근로자가 노출되며 연간 300만톤 이상 사용되고 있다. 이는 주물사를 사용하는 업종이다. 또한 농업, 도로건설, 보수 등에서도 노출된다. 발생공정으로는 블라스팅작업, 요업, 유리제조, 주물, 토사석 채취, 화강암 석수공, 내화, 분쇄 등이다(KOSHA 2007).

화학물질 유통·사용 실태조사 결과에 의하면 우리나라에서 결정형 유리규산을 제조 또는 사용하고 있는 사업장에 대한 분포를 조사한 결과 결정형 유리규산을 사용하고 있는 사업장 수는 215개 이고, 총 근로자는 47,725명, 취업근로자는 1,905명(1~696명), 사용 취업량은 2,960,469,661 kg/년(1~283,240,000 kg/년)이었다. 결정형 유리규산을 제조하는 사업장수는 총 6개소, 총 근로자수는 190명(6~73명), 취업 근로자수는 74명(1~58명), 취업량은 437,624,000 kg/년(24,000~363,000,000 kg/년)이었다(KOSHA, 2007). 제조하는 사업장 수는 적지만 사용하는 사업장이 많은 것을 알 수 있다.

과거 우리나라 유해물질 허용농도에서는 유리규산의 함유량에 따라 총 분진을 제 1,2,3종 분진으로 분류하여 허용농도를 달리 정하였으며, 호흡성 분진으로서 결정형 유리규산의 경우 석영 0.01 mg/m<sup>3</sup>, 트리디마이트와 크리스토팔라이트를 0.05 mg/m<sup>3</sup>로 따로 규정하였으나 개정되어 현재 3종류 모두 결정형 유리규산으로 포함되어 노출기준 0.05 mg/m<sup>3</sup>으로 정하고 있다(MoEL, 2016). 미국정부산업위생전문가협회(American Conference of Governmental Industrial Hygienist, ACGIH)는 0.025 mg/m<sup>3</sup>로 정하고 있다(ACGIH, 2015).

결정형 유리규산은 그 자체로 진폐증을 발생시킬 뿐 아니라, 석탄 분진, 활석, 규조토와 같이 혼합되면 분진의 독성은 더욱 증가된다(KOSHA, 2013). 국제암 연구기구(International Agency for Research on Cancer, IARC)에서는 결정형 유리규산에 호흡성 입자(respirable fraction)로 노출 시 인체에 폐암 발병의 충분한 근거가 있다고 하여 인체발암물질(Group1)로 구분하고 있다(IARC, 1997).

국내에서는 개별 업종에 따른 결정형 유리규산 노

출값과 그에 따른 건강 유해성을 연구한 학술 논문들은 있으나, 근로자의 과거 노출력 판단과 업무관련성 평가를 할 수 있는 업종별 시대별 노출수준에 대한 데이터베이스는 없는 실정이다. 이에 본 연구에서 발암 물질인 결정형 유리규산에 대한 노출수준 및 원료 및 공기 중 먼지 중 결정형 유리규산 함유량에 대해 2015년까지 발표된 국내 문헌을 수집 분석하여 데이터베이스를 구축하고자 하였다.

## II. 연구방법

### 1. 문헌 자료 수집

결정형 유리규산과 관련하여 2015년 9월까지 국내에서 발표된 연구논문, 학위논문, 보고서 자료를 수집하였다. 자료 검색은 국내 학술자료 검색 사이트인 디비피아(DBpia), 한국학술정보(KISS), 학술연구정보서비스(RISS)를 활용하여 ‘결정형 유리규산’, ‘유리규산’, ‘석영’ 그리고 ‘실리카’를 검색어로 검색하였다.

학술논문으로 발표되지는 않았으나 결정형 유리규산이 폐암 유발인자이기 때문에 직업성폐질환 연구소에서 2014년에 발표한 ‘업무상질병사례집(2007-2012)’도 분석 대상에 포함하였다. 또한 한국산업안전보건공단에서 수행한 연구보고서 자료도 검색 대상에 포함하여 관련 자료를 수집하였다.

수집된 자료 중 결정형 유리규산의 함유량이 있거나, 결정형 유리규산이 발생 가능한 업종에서 측정된 공기 중 총 분진, 호흡성 분진, 결정형 실리카에 대한 정량적 노출농도가 제시된 자료를 분석 대상에 포함 하였다.

최종 분석에 활용된 자료는 국내 전문 학술지에 발표된 논문 9편, 직업성폐질환연구소 보고서 1편, 한국산업안전보건공단 보고서 3편, 학술대회 발표 자료 5편 등 총 18편이었다.

### 2. 자료 입력

분석 대상 자료 18편에 대해 결정형 실리카의 함유량 분석 결과와 공기 중 노출 농도를 나누어 정리하였다. 각 자료 입력에 활용된 변수는 조사년도, 업종, 공정, 직종, 시료채취 방법, 시료분석 방법, 채취대상 물질, 분석대상 항목이었으며, 결과 값은 시료 수(N), 최소값(Min), 최대값(Max), 기하평균(GM), 기하표준편차(GSD),

산술평균(AM), 표준편차(SD)를 모두 입력하였다.

자료에 제시된 업종명을 통계청 고시 제2007-53호의 제9차 한국표준산업분류(KSIC)에 기준하여 세세분류(5 digit)까지 표준 업종으로 재분류하여 입력하였다.

### 3. 자료 처리

자료 처리 대상인 논문 중 일부는 GM, GSD로 제시되어 있었고, 일부는 최소-최대값만 제시된 경우가 있었다. 또한 일부 논문에서는 산술평균값만 제시된 경우도 있다. 따라서 전체 자료의 변수별 비교를 위해 모두 산술평균으로 변환( $AM_T$ )하였다.

기하평균으로 보고된 농도는 아래의 (식 1)을 이용하여 산술평균으로 변환하였다.

$$AM_T = GM \exp[1/2(\ln(GSD))^2] \quad (1)$$

농도가 최소-최대값의 범위로 보고된 경우 범위에 근거하여 아래 (식 2)에 대입 한 후 산술평균을 계산하였다. 계산식은 최소값과 최대값을 대수로 변환하여 그 중간값(mid-point)을 구하고( $\hat{\mu}_L$ ), 대수로 변환한 최소값과 최대값의 차이를 4로 나눈 값( $\hat{\sigma}_L$ )을 구하였다.

$$AM_T = \exp[\hat{\mu}_L + 1/2 \hat{\sigma}_L^2] \quad (2)$$

입력 대상 값 중 최소값이 ND(not detected)로 제시된 경우 통계 분석을 위해 0으로 입력하였고, 시료수가 제시되지 않고 평균값만 제시된 경우 시료수는 1로 입력하였다.

업종별 혹은 조사년도에 따른 비교 시 논문마다 측정한 시료 수가 차이가 있기 때문에 시료수의 차이에 따른 산술평균을 보정하기 위해 시료수에 대한 가중 산술평균(Weighted Arithmetic Mean, 이하 WAM이라 함)을 구하였다. 가중산술평균을 구할 때 시료의 수를 정확히 알 수 없는 데이터 값의 가중치는 1로 간주하여 계산하였다.

$$WAM = (N_1 \times AM_1 + N_2 \times AM_2 + \dots + N_i \times AM_i) / N_i \quad (3)$$

여기서  $N_i$ =i번째 자료의 시료수,  $AM_i$ =i번째 자료

의 산술평균,  $N_i$ =총 시료수이다.

## III. 연구결과

### 1. 연구대상 문헌의 특성

국내 학술지, 연구보고서, 포스터 그리고 폐질환연구소의 업무상 질병 사례집에서 얻은 모든 작업환경측정을 실시한 결정형 유리규산, 총 분진, 호흡성 분진의 농도 및 함량에 대한 데이터베이스를 정리하여 분석하였다. 데이터베이스의 세부 자료는 Appendix 1~6에 제시하였다. 데이터베이스를 구축하기 위해 참고하여 연구 했던 최종 참고문헌들의 정보는 Table 1에 나타내었다.

총 18편의 연구자료 중 다양한 업종을 대상으로 결정형 유리규산에 대해 연구가 수행된 자료 중 2000년 이전 연구자료는 1997년에 주물, 콘크리트, 벽돌, 유리, 분쇄, 요업 등의 제조업을 대상으로 김현욱 등이 실시한 연구(Kim et al., 1998, Kim et al., 1999)가 있었다. 2000년 이후 자료 중에는 산업안전보건연구원에서 수행한 ‘화학물질 유통·사용 실태조사 결과보고서’ 중 유리규산 편으로 연구된 자료(KOSHA, 2007)와 직업성폐질환 연구소에서 2014년에 발표한 ‘업무상질병사례집(2007-2012)’이 있다(KWCWS, 2014). 그러나 이 두 자료는 학술연구논문처럼 peer-review된 연구논문이 아니고 보고서라는 특성이 있다.

특히 산업안전보건연구원에서 수행된 유리규산에 대한 유통·사용 실태 보고서에서는 16개의 KSIC 소분류에 해당되는 다양한 업종의 자료가 수록되어 있으나, 결정형 실리카에 대한 노출평가 자료가 모두 산업안전보건법 제42조에 의해 2004년에 실시된 작업환경측정 자료이기 때문에 대부분 총분진(TD) 자료로 제시되어 있어 결정형 실리카의 정확한 농도를 예측하기 어려운 한계가 있다.

직업성 폐질환 연구소에서 펴낸 보고서 자료는 직업성폐질환연구소에서 역학조사를 수행하며 직접 현장 조사와 시료 분석을 하여 제시한 결과들이 제시되어 있어 보고서 자료이지만 자료의 정확도가 높다고 판단된다.

자료의 조사 시기별로 보면 1980년대에는 석탄광업에 대한 자료만 보고되고 있고, 1990년대와 2000년대에 걸쳐 모두 자료가 보고되고 있는 업종은 주

**Table 1.** Characteristics of 18 references with quantitative data of crystalline silica in Korea

| Reference         | Source   | Year      | Industry(KSIC-3digit)   | Sample type | Analyte              | Method              |
|-------------------|----------|-----------|---|-------------|----------------------|---------------------|
| Yoon & Lee, 1988  | Article  | 1987      | Mining of coal and lignite  | Bulk/Air    | CSC/RD               | FTIR, Weighing      |
| Lee & Lee, 1989   | Article  | 1989      | Mining of coal and lignite  | Bulk/Air    | CSC/RD               | FTIR, Weighing      |
| Oh et al., 1994   | Article  | 1994      | Manufacture of ceramic ware   | Bulk/Air    | CSC/RCS, TCS, RD, TD | FTIR, Weighing      |
| Phee et al., 1997 | Article  | 1996      | Cast of metals  | Bulk/Air    | CSC/RCS, RD, TD      | FTIR, Weighing      |
| Kim et al., 1998  | Article  | 1997      | Cast of metals  | Bulk/Air    | CSC/RCS, TD, RD      | FTIR, XRD, Weighing |
| Kim et al., 1999  | Article  | 1997      | Manufacture of cement, Lime and plaster and its products, Manufacture of ceramic ware, Manufacture of coke and briquettes, Manufacture of glass and glass products, Manufacture of other non-metallic mineral products  | Bulk/Air    | CSC/RCS, RD          | FTIR, XRD, Weighing |
| Shin et al., 2002 | Article  | 2000      | Mining of coal and lignite  | Bulk/Air    | CSC/RCS, TSC, RD, TD | FTIR, Weighing      |
| Choi et al., 2000 | Report   | 2000      | Mining of iron ores, Quarrying of stone, sand and gravel  | Bulk/Air    | CSC/TCS, RCS, TD, RD | FTIR, Weighing      |
| Yoo et al., 2003  | Report   | 2001      | Heavy construction  | Bulk/Air    | CSC/RCS, RD, TD      | FTIR, Weighing      |
| Park et al., 2003 | Article  | 2002      | Cast of metals  | Bulk/Air    | CSC/RCS, RD          | FTIR, Weighing      |
| KOSHA, 2007       | Report   | 2004      | Cast of metals, Manufacture of basic chemicals, Manufacture of basic iron and steel, Manufacture of basic precious and non-ferrous metals, Manufacture of cement, Lime and plaster and its products, Manufacture of ceramic ware, Manufacture of glass and glass products, Manufacture of other chemical products, Manufacture of other metal products; metal working service activities, Manufacture of other non-metallic mineral products, Manufacture of parts and accessories for motor vehicles and engines, Manufacture of plastic products, Manufacture of precious metals and ornamentations, Manufacture of rubber products, Manufacture of structural metal products, Tanks, Reservoirs and steam generators | Air         | CS, TD               | Weighing            |
| Kim et al., 2008a | Abstract | 2008      | Manufacture of cement, Lime and plaster and its products  | Bulk        | CSC                  | XRD                 |
| Kim et al., 2008b | Abstract | 2008      | Manufacture of basic iron and steel   | Air         | RCS                  | FTIR                |
| Kim et al., 2009  | Abstract | 2009      | Manufacture of cement, Lime and plaster and its products  | Bulk        | CSC                  | XRD                 |
| Kim et al., 2010  | Abstract | 2010      | Manufacture of ceramic ware   | Bulk/Air    | CSC/RCS, RD          | XRD, Weighing       |
| Kim et al., 2012  | Abstract | 2008-2012 | Manufacture of other non-metallic mineral products  | Air         | RCS                  | XRD                 |
| Kim et al., 2014  | Article  | 2012      | Manufacture of other non-metallic mineral products  | Air         | RCS, RD              | FTIR                |
| KWCWS, 2014       | Report   | 2006-2012 | Cast of metals, Farming of animals, Manufacture of ceramic ware, Manufacture of other chemical products, Manufacture of other non-metallic mineral products, Transit and ground passenger transportation, Farming of animals, Heavy construction, Manufacture of cement, lime and plaster and its products, Quarrying of stone, Sand and gravel, Site preparation and special trade construction for civil engineering and buildings  | Bulk/Air    | CSC/RCS, TD, RD      | FTIR, XRD, Weighing |

Note: CSC;crystalline silica content, RCS;respirable crystalline silica, TCS;total crystalline silica, RD;respirable dust, TD;total dust, CS;crystalline silica

물사업장이었다. 따라서 1990년대부터 최근까지 노출 시기별 결정형 실리카의 농도 평가는 주물 사업장을 대상으로 제한적으로 가능하다.

결정형 실리카의 분석 방법으로 보면 1980년대와 1990년대는 주로 FTIR 방법에 의해 실시되었으며, 최근에는 NIOSH 공정시험법인 XRD 방법에 의해 제시되고 있다. 본 논문에서는 업종별, 시기별 결정형 실리카의 농도를 비교할 때 시료수의 제한이 있기 때문에 FTIR과 XRD 분석 결과를 구분하지 않고 사용하였다.

## 2. 업종별 결정형 유리규산 농도와 함량

### 1) 업종별 농도 비교

총 분진, 호흡성 분진, 총 결정형 유리규산, 호흡성 결정형 유리규산, 결정형 유리규산 농도를 시료 수 가중산술평균으로 환산하여 통계청의 표준산업분류의 소분류 업종 별로 분석하였다. 모든 업종을 비교해 보았을 때 평균은 총 분진이 19.37 mg/m<sup>3</sup>, 호흡성 분진 5.61 mg/m<sup>3</sup>, 총 결정형 유리규산 0.22 mg/m<sup>3</sup>, 호흡성 결정형 유리규산 0.07 mg/m<sup>3</sup>, 결정형 유리규산 0.13 mg/m<sup>3</sup> 이었다(Table 2).

