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# Analysis on the emission of tritium from Qinshan nuclear power base of china in recent ten years

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# Analysis on the emission of tritium from Qinshan nuclear power base of china in recent ten years

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**Abstract**. The emissions of tritium in airborne and liquid effluent from Qinshan nuclear power base in the period from 2007 to 2016 are counted, and compared with the global average emission level. The results show that the tritium emissions from the Qinshan nuclear power base in the past ten years have met the Chinese national standard limits. Compared with the global average emission data and the US commercial pressurized water reactor nuclear power plant emission data, the tritium emissions of PWR units are at the same level. Emissions from heavy water reactors of the Qinshan nuclear power base are lower than global average emissions (about 10% of the global average) and lower than the Canadian average emission level.

## 1. Introduction

The neutron activation of $^{2}H$, $^{3}He$, $^{6}Li$ and $^{10}B$ during the operation of the nuclear power plant reactor assembly produces a large amount of tritium, and it cannot be processed by the conventional waste treatment system, thus the emission of tritium has attracted extensive attention [1]. In addition, the migration and diffusion characteristics of tritium are distinct from other nuclides. It is a weak beta emission element and does not enter the human body. There is no external irradiation hazard, but due to its longer half-life (12.28a), higher isotope exchange rate (T/H) and easy entry into organisms to form organically bound tritium (OBT), which makes it easy to participate directly in the circulation of organisms. It can be transferred to the human body through inhalation, skin absorption and ingestion, causing internal exposure to the public [2]. Therefore, it is necessary to control the emissions of tritium to ensure that it meets the management limits. This paper analyses the tritium emissions levels of the Qinshan nuclear power base (Qinshan Nuclear Power Plant(QSNPP), Qinshan phase II Nuclear Power Plant(QSIINPP), Third Qinshan Nuclear Power Plant(TQNPP) ) in the past ten years and compares with the global emission levels. The results can help regulators and operators determine the actual level of China's tritium emissions and provide advice on future operational management of tritium.

## 2. The operation of Qinshan nuclear power base in 2007-2016

Since the Qinshan nuclear power base was attached to the grid in 1991, a total of five PWR units and two HWR units have been invested. The cumulative power generation of Qinshan nuclear power base in the past ten years was about 295.4 TWh. The annual power generation of Qinshan nuclear power base is shown in Table 1.

**Table 1.** Qinshan nuclear power base in 2007-2016.

| NPP | Annual power generation/TWh | | | | | | | | | | type | power generation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | | MWe |
| QS NPP | 2.22 | 2.62 | 2.36 | 2.32 | 2.49 | 2.84 | 2.30 | 2.62 | 2.57 | 2.58 | PWR | 310 |
| QSII NPP | 8.9 | 9.96 | 9.96 | 10.4 | 14.7 | 20.2 | 20.4 | 20.2 | 20.3 | 20.8 | PWR | 650 |
| TQ NPP | 11.5 | 11.2 | 11.7 | 11.4 | 11.5 | 11.6 | 11.9 | 11.7 | 11.2 | 10.9 | HWR | 700 |

## 3. Qinshan nuclear power base tritium emission level

The data on the emissions of the Qinshan nuclear power base from 2007 to 2016 are listed [3-4] in Table 2 and Table3. The trends of the tritium emissions in gaseous and liquid effluents are shown in Figure 1 and Figure 2. In order to analyze the emission levels of tritium more directly and objectively, the normalized emissions of tritium in the effluent in the past decade are calculated. Trends of normalized data of tritium emissions in gaseous and liquid effluents are shown in Figure 3 and Figure 4. The calculation method is to use the annual tritium emissions of effluent divided by the annual power generation for the same period to obtain the normalized emissions.

