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**Abstract.** Main characteristics and prognosis of development of HIV epidemic in Dnipropetrovsk region. Shostakovych-Koretskaya L.R., Lytvyn K.Yu., Gubar I.O., Chukhalova I.V., Gudova M.G., Lopatenko A.A. The epidemiological situation on HIV infection in Ukraine remains complicated due to high morbidity and mortality, which requires a comprehensive study of this problem. Purpose of the work: to clarify the main patterns and characteristics of prevalence of HIV infection in Dnipropetrovsk region and develop a prognosis for changes in the main epidemic indicators. The study was based on reports from the Public Health Center of the Ministry of Health of Ukraine and Dnipropetrovsk Regional Center for AIDS Prevention and Control. (2005-2017). To determine the main trends of development and prognosis of epidemiological situation, methods of analysis of time series with the calculation of chain growth rates and regression analysis were used. Analysis of the number of newly registered cases of HIV infection and AIDS over a 13-year period (2005-2017) showed an increase in figures for HIV by 1.5 times, for AIDS - by 2.4 times in Ukraine, and in Dnipropetrovsk region – by 1.9 times and by 3.0 times, respectively. A significant prevalence of HIV/AIDS incidence rate in Dnipropetrovsk region as compared with national indicators in some years of the study and on average over the entire observation period was determined – 92.8±4.2 cases of HIV infection per 100 thousand and 45.2±5.2 cases of AIDS per 100 thousand in the region versus 41.0±1.4 and 16.1±1.6 per 100 thousand of the population in Ukraine ( $p<0.001$ ). According to prognostic algorithms, in Dnipropetrovsk region until 2020, the annual AIDS incidence rate is expected to increase to 80.7±2.56 cases per 100 thousand people; AIDS mortality to 33.7±0.99 per 100 thousand people, which also predicts an increase in the incidence and mortality associated with opportunistic infections. A calculated prognosis of HIV incidence rates and newly registered AIDS cases in Ukraine and the region for the coming years may be useful for predicting the number of opportunistic infections and calculating the needs for hospitalization and treatment of HIV/AIDS patients.

**Реферат.** Основные характеристики и прогноз развития эпидемии ВИЧ-инфекции в Днепропетровском регионе. Шостакович-Корецкая Л.Р., Литвин К.Ю., Губарь И.А., Чухалова И.В., Гудова М.Г., Лопатенко А.А. Эпидемиологическая ситуация по ВИЧ-инфекции в Украине остается сложной из-за высокой заболеваемости и смертности, что требует всестороннего изучения этой проблемы. Целью работы было выяснить основные закономерности и особенности распространенности ВИЧ-инфекции в Днепропетровском регионе и разработать прогноз относительно изменений основных эпидемических показателей. Исследование базировалось на материалах отчетов Центра общественного здоровья МОЗ Украины и Днепропетровского

областного центра по профилактике и борьбе со СПИДом (2005-2017 гг.). Для определения основных тенденций развития и прогнозирования эпидемиологической ситуации использовались методы анализа динамических рядов с расчетом цепных темпов прироста и регрессионный анализ. Анализ количества впервые зарегистрированных случаев ВИЧ-инфицирования и СПИД за 13-летний период показал рост показателей в Украине в 1,5 раза для ВИЧ и в 2,4 раза для СПИД, а в Днепропетровской области – в 1,9 раза и в 3,0 раза соответственно. Определено значительное преобладание уровня заболеваемости ВИЧ/СПИД в Днепропетровском регионе по сравнению с общегосударственными показателями в отдельные годы исследования и в среднем за весь период наблюдения – 92,8±4,2 случая ВИЧ-инфицирования на 100 тыс. и 45,2±5,2 случая СПИД на 100 тыс. в области против 41,0±1,4 и 16,1±1,6 на 100 тыс. населения в Украине ( $p < 0,001$ ). Согласно прогностическим алгоритмам, в Днепропетровской области до 2020 года ожидается рост показателей ежегодной заболеваемости СПИД до 80,7±2,56 случая на 100 тыс. населения; смертности от СПИД до 33,7±0,99 на 100 тыс. населения, что также прогнозирует рост заболеваемости и смертности, связанных с оппортунистическими инфекциями. Рассчитанный прогноз относительно уровней заболеваемости ВИЧ и впервые зарегистрированных случаев СПИД в Украине и области на ближайшие годы может быть полезным для прогнозирования количества случаев оппортунистических инфекций и расчета потребностей для госпитализации и лечения пациентов с ВИЧ/СПИД.