**Table 2.** Weighted average mean concentration of total dust, respirable dust, total crystalline silica, respirable crystalline silica and crystalline silica by industries

| Industry(KSIC 3-digit)  | Total dust |                            | Respirable dust |                           | Total crystalline silica |                           | Respirable crystalline silica |                           | Crystalline silica |                           |
|---|------------|----------------------------|-----------------|---------------------------|--------------------------|---------------------------|-------------------------------|---------------------------|--------------------|---------------------------|
|   | N          | WAM*,<br>mg/m <sup>3</sup> | N               | WAM,<br>mg/m <sup>3</sup> | N                        | WAM,<br>mg/m <sup>3</sup> | N                             | WAM,<br>mg/m <sup>3</sup> | N                  | WAM,<br>mg/m <sup>3</sup> |
| Cast of metals  | 86         | 2.43                       | 269             | 1.18                      |                          |                           | 570                           | 0.062                     | 3                  | 0.07                      |
| Farming of animals  | 4          | 9.86                       |                 |                           |                          |                           | 3                             | 0.021                     |                    |                           |
| Heavy construction  | 102        | 4.71                       | 103             | 1.35                      |                          |                           | 53                            | 0.098                     |                    |                           |
| Manufacture of basic chemicals  | 2          | 0.29                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of basic iron and steel   | 5          | 1.21                       |                 |                           |                          |                           | 2                             | 0.002                     |                    |                           |
| Manufacture of basic precious and non-ferrous metals                                | 4          | 1.74                       |                 |                           |                          |                           |                               |                           | 4                  | 0.004                     |
| Manufacture of cement, lime and plaster and its products                            | 5          | 0.61                       | 4               | 0.30                      |                          |                           | 9                             | 0.029                     |                    |                           |
| Manufacture of ceramic ware   | 134        | 2.28                       | 81              | 0.71                      | 26                       | 0.20                      | 59                            | 0.108                     | 5                  | 0.034                     |
| Manufacture of coke and briquettes  |            |                            | 4               | 0.62                      |                          |                           | 6                             | 0.016                     |                    |                           |
| Manufacture of glass and glass products   | 16         | 0.89                       | 4               | 1.23                      |                          |                           | 4                             | 0.038                     |                    |                           |
| Manufacture of other chemical products  | 2          | 1.54                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of other metal Products; metal working service activities               | 10         | 1.71                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of other non-metallic mineral products                                  | 20         | 1.98                       | 31              | 0.98                      |                          |                           | 62                            | 0.111                     | 10                 | 0.19                      |
| Manufacture of parts and accessories for motor vehicles and engines                 | 4          | 1.15                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of plastic products   | 4          | 0.64                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of precious metals and or namentations                                  | 1          | 0.04                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of rubber products  | 2          | 1.44                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Manufacture of structural metal products, tanks, reservoirs and steam generators    | 1          | 3.00                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Mining of coal and lignite  | 48         | 160.7                      | 243             | 15.50                     | 5                        | 0.30                      | 25                            | 0.14                      |                    |                           |
| Mining of Iron ores   | 3          | 1.11                       | 14              | 0.80                      |                          |                           | 9                             | 0.001                     |                    |                           |
| Quarrying of stone, sand and gravel   | 17         | 15.32                      | 25              | 1.36                      |                          |                           | 25                            | 0.004                     | 2                  | 0.42                      |
| Site preparation and special trade construction for civil engineering and buildings | 1          | 6.18                       |                 |                           |                          |                           |                               |                           |                    |                           |
| Total   | 471        | 19.37                      | 778             | 5.61                      | 31                       | 0.22                      | 827                           | 0.07                      | 24                 | 0.13                      |

\* WAM: weighted arithmetic mean

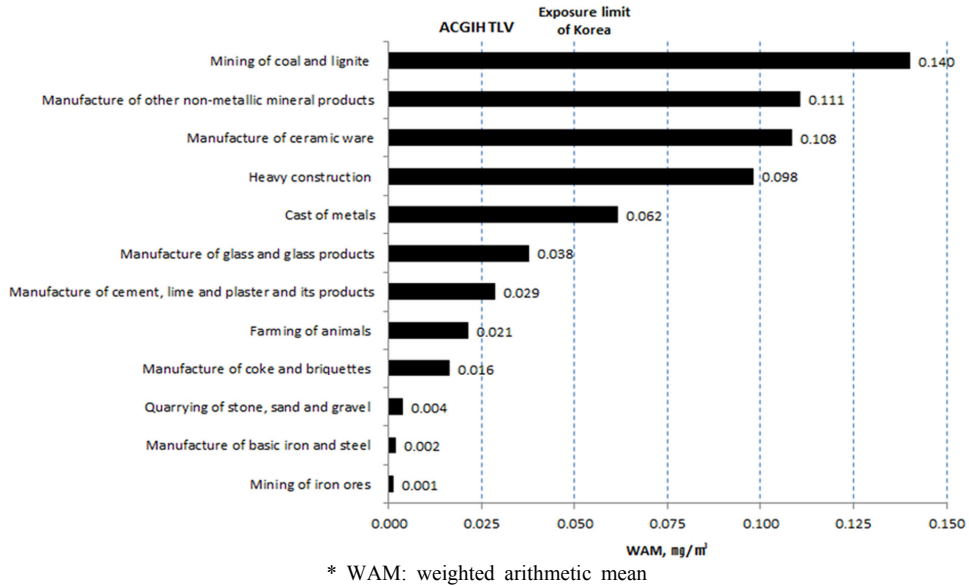


Figure 1. Comparison of respirable crystalline silica concentrations by industries

체내로 노출 될 경우 가장 유해한 영향을 끼치는 호흡성 결정형 유리규산이 높은 농도로 노출되는 업종은 석탄 광업에서 0.14 mg/m³, 기타 비금속 광물제품 제조업에서 0.111 mg/m³, 도자기 및 기타 요업 제품 제조업에서 0.108 mg/m³, 토목건설업 0.098 mg/m³ 그리고 금속 주조업에서 0.062 mg/m³로 나타났다. 이 노출 수준은 우리나라 고용노동부의 호흡성 결정형 유리규산 노출기준 0.05 mg/m³를 초과하는 수준이다. ACGIH에서 호흡성 결정형 유리규산 TLV 값은 우리

나라 노출기준 보다 낮은 0.025 mg/m³인데, 이를 초과하는 업종을 추가 해보면 유리 및 유리제품 제조업이 0.038 mg/m³, 플라스틱 제품 제조업이 0.029 mg/m³이다(Figure 1).

2) 업종별 함량 비교

공기 중 분진 시료와 벌크시료 중 결정형 유리규산 함량은 시료가중평균값으로 환산하여 Table 3에 나타났다. 표준산업분류는 소분류로 분석 하였으며

Table 3. Weighted average mean contents of airborne dust and bulk by industries

| Industry (KSIC 3-digit)                                  | Airborne dust |       | Bulk |       |
|--|---------------|-------|------|-------|
|  | N             | WAM,% | N    | WAM,% |
| Cast of metals   | 311           | 4.85  | 80   | 8.55  |
| Farming of animals                                       | 2             | 1.65  | 1    | 80    |
| Heavy construction                                       | 52            | 4.53  |      |       |
| Manufacture of cement, lime and plaster and its products | 6             | 3.67  | 11   | 0.311 |
| Manufacture of ceramic ware                              | 84            | 6.84  | 17   | 16.39 |
| Manufacture of coke and briquettes                       | 6             | 3.21  |      |       |
| Manufacture of glass and glass products                  | 4             | 4.02  |      |       |
| Manufacture of other chemical products                   |               |       | 4    | 5.74  |
| Manufacture of other non-metallic mineral products       | 10            | 7.33  | 1    | 6     |
| Mining of coal and lignite                               | 191           | 3.32  |      |       |
| Mining of iron ores                                      | 17            | 5.77  |      |       |
| Transit and ground passenger transportation              |               |       | 2    | 17.5  |
| Total  | 683           | 4.70  | 116  | 9.57  |

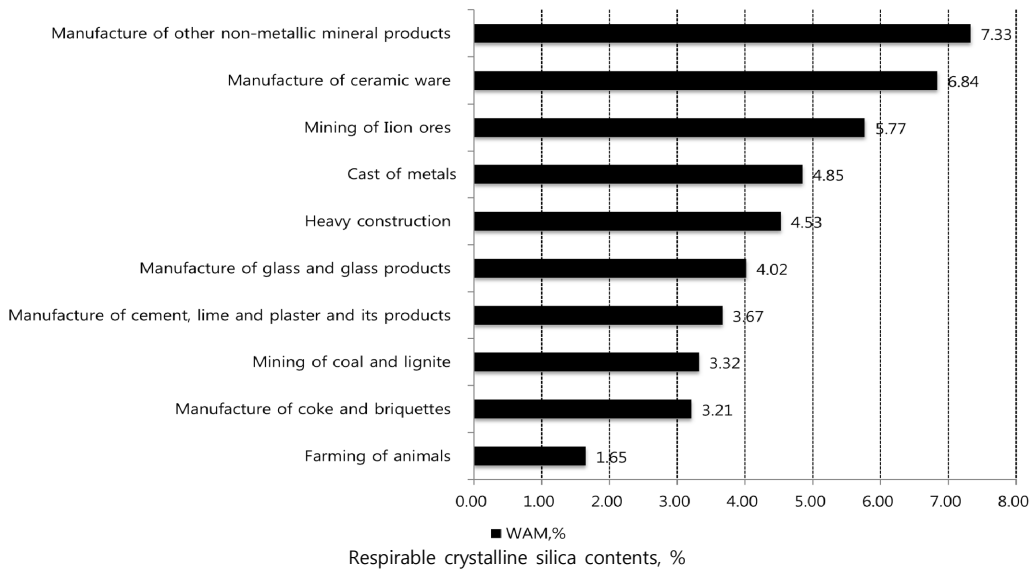


Figure 2. Comparison of respirable crystalline silica contents in airborne dust by industries

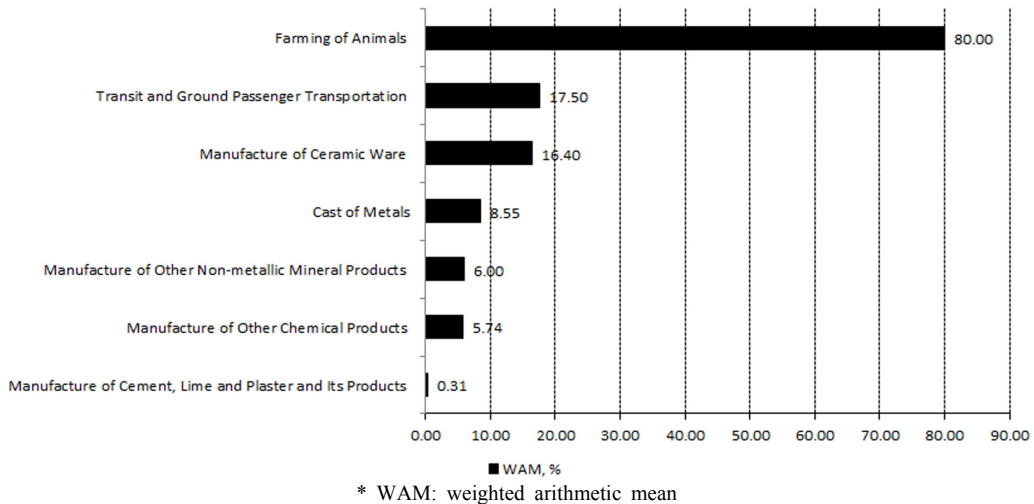


Figure 3. Comparison of respirable crystalline silica contents in bulk by industries

각각의 전체 평균은 공기 중 분진 시료 중 4.7%, 벌크시료 중에는 9.7%이다.

표준산업분류의 소분류를 기준으로 함량을 비교한 결과 공기 중 분진에서의 결정형 유리규산 함량이 가장 높은 업종은 기타 비금속 광물제품 제조업으로 7.33%이며 다음으로 도자기 및 기타 요업제품 제조업에서 6.84%이었다(Figure 2). 벌크시료 중 결정형 유리규산이 높은 업종은 축산업이 80%, 도시 정기육상 여객 운송업과 도자기 및 기타 요업제품 제조

업에서 각각 17.5%, 16.40%이다(Figure 3).

### 3) 호흡성 결정형 유리규산의 세세업종별 비교

인체에 영향을 끼치는 호흡성 결정형 유리규산의 통계청 표준산업분류에서의 세세분류에 따라 비교해 보았다(Figure 4). 호흡성 결정형 유리규산 농도에 대한 세세분류별 시료 수 가중평균으로 환산한 결과 전체 평균은 0.07 mg/m<sup>3</sup>이었고, 가장 농도가 높은 업종은 위생용 도자기 제조업 0.269 mg/m<sup>3</sup>, 석탄광업

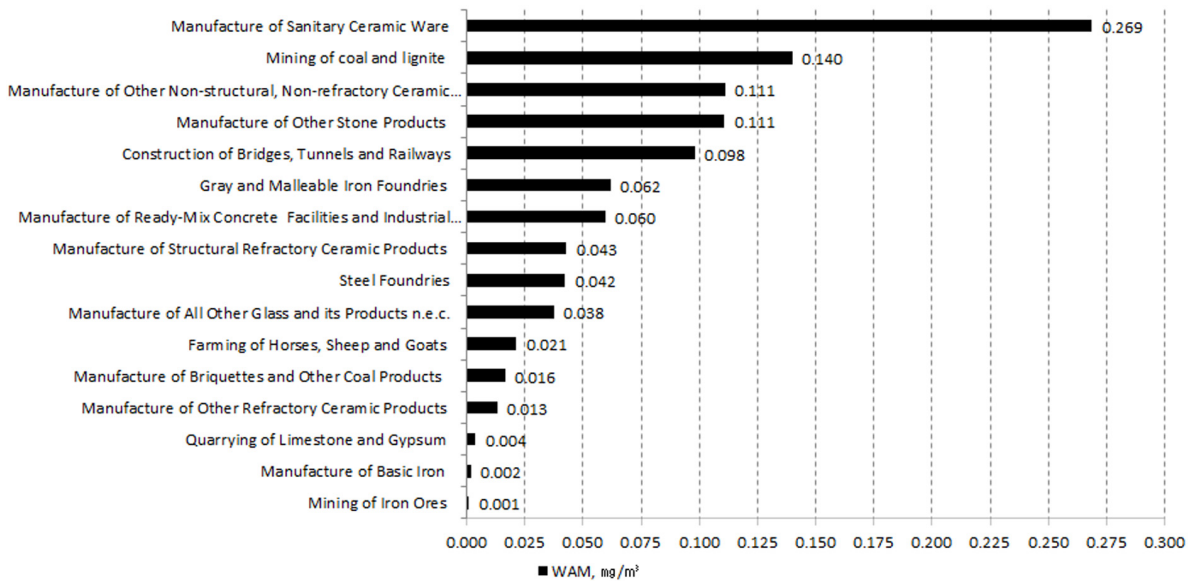


Figure 4. Comparison of respirable crystalline silica concentrations by industries((KSIC 5-digit)

0.14 mg/m<sup>3</sup>, 기타 일반 도자기 제조업 및 기타 석제품 제조업에서 0.111 mg/m<sup>3</sup>로 고용노동부 노출기준보다 높게 나타났다.

ACGIH - TLV 0.025 mg/m<sup>3</sup>을 초과하는 업종은 교량, 터널 및 철도 건설업 0.098 mg/m<sup>3</sup>, 선철주물 주조업 0.062 mg/m<sup>3</sup>, 그 외 기타 유리제품 제조업 0.038 mg/m<sup>3</sup>, 레미콘 제조업 0.06 mg/m<sup>3</sup>, 구조용 정형 내화제품

제조업 0.043 mg/m<sup>3</sup>, 강주물주조업 0.042 mg/m<sup>3</sup>이었다.

