Ministry of Agriculture, Natural Resources and Environment
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Nicosia – Cyprus

Risk Assessment due to the Presence of the Asbestos Mine, Troodos, Contract No. GSD/15/2002

Executive summary and overall conclusions

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EXECUTIVESUMMARY

Chrysotile asbestos fibres, naturally occurring in the highly serpentinised ultrabasic rocks of the Troodos Range in Cyprus, have been mined for hundreds of years. The former asbestos mining works at Amiantos ceased in 1988, leaving behind a huge open pit, extensive waste tips resting on steep slopes and infilling side valleys, as well as wide spread pollution with toxic fibres. The aim of the current study is to assess and evaluate the risk for the area due to the presence of the asbestos mine and the impact of the mine area to the quality of the air, water and soil and to the users and inhabitants of the broader area. The current mine rehabilitation works are also evaluated in the frame of the identified risks, and where necessary, additional remediation measures to reduce possible risks are proposed.

For this purpose, a project team was composed of staff from the Belgian consultant Ecorem n.v. (coordinator) and the local consultant Atlantis Consulting Cyprus Ltd. Furthermore, the team was supported by Fibrecount n.v., a consulting company in the field of asbestos investigations which has its own accredited laboratory to perform asbestos analyses, and by experts in the field of asbestos related diseases and epidemiology from the Universities of Brussels and the Finnish Institute of Occupational Health. The general supervision and evaluation of the project was executed by a the Steering Committee composed of Dr Eleni G. Morisseau (Geological Survey Dep.), Dr Kyriakos Kyrou (Water Development Dep.), Mr Themistoclis Kyriacou (Labour Inspection Dep.), Mr Takis Tsintidis (Forestry Dep.), Mr Antonis Antoniou (Environmental Service) and Mr Christodoulos Hadjigeorgiou (Geological Survey Dep.).

In a first phase, international literature was reviewed and relevant data were inventoried to provide a clear picture regarding the history of the mine and the local conditions, the occurrence of asbestos world-wide and related diseases. Based on this inventory, the guidelines set by international standards and the observations made during several field visits, a monitoring and sampling programme, which run over approx. three years was set up. This programme included extended surveys of the air, groundwater, surface water, soil and rock of the mining and broader area.

In total, 8 air surveys were executed. Due to the absence of power supply, most of the samples were taken by means of battery charged pumps. Four air samples were taken by means of a personal air sampler, carried by the workers occupied with the mine rehabilitation works. All analyses were performed by transmission electron microscopy (TEM), according to the NIOSH 7402 standard. From the results of this extensive grid of air monitoring stations, partly concentrated inside and in the immediate area of the mine, and partly extended towards the greater Troodos area, it was concluded that for the Amiantos area, the mine can be considered as a temporary single source for the observed asbestos burden. Inside and in the immediate area of the mine, air samples showed frequently asbestos concentrations between 0,1 - 1 fibres/l. Higher asbestos concentrations were observed in the mine mainly during the summer surveys of 2004 and 2005, with concentrations up to 100 fibres/l. These high concentrations are related to dry summer days when a lot of dust raising activities (rehabilitation works and associated vehicle traffic) took place. Mainly chrysotile fibres were observed inside the mine, however, asbestos fibres of the actinolite type were generally present as well.

In addition, data were obtained from personal samplers carried by workers executing earthworks in the mine. Up to 700 fibres/l were recorded in these personal samples. Mainly

chrysotile, but also actinolite was observed in important quantities.

For the greater Troodos area, airborne asbestos concentrations of 0,1 - 1 fibres/l were detected most frequently, but also concentrations of 1 - 10 fibres/l were abundant near Troodos Square, College Forest and up to Kyperounta. During the summer surveys of 2005, the highest concentrations, up to 40 fibres/l, were measured in the greater Troodos area. Here asbestos fibres of the actinolite type predominated the chrysotile fibres.