The issue of control of HIV/AIDS is one of the most pressing in health care in Ukraine and worldwide. According to UNAIDS/WHO, in 2017 the number of people living with HIV was 36.9 million, which is by 14% more than in 2010 (33.3 million people). In the European region, mainly at the expense of Eastern European countries, there is a negative trend in the HIV situation: compared to 2000, the number of new HIV cases registered annually increased by 20%, and the tendency to decrease in mortality is very slow – only 5%. A large number of AIDS cases in Eastern Europe indicates the seriousness of the problem associated with late diagnosis of HIV, delayed onset of treatment and low ART coverage [9]. The main epidemic indicators of HIV and AIDS in Ukraine are among the worst in Europe [8, 9], and in Dnipropetrovsk region the rates of AIDS-related morbidity and mortality are much higher than in most other regions of the country [3, 4], which requires special attention to this issue. There is a negative trend towards late detection of HIV, which is diagnosed in more than half of people with the 3rd and 4th clinical stages [1, 4, 5, 6, 7]. Herewith, about 37% of patients have an initial level of CD4+T lymphocytes  $< 200$  cells/ $\mu$ l. It is estimated that about half of people living with HIV are unaware of their status, which is very dangerous from an epidemiological point of view [1, 5, 6, 7]. A significant problem for the country is that more than 80% of cases of HIV infection for the first time are registered among people of working age – 25-49 years [1, 4]. Thus, the epidemiological situation with HIV infection in Ukraine and, in particular, in Dnipropetrovsk region remains complicated and requires a comprehensive study of this problem. Active measures of the Dnipropetrovsk Regional Center for AIDS Prevention and Control, which are carried out to stop the epidemic should contribute to the effective solution of this issue.

Aim of the work is to find out the main patterns and features of the prevalence of HIV infection in Dnipropetrovsk region and to develop a prognosis for changes in the main epidemic indicators.

#### MATERIALS AND METHODS OF RESEARCH

The information base of the study is formed from the materials of state and sectoral statistical reporting on the levels and structure of HIV infection, including reports of the Public Health Center of the Ministry of Health of Ukraine and information of the Dnipropetrovsk Regional Center for AIDS Prevention and Control (2005-2017) [3, 4]. Statistical processing of the study results was performed using licensed software packages STATISTICA v.6.1 (StatSoft, USA) (serial number AGAR909E415822FA). To determine the main trends (chronological trends) of development and forecasting of the epidemiological situation regarding the rate and number of morbidity and prevalence of HIV and AIDS, as well as the mortality rate from AIDS in Dnipropetrovsk region and Ukraine, time series analysis methods were used to calculate chain growth rates (CGR) and regression analysis [2]. The forecast was based on linear ( $y = a_0 + a_1 \cdot x$ ) regression equations for 3 years (2018-2020). The correspondence of the constructed regression models with the actual data (adequacy) was evaluated by Fisher's criterion (F), and the optimality was evaluated by the value of the coefficient of determination ( $r^2$ ) [2].

#### RESULTS AND DISCUSSION

Analysis of the number of first registered cases of HIV infection over a 13-year's period (2005-2017) showed an increase in morbidity in Ukraine by 1.5 times (from 29.2 to 42.8 per 100 thousand population), and in Dnipropetrovsk region – by 1.9 times (from 58.9 to 110.5 per 100 thousand population) (Table 1). Comparison of HIV incidence rates in Ukraine and Dnipropetrovsk region showed a

probable predominance of indicators in the region both in some years and on average for the whole period – 92.8±4.2 per 100 thousand in the region against 41.0±1.4 per 100 thousand population in Ukraine (p<0.001). There were fluctuations in some periods, including their decline in 2014-2015, which

may have been due to the situation in the country during this period and the corresponding difficulties in registering cases. On average, the growth rate of HIV incidence in Ukraine ranged within the median of 5.3 (IQR 0.2-7.9)%, in the region - the median – 7.2 (-3.7-16.0)%.

