Available online at www.sciencedirect.com

ScienceDirect

Energy Reports 00 (2022) 000–000

Oil tank farm emission trends of Russian refineries

Vladimir Pavlovich Klepikov[a]*, Liubov Vladimirovna Klepikova[b], Muhammad Shahbaz[c]

[a]*National Research University Higher School of Economics, Moscow, Russian Federation*
[b]*Russian University of Transport (MIIT), Moscow, Russian Federation*
[c]*Beijing Institute of Technology,Beijing,China*

Abstract

The oil refining industry has an important position in the Russian economy. However, most of the country's oil refineries have outdated production capacities of tank farms for storing oil, and the issue of emissions from Russian refineries is a research gap in this area. The aim of this study was to identify the dynamics of changes in the amounts of emissions from tank farms for oil storage in Russian refineries. A study period from 2008 to 2018 was considered. The contributions of this study include the development of methods for estimating emissions for the regions. In this study, an approach was developed that, based on the existing expressions of the unified methodology, allows us to estimate the emissions of tank farms at a regional scale.
The results showed that the greatest emissions occurred in the Volga Federal District. The volume of emissions from that region exceeded the total emissions of the next three districts: the Central, Siberian, and Northwestern Federal Districts of Russia. The largest growth rate of emissions was demonstrated by the refineries of the Southern Federal District, exceeding those of the Central, Siberian, and Northwestern Federal Districts during the study period. In the Far Eastern and Ural federal districts of the country, annual emissions were much lower. During the study period, the total accumulated emissions exceeded 2.5 million tons; therefore, the country needs to carry out work to modernize the tank farms of oil refineries in accordance with the proposed direction.
Keywords: Oil; Refinery; Emissions; Tank farms; Federal District

1. Introduction

The oil industry makes a significant contribution to the budget revenues of the Russian Federation and occupies an important position in the country’s economic system. In 2018, oil production in Russia [1] exceeded 555 million tons. Approximately half of all oil produced is directed to domestic refineries. Russian refineries can be divided into three groups: 1. refineries owned by vertically integrated companies, 2. large independent refineries, and 3. mini-refineries. Together, the first two groups process more than 90% of all oil sent for refining in Russia [2]. Therefore, in this study, the refineries belonging to these two groups were considered. The volume of oil refining by Russian refineries has grown substantially over the past two decades. In 2000, 179 million tons of oil were refined in the country, and by 2014, the refining volume exceeded 289 million tons. However, most refineries were built more than fifty years ago, have outdated production facilities, and require significant modernization [3]. In recent years,

* Corresponding author. Tel.: +7-905-731-72-36.
E-mail address: vklepikov@hse.ru (V.P. Klepikov).

Peer-review under responsibility of the European Academy for Sustainable Development (EURACA)

considerable attention has been given to improving oil refining equipment in Russia. The government has set the goal of achieving 90% in the production of light petroleum products [4]. The implementation of this requirement requires significant investment.

Nomenclature

P_l^j	volume of gross annual emissions of tank farms for oil storage in each district
$(Pst)_l^j$	annual emissions of tanks with the parameters of the "standard Russian" refinery for each district
F_l^j	accumulation of annual emissions F_L^j for each district
$(FP)_L^j$	relative amounts $(FP)_L^j$ of accumulated annual emissions

Many refineries are reconstructing the oil refining equipment used to produce final refined products. As a result, by 2018, the average oil refining depth at the country's refineries was 82.1%. Because of ongoing modernization, emissions of equipment engaged in the production of petroleum products have declined. However, obsolete oil storage tank farms continue to produce significant emissions that create negative environmental impacts. The determination of emission amounts is an urgent problem for research on the protection of nature and the health status of the populations living in oil refining regions. Studies [5] have shown that more than 40% of all emissions from Russian refineries come from tank farms for storing oil and oil products. Therefore, along with the improvement of production facilities for oil refining, it is necessary to modernize tank farms. However, the analysis of emissions from Russian refineries is a research gap in this area [6]. The aim of this study was to determine the trends in emissions from tank farms for oil storage in Russian refineries. To achieve these desired goals, the following steps were taken: a methodology for estimating the emissions of oil tank farms at oil refineries in the federal districts of Russia was developed, the trends in emissions were identified, various regions were compared in terms of emissions, and the possibility of improving the tanks was demonstrated. The period 2008–2018 was considered for this study.