### 3. 연도별 결정형 유리규산의 노출농도 현황

공기 중 결정형 유리규산 농도에서 연도별로 측정되었던 현황을 시료 수 가중평균농도로 분석했다. 분 석물질의 선정은 작업자에게 유해한 영향을 줄 수 있는 결정형 유리규산, 호흡성 결정형 유리규산, 총 결정

Table 4. Weighted average mean concentration of total crystalline silica, respirable crystalline silica and crystalline silica by year

| Year  | Crystalline silica     |    | Respirable crystalline silica |     | Total crystalline silica |    |
|-------|------------------------|----|-------------------------------|-----|--------------------------|----|
|       | WAM, mg/m <sup>3</sup> | N  | WAM, mg/m <sup>3</sup>        | N   | WAM, mg/m <sup>3</sup>   | N  |
| 1994  |                        |    | 0.26                          | 10  | 0.20                     | 26 |
| 1996  |                        |    | 0.03                          | 42  |                          |    |
| 1997  |                        |    | 0.04                          | 212 |                          |    |
| 2000  |                        |    | 0.06                          | 59  | 0.30                     | 5  |
| 2001  |                        |    | 0.10                          | 52  |                          |    |
| 2002  |                        |    | 0.08                          | 381 |                          |    |
| 2004  | 0.01                   | 7  |                               |     |                          |    |
| 2006  | 0.01                   | 1  |                               |     |                          |    |
| 2008  |                        |    | 0.002                         | 2   |                          |    |
| 2009  | 0.40                   | 6  | 0.06                          | 3   |                          |    |
| 2010  | 0.06                   | 7  | 0.03                          | 3   |                          |    |
| 2011  |                        |    | 0.03                          | 10  |                          |    |
| 2012  |                        |    | 0.12                          | 53  |                          |    |
| Blank | 0.07                   | 3  |                               |     |                          |    |
| Total | 0.13                   | 24 | 0.07                          | 827 | 0.22                     | 31 |



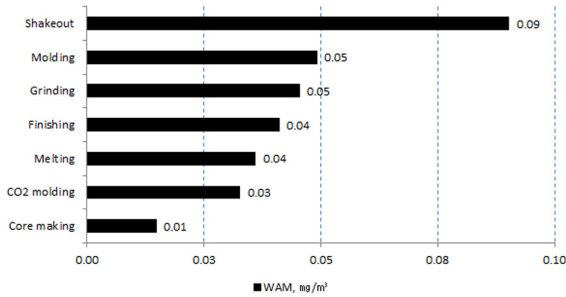


Figure 5. Comparison of respirable crystalline silica concentration in operation by cast of metal industry(KSIC 3-digit)

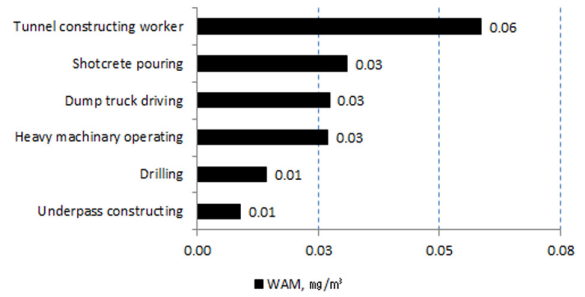


Figure 6. Comparison of respirable crystalline silica concentration in operation by heavy construction industry(KSIC 3-digit)

형 유리규산을 분석하였다. 폐질환연구소의 업무상질병사례집의 사례로 연도 정보가 없는 3개는 Blank로 처리했다. 총 결정형 유리규산은 1994년과 2000년대 초반에 연구가 많이 이루어졌고, 결정형 유리규산만 측정된 연구는 2000년 초반 이후부터 농도 값이 있지만 건수가 많지 않으며 주로 호흡성 결정형 유리규산에 대한 연구가 많은 것을 알 수 있다(Table 4).

4. 금속주조업과 토목건설업의 공정별 농도분포

본 연구대상 문헌들에서는 주물업을 대상으로 결정형 유리규산 농도 연구가 가장 많은 비중을 차지하고 있었다. 그에 비해 상대적으로 건설업에서의 결정형 유리규산의 노출농도 연구는 부족하였다. 그러므로 표준산업분류의 소분류(KSIC 3-digit)에서 금속주조업과 토목건설업을 대상으로 호흡성 결정형 유리규산 농도분포를 분석하여 공정별 노출농도의 차이를 알아보고자 하였다.

1) 금속주조업의 공정별 농도 분포

금속주조업의 전체 시료 수는 570건으로 연구대상 전체의 절반 이상이였다. 호흡성 결정형 유리규산 농도가 가장 높은 공정은 벤토나이트 조형과 형 해체 공정으로 0.09 mg/m³이었고, 연마공정과 조형공정에서 0.05 mg/m³로 고용노동부 노출기준을 초과하였다. 노출기준 미만인 공정은 마무리 및 용해공정이 0.04 mg/m³, 이산화탄소 조형 0.03 mg/m³, 중자 공정이 0.01 mg/m³로 가장 낮았다(Figure 5).

2) 토목건설업의 공정별 농도 분포

토목건설업의 전체 시료 수는 53건 이고 금속주조업에 비해 현저히 낮았다. 호흡성 결정형 유리규산 농도

는 버럭처리 공정에서 0.24 mg/m³이었고 터널 건설공정이 0.06 mg/m³이었고 덤프트럭 운전, 중장비 공정 및 슛크리트에서 모두 0.03 mg/m³였다. 드릴공정과 지하도 건설에서 모두 0.01 mg/m³으로 나타났다(Figure 6).

VI. 고 찰

결정형 유리규산이 노출 될 위험이 높은 직종은 이미 잘 알려져 있다. 웹사이트의 ‘직업성 폐암 매뉴얼’을 보면 금속광, 탄광, 채석과 석공, 내화벽돌, 주물업, 지하철, 댐, 터널 공사, 구조토 채굴 취급업, 용접, 콘크리트 벽돌 그리고 요업제조 등이다(직업성폐암 감시체계, <http://www.isaknox.com>). 이 연구의 분석대상이 된 국내 연구보고서 및 학술논문에서도 주로 주물업, 석탄광업, 요업을 대상으로 연구한 문헌들이 많았다. 호흡성 결정형 유리규산의 WAM은 금속주조업, 석탄 광업, 기타 비금속 광물제품 제조업, 도자기 및 기타 요업 제품 제조업, 토목 건설업에서 0.062 mg/m³ ~ 0.14 mg/m³ 수준으로 확인되었고, 노출기준 0.05 mg/m³을 초과하였다. 대부분 1980년대 후반에서 1990대 초반에 수행한 연구 이므로 산업보건학적 관리에 취약했던 시기였던 만큼 보호구 착용에 미흡할 것으로 예상한다면 근로자는 더욱 높게 노출되었을 것으로 보인다.

작업환경에서 근로자가 취급하는 원료나 채취분진에서의 결정형 유리규산 함량이 높은 업종은 축산업이 80%, 도시 정기 육상 여객 운송업과 도자기 및 기타 요업제품 제조업에서 각각 16.40%, 17.5%이었다. 축산업 자료는 경마장의 모래바닥이며 지하철의 분진에서도 다량 발생하는 것을 알 수 있다. 그러나 이 업종들에서의 연구가 부족하므로 이러한 업종에

서 작업환경측정을 하여 결정형 유리규산의 노출농도를 평가하는 연구가 필요하다고 판단된다.

특히 금속주조업과 토목건설업의 호흡성 결정형 유리규산의 농도 분포를 분석한 결과 각각 0.062 mg/m<sup>3</sup>, 0.098 mg/m<sup>3</sup>으로 토목건설업의 WAM 값이 상당히 높은 농도이다. 건설교통부가 발표하는 건설경제 주요통계에 의하면 외형적으로 2001년도 경사가 기준으로 국민총생산(GDP)중 건설투자가 차지하는 비율이 15.9%이고 건설업 생산은 8.2%에 이른다. 건설업 취업자는 2001년도에 약 157만 명이고, 건설업체 수는 '96년도 25,385개소에서 '01년도 47,533개소로 매년 증가하고 있는 추세이다. 이렇듯 건설업이 산업에서 차지하는 비중은 매우 크며 건설공사의 공중 및 공법의 종류 등에 따라 매우 다양한 작업환경을 가지고 있기 때문에 산업안전보건측 측면에서 중요하다고 할 수 있다(KOSHA, 2003). 그러므로 향후 건설업에서의 결정형 유리규산에 대한 노출 관리에 주목해야 한다고 판단된다.

본 연구의 한계점은 각 참모 문헌마다 노출 농도의 기하평균, 기하표준편차, 산술평균, 최소값, 최대값 등 모든 값이 분석된 자료는 거의 없어 완벽한 노출 데이터베이스를 구축하기 어려웠던 점이다. 하지만 WAM 값으로 환산하여 업종별 비교가 가능하도록 하였다. 연구대상 문헌의 대부분이 주물업, 석탄 광업, 요업을 대상으로 연구가 주를 이루었기 때문에 건설업, 지하철 등의 연구는 상대적으로 부족하여 전반적인 업종을 분석하기에 한계가 있었다.

본 연구의 대상된 문헌들을 통해 구축한 데이터베이스를 활용하여 향후 위험성 평가와 함께 결합하여 위험성 단계를 분석 할 수 있는 추가 연구가 가능하다고 보며, 업무관련성 조사에도 활용 할 수 있을 것이다. 이후 본 연구 자료를 토대로 추가적인 업종과 공정에 대한 노출자료들이 확대된다면 집중적으로 관리, 개선 되어야할 업종과 공정을 선정하고, 노출 관리를 위한 정책 결정, 발암 물질에 노출 된 근로자들의 직업성 암 발생 추이 파악 등 다양한 목적으로 활용 할 수 있을 것으로 기대 된다.

## V. 결 론

본 연구에서는 국내 문헌고찰을 통하여 얻은 문헌 18건을 대상으로 결정형 유리규산의 노출 농도 정보

를 변수를 정하여 데이터베이스를 구축하였다. 주요 연구결과를 요약하면 다음과 같다.

1. 모든 업종을 대상으로 시료형태 별 농도를 비교 해 보았을 때 평균은 총 분진이 19.37 mg/m<sup>3</sup>, 호흡성 분진 5.61 mg/m<sup>3</sup>, 총 결정형 유리규산 0.22 mg/m<sup>3</sup>, 호흡성 결정형 유리규산 0.07 mg/m<sup>3</sup>, 결정형 유리규산 0.13 mg/m<sup>3</sup>이었다. 근로자의 호흡기에 직접적으로 영향을 끼치는 호흡성 결정형 유리규산은 고용노동부 노출기준 0.05 mg/m<sup>3</sup>을 초과하였다.

2. 전체 데이터를 대상으로 호흡성 결정형 유리규산 농도를 표준산업분류 소분류로 분석한 결과 석탄 광업에서 0.14 mg/m<sup>3</sup>, 기타 비금속 광물제품 제조업에서 0.111 mg/m<sup>3</sup>, 도자기 및 기타 요업 제품 제조업에서 0.108 mg/m<sup>3</sup>, 토목건설업 0.098 mg/m<sup>3</sup> 그리고 금속주조업에서 0.062 mg/m<sup>3</sup>였다.

3. 호흡성 결정형 유리규산 농도에 대한 표준산업분류 세세분류에 의한 시료 수 가중평균 환산한 결과 가장 높은 업종은 위생용 도자기 제조업이 0.269 mg/m<sup>3</sup>, 석탄광업 0.14 mg/m<sup>3</sup>, 기타 일반 도자기 제조업 및 기타 석제품 제조업에서 0.111 mg/m<sup>3</sup>로 고용노동부 노출기준보다 높게 나타났다.

4. 표준산업분류의 소분류를 기준으로 함량을 비교한 결과 공기 중 분진에서 기타 비금속 광물제품 제조업 7.33%, 도자기 및 기타 요업제품 제조업에서 6.84%이었다. 벌크시료 중 함량이 높은 업종은 축산업이 80%, 도시 정기 육상 여객 운송업과 도자기 및 기타 요업제품 제조업에서 각각 16.40%, 17.5%이었다.

5. 호흡성 결정형 유리규산 농도의 전체 시료 수는 872건이다. 이 중 금속주조업이 570건으로 절반 이상을 차지하고 있으며 공정에서는 벤토나이트 조형과 형해체 공정으로 0.09 mg/m<sup>3</sup>이었고, 연마공정과 조형공정에서 0.05 mg/m<sup>3</sup>였다. 노출기준 미만인 공정은 마무리 및 용해공정이 0.04 mg/m<sup>3</sup>, 이산화탄소 조형 0.03 mg/m<sup>3</sup>, 중자 공정이 0.01 mg/m<sup>3</sup>로 가장 낮았다. 토목건설업에서 결정형 유리규산의 농도가 가장 높은 공정은 버럭처리 0.24 mg/m<sup>3</sup>, 터널 건설공정이 0.06 mg/m<sup>3</sup>, 덤프트럭 운전, 중장비 공정 및 슛크리트에서 모두 0.03 mg/m<sup>3</sup>였다.

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Appendix 1. Crystalline silica contents of bulk or airborne dust samples

| No | Reference         | Year | KSIC-3digit    | KSIC-5digit                       | Operation   | Sample type     | N  | Min (%) | Max (%) | GM (%) | GSD  | AM (%) | SD (%) | AMT (%) | Method |
|----|-------------------|------|----------------|-----------------------------------|-------------|-----------------|----|---------|---------|--------|------|--------|--------|---------|--------|
| 1  | KWCWS, 2014       | 2011 | Cast of metals | Steel foundries                   | Grinding    | Foundry sand    |    | 45      | 58      |        |      |        |        | 51.2    | XRD    |
| 2  | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Molding     | Respirable dust | 79 | 0.05    | 39.17   | 1.8    | 3.44 |        |        | 3.86    | FTIR   |
| 3  | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Respirable dust | 50 | 0.05    | 32.79   | 3.21   | 3.17 |        |        | 6.25    | FTIR   |
| 4  | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting     | Respirable dust | 6  |         |         |        |      | 3.53   | 2.93   | 3.53    | XRD    |
| 5  | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding     | Respirable dust | 13 |         |         |        |      | 5.09   | 3.14   | 5.09    | XRD    |
| 6  | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making | Respirable dust | 4  |         |         |        |      | 4.31   | 1.85   | 4.31    | XRD    |
| 7  | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Respirable dust | 6  |         |         |        |      | 5      | 4.97   | 5.00    | XRD    |
| 8  | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing   | Respirable dust | 7  |         |         |        |      | 3.44   | 2.18   | 3.44    | XRD    |
| 9  | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting     | Respirable dust | 6  |         |         |        |      | 5.94   | 6.61   | 5.94    | FTIR   |
| 10 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding     | Respirable dust | 13 |         |         |        |      | 4.27   | 3.81   | 4.27    | FTIR   |
| 11 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making | Respirable dust | 4  |         |         |        |      | 2.78   | 1.43   | 2.78    | FTIR   |
| 12 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Respirable dust | 6  |         |         |        |      | 4.26   | 1.74   | 4.26    | FTIR   |
| 13 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing   | Respirable dust | 7  |         |         |        |      | 4.29   | 2.49   | 4.29    | FTIR   |
| 14 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting     | Respirable dust | 3  |         |         |        |      | 3.12   | 1.65   | 3.12    | XRD    |
| 15 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding     | Respirable dust | 13 |         |         |        |      | 4.03   | 1.96   | 4.03    | XRD    |
| 16 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making | Respirable dust | 7  |         |         |        |      | 3.75   | 1.19   | 3.75    | XRD    |
| 17 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Respirable dust | 5  |         |         |        |      | 3.89   | 1.01   | 3.89    | XRD    |
| 18 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing   | Respirable dust | 6  |         |         |        |      | 3.3    | 1.22   | 3.30    | XRD    |
| 19 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting     | Respirable dust | 3  |         |         |        |      | 3.54   | 2.17   | 3.54    | FTIR   |
| 20 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding     | Respirable dust | 13 |         |         |        |      | 5.15   | 2.46   | 5.15    | FTIR   |
| 21 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making | Respirable dust | 7  |         |         |        |      | 3.52   | 2.46   | 3.52    | FTIR   |
| 22 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Respirable dust | 5  |         |         |        |      | 6.87   | 7.19   | 6.87    | FTIR   |
| 23 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing   | Respirable dust | 6  |         |         |        |      | 5.09   | 1.67   | 5.09    | FTIR   |
| 24 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting     | Bulk            | 2  |         |         |        |      | 8.18   | 1.39   | 8.18    | XRD    |
| 25 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding     | Bulk            | 15 |         |         |        |      | 12.92  | 15.4   | 12.92   | XRD    |
| 26 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making | Bulk            | 3  |         |         |        |      | 13.19  | 7.11   | 13.19   | XRD    |
| 27 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Bulk            | 5  |         |         |        |      | 8.04   | 3.89   | 8.04    | XRD    |
| 28 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing   | Bulk            | 4  |         |         |        |      | 11.37  | 7.3    | 11.37   | XRD    |
| 29 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting     | Bulk            | 2  |         |         |        |      | 6.23   | 6.23   | 6.23    | FTIR   |
| 30 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding     | Bulk            | 16 |         |         |        |      | 6.99   | 6.99   | 6.99    | FTIR   |
| 31 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making | Bulk            | 3  |         |         |        |      | 11.01  | 11.01  | 11.01   | FTIR   |
| 32 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Bulk            | 4  |         |         |        |      | 5.68   | 5.68   | 5.68    | FTIR   |
| 33 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing   | Bulk            | 5  |         |         |        |      | 5.15   | 5.15   | 5.15    | FTIR   |
| 34 | Phae et al., 1997 | 1996 | Cast of metals | Gray and malleable iron foundries | Molding     | Respirable dust | 11 | 1.23    | 15.87   | 4.32   | 1.96 |        |        | 5.42    | FTIR   |
| 35 | Phae et al., 1997 | 1996 | Cast of metals | Gray and malleable iron foundries | Shakeout    | Respirable dust | 7  | 2.64    | 7.53    | 4.84   | 1.41 |        |        | 5.13    | FTIR   |

