"The Natural Reduction of Threat in Selected Systems of Old Buildings Containing Asbestos"

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Research Article

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Abbreviations and terms

ACM - Asbestos Containing Materials

a-c – asbestos - cement (product, materials, etc.)

ARD: Asbestos-Related Diseases

CSRS - Czechoslovak Republic (*Československá socialistická republika – ČSSR*), was part of the Eastern Bloc

HEPA - High Efficiency Particulate Air filter

GK - Gypsum Plasterboard

MMMF - Man-Made Mineral Fibres

NOAEL - No-Observed Adverse Effect Levels

GDR - German Democratic Republic (German Deutsche Demokratische Republik, DDR, colloquially East Germany) - a non-existent German state that was part of the Eastern Bloc.

OM - Optical Microscope

PLM - Polarized Light Microscope

* corresponding author

PCM - Phase Contrast Microscope

PCOM - Phase Contrast Optical Microscope

PEL (OEL) - Permitted Exposure Limits (Occupational Exposure Limits)

PW3/A (and its modification e.g. PŻW3/A/S): Sandwich panels used up to the 90s in skeletal construction in layered curtain walls: thermal insulation core made of mineral wool or foamed polystyrene in a wooden frame, double-sided asbestos-cement flat plate. The panels were attached to the steel structure of curtain walls. From the inside, they were covered with plasterboards.

"rigid" construction with asbestos: building structures with masonry or reinforced concrete walls, containing sandwich walls with non-friable asbestos (e.g. PW3/A).

"non-rigid" construction with asbestos: light steel frame structure of the building (e.g building type "LIPSK") with sandwich walls with friable or/and non-friable asbestos.

SEM-EDS - Scanning Electron Microscopy – Energy Dispersion Spectroscopy

TEM - Transmission Electron Microscopy

"work area" - closed, encapsulated space in the building where asbestos dismantling works are carried out

Abstract

The aim of the research was measure changes asbestos dust concentration over long period of use in old building systems. Buildings from different systems during their exploitation and after asbestos removal were tested. Asbestos dust concentration decreasing in some building systems is due to air exchange and other phenomena, if there are no new active dust sources. Currently, with proper use of those buildings, average values of dust concentrations did not exceed range 300 - 400 f / m^3 with a downward trend to <300 f / m^3.

The results of these studies were obtained with a modified optical microscopy technique and verified by SEM and TEM methods. The graphical trend of the variability contaminations allows estimate them in the future better then theoretical models. Research proves that a single measurements done in short time as an applicable obligatory immediately after the asbestos removal may not detect the hazard appearing after some time. Monitoring buildings over longer periods of time allows to detect significant changes in their contamination. In many cases the minimal air contamination undermines the desirability of removing asbestos in old buildings.

1. Introduction

1.1 Literature review on differences in asbestos dust concentrations measured in buildings

This type of research brings different results, which makes it difficult to interpret and draw conclusions as to the hygienic condition of the indoor air and the real need to remove asbestos products, as well as the real benefits of the planned disassembly of asbestos. The process is complicated and can be defectively realized, what may pose a risk to the building's occupants. According available data[1,2], during asbestos removal, asbestos dust concentrations above 1 000 000 f / m^3 may be generated in the work zone. This value is 3 000 - 5 000 times higher than that generated on average in normal use of such buildings and 1000 times higher than the most frequently recorded values in buildings with poor technical condition. The individual results of dust concentration measurements at the same places can vary considerably. This applies to the asbestos removal process as well as to the condition of buildings before and after asbestos removal[3,4,5,6,7,8,9,10]. Some reports a low levels of occupational exposure (in relation to PEL) for roofing projects with ACM roofs[11] at 4700 - 75 200 f / m^3, and in work zones[8] 600 - 16 000 f / m^3. The levels of building contamination during exploitation can result[11,12] in a low values as 70 - 120 f / m^3 . Dust concentrations can reach there also high values in the workspace depending on the condition of the products and their destruction[13] approx. 50 000 – 388 000 f / m^3 and even[9] 300 000 – 600 000 f / m^3. Different concentrations of fibres were registered with different diameters and fibre sizes in the same building, e.g.: high concentration of "asbestos structures" 17 000 f / m^3, corresponds in the same concentration test[14] to a low number of respirable fibres - only 230 f / m^3. Depending on the actions activating the dust in the room[14,15], the average values in the facility could have increased from 2 500 f / m^3 to 60 000 f / m^3. When measuring using TEM[16,17] the max. and min. of asbestos dust concentration, the values differed by a factor of 10, as compared to the average concentration of 1500 f / m^3. Large differences in concentration values for the same room were described[17,18]. It is assumed that the elevated level of asbestos fibres in the air of used buildings is combined with the degree of damage to asbestos products[26,29]. However, the mere fact of damage to the product is not sufficient for aerosol formation and many factors can modify it[19,20,21,22,23,24,25]. The author's research[21,22,23] in renovated buildings or after renovations confirmed, that dust concentration in one building can significantly differ in the same time in single rooms : from < 600 to 7 000 f / m^3. In addition to various short-term changes, pollutants may change in the same premises over a long period of time with a specific trend. Value in the concentration of asbestos dust depend on the time elapsed between the moment of the appearance of the aerosol asbestos in the air (ACM mounting or removal) to start of sampling (after long time of building exploitation)[30]. The problem of estimating the value of dust concentrations in buildings, which can be considered acceptable, is discussed in a number of publications[42,43,44,45,46]. In terms of short time, changes in the concentration of asbestos dust were described[47] in experimental chamber relation to a period of 30 min - 70 min. Literature presented also monitoring of the concentration decay after asbestos removal[50] and evaluation of asbestos particles diffusion models in interiors based on the Pasquill and Gifford diffusion model for the external environment[51,52]. Changes over decades have not been recorded yet although models have been developed to simulate indoor dust concentrations.

