

## RESEARCH ARTICLE

# Analysis of Cancer Incidence and Mortality in the Industrial Region of South-East Siberia from 1991 through 2010

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### Abstract

Kemerovo is an industrial region of the Russian Federation characterized by highly developed mining, chemical, metallurgical and power industries. Many of the factories were closed down due to the socioeconomical crisis in the early 90's, and economic potential of the survivors has also decreased significantly. Paradoxically, this has led to the improvement of the ecological situation in the region and elimination of exposure to many chemical carcinogens. This factor, in combination with the improvement of oncological care, might be expected to have led to a decline of cancer incidence and mortality in the region. To assess trends of cancer incidence and mortality in Kemerovo Region, we therefore carried out an analysis of relevant epidemiological data during 1991-2010. In fact, a significant increase of cancer incidence overall was revealed during 2001-2010. Male cancer incidence was significantly higher than female cancer incidence. Regarding gastric cancer incidence, statistically significant differences during 2001-2010 were found only for men, and male incidence exceeded female incidence. Concerning colorectal cancer incidence, it was lower during 2001-2005 and 2006-2010 as compared to the period of 1991-1996. Lung cancer incidence was significantly higher during 1991-2000 compared to 2001-2010. Among urban populations, cancer incidence was higher in comparison with rural population, but a gradual steady convergence of trends of cancer incidence among urban and rural populations was noted. Lung cancer, breast cancer, colorectal cancer, non-melanoma skin cancer, and gastric cancer are the most prevalent cancer forms in Kemerovo Region. There were no differences in cancer mortality between 2001-2005 and 2006-2010; however, male cancer mortality exceeded female cancer mortality. A similar situation was observed for gastric cancer, colorectal cancer, and lung cancer. Cancer mortality among urban populations exceeded mortality among rural population, for both genders. We suggest that these data can be used for development of modern programs of cancer prevention and early diagnostics in industrial regions of Siberia.

**Keywords:** Cancer - incidence - prevalence - mortality - industry - industrial region - Russian Siberia

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### Introduction

According to the data of International Agency for Research on Cancer (IARC), about 12.4 millions of new cancer cases, 7.6 millions of cancer-caused deaths, and 28 millions of cancer survivors were registered in 2008 worldwide (Ferlay et al., 2010; Jemal et al., 2010; 2011). More than half of cancer cases and two-thirds of cancer deaths occur in low- and middle-income countries (Ferlay et al., 2010; Jemal et al., 2010; 2011).

The pattern of cancer incidence differs significantly in low-, middle-, and high-income countries due to a distinct prevalence of risk factors (Ferlay et al., 2010; Jemal et al., 2010; 2011). These risk factors include physical factors (ionizing and non-ionizing radiation), chemical factors (tobacco smoking, alcohol abuse, environmental pollution,

professional exposure), biological factors (carcinogenic infectious agents), and genetic factors (Ferlay et al., 2010; Jemal et al., 2010; 2011). According to the data of the World Bank (2012), Russian Federation is an upper-middle-income country (GNI per capita \$10,400 by Atlas method). The structure of cancer incidence and mortality in different Russian regions varies greatly depending on geographical position, socioeconomical and ecological status, ethnical features, etc (Zhivotovskiy et al., 2012).

Kemerovo Region is located in South-East Siberia, and it is an industrial Russian region with developed mining, chemical, metallurgical, and power industry. The population of the region is 2,821,600 (2010). Many of the factories were closed down due to socioeconomical crisis in the early 90's; therefore, the power of survived factories decreased significantly. It has led to the improvement of

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the ecological situation in the region and to the elimination of exposure to many chemical carcinogens. Since long latent period (10-40 years) is required for cancer development, it is feasible to suggest that cancer incidence in the region may start to decline only from 2006-2010, and, unfortunately, not earlier.

Methods of cancer prevention, early diagnostics and treatment have been substantially improved during the last decade. New methods of chemo- and radiotherapy have been introduced, and the possibilities for their conduction and general oncological care have been widened in the oncological units of Kemerovo Region. We suggest these factors might also lead to decline of cancer mortality in the region.