Five surface water surveys were executed, spread over the three years. In total 24 water samples were taken from the mine lagoon, the Livadhin river, running through the mine area, the Loumata river as from the mine down to the Kouris Reservoir and the Limnatis river near the Kouris Reservoir. Also ten groundwater samples were collected at various existing springs and wells around the mining area. Analysis of the water samples was performed by transmission electron microscopy (TEM), according to the EPA 800/4-83-403 standard. From the water monitoring surveys it was concluded that the concentrations of asbestos fibres in the surface water and groundwater are relatively low.

Soil and rock samples were taken inside the mine at rehabilitated and non-rehabilitated tailings, at the dry river beds and at different geological formations from the greater area. The samples included also some stucco material, bricks and dust samples from inside the mining buildings. Semi-quantitative analysis of the samples (76 soil samples and 72 rock samples) was performed according to the MDHS 77 / NEN 5896 standard using polarized light microscopy (PLM). Based on the semi-quantitative results, 13 samples were selected for further quantitative asbestos determinations, based on the California EPA Method 435. In addition, six drillings were executed in tailings in different stages of rehabilitation, with in total 20 samples taken over the different strata.

Chrysotile fibres were detected in almost all superficial soil samples collected in the mine. Asbestos concentrations up to 40%v were found in the superficial soil samples taken near the dirt roads and up to 80%v in the dust samples collected inside the buildings. No difference in asbestos concentration could be observed between samples from original and rehabilitated tailings (range of 1 - 20%v). It was demonstrated that asbestos fibres are also common in the superficial soil samples from the surrounding area (< 1%v - 10%v). Due to prevailing winds and dust deposits over more than hundred years chrysotile fibres can become widespread, also in areas with different geology. Most of the rock samples show asbestos concentrations lower than 10%v. The asbestos fibres were only of the chrysotile type, with the exception of a tremolite sample from the packing building wall.

The data set of airborne asbestos collected during these extended surveys was evaluated and related to local geological conditions, local topography and local meteorological conditions by means of dispersion modelling and some additional geological investigation in order to identify trends and distribution patterns, and other potential sources for fibre release.

It was concluded that peak concentrations of airborne asbestos in the sampling period 2003 - 2005 are characteristic for the northwestern area of the mine. Two factors have contributed to this distribution. One factor is the relative abundance of the restoration works and important truck traffic in this area. Airborne asbestos concentrations during the works is several times higher than the concentrations in days when no works are undertaken. This is also confirmed by the high concentrations recorded by the personal samplers on the workers.

The other factor that favored the high concentrations in the northwestern mine area is the wind direction. Especially in the warmer periods between May and October, daytime wind direction in the mine is largely influenced by anabatic winds. In the mountainous area, the wind direction follows basically the valley topography. As such, in the morning, when the atmosphere gets warm in the lower valleys, upward drafts produce S – SE winds. In the late afternoon these upward winds diminish and are gradually replaced by catabatic winds, which in general in the mine are westerly to north-westerly winds.

Due to the southern winds in the morning, any dust clouds due to earthworks will basically be trapped in the enclosure formed by the steep western cliffs. Thus high concentrations persist in this section of the mine. When the westerly winds take over in the afternoon to late evening, the dust-loaded air is driven to the east. In the evening, when works stop, the atmosphere carries less dust, and the winds blowing to the west to northwest towards Kato Amiantos do not contribute much to the further distribution of the asbestos fibres.

This model also explains the elevated values noted towards the east, in the direction of the Olympus Restaurant and further towards Karavounas Junction, while in Kato Amiantos, southeast of the mine, observed concentrations are relatively low.

Further it seems that the influence of the mine to the surrounding areas diminishes quickly with distance away from the mine borders. Concentrations outside the mine typically reduce to less than 5% of the peak concentrations found in the mine within distances of 1 – 2 km (Kato Amiantos, Troodos Square). For example, average values during the whole campaign period, show that the peak values of nearly 15.000 fibres/m^3 in the mine reduce to less than 250 fibres/m^3 in Kato Amiantos and Troodos Square. A similar trend is shown also clearly in the August, 2005 campaign when the highest concentrations of the entire study were recorded. In this case a peak value of app. 150.000 fibres/m^3 was found in the mine which reduced to about 500 fibres/m^3 in the Kato Amiantos area.

