Environmental Research 149 (2016) 57–65

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Impacts of sanitation upgrading to the decrease of fecal coliforms entering into the environment in China

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ARTICLE INFO

Article history:
Received 21 March 2016
Received in revised form
29 April 2016
Accepted 3 May 2016

Keywords:
Sanitation upgrading
Fecal coliforms
Human release
Rural
Feces

ABSTRACT

Identifying the sanitation efficacy of reducing fecal contaminations in the environment is important for evaluating health risks of the public and developing future management strategies to improve sanitation conditions. In this study, we estimated the fecal coliforms (FC) entering into the environment in 31 provinces in China under three sanitation scenarios. Our calculation results indicated that, the current FC release is disparate among regions, and the human releases in the rural regions were dominant, accounting for over 90% of the total human releases. Compared with the human release, the FC release from the livestock was of similar magnitude, but has a quite different spatial distribution. In China Women's Development Program, the Chinese government set the target to make over 85% of the population in the rural access to the toilets in 2020. If the target set by the Chinese government is achieved, a decrease of 34% (12–54%) in the FC releases would be anticipated. In the future, the improvement in sanitation and accesses to the safe drinking water in the less developed regions, such as Tibet, Qinghai, and Ningxia, should be considered as a priority.

1. Introduction

The quality of the surface water was largely determined by the fecal contaminants from humans and animals (Prüss-Üstün et al., 2008; Stuart et al., 2009; Graham and Polizzotto, 2013; Fuhrmeister et al., 2015; Schriewer et al., 2015). Animal feces harbor a large number of microbes, including bacteria, archaea, microbial eukarya, viruses, and potentially protozoa and helminthes (Cabral, 2010; Schriewer et al., 2015). Water polluted by the feces is a vehicle for transmission of microorganisms, which is responsible for some deadly diseases (Cabral, 2010). Monitoring the presence of fecal coliforms (FC) is an efficient tool for assessing fecal contaminations in the receiving water bodies because these bacteria exist in large quantities in the gastrointestinal tracts of most warm-blooded animals (Pachepsky and Shelton, 2011; Reder et al., 2015; Tran et al., 2015). Currently, the diarrheal diseases remain a major public health concern in the developing countries, and the regions with lowest financial resources and poorest hygiene facilities are the mostly affected (Cabral, 2010). In the low and middle income countries, an estimated 700,000 children under five years of age die due to gastroenteritis every year (Fuhrmeister et al., 2015; Walker et al., 2013). In the rural China, the average diarrheal incidence is 2.9 episodes per child per year among children under five years of age, and the diarrheal mortality rate of children under five is 13 times greater in rural regions than in the urban regions (Zhang, 2012). About 88% of diarrheal cases worldwide were attributed to the unsafe drinking water often caused by inadequate sanitation or insufficient hygiene measures (Prüss-Üstün et al., 2008). Reductions of the fecal pathogens in the surface water could reduce disease transmission risks significantly (Fewtrell, 2005; Fuhrmeister et al., 2015).

The importance of sanitation in controlling the diseases caused by microbes was recognized by international community when the coverage targets in the low-income countries were

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http://dx.doi.org/10.1016/j.envres.2016.05.009
0013-9351/

included in the Millennium Development Goals (MDGs) of United Nations (Prüss-Üstün et al., 2008; WHO, 2006, 2014). MDGs set the target to reduce, by half, the proportion of the population without access to the improved sanitation from 51% in 2010–25% by 2015 (WHO, 2006). In this target, improved sanitation is defined as the access to facilities that hygienically separate the feces from human contact, including flush or pour flush to piped sewer system, septic tank or pit latrine, ventilated improved pit latrines, pit latrines with slab and composting toilets (Cairncross et al., 2010; Fuhrmeister et al., 2015). In the Sustainable Development Goals (SDG), the United Nations set another target that, by 2030, if not earlier, all the world's population will have access to safe and sustainable water and sanitation (Sachs, 2012). In 2012, about 63% of the global population used toilets and other improved facilities, projected to reach only 67% by 2015, slower than the target set by the MDGs (Prüss-Üstün et al., 2008). Due to different income levels, huge disparities in the sanitation conditions still exist among countries and regions (Prüss-Üstün et al., 2008; Fuhrmeister et al., 2015). Twelve countries are home to almost three quarters of the remaining people practicing open defecation, including India (626 million) and China (14 million) (Prüss-Üstün et al., 2008). Even within countries, huge disparities in sanitation accesses between the rural and urban areas exist (Graham and Polizzotto, 2013).