To assess the trend of cancer incidence and mortality in Kemerovo Region, we carried out an analysis of the relevant epidemiological data during the period from 1991 to 2010.

## Materials and Methods

Cancer incidence and mortality rates in Kemerovo Region have been rendered by Federal Budget Healthcare Unit «Kemerovo Regional Centre of Hygiene and Epidemiology». Regarding cancer forms, we have selected the most widespread malignant tumors, namely, gastric cancer, colorectal cancer, lung cancer, breast cancer, ovarian cancer. In addition, thyroid cancer has been also included due to its topicality for Kemerovo Region since there is a lack of dietary iodine among the population. However, thyroid cancer has been excluded from the analysis of cancer mortality because of its low lethality. Crude ratios have been standardized by age. To precise the analysis of temporal trends, 20-year-period has been divided into two decades (1991-2000, 2001-2010) and into four 5-year-periods (1991-1995, 1996-2000, 2001-2005, and 2006-2010). We have also calculated the trend rate using the least square method and the mean ( $m$ ) with 95% confidence intervals (CI). 5-year-periods have been compared between each other by their means and confidence intervals; the same has been carried out for the decades. The differences between time periods have been regarded as statistically significant only when the confidence intervals of their means did not overlap. We have also assessed the prevalence of distinct malignant tumors during 2001-2010. For a more precise analysis, this time period has been divided into three parts (2001-2004, 2005-2008, and 2009-2010). In addition, we assessed the mortality rates during 2001-2010 by the same methods as the incidence rates. Unfortunately, the mortality rates from 1991-2000 have not been obtained due to technical difficulties. The statistical analysis has been performed using MS Excel 2010 (Microsoft Corporation, USA, license number X12-22652) and MedCalc v. 9.6.4.0 (MedCalc Software, Belgium).

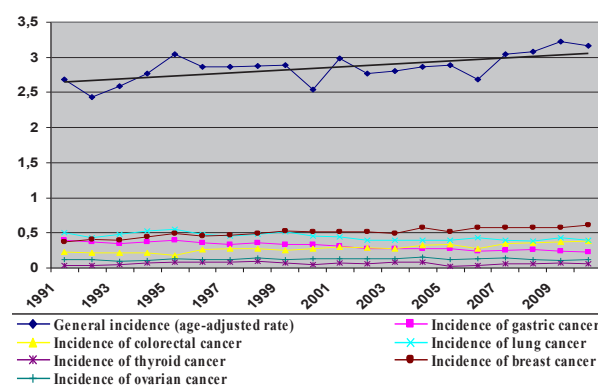
## Results

### Incidence

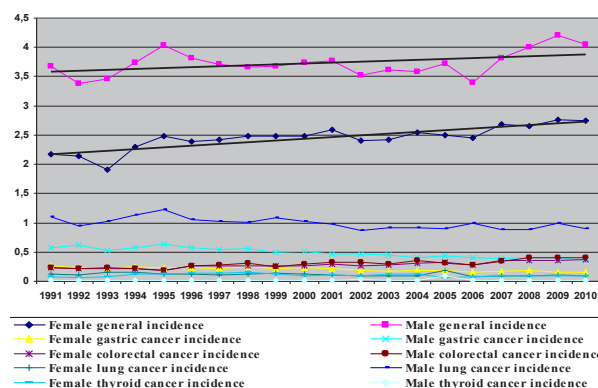
The statistical analysis revealed a statistically significant increase of cancer incidence during 2001-