| No | Reference         | Year | KSIC-3digit  | KSIC-5digit  | Operation   | Sample type      | N  | Min (%) | Max (%) | GM (%) | GSD  | AM (%) | SD (%) | AMT (%) | Method |
|----|-------------------|------|--|--|---|------------------|----|---------|---------|--------|------|--------|--------|---------|--------|
| 36 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Finishing   | Respirable dust  | 2  | 4.41    | 6.51    | 5.36   | 1.32 |        |        | 5.57    | FTIR   |
| 37 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Melting   | Respirable dust  | 2  | 1.88    | 6       | 3.36   | 2.27 |        |        | 4.70    | FTIR   |
| 38 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Molding   | Respirable dust  | 10 | 2.51    | 13.99   | 6.35   | 1.74 |        |        | 7.40    | FTIR   |
| 39 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Shakeout  | Respirable dust  | 6  | 3.5     | 7.53    | 4.59   | 1.35 |        |        | 4.80    | FTIR   |
| 40 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Finishing   | Respirable dust  | 4  | 9.3     | 22.67   | 14.69  | 1.5  |        |        | 15.95   | FTIR   |
| 41 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Molding   | Bulk             | 13 | 0.15    | 18.1    |        |      | 4.54   | 4.45   | 4.54    | FTIR   |
| 42 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Shakeout, finishing   | Bulk             | 7  | 0.33    | 8.83    |        |      | 4.7    | 4.69   | 4.70    | FTIR   |
| 43 | KWCWS, 2014       | 2011 | Farming of animals                                       | Farming of horses, sheep and goats                               | Lungeing  | Total dust       |    |         |         |        |      | 1.7    |        | 1.7     | XRD    |
| 44 | KWCWS, 2014       | 2011 | Farming of animals                                       | Farming of horses, sheep and goats                               | Lungeing  | Total dust       |    |         |         |        |      | 1.6    |        | 1.6     | XRD    |
| 45 | KWCWS, 2014       | 2011 | Farming of animals                                       | Farming of horses, sheep and goats                               | Lungeing  | Ground sand      |    |         |         |        |      | 80     |        | 80      | XRD    |
| 46 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Tunnel constructing   | Respirable dust  | 15 |         |         |        |      | 4.8    |        | 4.8     | FTIR   |
| 47 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Drilling  | Respirable dust  | 6  |         |         |        |      | 2.1    |        | 2.1     | FTIR   |
| 48 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Pay Loader operating  | Respirable dust  | 8  |         |         |        |      | 6.9    |        | 6.9     | FTIR   |
| 49 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Pay Loader operating  | Respirable dust  | 8  |         |         |        |      | 5.3    |        | 5.3     | FTIR   |
| 50 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Shotcrete pouring   | Respirable dust  | 2  |         |         |        |      | 1.6    |        | 1.6     | FTIR   |
| 51 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Dump truck driving  | Respirable dust  | 10 |         |         |        |      | 4.1    |        | 4.1     | FTIR   |
| 52 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Heavy machine operating   | Respirable dust  | 3  |         |         |        |      | 3.2    |        | 3.2     | FTIR   |
| 53 | Kim et al., 2009  | 2009 | Manufacture of cement, lime and plaster and its products | Manufacture of cement  |   | Portland cement  | 8  |         |         |        |      | 0.32   |        | 0.32    | XRD    |
| 54 | Kim et al., 2009  | 2009 | Manufacture of cement, lime and plaster and its products | Manufacture of cement  |   | White cement     | 2  | 0       | 0.67    |        |      |        |        | 0.34    | XRD    |
| 55 | Kim et al., 2008  | 2008 | Manufacture of cement, lime and plaster and its products | Manufacture of cement  |   | Cement           | 1  |         |         |        |      | 0.2    |        | 0.20    | XRD    |
| 56 | Kim et al., 1999  | 1997 | Manufacture of cement, lime and plaster and its products | Manufacture of other refractory ceramic products                 |   | Respirable dust  | 3  |         |         |        |      | 4.75   | 1.89   | 4.75    | XRD    |
| 57 | Kim et al., 1999  | 1997 | Manufacture of cement, lime and plaster and its products | Manufacture of other refractory ceramic products                 |   | Respirable dust  | 3  |         |         |        |      | 2.58   | 1.29   | 2.58    | FTIR   |
| 58 | Kim et al., 1999  | 1997 | Manufacture of ceramic ware                              | Manufacture of other non-structural, non-refractory ceramic ware |   | Respirable dust  | 16 |         |         |        |      | 7.18   | 6.51   | 7.18    | XRD    |
| 59 | Kim et al., 1999  | 1997 | Manufacture of ceramic ware                              | Manufacture of other non-structural, non-refractory ceramic ware |   | Respirable dust  | 14 |         |         |        |      | 10.33  | 9.7    | 10.33   | FTIR   |
| 60 | KWCWS, 2014       | 2010 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             | Developing, shaping, forming  | Gypsum powder    |    |         |         |        |      | 0.5    |        | 0.5     | XRD    |
| 61 | KWCWS, 2014       | 2009 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             | Mixing  | Total dust       | 2  | 4.872   | 6.913   |        |      |        |        | 5.89    | FTIR   |
| 62 | KWCWS, 2014       | 2009 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             | Mixing  | Total dust       | 2  | 2.168   | 2.868   |        |      |        |        | 2.52    | FTIR   |
| 63 | Kim et al., 2010  | 2010 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             |   | Gypsum powder    | 1  |         |         |        |      | 0.5    |        | 0.50    | XRD    |
| 64 | Kim et al., 2010  | 2010 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             |   | Forming products | 1  |         |         |        |      | 35.9   |        | 35.90   | XRD    |
| 65 | Kim et al., 2010  | 2010 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             |   | Raw metaerial    | 7  | ND      | 56.6    |        |      | 26.7   |        | 26.70   | XRD    |
| 66 | Kim et al., 2010  | 2010 | Manufacture of ceramic ware                              | Manufacture of sanitary ceramic ware                             | Forming   | Respirable dust  | NA |         |         |        |      | 46     |        | 46.00   | XRD    |
| 67 | Kim et al., 1999  | 1997 | Manufacture of ceramic ware                              | Manufacture of structural refractory ceramic products            | Others(building exterior insulation, dust polishing and casting subsidiary) | Respirable dust  | 8  |         |         |        |      | 7.54   | 7.95   | 7.54    | XRD    |

| No  | Reference         | Year | KSIC-3digit  | KSIC-5digit  | Operation   | Sample type            | N  | Min (%) | Max (%) | GM (%) | GSD  | AM (%) | SD (%) | AMT (%) | Method |
|-----|-------------------|------|--|--|---|------------------------|----|---------|---------|--------|------|--------|--------|---------|--------|
| 68  | Kim et al., 1999  | 1997 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  | Others(building exterior insulation, dust polishing and casting subsidiary) | Respirable dust        | 8  |         |         |        |      | 7.97   | 6.57   | 7.97    | FTIR   |
| 69  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Total dust             | 11 |         |         |        |      | 8.03   | 4.8    | 8.03    | FTIR   |
| 70  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Total, respirable dust | 10 |         |         |        |      | 1.32   | 0.69   | 1.32    | FTIR   |
| 71  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Total, respirable dust | 13 |         |         |        |      | 5.59   | 3.6    | 5.59    | FTIR   |
| 72  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Glaze                  | 1  |         |         |        |      | 9.09   |        | 9.09    | FTIR   |
| 73  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Precipitated dust      | 1  |         |         |        |      | 7.32   |        | 7.32    | FTIR   |
| 74  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Raw metaerial          | 1  |         |         |        |      | 11.75  |        | 11.75   | FTIR   |
| 75  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Glaze                  | 1  |         |         |        |      | 10.94  |        | 10.94   | FTIR   |
| 76  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Raw metaerial          | 1  |         |         |        |      | 10.11  |        | 10.11   | FTIR   |
| 77  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Raw metaerial          | 1  |         |         |        |      | 0.5    |        | 0.50    | FTIR   |
| 78  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Bulk                   | 1  |         |         |        |      | 5.03   |        | 5.03    | FTIR   |
| 79  | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |   | Precipitated dust      | 1  |         |         |        |      | 0.72   |        | 0.72    | FTIR   |
| 80  | Kim et al., 1999  | 1997 | Manufacture of coke and briquettes                 | Manufacture of briquettes and other coal products      | Briquets  | Respirable dust        | 3  |         |         |        |      | 3.41   | 1.3    | 3.41    | XRD    |
| 81  | Kim et al., 1999  | 1997 | Manufacture of coke and briquettes                 | Manufacture of briquettes and other coal products      | Briquets  | Respirable dust        | 3  |         |         |        |      | 3.01   | 1.35   | 3.01    | FTIR   |
| 82  | Kim et al., 1999  | 1997 | Manufacture of glass and glass products            | Manufacture of all other glass and its products n.e.c. |   | Respirable dust        | 3  |         |         |        |      | 4.52   | 5.63   | 4.52    | XRD    |
| 83  | Kim et al., 1999  | 1997 | Manufacture of glass and glass products            | Manufacture of all other glass and its products n.e.c. |   | Respirable dust        | 1  |         |         |        |      | 2.53   |        | 2.53    | FTIR   |
| 84  | KWCWS, 2014       |      | Manufacture of other chemical products             | Manufacture of general paints and similar products     | Paints mixing   | Paint                  | 2  |         |         |        |      | 10.53  |        | 10.53   | XRD    |
| 85  | KWCWS, 2014       |      | Manufacture of other chemical products             | Manufacture of general paints and similar products     | Paints mixing   | Calsite, clay          | 2  |         |         |        |      | 0.95   |        | 0.95    |        |
| 86  | KWCWS, 2014       | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products   | Crushing, cleaning  | Tuff                   | 1  |         |         |        |      | 6      |        | 6       |        |
| 87  | Kim et al., 1999  | 1997 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                    |   | Respirable dust        | 6  |         |         |        |      | 5.47   | 1.86   | 5.47    | XRD    |
| 88  | Kim et al., 1999  | 1997 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                    |   | Respirable dust        | 4  |         |         |        |      | 10.12  | 4.96   | 10.12   | FTIR   |
| 89  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Rock drilling   | Total dust             | 2  | 0.42    | 9.76    |        |      |        |        | 5.09    | FTIR   |
| 90  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Beam construction   | Respirable dust        | 3  |         |         |        |      | 2.6    | 4.2    | 2.60    | FTIR   |
| 91  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Rock drilling   | Respirable dust        | 8  |         |         |        |      | 6.3    | 6.7    | 6.30    | FTIR   |
| 92  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Coal face   | Total dust             | 1  |         |         |        |      | 2.36   |        | 2.36    | FTIR   |
| 93  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Coal face   | Respirable dust        | 6  |         |         |        |      | 0.39   | 0.3    | 0.39    | FTIR   |
| 94  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Loading, transportation   | Total dust             | 1  |         |         |        |      | 0.61   |        | 0.61    | FTIR   |
| 95  | Shin et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite                             | Loading, transportation   | Respirable dust        | 6  |         |         |        |      | 4.7    | 1.4    | 4.70    | FTIR   |
| 96  | Lee & Lee, 1989   | 1989 | Mining of coal and lignite                         | Mining of coal and lignite                             | Coal face   | Respirable dust        | 3  |         |         | 1.52   | 2.34 | 2.1    | 1.71   | 2.1     | FTIR   |
| 97  | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                         | Mining of coal and lignite                             | Drilling  | Respirable dust        | 41 | 0       | 18.9    | 2.9    | 4.3  | 5.5    | 5.3    | 5.5     | FTIR   |
| 98  | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                         | Mining of coal and lignite                             | Coal cutting  | Respirable dust        | 48 | 0       | 13.5    | 0.6    | 4.4  | 1.8    | 3.1    | 1.8     | FTIR   |
| 99  | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                         | Mining of coal and lignite                             | Hauling   | Respirable dust        | 13 | 0       | 8.9     | 1.2    | 2.3  | 2.4    | 2.6    | 2.4     | FTIR   |
| 100 | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                         | Mining of coal and lignite                             | Separating  | Respirable dust        | 15 | 0       | 5.8     | 1.2    | 3.1  | 1.7    | 1.4    | 1.7     | FTIR   |

| No  | Reference         | Year | KSIC-3digit                                 | KSIC-5digit                | Operation                 | Sample type        | N  | Min (%) | Max (%) | GM (%) | GSD | AM (%) | SD (%) | AMT (%) | Method |
|-----|-------------------|------|---|----------------------------|---------------------------|--------------------|----|---------|---------|--------|-----|--------|--------|---------|--------|
| 101 | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                  | Mining of coal and lignite | Drilling                  | Respirable dust    | 12 | 0       | 14.8    | 2.5    | 4.9 | 5.2    | 5      | 5.2     |        |
| 102 | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                  | Mining of coal and lignite | Drilling helper           | Respirable dust    | 13 | 0       | 16.6    | 2.9    | 3.7 | 4.8    | 4.3    | 4.8     |        |
| 103 | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                  | Mining of coal and lignite | Coal cutting              | Respirable dust    | 9  | 0       | 11.6    | 1.6    | 4.5 | 3.1    | 3.5    | 3.1     |        |
| 104 | Yoon & Lee, 1988  | 1987 | Mining of coal and lignite                  | Mining of coal and lignite | Coal cutting helper       | Respirable dust    | 10 | 0       | 2.2     | 0.3    | 3.3 | 0.6    | 0.7    | 0.6     |        |
| 105 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Total dust         | 2  |         |         |        |     | 1      | 0.65   | 1       | FTIR   |
| 106 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Total dust         | 1  |         |         |        |     | 2.9    | 2.9    | 2.9     | FTIR   |
| 107 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Total dust         | 1  |         |         |        |     | 0.6    | 0.6    | 0.6     | FTIR   |
| 108 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Respirable dust    | 1  |         |         |        |     | 0.9    | 0.9    | 0.9     | FTIR   |
| 109 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Respirable dust    | 2  |         |         |        |     | 5.7    | 7.1    | 5.7     | FTIR   |
| 110 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Respirable dust    | 3  |         |         |        |     | 0.65   | 0.52   | 0.65    | FTIR   |
| 111 | Choi et al., 2000 | 2000 | Mining of iron ores                         | Mining of iron ores        |                           | Respirable dust    | 7  |         |         |        |     | 11.2   | 16.6   | 11.2    | FTIR   |
| 112 | KWCWS, 2014       | 2010 | Transit and ground passenger transportation | Commuter rail systems      | Frequency dividing        | Sedimentation dust | 1  |         |         |        |     | 12     |        | 12      | XRD    |
| 113 | KWCWS, 2014       | 2010 | Transit and ground passenger transportation | Commuter rail systems      | Track device installation | Sedimentation dust | 1  |         |         |        |     | 23     |        | 23      | XRD    |