1.2 The research goals

Some countries, such as Germany and France, defined in internal regulations the limit value (acceptable) number of asbestos fibres as an air pollution of residential buildings and after asbestos removal process. Others don't. Nevertheless, programs for compulsory removal of asbestos from buildings are developed regardless of the level of this pollution. Such a process is expensive, dangerous and can sometimes worsen the hygienic condition of the building. In view of the above, in order to assess the actual need for asbestos disassembly, it is necessary to determine the current state of contamination, as it varies over time and may be subject to constant trends. The purpose of this study is going to answer some questions: Does the dust concentration decrease over time, as a result of ventilation and dust removal from the building, or does it increase as a result of ageing ACM products? Since many decades have passed since buildings with asbestos were constructed and surveyed, and many factors have shaped the level of indoor pollution, can we consider those results (e.g. from 1980 to 2015) to be valid today? Is asbestos removal beneficial in all types of buildings? The originality of the study consists in the use of simplified dust measurement over different period of time in the same buildings, to demonstrate the “self-cleaning” process of the buildings progressing over time. In the article for the various categories of buildings applied a common method of sampling and research was used. This ensured constant measurement sensitivity and a repetitive laboratory error. For this reason, the main focus of the study was buildings with potentially significant contamination, where changes in the concentration of asbestos dust in the air can be easily recorded.

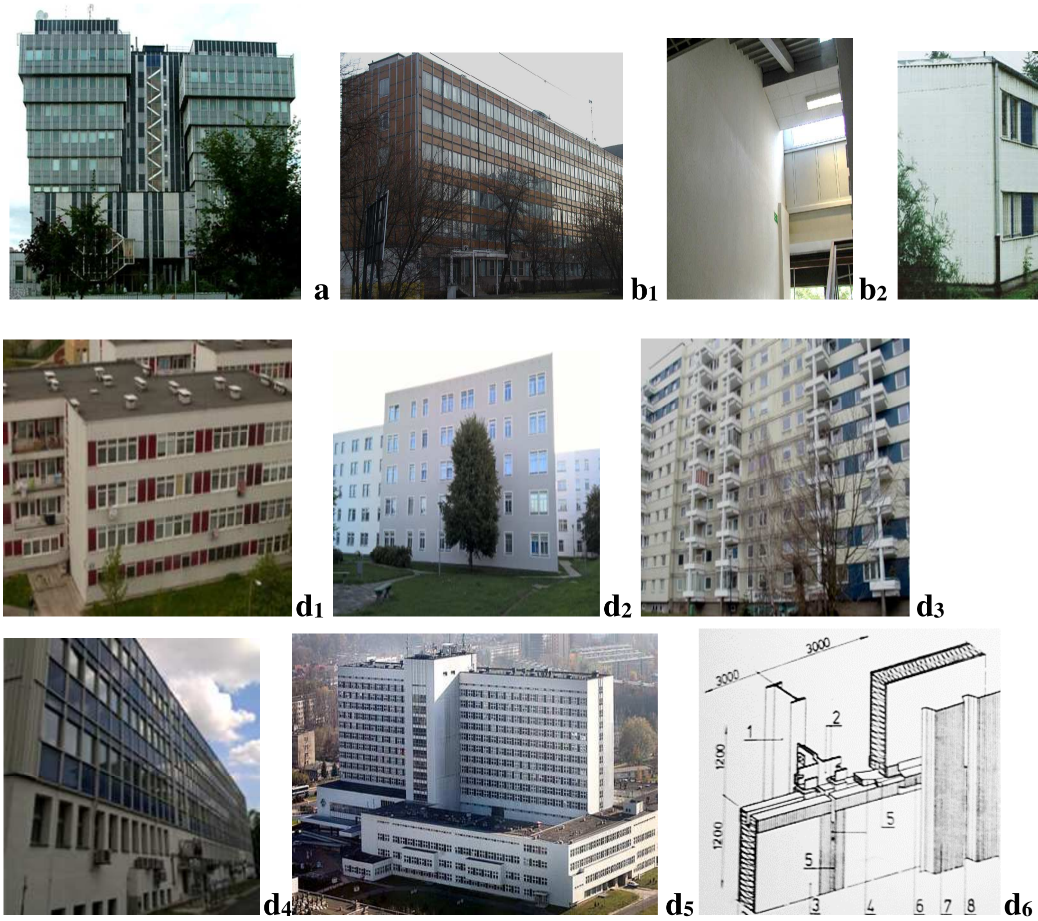
2. The method of analysis

As a main technique in this study was chose modified OM. The results were verified in selected cases by SEM and TEM analyses. The samples for these methods were collected in parallel at the same time and place. The OM method had to be modified according to the required tests of asbestos measurement adopted for recording of a low operational dust concentrations (<10 000 f / m^3). The identification of asbestos fibres was necessary[31]. The phase contrast method (PCOM) NIOSH 7400 [32], used in the research is suitable only for quantitative analysis[33]. It is a facilitation for use in the assessment of asbestos exposure and enables comparison of the results of historical and contemporary research[34]. This technique does not give accurate fibres concentration measurements at the extremely low levels of the air pollution. However, it can easily record the pollution values above 300 f/m^3. Respirable asbestos fibres were counted using PCOM analogous to the Polish standard PN-88/Z-04202/02 and NIOSH 7400[32]. The prerequisite for counting fibres as asbestos was to record their respirable size during phase contrast observation and when the microscope mode was switched to polarized light observation, to identify the optical characteristics of the fibres as asbestos. Observations were carried out at a magnification of 500 x or 1000 x + immersion (if necessary). The modifications to sampling and microscopic analysis for the 7400 NIOSH are reported in the literature[20, 25].

3. Research material - building systems tested

The subject of the research were typical buildings in Eastern European countries from 1970–1990. They differed in construction, size, amount of ACM materials used, their structure (outside, inside), cohesion (friable and non- friable), as well as the condition of operation (during use, renovated, and after asbestos removal). The research covered buildings with the so-called “rigid” with brick walls and "non-rigid" construction. Analyzed systems of buildings were presented in Fig.1. Buildings of "non-rigid construction" with higher air pollution are: a, b, c. Buildings with a "rigid structure" with less air pollution are d_1 - d_5.

Fig.1 Analyzed systems of buildings as examples of rigid and nor-rigid structures.



a View of the “BOLETICE” from CSRS, front sandwich wall with glass facade.

b_1 “LIPSK” from DDR, building facade. Under the facade there are the GLAGIT hard asbestos cement plates contain13 % asbestos.

b_2 Internal walls in the stairwell of the building type „LIPSK” contain “SOKALIT”, soft plates (20% asbestos, "friable" ACM as fire - proof product);

c System “BERLIN” from DDR

d Different buildings type of “BISTYP” (Polish system): **d_{1-3}** residential,**d_4** office,**d_5** hospital)

d_6 Construction of BISTYP sandwich wall with PW3/A or PŻ3W panel.