2010 compared to 1991-2000 ( $m=3.04$ ; 95%CI=2.9-3.0 and  $m=2.76$ ; 95%CI=2.7-2.8, trend rate 0.04 and 0.02, respectively, Figure 1). A trend to increase of cancer incidence during 1991-2010 was also noticed (trend rate 0.022). Similar differences were found between 2006-2010 and 1991-1996 ( $m=3.04$ ; 95%CI=2.9-3.0 and  $m=2.7$ ; 95%CI=2.6-2.8, trend rate 0.11 and 0.1, respectively). Female cancer incidence was also higher during 2001-2010 in comparison with 1991-2000 ( $m=2.58$ ; 95%CI=2.5-2.7 and  $m=2.33$ ; 95%CI=2.3-2.4, trend rate 0.033 and 0.051, respectively, Figure 2). A similar trend was observed between 5-year periods: 1991-1995 ( $m=2.2$ ; 95%CI=2.1-2.3, trend rate 0.08), 1996-2000 ( $m=2.45$ ; 95%CI=2.4-2.5, trend rate 0.03), 2001-2005 ( $m=2.49$ ; 95%CI=2.4-2.6, trend rate 0.003), 2006-2010 ( $m=2.66$ ; 95%CI=2.6-2.7, trend rate 0.07). Among men, a significant increase of cancer incidence was revealed during 2006-2010 compared to 2000-2005 ( $m=3.89$ ; 95%CI=3.8-4.0 and  $m=3.64$ ; 95%CI=3.5-3.7, trend rate 0.17 and -0.002, respectively, Figure 2). When gender differences were analyzed, male cancer incidence during all time periods was significantly higher than female cancer incidence (for 1991-2010  $m=3.73$ ; 95%CI=3.6-3.8 and  $m=2.45$ ; 95%CI=2.4-2.6, respectively). Among both men and women the trend to increase of cancer incidence during 1991-2010 was noted (trend rate 0.02 and 0.03, respectively).

Regarding gastric cancer incidence, statistically significant differences were found only for men. During 1991-2000 incidence was higher than during 2001-2010 ( $m=0.56$ ; 95%CI=0.5-0.6, and  $m=0.42$ ; 95%CI=0.37-0.42, respectively, trend rate was -0.01 in both time periods).



**Figure 1. Cancer Incidence in Kemerovo Region During 1991-2010.**



**Figure 2. Gender Differences in Cancer Incidence in Kemerovo Region During 1991-2010.**

Male incidence exceeded female incidence (for 1991-2010  $m=0.49$ ; 95%CI=0.46-0.53 and  $0.2$ ; 95%CI=0.17-0.23, trend rate -0.01 and -0.005, respectively).

Concerning colorectal cancer incidence, during 1991-1996 ( $m=0.21$ ; 95%CI=0.18-0.23, trend rate -0.01) it was lower than during 2001-2005 and 2006-2010 ( $m=0.31$ ; 95%CI=0.29-0.34 and  $m=0.35$ ; 95%CI=0.3-0.4, trend rate 0.01 and 0.02, respectively). Among women there were no temporal differences, whilst among men they were the same as the general ones. However, there were no statistically significant gender differences in colorectal cancer incidence.

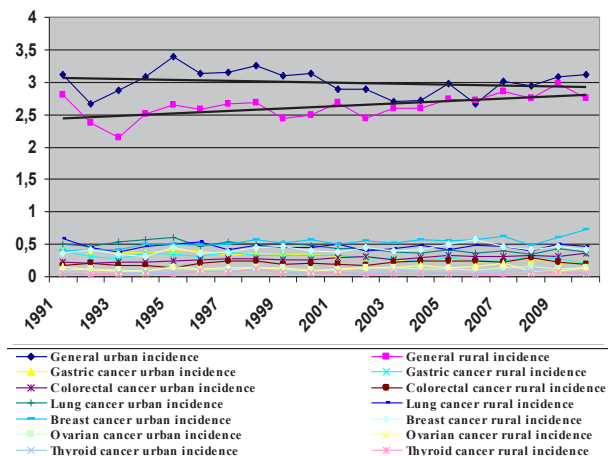
Lung cancer incidence was significantly higher during 1991-2000 compared to 2001-2010 ( $m=0.49$ ; 95%CI=0.47-0.52 and  $m=0.41$ ; 95%CI=0.37-0.46, respectively, trend rate was -0.001 in both periods). Among men, lung cancer incidence was significantly higher than in women during all time periods (for 1991-2010  $m=0.99$ ; 95%CI=0.9-1.0 and  $m=0.12$ ; 95%CI=0.09-0.15, trend rate was 0.01 and -0.002, respectively).