**Appendix 2.** Crystalline silica concentration of airborne dust samples

| No | Reference   | Year | KSIC-3digit  | KSIC-5digit   | Operation                 | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method |
|----|-------------|------|--|---|---------------------------|-------------|--------------------------|--------------------------|-------------------------|-----|-------------------------|-------------------------|---------|--------|
| 1  | KWCWS, 2014 | NA   | Cast of Metals                                     | Steel foundries                                       | Grinding                  | Personal    |                          |                          |                         |     | 0.04                    |                         | 0.04    | XRD    |
| 2  | KWCWS, 2014 | NA   | Cast of Metals                                     | Steel foundries                                       | Grinding                  | Personal    |                          |                          |                         |     | 0.034                   |                         | 0.03    | XRD    |
| 3  | KWCWS, 2014 | NA   | Cast of Metals                                     | Steel foundries                                       | Heating                   | Area        |                          |                          |                         |     | 0.136                   |                         | 0.14    |        |
| 4  | KOSHA, 2007 | 2004 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products | Crushing                  | Personal    | 0.00721                  | 0.02426                  |                         |     | 0.016                   |                         | 0.016   |        |
| 5  | KOSHA, 2007 | 2004 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products | Drying                    | Personal    | 0.00446                  | 0.05243                  |                         |     | 0.028                   |                         | 0.028   |        |
| 6  | KWCWS, 2014 | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware                  | Forming                   |             |                          |                          |                         |     | 0.08                    |                         | 0.08    |        |
| 7  | KOSHA, 2007 | 2004 | Manufacture of other chemical products             | Manufacture of Ceramic Enamels and Related Products   | Mixing                    | Personal    | 0.00036                  | 0.00384                  |                         |     | 0.0024                  |                         | 0.0024  |        |
| 8  | KWCWS, 2014 | 2006 | Manufacture of other chemical products             | Manufacture of general paints and similar products    | Painting                  | Personal    | 0.006                    | 0.013                    |                         |     |                         |                         | 0.009   | XRD    |
| 9  | KWCWS, 2014 | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products  | Crushing                  | Personal    |                          |                          |                         |     | 0.028                   |                         | 0.03    | XRD    |
| 10 | KWCWS, 2014 | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products  | Heavy machinery operating | Area        |                          |                          |                         |     | 0.031                   |                         | 0.03    | XRD    |
| 11 | KWCWS, 2014 | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products  | Conveyor belt             | Area        |                          |                          |                         |     | 0.173                   |                         | 0.17    | XRD    |
| 12 | KWCWS, 2014 | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products  | Stone dust compression    | Personal    |                          |                          |                         |     | 0.017                   |                         | 0.02    |        |
| 13 | KWCWS, 2014 | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products  | Stone dust compression    | Personal    |                          |                          |                         |     | 0.082                   |                         | 0.08    |        |
| 14 | KWCWS, 2014 | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products  | Heavy machinery operating | Area        | 0.031                    | 0.04                     |                         |     |                         |                         | 0.04    |        |
| 15 | KWCWS, 2014 | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                   | Cutting                   | Area        |                          |                          |                         |     | 0.585                   |                         | 0.59    | XRD    |
| 16 | KWCWS, 2014 | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                   | Cutting, grinding         | Area        |                          |                          |                         |     | 0.769                   |                         | 0.77    | XRD    |
| 17 | KWCWS, 2014 | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                   | Carving                   | Area        |                          |                          |                         |     | 0.05                    |                         | 0.05    | XRD    |
| 18 | KWCWS, 2014 | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                   | Surface treatment         | Area        |                          |                          |                         |     | 0.128                   |                         | 0.13    | XRD    |
| 19 | KWCWS, 2014 | 2009 | Quarrying of stone,sand and gravel                 | Quarrying of crushed and broken building stone        | Grinding                  | Area        |                          |                          |                         |     | 0.796                   |                         | 0.80    | XRD    |
| 20 | KWCWS, 2014 | 2009 | Quarrying of stone,sand and gravel                 | Quarrying of crushed and broken building stone        | Carving                   | Area        |                          |                          |                         |     | 0.05                    |                         | 0.05    | XRD    |

Appendix 3. Respirable crystalline silica concentration of airborne dust samples

| No | Reference         | Year | KSIC-3digit    | KSIC-5digit                       | Operation         | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD    | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method |
|----|-------------------|------|----------------|-----------------------------------|-------------------|-------------|--------------------------|--------------------------|-------------------------|--------|-------------------------|-------------------------|---------|--------|
| 21 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Molding           | Personal    |                          |                          |                         |        | 0.11                    |                         | 0.11    |        |
| 22 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Melting           | Personal    |                          |                          |                         |        | 0.019                   |                         | 0.02    |        |
| 23 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Molding           | Personal    |                          |                          |                         |        | 0.036                   |                         | 0.04    |        |
| 24 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Melting           | Personal    |                          |                          |                         |        | 0.025                   |                         | 0.03    |        |
| 25 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Molding           | Area        |                          |                          |                         |        | 0.015                   |                         | 0.02    |        |
| 26 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Grinding          | Area        |                          |                          |                         |        | 0.056                   |                         | 0.06    |        |
| 27 | KWCWS, 2014       | 2011 | Cast of Metals | Steel foundries                   | Grinding          | Area        |                          |                          |                         |        | 0.035                   |                         | 0.04    |        |
| 28 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.0007                   | 0.3045                   | 0.0206                  | 3.8962 |                         |                         | 0.052   | FTIR   |
| 29 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.0014                   | 0.3757                   | 0.0426                  | 3.7547 |                         |                         | 0.102   | FTIR   |
| 30 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.0295                   | 0.3045                   | 0.0859                  | 1.8908 |                         |                         | 0.11    | FTIR   |
| 31 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.014                    | 0.3757                   | 0.1006                  | 2.4303 |                         |                         | 0.15    | FTIR   |
| 32 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.0007                   | 0.0419                   | 0.0139                  | 2.7047 |                         |                         | 0.02    | FTIR   |
| 33 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.0014                   | 0.0757                   | 0.0186                  | 3.1963 |                         |                         | 0.04    | FTIR   |
| 34 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.0007                   | 0.1047                   | 0.0161                  | 2.8377 |                         |                         | 0.03    | FTIR   |
| 35 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.0014                   | 0.0678                   | 0.016                   | 3.222  |                         |                         | 0.03    | FTIR   |
| 36 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.0347                   | 0.3045                   | 0.0926                  | 1.8589 |                         |                         | 0.11    | FTIR   |
| 37 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.0111                   | 0.3757                   | 0.0941                  | 2.4645 |                         |                         | 0.14    | FTIR   |
| 38 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | CO2molding        | Personal    | 0.0014                   | 0.3757                   | 0.0316                  | 1.306  |                         |                         | 0.03    | FTIR   |
| 39 | Park et al., 2003 | 2002 | Cast of metals | Gray and malleable iron foundries | Bentonite molding | Personal    | 0.0007                   | 0.3154                   | 0.0498                  | 3.0926 |                         |                         | 0.09    | FTIR   |
| 40 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting           | Personal    | 0.00823                  | 0.06971                  | 0.01769                 | 2.48   |                         |                         | 0.027   | XRD    |
| 41 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.01108                  | 0.03313                  | 0.02139                 | 1.34   |                         |                         | 0.022   | XRD    |
| 42 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making       | Personal    | 0.01271                  | 0.02227                  | 0.01538                 | 1.29   |                         |                         | 0.016   | XRD    |
| 43 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.00577                  | 0.03929                  | 0.01898                 | 2.03   |                         |                         | 0.024   | XRD    |
| 44 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing         | Personal    | 0.01354                  | 0.05683                  | 0.02314                 | 1.67   |                         |                         | 0.026   | XRD    |
| 45 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting           | Personal    | 0.00246                  | 0.14009                  | 0.023                   | 4.71   |                         |                         | 0.076   | FTIR   |
| 46 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding           | Personal    | 0.00206                  | 0.06072                  | 0.01585                 | 3.2    |                         |                         | 0.031   | FTIR   |
| 47 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making       | Personal    | 0.00766                  | 0.02534                  | 0.01084                 | 1.77   |                         |                         | 0.013   | FTIR   |
| 48 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Personal    | 0.00599                  | 0.07543                  | 0.02385                 | 2.45   |                         |                         | 0.036   | FTIR   |
| 49 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing         | Personal    | 0.00195                  | 0.13267                  | 0.03175                 | 3.83   |                         |                         | 0.078   | FTIR   |
| 50 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Melting           | Area        | 0.01181                  | 0.01576                  | 0.01387                 | 1.16   |                         |                         | 0.014   | XRD    |
| 51 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Molding           | Area        | 0.00882                  | 0.04227                  | 0.01709                 | 1.58   |                         |                         | 0.019   | XRD    |
| 52 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Core making       | Area        | 0.00725                  | 0.02725                  | 0.01319                 | 1.56   |                         |                         | 0.015   | XRD    |
| 53 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Shakeout          | Area        | 0.00822                  | 0.01829                  | 0.01267                 | 1.39   |                         |                         | 0.013   | XRD    |
| 54 | Kim et al., 1998  | 1997 | Cast of metals | Gray and malleable iron foundries | Finishing         | Area        | 0.00807                  | 0.03795                  | 0.02084                 | 1.78   |                         |                         | 0.025   | XRD    |



| No | Reference         | Year | KSIC-3digit   | KSIC-5digit   | Operation                        | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method |
|----|-------------------|------|---|---|----------------------------------|-------------|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|--------|
| 55 | Kim et al., 1998  | 1997 | Cast of metals  | Gray and malleable iron foundries                                   | Melting                          | Area        | 0.01016                  | 0.03183                  | 0.01611                 | 1.83 |                         |                         | 0.019   | FTIR   |
| 56 | Kim et al., 1998  | 1997 | Cast of metals  | Gray and malleable iron foundries                                   | Molding                          | Area        | 0.00296                  | 0.09492                  | 0.02263                 | 2.62 |                         |                         | 0.036   | FTIR   |
| 57 | Kim et al., 1998  | 1997 | Cast of metals  | Gray and malleable iron foundries                                   | Core making                      | Area        | 0.00402                  | 0.0392                   | 0.0114                  | 2.22 |                         |                         | 0.016   | FTIR   |
| 58 | Kim et al., 1998  | 1997 | Cast of metals  | Gray and malleable iron foundries                                   | Shakeout                         | Area        | 0.00317                  | 0.05627                  | 0.0171                  | 2.72 |                         |                         | 0.028   | FTIR   |
| 59 | Kim et al., 1998  | 1997 | Cast of metals  | Gray and malleable iron foundries                                   | Finishing                        | Area        | 0.01566                  | 0.10354                  | 0.03085                 | 1.95 |                         |                         | 0.039   | FTIR   |
| 60 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Molding                          | Personal    | 0.011                    | 0.0958                   | 0.02775                 |      |                         |                         | 0.0376  | FTIR   |
| 61 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Shakeout                         | Personal    | 0.01969                  | 0.13926                  | 0.04563                 |      |                         |                         | 0.0590  | FTIR   |
| 62 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Finishing                        | Personal    | 0.02017                  | 0.02241                  | 0.02126                 |      |                         |                         | 0.0213  | FTIR   |
| 63 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Melting                          | Area        | 0.01372                  | 0.01684                  | 0.01519                 |      |                         |                         | 0.0152  | FTIR   |
| 64 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Molding                          | Area        | 0.00996                  | 0.03632                  | 0.02032                 |      |                         |                         | 0.0200  | FTIR   |
| 65 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Shakeout                         | Area        | 0.01475                  | 0.05041                  | 0.03091                 |      |                         |                         | 0.0286  | FTIR   |
| 66 | Phee et al., 1997 | 1996 | Cast of metals  | Gray and malleable iron foundries                                   | Finishing                        | Area        | 0.01028                  | 0.11333                  | 0.03457                 |      |                         |                         | 0.0409  | FTIR   |
| 67 | KWCWS, 2014       | 2012 | Farming of animals                                      | Farming of horses,sheep and goats                                   | Race ground                      | Personal    |                          |                          |                         |      | 0.02                    |                         | 0.02    | XRD    |
| 68 | KWCWS, 2014       | 2011 | Farming of animals                                      | Farming of horses,sheep and goats                                   | Race ground                      | Area        |                          |                          |                         |      | 0.018                   |                         | 0.02    | XRD    |
| 69 | KWCWS, 2014       | 2011 | Farming of animals                                      | Farming of horses,sheep and goats                                   | Race ground                      | Area        |                          |                          |                         |      | 0.026                   |                         | 0.03    | XRD    |
| 70 | KWCWS, 2014       | 2011 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Under pass constructing          | Area        | 0.004                    | 0.014                    |                         |      | 0.009                   |                         | 0.01    | XRD    |
| 71 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Tunnel constructing worker       | Personal    |                          | 0.48                     | 0.021                   | 4.19 |                         |                         | 0.06    | FTIR   |
| 72 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Drilling                         | Personal    |                          | 0.0265                   | 0.01                    | 2.34 |                         |                         | 0.01    | FTIR   |
| 73 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Pay loader operating             | Personal    |                          | 0.474                    | 0.0638                  | 5.46 |                         |                         | 0.27    | FTIR   |
| 74 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Pay loader operating             | Personal    |                          | 0.333                    | 0.116                   | 2.92 |                         |                         | 0.21    | FTIR   |
| 75 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Shotcrete pouring                | Personal    |                          | 0.0387                   | 0.027                   | 1.7  |                         |                         | 0.03    | FTIR   |
| 76 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Dump truck driving               | Personal    |                          | 0.0436                   | 0.023                   | 1.8  |                         |                         | 0.03    | FTIR   |
| 77 | Yoo et al.,2003   | 2001 | Heavy construction                                      | Construction of bridges, tunnels and railways                       | Heavy machinery operating        | Personal    |                          | 0.0438                   | 0.023                   | 1.76 |                         |                         | 0.03    | FTIR   |
| 78 | Kim et al., 2008  | 2008 | Manufacture of basic iron and steel                     | Manufacture of basic iron   | Heating                          | Area        | ND                       | 0.0034                   |                         |      | 0.0017                  |                         | 0.0017  | FTIR   |
| 79 | Kim et al., 1999  | 1997 | Manufacture of cement,lime and plaster and its products | Manufacture of other refractory ceramic products                    | Concrete manufacturing           | Personal    | 0.01139                  | 0.01529                  | 0.01336                 | 1.16 |                         |                         | 0.014   | XRD    |
| 80 | Kim et al., 1999  | 1997 | Manufacture of cement,lime and plaster and its products | Manufacture of other refractory ceramic products                    | Concrete manufacturing           | Personal    | 0                        | 0.01574                  | 0.00764                 | 2.78 |                         |                         | 0.013   | FTIR   |
| 81 | KWCWS, 2014       | 2009 | Manufacture of cement,lime and plaster and its products | Manufacture of ready-mixconcrete facilities and industrial supplies | Mixer,hopper,conveyer belt clean | Area        | 0.041                    | 0.084                    |                         |      |                         |                         | 0.06    | XRD    |
| 82 | Kim et al., 1999  | 1997 | Manufacture of ceramic ware                             | Manufacture of other non-structural, non-refractory ceramic ware    |                                  | Personal    | 0.00697                  | 0.1352                   | 0.02227                 | 2.27 |                         |                         | 0.031   | XRD    |