Table 1

**Dynamics of HIV/AIDS incidence rate in population of Ukraine and Dnipropetrovsk region for the period of 2005-2017**

Years	HIV patients						AIDS patients					
	Ukraine			Dnipropetrovsk region			Ukraine			Dnipropetrovsk region		
		per 100 thousand	growth rates, %	abs. number	per 100 thousand	growth rates, %	abs. number	per 100 thousand	growth rates, %	abs. number	per 100 thousand	growth rates, %
2005	13770	29.2	–	2045	58.9	–	4217	9	–	778	22.4	–
2006	16078	34.4	17.8	2465	71.8	21.9	4723	10.1	12.2	1050	30.6	36.6
2007	17669	38	10.5	2668	78.2	8.9	4573	9.8	-3.0	715	21	-31.4
2008	18963	40.9	7.6	3084	90.5	15.7	4380	9.5	-3.1	782	23	9.5
2009	19840	43.2	5.6	3626	107.8	19.1	4437	9.7	2.1	928	27.6	20.0
2010	20489	44.6	3.2	3258	96.9	-10.1	5861	12.8	32.0	1116	33.4	21.0
2011	21177	46.2	3.6	3447	103.3	6.6	9189	20.1	57.0	1784	53.6	60.5
2012	19410	44.9	-2.8	3429	103.4	0.1	9690	22.4	11.4	1903	57.4	7.1
2013	20294	47.1	4.9	3450	104.7	1.3	9450	20.8	-7.1	2071	62.9	9.6
2014	19273	44.8	-4.9	3184	96.9	-7.4	9844	22.9	10.1	2120	64.5	2.5
2015	15869	37	-17.4	2881	88.2	-9.0	8468	19.8	-13.5	2047	62.7	-2.8
2016	17066	40	8.1	3085	95.1	7.8	8852	20.7	4.5	1982	61.1	-2.6
2017	18194	42.8	7.0	3581	110.5	16.2	9308	21.9	5.8	2181	67.3	10.1
Average												
M±m or Me (IQR)	18314.8±595.6	41.0±1.4	5.3 (0.2-7.9)	3092.5±130.1*	92.8±4.2*	7.2 (-3.7-16.0)	7153.2±671.2	16.1±1.6	5.2 (-3.0-11.8)	1496.7±165.6*	45.2±5.2*	9.6 (0.0-20.5)

Note: growth rate of indicator calculated relative to previous period in %; \* – p<0.001 compared to Ukraine.

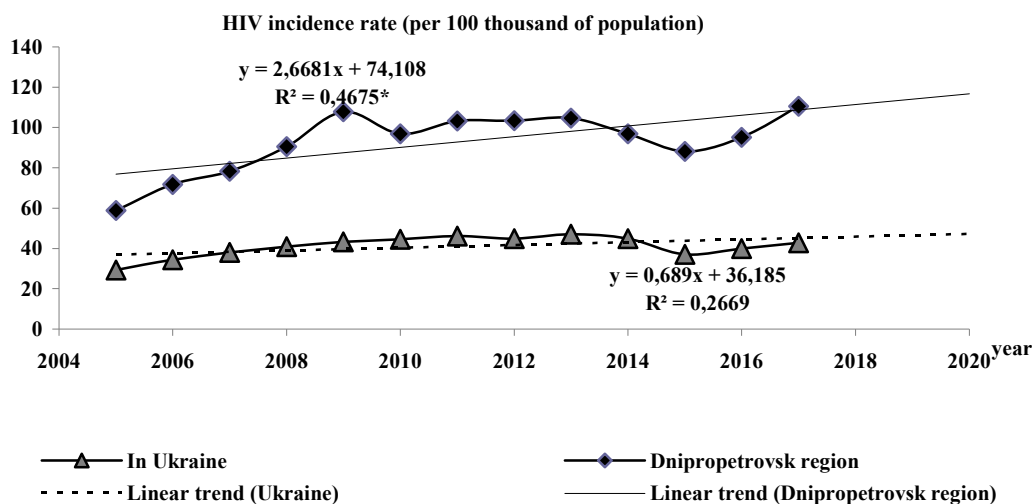
Using regression analysis methods, mathematical trend lines for HIV incidence rates have been constructed (Fig. 1), which show a steady trend of growth in the incidence rate at the regional level. The regression equation for approximating the

incidence of HIV in Dnipropetrovsk region is as follows:

$$y=2.6681 * x+74.108, \tag{1}$$

where y – predicted number of HIV cases per 100 thousand of population, x – (year of prediction – 2004), 2.6681; 74.108 – calculated coefficients of regression.





Notes: \* –  $p < 0.01$ ; x – (year of prediction – 2004).