**Table 2.** Tritium released in gaseous effluents from Qinshan nuclear power base (Bq/a).

| NPP | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| QSNPP | 6.82E+11 | 6.47E+11 | 3.38E+11 | 5.37E+11 | 7.83E+11 |
| QSIINPP | 8.09E+10 | 2.17E+11 | 1.97E+11 | 3.50E+11 | 6.62E+11 |
| TQNPP | 4.53E+13 | 5.57E+13 | 3.53E+13 | 3.95E+13 | 3.98E+13 |
| NPP | 2012 | 2013 | 2014 | 2015 | 2016 |
| QSNPP | 3.47E+11 | 1.02E+12 | 2.79E+12 | 4.40E+12 | 4.05E+12 |
| QSIINPP | 5.89E+11 | 5.76E+11 | 8.09E+11 | 1.60E+12 | 1.85E+12 |
| TQNPP | 3.87E+13 | 5.56E+13 | 8.12E+13 | 6.83E+13 | 1.12E+14 |

**Table 3.** Tritium released in liquid effluents from Qinshan nuclear power base(Bq/a).

| NPP | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| QSNPP | 3.62E+12 | 2.88E+12 | 3.71E+12 | 3.11E+12 | 3.19E+12 |
| QSIINPP | 2.37E+13 | 3.72E+13 | 2.85E+13 | 3.03E+13 | 4.40E+13 |
| TQNPP | 5.69E+13 | 5.33E+13 | 4.20E+13 | 4.26E+13 | 4.06E+13 |
| NPP | 2012 | 2013 | 2014 | 2015 | 2016 |
| QSNPP | 1.59E+12 | 3.59E+12 | 5.86E+12 | 6.45E+12 | 5.90E+12 |
| QSIINPP | 5.43E+13 | 6.35E+13 | 6.45E+13 | 8.33E+13 | 7.41E+13 |
| TQNPP | 3.18E+13 | 4.79E+13 | 6.72E+13 | 5.79E+13 | 9.92E+13 |