| No  | Reference          | Year      | KSIC-3digit  | KSIC-5digit  | Operation  | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD   | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method |
|-----|--------------------|-----------|--|--|--|-------------|--------------------------|--------------------------|-------------------------|-------|-------------------------|-------------------------|---------|--------|
| 83  | Kim et al., 1999   | 1997      | Manufacture of ceramic ware                        | Manufacture of other non-structural, non-refractory ceramic ware |  | Personal    | 0                        | 0.55399                  | 0.02597                 | 7.59  |                         |                         | 0.203   | FTIR   |
| 84  | Oh et al., 1994    | 1994      | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware                             | Sanitary ware  | Personal    |                          |                          | 0.0279                  | 10.2  |                         |                         | 0.414   | FTIR   |
| 85  | Kim et al., 2010   | 2010      | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware                             | Forming  | Personal    |                          |                          |                         |       | 0.08                    |                         | 0.08    | XRD    |
| 86  | Kim et al., 2010   | 2010      | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware                             | Developing   | Personal    |                          |                          |                         |       | ND                      |                         | 0       | XRD    |
| 87  | Kim et al., 2010   | 2010      | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware                             | Shaping  | Personal    |                          |                          |                         |       | ND                      |                         | 0       | XRD    |
| 88  | Kim et al., 1999   | 1997      | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products            | Others(building exterior insulation, polishing and casting subsidiary) | Personal    | 0.00663                  | 0.03071                  | 0.01033                 | 1.56  |                         |                         | 0.011   | XRD    |
| 89  | Kim et al., 1999   | 1997      | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products            | Others(building exterior insulation, polishing and casting subsidiary) | Personal    | 0                        | 0.06514                  | 0.0149                  | 3.63  |                         |                         | 0.034   | FTIR   |
| 90  | Oh et al., 1994    | 1994      | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products            |  | Personal    |                          |                          | 0.0058                  | 11.2  |                         |                         | 0.107   | FTIR   |
| 91  | Kim et al., 1999   | 1997      | Manufacture of coke and briquettes                 | Manufacture of briquettes and other coal products                | Briquets   | Personal    | 0.01161                  | 0.01554                  | 0.01317                 | 1.16  |                         |                         | 0.013   | XRD    |
| 92  | Kim et al., 1999   | 1997      | Manufacture of coke and briquettes                 | Manufacture of coke and other coal products                      | Briquets   | Personal    | 0                        | 0.03526                  | 0.01267                 | 2.52  |                         |                         | 0.019   | FTIR   |
| 93  | Kim et al., 1999   | 1997      | Manufacture of glass and glass products            | Manufacture of all other glass and its products n.e.c.           |  | Personal    | 0.00685                  | 0.08613                  | 0.01656                 | 4.18  |                         |                         | 0.046   | XRD    |
| 94  | Kim et al., 1999   | 1997      | Manufacture of glass and glass products            | Manufacture of all other glass and its products n.e.c.           |  | Personal    | 0                        | 0.01183                  | 0.01183                 |       |                         |                         | 0.012   | FTIR   |
| 95  | Kim et al., 2012   | 2008-2012 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                              | Stone processing   | Personal    | NA                       | 0.796                    |                         |       | 0.149                   |                         | 0.15    | XRD    |
| 96  | Kim et al., 2012   | 2008-2012 | Manufacture of other non-metallic mineral products | Manufacture of other stone products                              | Stone installation   | Personal    | NA                       | 0.133                    |                         |       | 0.038                   |                         | 0.04    | XRD    |
| 97  | Kim et al., 2014   | 2012      | Manufacture of other non-metallic mineral products | Manufacture of other stone products                              | Stone grinding   | Personal    | 0.049                    | 0.554                    | 0.17                    | 2.181 | 0.225                   | 0.175                   | 0.23    | FTIR   |
| 98  | Kim et al., 1999   | 1997      | Manufacture of other non-metallic mineral products | Manufacture of other stone products                              | Stone  | Personal    | 0.00628                  | 0.32708                  | 0.02408                 | 4.39  |                         |                         | 0.072   | XRD    |
| 99  | Kim et al., 1999   | 1997      | Manufacture of other non-metallic mineral products | Manufacture of other stone products                              | Stone  | Personal    | 0                        | 0.03807                  | 0.01716                 | 2.25  |                         |                         | 0.024   | FTIR   |
| 100 | Shin, et al., 2002 | 2000      | Mining of coal and lignite                         | Mining of coal and lignite                                       | Coal mine  | Personal    | 0.001                    | 0.45                     | 0.05                    | 4.2   |                         |                         | 0.1     | FTIR   |
| 101 | Choi et al., 2000  | 2000      | Mining of iron ores                                | Mining of iron ores  | Rock drilling  | Personal    | 0.0001                   | 0.005                    |                         |       |                         |                         | 0.0011  | FTIR   |
| 102 | Choi et al., 2000  | 2000      | Mining of iron ores                                | Mining of iron ores  | Hauling  | Personal    | 0.0001                   | 0.004                    |                         |       |                         |                         | 0.0010  | FTIR   |
| 103 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                | Hauling  | Personal    | 0.002                    | 0.041                    | 0.004                   | 2.9   |                         |                         | 0.007   | FTIR   |
| 104 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                | Loading  | Personal    | 0.002                    | 0.007                    |                         |       |                         |                         | 0.0039  | FTIR   |
| 105 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                | Drilling, blasting   | Personal    | 0.002                    | 0.004                    | 0.003                   | 1.4   |                         |                         | 0.0032  | FTIR   |
| 106 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                | Milling  | Personal    | 0.0001                   | 0.002                    |                         |       |                         |                         | 0.0006  | FTIR   |
| 107 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                |  | Personal    | 0.0001                   | 0.002                    |                         |       |                         |                         | 0.0006  | FTIR   |
| 108 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                |  | Personal    | 0.0001                   | 0.009                    |                         |       |                         |                         | 0.0018  | FTIR   |
| 109 | Choi et al., 2000  | 2000      | Quarrying of stone,sand and gravel                 | Quarrying of limestone and gypsum                                |  | Personal    | 0.0001                   | 0.003                    |                         |       |                         |                         | 0.0008  | pFTIR  |

Appendix 4. Respirable dust concentration of airborne dust samples

| No  | Reference         | Year | KSIC-3digit  | KSIC-5digit   | Operation                  | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD    | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|-------------------|------|--|---|----------------------------|-------------|--------------------------|--------------------------|-------------------------|--------|-------------------------|-------------------------|---------|----------|
| 110 | Park et al., 2003 | 2002 | Cast of Metals   | Gray and malleable iron foundries   | Molding                    | Personal    | 0.3024                   | 7.0428                   | 1.1457                  | 1.9271 |                         |                         | 1.42    | Weighing |
| 111 | Park et al., 2003 | 2002 | Cast of Metals   | Gray and malleable iron foundries   | Shakeout                   | Personal    | 0.1524                   | 5.0683                   | 1.3258                  | 2.3071 |                         |                         | 1.88    | Weighing |
| 112 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Melting                    | Personal    | 0.4                      | 1.03                     | 0.69                    | 1.44   |                         |                         | 0.74    | Weighing |
| 113 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Molding                    | Personal    | 0.16                     | 1.18                     | 0.46                    | 1.66   |                         |                         | 0.52    | Weighing |
| 114 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Core making                | Personal    | 0.25                     | 0.66                     | 0.46                    | 1.4    |                         |                         | 0.49    | Weighing |
| 115 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Shakeout                   | Personal    | 0.18                     | 1.22                     | 0.53                    | 2.03   |                         |                         | 0.68    | Weighing |
| 116 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Finishing                  | Personal    | 0.3                      | 3.1                      | 1.06                    | 2.19   |                         |                         | 1.44    | Weighing |
| 117 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Melting                    | Area        | 0.13                     | 1                        | 0.38                    | 2.03   |                         |                         | 0.49    | Weighing |
| 118 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Molding                    | Area        | 0.05                     | 2.32                     | 0.34                    | 2.55   |                         |                         | 0.53    | Weighing |
| 119 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Core making                | Area        | 0.26                     | 0.74                     | 0.43                    | 1.49   |                         |                         | 0.47    | Weighing |
| 120 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Shakeout                   | Area        | 0.22                     | 0.55                     | 0.36                    | 1.43   |                         |                         | 0.38    | Weighing |
| 121 | Kim et al., 1998  | 1997 | Cast of Metals   | Gray and malleable iron foundries   | Finishing                  | Area        | 0.32                     | 1.59                     | 0.73                    | 1.67   |                         |                         | 0.83    | Weighing |
| 122 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Melting                    | Personal    | 0.78                     | 1.19                     | 0.96                    | 1.35   |                         |                         | 1.00    | Weighing |
| 123 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Molding                    | Personal    | 0.38                     | 1.54                     | 0.85                    | 1.58   |                         |                         | 0.94    | Weighing |
| 124 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Shakeout                   | Personal    | 0.16                     | 5.36                     | 1.2                     | 3.11   |                         |                         | 2.28    | Weighing |
| 125 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Finishing                  | Personal    | 0.53                     | 3.43                     | 1.28                    | 2.03   |                         |                         | 1.64    | Weighing |
| 126 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Melting                    | Area        | 0.23                     | 0.89                     | 0.45                    | 2.62   |                         |                         | 0.72    | Weighing |
| 127 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Molding                    | Area        | 0.08                     | 3.94                     | 0.41                    | 3.18   |                         |                         | 0.80    | Weighing |
| 128 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Shakeout                   | Area        | 0.31                     | 0.94                     | 0.56                    | 1.57   |                         |                         | 0.62    | Weighing |
| 129 | Phee et al., 1997 | 1996 | Cast of Metals   | Gray and malleable iron foundries   | Finishing                  | Area        | 0.06                     | 0.82                     | 0.23                    | 3.43   |                         |                         | 0.49    | Weighing |
| 130 | KWCWS, 2014       | 2011 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Underpass constructing     | Area        | 0.061                    | 0.114                    |                         |        | 0.093                   |                         | 0.09    | Weighing |
| 131 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Tunnel constructing worker | Personal    |                          | 5.91                     | 0.46                    | 2.69   |                         |                         | 0.75    | Weighing |
| 132 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Drilling                   | Personal    |                          | 0.77                     | 0.35                    | 2.34   |                         |                         | 0.50    | Weighing |
| 133 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Pay loader operating       | Personal    |                          | 4.59                     | 1.08                    | 3.11   |                         |                         | 2.06    | Weighing |
| 134 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Pay loader operating       | Personal    |                          | 4.86                     | 2.46                    | 1.92   |                         |                         | 3.04    | Weighing |
| 135 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Shotcrete pouring          | Personal    |                          | 4.82                     | 2.21                    | 1.72   |                         |                         | 2.56    | Weighing |
| 136 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Dump truck driving         | Personal    |                          | 0.86                     | 0.38                    | 3.01   |                         |                         | 0.70    | Weighing |
| 137 | Yoo et al., 2003  | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways   | Heavy machinery operating  | Personal    |                          | 5.91                     | 0.98                    | 1.82   |                         |                         | 1.17    | Weighing |
| 138 | Kim et al., 1999  | 1997 | Manufacture of cement, lime and plaster and its products | Manufacture of other refractory ceramic products  | Concrete manufacturing     | Personal    | 0.14                     | 0.45                     | 0.26                    | 1.66   |                         |                         | 0.30    | Weighing |
| 139 | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                              | Manufacture of non refractory ceramic building bricks, flooring blocks and similar products                   | Tile                       | Personal    |                          |                          | 0.39                    | 2.73   |                         |                         | 0.65    | Weighing |
| 140 | Kim et al., 1999  | 1997 | Manufacture of ceramic ware                              | Manufacture of other non-structural, non-refractory ceramic ware  |                            | Personal    | 0.06                     | 4.53                     | 0.43                    | 3.29   |                         |                         | 0.87    | Weighing |
| 141 | Oh et al., 1994   | 1994 | Manufacture of ceramic ware                              | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Crushing, milling          | Personal    |                          |                          | 0.45                    | 1.51   |                         |                         | 0.49    | Weighing |

| No  | Reference        | Year | KSIC-3digit  | KSIC-5digit  | Operation  | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD   | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|------------------|------|--|--|--|-------------|--------------------------|--------------------------|-------------------------|-------|-------------------------|-------------------------|---------|----------|
| 142 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of other non-structural,non-refractory ceramic ware bricks, flooring blocks and similar products | Mold making  | Personal    |                          |                          | 0.25                    | 2.83  |                         |                         | 0.43    | Weighing |
| 143 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of other non-structural,non-refractory ceramic ware bricks, flooring blocks and similar products | Forming, shaping   | Personal    |                          |                          | 0.17                    | 1.09  |                         |                         | 0.17    | Weighing |
| 144 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of other non-structural,non-refractory ceramic ware bricks, flooring blocks and similar products | Trimming   | Personal    |                          |                          | 0.48                    | 1.5   |                         |                         | 0.52    | Weighing |
| 145 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of other non-structural,non-refractory ceramic ware bricks, flooring blocks and similar products | Glazing  | Personal    |                          |                          | 0.62                    | 2.85  |                         |                         | 1.07    | Weighing |
| 146 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of other non-structural,non-refractory ceramic ware bricks, flooring blocks and similar products | Drying, firing   | Personal    |                          |                          | 0.12                    | 5.37  |                         |                         | 0.49    | Weighing |
| 147 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of other non-structural,non-refractory ceramic ware bricks, flooring blocks and similar products | Packing  | Personal    |                          |                          | 0.17                    | 1.76  |                         |                         | 0.20    | Weighing |
| 148 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of pottery and ceramic household or ornamental ware  | Table ware   | Personal    |                          |                          | 0.29                    | 1.81  |                         |                         | 0.35    | Weighing |
| 149 | KWCWS, 2014      | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Developing   |             |                          |                          |                         |       | 0.067                   |                         | 0.07    | Weighing |
| 150 | KWCWS, 2014      | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Shaping  |             |                          |                          |                         |       | 0.054                   |                         | 0.05    | Weighing |
| 151 | KWCWS, 2014      | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Forming  |             |                          |                          |                         |       | 0.196                   |                         | 0.20    | Weighing |
| 152 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Sanitary ware  | Personal    |                          |                          | 0.88                    | 5.44  |                         |                         | 3.69    | Weighing |
| 153 | Kim et al., 2010 | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Forming  | Personal    |                          |                          |                         |       | 0.196                   |                         | 0.196   | Weighing |
| 154 | Kim et al., 2010 | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Developing   | Personal    |                          |                          |                         |       | 0.067                   |                         | 0.067   | Weighing |
| 155 | Kim et al., 2010 | 2010 | Manufacture of ceramic ware                        | Manufacture of sanitary ceramic ware   | Shaping  | Personal    |                          |                          |                         |       | 0.054                   |                         | 0.054   | Weighing |
| 156 | Kim et al., 1999 | 1997 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  | Others(building exterior insulation, polishing and casting subsidiary) | Personal    | 0.04                     | 0.93                     | 0.29                    | 2.43  |                         |                         | 0.43    | Weighing |
| 157 | Oh et al., 1994  | 1994 | Manufacture of ceramic ware                        | Manufacture of structural refractory ceramic products  |  | Personal    |                          |                          | 0.4                     | 1.88  |                         |                         | 0.49    | Weighing |
| 158 | Kim et al., 1999 | 1997 | Manufacture of coke and briquettes                 | Manufacture of briquettes and other coal products  | Briquettes   | Personal    | 0.29                     | 0.88                     | 0.53                    | 1.75  |                         |                         | 0.62    | Weighing |
| 159 | Kim et al., 1999 | 1997 | Manufacture of glass and glass products            | Manufacture of all other glass and its products n.e.c.   |  | Personal    | 0.11                     | 1.5                      | 0.42                    | 4.34  |                         |                         | 1.23    | Weighing |
| 160 | KWCWS, 2014      | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products   | Crushing   | Personal    | 0.23                     | 0.369                    |                         |       |                         |                         | 0.29    | XRD      |
| 161 | KWCWS, 2014      | 2010 | Manufacture of other non-metallic mineral products | Manufacture of non-metallic crushed mineral products   | Stone dust compression   | Personal    | 0.044                    | 0.234                    |                         |       |                         |                         | 0.11    | Weighing |
| 162 | Kim et al., 2014 | 2012 | Manufacture of other non-metallic mineral products | Manufacture of other stone products  | Stone grinding   | Personal    | 0.548                    | 2.657                    | 1.372                   | 1.744 | 1.567                   | 0.777                   | 1.57    | FTIR     |
| 163 | KWCWS, 2014      | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products  | Stone treating   | Area        |                          |                          |                         |       | 0.621                   |                         | 0.62    | XRD      |
| 164 | KWCWS, 2014      | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products  | Cutting, grinding  | Area        |                          |                          |                         |       | 2.071                   |                         | 2.07    | XRD      |

