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Study on the concentration of airbone respirable asbestos fibres in rural areas of the Lublin region in south-east Poland

Agnieszka Buczaj[1], Wojciech Brzana[1], Joanna Tarasińska[2], Marcin Buczaj[3], Piotr Choina[4]

[1] *Institute of Rural Health, Lublin, Poland*
[2] *Department of Applied Mathematics and Computer Science, University of Life Sciences, Lublin, Poland*
[3] *Electrical Engineering and Computer Science Faculty, Lublin University of Technology, Poland*
[4] *Department of Public Health, Institute of Rural Health, Lublin, Poland*

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Abstract

Objective. The objective of the study was measurement of the concentrations of airborne asbestos fibres in the rural environment of the Lublin Region in south-east Poland.
Methods. Measurements of concentrations of respirable asbestos fibres were carried out in the rural areas of the Lublin Region (Lublin and Włodawa counties) for a period of 24 months. The studies were conducted on 3 farms with various technical conditions of asbestos-containing materials: Farm A – good technical condition of asbestos products, Farm B – poor technical condition, and Farm C – with no asbestos containing products and no such products in its direct vicinity (up to 500 m). On the selected farms, 3 samples on each were simultaneously collected at 3 measuring sites. During the period 2009–2011, a total number of 216 samples were collected on all farms. Sampling was performed using JSH 16,000 stationary aspirators, with air flow velocity of 16 l/min. and sampling time 60–80 minutes. The number of fibres on filters was determined using an optical phase contrast microscope.
Results. The study showed that the mean concentration of respirable asbestos fibres on the farms examined was 296 fibres·m^{-3}. The highest concentrations were noted on Farm B was 529 fibres·m^{-3}, on average; on farm A the mean concentration of respirable fibres was 328 fibres·m^{-3}, whereas the lowest mean concentration of airborne respirable asbestos fibres was noted on farm C, where there were no asbestos products (30 fibres·m^{-3}).

Key words

asbestos, respirable asbestos fibres, exposure, rural environment

INTRODUCTION

The name asbestos refers to minerals from the group of serpentines and amphiboles which are hydrated silicates of magnesium, iron, calcium and other elements. These minerals possess unique physical and chemical properties, including high mechanical endurance, resistance to temperatures, low electrical conductivity, resistance to corrosion and high flexibility. Due to this, asbestos products were applied in energy production, transport and the chemical industry, and primarily in the construction industry.

The period of safe use of asbestos cement sheets applied in construction is from 30–60 years. After this period, in average conditions, asbestos-cement sheets are not subject to total degradation, although their surface is sometimes considerably damaged as a result of atmospheric conditions and chemical air contaminants, which wash out the asbestos binding material [1]. It is estimated that the emission of fibrous asbestos structures of the length of more than 5 µm from asbestos-cement sheets into the air may reach even 6,900 fibres from one square meter [2]. In addition, an inadequate method of dismantling asbestos products, breaking, cutting, or crushing, results in the release of considerable amount of fibres into the environment. For example, the concentration of the number of fibres during the dry crushing and breaking of cladding panels while disassembling siding at a distance of approx. 1.5 m is on the level of several dozen thousand per square meter [3].

The Lublin Region is one of the 2 regions (after the Warsaw Region) where the concentration of products containing asbestos is the highest (approx. 2 mln Mg, which is about 14% of the amount in the whole of Poland). The majority of the population of the Lublin Region are rural inhabitants (53.4%). In the rural areas the use of asbestos-containing materials for roofing and thermal isolation of farm buildings and houses is commonly observed, which is associated with the functioning in the past in this region of 4 enterprises producing asbestos products.

The data from the 'Programme for removal of asbestos-containing materials in the Lublin Region' of 2005 [4] show that the greatest amount of asbestos-cement sheets (approx. 97%) are located in the rural areas. They are primarily placed on farm buildings (about 74% of the total number of buildings), and the percentage of asbestos-cement sheets used for roofing and cladding of residential buildings in the rural areas is 90%. Frequently, the period of safe use of these products has expired. Also, in many cases, the roofing has not been used and protected in the proper way, and its mantling performed in an inadequate way.

This brings about the possibility of releasing asbestos fibres into the ambient air, thus exposing the rural inhabitants to the hazardous health effect of asbestos fibres.