**Fig. 1. Dynamics of HIV incidence rate in Ukraine and Dnipropetrovsk region for the period of 2005-2017 and prognosis for 2018-2020**

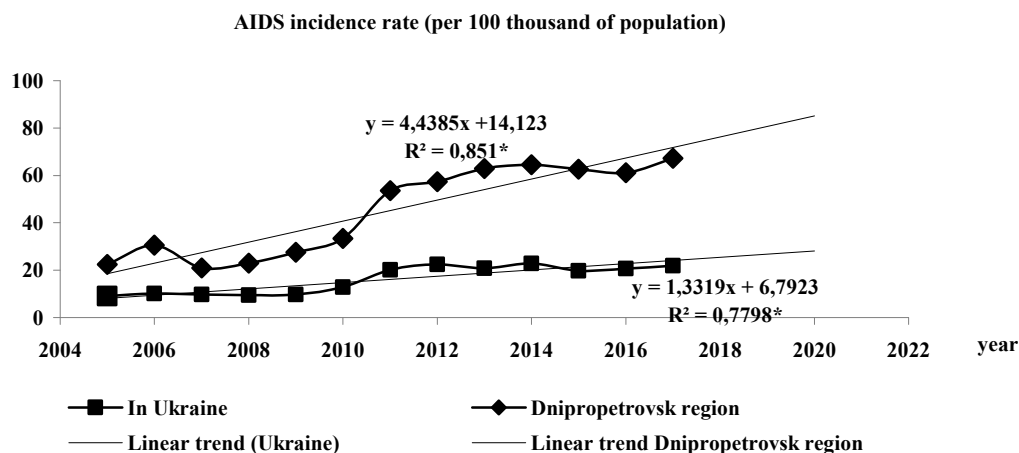
Operational characteristics of the model: the coefficient of determination –  $R^2=0.4675$  and Fisher's criterion  $F=9.66$  ( $p=0.010$ ) indicate the probability of approximation and allow to predict the level of HIV incidence in the region in the coming years. Thus, the calculated prediction levels of HIV incidence in Dnipropetrovsk region in 2018-2020 average  $114.1 \pm 1.54$  cases per 100 thousand of population per year. At the national level, the tendencies to increase in the level of HIV incidence were less pronounced:  $R^2=0.2669$ , Fisher's criterion  $F=4.0$ ,  $p=0.070$ .

The incidence of AIDS cases grew more significantly, the level of which in Ukraine increased from 9.0 per 100 thousand in 2005 to 21.9 per 100 thousand in 2017 (2.4 times), in the region – from

22.4 up to 67.3 per 100 thousand of population (3 times) (Table 1), which indirectly indicates an increase in the incidence of opportunistic diseases [4, 5]. On average, the growth rate of the indicator in Ukraine fluctuated within the median 5.2 (IQR -3-11.8)%, in the region - the median 9.6 (0.0-20.5)%.

Mathematical lines of AIDS incidence trends also show clear trends of growth of these indicators at the national and regional levels. The regression equations for approximating the level of AIDS incidence shown in Figure 2 have high operational characteristics:

- for Ukraine:  $R^2=0.7798$ , Fisher's criterion  $F=38.95$ ,  $p < 0.001$ ;
- for the region:  $R^2=0.851$ , Fisher's criterion  $F=62.83$ ,  $p < 0.001$ .



Note: \* –  $p < 0.001$ ; x – (year of prediction – 2004).

**Fig. 2. Dynamics of AIDS incidence rate in Ukraine and Dnipropetrovsk region for the period of 2005-2017 and prognosis for 2018-2020**

The predicted levels of AIDS incidence in Ukraine in 2018-2020 average  $26.8 \pm 0.77$  cases per 100 thousand of population per year; in Dnipropetrovsk region –  $80.7 \pm 2.56$  per 100 thousand per year, which is 3 times more than the national indicator.

The increase in the primary incidence of HIV/AIDS leads to an increase in the number of such patients. Analysis of dispensary statistics for

2005-2017 showed significant growth rates of these indicators at both national and regional levels (Table 2), as well as a probable predominance of intensive indicators of HIV/AIDS in the region compared to Ukraine ( $p < 0.001$ ).

These tendencies to growth of indicators are shown also by the constructed mathematical lines of trends (fig. 3, 4) which have very high indicators of adequacy and optimality of models (Table 3).

