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2022 Survey of Effluent Quality and Water Use at European Refineries

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2022 Survey of Effluent Quality and Water Use at European Refineries

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ABSTRACT

Since 1969, Concawe has been gathering and compiling data on aqueous effluents from European oil refinery installations. Surveys have been completed at 3-5 yearly intervals. Since 2010, the data collection also focused on water uses within the installations. This report presents the findings of the survey for the 2022 reporting year of European refinery effluent quality and water use.

A total of 48 refineries participated in the survey from the EU-27 countries, Norway, and United Kingdom. A statistical assessment of site water use is presented, including aggregated data on intake and effluent volumes, water consumption and water treatment processes. In addition, annual average concentration and discharge mass for a number of substances and parameters regulated at EU level are compared with survey data from previous years. The data returned from the surveys provides perspective on historic trends in refinery water use and effluent discharge and insights into the recent refinery sector performance.

A total of 1.5 billion m^3 of water was withdrawn in 2022 by the 48 refineries that returned data on site water intakes. Approximately 1.143 billion m^3, or 75% of the total water intake, was brackish or saline and used mostly for once-through cooling. The total freshwater intake was 366 million m^3 (average 7.6 million m^3 per refinery), with 336 million m^3 (average 7 million m^3 per refinery) used for purposes other than once-through cooling. A total of 1.34 billion m^3 of effluent was discharged to the environment in 2022, including once-through cooling water. This equates to a relative discharge of 4.37 m^3/ton of throughput, down from 5.03 m3/ton and 4.51 m^3/ton in 2016 and 2019 respectively. Some 200 million m^3 of effluent were treated in 2022, equivalent to 0.65 m^3/ton of throughput. In 2022, 48 refineries consumed a total of 197 million m^3 of fresh water. The average relative freshwater consumption in 2022 was 0.64 m^3/ton of throughput, lower than in 2019 when it was 0.67 m^3/ton, reported for 61 refineries.

With regard to effluent quality, the results of the 2022 survey continue to show a decrease in the discharge of Oil in Water (OiW) consistent with the long-term trend towards reduced discharge of OiW or Total Petroleum Hydrocarbons (TPH). Relative TPH loads in 2022 were much lower than in 2019 and 2016. Similar decreasing trends are observed for Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), total phosphorous and total nitrogen, BTEX and phenols and for some heavy metals.

KEYWORDS

Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Organic Carbon (TOC), oil in water, total petroleum hydrocarbon (TPH), phenols, effluent, water intake, water discharge, water consumption, water withdrawal, water use, waste water, treatment, refinery, survey.

INTERNET

This report is available as an Adobe pdf file on the Concawe website (www.concawe.eu).

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SUMMARY

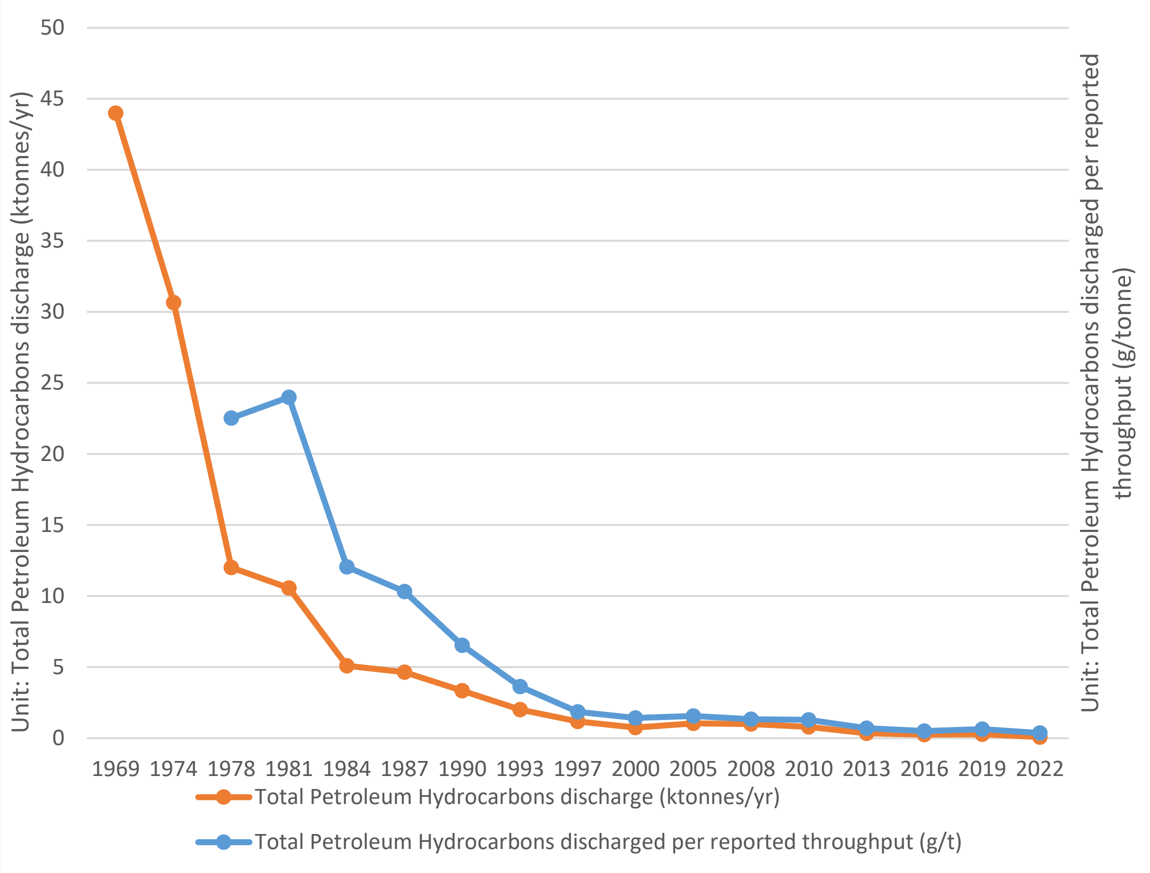
Since 1969, Concawe has been gathering and compiling data on aqueous effluents from European oil refinery installations. Surveys have been completed at 3-5 yearly intervals. Since 2010, for example, the data collection also focused on water uses within the installations. This report presents the findings of the survey completed in 2024 for the 2022 reporting year of European refinery effluent quality and water use. A total of 48 refineries from the EU-27 countries, Norway, and the United Kingdom participated in the survey from 86 potential respondents (56% response rate). The data returned from the survey provide perspective on historic trends in refinery water use and effluent discharge and insight into the recent refinery sector performance. The data also allows Concawe to assess the potential impact of proposed changes to existing European legislation.

A total of 1.5 billion m^3 of water was withdrawn in 2022 by the 48 refineries that returned data on site water intakes. Approximately 1.14 billion m^3 or 75 % of the total water intake was brackish or saline and used for once-through cooling. The total freshwater withdrawal was 366 million m^3 (average 7.6 million m^3 per refinery), with 336 million m^3 (average 7 million m^3 per refinery) used for purposes other than once-through cooling and equating to some 1.09 m^3 of freshwater per ton of throughput. This relative freshwater withdrawal is higher than in 2019 and 2016 respectively. Using the IPIECA definition for freshwater consumption (indicator ENV-1:Freshwater; IPIECA, API and IOGP, 2020), refineries consumed a total of 197 million m^3 of fresh water in 2022 with average relative freshwater consumption of 0.64 m^3/ton of throughput

In 2022, total aqueous effluents (including once through cooling water) discharged from the reporting refineries was 1.348 billion m^3, or a relative of 4.37 m^3/ton of throughput. In 2019 the relative discharge was 4.51 m^3/ton) and in 2016 5.03 m^3/ton. In 2022, aqueous discharges into fresh water receiving environments amounted to 353 million m^3, and 992 million m^3 were discharged into brackish/salty receiving environments. A total of 3.6 million m^3 were transferred to external facilities for treatment and their final receiving environment is unknown. When treated effluents are considered, in 2022 a total 200 million m^3 were discharged representing 0.65 m^3/ton of throughput.

With regard to effluent quality, the results of the 2022 survey are consistent with the long- term trend towards reduced discharge of oil (reported as Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)), as shown in **Figure 1**. Comparing with the previous two surveys Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) showed slight (BOD) to strong decreases of their relative loads. Total phosphorous, ammonia and total nitrogen relative load remained fairly constant. Good discharge load decreases were also observed for BTEX, phenols, cadmium and lead in relative loads. Finally, mercury and vanadium show no decrease in relative discharge loads, with vanadium showing an actual increase in its relative discharge load.

Figure 1. Trends in total petroleum hydrocarbons (TPH) loadings in effluents, and total petroleum hydrocarbons discharged per throughput, 1969 to 2016.



1. INTRODUCTION

Since 1969, Concawe has been gathering and compiling data on water use and effluent quality for European refineries. Surveys have been completed at 3-5 yearly intervals and the survey design has been updated over time to address various scientific and legislative developments. This report presents the findings of a Concawe survey completed in 2024 for the 2022 reporting year. The data returned from the surveys provide perspective on historic trends in refinery water use and effluent discharge and insight into the recent refinery sector performance. The data also allow Concawe to assess the potential impact of proposed changes to existing European legislation.

1.1. PROJECT DESCRIPTION AND EXECUTION

The water/effluent survey for the 2022 reporting year was initiated in mid-July 2023 when the Concawe web-based survey platform was opened to participating Concawe member companies' refineries. The 2022 survey design presented some differences compared to previous surveys; the main difference being the need for participating member refineries to complete a water diagram including water intakes, water uses and water discharge volumes, as a first step to define the water balance within their refineries. Water use, water consumption and water losses are all calculated based on the construction of this water diagram and the associated reported data. It also included the availability of a longer list of water reuses and a question about cross media effects.

A total of 48 responses were received out of 86 potential respondents[1] (56% response rate collected from refineries of varying type and complexity across Europe[2])· For comparison, 61 refineries out of a potential of 98 responded to the 2019 survey (62% response rate). The numbers of refineries which have reported refining capacity and total annual feedstock throughput data in each survey year are given in **Table 1**, while **Table 2** shows a breakdown of the survey's responses by refinery type. To facilitate comparison between the 2022 survey and previous survey findings, key metrics have been normalised to refinery throughput. Comparison between years is not fully possible since there is a difference between the refineries included in 2022 compared to the previous years, but comparison in relative terms, i.e. normalised to throughput, gives nevertheless an indication.

[1] The number of potential respondents represents the number of refineries within the EU-27 countries + Norway, Switzerland and the United Kingdom that were declared to be operational in 2022.

[2] Complexity groups were derived for each site using their Nelson Complexity index from 2013 (Oil & Gas Journal, December 2, 2013).

