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A comparative study on effects of static electric field and power frequency electric field on hematology in mice

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Abbreviations:
SEF, static electric field
PFEF, power frequency electric field
ICR, Institute of Cancer Research
UHV, ultra high voltage
DC, direct current
AC, alternating current
ICNIRP, the International Commission on Non-Ionizing Radiation Protection
IEEE, the Institute of Electrical and Electronics Engineers
EG, experimental group
CG, control group
Mean ± SD, mean value ± standard deviation
WBC, white blood cell count
RBC, red blood cell count
HGB, hemoglobin concentration
NE%, proportion of neutrophil
LYM%, proportion of lymphocyte
MO%, proportion of monocyte
EO%, proportion of eosinophil
BAS%, proportion of basophil

Keywords:
Ultra-high-voltage transmission
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Immune function
White blood cell

ABSTRACT

With the development of the ultra high voltage transmission technology, the voltage level of transmission line rised. Accordingly, the strength of electric field in the vicinity of transmission line increased, thus possible health effects from electric field have caused many public attentions. In this study, in order to compare effects induced by static electric field (SEF) and power frequency electric field (PFEF) on immune function, Institute of Cancer Research (ICR) mice were exposed to 35 kV/m SEF (0 Hz) and PFEF (50 Hz),respectively. Several indicators of white blood cell, red blood cell as well as hemoglobin in peripheral blood were tested after exposure of 7, 14 and 21 days, respectively. There was no significant difference in any indicators under SEF exposure of 35 kV/m for 7d, 14d and 21d between experimental group and control group. Under the PFEF exposure of 35 kV/m, white blood cell count significantly reduced after exposure of 7d, 14d and 21d. Meanwhile, red blood cell count significantly reduced after exposure of 7d, and returned to normal level through the compensatory response of organism after exposure of 14d and 21d. Hemoglobin concentration significantly decreased only after exposure of 21d. Based on tested results of hematological indicators, SEF exposure of 35 kV/m did not affect immune functions in mice but PFEF exposure of 35 kV/m could cause a decline of immune function. This difference of effects from SEF and PFEF on immune function was possibly caused by the difference of the degree of molecular polarization and ion migration in organism under exposure of two kinds of electric fields.

1. Introduction

In China, energy sources such as coal and petroleum are mainly concentrated in the west, while electric power demand is mainly concentrated in the east. It is a more effective way to solve this problem that energy sources are converted into electric energy transmitted by transmission lines in situ. To reduce the cost of power transmission, ultra high voltage (UHV) transmission technology being suitable for large-capacity and long-distance power transmission has been developed in recent years. Several 800 kV UHV direct current (DC) transmission lines and 1000 kV UHV alternating current (AC) transmission lines have been built. DC transmission lines generate static electric field (0 Hz), and AC transmission lines generate power frequency electric field (50 Hz). Compared with high voltage (110 kV and 220 kV) or extra-high voltage (330 kV and 500 kV) transmission lines, UHV (> 500 kV) transmission lines have a higher voltage level and a larger current intensity. Thus, the electric field strength under UHV transmission lines is much larger than that under high voltage or extra-high voltage transmission lines. Accordingly, the potential health effects of electric field from UHV transmission lines have aroused public

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concern.

On the basis of biological effects of static magnetic field which have been studied widely currently, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has established a criterion for the limitation of static magnetic field exposure, namely Guidelines on limits of Exposure to Static Magnetic Fields (ICNIRP, 2009). However, studies on biological effects of SEF are scarce, and there is no international criterion for the limitation of SEF exposure for now (WHO, 2006). Many criteria for the limitation of time-varying electromagnetic fields exposure in environment have been established by relevant international organizations, such as Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz) (ICNIRP, 2010) established by ICNIRP and IEEE Standard for Safety Level with Respect to Human Exposure to Electromagnetic Field, 0–3 kHz (C95.6TM-2002) (IEEE, 2002) established by the Institute of Electrical and Electronics Engineers (IEEE) of USA. Therefore, referring to the limitation of PFEF exposure, the limitation of SEF exposure can be formulated by studying biological effects of SEF and PFEF comparatively.

Immune functions have been one of the research priorities for biological effects of electromagnetic fields. Epidemiological surveys on people living in the vicinity of high-voltage transmission lines showed that long-term exposure to power frequency electromagnetic fields would increase the risk of cancer, especially the childhood leukemia (Wertheimer and Leeper, 1979; Draper, 1993; Charatan, 1999; Olsen et al., 1993; Draper et al., 2005; Ahlbom et al., 2001). At the same time, laboratory studies also showed that power frequency electromagnetic fields would reduce immune functions (Rollwitz et al., 2004; Simkó and Mattsson, 2004; Nikolova et al., 2005). Physiological and biochemical indicators in blood could indicate the functions and status of various tissues and organs in body, which are usually used as important basic indices in biomedical research. These indicators in blood are also sensitive to electromagnetic fields, thus they can be used for early detection of immune diseases such as leukemia. Svedenstal et al. (1999) reported that exposure of power frequency electromagnetic field (50 Hz, 8 μT) generated by high voltage transmission lines of 220 kV for 20 days could significantly reduce monocytes in mice. Cabrales et al. (2001) found that exposure of power frequency magnetic field (60 Hz, 0.11mT) for 6 months could significantly reduce neutrophil, hemoglobin concentration and hematocrit in mice. Cakir et al. (2009) also found that exposure of magnetic field (50 Hz, 0.97 mT) for 50 days or 100 days could significantly reduced the eosinophils, hemoglobin concentration and hematocrit in rats. However, studies from Margonato et al. (1995) and Selmaoui et al. (1996) showed that power frequency electromagnetic fields had no effect on blood routine indicators. Previous studies on effects of power frequency electromagnetic field on immune function focused on power frequency magnetic fields, and it was not clear which exposure led to corresponding effects among single power frequency magnetic field, single power frequency electric field and power frequency electromagnetic. Besides, the evidences of effects of power frequency electromagnetic on immune functions were inconsistent, while the studies on effects of SEF were even less. Therefore, it is necessary to study the effects of single SEF and PFEF on immune functions further.