Regarding thyroid cancer, there were no differences between time periods, but female incidence was

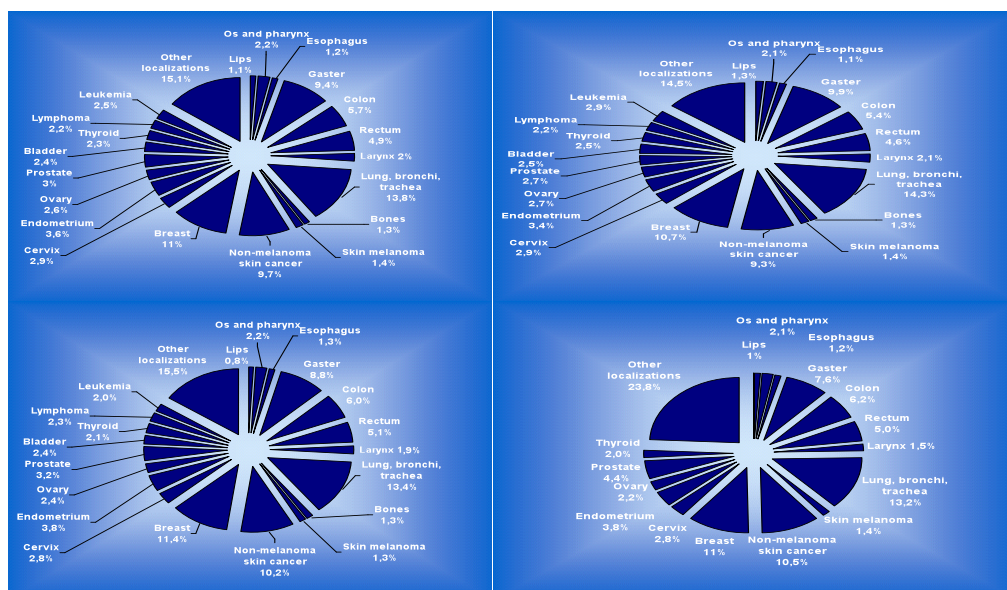
significantly higher than male incidence (for 1991-2010  $m=0.1$ ; 95%CI=0.08-0.12 and  $m=0.02$ ; 95%CI=0.01-0.03, trend rate was -0.001 and 0.001, respectively). There were also no differences in breast cancer and ovarian cancer incidence between distinct time periods, trend rate during 1991-2010 was 0.01 for breast cancer and -0.001 for ovarian cancer.

We also calculated differences in incidence between urban and rural population (Figure 3). Among urban female population cancer incidence was higher in comparison with rural female population (for 1991-2010  $m=2.62$ ; 95%CI=2.5-2.7 and  $m=2.21$ ; 95%CI=2.0-2.4, trend rate was -0.005 and 0.02, respectively). A similar trend was also observed for males (for 1991-2010  $m=4.04$ ; 95%CI=3.9-4.2 and  $3.4$ ; 95%CI=3.2-3.7, trend rate -0.06 and 0.02, respectively), but in this case these differences were based on 1991-2000 period ( $m=4.42$ ; 95%CI=4.3-4.5 and  $m=3.28$ ; 95%CI=3.0-3.5, trend rate -0.1 and -0.05, respectively), since during 2001-2010 differences in cancer incidence between urban and rural male population were not statistically significant. It is also important to note gradual steady convergence of trends of cancer incidence among urban and rural population due to decrease of incidence among urban population (trend rate during 1991-2010 was -0.02) and to increase of incidence among rural population (trend rate during 1991-2010 was 0.02).