The BEEST dispersion model was applied in order to examine the distribution of airborne fibres in a typical summer day (24-hr period), and also to assess risk to the nearby areas of Kato Amiantos and Troodos Square in terms of the maximum potential concentrations that may occur under worst case scenarios, i.e., under steady low wind conditions. From the typical day scenario it could be concluded that daily maximum values are located in the northwestern section of the mine as a result of the southeasterly daytime winds. Nighttime maximum values are distributed in he eastern section of the mine. Peak values in the surrounding areas diminish to less than 10% of peak values within 1-2 km from the mine. As described above, these findings are confirmed by the field observations. From the scenarios it was concluded that the area of influence of the mine is limited to the area between Kato Amiantos to the east and Troodos Square to the west. In the worst-case scenarios of steady low easterly winds, airborne asbestos concentrations in Troodos Square can reach as much as 50% of peak concentrations found in the mine. This is caused be upward funneling of the easterly winds towards the Square which reduces the dispersion of fibres. West of the Square, a different wind regime occurs making it unlikely that the easterly wind is extended further west from Troodos Square. In Kato Amiantos, the influence is smaller due to the large elevation drop between the mine and the village, which facilitates better vertical as well as horizontal dilution of fibres. However, again or the worst-case scenario of low steady winds directed towards Kato Amiantos, airborne concentrations can be in the order of 15- 25% of the peak

concentration values. As a result, for the greater area, the influence of the mine is negligible, and other local sources of asbestos are to be considered, like the natural outcrops of serpentinised harzburgite and the weathered uralite gabbro occurring at various locations.

The presence of these permanent and temporary outcrops of suspect rocks was investigated around the mine and in areas with raised airborne asbestos values, in order to identify potential sources for the loose asbestos fibres.

Near the Olympus restaurant high values of chrystotile and the presence of actinolite is still associated to dust from the mine. Further away from the mining area, in Kato Amiantos, the observed actinolite values are likely mainly associated to weathered uralite gabbro exposed at close distance and to some dust transport from the tailings and terraces of the mine. Relatively high values of actinolite are recorded in the Kyperounta area where abundant uralite gabbro outcrops exist. High concentrations are also measured near the Troodos Square and Prodromos (College Forest). At Troodos, situated on harzburgite bedrock, release from temporary construction works on a parking lot is expected to have produced at least a portion of the airborne fibres. A local source should be assumed both for Prodromos and Kyperounta with weathered uralite gabbro formations at close distance. The mine is at sufficient distance from these areas so that it can be safely assumed that it cannot have any significant direct contribution of fibres.

The mine area itself can be considered as a temporary single source for the observed asbestos burden. The highly serpentinised harzburgite, covered with loose serpentinite materials from the ceased mining activities, constitutes the main source of chrysotile asbestos fibres in the air. Especially the truck transport and earthworks on the recent burial place for asbestos waste materials has raised a lot of fine asbestos dust. Major whitish dust clouds were observed while driving through this part of the mine for the fourth monitoring survey. During rehabilitation works in the mining area other type of rocks and soil have been imported, among them weathered uralite gabbro. Airborne fibrous actinolite, presently recorded at various places in the mine, may be related to the leveling works. However, other sources, including the highly uralite gabbro outcrops in the surrounding area, cannot be fully excluded.

For the assessment of risks related to environmental exposure to asbestos, risk estimates are merely based on extrapolations of dose-exposure relationships from relatively high exposures and animal studies. The US EPA and WHO provide estimates to assess the carcinogenic risks associated to low non-occupational exposures. For most of the concentrations measured inside and near the mine, (worst-case) life-time exposure would gave rise to a risk for developing cancer of less than 1/100.000. For almost 30% of the sample locations (concentrations of 0,1 – 1f/l) life-time exposure would gave rise to a risk between 1/100.000 to 1/10.000. Concentrations of more than 10 fibres / l are observed in some 4% of the samples, and life-time exposure to this concentrations would gave rise to a risk for developing cancer higher than 1/1.000. As indicated above, exposure to such high concentrations will exist only for shorter periods, but possibly several times during the year. Because high concentrations inside the mine are reduced to less than 5% of those peak concentrations at a distance of 1 – 2 km, risks are reduced with a factor 10 - 100.