2. Method

In Russia, a unified methodology is in place [7] for determining emissions of pollutants into the atmosphere from tanks at operating, designed, and reconstructed enterprises. This methodology allows the determination of emissions of pollutants from storage tanks for oil and petroleum products. Based on current legislation, this methodology is the main regulatory document for all nature conservation enterprises. However, the use of this technique presents significant difficulties for conducting research on a regional scale because in this case, it is necessary to have detailed information about the technological features of each refinery, and such data are not published in open sources. In this study, an approach was developed that, based on the existing expressions of the unified methodology, allowed estimates of the emissions of tank farms at a regional scale.

2.1 Time period and study regions

Over the past two decades, Russia has seen an increasing trend in oil refining volumes. From 2000–2014, there were annual increases in oil refining volumes [8]. However, in 2015–2018, fluctuations in these volumes were observed. The slight decrease in the volume in oil refining is explained by the desire of the refineries to improve the processes of secondary processing of oil and to produce better quality oil products. The modernization of processing equipment may allow refineries to reduce emissions from the processing of raw materials. However, tank farm improvement is an independent task that awaits solution. In our study, we considered the time interval of 2008–2018, including the period of annual growth in oil refining volumes (2008–2014) and the period with fluctuations in oil refining volumes (2015–2018).

In the process of its development, the oil refining capacity of Russia was concentrated not far from the places of oil extraction or in the same regions, ensuring the development of industry and supply for the population. As a result of this development, significant oil refining capacities are located in all federal districts (FDs) (Fig. 1) [9].

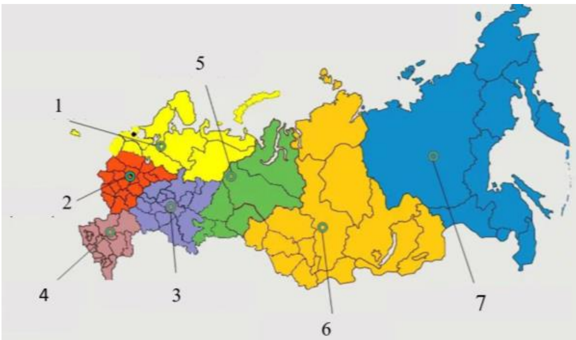

Fig. 1 Federal districts of Russia with designations used in the paper

1 - Northwestern (NW), 2 - Central, 3 - Volga, 4 - Southern (South), 5 - Ural, 6 - Siberian, 7 - Far Eastern (Far East) federal district. For this study, the annual data of the largest oil refineries in Russia were used. In Volga, these were the Novo-Kuibyshevsky, Syzran, Kuibyshevsky, Saratov, Ufa group, Nizhny Novgorod, Mari, Orsky, Salavat, TAIF, TANECO, and Perm refineries. In the South, these were the Volgograd, Tuapse, Afipsky, Novoshakhtinsky, Krasnodar, Ilsky, and Slavic refineries. In Siberian, these were the Achinsk, Angarsk, Omsk, Nizhnevartovsk, and Yaya refineries. In Central, these were the Ryazan, Yaroslavl, and Moscow refineries. In NW, these were the Kirishsky, Ukhta, and Usinsky refineries. In the Far East, these were the Komsomolsky and Khabarovsky refineries. Finally, in Ural, this was the Antipinsky refinery. The annual volume of oil refining by each of the refineries under consideration during the study period exceeded 1 million tons.

2.2 Calculation expressions

If it is assumed the expressions of the methodology used in Russia [7] in accordance with the purpose of this study, then the volume of gross annual emissions of tank farms for oil storage in each district (P_l^j, ton/year) can be determined by the following (1) equation:

$$P_l^j = \sum_i^{m_j} A \cdot ((Kt\max)_{l,i}^j \cdot (Ka)_{l,i}^j + (Kt\min)_{l,i}^j) \cdot (Kp)_{l,i}^j \cdot (Ko)_{l,i}^j \cdot B_{l,i}^j, A = \frac{0.294 \cdot P_{38} \cdot M}{10^7 \cdot \rho} \quad (1)$$

Here, the index $j = 1 - 7$ corresponds to the number of districts (Fig. 1), m_j is equal to the number of refineries operating in the territory of each district, $i = 1 - m_j$, $l = 2008 - 2018$, P_{38} is the pressure value of saturated oil vapor at 38°C (specified in mm of mercury), M is the molecular weight of oil vapor, and ρ is the density of oil (tons/m^3). In addition, $(Ktmin)_{l\,i}^j$ and $(Ktmax)_{l\,i}^j$ are tabular parameters that depend on the minimum and maximum temperatures of oil when it is injected into a tank, $(Ka)_{l\,i}^j$ is a tabular parameter depending on the oil vapor pressure in the tank, $(Kp)_{l\,i}^j$ is a tabular parameter determined by the operating characteristics of the tank, $(Ko)_{l\,i}^j$ is a tabular parameter determined by the annual oil turnover through the tank farm of the refinery, and $B_{l\,i}^j$ is the amount of oil passing through the tank farms of each refinery in a year. The values of the tabular parameters were selected from the tables compiled by [5], [7] at all possible temperatures, tank types, oil vapor pressures, and annual oil turnover amounts. If this procedure is fully followed, then it is necessary to determine the tabular parameters for each refinery. With the considered number of refineries, the solution of such a problem presents significant difficulties.