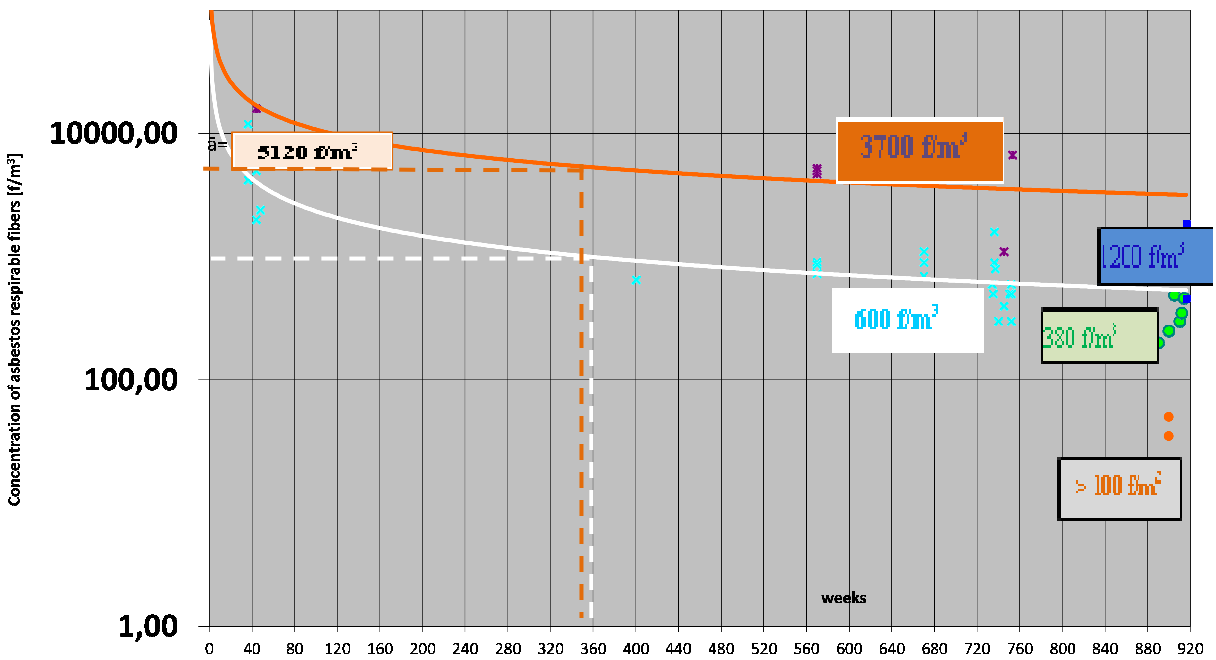
Description of drawing elements: 1. Steel pole, 2. Steel connector, 3. PW3 / A or PŻW3/A, 4. Polyurethane gasket, 5. Permanent plastic putty, 6. Steel spacer with screws, 7. Facade corrugated steel, 8. Rivet fixing the facade.

4. The results of the study

4.1 “BOLETICE” systems

Measurements were made in the building during its operation from very beginning of start use up to after its completion of use. Fig. 2 show the values of groups of 80 measurements made in this building, marked with colours, taking into account different methods of air sampling.

Fig. 2 The trend of changes in dust concentration in the “BOLETICE” system building .



White color of curve presents static sampling, orange - dynamic sampling.

x The determination of air samples taken in a dynamic way (one point means the average of two measurements made at the same time and in the same room). The trend of concentration changes at such sampling was marked as an orange curve.

x The averaged values of dust concentration obtained in conditions of normal use of the building (standard user activity, working central ventilation, without cabinet fans). The trend of concentration changes was presented as the white colour curve.

● The measurements made after a period of 12 months from cessation of exploitation (this was about 19 years of the object's existence). The test was carried out in the same rooms in the building during its operation. Test conditions: mechanical ventilation and heating excluded in the building, no operational vibrations related to the use of the building. Dynamic air sampling (analogous to earlier techniques: activities to run dust seated on horizontal surfaces).

■ The measurements made at the same time in rooms with fresh, large damage to the sandwich wall created after cessation of exploitation: exposed, damaged soft products (friable) – “PYRAL” board. Dynamic air sampling: the average value of asbestos dust concentration was 1200 f/m^3.

• The measurements made in outdoor at a distance of about 8 m from the building. The mean concentration was <100 f / m^3

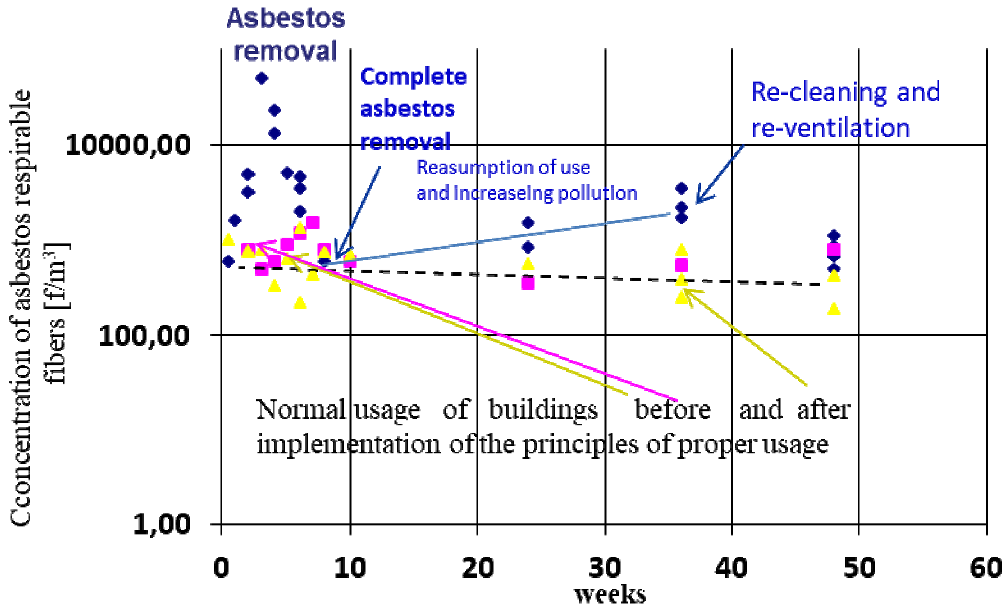
Thanks to these trends, it is possible to estimate the likely pollution at any time, which takes into account different sampling techniques. In the given time, it should be the given point of contamination, not greater than the value of the orange curve and not less than the value of the white curve. For example: at 360 weeks, pollution should be in the range of > 1000 f / m^3 to <5000 f/m^3. The function that optimally approximates the trend of changes in the measured values between period of building's use is determined by the power function curve, defined by the formula $y=54168\ x^{-0,6462}$. The approximation of values measured to the designated curve R^2= 0,8341. In the first year of operation, maximum values of 16 000 f/m^3 were recorded with the dynamic sampling collection technique, 10 000 using static sampling collection (average value of concentration from all measurements was 5 120 f/m^3). Between 11 and 15 years of exploitation, the average concentration value in static measurements was 600 f/m^3. During the same time period, the average concentration value in dynamic measurements was 3 700 f/m^3. In the initial period of research, the concentration values were rapidly decreasing. The rate of concentration changes gradually decreased over time, asymptotically approaching the value of about 400 f/m^3.