Address for correspondence: Agnieszka Buczaj, Institute of Rural Health, Jaczewskiego 2, 20-090 Lublin, Poland
e-mail: a.buczaj@tlen.pl

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It is known that occupational exposure to asbestos dust may be the cause of many respiratory system diseases, i.e. asbestos pneumoconiosis (asbestosis), mild pleural changes, lung cancer and pleural and peritoneal mesotheliomas. Considering para-occupational and environmental exposure to asbestos fibres the major effect is pleural mesothelioma, also an increase in the risk of lung cancer is observed according to the level of exposure [5, 6, 7, 8].

Therefore, it is justifiable to perform measurements of concentrations of asbestos fibres in ambient air in the rural areas in the Lublin Region, which would allow recognition of the degree of ambient air contamination in the rural environment, and determine the degree of health risk among the rural inhabitants from the aspect of environmental exposure to asbestos fibres.

Objective. The objective of the study was the performance of measurements of concentrations of asbestos fibres in ambient air in the rural environment in the Lublin Region.

MATERIALS AND METHOD

Measurements of concentrations of respirable asbestos fibres were carried out in 2 rural areas in the Lublin Region for a period of 24 months (once a quarter at each measurement site). The study was conducted on private farms in the Lublin Region – in the counties of Włodawa and Lublin, and covered 3 farms with varies technical states of asbestos materials:

- 1 farm where asbestos products were in good technical condition (Farm A);
- 1 farm where asbestos products were in a poor technical condition (Farm B);
- 1 farm where there were no products containing asbestos and no such products in its direct vicinity (up to 500 m) (Farm C).

Information concerning the amount, degree of wearing out, way of use and maintenance of asbestos products on individual farms was obtained based on a survey. This allowed the distribution of measuring sites with consideration of the localization of the sources of emission of asbestos fibres.

On Farm A, of a compact building design, there was a residential house, 2 farm buildings and a livestock house. Roofing was made of waveform asbestos-cement sheets, and their total amount on the farm was 680 m^2. Roofing panels on the residential building and on one livestock building were assembled by the farm's owner in 1970, and on the remaining buildings during the period 1982–1985. The state of asbestos products was evaluated as good. The products were characterized by a tight structure of fibres with lack of a protective layer and slight wastages. The surfaces were not preserved for the entire period of use, and asbestos products were exposed to the effect of atmospheric conditions.

Farm B was also characterized by a compact building design, with the following buildings: residential, livestock, and 3 farm buildings. On this farm, there occurred asbestos-containing products in the form of waveform asbestos-cement sheets used for roofing, their total amount being 640 m^2. The roofing on the livestock building was assembled in 1980, and on the remaining buildings in the 1970s. All roofs were installed by the owner of the farm. The state of asbestos products was evaluated as poor, with the recommendation of the need for their urgent disassembling and exchange. The products were characterized by large defects of the surfaces and damaged structure of fibres, with visible effects of corrosion. The surfaces were not preserved for the entire period of use of asbestos products, which were exposed to atmospheric conditions.

On farm C, likewise with a compact building design, there were: a residential house, a farm house, and a livestock house. On this farm there were no products containing asbestos, and these products had never been used on this farm previously. Also in the direct vicinity of the buildings (up to 500 m), no asbestos products were found.

On the selected farms, 3 air samples were taken simultaneously at 3 measurement sites located as follows: at the entrance to the residential building (approx. 0.5–1 m from the front door), at the entrance to the farm building/livestock house, and in the open air within the farm yard. During the period 2009–2011, a total number of 216 samples were collected on all farms.

Measurement sites were selected according to the Polish standard PN-84/Z-04008.02 [9], and the samples collected according to PN-88/Z-04202/02 [10] with modification of the guidelines concerning the levels expected in the ambient air. The method consists in passing a specified air volume through a cellulose ester membrane filter of 25 mm diameter with pores of 0.8 μm size by use of pump with a controlled air volume flow. Samples were taken using JSH 16 000 stationary aspirators. Air flow speed was 16 l/min, and sampling duration was 60–80 minutes.