For the purposes of this study, the following hypothesis was used. The parameters $Ktmax, Ktmin, Kp, Ka,$ and Ko, which were used to calculate the emissions of tanks of the “standard” Russian refineries, were set equal to the parameters used in the calculation example of the annual gross emissions of tanks in the unified methodology [7]. The values of emissions obtained from their use generally correspond to the amount of emissions of Russian refineries during the study period.

Under these assumptions, the calculated expressions (2) for determining the annual volumes of emissions from tank farms in the territory of the country's district are as follows:

$$P_l^j = A\cdot((Kt\max)\cdot(Ka)+(Kt\min))\cdot(Kp)\cdot(Ko)\cdot\sum_{i=1}^{m_j} B_{l,i}^j \qquad (2)$$

If the accepted hypothesis and the average physical parameters of Russian oil are used, then the parameters $Ktmax, Ktmin, Kp, Ka,$ and Ko were set equal to the parameters used in the calculation example of the annual gross emissions of tanks in the unified methodology [7]:

$$Kt\max = 0.78, Kt\min = 0.42, Ka = 1, Kp = 0.62, Ko = 1.35, A = (0.294\cdot 420\cdot 63.7)/(10^7\cdot 0.85) = 9.254\cdot 10^{-4}$$

Substituting the values of these parameters into Equation (2), Equation (3) was obtained for estimating the annual emissions $(Pst)_l^j$ of tanks with the parameters of the “standard Russian” refinery for each district:

$$(Pst)_l^j = 9.295\cdot 10^{-4}\cdot\sum_{i=1}^{m_j} B_{l,i}^j \qquad (3)$$

To determine the trend in the accumulation of annual emissions F_L^j for each district, Equation (4) was used:

$$F_L^j = \sum_{l=2008}^{L}(Pst)_l^j \quad , \qquad (4)$$

where L is the given year of study.

When determining the relative amounts $(FP)_L^j$ of accumulated annual emissions, Equation (5) was used, obtained based on the ratio of the accumulated annual emissions F_l^j to emissions in 2008:

$$(FP)_L^j = \left(\sum_{l=2008}^{L}(Pst)_l^j\right)\Big/ P_{2008}^j \qquad (5)$$

In addition to the emissions of tanks with the parameters of the “standard” Russian refinery (Equations (3)–(5)), the emissions obtained using the minimum and maximum values of the parameters of the unified methodology [5], [7] were considered. This approach allowed for determination of the boundary values of the range of allowable emissions. The maximum and minimum values for the tabular parameters from all tables of the unified methodology are presented below.

$$Kt\min = 0.09; Kt\max = 1.1; (Ka)_{\min} = 1; (Ka)_{\max} = 2.32; (Kp)_{\min} = 0.074; (Kp)_{\max} = 1; (Ko)_{\min} = 1.35; (Ko)_{\max} = 2.5; A = 9.254\cdot 10^{-4}$$

The minimum value of the tabular parameter Kp corresponds to vertical tanks with a volume of more than 2,000 m^3 with a floating roof, operated in the "Mernik" mode. The filling of the tank occurs, after it is completely empty. The constant parameter A corresponds to its value in Equation (3). Then, taking into account Equations (2) and (3), the expressions for the minimum, maximum, and emissions of the “standard” refinery will be as follows (6):

$$(P_l^j)_{\min} = 0.018\cdot(Pst)_l^j, (P_l^j)_{\max} = 9.13\cdot(Pst)_l^j \qquad (6)$$

where $(P_l^j)_{min}$ represents the minimum emissions of refineries in the district, and $(P_l^j)_{max}$ represents the maximum values of possible emissions.

This study examines the possibility of reducing emissions, and emission values at parameters for the “standard” Russian refinery are already 9.13 times lower than the maximum possible emissions (6). Therefore, emissions are further considered in the range of parameters from the minimum values of the unified methodology relative to the values of the “standard” Russian refinery.