4.2. Systems: " LIPSK" , "BISTYP", " BERLIN"

Building systems "LIPSK" were presented in Fig. 3 and Fig. 4, compared to the "BISTYP" building. Groups of measurements of asbestos concentration in indoor air were marked with different colors for different buildings. The vertical axis means the values of asbestos dust concentration on a logarithmic scale. The horizontal axis denotes of the time (weeks) on a linear scale. Each coloured point representing the average values from at least 6 measurements of asbestos dust concentrations in individual buildings. There were 40 - 160 measurements for individual buildings.

Building no.1 is the object, from which asbestos was removed. After asbestos removal and complete final cleaning, there was an increase of an air pollution between weeks 8 and 35. This was caused by the drying out of the walls and the release of dust left over from ACM removal. After the 35th week, additional cleaning with vacuum cleaners and airing of the building was applied. It caused a drop in the concentration of asbestos fibres to the levels preceding the disassembly (500–680 f/m^3).

Fig. 3 Changes in air pollution of 3 buildings “LIPSK” during use and asbestos removal.



♦ Building (1) during asbestos dismantling in the first three weeks. Final cleaning was completed by week 8. Re-cleaning was carried out after 35 weeks.

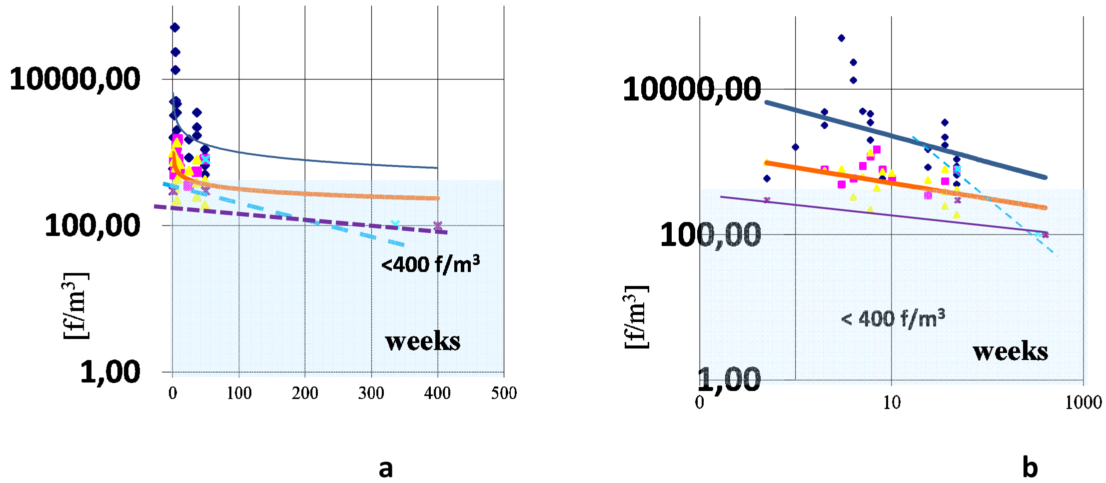
■ Building (2), normal room operation

▲Building (3), normal room operation. After the tenth week of research, special operating rules were introduced in buildings 1 and 2

Buildings no.: 2, 3, were in normal use. After measurements carried out over 10 weeks, special operating procedures were introduced, resulting in a reduction of pollutants and a smaller dispersion of results.

Fig. 4 present the curves connecting these measuring points of the same colour, represent the tendency of the asbestos dust concentration in the tested buildings. Both Fig. 4a and 4b present the same data with a different coordinate system. One of them better shows the measured values, the othetr - trends of their changes for individual buildings. The figures show a reduction of the rate of change in the concentration of asbestos dust over a period of time after reaching concentration value <400 f/m^3. This range of values was considered by the author to be acceptable pollution for these buildings and marked blue in the graphs. This applies to objects operated in the same way for a longer period of time, without damaging the ACM.

Fig. **4** Comparison of contamination in buildings systems “LIPSK ” and “BISTYP”.



a Time of measurements [weeks] on a linear scale of time (the horizontal axis)

b Time of measurements [weeks] on a logarithmic scale of time (the horizontal axis)