Since 1990s, the Chinese government has recognized the importance of sanitation improvement in the rural regions, and a sanitation project (named as "Toilet Revolution") targeting at the rural population was started (National Health and Family Planning Commission, China, 2014a). The access rates to the toilets in the rural regions increased sharply from 7.5% in 1995–76.1% in 2014 (National Bureau of Statistics, China, 2004–2015). In the China Women's Development Program, the Chinese government set the target that, in 2015, access rate to the toilets should reach 75% in the rural regions, and 85% in 2020 (General Office of the State Council, China, 2011). However, the majority of the toilets in the rural of China were in the form of pit latrines. Pit latrines generally lack physical barriers, such as concrete, between stored excreta and water sources and they are not effective in the removal of fecal contaminants (Van Ryneveld and Fourie, 1997; National Health and Family Planning Commission, China, 2014b). Besides, accesses to the toilets and other sanitation facilities in the rural regions also show disparities between the developed and less-developed regions of the country (National Bureau of Statistics, China, 2004–2015).

Identifying the sanitation efficacy to reduce fecal contaminants in the environment is important for evaluating the health risks for the public and developing future management strategies (Fuhrmeister et al., 2015). Currently, lack of data is the main constraint which limits the comprehensive understanding of the relationships between microbial contaminations in our environment, human behavior and public health. In this study, we estimated the efficacies of sanitation upgrading by modeling microbial pollutions entering into the environment from human and livestock under three policy scenarios. The results could help improve the country sanitation accesses planning under the condition of lack of direct monitoring of pollution data.

2. Methods and materials

2.1. Conceptual framework

We used a mechanistic-stochastic model (shown in Fig. 1) to estimate the feces and FC releases from human and livestock in 31 provinces in China, including North China (Beijing, Tianjin, Shanxi, Hebei, Inner Mongolia), East China (Fujian, Zhejiang, Shandong, Anhui, Jiangsu, Shanghai), South China (Guangdong, Guangxi, Hainan), Central China (Jiangxi, Henan, Hubei, Hunan), Southwest China (Chongqing, Sichuan, Guizhou, Yunnan, Tibet), Northwest China (Shan'xi, Gansu, Qinhai, Ningxia, Xinjiang) and Northeast China (Heilongjiang, Jilin, Liaoning) (details shown in Table S1). The calculation uses the province-level data, divided into urban, county and rural areas, respectively, on types of sanitation technologies to estimate the FC entering into the environment. The FC release in each province was calculated according to Eqs. (1)–(4). The impacts of sanitation upgrading influencing human feces release were examined under two sanitation upgrading scenarios (details described in Section 2.3). The FC removal efficiency by sanitation was calculated by Eq. (5).

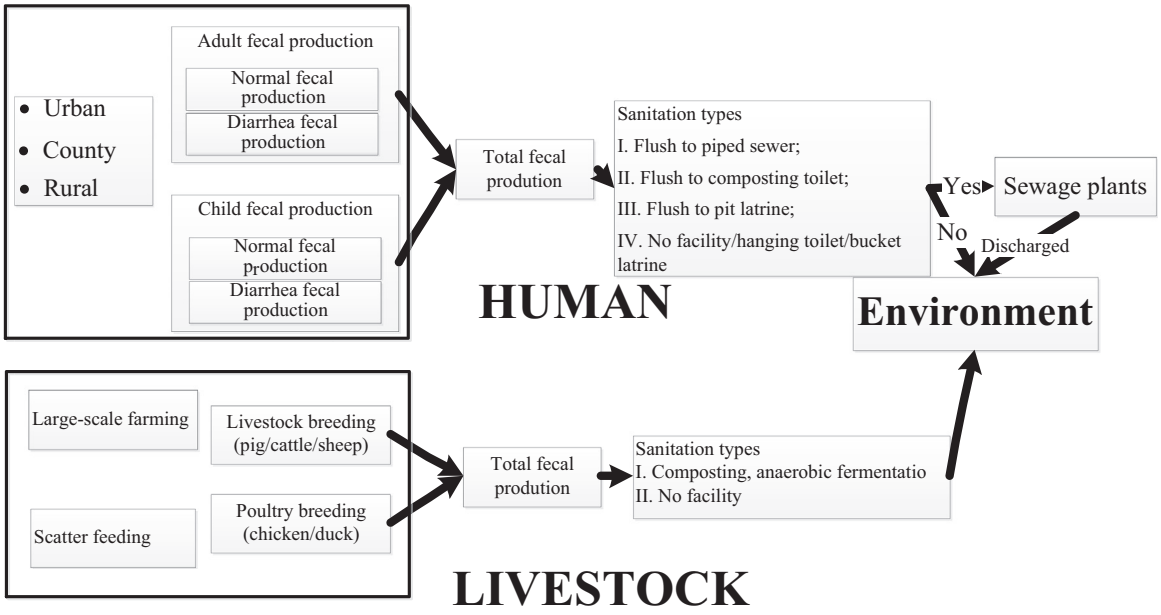

Fig. 1. Diagram of mechanistic-stochastic model of fecal and fecal coliform productions.