For Kato Amiantos, life-time exposure to the highest observed concentrations could result in a risk for developing cancer between 1/100.000 to 1/10.000. For the surrounding area of Kyperounta, a risk of up to 1/1.000 exists if life-time exposure to the observed peak concentrations occurs. Near Troodos Square the highest concentrations observed could result

in a risk of more than 1/1.000 if exposed continuously. For the area of the College forest risks vary between 1/10.000 to 1/1.000. Similarly to the mine, the elevated concentrations of airborne asbestos in the greater Troodos area are characteristic for summer conditions, and should not be considered as averages for life-time exposure.

For the employers occupied with the rehabilitation works in the mine, the personal samples indicate the necessity of appropriate protection measures, according to EU Directive 2003/18/EC.

All the actual concentrations in the water are far below the value of 7 Mio fibres / l, indicating that there is no significant risk at present day. Presumably, the situation in the past may have been different.

From above results it is concluded that the mine area is a potentially hazardous territory which under circumstances may impose a risk to human health, and is of concern to inhabitants, workers, and visitors. Therefore, risk should be reduced at all times by the implementation of safety measures, control and monitoring actions. For the mining area, the proposed recommendations are designed to minimize the public's exposure to asbestos by requiring work practices that will minimize dust emissions from activities associated with the actual situation of the mine and further works in the area. Recommendations include the set-up of an awareness campaign to inform the public, source reduction through the completion of the restoration activities, the surfacing of the access roads in the mine, the prevention of water erosion by collection of the runoff water in small channels, a more dense vegetation in the flat areas, the installation of an appropriate wheel washing system to limit track out, the covering or sprinkling of loads of potentially contaminated rocks / soils during truck transport, speed reduction of trucks in the mine. Moreover, a monitoring programme has to be implemented for the duration of the rehabilitation works and at least one summer period subsequent to the completion of the works. Beside detailed soil mapping, six permanent monitoring stations should be sampled twice a year in the mine, preferably in May and in early September. During each campaign two samples should be taken from each of the selected stations, one during rehabilitation works and one in days without. Also personal sampling of the workers is recommended during the execution of the rehabilitation works. When permissible exposure limits are exceeded, personal safety equipment should be used.

It is also recommended to foresee monitoring and awareness campaigns in the areas affected by high asbestos burden originating from other sources than the mine. For this purpose, additional targeted studies including baseline mapping of soils and rocks and air monitoring need to point out if any actions need to be undertaken to reduce potential sources. As such, possible actions in a management plan could be the covering of outcrops of soils and weathered basement rocks with asbestos minerals, the reduction of excavations (roads, buildings, other infrastructure) by limiting the size or time of excavation, or the period of excavation, track out / speed control on dirt roads, and restrictions for land use (agriculture, recreation, building permits).

OVERALLCONCLUSIONS

1. Inside and in the immediate area of the mine and over the different surveys airborne asbestos concentrations of 0,1 - 1 fibres/l are most common among the asbestos samples.

Life-time exposure to this concentration range can give rise to a cancer risk between 1/100.000 - 1/10.000. Higher asbestos concentrations were observed in the mine during the summer surveys of 2004 and 2005, with concentrations up to 100 fibres/l. Life-time exposure to such elevated concentrations can give rise to a cancer risk of 1/100. These high concentrations are related to dry summer days when a lot of dust raising activities (rehabilitation works and associated vehicle traffic) take place. Therefore, these asbestos exposures will exist only for shorter periods, but possibly several times a year.