Common legend for **a** and **b**

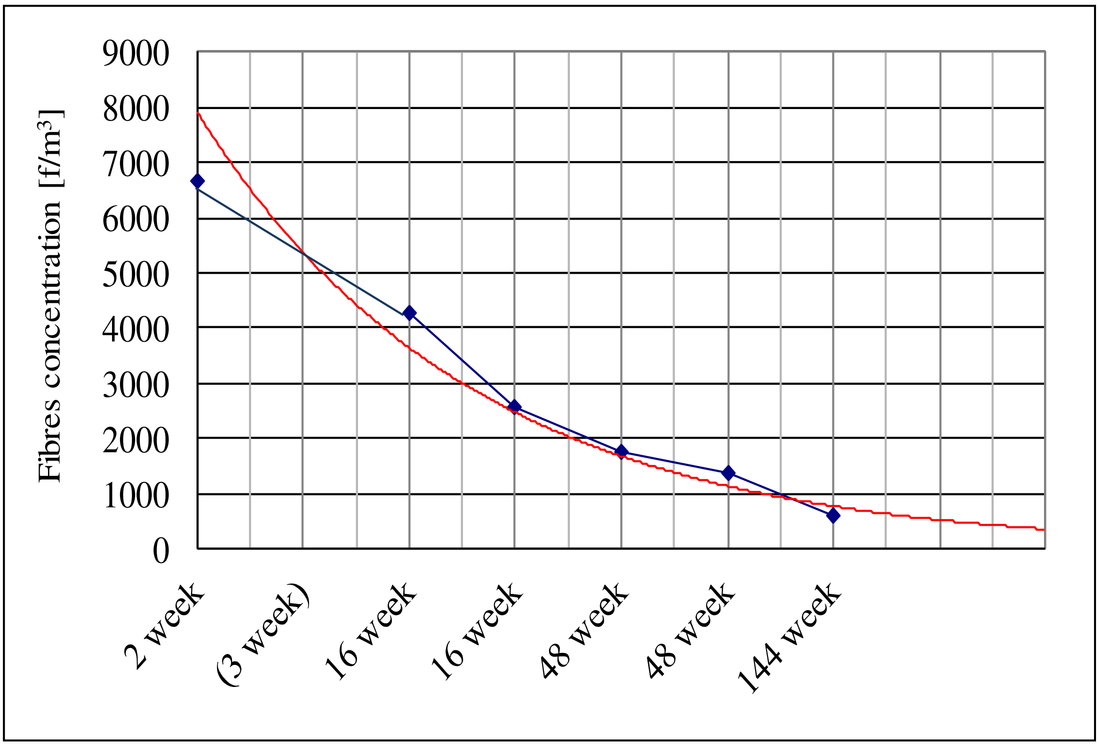
System “LIPSK”
- Building No.1 ♦ Asbestos dismantling
- Building No. 2 ■ No disassembly
- Building No. 3 ▲ No disassembly
- Building No. 4 x (ACM were covered with additional layers from the inside and outside of the building)

(Buildings No. 1–3: as in the Fig 3)

System “BISTYP” Building No. 5 **x**

The changes in asbestos dust concentration recorded in the building in operation after accidental ACM desturbing as a result of improperly conducted and interrupted renovation of walls are presented below. The research was carried out in the BERLIN building and the results are shown in Fig. 5 and Tab. 1.

Fig. 5 Fibre concentration in the "BERLIN" building during its renovation, recorded from the 2nd to the 144th week after the work was stopped. (works were carried out without knowledge of ACM presence in the building).



The red line in Fig. 5 marks the trend line of changes over time. The results of measurements in various rooms are shown in Table 1

Tab. 1 The concentration variability with time in the "BERLIN" building, which was renovated without removing asbestos-containing products.

Degree of exploitation	Unused rooms [f/m^3]	Used rooms [f/m^3]
1 month after renovation	860	3810
2 month after renovation	-	440*
0.5 years after renovation	680	-
1 year after renovation	-	1360-1760
3 years after renovation	-	660- 750
Non-renovated used rooms	1420**	

* Intensive ventilation rooms between the repair and the beginning of the tests

** Active sources of dust contamination existing in rooms

5. Discussion of results

5.1 Data summary

About 22 ml m^2 of a-c boards used in sandwich panels of BISTYP systems and others were produced in Poland. The contemporary concentration of asbestos fibres in the indoor air of "rigid structures" such as "BISTYP" is often <300 f/m^3. These values can be called “acceptable" surplus of asbestos fibres concentration over the values recorded in the background, i.e. atmospheric air. With regard to the "non-rigid structure” (as in Figures 4a, 4b), it can be concluded that only after about 1000 weeks (i.e. 20 years) after the removal of asbestos, the concentration of asbestos dust (see dark blue line) will reach the same level as in the building properly used before asbestos removal (orange line). This is due to the errors encountered in practice by asbestos dismantling contractors who are unable to limit the high concentrations of dust generated by ACM removal. This example calls into question the advisability of removing asbestos from certain building systems if the current value of asbestos dust in them is low and the removal of these products may temporarily worsen existing indoor air quality to a significant degree.

In building structures “rigid” with sandwich walls containing ACM, the highest probability of the concentration of respirable asbestos fibres (mode) is from 0 to <300 [f / m^3]. In “non-rigid” construction buildings, depending on many factors, including the technical condition, this range is significantly wider and can be amounts to 0 - 1400 [f / m^3]. Tab. 2 shows the collective results of indoor air pollution for asbestos-containing building systems, measured in this work. Presented here:

A - Average value from 20 – 200 tests of the concentration of asbestos respirable fibers in all tested rooms.

B - Median of recorded values.

C – Mode - the value with the highest probability of occurrence.

D - The highest concentration of fibers in the air.

E – The lowest concentration of fibers in the air.

Tab. 2 The values of indoor air pollutants for several typical asbestos building systems.

No		Building system	A	B	C	D	E	Comments
1	Construction rigid[1]	„BISTYP”	320	420	-	590	0	6 years after the start of operation
2			< 300	<300	0	<300	0	36 years after the start of operation
3			0	0	0	0	0	
4			0	0	0	0	0	
5			< 300	0	0	300	0	
6		Other different sandwich walls inside the curtain wall	330	450	<300	1000	0	about 40 years from the start of operation
7			<300	<300	<300	600	<300	
8			<300	0	0	<300	0	
9			<300	<300	<300	300	0	
10			<300	<300	<300	340	0	
11	construction non-rigid[2]	Buildings type “LIPSK” with different condition of ACM	710	800	760	1200	350	normal operation
12			<300	0	0	<300	0	6 years after implementation of the principles of proper operation
13			720	700	700	1400	0	normal operation
14			310	<300	0	1200	0	1 year after implementation of the principles of proper operation
15			300	<300	0	1500	0	2 year after implementation of the principles of proper operation
16			<300	0	0	390	0	3 year after implementation of the principles of proper operation
17			1370	1000	1000	8700	0	normal operation
18			390	350	400	1500	0	operation limited to approximately 2/3 of all rooms in building
19			<300	0	0	300	0	no operation for about 7 years
20			854	680	500	1500	<300	8 months after asbestos removal
21			<300	0	0	<300	0	6 years after asbestos removal

[1] A long-wall structures with brick walls or frame structure, reinforced concrete, containing sandwich element with asbestos – cement plates.

[2] Lightweight steel construction with sandwich walls containing asbestos plates

The median concentration of dust is also within the wide range of 0 - 800 [f/m^3] depending on the model of use or technical condition.

5.2 To understanding the results

Proper use of buildings, confirmed by a low concentration of asbestos in the indoor air, leads to the reduction of this pollution to the level of the outside air over time. This applies to buildings with non-friable ACM, without destroyed, and any vibrations of the object and /or structure which can be transmitted to ACM. Moreover, ACM must no direct contact with indoor air. The implementation of the principles of proper usage (Fig 3) brings a radical improvement of the air.