Table 1. Refining capacity and throughput for each survey year

Year of survey	Number of refineries reporting in each survey	Reported capacity (million tonne/year)	Reported throughput (million tonne/year)[1]
1969	82	400	Not requested
1974	112	730	Not requested
1978	111	754	540
1981	105	710	440
1984	85	607	422
1987	89	587	449
1990	95	570	511
1993	95	618	557
1997	105	670	627
2000	84	566	524
2005	96	730[2]	670
2008	125	840	748
2010	98[3]	720	605
2013	78[3]	507[2]	500
2016	72	585	510
2019	61	503	443
2022	48	381[4]	308[4]

[1] Throughput refers to total throughput, i.e. including both crude oil and other feedstocks.
[2] Some refineries reported throughput but did not report capacity. This capacity number represents the total capacity reported and may be under-represented.
[3] Revised number compared to Concawe Report 12/18 due to reporting entity definition (decreased by 3 for 2010 and decreased by 1 for 2013).
[4] Two refineries did not report capacity and throughput in 2022. Their capacities were obtained from Concawe's website for 2022, and their throughput were assumed equal to their capacity.

Table 2. Summary of collected responses by refinery site type in 2022

Type of Site	Response spilt by percentage
Refinery with or without a crude oil terminal	77 %
Combined refinery and chemical plant	23 %
Other[1]	18 %

[1] Percentage of refineries or combined refineries and chemical plants that also include bitumen or lubricant plants

Survey findings are presented for the refinery sector in Europe as a whole and also for refineries in different geographic regions, as shown in **Figure 2** and **Table 3**. Geographic regions have been created to facilitate regional comparisons, while maintaining the anonymity of individual refineries. Findings are also presented for refineries grouped by complexity classes derived from Nelson complexity index, as shown in **Table 4**. Comparing responses per complexity classes with 2016 responses it corresponds well, with similar percentages of responses in terms of throughput coming from Class 1 (3 % in 2022 vs. 4 % in 2016 and 2019), Class 2 (9 % in 2022 vs 10% in 2019 vs. 15 % in 2016), Class 3 (31 % in 2022 vs. 38 % in 2016 and 2019), Class 4 (15 % in 2019 and 2022 vs. 16 % in 2016) and Class 5 (19 % in 2022 vs 21% in 2019 vs. 24 % in 2016). This comparison indicates that the datasets from 2022, 2019 and 2016 are more or less comparable although the refineries responding in the different years may differ.

Figure 2. Geographic Extent of Country Groupings

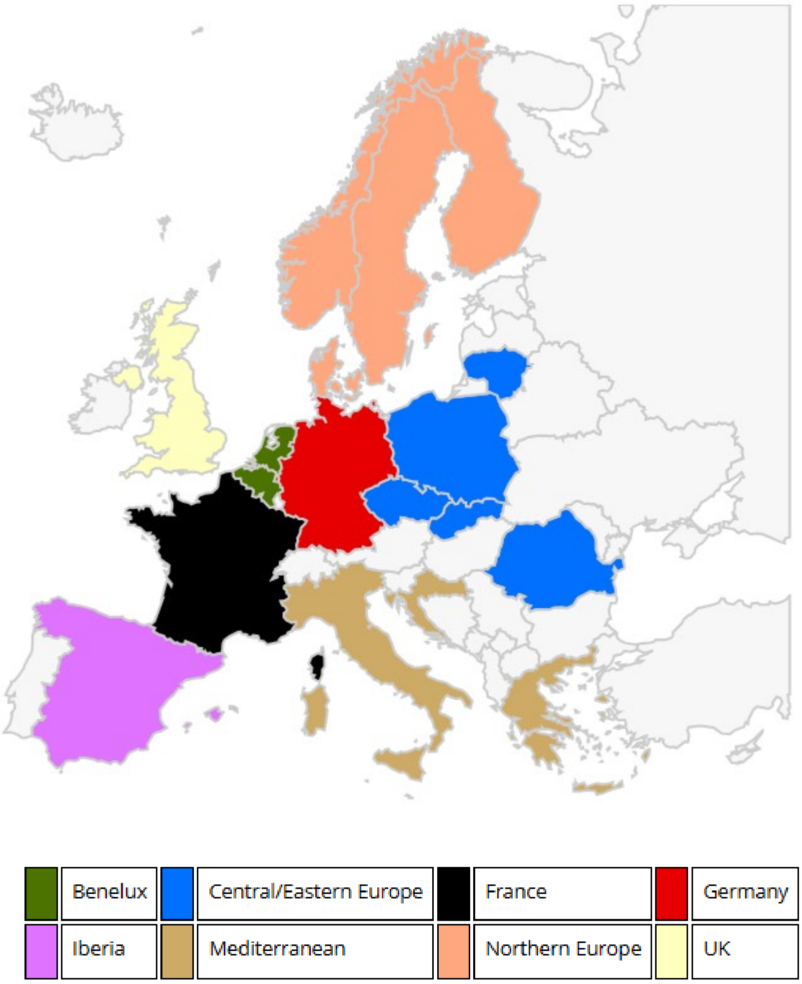


Table 3. Summary of responses collected by country group in 2022

Country Group Names (countries included in country group)	Number of Responses	Total Throughput (Kiloton/year	Percentage of reporting refineries per region (%)
Northern Europe (Denmark, Finland, Norway and Sweden)	6	42,097	66.6
Benelux (Belgium and Netherlands)	6	56,830	85
Central/Eastern Europe (Czech Republic, Poland, Slovakia, Lithuania and Romania)	7	27,575	63.6
Iberia (Portugal and Spain)	8	61,930	80
Mediterranean (Croatia, Greece and Italy)	9	41,319	53
France	5	31,858	71
Germany	4*	20,849	25
United Kingdom	3	25,184	42

* The Germany and UK country groups are not very representative of their respective country refining within this survey (26% and 42 % refineries responded)

Table 4. Summary of collected responses by site complexity groupings in 2022.

Complexity Group[1]	Number of Responses	Total Throughput (kiloton/year)
Class 1	2	8,464
Class 2	6	27,241
Class 3	12	94,577
Class 4	7	45,543
Class 5	6	57,309
Unknown	15	74,509

[1] Complexity groups were derived for each site using their Nelson Complexity index from Oil & Gas, Journal, December 2, 2013. Complexity groups are categorized using these complexity indexes for analyses: Class 1 <4; Class 2 4-6; Class 3 6-8; Class 4 8-10; Class 5 >10

1.2. DATA RESPONSE, QUALITY CONTROL AND QUALITY ASSURANCE

Since the 2019 survey, refineries input their data directly into the Concawe web survey tool. This was also the case for the 2022 water survey. For some refineries, data was sent to Concawe in a spreadsheet and the data was manually input into the web survey tool by the web tool manager.

Data QA/QC included the identification of data incongruities during review of data sets and automatically constructed tables and figures. In this way, refinery sites were identified that had data incongruities to receive follow-up such as:

- Concentration and load values outliers for specific refineries.
- Data compared with data entered in 2016 and 2019 for magnitude and type.
- Negative freshwater consumption.
- Checking designation of receiving environment types (fresh or marine).
- Incongruities regarding capacity and throughput values (i.e., throughputs higher than capacity)
- Once through cooling water with an up-stream use (i.e. likely not once through).

The QA/QC checks resulted in a limited number of follow-ups with respondents. After confirmation, some of the reported values were then updated in the database. All changes were documented along with valid reasoning for each change and preservation of the original respondents' input.

2. WATER INTAKE, DISCHARGE AND CONSUMPTION IN THE EUROPEAN REFINING INDUSTRY

This section provides summaries and graphics on the characteristics and quantities of water intakes and discharges. Also, the consumption of fresh water based on the IPIECA definition of their indicator Env-1 Freshwater (IPIECA, API and IOGP, March 2020, Revised 2023) is presented in this section.

2.1. WATER INTAKES[3]

As in previous surveys, respondents were asked to classify their water intake streams by water intake source, as summarised in **Table 5**. For each classified water intake stream, respondents provided total volumes withdrawn on an annual basis, as well as subsequent water use as appropriate. Water recycled/reused flows (such as aggregated sour water) were also reported.

Classifications of water types for water intake streams were classified as either fresh or salt/brackish. Fresh water was defined based on the IPIECA limit of 2000 mg/L[4] total dissolved solids. This criterion was used by all respondents but two.

Table 5. Classifications of water sources

Water Intake Source
Groundwater
Purchased demineralised water
Purchased potable water[1]
Purchased raw water[2]
Purchased recycled water
Purchased steam
Remediation/hydraulic control
Storm/rainwater
Surface water
Tank bottom draws

[1] Purchased potable water was defined as water that is supplied by a vendor of water that is fit for consumption without any further treatment (i.e., tap water).
[2] Purchased raw water was defined as water that is supplied by a vendor that is not fit for consumption.

For the 48 refineries included in the analyses, a total of just over 1.5 billion m^3 (1,509,868,600 m^3) of water were withdrawn in 2022 for use in the European refining industry (vs 2.38 billion m^3 in 2019 for 61 refineries). Out of the total water intake, approximately 72% (1.09 billion m^3) is represented by once-through cooling water, which is primarily salty/brackish surface water (97%) (see **Table 6**).

[3] For clarification, the definition of water intake follows the definition of water withdrawal of IPIECA (Sustainability Reporting Guidance for the Oil and Gas Industry, March 2020, Revised 2023), except that it includes remediation/hydraulic control and tank bottom draws, and "purchased other" in the guidance has been replaced by purchased demineralised water.

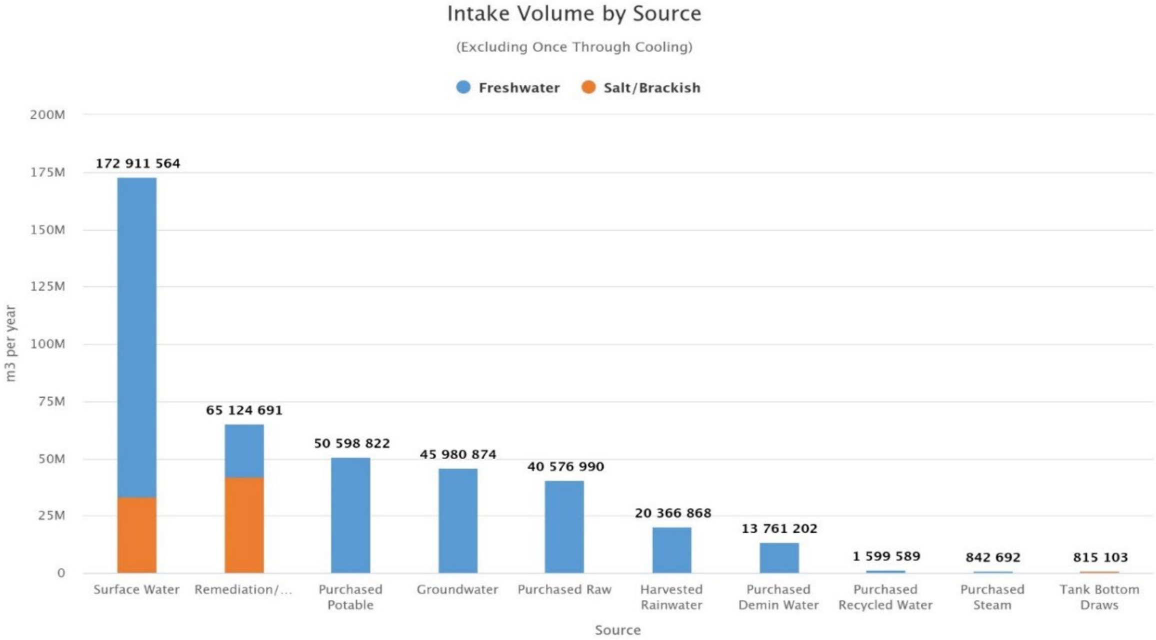
[4] IPIECA, Sustainability Reporting Guidance for the Oil and Gas Industry, March 2020, Revised 2023.