As follows from Equation (6), the amount of emissions corresponding to the parameters of the “standard” Russian refinery is 55.6 times higher than the minimum possible emissions. Analysis of the presented expressions allows us to outline possible steps to reduce emissions of oil tank farms at Russian refineries. In Equations (2)–(3), the parameter Ko already has a minimum value. Reducing the values of $Ktmin, Ktmax$, and Ka requires the development and application of appropriate technological solutions. These decisions should ensure the reduction and stabilization of the temperature of the injected oil, as well as the reduction and regulation of oil gas pressure. As follows from Equation (2), a significant reduction in emissions can be achieved by lowering the value of the parameter Kp, which determines the operational characteristics of the tank. This can be achieved by introducing vertical tanks with volumes of more than 2.000 m^3 with floating roofs (FRTs) at all Russian oil refineries operating in the "Mernik" mode. Such tanks correspond to the minimum value of the parameter Kp. In this case, in Equations (2)–(3), the parameter Kp becomes equal to 0.074. For the tank farms of the “standard” refinery, Kp = 0.62, and with the use of FRTs, the emission value $(P_l^j)_{(FRT)}$ decreases by a factor of 8.4 (0.62/0.074 = 8.4) compared with the values for a “standard” refinery and is determined by Equation (7):

$$(P_l^j)_{(FRT)} = 0.12 \cdot (Pst)_l^j \qquad (7)$$

3. Results

Analysis of annual reports and website information in Russian refineries [10]-[41] enabled the definition of an array, $B_{l\ i}^{j}$, of refinery annual volumes of oil refining.

Fig. 2 shows the dynamics of annual emissions of tank farms with the parameters of the “standard” Russian oil refinery in the districts, obtained using Equation (3).

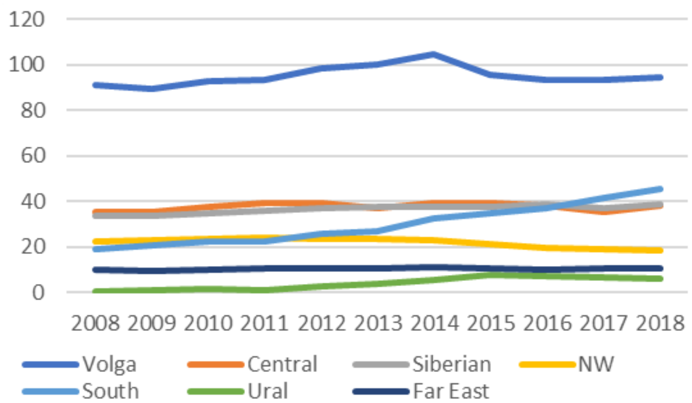

Fig. 2 Dynamics of annual emissions in the districts (thousand tons)

The data in Fig. 2 show that the greatest emissions during the entire study period were observed in Volga, where the annual volume of emissions was in the range of 89-104 thousand tons. The volumes in Central and Siberian were in the range of 33-40 thousand tons. The emissions in NW initially increased from 22.7 thousand tons in 2008 to 24.3 thousand tons in 2011 and then decreased to 18.7 thousand tons in 2018. Emissions in the South showed annual increases from 19.3 thousand tons in 2008 to 45.5 thousand tons in 2018. The dynamics of emissions in Ural are related to the activities of the Antipinsky refinery. From 2008–2010, the enterprise was in the start-up phase; therefore, its emissions amounted to 0.65-0.93 thousand tons. After commissioning in 2011–2015, emissions in this district reached 7.53 thousand tons, and in the period of 2016–2018, there was a decrease to 6.4 thousand tons. The amount of emissions in the Far East changed from 9.9 thousand tons in 2008 to 10.7 thousand tons in 2018.

Based on the data used to build Fig. 2, we determined the contributions of regions to the total emissions (Table 1).

Table 1. The contributions of regions to total emissions by district (%)

District	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Volga	42.82	42.18	41.66	41.25	41.53	41.88	41.12	38.67	38.28	38.32	37.40
Central	16.70	16.75	16.80	17.27	16.50	15.40	15.55	15.98	15.58	14.55	15.22
Siberian	15.76	15.82	15.60	15.80	15.57	15.71	14.78	15.35	15.82	15.24	15.38
NW	10.67	10.76	10.57	10.69	10.01	9.80	9.00	8.61	8.06	7.82	7.39
South	9.09	9.65	9.98	9.95	10.79	11.23	12.89	14.11	15.15	17.03	18.00
Ural	0.31	0.35	0.79	0.41	1.13	1.52	2.27	3.05	2.97	2.82	2.39
Far East	4.65	4.49	4.59	4.64	4.46	4.47	4.40	4.23	4.15	4.23	4.22

As the data in Table 1 show, Volga made the greatest contribution to total annual emissions. To decrease emissions in 2018, the rest of districts can be arranged as follows: South, Siberian, Central, NW, Far East, and Ural.