5.3 Long-term consequences

Although there are differences in the content and types of asbestos in individual products, the approximate content in typical and often used ACM, are similar in many countries[25,26,27]. Therefore, conclusions of dust changes and the described building self-cleaning process applies not only to the tested buildings systems, but to all others with similar characteristics. The OM method requires high precision of determinations and maintaining high proficiency of analysts in inter-laboratory tests[38,39]. The obtained in the past test results for the concentration of respirable fibres with ø > 0.2 µm in used buildings, now are out of date. Real values are often at limit or below the limit of OM quantification[40,41]. Many of the systems presented here ware characterised range from 0 to < 300 f/m^3. They will fulfil this condition for the next years without any intervention.

The health aspect of asbestos works must be taken into account in relation to the contemporary tendencies of absolute asbestos removal from buildings. Pleural mesothelioma cancer is characterized by a period of about 40 years of latency. Therefore, the results of the exposition from 1990-2019 will result in diseases arising in the years 2030-2059. This applies in particular to the higher asbestos exposures arising during the asbestos removal programs. Accelerated and imprecise disassembly, may result in a "pandemic" mesothelioma in future decades. Research on the increase in mortality in the USA in the 1980s caused by asbestos removal confirmed the problem.

6. Conclusions

1. A concentration of asbestos fibres in indoor air of a "rigid - constructions" is most often about 0-300 f /m^3.
2. In a such buildings after many years of operation the air quality getting better over time.
3. If there is no evidence of an increase in the concentration of asbestos in the air, the removal of ACM from such facilities should be postponed until the end of a building use.
4. Repeated confirmation of low concentration and / or confirmed decreasing trend of concentrations in the building allows to extend the facility's operation as safe.
5 The reduction of asbestos dust in buildings seems to be a normal and natural process after proper and long service life (if the operation is not accompanied by the destruction of asbestos.) Such conditions are met by many buildings in which asbestos is insulated from the internal air.

Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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HIGHLIGHTS

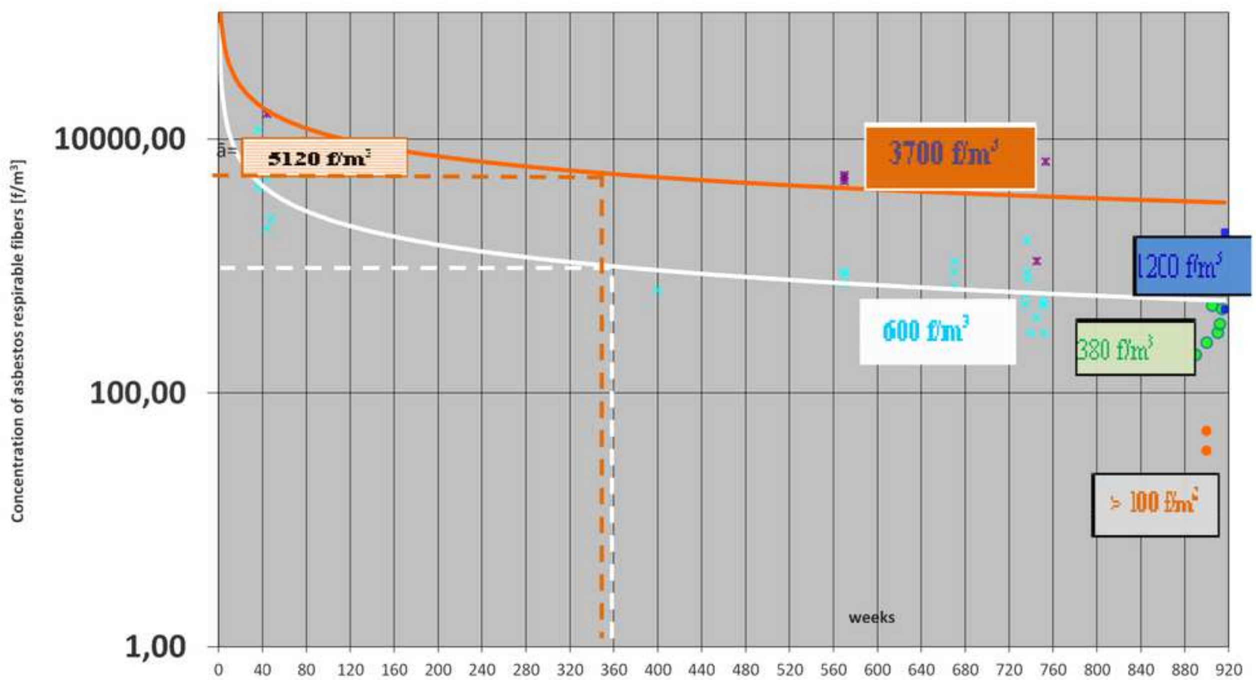
- Asbestos concentrations indoor in properly used buildings decrease to outdoor
- The speed decay of asbestos dust concentration in the air decreases with usage time
- Most of such old buildings have concentrations <300 - 400 f / m^3
- These are conditions that do not require a reduction of dust in the indoor air
- Asbestos removal in such buildings usually increases temporarily indoor pollution

Figures

a View of the “BOLETICE” from CSRS, front sandwich wall with glass facade.
b_1 “LIPSK” from DDR, building facade. Under the facade there are the GLAGIT hard asbestos cement plates contain13 % asbestos.
b_2 Internal walls in the stairwell of the building type „LIPSK” contain “SOKALIT”, soft plates (20% asbestos, "friable" ACM as fire - proof product);
c System “BERLIN” from DDR
d Different buildings type of “BISTYP” (Polish system): **$d_{1\text{-}3}$** residential,**d_4** office,**d_5** hospital)
d_6 Construction of BISTYP sandwich wall with PW3/A or PŻ3W panel.
Description of drawing elements: 1. Steel pole, 2. Steel connector, 3. PW3 / A or PŻW3/A, 4. Polyurethane gasket, 5. Permanent plastic putty, 6. Steel spacer with screws, 7. Facade corrugated steel, 8. Rivet fixing the facade.

Figure 1

Analyzed systems of buildings as examples of rigid and nor-rigid structures.



White color of curve presents static sampling, orange - dynamic sampling.

x The determination of air samples taken in a dynamic way (one point means the average of two measurements made at the same time and in the same room). The trend of concentration changes at such sampling was marked as an orange curve.

x The averaged values of dust concentration obtained in conditions of normal use of the building (standard user activity, working central ventilation, without cabinet fans). The trend of concentration changes was presented as the white colour curve.