Table 6. Total Water Intake

Intake Type	Once-through cooling volume (m^3/y)	Onsite utilised volume (m^3/y)	Pass-through volume (m^3/y)	Total (m^3/y)
Freshwater	29,471,087	294,469,195	42,845,584	366,785,866
Salt/Brackish	1,066,768,906	76,061,242	253,586	1,143,083,734
Total	1,096,239,993	370,530,437	43,099,170	1,509,868,600

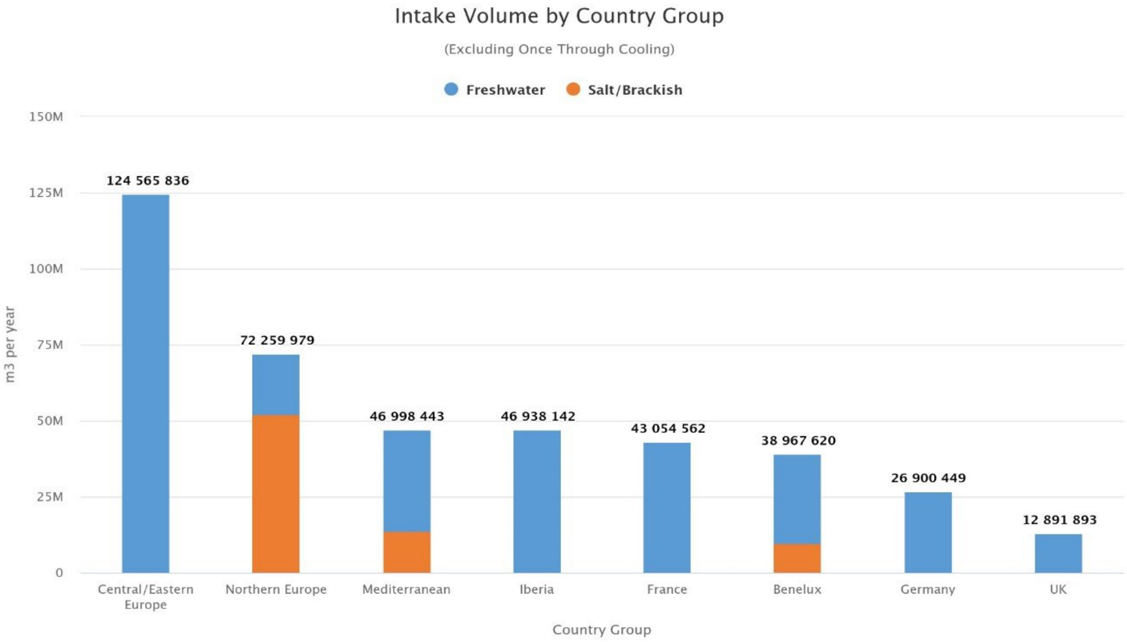
As indicated in **Figure 3**, the majority of water intake not associated with once-through cooling was derived from surface water (42 %), followed by water from remediation and hydraulic control activities (approx.16%) and purchased potable water (12.2%). Groundwater, in fourth place, represented approximately 11.2% of the total water intake, likely representing the minimum threshold, as it is more than likely that some of the water purchased from external sources also originally derived from groundwater sources. When considering all the purchased water categories, purchased water accounted for approximately 25 % of the total intake volume. The reliance on purchased water highlights the potential vulnerability of European refineries on water pricing initiatives. The purchased of recycled water from external sources represented less than 0.4% of all water intakes (excluding once-through cooling water). Harvested rainwater was reported by most refineries representing approx. 5% of all freshwater intake excluding once-through cooling water. This volume of harvested rainwater seems high when we consider the need for additional infrastructure to be able to collect and reuse this water. Further examination of refinery reported data and water diagrams seem to confirm a much lower volume of rainwater collected for further use. In fact, most rainwater is sent directly to discharge points without use within the refineries. While an exact volume of actual harvested rainwater is difficult to confirm based on the information provided, a volume of between 4 and 4.5 million m^3 is more likely (approximately 1.4% of total freshwater intake excluding once-through cooling). This figure corresponds to reported harvested rainwater from a total of 7 refineries.

Figure 3. Total water intake by water source. Once-through cooling volumes have been excluded. Harvested rainwater volumes are likely significantly less than reported as explained in the report.



Total water intakes by country group without once-through cooling are summarised in **Figure 4**. Most country groups primarily utilise fresh water, except for Northern Europe which uses mostly salt/brackish water.

Figure 4. Total water intake by country group (once-through cooling volumes have been excluded)



The total freshwater intake was 336 million m^3 (**Figure 5**) excluding once-through cooling and 294 million m^3 when considering only freshwater used on site (i.e., excluding pass- through freshwater). This includes harvested rainwater utilized onsite.

Figure 5. Total fresh water intake by country group (once-through cooling volumes have been excluded)

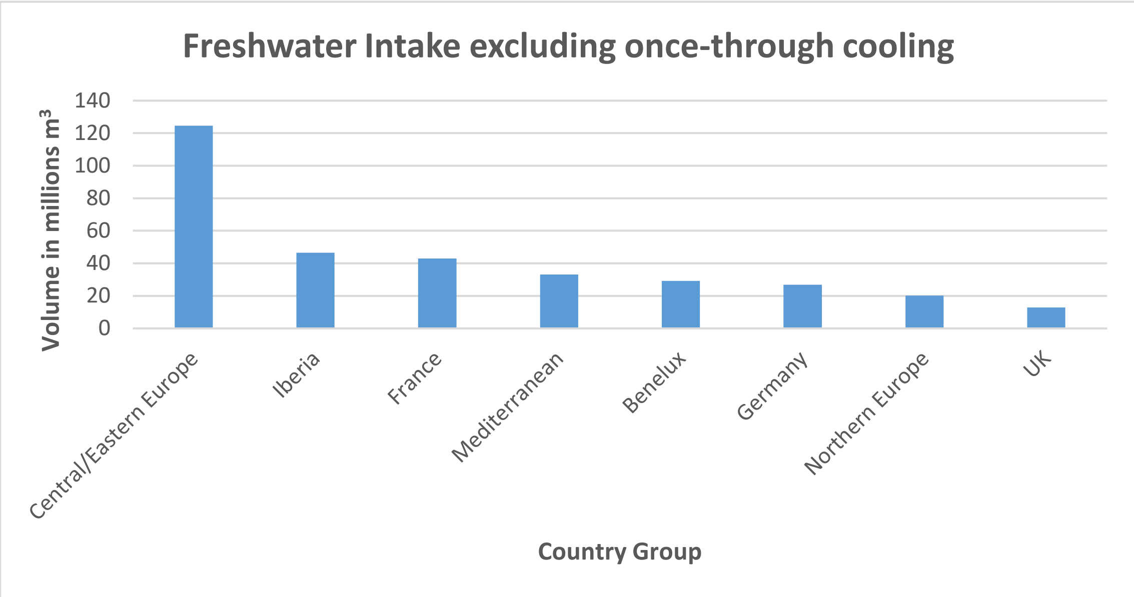


Figure 6 shows relative freshwater intake volumes per country regions, in m^3 per kiloton (kt) of throughput, and excluding freshwater intakes for once-through cooling. When relative freshwater intakes are considered, Central and Eastern Europe presents the highest relative freshwater intake volume with 4517 m^3 per kt of throughput, with Northern Europe presenting the lowest with 478 m^3 per kt of throughput, and UK the second lowest with 511 m^3 per kt of throughput.

Figure 6. Relative Freshwater intake per country group (once-through cooling volumes have been excluded)

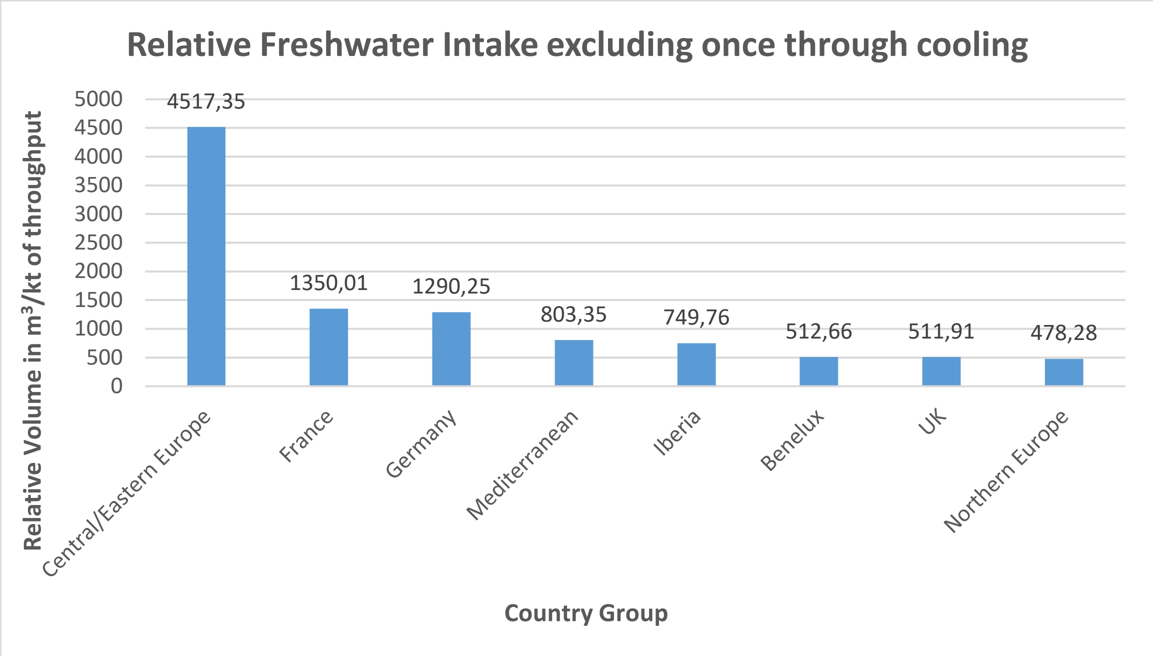
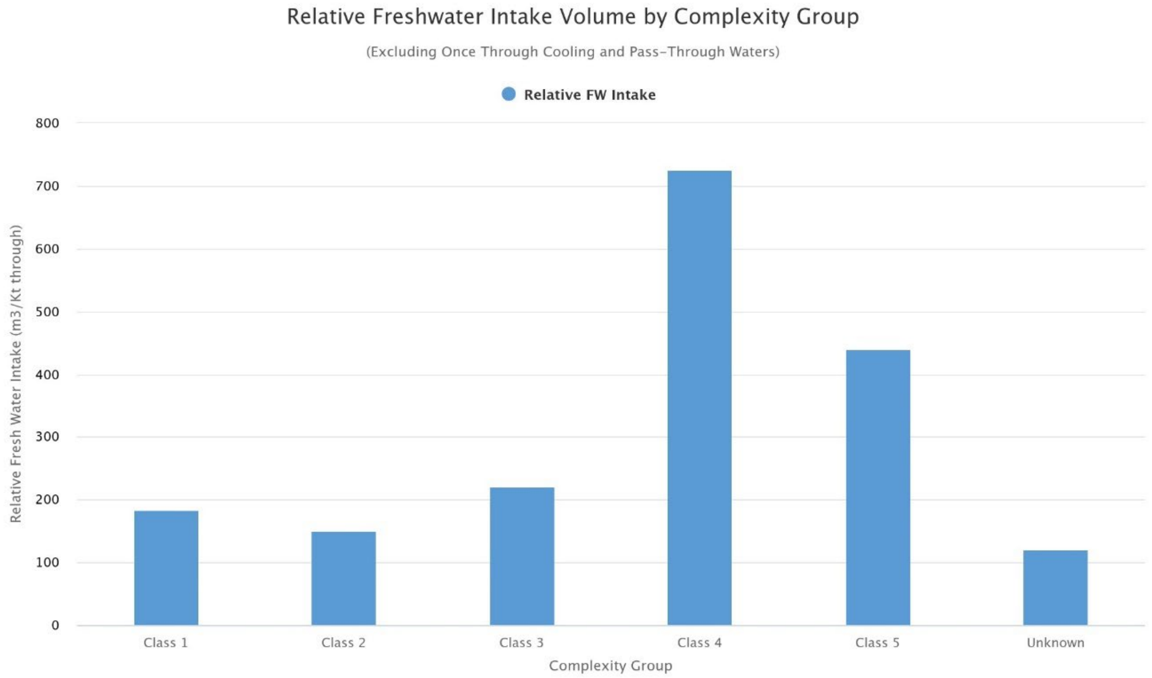