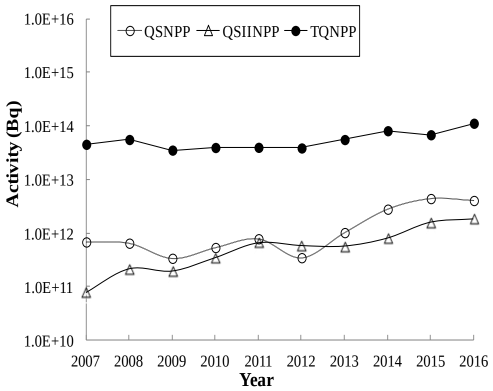


**Figure 1.** Tritium activity released in gaseous effluents from Qinshan nuclear power base.

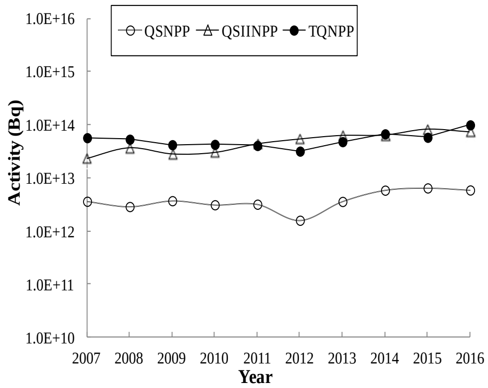


**Figure 2.** Tritium activity released in liquid effluents from Qinshan nuclear power base.

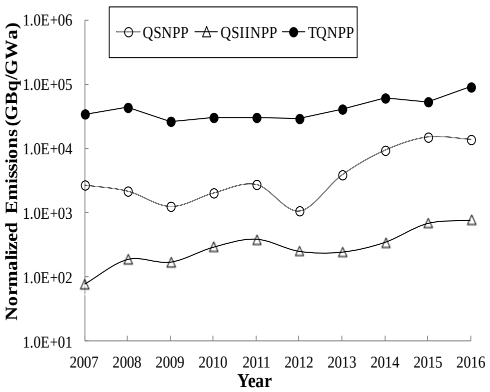


**Figure 3.** Tritium normalized Emissions in gaseous effluents from Qinshan nuclear power base.

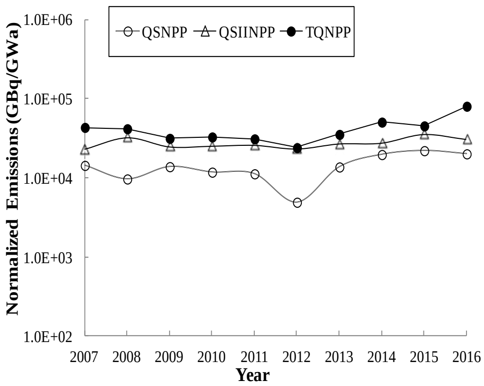


**Figure 4.** Tritium normalized Emissions in liquid effluents from Qinshan nuclear power base.

### *3.1. Tritium released in gaseous effluents*

For the past ten years, the total emissions of tritium airborne effluent from Qinshan nuclear power base are $5.94\times10^5$ GBq, where the PWR units emissions are $2.25\times10^4$ GBq, and the HWR units emissions are $5.71\times10^5$ GBq. The annual average emissions of tritium airborne effluent from the PWR units are $1.13\times10^3$ GBq and the HWR units emissions are $5.71\times10^4$ GBq. Average normalized emissions of tritium airborne effluent from the PWR units are $2.87\times10^3$ GBq/GWa, and the HWR units are $4.39\times10^4$ GBq/GWa.

The statistical analysis shows that:

The annual average release of tritium airborne effluent form Qinshan Nuclear power base meets the China management limits "Regulations for environmental radiation protection of nuclear power plant" (GB6249-2011) (PWR unit management limit is $1.50\times10^4$ GBq/a, HWR unit management limit is $4.50\times10^5$ GBq/a) [5].

Total discharge of tritium airborne effluent from HWR units of Qinshan nuclear power base accounts for 96% of the total emissions, which are the largest source of tritium emissions. Moreover, the annual average tritium emissions of HWR units are 20 times higher than that of PWR units, which is mainly due to the large release of tritium caused by HWR units activation.

The average normalized discharge of tritium airborne effluent from the PWR units of Qinshan nuclear power base is $2.87\times10^3$ GBq/GWa, which is lower than the China management limits "Authorized limits for normalized releases of radioactive effluents from nuclear fuel cycle" (GB 13695-92) ($1.50\times10^4$ GBq/GWa) [6].

The average normalized discharge of tritium airborne effluent from HWR units of Qinshan nuclear power base is $4.39\times10^4$ GBq/GWa, which is about an order of magnitude higher than the normalized discharge of PWR units. It can be seen that the discharge of HWR units should focus on its gaseous pathways.

### *3.2. Tritium released in liquid effluents*

For the past ten years, the total emissions of tritium liquid effluent from Qinshan nuclear power base are $1.08\times10^6$ GBq, where the PWR units emissions are $5.43\times10^5$ GBq, and the HWR units emissions are $5.39 \times 10^5$GBq. The annual average emissions of tritium liquid effluent from PWR units are $2.72\times10^4$ GBq. The annual average emissions of tritium airborne effluent from PWR units are $5.39\times10^4$ GBq. Average normalized emissions of tritium liquid effluent from the PWR units are $2.10\times10^4$ GBq/GWa, and the HWR units are $4.14\times10^4$ GBq/GWa.

The statistical analysis shows that:

The annual average discharge of tritium liquid effluent form Qinshan nuclear power base meets the China management limits "Regulations for environmental radiation protection of nuclear power plant" (GB6249-2011) (PWR unit management limit is $7.50\times10^4$ GBq/a, HWR unit management limit is $3.50\times10^5$ GBq/a) [5].