● The measurements made after a period of 12 months from cessation of exploitation (this was about 19 years of the object's existence). The test was carried out in the same rooms in the building during its operation. Test conditions: mechanical ventilation and heating excluded in the building, no operational vibrations related to the use of the building. Dynamic air sampling (analogous to earlier techniques: activities to run dust seated on horizontal surfaces).

■ The measurements made at the same time in rooms with fresh, large damage to the sandwich wall created after cessation of exploitation: exposed, damaged soft products (friable) – "PYRAL" board. Dynamic air sampling: the average value of asbestos dust concentration was 1200 f/m^3.

• The measurements made in outdoor at a distance of about 8 m from the building. The mean concentration was <100 f / m^3

Figure 2

The trend of changes in dust concentration in the "BOLETICE" system building .

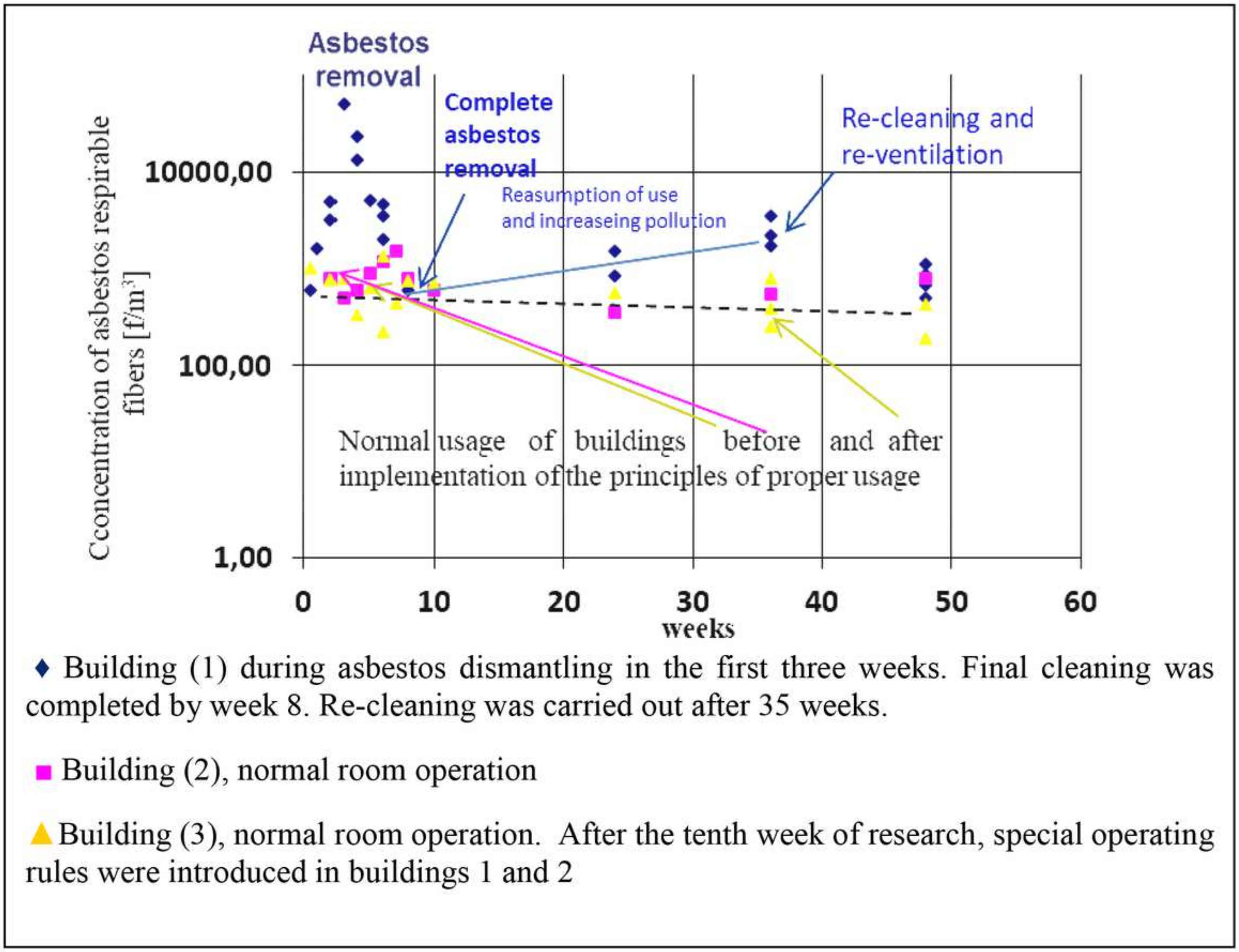


Figure 3

Changes in air pollution of 3 buildings “LIPSK” during use and asbestos removal.