Equation (4) revealed the accumulated emissions of regions with the parameters of the “standard” Russian refinery. The largest amount occurred in Volga, reaching 1048 thousand tons in 2018, up to 415 thousand tons in Central, up to 403 thousand tons in Siberian, up to 329 thousand tons in South, up to 242 thousand tons in NW, up to 114 thousand tons in Far East, and up to 44 thousand tons in Ural. The total value of accumulated emissions in all districts for the study period reached 2594 thousand tons.

Based on Equations (6) and (7), Table 2 shows the ranges of values of possible emissions for the studied period for each considered district $(P_i^j)_{min}$ with the minimum table parameters and $(P_i^j)_{(FRT)}$ for floating roof tank parameters.

Table 2. Emission ranges by region (thousand tons)

Emissions	Volga	Central	Siberian	NW	South	Ural	Far East
$(P_i^j)_{min}$	1,62-1,88	0,64-0,71	0,60-0,70	0,34-0,44	0,35-0,82	0,01-0,14	0,17-0,20
$(P_i^j)_{(FRT)}$	10,77-12,56	4,26-4,75	4,02-4,67	2,24-2,91	2,32-5,46	0,08-0,90	1,15-1,34

The total emissions accumulated over the study period for all districts for tank farms with floating roofs $(\sum_{2008}^{2018}(P_i^j)_{(FRT)})$ were 311 thousand tons, whereas those with the minimum table parameters $(\sum_{2008}^{2018}(P_i^j)_{\min})$ were 47 thousand tons.

Using Equation (5) in Table 3, we estimated the dynamics of the relative accumulated emissions in the districts.

Table 3. The dynamics of relative cumulative emissions by district.

District	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Volga	1	1.99	3.01	4.04	5.12	6.22	7.37	8.42	9.45	10.47	11.51
Central	1	2.00	3.06	4.16	5.27	6.31	7.42	8.53	9.61	10.61	11.69
Siberian	1	2.00	3.04	4.11	5.22	6.34	7.46	8.59	9.75	10.86	12.02
NW	1	2.01	3.05	4.12	5.17	6.20	7.21	8.15	9.02	9.86	10.68
South	1	2.06	3.22	4.38	5.71	7.10	8.80	10.60	12.52	14.67	17.02

Ural	1	2.14	4.86	6.29	10.43	16.00	24.89	36.46	47.60	58.17	67.46
Far East	1	1.97	3.01	4.07	5.14	6.23	7.36	8.42	9.44	10.49	11.57

The data in Table 3 show that Ural demonstrated the maximum annual growth rate of relative accumulated emissions; during the study period, the annual emissions in 2018 compared with those in 2008 increased by a factor of 67. In the South, for the study period, the annual emissions by 2018 increased by a factor of 17. This was followed by Siberian, with a 12-fold increase. After this, in descending order, were Central, Far East, and Volga. Finally, NW showed the smallest growth with an increase in accumulated emissions by a factor of 10.7 in 2018 relative to 2008.

4. Discussion

Using [7], Equation (1) was derived for the estimation of gross annual emissions of tank farms for oil storage in each district. The amounts $B_{l\ i}^{j}$ contributing the most to Equation (1). Therefore, all used dimensionless tabular parameters [5], [7] vary in the range between several units and fractions of units, while the values of $B_{l\ i}^{j}$ are equal to millions or tens of million tons.

Open sources lack initial information on determining tabular parameters for refineries. Therefore, to select an initial estimate of the emission values, a hypothesis was adopted (Section 2.2). This made it possible to use the tabular parameters used in the examples of calculations [7], to obtain Equations (2) - (5), (7) and to estimate the values of regional emissions. Equation (6) is derived from Equation (1) using the maximum and minimum tabular parameters from [5], [7]. Using Equation (6), it was possible to determine the maximum and minimum possible values of annual emissions and relate them to the used values of emissions of the “standard” Russian refinery. In particular, from Equation (6) it follows that the emissions of the “standard” Russian refinery obtained in Section 2 are 9.13 times less than the maximum possible emissions.