| No  | Reference          | Year | KSIC-3digit  | KSIC-5digit                         | Operation               | Sample type | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|--------------------|------|--|-------------------------------------|-------------------------|-------------|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|----------|
| 165 | KWCWS, 2014        | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products | Carving                 | Area        |                          |                          |                         |      | 0.102                   |                         | 0.10    | XRD      |
| 166 | KWCWS, 2014        | 2009 | Manufacture of other non-metallic mineral products | Manufacture of other stone products | Surface treatment       | Area        |                          |                          |                         |      | 0.224                   |                         | 0.22    | XRD      |
| 167 | Kim et al., 1999   | 1997 | Manufacture of other non-metallic mineral products | Manufacture of other stone products | Stone                   | Personal    | 0.08                     | 1.26                     | 0.24                    | 2.48 |                         |                         | 0.36    | Weighing |
| 168 | Shin, et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite          | Coal mine               | Personal    | 0.2                      | 213.2                    | 5.14                    | 9.1  |                         |                         | 58.9    | Weighing |
| 169 | Shin, et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite          | Rock drilling           | Personal    |                          |                          | 1.37                    | 3.3  |                         |                         | 2.8     | Weighing |
| 170 | Shin, et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite          | Coal face               | Personal    |                          |                          | 37.7                    | 2.3  |                         |                         | 53.3    | Weighing |
| 171 | Shin, et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite          | Transportation          | Personal    |                          |                          | 0.59                    | 3    |                         |                         | 1.1     | Weighing |
| 172 | Shin, et al., 2002 | 2000 | Mining of coal and lignite                         | Mining of coal and lignite          | Loading, transportation | Personal    |                          |                          | 2.89                    | 1    |                         |                         | 2.9     | Weighing |
| 173 | Lee & Lee, 1989    | 1989 | Mining of coal and lignite                         | Mining of coal and lignite          | Coal face               | Area        |                          |                          | 6.72                    | 2.38 | 9.02                    | 6.42                    | 9.02    | Weighing |
| 174 | Yoon & Lee, 1988   | 1988 | Mining of coal and lignite                         | Mining of coal and lignite          | Drilling                | Personal    | 0.5                      | 30.8                     | 2.8                     | 2.4  | 4.3                     | 5.4                     | 4.30    | Weighing |
| 175 | Yoon & Lee, 1988   | 1988 | Mining of coal and lignite                         | Mining of coal and lignite          | Coal cutting            | Personal    | 0.3                      | 93.7                     | 8.3                     | 3.4  | 16.9                    | 24.2                    | 16.90   | Weighing |
| 176 | Yoon & Lee, 1988   | 1988 | Mining of coal and lignite                         | Mining of coal and lignite          | Hauling                 | Personal    | 0.4                      | 6.1                      | 1.8                     | 1.4  | 2.4                     | 1.9                     | 2.40    | Weighing |
| 177 | Yoon & Lee, 1988   | 1988 | Mining of coal and lignite                         | Mining of coal and lignite          | Separating              | Personal    | 0.8                      | 27.8                     | 3.7                     | 2.9  | 6.8                     | 7.2                     | 6.80    | Weighing |
| 178 | Yoon & Lee, 1988   | 1987 | Mining of coal and lignite                         | Mining of coal and lignite          | Driller                 | Personal    | 0.5                      | 6.7                      | 2.4                     | 2.3  | 3.1                     | 2.1                     | 3.10    | Weighing |
| 179 | Yoon & Lee, 1988   | 1987 | Mining of coal and lignite                         | Mining of coal and lignite          | Drilling helper         | Personal    | 0.5                      | 6.7                      | 2.2                     | 2.2  | 2.7                     | 1.7                     | 2.70    | Weighing |
| 180 | Yoon & Lee, 1988   | 1987 | Mining of coal and lignite                         | Mining of coal and lignite          | Coal cutting            | Personal    | 2.2                      | 93.3                     | 11.7                    | 3.8  | 19.3                    | 24.6                    | 19.30   | Weighing |
| 181 | Yoon & Lee, 1988   | 1987 | Mining of coal and lignite                         | Mining of coal and lignite          | Coal cutting helper     | Personal    | 2.2                      | 134.2                    | 7.9                     | 2.3  | 10.7                    | 8.7                     | 10.70   | Weighing |
| 182 | Choi et al., 2000  | 2000 | Mining of iron ores                                | Mining of iron ores                 | Rock drilling           | Personal    |                          |                          | 0.47                    | 1.02 |                         |                         | 0.47    | Weighing |
| 183 | Choi et al., 2000  | 2000 | Mining of iron ores                                | Mining of iron ores                 | Hauling                 | Personal    |                          |                          | 0.78                    | 1.58 |                         |                         | 0.87    | Weighing |
| 184 | Choi et al., 2000  | 2000 | Mining of iron ores                                | Mining of iron ores                 | Loading                 | Personal    |                          |                          | 1.57                    | 1.15 |                         |                         | 1.59    | Weighing |
| 185 | Choi et al., 2000  | 2000 | Mining of iron ores                                | Mining of iron ores                 | Others                  | Personal    |                          |                          | 0.56                    | 1.38 |                         |                         | 0.59    | Weighing |
| 186 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   | Hauling                 | Personal    |                          |                          | 0.15                    | 2.2  |                         |                         | 0.20    | Weighing |
| 187 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   | Loading                 | Personal    |                          |                          | 0.1                     | 3.4  |                         |                         | 0.21    | Weighing |
| 188 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   | Drilling, blasting      | Personal    |                          |                          | 0.34                    | 5.2  |                         |                         | 1.32    | Weighing |
| 189 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   | Milling                 | Personal    |                          |                          | 1.47                    | 2.4  |                         |                         | 2.16    | Weighing |
| 190 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   | Maintenance             | Personal    |                          |                          |                         |      | 0.42                    |                         | 0.42    | Weighing |
| 191 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   |                         | Personal    | 0.25                     | 27.3                     | 1.62                    | 12   |                         |                         | 5.20    | Weighing |
| 192 | Choi et al., 2000  | 2000 | Quarrying of stone, sand and gravel                | Quarrying of limestone and gypsum   |                         | Personal    |                          |                          |                         |      | 1.6                     |                         | 1.60    | Weighing |

**Appendix 5.** Total crystalline silica concentration of airborne dust samples

| No  | Reference          | Year | KSIC-3digit                 | KSIC-5digit   | Operation     | Sample type | N | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method |
|-----|--------------------|------|-----------------------------|---|---------------|-------------|---|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|--------|
| 193 | Oh et al., 1994    | 1994 | Manufacture of ceramic ware | Manufacture of pottery and ceramic household or ornamental ware | Table ware    | Personal    | 6 |                          |                          | 0.0199                  | 4.1  |                         |                         | 0.054   | FTIR   |
| 194 | Oh et al., 1994    | 1994 | Manufacture of ceramic ware | Manufacture of pottery and ceramic household or ornamental ware | Table ware    | Personal    | 5 |                          |                          | 0.0263                  | 4.9  |                         |                         | 0.093   | FTIR   |
| 195 | Oh et al., 1994    | 1994 | Manufacture of ceramic ware | Manufacture of sanitary ceramic ware                            | Sanitary ware | Personal    | 8 |                          |                          | 0.0862                  | 6.2  |                         |                         | 0.455   | FTIR   |
| 196 | Oh et al., 1994    | 1994 | Manufacture of ceramic ware | Manufacture of structural refractory ceramic products           |               | Personal    | 7 |                          |                          | 0.0457                  | 4.2  |                         |                         | 0.128   | FTIR   |
| 197 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite                                      | Coal mine     | Personal    | 5 | 0.001                    | 2.2                      | 0.13                    | 15.1 |                         |                         | 0.3     | FTIR   |

Appendix 6. Total dust concentration of airborne dust samples

| No  | Reference         | Year | KSIC-3digit  | KSIC-5digit  | Operation                  | Sample type | N  | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|-------------------|------|--|--|----------------------------|-------------|----|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|----------|
| 198 | KWCWS, 2014       | 2011 | Cast of Metals   | Steel foundries  | Molding                    | Area        | 1  |                          |                          |                         |      | 0.976                   |                         | 0.98    | Weighing |
| 199 | KWCWS, 2014       | 2011 | Cast of Metals   | Steel foundries  | Grinding                   | Area        | 1  |                          |                          |                         |      | 2.45                    |                         | 2.45    | Weighing |
| 200 | KOSHA, 2007       | 2004 | Cast of metals   | Gray and malleable iron foundries                                |                            | Personal    | 9  | 0.81                     | 1.23                     |                         |      | 1.02                    |                         | 1.02    |          |
| 201 | Kim et al., 1998  | 1997 | Cast of metals   | Gray and malleable iron foundries                                | Melting                    | Area        | 6  | 0.57                     | 3.35                     | 1.44                    | 1.91 |                         |                         | 1.78    | Weighing |
| 202 | Kim et al., 1998  | 1997 | Cast of metals   | Gray and malleable iron foundries                                | Molding                    | Area        | 17 | 0.38                     | 6.7                      | 1.42                    | 1.99 |                         |                         | 1.80    | Weighing |
| 203 | Kim et al., 1998  | 1997 | Cast of metals   | Gray and malleable iron foundries                                | Core making                | Area        | 7  | 0.67                     | 3.16                     | 1.52                    | 1.85 |                         |                         | 1.84    | Weighing |
| 204 | Kim et al., 1998  | 1997 | Cast of metals   | Gray and malleable iron foundries                                | Shakeout                   | Area        | 9  | 0.37                     | 7                        | 1.24                    | 2.49 |                         |                         | 1.88    | Weighing |
| 205 | Kim et al., 1998  | 1997 | Cast of metals   | Gray and malleable iron foundries                                | Finishing                  | Area        | 7  | 1.03                     | 8.37                     | 3.4                     | 1.95 |                         |                         | 4.25    | Weighing |
| 206 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Melting                    | Area        | 2  | 1.14                     | 5.03                     | 2.4                     | 2.85 |                         |                         | 4.15    | Weighing |
| 207 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Molding                    | Area        | 13 | 0.34                     | 11.22                    | 1.89                    | 2.48 |                         |                         | 2.85    | Weighing |
| 208 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Shakeout                   | Area        | 7  | 0.77                     | 10.81                    | 2.32                    | 2.44 |                         |                         | 3.45    | Weighing |
| 209 | Phee et al., 1997 | 1996 | Cast of metals   | Gray and malleable iron foundries                                | Finishing                  | Area        | 4  | 1.29                     | 14.15                    | 3.32                    | 2.91 |                         |                         | 5.87    | Weighing |
| 210 | KOSHA, 2007       | 2004 | Cast of metals   | Other cast of non-ferrous metals                                 |                            | Personal    | 1  |                          |                          |                         |      | 0.78                    |                         | 0.78    |          |
| 211 | KOSHA, 2007       | 2004 | Cast of metals   | Steel foundries  |                            | Personal    | 2  |                          |                          |                         |      | 0.967                   |                         | 0.97    |          |
| 212 | KWCWS, 2014       | 2006 | Farming of animals                                       | Farming of horses, sheep and goats                               | Race ground                | Personal    | 1  |                          |                          |                         |      | 5.48                    |                         | 5.48    | Weighing |
| 213 | KWCWS, 2014       | 2006 | Farming of animals                                       | Farming of horses, sheep and goats                               | Race ground                | Personal    | 1  |                          |                          |                         |      | 5.06                    |                         | 5.06    | Weighing |
| 214 | KWCWS, 2014       | 2006 | Farming of animals                                       | Farming of horses, sheep and goats                               | Race ground                | Personal    | 1  |                          |                          |                         |      | 13.87                   |                         | 13.87   | Weighing |
| 215 | KWCWS, 2014       | 2006 | Farming of animals                                       | Farming of horses, sheep and goats                               | Race ground                | Personal    | 1  |                          |                          |                         |      | 15.033                  |                         | 15.03   | Weighing |
| 216 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Tunnel constructing worker | Personal    | 34 |                          | 71.95                    | 1.47                    | 3.76 |                         |                         | 3.53    | Weighing |
| 217 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges tunnels and railways                     | Drilling                   | Personal    | 12 |                          | 1.2                      | 0.4                     | 1.96 |                         |                         | 0.50    | Weighing |
| 218 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Pay loader operating       | Personal    | 11 |                          | 25.34                    | 2.85                    | 4.55 |                         |                         | 8.98    | Weighing |
| 219 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Pay loader operating       | Personal    | 9  |                          | 16.38                    | 3.85                    | 3.39 |                         |                         | 8.11    | Weighing |
| 220 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Shotcrete pouring          | Personal    | 13 |                          | 25.46                    | 9.37                    | 1.77 |                         |                         | 11.03   | Weighing |
| 221 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Dump truck driving         | Personal    | 15 |                          | 1.19                     | 0.69                    | 1.49 |                         |                         | 0.75    | Weighing |
| 222 | Yoo et al.,2003   | 2001 | Heavy construction                                       | Construction of bridges, tunnels and railways                    | Heavy machinery operating  | Personal    | 8  |                          | 10.17                    | 2.39                    | 2.42 |                         |                         | 3.53    | Weighing |
| 223 | KOSHA, 2007       | 2004 | Manufacture of basic chemicals                           | Manufacture of inorganic pigments and other metal oxides         | Mixing                     | Personal    | 2  | 0.06                     | 0.41                     |                         |      | 0.2912                  |                         | 0.2912  |          |
| 224 | KOSHA, 2007       | 2004 | Manufacture of basic iron and steel                      | Manufacture of ferro-alloys                                      |                            | Personal    | 3  | 0.92                     | 1.11                     |                         |      | 1.02                    |                         | 1.02    |          |
| 225 | KOSHA, 2007       | 2004 | Manufacture of basic iron and steel                      | Manufacture of Other Basic Iron and Steel n. e. c.               |                            | Personal    | 2  | 1.407                    | 1.567                    |                         |      | 1.487                   |                         | 1.49    |          |
| 226 | KOSHA, 2007       | 2004 | Manufacture of basic precious and non-ferrous metals     | Manufacture of other basic precious and non-ferrous metals       |                            | Personal    | 4  | 1.25                     | 2.28                     |                         |      | 1.74                    |                         | 1.74    |          |
| 227 | KOSHA, 2007       | 2004 | Manufacture of cement, lime and plaster and Its products | Manufacture of cement  |                            | Personal    | 2  | 0.1103                   | 0.4722                   |                         |      | 0.2912                  |                         | 0.29    |          |
| 228 | KOSHA, 2007       | 2004 | Manufacture of cement, lime and plaster and Its products | Manufacture of concrete roofing tiles,bricks and blocks          | Pouring                    | Personal    | 1  |                          |                          |                         |      | 0.4815                  |                         | 0.48    |          |
| 229 | KOSHA, 2007       | 2004 | Manufacture of cement, lime and plaster and Its products | Manufacture of concrete roofing tiles, bricks and packing blocks | Seperating,                | Personal    | 2  |                          |                          |                         |      | 0.9814                  |                         | 0.98    |          |