Figure 7 shows the relative freshwater intakes by complexity group excluding once through cooling as well as direct or pass through discharges. Refineries in the class 4 complexity group presented the highest relative freshwater intake volume with 726 m^3 per kiloton of throughput. This high relative freshwater intake is due to one refinery's high intake of freshwater representing approx. 65% of the water intake in this complexity group.

Figure 7. Relative Freshwater intake per Refinery Complexity Excluding Once-trough cooling and passing through waters)



By way of comparison (**Table 7**), the 2016 survey (72 refineries) and 2019 survey (61 refineries) indicated a total freshwater intake of 352 million m^3 and 361 million m^3 respectively, for purposes other than once-through cooling. However, comparison with previous surveys could reflect the different population of refineries reported under the surveys, or differences in survey definitions (volumes defined as the sum of intakes vs. volumes defined as the sum of water uses like in 2013 and 2010). Presenting the numbers relative to throughput decreases this bias, however, and increase in relative freshwater withdrawal is observed for 2019 and 2022 in comparison to previous surveys. If direct pass-through water is excluded, a relative freshwater withdrawal of 953 m^3/kiloton is obtained, still higher than previous years.

Table 7. Historical freshwater Withdrawal and Relative freshwater withdrawal volumes (excludes water withdrawn for once-through cooling).

Year of Survey	Number of Reporting Refineries	Freshwater withdrawal (million m^3/year)	Relative freshwater withdrawal (m^3/kiloton throughput)
2010	98	419	693
2013	78	371	742
2016	72	352	690
2019	61	361	821
2022	48	336	1093

2.2. USES

The 2022 web form survey considered the water use classifications shown in **Table 8**.

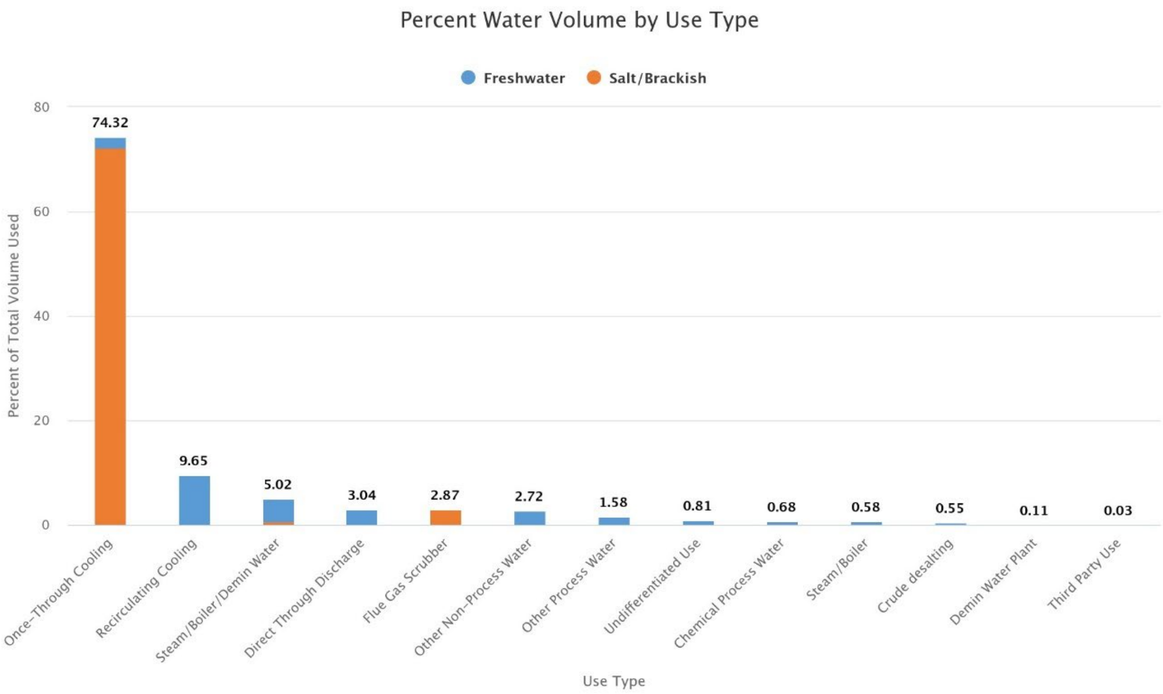
Table 8. Classifications of water uses.

Water Uses
Chemical process water
Crude desalting
Direct through discharge[1]
Flue gas scrubber
Once-through cooling
Other non-process water
Recirculating cooling
Steam/boiler/demin water
Steam /boiler plant
Demin water plant
Third party use
Other process water
Undifferentiated use
Sour water stripper

[1] Direct through discharge has been included for information purposes but is not strictly a use. It includes rainwater, and water derived from remediation/hydraulic control.

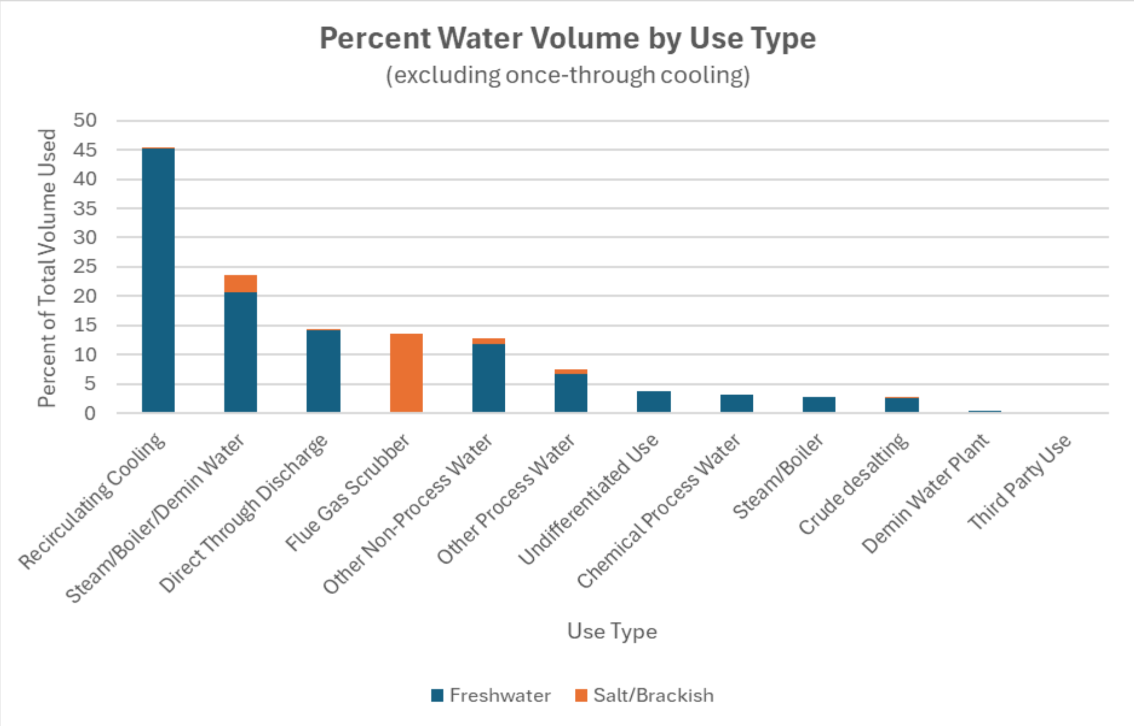
Water uses, by percentage of water used, are shown in **Figure 8**. The water usage is shown by percentage to provide a relative comparison of the water utilized for each use, considering not all respondents provided volumes for all water uses. **Figure 8** includes once-through cooling volumes which represent approximately 74% of all water use and comes primary from salty/brackish sources (approximately 97%).

Figure 8. Percent of water use split by type (including once-through cooling)



When plotted in the same graph, the high volumes of water used for once-through cooling relative to other use volumes dominate the scale of the graph while occluding meaningful analyses of other water use types. Therefore, in most subsequent analyses, once-through cooling waters have been removed and, where useful, have been included in stand-alone graphs. As shown in **Figure 9,** the largest use was recirculating cooling (45%), followed by steam/boiler/denim water (23%), flue gas scrubber (13.5%) and other non-process water (approximately 12%). Direct through discharge represented approximately 14% of the total water use excluding once-through cooling. Most of the water used was freshwater (approximately 80%) with salt/brackish water used primarily in the flue gas scrubber, and smaller volumes used in steam/boiler/denim and for other process and non-process water.

