1. Introduction
The present study is the result of the first analysis of lung malignant neoplasms incidence for different histological types in male Mayak Production Association workers with follow-up longer than 50 years. The risks of cancer incidence are derived for the first time using the recently updated organ-specific dose estimates, Mayak doses-2006 (MVD-M2006).

2. Objectives
The estimation of radiation risk for lung cancer at prolonged occupational exposure for different histological types of tumor.

3. Study Population and Methods
The cohort included 16,685 male workers employed at the reactor, radioactive waste, and plutonium production facilities during 1946-1982 (Table 1). This cohort was followed up to the first cancer diagnosis or non-malignant skin cancers (NMSC) mortality or non-cancer death, whichever occurred first, on December 31, 2004, which was the earlier of the two. This represents 389,154 person-years of experience. 65 workers had cancer and 414 had lung cancer. Histological verification was available for 77.5% cases (Fig. 1). Information on internal gamma doses was available for all 100% of workers, but only 47.5% (77.5%) of individuals potentially exposed to internal radiation were examined and 2317 of 2187 (1058) workers accumulated cancer to lung dose at 0.46 Gy (0.97 Gy), accumulated average Pd 0.11 Gy. Workers from the early period of plutonium without biomass measurements, were regarded as the monitored subjects with zero accumulated dose for the purpose of risk analyses. For workers with radiochromium and plutonium production facilities, who were not subject to biomass measurements, 6 ontogenetic based surrogates variable using methods described elsewhere (1) was introduced to account for effects of internal alpha-radiation for the risk assessment. Model parameters of the MN incidence rate were estimated with the Poisson software (2). The risk model has the form: \( A(\alpha) = A_0 \times (1 + \alpha \times \text{age} + \text{status} + \text{calendar}) \), where the ExF function were expressed as the sum of excess risk associated with external exposure (10% allocated external lung dose), monitored plutonium exposure (10% allocated plutonium exposure and 90% plutonium and high plutonium surrogates) as follows: ERR external (ERRE) plus ERR plutonium (ERRP) plus ERR omnium (ERRO). ERRO model and ERRE model were based on the excess risk associated with external exposure, monitored plutonium exposure and unmonitored plutonium exposure respectively.

4. Results
Risk estimates for lung cancer in general and for histological types of lung cancer from external, internal plutonium and lung dose and the high plutonium surrogate are shown in Table 2. A stronger dose-response relationship was found for adenocarcinoma lung cancer compared to other lung cancer types for plutonium internal dose to the lung, external dose and also for combined plutonium and adenocarcinoma lung dose. Estimated ERR external to adenocarcinoma lung cancer in relation to internal plutonium dose were 0.08% (95% CI: 0.03-0.23%), which was 14 times larger than the estimate for squamous cell lung cancer (ERR external = 0.06; 95% CI: <0.05-0.06) and about twice as large for other epithelial lung cancer (ERR=0.05; 95% CI: 0.01-0.14). For workers who were potentially exposed to plutonium, but not monitored, only significant association was observed for adenocarcinoma (ERRO=3.26; 95% CI of 0.16; 11.20) for combined surrogate category 5&6.

5. Discussion
In the current dosimetry system (MWSOS 2008) internal doses from alpha-radiation are averaged over the whole lung without accounting for non-uniformity of the radiation distribution. Therefore, there was a lot of studies on the dynamics of plutonium distribution in lung after intake of inhaled nuclides. These studies demonstrated a highly non-uniform distribution in lung, while most of the radionuclide was retained in the upper respiratory tracts and peripheral regions, which could be explained not by its high intake in those compartments, but rather by its slow clearance due to the low ventilation rates of those regions and long residence times of inhaled and alveolar-lung compartments might be higher than that averaged over the whole lung. When estimating risk not by homogeneous dose, but rather by dose distribution, ERR might be significantly different for different regions of the pathogen. The squamous-cell cancer was mainly localized in central lung compartments, which were exposed to higher doses in the process of plutonium intake with less exposure after exposure termination; therefore, they were estimated for squamous-cell lung cancer (ERR=0.08; 95% CI: <0.05-0.06) and about twice as large for other epithelial lung cancer (ERR=0.05; 95% CI: 0.01-0.14). For workers who were potentially exposed to plutonium, but not monitored, only significant association was observed for adenocarcinoma (ERRO=3.26; 95% CI of 0.16; 11.20) for combined surrogate category 5&6.

6. Conclusions
The study proved importance of epidemiological analysis of radiation risk based on incidence data, considering histological tumor type in particular. Besides the present study emphasizes significance of further studies in the course of internal dosimetry improvement in the field of Pu biodistribution in lung tissue, as well as through thorough study of non-radiation effect factors.

References

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