The samples collected were prepared for microscopic analysis in order to determine the number of fibres on filters. The filters were cleared (made transparent) in hot acetone vapours. Respirable asbestos fibres were counted using a phase contrast microscope with a green filter. During the observation of a single specimen, at least 200 counting fields were analyzed, limited by a Walton-Beckett eyepiece graticule at total zoom 600×.

Considering the specificity of data – non-homogenous variance in groups and lack of normality of distribution – the non-parametric Kruskal-Wallis test was used**.** If the Kruskal-Wallis test detects differences, the non-parametric pair-wise comparisons are used to determine which pairs differ significantly [11].

RESULTS

Measurements of the concentrations of asbestos fibres in ambient air in the rural environment in the Lublin Region showed that the mean concentration of asbestos fibres on the 3 farms in the study was 296 fibres·m^{-3}.

In 45% of the samples examined, the result was below 220 fibres·m^{-3}, including 39% of those where the presence of asbestos fibres was not noted. This indicates that for the measurement method applied the results of measurements were below the limit of determination. A large percentage of samples without asbestos fibres (71%) were collected on Farm C. On Farm A, no asbestos fibres were found in 24% of the samples, while on Farm B – in 10%. Concentrations within the range of 200–400 fibres·m^{-3} were observed in 23% of the samples examined, while the concentrations within 400–600 fibres·m^{-3} and 600–800 fibres·m^{-3} – in 14% and 10%, respectively. In 8% of the samples examined this concentration was higher than 800 fibres·m^{-3}. On the farm where the technical condition of asbestos products was good, the mean concentration of respirable fibres being 328 f·m^{-3}.

At measurement sites on Farm A the highest mean concentration of asbestos fibres was noted in front of the livestock house, during the entire period of measurement it was 339 f·m^{-3}, on average. At the remaining measurement sites the mean concentration values remained on a similar level 321 f·m^{-3}, on average, at the site located at the residential house, and 325 f·m^{-3} in the yard. Kruskal-Wallis test showed the lack of significant differences between the measurement sites (p-value=0.565).

It was found that in the 2nd and 3rd quarter at all measurement sites on Farm A the mean concentrations were the highest – from 373–536 f·m^{-3}, while the lowest concentrations were noted in the 1st quarter (115–192 f·m^{-3}) (Fig. 1). Kruskal-Wallis test did not show any significant differences in concentrations between quarters for any of the sites.

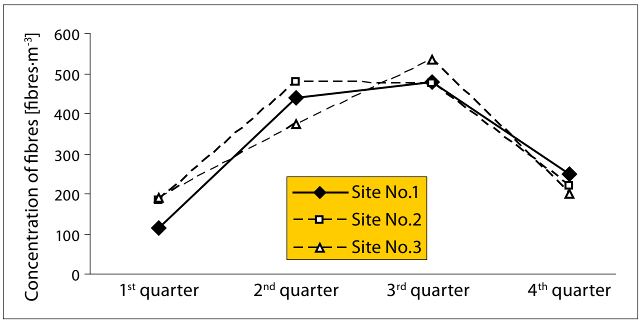

Figure 1. Mean concentration of respirable asbestos fibres in individual quarters at measurement sites on farm A [fibres·m^{-3}]

On the farm with poor technical condition of asbestos products the mean concentration of respirable asbestos fibres was 529 f·m^{-3}.

At measurement sites on Farm B, the highest mean concentration of asbestos fibres was noted in front of the animal house; during the entire measurement period it was 615 f·m^{-3}, on average. At the site near the residential building, the mean concentration of asbestos fibres was 412 f·m^{-3}, and in the farmyard – 560 f·m^{-3}. Kruskal-Wallis test showed lack of significant differences between measuring sites (p-value=0.276).

The results of measurements conducted on farm B indicate that at all measurement sites in the 1st quarter the lowest mean values of respirable asbestos fibres concentration were observed (173–278 f·m^{-3}), whereas in the 2nd, 3rd, and 4th quarters the mean concentrations of respirable asbestos fibres remained on the level from 306 f·m^{-3}–900 f·m^{-3} (Fig. 2).