Figure 9. Percent of water use split by type (excluding once-through cooling)



Of the total fresh water used on site, approximately 130 million m^3 (44%) was being utilized for recirculating cooling purposes. The percentage of fresh water utilized for recirculating cooling was calculated for all the refineries in a country group that indicated use of fresh water for this purpose. As shown in **Table 9**, the percentages ranged from as little as 0% in the Northern Europe Region to a maximum of 54% in Central and Eastern Europe. The percentages tend to be higher in country groups with limited access to brackish/saltwater sources such as Central and Eastern Europe. Conversely, the percentage is lowest in those regions with relatively easy access to saltwater sources, such as in Northern Europe and UK.

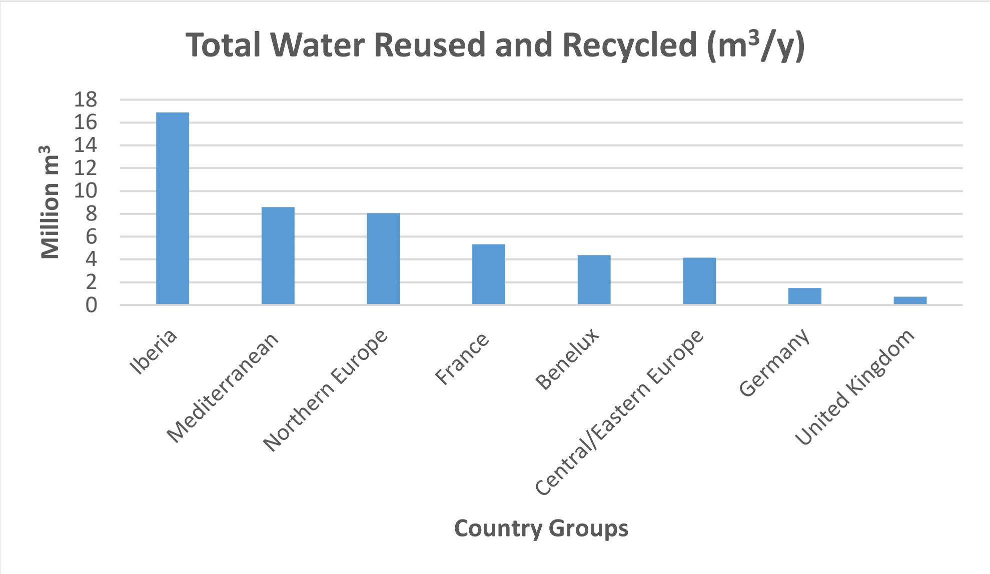
Table 9. Percent of fresh water intake used for recirculating cooling across country groups.

Country Group	Percent of fresh water intake used for recirculating cooling	Number of sites within each country group that utilizes once-through cooling
Benelux	5.63%	2
Central and Eastern Europe	54%	3
France	9.9%	1
Germany*	10.1%	1
Iberia	12.5%	1
Mediterranean	6.4%	3
Northern Europe	0%	2
UK**	0.5%	0

* Since only 4 out of 15 relevant refineries responded, the Germany country group is not representative within this survey.
** Since only 3 out of 7 relevant refineries responded, the UK country group is not representative within this survey.

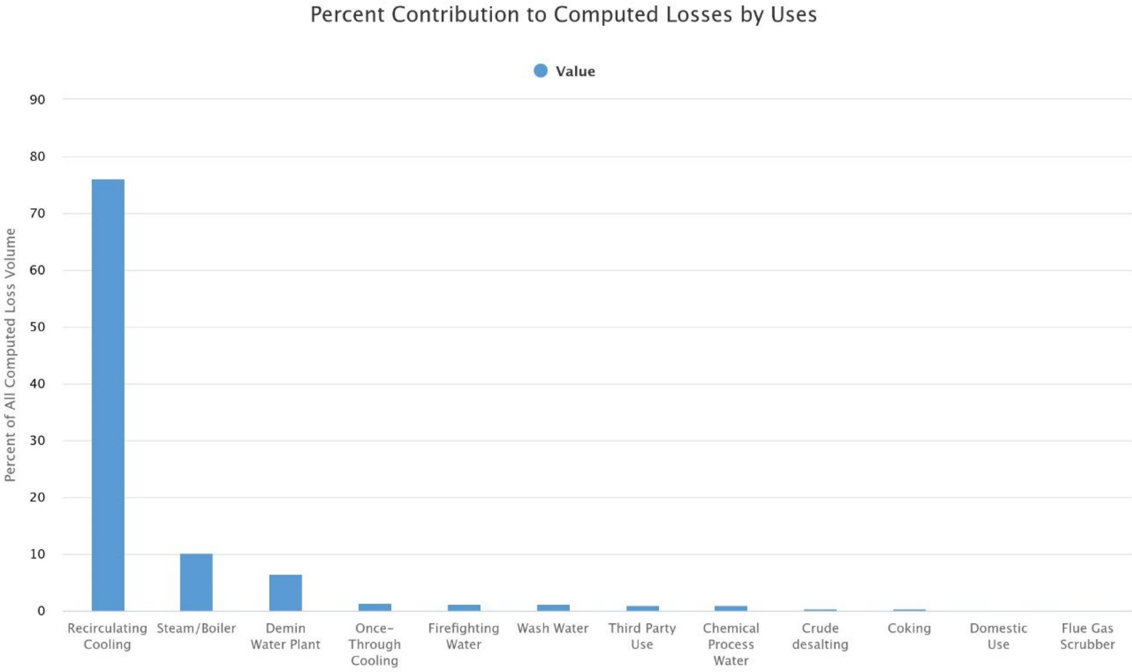
The uses also contain reused/recycled water, which was calculated at about 85 million m^3 by the water survey tool as filled in by the respondents. This volume seems high and a closer look at individual refineries water diagrams suggests a lower volume in the order of 49.5 million m^3. Most of the reuse/recycling volumes originate from the reuse of sour water and the reuse of refinery effluent after further treatment. As shown in **Figure 10**, Iberia showed the highest volume of water reused/recycled with Germany and the United Kingdom showing the lowest volumes.

Figure 10. Water Reused and recycled per Country Group.



Respondents defined water uses and were asked to provide the amount of water directed into the use as well as the amount of water leaving the use and being directed to subsequent uses or effluent streams. In some cases, the respondents did not know the specific volumes but were able to provide an estimate of the water loss occurring in the use. These data made it possible to compute the relative loss of each of the uses by taking the difference of incoming and outgoing flows for each use. Since not all of the respondents were able to provide loss data on each use, the specific volumes computed may not be fully representative. Therefore, loss values are presented in terms of percent of all computed losses, as shown in **Figure 11**. Recirculating cooling represents the vast majority of computed loss volumes across all uses. This result is not surprising considering the recirculating cooling process circulates the same water through the cooling system multiple times and has substantial evaporative loss and relatively minimal blowdown volumes.

Figure 11. Percent of all computed loss water by use type



2.3. EFFLUENT DISCHARGE VOLUMES

This section provides an overview of the quantities and types of effluent discharges. Also provided are information on the water body types receiving the effluent. Finally, a summary of water treatment types is also provided. With respect to refinery effluent volumes, Concawe has been collecting data from its membership regularly since 1969, and refinery effluent discharge volume data for these survey years are summarised in **Table 10**. Comparisons to previous surveys is difficult given the way data was reported. For example, in 2005 data did not include once-through cooling volumes while 2008 and 2010 surveys contains some but not all once-through cooling volumes. Excluding once-through cooling showed a reduction in 2016 compared to 2013, and even further so compared to 2005. Data for 2019 and 2022 include once-through cooling volumes. A potentially most meaningful indicator is the volume of effluent per tonne of throughput, which indicated that the relative total effluents have decreased in 2019 and 2022 compared to previous years when considering total effluents.

Table 10. Effluent discharge data from 1969 to 2022

Year of survey	Number of reporting refineries	Total aqueous effluent[1] (million m^3/year)	Relative Aqueous effluent (m^3/tonne throughput)
1969	80	3,119	n.d.
1974	108	3,460	n.d.
1978	111	2,938	5.4
1981	104	2,395	5.4
1984	85	1,934	4.6
1987	89	1,750	3.9
1990	95	1,782	3.5
1993	95	2,670	4.8
1997	105	2,942	4.7
2000	84	2,543	4.9
2005	96	790[2]	1.2[2]
2008	125	1,112[3]	1.5[3]
2010	98	1,583	2.6
2013	78	2,370 (465)[2]	4.7 (0.92)[2]
2016	72	2,693 (371)[2]	5.03 (0.73)[2]
2019	61	1998[3]	4.51[3]
2022	48	1348[3]	4.37[3]

n.d. = not determined

[1] Total aqueous effluent in the table have been reported under different definitions and therefore past years are not always comparable. At times it had referred to the sum of process effluents, cooling water and other flows such as lightly contaminated rainwater. At other times it meant only treated effluents, with or without once trough cooling.

[2]In parenthesis, excluding once-through cooling volumes.

[3] Values include once-through cooling volumes, and transfers (3.6 mln m^3).

Total water discharge volumes for 2022 are shown in **Table 11**. The table also shows the type of receiving water body, indicating fresh water bodies such as rivers and lakes, and brackish/salty receiving water bodies such as the sea and estuaries. **Table 11** also shows the volume of water transfers to external facilities.

Table 11. Total water discharged in 2022 grouped by receiving water body classification

Receiving water body	Total Discharge Volumes (m^3/y)
Fresh water	353,340,873
Brackish/salty water	991,889,445
Transfer	3,661,600
Total	1,348,891,918

In contrast to total aqueous effluent volumes, **Table 12** shows treated effluent volume data for 2022 and previous years. When compared with previous data (back to 2010) the table shows a general decrease in treated effluents and relative treated effluents since 2010, which, for the last three surveys has remained fairly constant.

Table 12. Treated effluent discharge data from 2010 to 2022

Year of Survey	Number of reporting refineries	Treated Effluent[1] (million m^3/year)	Treated Relative Effluent (million m^3/tonne throughput)
2010	95	569	0.92
2013	78	451	0.90
2016	72	330	0.65
2019	61	232	0.52
2022	48	200	0.65

[1]Including treated transfer streams

Figures 12 and **13** present total and relative effluent quantities by country group type and partitioned by receiving environment (fresh, salt/brackish, transfers) and including once-through cooling. In the Northern region, a limited number of refineries contributed to the high discharge volumes. These refineries are adjacent to an ocean shore and are equipped with once-through cooling systems that discharge either in harbours/estuaries or directly in the marine environment. The corresponding relative discharge volumes gives a more balanced picture (**Figure 13**).

Figure 12. Annual effluent discharge volumes, plotted according to salinity of receiving environment. Values include once-through cooling volumes.

