INTRODUCTION
Recent years much effort has been made to define harmful exposure conditions to ionising radiation and to monitor populations that could be suffering excessive exposure, to prevent adverse consequences. Radiation protection standards assume that radiation doses over natural background doses cause additional health risks, notably increase in the induction of cancers [1]. The main source of data on radiation risk comes from studies on Hiroshima and Nagasaki survivors, subjects exposed to high radiation doses in accidents or patients irradiated for medical reasons. The effects of chronic exposure to low doses of radiation are still not completely clear.

Monitoring of personnel occupationally exposed to ionising radiation consists of regular film dosimetric control and periodic health examination. The follow-up of certain specific biological parameters provides additional information which complements physical dosimetry and enables better evaluation of radiation effects. Even very low radiation doses of several mSv may cause changes in tissues and organs. While tissues greatly differ in sensitivity to irradiation, it is also important to distinguish whether an organism received a single, higher dose of irradiation or several dose fractions. The tolerance to fractionated irradiation is higher because most tissues have great capacity to recover unless permanently injured. Therefore, minor damages will never be observed. Genetic material in a living organism is particularly sensitive to irradiation. Mutagenic effect of ionising radiation has been extensively described. Monitoring studies have been accepted as parameters to evaluate the damage caused by ionising radiation on exposed professionals [2]. DNA damage caused by ionising radiation may be detected immediately after the exposure by the comet assay. It may also turn into chromosome damage.

METHODS
Chromosomal aberration (CA) analysis in human peripheral blood lymphocytes is an important technique for risk assessment in occupational exposure. Chromosome aberrations may be divided into two categories: stable or
symmetrical aberrations (pericentric inversions and translocations) which can pass through repeated divisions and persist in a cell population, and are potentially more serious, and unstable or asymmetrical aberrations (dicentrics, acentric fragments and ring chromosomes) in which the chromosome material does not divide equally between daughter cells so that damaged cells will be eliminated during successive cell divisions.

It is considered that stable and unstable aberrations are induced with equal frequency, but unstable aberrations appear to be less frequent in subsequent divisions because they lead to cell death [3,4]. As cells bearing dicentrics decline about 60% per cell generation, it has been shown that translocations are also not completely stable. Translocations also decline in cells, but much more slowly than dicentrics [5]. Fluorescence in situ hybridization (FISH) using whole-chromosome painting probes enables, in addition to asymmetrical aberrations, the detection of symmetrical aberrations, most notably translocations. But due to a high cost of that method, it is not possible to use it for a routine examination of all professionals handling ionising radiation sources.

RESULTS

Conventional chromosome aberrations analysis is limited to unstable aberrations. Dicentric chromosomes were reported to increase at doses as low as 20 mGy [6]. Chromosome damages are long lasting and are visible even years after irradiation. Follow-up studies of subjects with partial body irradiation demonstrated that these aberrations were present in lymphocytes even three years after exposure. However, it has been shown that rate of unstable aberrations declines 50% per year in the first 2-3 years [7]. Chromosome dosimetry is considered to be a useful biological technique in radiobiological protection not only in accidental cases, but also in estimating exposure of medical and industrial workers to ionising radiation when the physical dose is uncertain.

The analysis of chromosome aberrations has been obligatory in medical examination of personnel handling radiation sources in Croatia more than 20 years. According to the Croatian Public Health Act, a preemployment check-up for subjects that are going to work in controlled area includes CA analysis. The results of several follow-up studies have been published. Our results show an increase in CA in exposed subjects when compared to control (Table 1.). Statistical evaluation of data showed the positive correlation with a dose and duration of exposure, but the doses registered by dosimeters over the past year were below the annual maximum permissible limit. Our results are in agreement with some other authors results [11,12].
Table 1. The incidence of chromosome aberrations in 3 surveys of exposed and control subjects

<table>
<thead>
<tr>
<th>Survey</th>
<th>Group</th>
<th>No. of subjects</th>
<th>Dicentrics (mean/200 cells)</th>
<th>Acentrics (mean/200 cells)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>160</td>
<td>0.03</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Exposed</td>
<td>323</td>
<td>0.29</td>
<td>0.62</td>
</tr>
<tr>
<td>2</td>
<td>Control</td>
<td>241</td>
<td>0.09*</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>Exposed</td>
<td>1260</td>
<td>0.44*</td>
<td>1.08</td>
</tr>
<tr>
<td>3</td>
<td>Control</td>
<td>43</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Exposed</td>
<td>43</td>
<td>0.35</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Survey 1: ref. [8]; Survey 2: ref. [9]; Survey 3: ref. [10]; *dicentrics and dicentric equivalents

CONCLUSION

The lack of correlation between the physical dose and biological effects may be influenced by different factors: failure to wear dosimeters at the time of irradiation, earlier acute overexposure, exposure to radiation during personal medical examination, possible inter-individual differences in sensitivity to radiation and slow disappearance of aberration-bearing cells from circulation.

A better understanding of the mechanisms of low dose effects is necessary for estimating of risk. The shape of dose-response relationship at low doses seems to be influenced by two conflicting phenomena: the bystander effects, DNA damage in cells that were not themselves irradiated, but were in the neighbourhood of irradiated cells, and adaptive response, a reduction of radiobiological response in cells that were preexposed to low doses of radiation [13].

Although at present it is not known to what extent these effects contribute to overall cellular radiation responses in vivo, it is possible that future investigations of these phenomena will result in re-examination of current model used in radiation risk. No doubt that new and more sensitive techniques for individual protection will be developed. Till then, chromosome aberrations as indicators of chronic exposure will do as one of most reliable methods in radiation protection.

213
REFERENCES


ABSTRACT

Numerous cytogenetic studies have shown an increase in lymphocyte chromosome damages in radiation workers exposed to low doses (<0.1 Gy) of ionising radiation. Chromosome aberration frequency provides the most reliable biomarker of radiation dose. Dosimetric studies in occupationally exposed populations in which cytogenetic markers were used showed contradictory results. Some showed a correlation between chromosomal aberration frequency and the absorbed dose, whereas the majority found no correlation whatsoever. Most results show that low doses produce more aberrations than expected when one extrapolates dose-response curves from higher doses. It was shown that in populations exposed to low doses of ionising radiation different factors might influence aberration yield such as the induction of DNA repair enzymes, half-life of lymphocytes, age, sex, smoking and duration of exposure. The analysis of chromosome aberrations has a great importance in evaluating individual risk of ionising radiation. Periodic controls of professionals chronically exposed to low doses of ionising radiation significantly contribute to their protection.