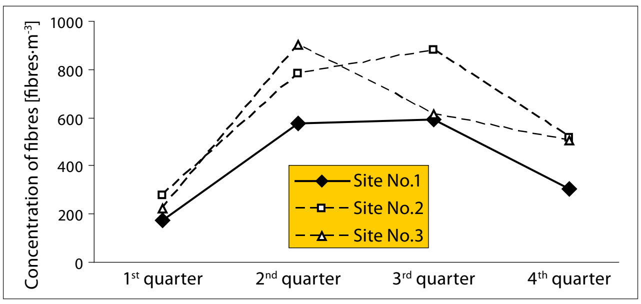

Figure 2. Mean concentration of respirable asbestos fibres in individual quarters at measurement sites on Farm B [fibres·m^{-3}]

Kruskal-Wallis test did not show any significant differences in concentrations between quarters for any of the sites.

On the farm where there were no asbestos-cement products and no such products in its direct vicinity (up to 500m), most frequently no presence of respirable asbestos fibres was found (83% of samples from this farm). The mean concentration of respirable asbestos fibres on this farm was 30 fibres·m^{-3}, while the max. concentration was 459 fibres·m^{-3}.

At measuring sites on Farm C, the highest mean concentration of respirable asbestos fibres was found in the farmyard during the entire period of measurement (43 f·m^{-3}). At the measuring site near the residential building and animal house the mean concentrations were 14 and 34 f·m^{-3}. Kruskal-Wallis test showed the lack of significant differences between measuring sites (p-value=0.257).

The results of measurements carried out on farm C indicated that in the 1st quarter, at all measuring sites, respirable asbestos fibres were not found, whereas in the 2nd and 3rd quarters the mean concentrations of respirable asbestos fibres were on the level from 19 f·m^{-3}–115 f·m^{-3} (Fig. 4). Kruskal-Wallis test did not confirm significant differences between quarters at any of the established measuring sites.

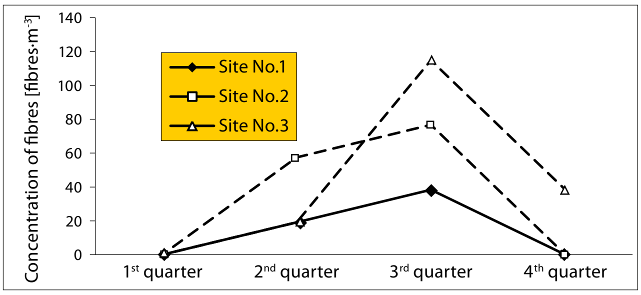

Figure 3. Mean concentration of respirable asbestos fibres in individual quarters at measurement sites on Farm C [fibres·m^{-3}]

On the farm where the technical condition of asbestos products was good, the highest mean concentrations were observed in the 2nd and 3rd quarter of the year was 431 and 496 fibres, respectively. In the 4th quarter, the mean concentration of respirable fibres was 223 f·m^{-3}, while in the 1st quarter it was the lowest during the year – 163 f·m^{-3} (Fig. 4). Kruskal-Wallis test confirmed significant differences between the quarters (p-value=0.0006). The pair-wise comparisons carried out between the quarters indicated a lack of differences between the 1st and 4th, and 2nd and 3rd quarters.

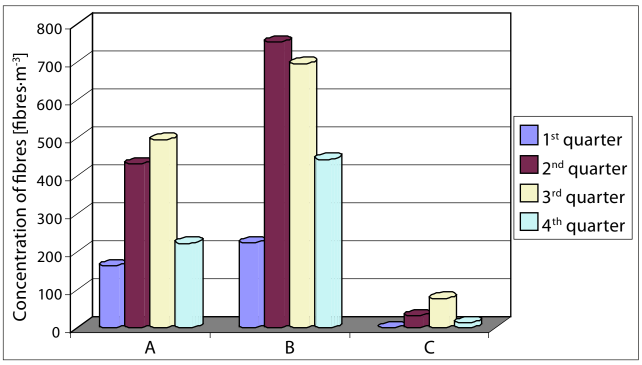

Figure 4. Mean concentration of respirable asbestos fibres in individual quarters on farms A, B and C [fibres·m^{-3}]

On the farm with poor technical condition of asbestos products, the highest mean concentrations were noted in the 2nd and 3rd quarter – 753 and 696 $f{\cdot}m^{-3}$, respectively (Fig. 4). In the 4th quarter, the main concentration of respirable fibres was 444 $f{\cdot}m^{-3}$, and in the 1st quarter was the lowest at 224 $f{\cdot}m^{-3}$. Kruskal-Wallis test showed significant difference between quarters (p-value=0.0032). Pairwise comparisons between quarters indicated an insignificant difference between the 2nd and 3rd quarters, while the remaining differences were significant.