Concerning colorectal cancer, incidence among urban population was significantly higher compared to rural population only during 2006-2010 ( $m=0.33$ ; 95%CI=0.28-0.4 and  $m=0.24$ ; 95%CI=0.2-0.27, trend rate 0.01 and -0.01, respectively), and this difference may be based on increase of incidence among male urban population in comparison with male rural population ( $m=0.37$ ; 95%CI=0.3-0.4 and  $m=0.25$ ; 95%CI=0.2-0.28, trend rate 0.01 and -0.001, respectively). Among female urban population, colorectal cancer incidence was significantly higher than among female rural population only during 1991-1995 ( $m=0.25$ ; 95%CI=0.2-0.3 and  $m=0.16$ ; 95%CI=0.13-0.19, trend rate -0.02 and -0.004,



**Figure 3. Differences in Cancer Incidence among Urban and Rural Population in Kemerovo Region During 1991-2010.**



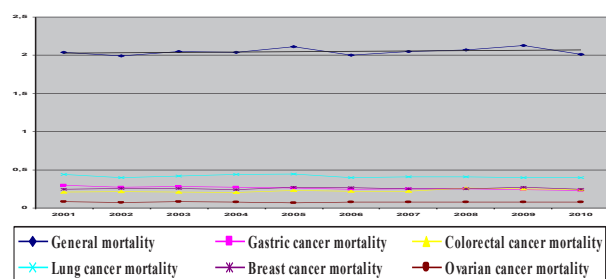
**Figure 4. Cancer Prevalence in Kemerovo Region During 2001-2010.** Upper left Diagram-2001-2010, Upper right Diagram-2001-2004, Lower left Diagram-2005-2008, Lower right Diagram-2009-2010.



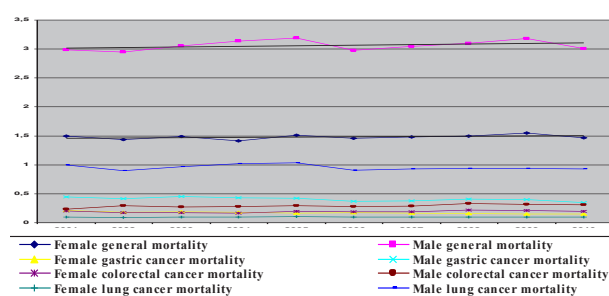
respectively).

Breast cancer incidence among the urban population was higher than among rural population only during 1996-2001 ( $m=0.53$ ; 95%CI=0.48-0.61 and  $m=0.41$ ; 95%CI=0.34-0.47, trend rate 0.02 and 0.01, respectively) and during 2001-2005 ( $m=0.54$ ; 95%CI=0.5-0.6 and  $m=0.43$ ; 95%CI=0.33-0.49), that led to statistically significant differences during 1991-2010 ( $m=0.53$ ; 95%CI=0.49-0.58 and  $m=0.42$ ; 95%CI=0.34-0.48). There were no statistically significant differences between urban and rural population regarding gastric cancer, lung cancer, thyroid cancer, and ovarian cancer incidence.

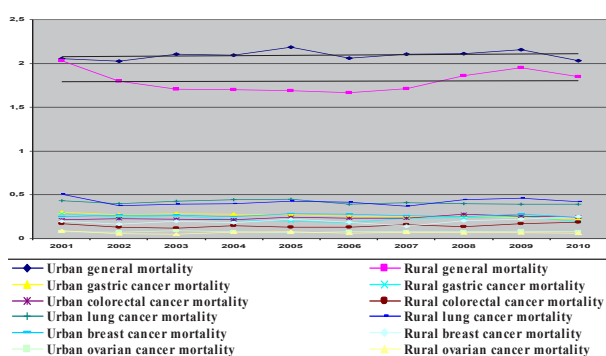
When the analysis of cancer prevalence during 2001-2010 was performed (Figure 4), we found that the first most common cancer was lung cancer (together with cancer of trachea and bronchi its share reached 13.8%), the second most common cancer was breast cancer (11%), the third most common cancer was colorectal cancer (10.6%), the fourth most common cancer was basal cell and squamous cell skin cancer (9.7%), the fifth most common cancer was gastric cancer (9.4%). Share of every other malignant tumor did not exceed 4%. During 2001-2004 the pattern of prevalence was similar excluding