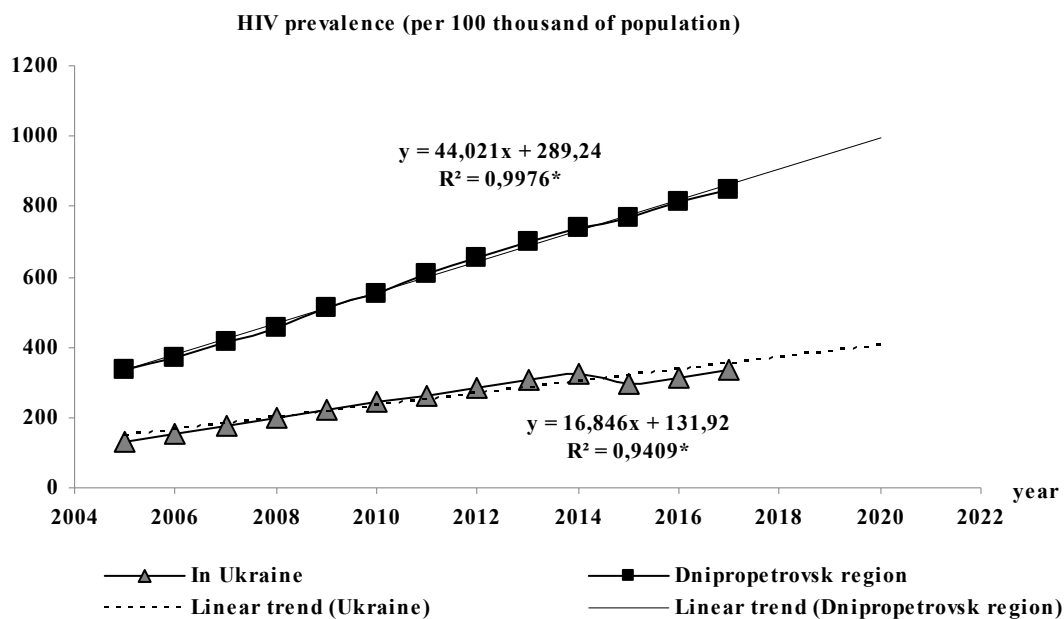
Table 2

**Dynamics of HIV/AIDS prevalence among population of Ukraine and Dnipropetrovsk region for the period of 2005-2017**

Years	HIV patients						AIDS patients					
	Ukraine			Dnipropetrovsk region			Ukraine			Dnipropetrovsk region		
	abs. number	per 100 thousand	growth rates, %	abs. number	per 100 thousand.	growth rates, %	abs. number	per 100 thousand	growth rates, %	abs. number	per 100 thousand	growth rates, %
2005	62888	133.5	-	11660	335.7	-	5092	10.8	-	709	20.4	-
2006	71958	154.3	15.6	12730	371.9	10.8	7175	15.4	42.6	1191	34.8	70.6
2007	81741	176.2	14.2	14079	414.2	11.4	8944	19.3	25.3	1444	42.5	22.1
2008	91717	198.6	12.7	15453	455.2	9.9	10410	22	14.0	1641	48.3	13.6
2009	101182	220.9	11.2	17196	512.7	12.6	11827	25.8	17.3	1983	59.1	22.4
2010	110401	242	9.6	18470	553.8	8.0	14030	30.8	19.4	2345	70.3	19.0
2011	120148	264.3	9.2	20105	605.9	9.4	18751	41.2	33.8	3218	97	38.0
2012	129136	283.4	7.2	21571	651.7	7.6	24090	52.9	28.4	4065	122.8	26.6
2013	139573	308.4	8.8	22962	697.8	7.1	29005	64.1	21.2	5073	154.2	25.6
2014	137970	322.5	4.6	24125	736.6	5.6	33279	77.8	21.4	6156	188	21.9
2015	126604	297.2	-7.8	25181	769.2	4.4	34016	79.8	2.6	7142	218.1	16.0
2016	132945	313.3	5.4	26338	815.1	6.0	38730	91.3	14.4	7986	247.1	13.3
2017	141371	333.3	6.4	27311	846.3	3.8	43816	103.3	13.1	8976	278.1	12.5
Average												
M±m or Me (IQR)	111356.5±7496	249.8±18.8	9.0 (5.9-12.0)	19783.2±1468.6*	597.4±47.6*	7.8 (5.8-10.3)	21474.2±3638.5	48.8±8.7	20.3 (14.2-26.9)	3994.5±778.6*	121.6±24.2*	22.0 (14.8-26.1)