On the farm where there were no asbestos-cement products, the highest concentrations on this farm were noted in the 2nd and 3rd quarters – 32 and 77 $f{\cdot}m^{-3}$, respectively (Fig. 4). In the 4th quarter, the mean concentration of respirable fibres was 13 $f{\cdot}m^{-3}$, while in the samples taken in the 1st quarter no presence of respirable asbestos fibres was observed. Kruskal-Wallis test showed significant differences between quarters (p-value=0.0039). Pair-wise comparisons between the pairs of quarters indicated insignificant differences between quarters 1 and 4, and 2 and 4.

Based on the total data from all farms, Kruskal-Wallis test showed significant differences between quarters (p-value 0.0006). Pair-wise comparisons indicated that the quarters formed 2 groups: 1st, 4th and 2nd, 3rd.

Kruskal-Wallis test showed significant differences between farms (p-value=0.0008). Each pair of farms differed significantly (Fig. 5).

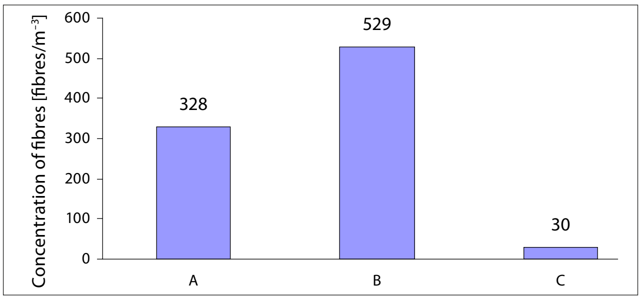

Figure 5. Mean concentration of respirable asbestos fibres in individual quarters on Farms A, B, C [$fibres{\cdot}m^{-3}$]

DISCUSSION

Studies of concentrations of asbestos fibres in highly urbanized areas in Poland conducted by Krakowiak et al. [12] showed concentrations within the range 1,000–9,000 $f{\cdot}m^{-3}$, with the highest values noted in the close vicinity of buildings, where the deposition of asbestos containing products was high (1,800 $f{\cdot}m^{-3}$ on average), compared to places at the distance of 100–500 m from such buildings (1,000 $f{\cdot}m^{-3}$, on average), or buildings without asbestos (1,000 $f{\cdot}m^{-3}$). In the presented study, these values were 529 and 320 $f{\cdot}m^{-3}$ for farms with asbestos-cement products, and 30 $f{\cdot}m^{-3}$ for farms without asbestos. This difference resulted from the fact that in the rural areas, despite the greater global amount of asbestos material deposited, their accumulation per m^2 is lower due to the dispersion of farms in a given area. For example, in the counties where the presented measurements were performed, the asbestos products accumulation rate was 82.5 Mg/km^2 for Lublin county and 25.9 Mg/km^2 for Włodawa county, whereas in the city of Lublin it was as much as 215.5 Mg/km^2 [4].

Studies by Szeszenia-Dąbrowska et al. [13] confirmed that the mean concentration of asbestos fibres in Poland is 492 $f{\cdot}m^{-3}$, and in the Lublin Region – 677 $f{\cdot}m^{-3}$. In Poland, at places adjacent to former enterprises producing asbestos products, the concentration of asbestos fibres (732 $f{\cdot}m^{-3}$) was considerably higher than for other areas. This suggests that most probably the measurements were carried out at sites located in areas with a high accumulation of asbestos products in the Lublin Region, which are in a poor technical condition, because the results are the closest to the levels obtained in the presented study on Farm B.

The size of emission of fibres from the sheets does not directly depend on the age of the asbestos plates but, to a great extent, from the quality of the surface. The surface emission factor increases with the deterioration of the surface from $2.7{\times}10^3{\cdot}m^{-2}{\cdot}J^{-1}$ for a good condition of the surface of sheets, to $6.9{\times}10^3{\cdot}m^{-2}{\cdot}J^{-1}$ for surfaces in a poor condition [2]. These studies show that atmospheric corrosion results in the release of asbestos fibres into the air; however, mechanical damage of the asbestos-cement sheets exerts a considerably greater effect on fibres emission.