**Figure 5. Cancer Mortality in Kemerovo Region During 2001-2010.**



**Figure 6. Gender Differences in Cancer Mortality in Kemerovo Region During 2001-2010.**



**Figure 7. Differences in cancer mortality among urban and rural population of Kemerovo Region during 2001-2010**

the fact that gastric cancer was the fourth most common cancer (9.9%), and basal cell and squamous cell skin cancer was only the fifth most common cancer (9.3%). During 2005-2008 the pattern of prevalence was the same as during 2001-2010, and during 2009-2010 colorectal cancer became the second most common cancer, so breast cancer became the third most common cancer (11.2% and 11%, respectively). During the all three time periods we observed a steady decline of gastric cancer prevalence (9.9% during 2001-2004, 8.8% during 2005-2008, and 7.6% during 2009-2010), lung cancer prevalence (14.3% during 2001-2004, 13.4% during 2005-2008, and 13.2% during 2009-2010), ovarian cancer prevalence (2.7% during 2001-2004, 2.4% during 2005-2008, and 2.2% during 2009-2010), thyroid cancer prevalence (2.5% during 2001-2004, 2.1% during 2005-2008, and 2% during 2009-2010), and laryngeal cancer prevalence (2.1% during 2001-2004, 1.9% during 2005-2008, and 1.5% during 2009-2010), and steady elevation of basal and squamous cell skin cancer prevalence (9.3% during 2001-2004, 10.2% during 2005-2008, and 10.5% during 2009-2010), colorectal cancer prevalence (10% during 2001-2004, 11.1% during 2005-2008, and 11.2% during 2009-2010), and prostate cancer prevalence (2.7% during 2001-2004, 3.2% during 2005-2008, and 4.4% during 2009-2010).

### Mortality

Analysis of cancer mortality in Kemerovo Region was carried out only during 2001-2010, since due to technical reasons it was not possible to obtain the relevant data about the previous years. There were no differences in cancer mortality between 2001-2005 and 2006-2010 (trend rate 0.004, Figure 5). However, significant gender differences were found, and male cancer mortality significantly exceeded female cancer mortality (for 2001-2010  $m=3.06$ ; 95%CI=3.0-3.2 and 1.48; 95%CI=1.42-1.55, trend rate 0.01 and 0.004, respectively, Figure 6). A similar situation was observed for some malignant tumors, such as gastric cancer (for 2001-2010  $m=0.4$ ; 95%CI=0.37-0.42 and  $m=0.17$ ; 95%CI=0.15-0.19, trend rate -0.01 and -0.005, respectively), colorectal cancer (for 2001-2010  $m=0.29$ ; 95%CI=0.26-0.32 and  $m=0.19$ ; 95%CI=0.17-0.21, trend rate 0.01 and 0.003, respectively) and lung cancer (for 2001-2010  $m=0.96$ ; 95%CI=0.9-1.0 and 0.1; 95%CI=0.08-0.12, trend rate -0.005 and 0.0003).

Cancer mortality among urban population exceeded the one among rural population (for 2001-2010  $m=2.09$ ; 95%CI=2.0-2.2 and 1.8; 95%CI=1.7-1.9, trend rate 0.004 and 0.001, respectively, Figure 7). It was fair for both genders (for males  $m=3.14$ ; 95%CI=3.0-3.2 and 2.68; 95%CI=2.5-2.9, trend rate 0.01 and -0.01, respectively; for females  $m=1.52$ ; 95%CI=1.5-1.6 and 1.23; 95%CI=1.1-1.4, respectively, trend rate 0.004 in both cases). In addition, colorectal cancer mortality among males was also higher among urban population compared to the rural population (for 2001-2010,  $m=0.3$ ; 95%CI=0.26-0.33 and  $m=0.19$ ; 95%CI=0.16-0.23, trend rate 0.01 and 0.006, respectively). There were no statistically significant differences in mortality among urban and rural population regarding gastric cancer, lung cancer, breast cancer, and ovarian cancer.