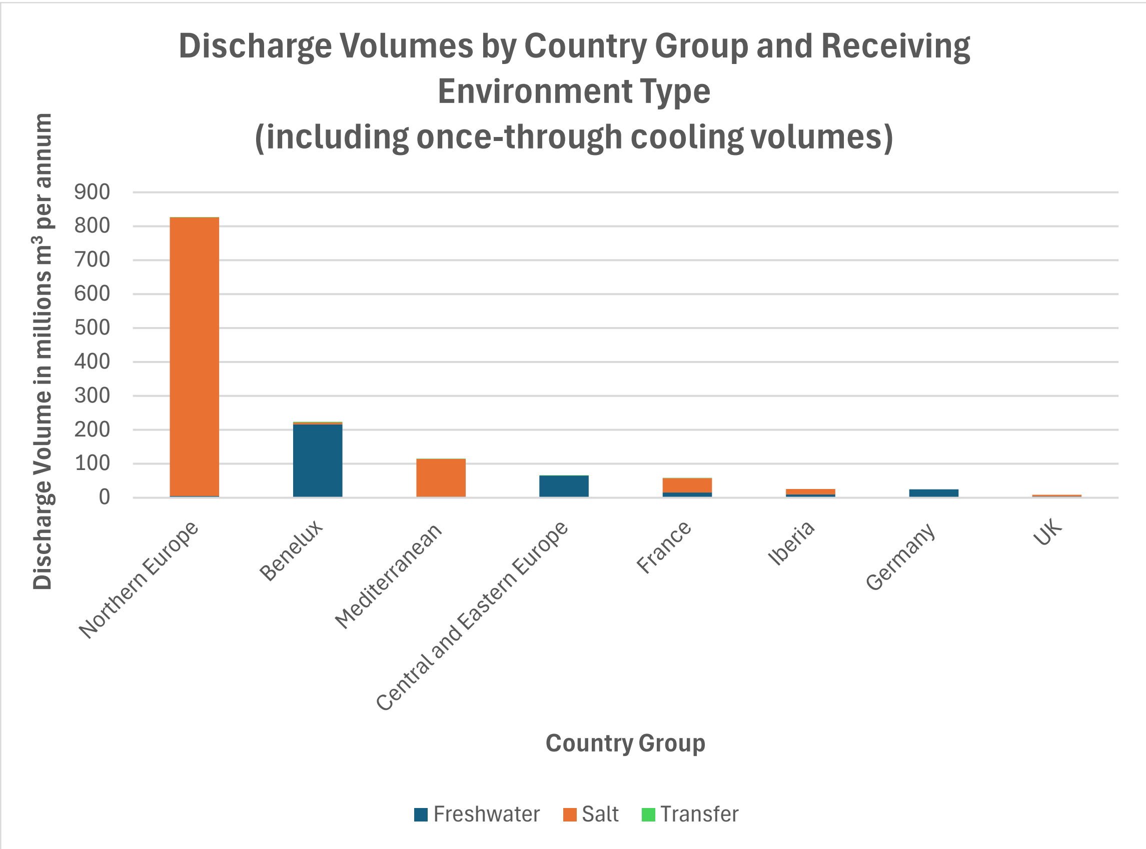


Figure 13. Relative annual effluent discharge volumes, plotted according to salinity of receiving environment. Values include once-through cooling volumes.

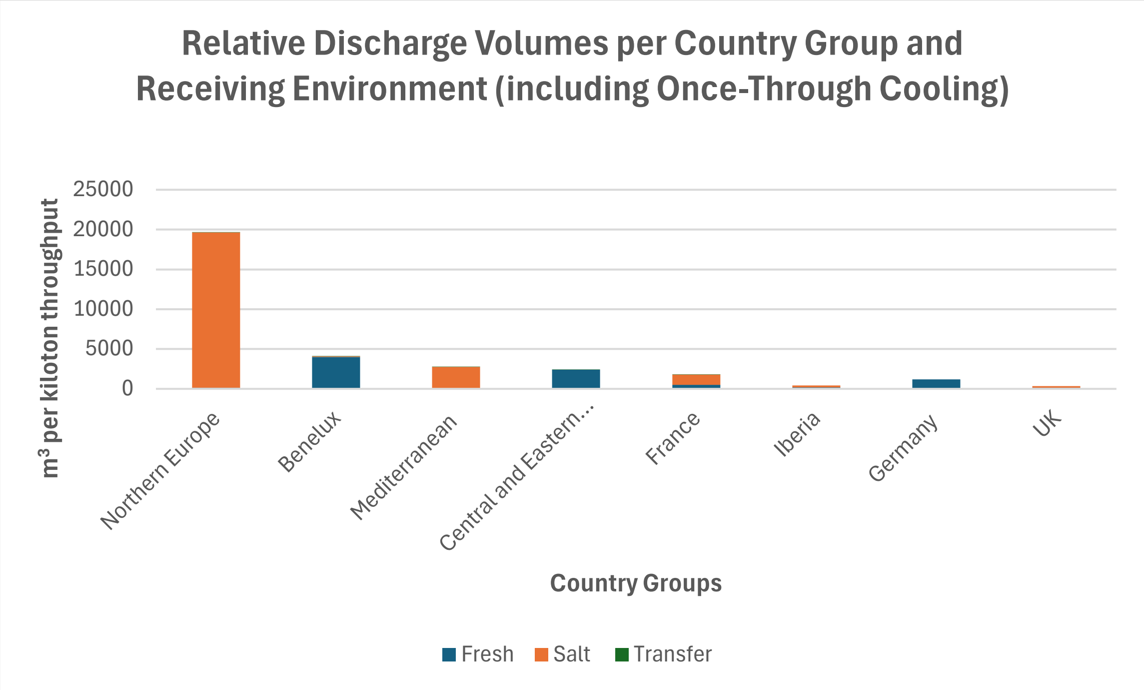


Figure 14 and **Figure 15** show water effluent quantities by country group and by receiving environment in total and relative volume, excluding once-through cooling volumes. Those country groups that have refineries discharging into large rivers and in landlock areas such as Central and Eastern Europe, Germany, and Benelux understandably have higher volumes of water discharged to fresh water environments than country groups such as Northern Europe, Iberia or Mediterranean, that have ready access to the sea. When relative effluent volumes are considered, Central and Eastern Europe and France continue to have the largest discharge volumes.

Figure 14. Annual effluent discharge volumes, plotted according to salinity of receiving environment. Values exclude once-through cooling volumes.

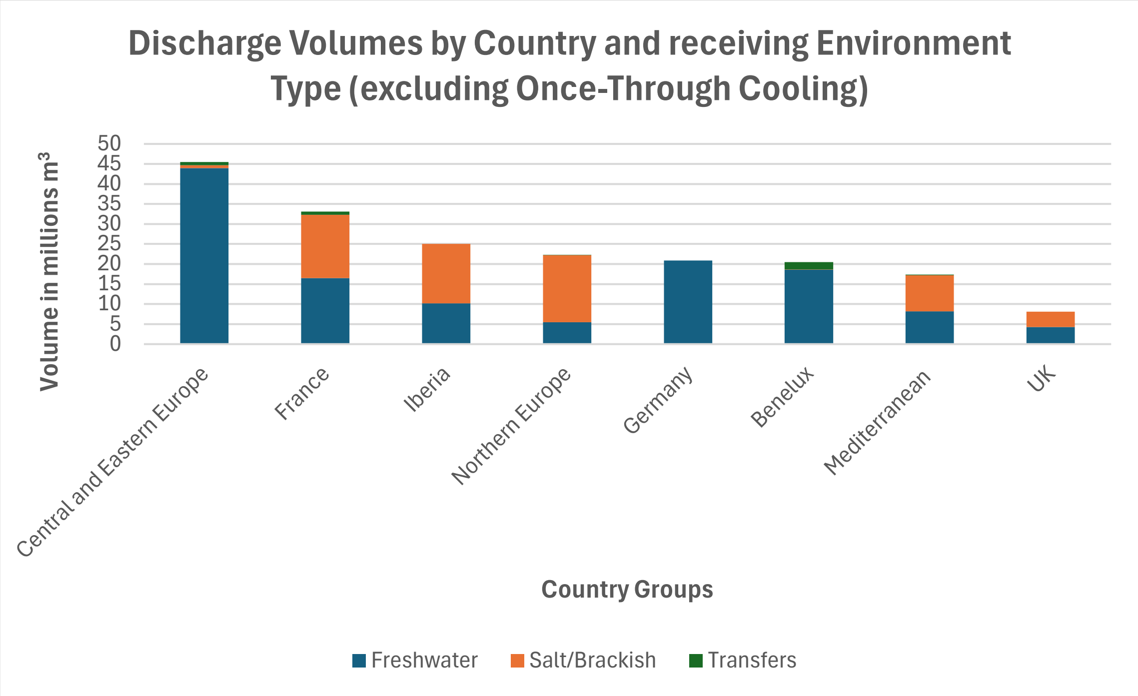
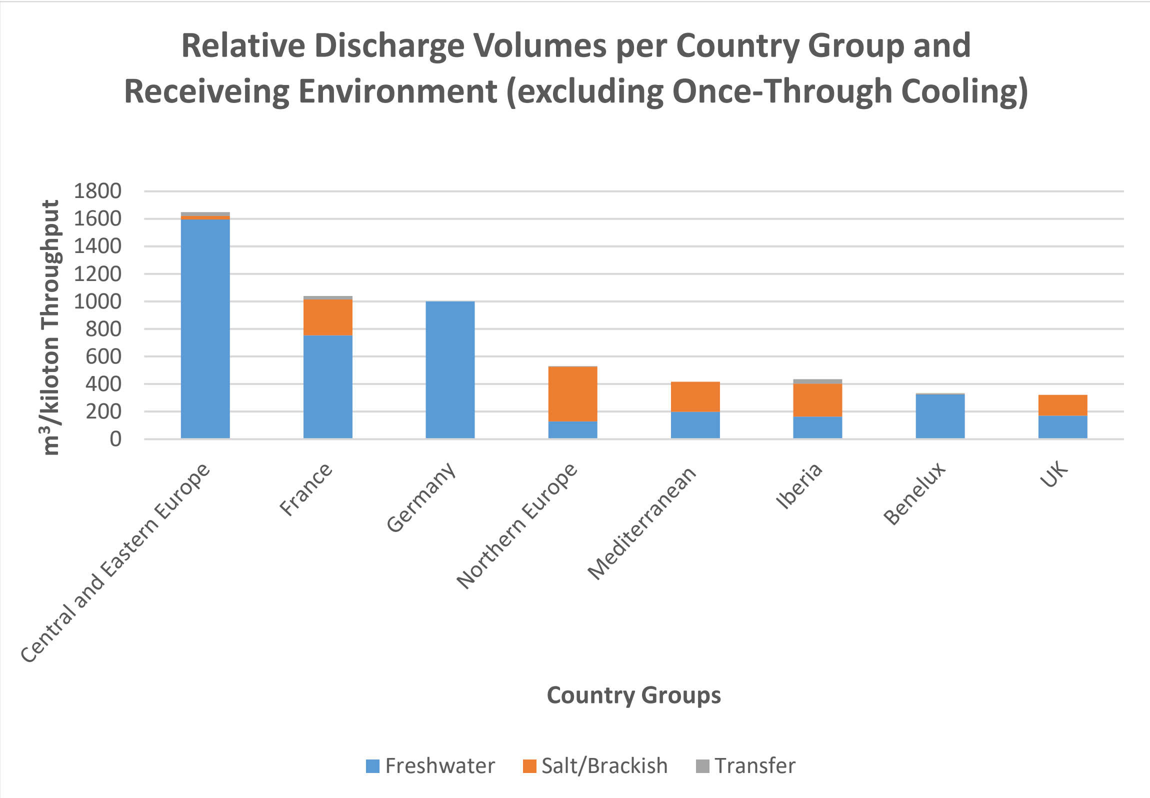


Figure 15. Relative Annual effluent discharge volumes, plotted according to salinity of receiving environment. Values exclude once-through cooling volumes.