The presented study shows that the state of asbestos-containing products affects the size of air pollution with asbestos fibres. Poor condition of asbestos-cement materials on the farms in the study resulted not only from mechanical damage (e.g. inadequate assembly), but also from the effect of atmospheric factors.

The available literature data pertaining to the levels of fibres concentrations in the rural areas usually concern areas where there occur natural resources of fibrous materials, which often are being or have been exploited [14, 15]. According to such data, in the rural areas in Japan, the concentration of asbestos fibres is 4,000 $f{\cdot}m^{-3}$, 9,000 or even 11,000 $f{\cdot}m^{-3}$ [14].

The mean concentration of fibres in the rural areas of Korea was 620 $f{\cdot}m^{-3}$, and was considerably higher compared to the rural areas where it was 300 $f{\cdot}m^{-3}$ [16]. In urbanized areas in Iran, significant differences in the concentration of asbestos fibres were found between areas and seasons of the year, with the mean concentration 3,400 $f{\cdot}m^{-3}$ which, according to the researchers, is considerably higher than the levels noted in the USA, and urbanized environment in Europe [17]. In Germany, the concentrations are from 200–5,000 $f{\cdot}m^{-3}$, in Austria – 4,600 $f{\cdot}m^{-3}$ in locations with dense road traffic, and below 100 $f{\cdot}m^{-3}$ in the rural areas [18].

The effects of environmental exposure to asbestos (tremolite) brought by inhabitants of small towns in the area of Malatya in Turkey from the nearby mountains and used, among other things, as a white plaster on walls, was described by Hasanoglu H.C et al. [19], and in the areas of Greece, Corsica, New Caledonia and Cyprus – by Constatopolous S.H [15].

The comparison of results from various countries and research centres may be hindered due to the various types of asbestos products used in individual countries, and various methods of determination of asbestos fibres (from Phase Contrast Microscope to Transmission Electron Microscopy and Scanning Electron Microscopy).

It should be kept in mind that there is no safe level for the concentration of asbestos fibres below which clinical effects would not occur; therefore, the exposure should the lowest possible [20]. According to Szeszenia-Dąbrowska et al. [13], during the period 2010–2020, an increase may be expected in the number of deaths due to cancer caused by asbestos, which is related with a very long morbidity latency period, which is even up to 40 years after exposure.

CONCLUSION

The presented measurements of concentrations of asbestos fibres in ambient air on selected farms in the Lublin Region characterized by various technical conditions of asbestos-containing products allowed recognition of the degree of contamination of ambient air with asbestos fibres in the rural environment. This indicates that the mean concentration of respirable asbestos fibres on the examined farms was 296 $f{\cdot}m^{-3}$.

The presented measurements confirm that the technical condition of asbestos-containing materials, associated with levels of farmer's knowledge about assembly and maintenance of asbestos containing materials, affect the concentration of asbestos fibres in ambient air.

The highest concentrations were noted on the farm where asbestos-containing products were in a poor technical condition. The mean concentration of respirable asbestos fibres on this farm was 529 $f{\cdot}m^{-3}$. From among the 3 farms in the study, the highest concentration of respirable asbestos fibres on these farms resulted from the poor technical condition, inadequate assembly by the owner of the farm, lack of maintenance and protection against the effect of external agents. The products were characterized by severe damage of the surface and broken structure of the fibres, with visible effects of corrosion.

On the farm where asbestos-containing products were in a good technical state, the mean concentration of respirable asbestos fibres was 328 $fibres{\cdot}m^{-3}$, while the lowest concentrations of respirable asbestos fibres in ambient air were noted on the farm where there were no asbestos-containing products (30 $f{\cdot}m^{-3}$). Therefore, inadequate assembly and use of asbestos containing materials decreases by 40% the levels of mean concentration of respirable asbestos fibres, compared with the farm with poor technical condition of asbestos products. It is significant that the time use of these asbestos products was similar.

The lack of asbestos-cement products in farms does not completely eliminate asbestos fibres from ambient air, because of background level affects on the concentrations of respirable asbestos fibres in ambient air.

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