The results for the annual emissions of the tank farms have shown that the largest volume of emissions was accounted for by Volga. It exceeded (Fig. 2) the total values that followed it in terms of emissions for Central, Siberian, and NW. In the period from 2008 to 2014, there was an increase from 91 thousand tons to 104 thousand tons (+15%). That amounted to 41-43 (%) of the annual total emissions of all regions (Table 1). This finding was consistent with the general trend of increasing volumes of oil refining by Russian refineries. During this period, the government set the task of improving the quality of products, and the investment resources of many companies were directed towards the modernization of processing plants. Thus, oil refining growth slowed. This led to a slight decrease in emissions in Volga from 2015 to 2018 to 94.6 thousand tons (−10%). The contribution of this region to the annual total emissions during this period was 38-37 (%). However, in absolute terms, the level in 2018 was higher than the 2008 emissions in this district. In other districts, similar trends can be traced. In Central, from 2008 to 2014, the volume increased from 35.5 thousand tons to 39.6 thousand tons (+11%), and by 2018, it decreased to 38.5 thousand tons (−3%). The share of the annual total emissions for the study period in this district was 14-17 (%). From 2008 to 2013, there was an increase in NW from 22.7 thousand tons to 23.5 thousand tons (+3%) and then a decrease to 18.7 thousand tons (−20%) in 2018. The contribution of the region to the total amount was 7-11 (%). In the Far East, in the period of 2008–2014, there was an increase from 9.9 thousand tons to 11.2 thousand tons (+13%) and then a decrease to 10.7 thousand tons (−5%) by 2018. The share of the annual total emissions was 4-5 (%). In Ural, growth in the period of 2008–2015 amounted to 0.6-7.5 thousand tons (+1159%), which was then followed by a decrease to 6.04 thousand tons (−20%) by 2018. These changes are attributed to the fact that the Antipinsky refinery was in the launch stage until 2010 and reached its calculated indicators beginning in 2011. In the study period, the region’s share was 0.3-3 (%). In Siberian, there was no reduction in annual emissions, and during the study period, small annual growth continued. This can be explained by the growing demands of consumers in the region for oil refining products. As a result, refineries were forced to increase oil refining volumes. The process of reconstruction of processing units was not as active there as in other regions. This allowed the refineries to increase oil refining volumes, but emissions increased from 33.5 thousand tons in 2008 to 39 thousand tons (+16%) in 2018. The region’s share was 14.8-15.8 (%) of the total. In the South, in the period from 2008 to 2018, there was an increase from 19.3 thousand tons to 45.5 thousand tons (+136%). This was caused by the increase in oil refining volumes associated with favorable market conditions, the convenient locations of the region's refineries relative to export routes, and growth in consumer activity. The region's contribution to the annual total emissions increased from 9% in 2008 to 18% in 2018.

The amount of accumulated emissions during the study period reached 1048 thousand tons in Volga. This is close to the value obtained by summing the accumulated emissions of Central (415 thousand tons), Siberian (403 thousand tons), and Southern (329 thousand tons), although the growth relative to 2008 values (Table 3) was different for the different regions. For Volga, Central, Siberian, and NW, it was in the range of 11–12 times; for South, it was 17 times; and in Ural, it was 67 times. Additionally, the absolute values of the accumulated emissions for the study period in the Far East (114 thousand tons) and Ural (44 thousand tons) combined were less than that in NW (242 thousand tons). The growth relative to 2008 values for NW (10.7 times) was inferior to that of Far East (11.6 times) but was more than twice the amount of Far East (114 thousand tons) in absolute value.

The emission amounts of the tank farms can be significantly reduced (Section 2). The use of tanks with volumes of more than 2,000 m3 and floating roofs at all oil refineries in the country can reduce emissions by a factor of 8.4, and further improvement of the tank farms can reduce emissions by a factor of 55. In particular, for Volga, instead of 89-104 thousand tons per year for the study period (Section 3), the value of emissions from the use of tanks with a floating roof (Table 2) will lead to emissions of 10.8-12.6 thousand tons per year, and the minimum value may be 1.6-1.9 thousand tons per year. The volumes of emissions of Central and Siberian would each be in the ranges of 4-4.7 thousand tons per year using tanks with floating roofs and 0.6-0.7 thousand tons per year with minimum values of the tabulated parameters; these ranges would be 2.2-2.9 and 0.34-0.44 thousand tons per year in NW, 2.3-5.5 and 0.3-0.8 thousand tons per year in South, 1.1-1.3 and 0.01-0.14 thousand tons per year in Far East, and 0.08-0.9 and 0.2-0.3 thousand tons per year in Ural, respectively. The total cumulative emission of all districts for the study period exceeded 2.5 million tons, but with the use of tank farms with floating roofs, it would be 311 thousand tons, and with subsequent improvement of the tanks, it could reach 47 thousand tons with the same volume of oil refining.