In this study, ICR mice were exposed to 35 kV/m SEF (0 Hz) and PFEF (50 Hz) generated by simulation devices in laboratory, respectively. Some indicators such as red blood cell count, hemoglobin concentration, white blood cell count and the proportion of different types of white blood cells in peripheral blood were tested to compare the effects of SEF and PFEF on immune functions.

2. Materials and methods

2.1. Animals

Purchased from Experimental Animal Center of Zhejiang Province (Hangzhou, China), male Institute of Cancer Research (ICR) mice from a same batch (n = 120, 4-week-old, weighing 24.5 ± 1.3 g) were used in experiments. SEF and PFEF exposure experiments were carried out separately and in each experiment 60 mice were randomly divided into two groups, experimental group (EG, n = 30) and control group (CG, n = 30). All mice were housed in a clean room with constant temperature (21 ± 2 °C), constant humidity (40–50%) and a 12 h/12 h light/dark cycle (light on from 08:00 to 20:00), and they had free access to water and food. The experimental procedures were in accordance with the Guidelines for the Care and Use of Laboratory Animals established by the National Institutes of Health (NIH 1996) and all efforts were made to minimize the number of animals and their suffering. The animal experiments were approved by the Animal Ethical Committee of Zhejiang University (Permission No.12923).

2.2. Exposure of electric fields

Johnson (1983) monitored the synthetic field strength generated by a ± 400 kV HVDC transmission line in the United States for 6 months and found that the maximum strength was 34.4 kV/m in the vicinity of ground. Leitgeb (2014) also pointed out that the maximum strength produced by HVDC transmission lines could exceed 30 kV/m in the vicinity of ground under the worst conditions. Song et al. (2012) found that 80% of monitoring results on maximum strengths produced by ± 800 kV Xiangjiaba-Shanghai UHVDC transmission line in China were less than 25 kV/m near the ground. Therefore, the maximum strength was about 35 kV/m near the ground under actual transmission lines. This strength was chosen as the actual exposure strength in SEF exposure experiment. In order to compare the biological effects of SEF and PFEF, 35 kV/m was also chosen as the actual exposure strength in PFEF exposure experiment which was about 7 times the limitation in IEEE (2002).

SEF exposure device was the same as that used by Wu et al. (2017). It consisted of a boost unit, a rectifier unit, a control unit and an electrode unit. Similar to SEF exposure device, PFEF exposure device consisted of a boost unit, a control unit and an electrode unit. The electrode unit of two devices was same and was composed of an upper and a lower plate of 3 m in diameter. The control unit could set the electric field strength. The output voltage of the boost unit of the SEF exposure device could reach up to 100 kV (DC), while the input voltage was 220 V (AC). And the strength up to 100 kV/m generated between the two parallel electrode plates with a span of 1 m was adjustable continuously. The output voltage of the boost unit of the PFEF exposure device could reach up to 50 kV (AC), while the input voltage was 220 V (AC). And the strength up to 50 kV/m generated between the two electrode plates was adjustable continuously. The mice in EG and CG were housed in plastic cages (35 cm × 25 cm × 46 cm; length × width × height) with top open. The cages in EG were placed on the lower electrode plate and exposed to electric field, while the cages in CG were placed on the ground below the lower electrode plate. Because the lower electrode plate was grounded, the theoretical field strength between the lower plate and the ground was 0 kV/m. The actual exposure strength of PFEF at the center of cage (about 8 cm above the bottom) measured by an electromagnetic radiation analyzer (SEM-600, Beijing Safety Test Technology Co., Ltd., China) was 35 ± 0.9 kV/m (mean value ± standard deviation, Mean ± SD). The actual exposure strength of SEF at the center of cage (about 8 cm above the bottom) measured by an SEF strength detection system (HDEM-1, Beijing Safety Test Technology Co., Ltd., China) was 35 ± 1.1 kV/m (Mean ± SD).

The exposure duration in previous studies on electric field effects varied from a few hours (Hori et al., 2015) to several months (Seto et al., 1986), and mostly ranged from 5 to 20 days (Petri et al., 2017). Thus, 7, 14 and 21 days were chosen as exposure durations of SEF and PFEF and exposure was continuous during 24 h/day in this study.