## Discussion

An improvement of methods of cancer diagnostics and regular conduction of screening measures may be the reasons for an increase in cancer incidence in Kemerovo Region. In addition, distinct temporal risk factor patterns and differences in tumor latent period may also affect the incidence. Such alterations may lead to stochastic elevation or decline of cancer incidence in certain time periods. An increased cancer incidence (particularly gastric cancer, colorectal cancer and lung cancer incidence) among males compared to females may be related to a larger proportion of males among workers on mining, chemical, and metallurgical factories where exposure to carcinogens is high. In addition, the share of smoking- and alcohol-caused cancer cases is greater among males than among females (in both past and present times). In addition, decline of gastric and lung cancer incidence among males may be connected with the shutdown (in 90's) of the majority of factories emitting various carcinogens. Gastric cancer incidence could also decline due to the implemented programs of detection of precancerous gastric lesions in the combination with implemented therapeutic ways to eradicate *Helicobacter pylori*. Lung cancer incidence might also decrease because of improvement of cigarettes' quality.

An increase in cancer incidence among urban population in comparison with rural population, possibly, can be explained by worse ecological situation (higher concentration of carcinogens in the air, water, and soil), by concentration of factories emitting carcinogens in the cities, and, feasibly, by presence of the modern methods of diagnostics. An observed trend to convergence of cancer incidence among urban and rural population may be explained by the gradual improvement of ecological situation and decrease of power of factories (that can lead to decline of cancer incidence among urban population) in combination with improving cancer diagnostics and urbanization of lifestyle among rural population (that may result in elevation of cancer incidence among rural population).

An increase in cancer mortality among males compared to females, and among urban population in comparison with the rural population is possibly due to elevated incidence in these groups. However, among male urban population colorectal cancer mortality is significantly higher than in male rural population, although there are no significant differences in incidence. Nevertheless, during 2006-2010 (in the second half of analyzed time period) colorectal cancer incidence among male urban population was significantly higher than among male rural population, than, feasibly, can explain observed mortality increase.

On the basis of conducted analysis of incidence, prevalence, and mortality, it is possible to conclude that lung cancer, breast cancer, colorectal cancer, gastric cancer and non-melanoma skin cancer are the most problematic malignant tumors in Kemerovo Region.

In Kazakhstan, a list of the most common neoplasms include esophageal cancer, lung cancer, stomach cancer, and breast cancer, with the trend to decrease of overall cancer incidence but to increase of breast cancer incidence

(Igissinov et al., 2011; Bilyalova et al., 2012). In European Union (EU) countries, significant decline of cancer mortality was observed from 80's among males, and even earlier among females (La Vecchia et al., 2010). In the time period between 1990-1994 and 2000-2004 cancer mortality in EU countries decreased by 9% among males and by 8% among females, reaching 168.0/100,000 and 96.9/100,000, respectively (La Vecchia et al., 2010). In the following years, cancer mortality still continued to decline among both males and females, and in 2011, according to the calculations, it should reach 142.8/100,000 among males and 85.3/100,000 among females compared to 153.8/100,000 and 90.7/100,000 in 2007 among males and females, respectively (Malvezzi et al., 2010). So, during 2007-2011 cancer mortality in EU countries should decrease by 7% among males and by 6% among females (Malvezzi et al., 2010). The reasons of such decline may include increase of oncological awareness in the population, implementation of new programs of prevention and early diagnostics (particularly, revealing of precancerous lesions), and improvement of treatment schemes. The absence of such decline in investigated region, possibly, can be explained by insufficient development of measures indicated above. However, cancer incidence still increases as in Kemerovo Region as in EU countries, meaning the necessity of improvement of existing measures and implementation of effective programs of cancer prevention and early diagnostics.

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