| No  | Reference       | Year | KSIC-3digit                 | KSIC-5digit   | Operation         | Sample type | N  | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|-----------------|------|-----------------------------|---|-------------------|-------------|----|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|----------|
| 230 | KOSHA, 2007     | 2004 | Manufacture of ceramic ware | Manufacture of ceramic tiles and similar products   |                   | Personal    | 2  | 1.0818                   | 2.2469                   |                         |      | 1.6644                  |                         | 1.66    |          |
| 231 | KOSHA, 2007     | 2004 | Manufacture of ceramic ware | Manufacture of industrial ceramic ware  |                   | Personal    | 1  |                          |                          |                         |      | 0.7                     |                         | 0.7     |          |
| 232 | KOSHA, 2007     | 2004 | Manufacture of ceramic ware | Manufacture of non refractory ceramic building bricks, flooring blocks and similar products                   |                   | Personal    | 1  |                          |                          |                         |      | 2.02                    |                         | 2.02    |          |
| 233 | KOSHA, 2007     | 2004 | Manufacture of ceramic ware | Manufacture of other refractory ceramic products  |                   | Personal    | 2  | 0.895                    | 1.446                    |                         |      | 1.171                   |                         | 1.171   |          |
| 234 | KOSHA, 2007     | 2004 | Manufacture of ceramic ware | Manufacture of pottery and ceramic household or ornamental ware   |                   | Personal    | 1  |                          |                          |                         |      | 10                      |                         | 10.0    |          |
| 235 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of non refractory ceramic building bricks, flooring blocks and similar products                   | Tile              | Personal    | 14 |                          |                          | 0.63                    | 6.4  |                         |                         | 3.53    | Weighing |
| 236 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Crushing, milling | Personal    | 10 |                          |                          | 1.75                    | 2.8  |                         |                         | 2.97    | Weighing |
| 237 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Weighing, mixing  | Personal    | 6  |                          |                          | 1.25                    | 2.36 |                         |                         | 1.81    | Weighing |
| 238 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Mold making       | Personal    | 3  |                          |                          | 0.37                    | 1.53 |                         |                         | 0.41    | Weighing |
| 239 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Forming, shaping  | Personal    | 16 |                          |                          | 0.91                    | 4.36 |                         |                         | 2.69    | Weighing |
| 240 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Trimming          | Personal    | 9  |                          |                          | 1.21                    | 4.08 |                         |                         | 3.25    | Weighing |
| 241 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Glazing           | Personal    | 5  |                          |                          | 0.77                    | 2.79 |                         |                         | 1.30    | Weighing |
| 242 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Drying, firing    | Personal    | 6  |                          |                          | 0.46                    | 6.75 |                         |                         | 2.85    | Weighing |
| 243 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Sand balsting     | Personal    | 4  |                          |                          | 1.24                    | 2.22 |                         |                         | 1.70    | Weighing |
| 244 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of other non-structural, non-refractory ceramic ware bricks, flooring blocks and similar products | Packing           | Personal    | 4  |                          |                          | 0.24                    | 2.06 |                         |                         | 0.31    | Weighing |
| 245 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of pottery and ceramic household or ornamental ware   | Table ware        | Personal    | 28 |                          |                          | 0.68                    | 3.24 |                         |                         | 1.36    | Weighing |
| 246 | KWCWS, 2014     | 2010 | Manufacture of ceramic ware | Manufacture of sanitary ceramic ware  | Shaping           | Area        |    | 0.315                    | 3.669                    |                         |      | 1.776                   |                         | 1.78    | Weighing |
| 247 | KWCWS, 2014     | 2009 | Manufacture of ceramic ware | Manufacture of sanitary ceramic ware  | Forming           |             |    | 0.1518                   | 4.606                    |                         |      |                         |                         | 1.20    | Weighing |
| 248 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware | Manufacture of sanitary ceramic ware  | Sanitary ware     | Personal    | 12 |                          |                          | 1.62                    | 3.1  |                         |                         | 3.07    | Weighing |

| No  | Reference       | Year | KSIC-3digit  | KSIC-5digit  | Operation | Sample type | N | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|-----------------|------|--|--|-----------|-------------|---|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|----------|
| 249 | Oh et al., 1994 | 1994 | Manufacture of ceramic ware  | Manufacture of structural refractory ceramic products              |           | Personal    | 8 |                          |                          | 1.39                    | 2.04 |                         |                         | 1.79    | Weighing |
| 250 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of all other glass and its products n.e.c.             |           | Personal    | 1 |                          |                          |                         |      | 0.03                    |                         | 0.030   |          |
| 251 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of all other glass and its products n.e.c.             |           | Personal    | 2 | 0.26                     | 1.12                     |                         |      | 0.69                    |                         | 0.690   |          |
| 252 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of glass containers blown or pressed                   |           | Personal    | 2 |                          |                          |                         |      | 1.97                    |                         | 1.970   |          |
| 253 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of glass fibers and optical glass                      |           | Personal    | 3 | 0.36                     | 0.658                    |                         |      | 0.525                   |                         | 0.525   |          |
| 254 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of household glassware                                 |           | Personal    | 2 | 0.4848                   | 1.6667                   |                         |      | 1.0758                  |                         | 1.076   |          |
| 255 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of laboratory and other industrial glassware           | Grinding  | Personal    | 2 |                          | 1.73                     |                         |      | 0.842                   |                         | 0.842   |          |
| 256 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of laboratory and other industrial glassware           | Cutting   | Personal    | 2 |                          |                          |                         |      | 0.352                   |                         | 0.352   |          |
| 257 | KOSHA, 2007     | 2004 | Manufacture of glass and glass products                              | Manufacture of plateglass  |           | Personal    | 2 | 0.88                     | 1.86                     |                         |      | 1.37                    |                         | 1.370   |          |
| 258 | KOSHA, 2007     | 2004 | Manufacture of other chemical products                               | Manufacture of all other chemical products n.e.c.                  |           | Personal    | 2 | 0.6486                   | 2.4312                   |                         |      | 1.5399                  |                         | 1.540   |          |
| 259 | KOSHA, 2007     | 2004 | Manufacture of other metal products;metal working service activities | Coating and similar treatment of metals                            |           | Personal    | 1 |                          |                          |                         |      | 2.558                   |                         | 2.56    |          |
| 260 | KOSHA, 2007     | 2004 | Manufacture of other metal products;metal working service activities | Manufacture of articles made from metal wires                      |           | Personal    | 2 | 1.011                    | 6.684                    |                         |      | 3.8475                  |                         | 3.85    |          |
| 261 | KOSHA, 2007     | 2004 | Manufacture of other metal products;metal working service activities | Manufacture of hand-operated kitchen appliances and metal ware     |           | Personal    | 2 |                          |                          |                         |      | 1.17945                 |                         | 1.18    |          |
| 262 | KOSHA, 2007     | 2004 | Manufacture of other metal products;metal working service activities | Manufacture of metal pressed and stamped products                  |           | Personal    | 2 | 0.0287                   | 0.5789                   |                         |      | 0.3038                  |                         | 0.30    |          |
| 263 | KOSHA, 2007     | 2004 | Manufacture of other metal products;metal working service activities | Manufacture of metal sanitary ware                                 |           | Personal    | 2 | 1.74                     | 2.15                     |                         |      | 1.945                   |                         | 1.95    |          |
| 264 | KOSHA, 2007     | 2004 | Manufacture of other metal products;metal working service activities | Manufacture of other fabricated and processed metal products n.e.c |           | Personal    | 1 |                          |                          |                         |      | 0.029                   |                         | 0.03    |          |
| 265 | KOSHA, 2007     | 2004 | Manufacture of other non-metallic mineral products                   | Manufacture of abrasive articles                                   |           | Personal    | 6 | 0.14                     | 2.85                     |                         |      | 1.49                    |                         | 1.49    |          |
| 266 | KOSHA, 2007     | 2004 | Manufacture of other non-metallic mineral products                   | Manufacture of non-metallic crushed mineral products               |           | Personal    | 2 | 0.09                     | 0.27                     |                         |      | 0.18                    |                         | 0.18    |          |
| 267 | KOSHA, 2007     | 2004 | Manufacture of other non-metallic mineral products                   | Manufacture of other stone products                                |           | Personal    | 1 |                          |                          |                         |      | 0.04                    |                         | 0.04    |          |
| 268 | KOSHA, 2007     | 2004 | Manufacture of other non-metallic mineral products                   | Manufacture of other unclassified non-metallic minerals n.e.c.     |           | Personal    | 1 |                          |                          |                         |      | 4.87                    |                         | 4.87    |          |
| 269 | KOSHA, 2007     | 2004 | Manufacture of other non-metallic mineral products                   | Manufacture of other unclassified non-metallic minerals n.e.c.     |           | Personal    | 1 |                          |                          |                         |      | 3.875                   |                         | 3.88    |          |
| 270 | KOSHA, 2007     | 2004 | Manufacture of other non-metallic mineral products                   | Manufacture of ready-mixAsphaltconcrete                            |           | Personal    | 2 | 0.64                     | 1.04                     |                         |      | 0.84                    |                         | 0.84    |          |
| 271 | KWCWS, 2014     | 2007 | Manufacture of other non-metallic mineral products                   | Manufacture of non-metallic crushed mineral products               | Mixing    | Area        | 1 | 0.2009                   | 1.1194                   |                         |      |                         |                         | 0.52    | Weighing |



| No  | Reference          | Year | KSIC-3digit   | KSIC-5digit  | Operation                    | Sample type | N  | Min (mg/m <sup>3</sup> ) | Max (mg/m <sup>3</sup> ) | GM (mg/m <sup>3</sup> ) | GSD  | AM (mg/m <sup>3</sup> ) | SD (mg/m <sup>3</sup> ) | AMT (%) | Method   |
|-----|--------------------|------|---|--|------------------------------|-------------|----|--------------------------|--------------------------|-------------------------|------|-------------------------|-------------------------|---------|----------|
| 272 | KWCWS, 2014        | 2007 | Manufacture of other non-metallic mineral products                                  | Manufacture of non-metallic crushed mineral products                 | Packing                      | Area        | 1  | 0.4016                   | 3.5847                   |                         |      |                         |                         | 1.39    | Weighing |
| 273 | KWCWS, 2014        | 2010 | Manufacture of other non-metallic mineral products                                  | Manufacture of non-metallic crushed mineral products                 | Heavy machinery operating    | Area        |    |                          |                          |                         |      | 0.382                   |                         | 0.38    | XRD      |
| 274 | KWCWS, 2014        | 2010 | Manufacture of other non-metallic mineral products                                  | Manufacture of non-metallic crushed mineral products                 | Conveyor belt                | Area        |    |                          |                          |                         |      | 0.261                   |                         | 0.26    | XRD      |
| 275 | KWCWS, 2014        | 2010 | Manufacture of other non-metallic mineral products                                  | Manufacture of non-metallic crushed mineral products                 | Heavy machinery operating    | Area        |    | 0.057                    | 0.072                    |                         |      |                         |                         | 0.06    |          |
| 276 | KWCWS, 2014        | 2009 | Manufacture of other non-metallic mineral products                                  | Manufacture of other stone products                                  | Stone treating               | Area        |    |                          |                          |                         |      | 2.994                   |                         | 2.99    | XRD      |
| 277 | KWCWS, 2014        | 2009 | Manufacture of other non-metallic mineral products                                  | Manufacture of other stone products                                  | Cutting, grinding            | Area        |    |                          |                          |                         |      | 14.19                   |                         | 14.19   | XRD      |
| 278 | KOSHA, 2007        | 2004 | Manufacture of parts and accessories for motor vehicles and engines                 | Manufacture of other parts and accessories for motor vehicles n.e.c. |                              | Personal    | 4  | 0.99                     | 1.55                     |                         |      | 1.15                    |                         | 1.15    |          |
| 279 | KOSHA, 2007        | 2004 | Manufacture of Plastic Products   | Manufacture of other fabricated structural plastic products          | Sandwich panel manufacturing | Personal    | 4  | 0.145                    | 1.027                    |                         |      | 0.64                    |                         | 0.640   |          |
| 280 | KOSHA, 2007        | 2004 | Manufacture of precious metals and ornamental articles                              | Manufacture of precious metals and related articles                  |                              | Personal    | 1  |                          |                          |                         |      | 0.0364                  |                         | 0.04    |          |
| 281 | KOSHA, 2007        | 2004 | Manufacture of Rubber Products  | Manufacture of industrial un-vulcanized rubber products              | Blanking                     | Personal    | 2  | 1.24                     | 1.63                     |                         |      | 1.435                   |                         | 1.435   |          |
| 282 | KOSHA, 2007        | 2004 | Manufacture of structural metal products, tanks, reservoirs and steam generators    | Manufacture of other structural metal products                       |                              | Personal    | 1  |                          |                          |                         |      | 3                       |                         | 3.00    |          |
| 283 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite   | Coal mine                    | Personal    | 24 | 0.49                     | 331.6                    | 18.9                    | 9.4  |                         |                         | 232.7   | Weighing |
| 284 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite   | Rock drilling                | Personal    | 5  |                          |                          | 5.96                    | 4.1  |                         |                         | 16.1    | Weighing |
| 285 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite   | Coal face                    | Personal    | 10 |                          |                          | 180.4                   | 1.5  |                         |                         | 195.9   | Weighing |
| 286 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite   | Transportation               | Personal    | 4  |                          |                          | 1.7                     | 5.2  |                         |                         | 6.6     | Weighing |
| 287 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite   | Beam construction            | Personal    | 3  |                          |                          | 7.32                    | 3.4  |                         |                         | 15.5    | Weighing |
| 288 | Shin, et al., 2002 | 2000 | Mining of coal and lignite  | Mining of coal and lignite   | Loading, transportation      | Personal    | 2  |                          |                          | 2.28                    | 5.2  |                         |                         | 8.9     | Weighing |
| 289 | Choi et al., 2000  | 2000 | Mining of iron ores   | Mining of iron ores  | Rock drilling                | Personal    | 2  |                          |                          | 0.65                    | 1.06 |                         |                         | 0.65    | Weighing |
| 290 | Choi et al., 2000  | 2000 | Mining of iron ores   | Mining of iron ores  | Loading                      | Personal    | 1  |                          |                          |                         |      | 2.02                    |                         | 2.02    | Weighing |
| 291 | Choi et al., 2000  | 2000 | Quarrying of stone,sand and gravel  | Quarrying of limestone and gypsum                                    | Hauling                      | Personal    | 6  |                          |                          | 0.54                    | 1.5  |                         |                         | 0.59    | Weighing |
| 292 | Choi et al., 2000  | 2000 | Quarrying of stone,sand and gravel  | Quarrying of limestone and gypsum                                    | Loading                      | Personal    | 4  |                          |                          | 0.57                    | 3.3  |                         |                         | 1.16    | Weighing |
| 293 | Choi et al., 2000  | 2000 | Quarrying of stone,sand and gravel  | Quarrying of limestone and gypsum                                    | Drilling, blasting           | Personal    | 2  |                          |                          | 0.47                    | 1.59 |                         |                         | 0.52    | Weighing |
| 294 | Choi et al., 2000  | 2000 | Quarrying of stone,sand and gravel  | Quarrying of limestone and gypsum                                    | Milling                      | Personal    | 3  |                          |                          | 3.76                    | 2.6  |                         |                         | 5.94    | Weighing |
| 295 | Choi et al., 2000  | 2000 | Quarrying of stone,sand and gravel  | Quarrying of limestone and gypsum                                    | Maintenance                  | Personal    | 1  |                          |                          |                         |      | 11                      |                         | 11.0    | Weighing |
| 296 | Choi et al., 2000  | 2000 | Quarrying of stone,sand and gravel  | Quarrying of limestone and gypsum                                    | Cleaning                     | Personal    | 1  |                          |                          |                         |      | 222.5                   |                         | 222.5   | Weighing |
| 297 | KWCWS, 2014        | 2007 | Site preparation and special trade construction for civil engineering and buildings | Brick laying and stone setting works                                 | Marble treating              | Area        |    |                          |                          |                         |      | 6.1774                  |                         | 6.18    | XRD      |