2. For the employers occupied with the rehabilitation works in the mine, the personal samples indicate the necessity of appropriate protection measures, according to EU directive 2003/18/EC.

3. From the results of the two-year monitoring campaign it can be concluded that the asbestos mine can be considered as a temporary, single source for the airborne asbestos burden in the Amiantos area. The concentrations of airborne asbestos are lower during the winter months and periods of wet weather conditions. Higher concentrations are related to dry summer days when a lot of dust raising activities taken place.

4. Analysis of the mineralogy and the geographical distribution of the airborne asbestos and based on meteorological data, mathematical modelling shows that the impact of the mine is generally restricted to the west as far as Troodos and to the east as far as Karavounas Junction. The influence of the mine to the surrounding areas seems to diminish quickly with distance away from the mine borders. Concentrations outside the mine typically reduce to less than 5% of the peak concentrations found in the mine within distances of 1 – 2 km.

5. The northwestern area of the mine is considered as the zone in the mine with the highest risk. This is mainly due to the local meteorological conditions and the fact that a lot of works including the movement of vehicles are concentrated in this area.

6. Based on the results of the monitoring of airborne asbestos and the record keeping of the activities in the mine, a direct relationship can be found between the said earthworks and the observed fibre concentrations. In periods without works the concentration of fibres in the air is related to loose materials produced during the previous days.

7. Cumulative dust deposits and soils carried out of the mine due to erosion or track out can be considered as a second source. The impact of such second sources could not be evaluated within this project.

8. The rehabilitation works (reprofiling and reforestation of the waste tips) aim to reduce the environmental impact of the mine on the surrounding area. From the air and soil monitoring no real difference could be observed between the reprofiled and reforested, the reprofiled and the not-rehabilitated tailings. Possibly, dust raising activities and the local meteorological conditions may contaminate the areas that already are rehabilitated. Fertile soil is imported to allow vegetation to grow on the reprofiled terraces. It has been observed that among the imported soil and rocks, weathered uralite gabbro is present. The presence of airborne amphibole asbestos in the mine indicates contamination from the imported gabbro soils. As such, it is recommended that a baseline soil mapping in the mine is performed and a close follow-up of the nature and emplacement of the imported soils.

9. Due to the environmental risk of the mine, the planning of the rehabilitation works should consider the priorities for urgent rehabilitation in certain subzones in the mine, like the area of the burial site and hammer mill, NW in the mine.

10. Frequent air monitoring in the mine and the affected surroundings is necessary to evaluate the rehabilitation works, and to take complementary actions, if needed.

11. The mine can be developed for restricted public use when the soil is stabilized and covered, the remaining infrastructure is removed or cleared, and the release of asbestos fibres has dropped below internationally accepted safe limits.

12. In the greater Troodos area, airborne asbestos concentrations between 0,1 - 1 fibres/l were detected most frequently, but also values of 1 - 10 fibres/l were common. During the summer of 2005, the highest measurements were observed with 10 - 100 fibres/l.

13. On the basis of the findings in the present study, any relationship between the activities in the mine and the air quality in the Prodromos area is excluded. Other local sources of asbestos are to be considered, like the natural outcrops of serpentinised harzburgite and the weathered uralite gabbro occurring at various locations. Release from other sources like temporary construction works taking place for example at Troodos Square (construction of a parking lot) is expected to have produced at least a portion of the airborne fibres.

14. All the actual concentrations in the water are far below the value of 7 Mio fibres / l, indicating that there is no significant risk at present day. Presumably, the situation in the past may have been different. Chrysotile-bearing debris in landslides, e.g. in the mine, may have provided sources of asbestos materials to local streams. Sedimentary deposits derived from the asbestos-bearing dust and rocks, accumulated over long periods of time, provide asbestos for redistribution by water and wind. Records of chrysotile in Loumata river sediments and in corresponding air monitoring stations confirm the wide distribution and long existence of these fibres. The actual records of the water samples, however, did not reveal high asbestos concentrations in the surface water (Loumata and Livadhin river) likely due to the ceasing of the mine activities.