The discharge of tritium liquid effluent from HWR units of Qinshan nuclear power base accounts for 50% of the total discharge, which is equivalent to the total discharge from the PWR units. It can be seen that the discharge of PWR units should focus on the liquid route.

The average normalized discharge of tritium liquid effluent from PWR units of Qinshan nuclear power base is $2.10\times10^4$ GBq/GWa, which is lower than the China management limits "Authorized limits for normalized releases of radioactive effluents from nuclear fuel cycle" (GB 13695-92)($3.50\times10^4$ GBq/GWa) [6].

The average normalized discharge of tritium liquid effluent from HWR units of Qinshan nuclear power base is at the same level as the PWR units.

## 4. Average tritium emission level of other countries

### *4.1. global units tritium emission level*

As of the end of December 2016, there were 448 operational nuclear power reactors in worldwide, operating in 30 countries with a total installed capacity of 391.1GWa[7]. The United Nations Scientific Committee on Atomic Radiation Effects (UNSCEAR) [8-10] statistics the normalized emissions of tritium airborne and liquid effluents from nuclear power plants in the world from 1970 to 2002. The average normalized discharge of tritium airborne effluents from PWR units is $4.09\times10^3$ GBq/GWa, and the average normalized emission of tritium liquid effluent is $2.31\times10^4$ GBq/GWa. The average normalized discharge of tritium liquid effluents from HWR units is $6.33\times10^5$ GBq/GWa, and the average normalized emission of tritium liquid effluent is $4.07\times10^5$ GBq/GWa. The normalized emissions of the tritium effluent from the Qinshan nuclear power base in the past decade compared with the global level is shown in Figure 5~8.

The statistical analysis shows that:

The normalized emissions of tritium airborne effluent from PWR units of Qinshan nuclear power base are in the same order of magnitude compared with the average global level. The normalized discharge of tritium liquid effluent from PWR units of Qinshan nuclear power base is in the same order of magnitude as the average global level, and the normalized emissions fluctuate around $1.0\times10^4$ GBq/GWa.

The emissions of tritium airborne effluent and liquid effluent from HWR units of Qinshan nuclear power base are lower than the global average emission level (about 10% of the global average). It can be seen HWR units have positive effects in controlling emissions.

