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Genotoxic activity of organic contamination of the Songhua River in the north-eastern region of the People's Republic of China

Jia-Ren Liu [a,*], Yong-Xun Pang [a], Xuan-Le Tang [a], Hong-Wei Dong [a], Bing-Qing Chen [b], Chang-Hao Sun [b]

[a] *Department of Environmental Health, Public Health College, Harbin Medical University, 157 Baojian Road, Nangang District, Harbin 150081, China*
[b] *Department of Nutrition and Food Hygiene, Harbin Medical University, Harbin, Heilongjiang Province 150086, China*

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Abstract

The Songhua River is one of the biggest rivers in China and is the major freshwater source for industry and agriculture, as well as the source of the drinking water for millions of residents living along it. Heavy contamination of the Songhua River is due to domestic sewage and industrial wastewater. Thus, we set out to determine the carcinogenic potential of water samples taken from drinking water source of Harbin city in the Songhua River. Short-term genotoxic bioassays using Ames, SCE, and cell transformation assays were employed to examine the genotoxic activity of the ether extracts of water samples taken from the Songhua River. The results of the Ames test indicated that there were frame shift mutagens in the water samples, which were both direct and indirect. A dose–response relationship for the SCE assay was obtained, and the SCE cumulative frequency moved obviously to the right with increasing doses of water samples. Typical transformed foci were formed in NIH3T3 cells induced by ether extracts of water samples and the transformation frequency showed a dose–response relationship. The transformed cells showed the characteristics of malignant cells. All of the results indicated that the ether extracts of water samples taken from the Songhua River showed genotoxic activity.

Keywords: Organic contamination; Genotoxic activity; The Songhua River; Ames assay; Sister-chromatid exchange assay; Cell transformation test

1. Introduction

The surface waters (rivers, lakes, and seas) receive large quantities of wastewater from industrial, agricultural, and domestic sources including municipal sewage. Water pollution is a very serious public health and aquatic ecosystem problem especially since the surface waters are often used as a source of drinking water [1–3]. Ohe et al. [1] in an extensive review reported that mutagens from surface waters in Europe, Asia, and South America were studied to determine their mutagenicity/genotoxicity using a variety of bioassays. These studies demonstrated that these environmental mixtures contained many toxicants which may have the risk of carcinogenic potential. In this review, the response of *Salmonella* strains possessing sensitivity to different chemical classes were recommended to help in the

* Corresponding author at: 127 Stocking Hall, Cornell University, Ithaca, NY 14853-7201, United States. Tel.: +1 607 342 3623.
E-mail addresses: JiarL@ems.hrbmu.edu.cn, JL526@cornell.edu (J.-R. Liu).

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identification of the classes of genotoxicants present in surface waters as the main assay, followed by conventional chemical analysis, other genotoxicity assays, as well as water quality monitoring programs. Potable water may contain potentially harmful compounds and it is now well recognized that most drinking water has genotoxic activity [4–7]. A number of mutagenic compounds have been isolated from drinking water [8–10]. Very high mutagenicity has been detected in water treated with chlorine for disinfection purposes [11–13]. The variations in the mutagenicity of drinking water appear to be related to organic contamination of the water, as well as to chlorine disinfection [1,14,15].

The Songhua River is one of the biggest rivers in the People's Republic of China (PRC) and its watershed is located between 41°42′–51°48′ north latitude and 119°52′–132°31′ east longitude, in the north-eastern region of the PRC, with a catchment area of about 556,800 km^2 (Fig. 1). The Songhua River, located at the junction of the temperate and cold-temperate zones. The region has a long, cold winter, a torridy, rainy summer; and a dry, windy spring. The Songhua River system crosses two of the three provinces of the north-eastern region (Heilongjiang and Jilin) and inner Mongolia and consists of the NenJiang River, the Second Songhua River, and the Songhua River. The NenJiang River with the length of 1370 km originates from the mountain of Da-Xing-An-Ling. The Second Songhua River originates from Tian-Chi Lake in the Chang-Bai Mountains and has a length of 958 km. The Songhua River arises from these two rivers at San-Cha-He in FuYu city and then empties at Tongjiang city into the Heilongjiang River, which separates the PRC and Russia. The length of the Songhua River is 939 km [16]. The Songhua River is the major freshwater source for industry and agriculture,

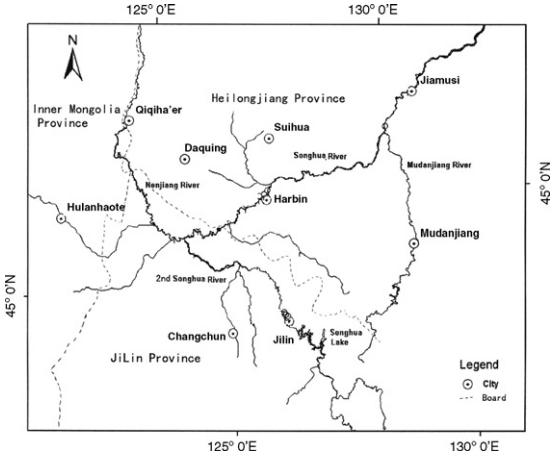

Fig. 1. Draft map of the Songhua River. Based on Ref. [16].

as well as the source of the drinking water for millions of residents living along it. Heavy contamination of the Songhua River is due to domestic sewage and industrial wastewater. In a previous study [17], 152 organic compounds were detected in the Songhua River by methods of gas chromatography (GC), gas chromatography/mass spectrometry (GC/MS), high pressure liquid chromatography (HPLC) and total ion chromatography (TIC). Of these compounds, 19% were polycyclic aromatic hydrocarbon (PAHs), 14% were chlorocompounds, 13% were aromatic compounds and 54% were other compounds. An epidemiological investigation indicated that the organic contamination in the Songhua River was a risk factor for tumor development among the residents living along it. The organic pollutants of water samples taken from the Songhua River were tested for mutagenicity using the *Salmonella typhimurium* assay and showed that ether extracts of 1.7 or 3.5 L water equivalent/plate were positive with TA98(−S9) and TA1538(−S9) [18].

At present, data are available on the genotoxic hazards associated with the ingestion of organic pollutant-containing drinking water [19–21]. However, few studies of carcinogenic potential on organic pollutant extracts of water have, as of yet, been reported [18,22]. Most human carcinogens are genotoxic but not all genotoxic agents have been shown to be carcinogenic in humans [23]. Because organic pollutant compounds are not known to produce many genotoxic activities such as damaging DNA, or chromatids, or the whole cell transformation, a battery of *in vitro*, short-term genotoxicity tests with different genetic endpoints were used to study the genotoxic activities of surface water pollution [23,24]. Haseman et al. [23] reported that in four *in vitro* assays (*S. typhimurium* (SAL) and in mouse lymphoma cells (MLA) and chromosome aberrations (CA) and SCE in Chinese hamster ovary cells) were employed to evaluate 114 chemicals for rodent carcinogenicity by the USA National Toxicology Program (NTP). SAL showed the strongest overall association with rodent carcinogenicity, with a 66% (75/114) concordance, an 89% (32/36) positive predictivity and a 55% (43/78) negative predictivity. CA also showed a significant association with rodent carcinogenicity, but no correction was observed for the SCE or MLA assays. Kim and Margolin [24] also reported that a battery of short-term tests (SAL, MLA, CA, and SCE) could predict carcinogenicity from data of NTP by stepwise regression.

The objectives of this study were to (1) investigate the genotoxic activity of the ether extracts of water samples taken from the Songhua River and (2) compare the *Salmonella* mutagenicity of organic contamination of the Songhua River during the 1990s with 1982.