When once through cooling volumes are included, as shown in **Figures 16** and **17**, Benelux and Central and Eastern Europe present the largest discharges of effluent into freshwater environments. In order to get better refinement on industry discharge waters, since 2016 the surveys asked responders to specify the final discharge environment of waters that were transferred to third parties for treatment or for recycling purposes. Based on the 2022 survey responses, no transferred waters discharging into fresh water environments were reported.

Figure 16. Annual effluent discharge volumes into freshwater. Values include once-through cooling volumes

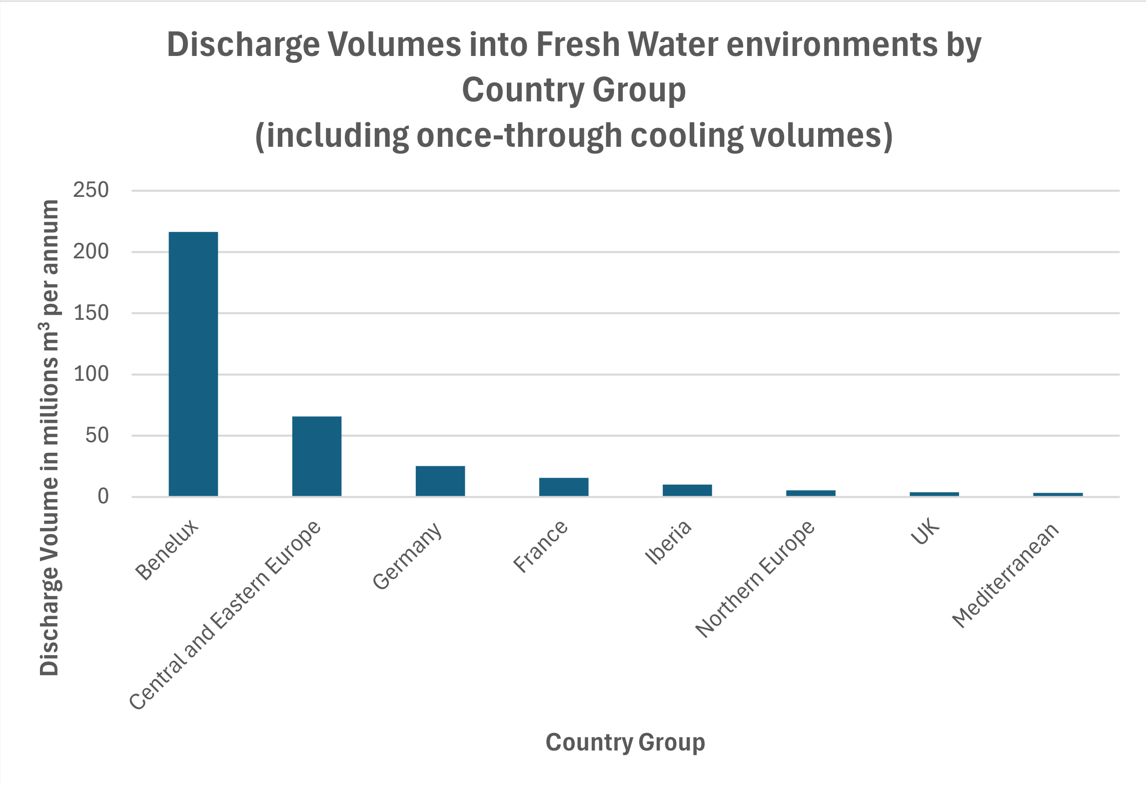


Figure 17. Annual effluent discharge volumes into freshwater. Values include once-through cooling volumes

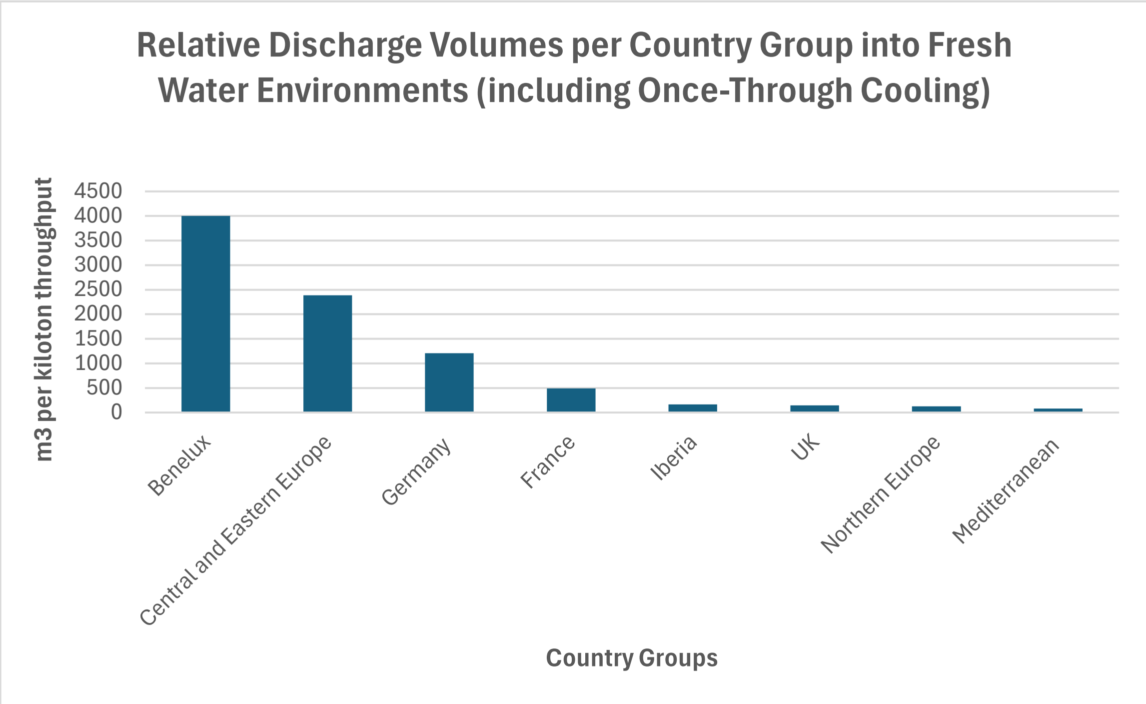


Figure 18 shows water quantities of treated effluents and effluents that received no treatment (uncontaminated water), with Northern Europe showing the largest volume of uncontaminated water discharged to sea. While the reason for this was not confirmed in the 2022 survey, the Northern region has shown similar volumes of untreated effluents in previous surveys which included a large volume of scrubber water that was mixed with cooling water prior to discharge and that did not require treatment.

Figure 18. Water effluent volumes by treatment and no treatment (once-through cooling volumes excluded)

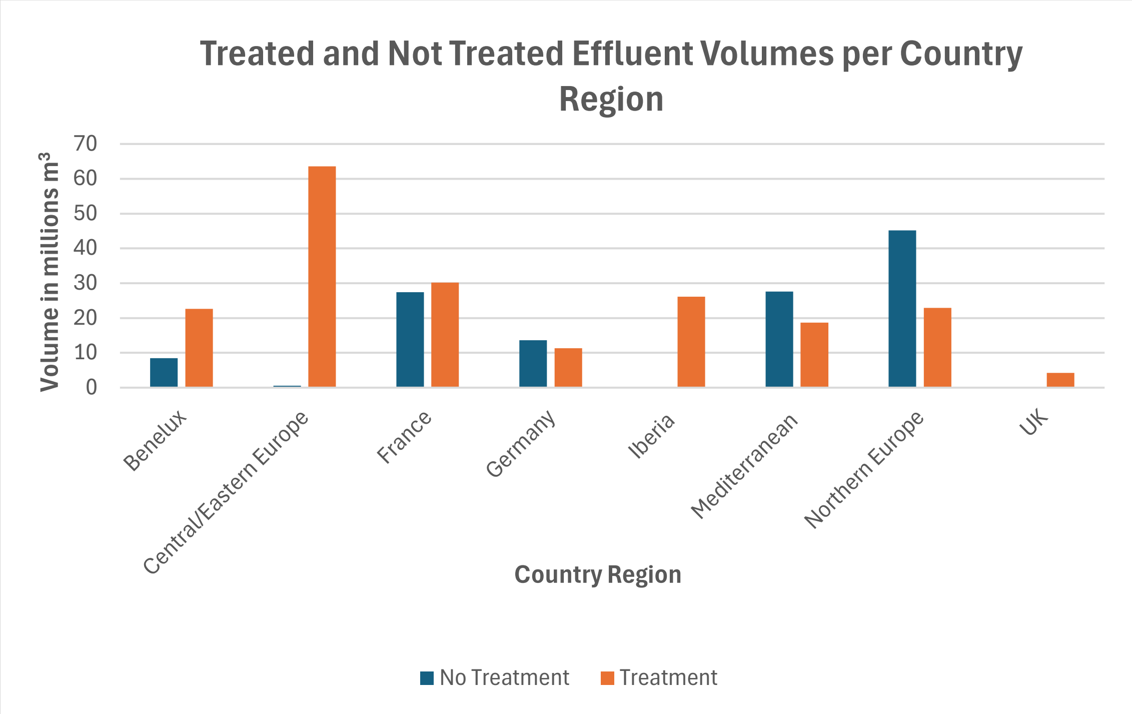
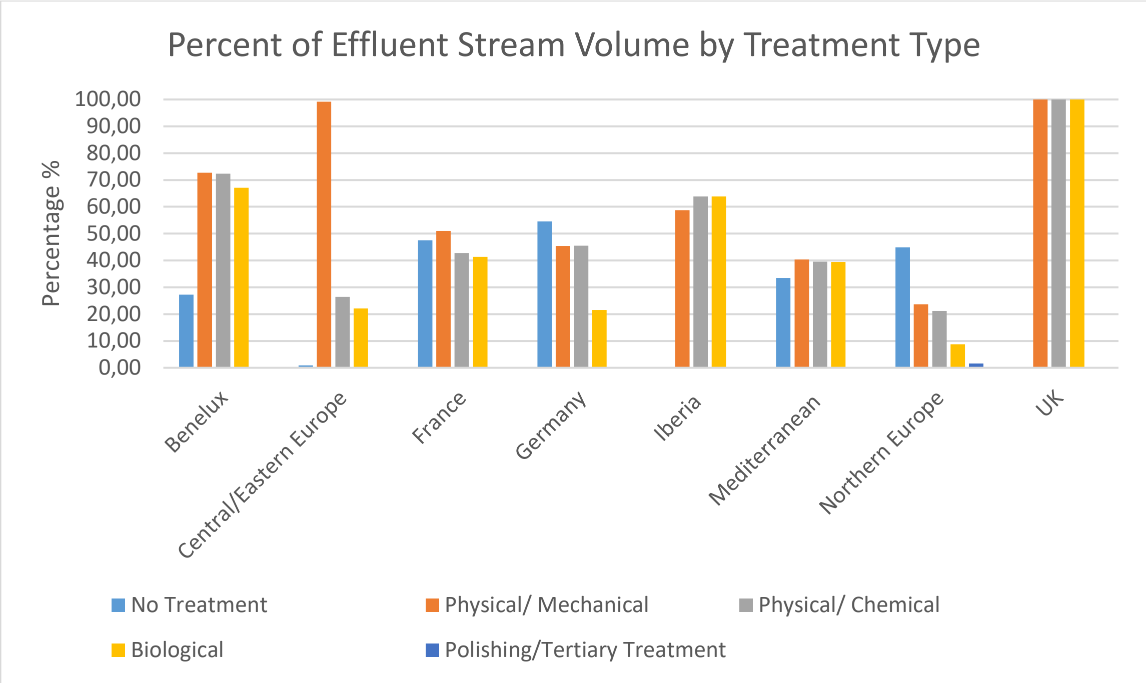