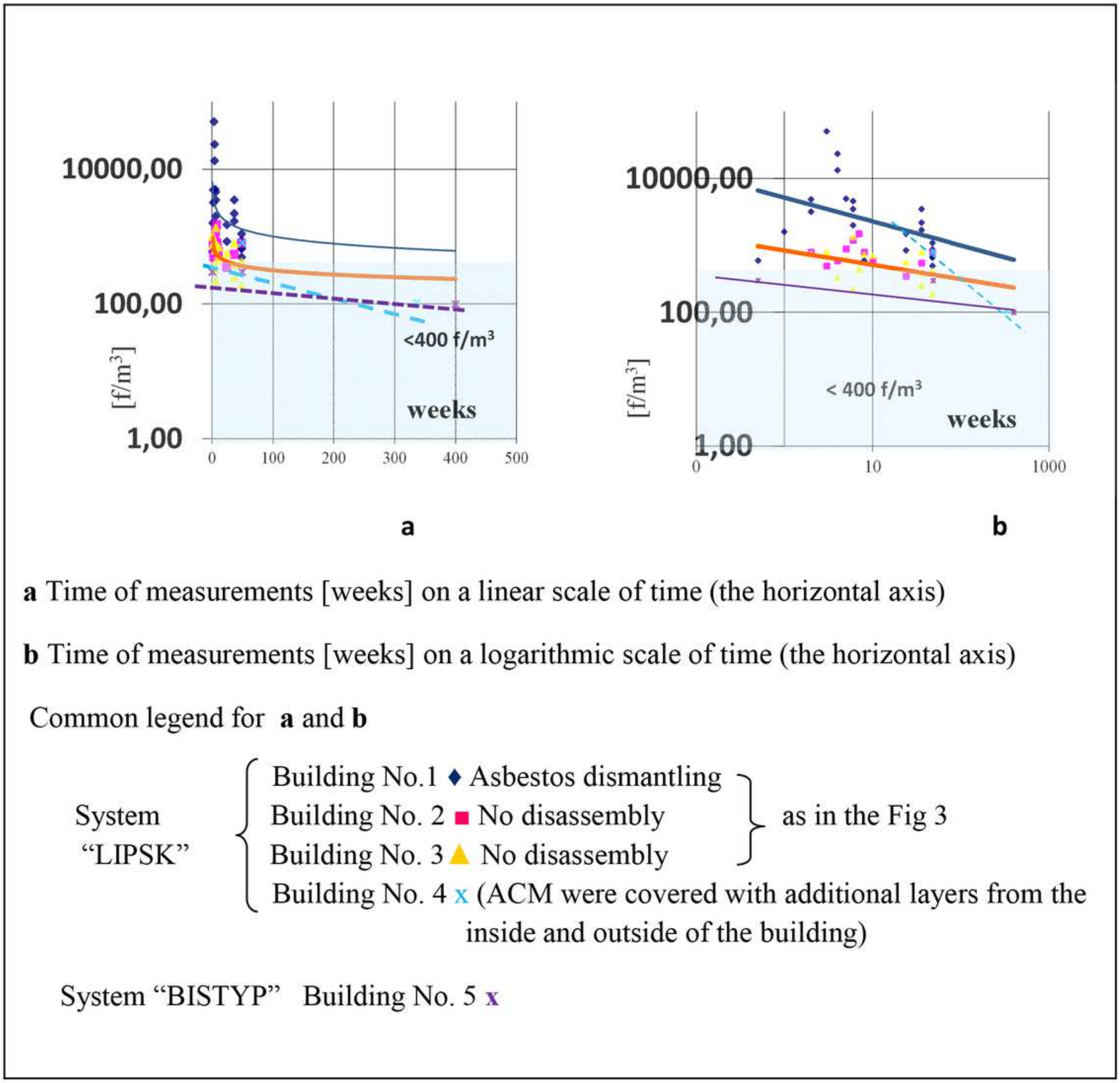


Figure 4

Comparison of contamination in buildings systems "LIPSK " and "BISTYP".

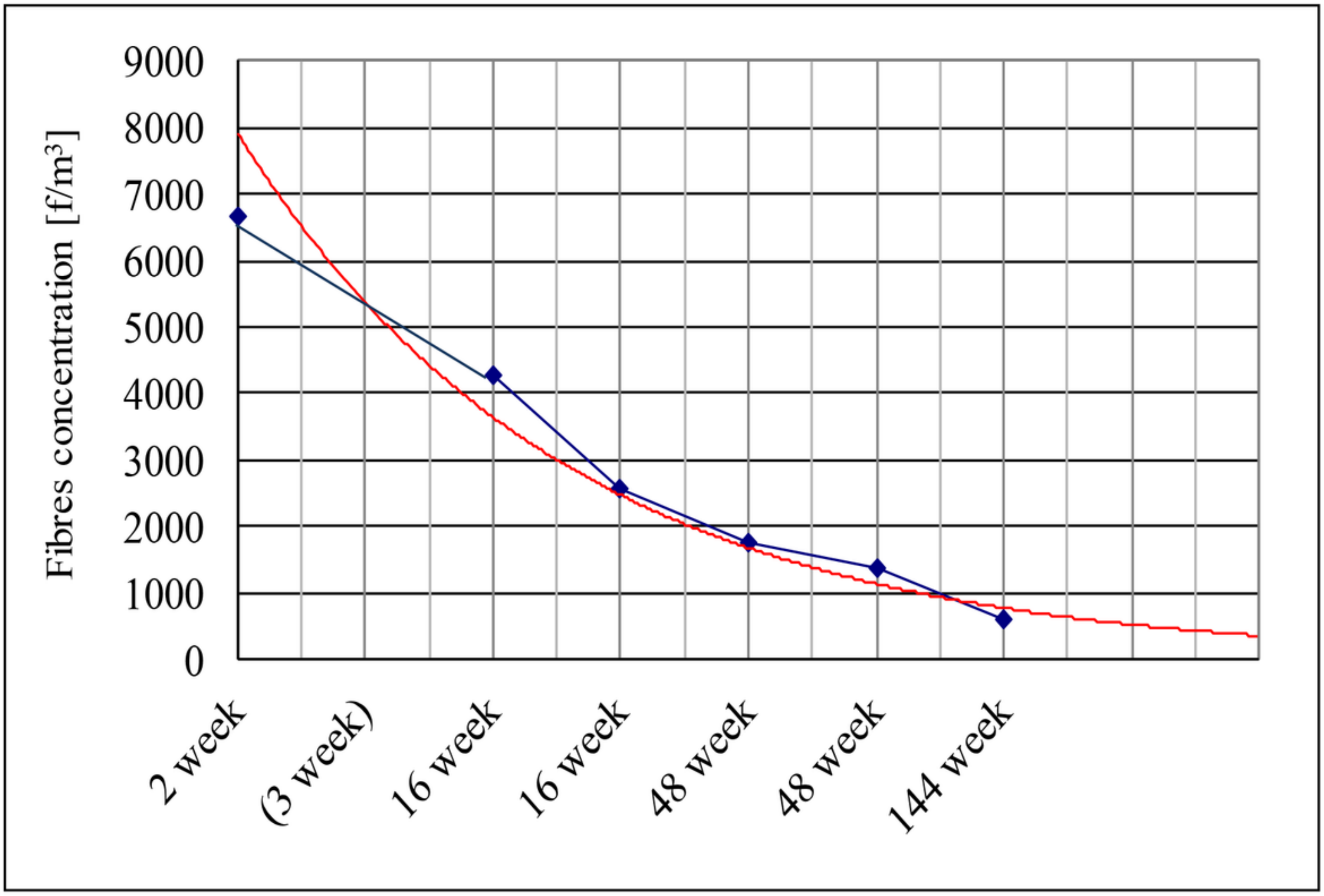


Figure 5

Fibre concentration in the "BERLIN" building during its renovation, recorded from the 2nd to the 144th week after the work was stopped. (works were carried out without knowledge of ACM presence in the building).