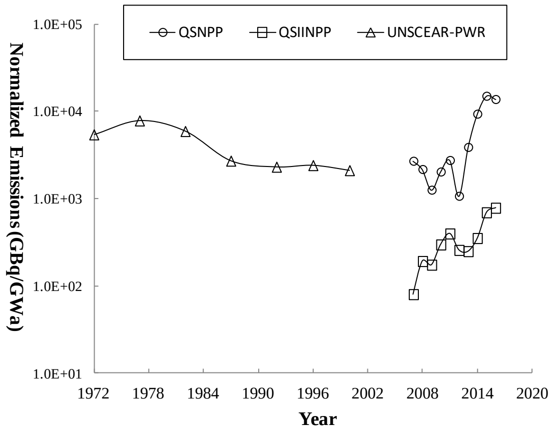


**Figure 5.** Tritium normalized Emissions in gaseous effluents from PWR units of Qinshan and UNSCEAR.

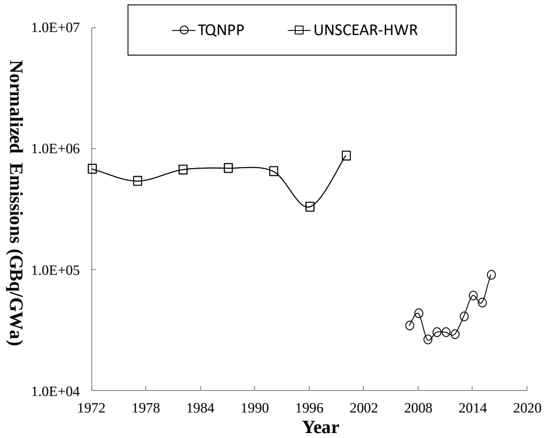


**Figure 6.** Tritium normalized Emissions in gaseous effluents from HWR units of Qinshan and UNSCEAR.

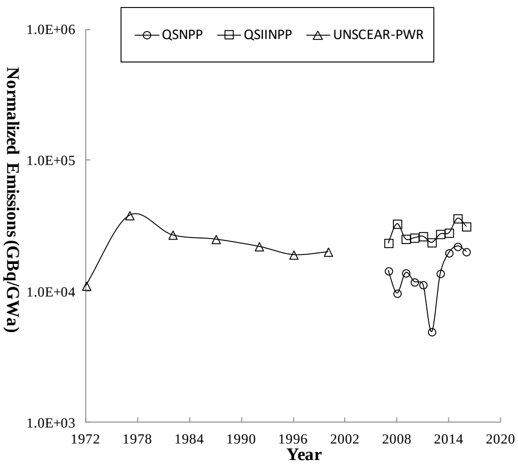


**Figure 7.** Tritium normalized Emissions in liquid effluents from PWR units of Qinshan and UNSCEAR.

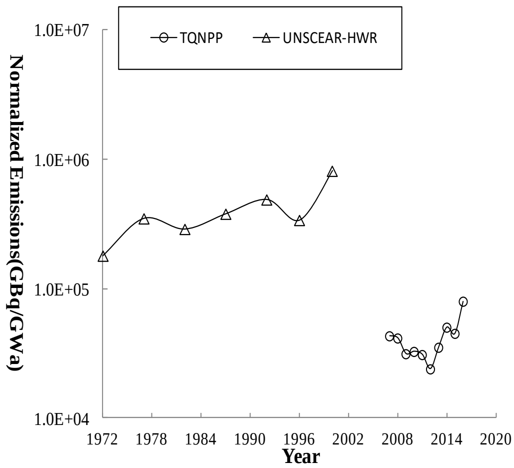


**Figure 8.** Tritium normalized Emissions in liquid effluents from HWR units of Qinshan and UNSCEAR.

*4.2. US PWR units tritium emission level*

There are currently 99 nuclear power plants in operation in the United States, with a total installed capacity of 99.9 GWa. The main types are PWR units and BWR units. The US Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) have compiled effluent emissions data for US commercial nuclear power plants from 1994 to 2006 [11]. The statistical results are shown that the emissions of tritium airborne effluent from the US PWR units are between $10^5$ and $10^6$ GBq (the average normalized emissions are about $10^3$-$10^4$ GBq/GWa). The effluent from the tritium liquid effluent of the PWR units is about $10^6$ GBq, and its average normalized emissions are about $10^4$ GBq/GWa. In both US commercial nuclear power plant and Qinshan nuclear power base, the emissions of tritium effluent from PWR units are all in the same level.

### *4.3. Canadian HWR units tritium emission level*

There are currently 5 nuclear power plants in operation in Canada, with 19 units with a total installed capacity of 13.5 GWa. The units are CANDU-type heavy water reactors. According to the statistical report of Canadian Nuclear Safety Committee [12], it shows the tritium emission data from the Canadian nuclear power plant from 1994 to 2003. The normalized emissions of tritium airborne effluent and liquid effluent from Canada's HWR units are about $10^5$GBq/GWa, which is higher than the HWR units of Qinshan nuclear power base.

## 5. Conclusions

In the past ten years, the tritium emissions from the Qinshan nuclear power base have met the Chinese national standard limits. In the operation and management of HWR units, attention should be paid to the emissions from the airborne route (accounting for 96% of the total emissions). The emissions of tritium in the effluent of the PWR units at Qinshan nuclear power base are at the same level as the global average and the US commercial PWR units. The emissions from HWR units are lower than global average emissions (about 10% of the global average) and lower than emissions from Canadian HWR units. It can be observed that in the past ten years, China has achieved positive results in controlling tritium emissions of HWR units.

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