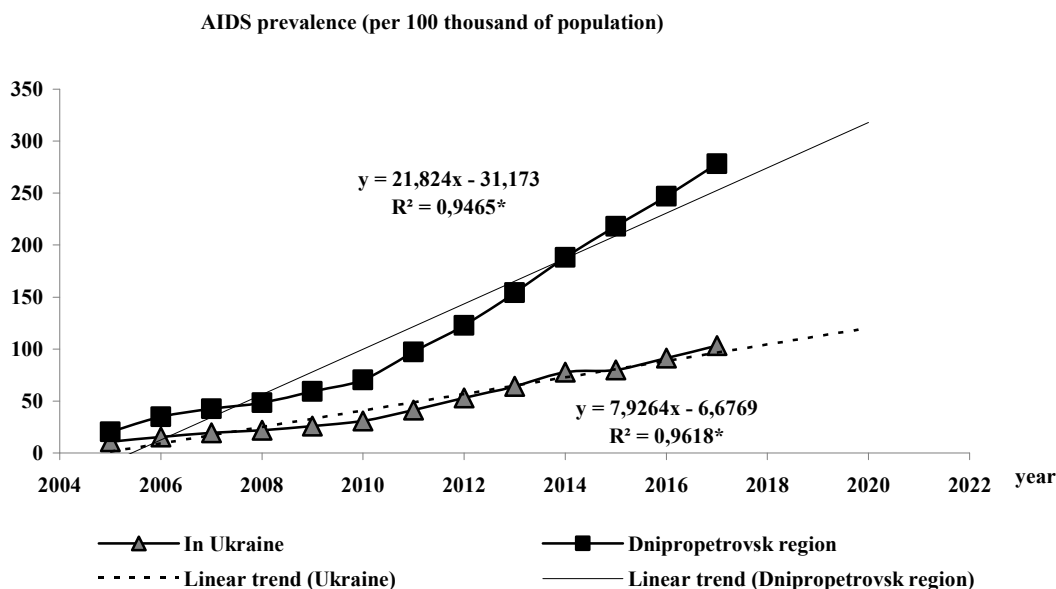
Note: growth rate of indicator calculated relative to previous period in %; \* –  $p < 0.001$  compared to Ukraine.





Note: \* –  $p < 0.001$ ;  $x$  – (year of prediction – 2004).

**Fig. 3 Dynamics of HIV prevalence in Ukraine and Dnipropetrovsk region for the period of 2005-2017 and prognosis for 2018-2020**



Note: \* –  $p < 0.001$ ;  $x$  – (year of prediction – 2004).

**Fig. 4. Dynamics of AIDS prevalence in Ukraine and Dnipropetrovsk region for the period of 2005-2017 and prognosis for 2018-2020**

As can be seen from Table 3, calculated from the regression equations, the predicted levels of HIV prevalence in Ukraine in 2018-2020 average  $384.6 \pm 9.7$  cases per 100 thousand of population annually, in Dnipropetrovsk region –  $949.6 \pm 25.4$  per 100 thousand.

Relevant prognostic indicators of AIDS prevalence in these periods are: in Ukraine –  $112.2 \pm 4.6$  per 100 thousand of population, in the region –  $296.2 \pm 12.6$  per 100 thousand of population annually.

Table 3.

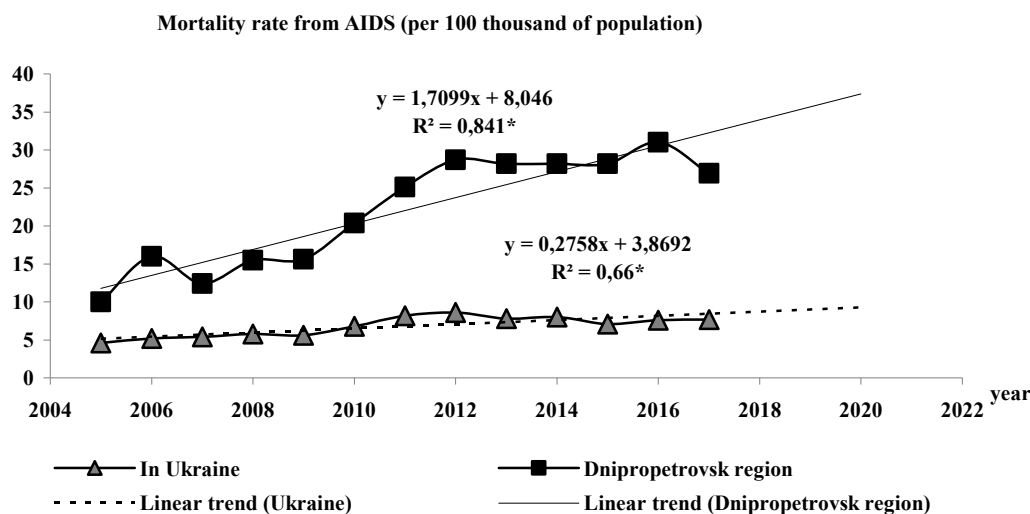
**Characteristics of mathematical models and prognosis of HIV/AIDS prevalence in Dnipropetrovsk region for the period of 2018-2020**