The unified approach [7] also needs to be improved. In the methodology [42] recommended for determining the amount of emissions from tanks at Russian oil fields, in Equations (1)–(2), it is already proposed to use the factor $K_{ссв}$ in addition to the parameters Kp and Ko, for the use of gas equalization or gas capture systems. Application of this recommendation will allow the values of emissions considered herein to be reduced by over an order of magnitude. In addition, the value of the parameter Ko (at more frequent turns of oil in tanks) reaches a value of 0.6 compared with 1.35 in the unified methodology. This allows an additional reduction in emissions by more than twofold.

5. Conclusion

Based on the research that was performed, a conclusion was made concerning that the greatest emissions occurred in Volga. The volume of emissions from that region exceeded the total emissions of the next three districts: Central, Siberian, and NW. The largest growth rate of emissions was demonstrated by the South, exceeding those of the Central, Siberian, and NW. In the Far East and Ural, annual emissions were much lower. During the study period, the total accumulated emissions exceeded 2.5 million tons; therefore, the country needs to carry out work to modernize the tank farms of oil refineries in accordance with the proposed direction.

The scientific novelty of the developed approach compared with current methods was the assessment of the emissions of tank farms at a regional scale, revealing their development trends, and examining the possibilities of reducing emissions.

The lack of research to determine emissions from Russian refineries is a gap in the scientific literature. Our study allows the estimation of the scale and distribution of emissions, reveals their trends, and provides direction for improving the oil tank farms of oil refineries in Russia. The work on the problem considered can be continued in the future, when information on the initial parameters for calculating refinery emissions will be provided in open official sources. Important topics for continuing research include determining the trends in emissions of tank farms for storing petroleum products, identifying the chemical compositions of regional emissions, and determining the degrees of associated environmental impacts. In further studies, emissions of the most hazardous substances should be highlighted. The results presented in this study can be used in the preparation of university courses on environmental protection, energy, and oil refining.

References

[1] Oil production in Russia: 1991 – 2021. 2022, http://global-finances.ru/dobyicha-nefti-v-rossii-po-godam/. [Accessed 11 Januar 2022].

[2] Vladimir Pavlovich Klepikov, and Liubov Vladimirovna Klepikova. (2021) “Distribution of Oil Refining Resources in Russia in the Context of the Capacity Development of Refiners and Regions.” Energy Reports 7 (2021): 767-779. https://doi.org/10.1016/j.egyr.2021.07.063.

[3] Production records of the fuel and energy complex of Russia in 2018. 2021, https://sdelanounas.ru/blogs/116801/. [Accessed 27 February 2021].

[4] Nikita O. Kapustin, and Dmitry A. Grushevenko. (2018) “Exploring the implications of Russian Energy Strategy project for oil refining sector.” Energy Policy 117 (2018): 198-207. https://doi.org/10.1016/j.enpol.2018.03.005.

[5] Pavel Georgievich Bannov (2006) “Basic methods of monitoring environmental pollution at refineries”, Khimizdat, St. Petersburg.

[6] E. Shvarts, A. Pakhalov, A. Knizhnikov, and L. Ametistova. (2018) “Environmental rating of oil and gas companies in Russia: How assessment affects environmental transparency and performance.” Business Strategy and the Environment 27.7 (2018): 1023-1037. https://doi.org/10.1002/bse.2049.

[7] Procedural Guidelines for Determining Atmospheric Emissions of Pollutants from Tanks. 1999, https://standartgost.ru/g/pkey-14294849188. [Accessed 22 February 2021].

[8] Russian oil refining: stay alive. For domestic oil refining, 2018 was not easy. 2021. https://vygon.consulting/upload/iblock/5f3/OGJR_2019_03.pdf. [Accessed 27 February 2021].

[9] Decree of the President of the Russian Federation no 849, dated 13 may 2000 "On the authorized representative of the President of the Russian Federation in the federal district.” 2000, http://base.garant.ru/12119586/#ixzz6P4p9CiD2. [Accessed 25 February 2021].

[10] Novoshakhtinsk refinery website. 2021, https://nznp-nznp.ru/. [Accessed 9 February 2021].

[11] Novoshakhtinsky refinery annual report. 2009, https://docplayer.ru/40720309-Godovoy-otchet-otkrytogo-akcionernogo-obshchestva-novoshahtinskiy-zavod-nefteproduktov-za-2009-god.html. [Accessed 7 February 2021].

[12] Ilsky refinery website. 2021, https://www.i-npz.ru/en/home-en/. [Accessed 6 Februars_and_py 2021].

[13] Rosneft annual reports. 2021. https://www.rosneft.ru/Investors/statementresentations/annual_reports/. [Accessed 10 February 2021].

[14] Gazprom Neft annual reports. 2021, https://ir.gazprom-neft.ru/news-and-reports/annual-reports/. [Accessed 10 February 2021].