Parameters		Ukraine	Dnipropetrovsk region
<i>Prevalence of HIV-infection</i>			
Equation and characteristics of regression line (trend)		$y = 16.846x + 131.92$ F=175.2; p<0.001; R <sup>2</sup> =0.9409	$y = 44.021x + 289.24$ F=4633.7; p<0.001; R <sup>2</sup> =0.9976
Prognosis, per 100 thousand.	M±m	384.6±9.7	949.6±25.4
<i>AIDS prevalence</i>			
Equation and characteristics of regression line (trend)		$y = 7.9264x - 6.6769$ F=277.3; p<0.001; R <sup>2</sup> =0.9618	$y = 16.846x + 131.92$ F=194.8; p<0.001; R <sup>2</sup> =0.9465
Prognosis, per 100 thousand	M±m	112.2±4.6	296.2±12.6

Over the last 5 years, the number of cases of late HIV detection (in 3-4 clinical stages) remains almost unchanged (58.8% in 2012 and 56.1% in 2017 in Dnipropetrovsk region), which corresponds to the national data [4] and affects the prevalence of HIV infection and high mortality rate [1, 6, 9]. The analysis of AIDS mortality rates (2005-2017) also showed negative trends in their growth. Every year in Ukraine, more than 2,500 patients die of AIDS, an average of 3024.7±151.2 people or 6.8±0.4 per 100 thousand of population, the average growth rate is a median – 3.8 (IQR -3.4-13,0)%. In the Dnipro-

petrovsk region, the average mortality rate is 715.3±66.9 people or 21.5±2.1 per 100 thousand of population, with an annual growth rate by 9.9 (IQR -1.7-25.0)%. The constructed regression lines (trends) of mortality from the consequences of AIDS also show clear tendencies to increase in indicators at the national and regional levels and have high operational characteristics (Fig. 5):

- for Ukraine: R<sup>2</sup>=0.660, Fisher's criterion F=21.35, p<0.001;
- for the region: R<sup>2</sup>=0.841, Fisher's criterion F=58.16, p<0.001.



Note: \* – p<0.001; x – (year of prediction – 2004).

**Fig. 5. Dynamics of mortality rate from AIDS in Ukraine and in Dnipropetrovsk region for the period of 2005-2017 and prognosis for 2018-2020**

Predicted AIDS mortality rates in Ukraine in 2018-2020 average  $8.01 \pm 0.16$  cases per 100 thousand of population per year; in the Dnipropetrovsk region –  $33.7 \pm 0.99$  per 100 thousand per year.

Given the data of studies in our country [1, 4], which indicate a significant number of people who do not know about their HIV status, and those who, even knowing about the status, remain out of the dispensary, the situation with HIV in the region and in Ukraine seems even more tense and it is needed to raise awareness about the scale of this problem [5].

The calculated prognostic levels of AIDS morbidity and mortality in Ukraine and in the Dnipropetrovsk region naturally reflect the growth of the incidence of opportunistic infections and mortality from these diseases.

### CONCLUSIONS

Thus, the analysis of statistical data and mathematical modeling of trends showed some variability in HIV incidence in Ukraine and Dnipropetrovsk

region, with probably higher incidence rates and a tendency to increase in the coming years at the regional level. There are clear trends in the growing number of newly registered AIDS cases, the total number of HIV/AIDS patients and mortality from their consequences both in Ukraine as a whole and in the Dnipropetrovsk region. Calculated predictions for HIV incidence rates and first-reported AIDS cases in Ukraine and the region in the coming years may be useful for predicting the number of opportunistic infections and planning needs for hospitalization and treatment of HIV/AIDS patients.

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