[15] Slavneft website. 2021, http://www.refinery.yaroslavl.su/pressroom/news/main/obem-pererabotki-nefti-na-janose-v-2017-g-prevysil-15-4-ln-tonn/. [Accessed 10 February 2021].

[16] Slavneft annual reports. 2021, http://www.slavneft.ru/shareholder/disclosure/slavneft_yearreport/. [Accessed 9 February 2021].

[17] Khabarovsk refinery annual reports. 2021, https://www.e-disclosure.ru/portal/files.aspx?id=1266&type=2. [Accessed 10 February 2021].

[18] NK Alliance annual reports. 2021, http://www.nk-alliance.ru/page.phtml/rus/areps. [Accessed 11 February 2021].

[19] Khabarovsk Oil Refinery website. 2021, http://khab-npz.ru/. [Accessed 10 February 2021].

[20] Bashneft annual reports. 2021, http://www.bashneft.ru/disclosure/annual/. [Accessed 12 February 2021].

[21] TNK-BP annual report. 2009, http://nfotchet.narod2.ru/olderfiles/1/TNK_BP_SocialReport09_RUS.pdf. [Accessed 11 February 2021].

[22] Saratov refinery annual reports. 2021, https://www.conomy.ru/emitent/saratovskij-npz/krkn-otchety. [Accessed 11 February 2021].

[23] Lukoil annual reports. 2021, http://www.lukoil.ru/InvestorAndShareholderCenter/RegulatoryDisclosure/AnnualReport. [Accessed 10 May 2021].

[24] Surgutneftegas annual reports. 2021, https://www.surgutneftegas.ru/investors/essential_information/reporting/godovye-otchety/. [Accessed 10 May 2021].

[25] Surgutneftegas annual report. 2012, ht8ps://docplayer.ru/41456867-Otkrytoe-akcionernoe-obshchestvo-surgutneftegaz-godovoy-otchet.html. [Accessed 10 May 2021].

[26] Mari Oil Refinery website. 2021,https://marnpz.ru/manufacturing/. [Accessed 11 May 2021].

[27] Forteinvest website. 2021, https://www.forteinvest.ru/about/. [Accessed 15 May 2021].

[28] Orsknefteorgsintez annual reports. 2021, http://www.ornpz.ru/investoram/otchetyi.html. [Accessed 14 May 2021].

[29] Salavatnefteorgsintez annual report. 2009, http://files.conomy.ru/files/otchety/185/185-2009.pdf. [Accessed 18 September 2021].

[30] JSC Gazprom Neftekhim Salavat annual report. 2011, http://files.conomy.ru/files/otchety/185/185-2011.pdf. [Accessed 19 September 2021].

[31] Gazprom Neftekhim Salavat OJSC annual report. 2015, http://files.conomy.ru/files/otchety/185/185-2015.pdf. [Accessed 18 September 2021].

[32] PJSC Gazprom annual report. 2017, https://www.gazprom.ru/f/posts/85/227737/gazprom_annual_report_2017_rus.pdf. [Accessed 19 September 2021].

[33] TAIF-NK OJSC annual report. 2014, https://docplayer.ru/47415890-Oao-taif-nk-godovoy-otchyot.html. [Accessed 19 September 2021].

[34] TAIF-NK website. 2021, https://www.taifnk.ru/act/. [Accessed 20 September 2021].

[35] Tatneft website. 2021, https://www.tatneft.ru/. [Accessed 20 October 2021].

[36] TANECO annual report. 2011, http://www.taneco.ru/ru/investors/reports/taneco_annual_report_2011.pdf. [Accessed 12 October 2021].

[37] TANECO annual report. 2013. http://www.taneco.ru/ru/investors/reports/taneco_annual_report_2013.pdf. [Accessed 12 October 2021].

[38] Tatneft annual report. 2015, https://www.tatneft.ru/storage/block_editor/files/7b015fcff5f44cdcc6b1373b537161c29397b5ac.pdf. [Accessed 12 October 2021].

[39] Tatneft annual report. 2017, https://2017.tatneft.ru/otchet_soveta_direktorov/neftegazopererabotka/neftepererabotka/.[Accessed 14 October 2021].

[40] Antipinsky Oil Refinery website. 2021, https://www.annpz.ru/about/. [Accessed 26 October 2021].

[41] Russia’s oil industry in the face of global challenges and threats. 2018, https://burneft.ru/archive/issues/2018-11/3. [Accessed 27 October 2021].

[42] Guidelines for the determination of technological oil loses from technological tanks during oil production. 2015, http://docs.cntd.ru/document/420285750. [Accessed 28 February 2021].