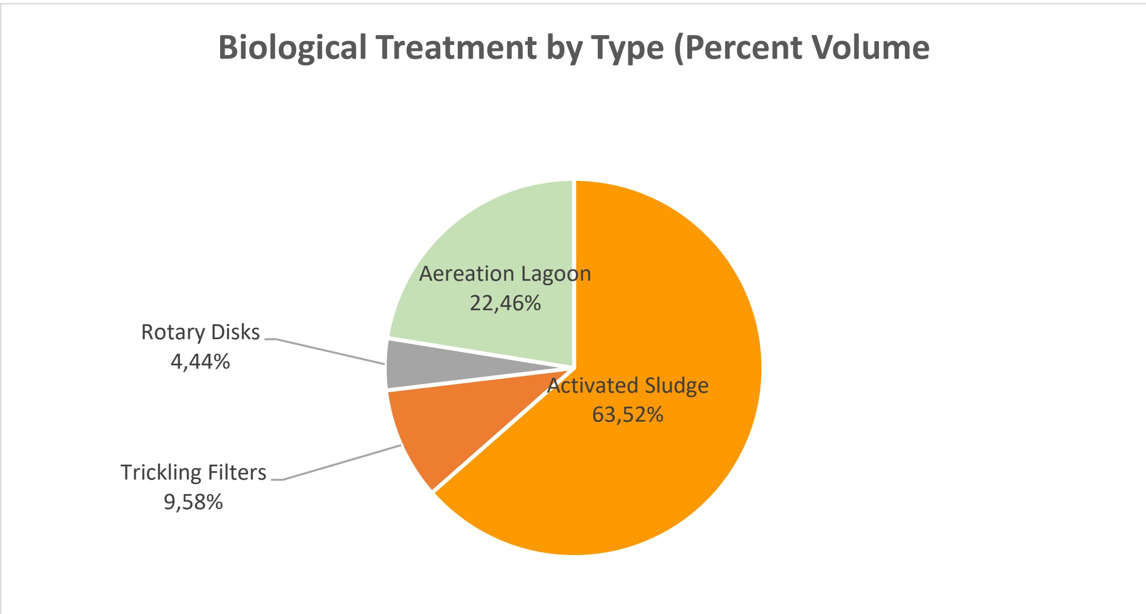
Figure 19 shows the percentage of effluent by treatment type, excluding once-through cooling volumes. Note that some country groups (Iberia, UK) presented similar volumes for physical/mechanical treatment (such as API separators), physical/chemical treatment (such as DAF) and biological representing a three stage WWTP. Final polishing was reported by two refineries representing some 4,6 million m^3.

Figure 19. Percent of effluent stream volumes by treatment type. Once-through cooling volumes have been excluded.



Further analysis of the type of biological treatment carried out by the reporting refineries is shown in **Figure 20**, that shows the percent of effluent stream volumes receiving biological treatment segregated by biological treatment type. The activated sludge process is by far the most common biological treatment technique applied (63% of treated volume), followed by aeration lagoons (22.5%), trickling filter (9.5%) and rotary disks with just 4.5% of the treated volumes.

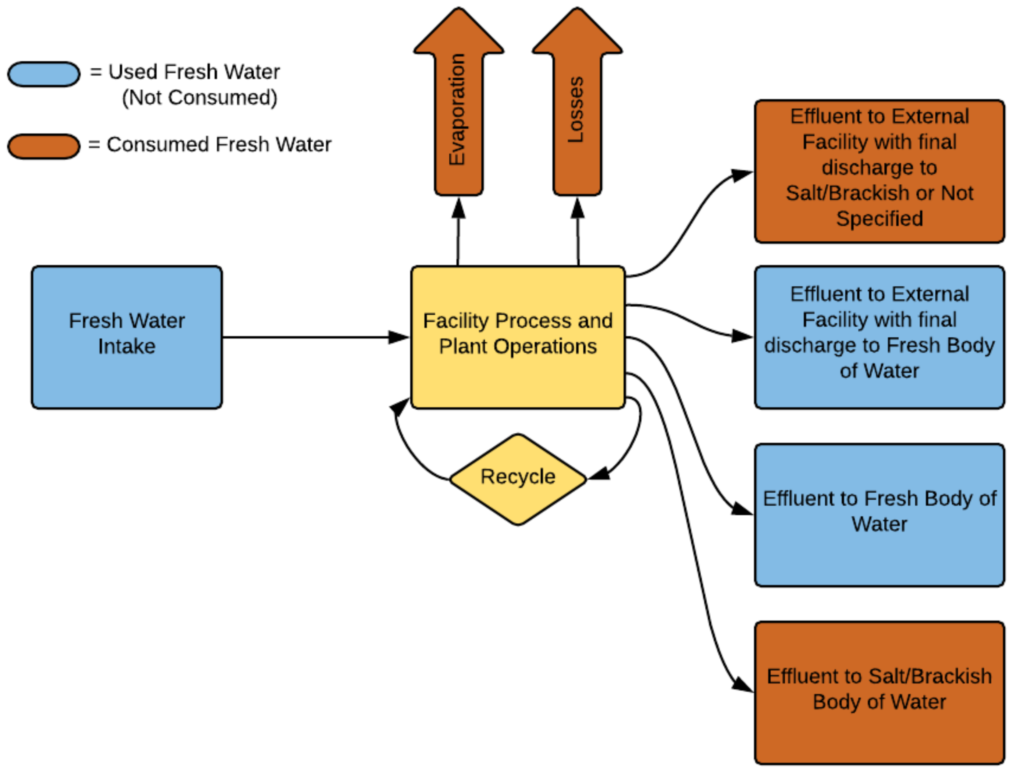
Figure 20. Percent of effluent stream volumes with biological treatment by biological treatment type



2.4. FRESHWATER CONSUMPTION

The refining industry handles substantial quantities of water of various types and from various sources. Of particular interest is the amount of fresh water that is utilized in the industry and ultimately consumed as a result of operations. This freshwater consumption metric provides a relevant parameter for assessing resource efficiency. However, solely relying on freshwater intake volumes does not provide an accurate picture of the actual water consumed as some intake water is passed through the facility without being depleted. In practice, fresh water is consumed directly through evaporation and losses or indirectly through discharge to salt/brackish water bodies, as shown in **Figure 21.**

Figure 21. Flow diagram of freshwater consumption accounting



Freshwater consumption was calculated as the amount of fresh water withdrawn by the refining industry not including once-through cooling volumes and subtracting out the amount of fresh water that is returned to a freshwater body, as per the IPIECA definition of freshwater consumption, indicator Env-1 Freshwater (IPIECA, API and IOGP, March 2020, Revised 2023). The rationale for this approach is that fresh water that is returned to freshwater bodies is not taken out of the regional water cycle, remaining available to other users downstream. Evaporation and losses were calculated, where available, based on the difference between water flowing into a given use and the water flowing from the use and are separately from the consumption calculations as not every company reported losses. In the consumption calculation, losses are included in the calculations by using the difference between site intake and site discharge volumes. In addition, fresh water withdrawn for once-through cooling purposes but subsequently discharged to a salt/brackish body was also included in the freshwater consumption computation, as shown below:

$$FW_{consumption} = (FW_{intake} - Disch_{FW\ body}) + FW_{once\ thru\ disch\ to\ brackish}$$

To provide an accurate accounting of freshwater consumption, the freshwater intakes not utilized for processing and not in contact with refinery product or intermediate streams were excluded, as follows:

- Fresh water, used for once-through cooling water, returned unchanged, excluding thermal effects, to a freshwater source. The large volumes often used in cooling do not represent consumption since the water is returned and are therefore removed as they would otherwise distort freshwater withdrawal data.
- Fresh water already quantified as an intake stream but utilized in other intakes at the site (e.g.: internal recycles are only accounted on primary intake).

In some cases, fresh water intake was discharged to an external facility for treatment (waste water treatment plant) or reuse (recycling). In the 2022 survey, responders were asked to provide data on the final discharge of transferred waters, if known.

The freshwater consumption was calculated for each refinery individually and subsequently aggregated across the entire industry. If effluents related to fresh water exceeded the freshwater intake for the given refinery, it was assumed that fresh water being discharged was equal to the intake and therefore evaporation and losses were set to zero for the given refinery. This conservative approach prevented scenarios of “created fresh water” (where a refinery discharged more fresh water than it withdrew) from being included in the freshwater consumption values.

The industry-wide freshwater consumption aggregated from all considered sites was calculated to be 197.8 million m^3. Of these, 130.7 million m^3 were due to freshwater consumption within the facility (evaporation and losses), corresponding to a relative freshwater consumption of 425 m^3/kiloton of throughput, and 67 million m^3 (218 m^3 per kiloton of throughput) due to freshwater water effluent discharging into a salt/brackish receiving water body. Total relative freshwater consumption (both losses and evaporation, and discharge to a salt/brackish environment) was 643 m^3 per kiloton of throughput.

Figure 22 presents the freshwater consumption aggregated by country group whereas **Figure 23** presents the same relative to throughput. Central/Eastern Europe had the highest country group freshwater consumption followed by the Iberia and Mediterranean country groups. The high freshwater consumption in the Central/Eastern Europe country region is due to one refinery that reported a large volume of freshwater consumption due to evaporation and losses related to recirculation cooling. Central/Eastern Europe had also the highest relative freshwater consumption followed by France and Iberia.

Figure 22. Freshwater consumption per country group

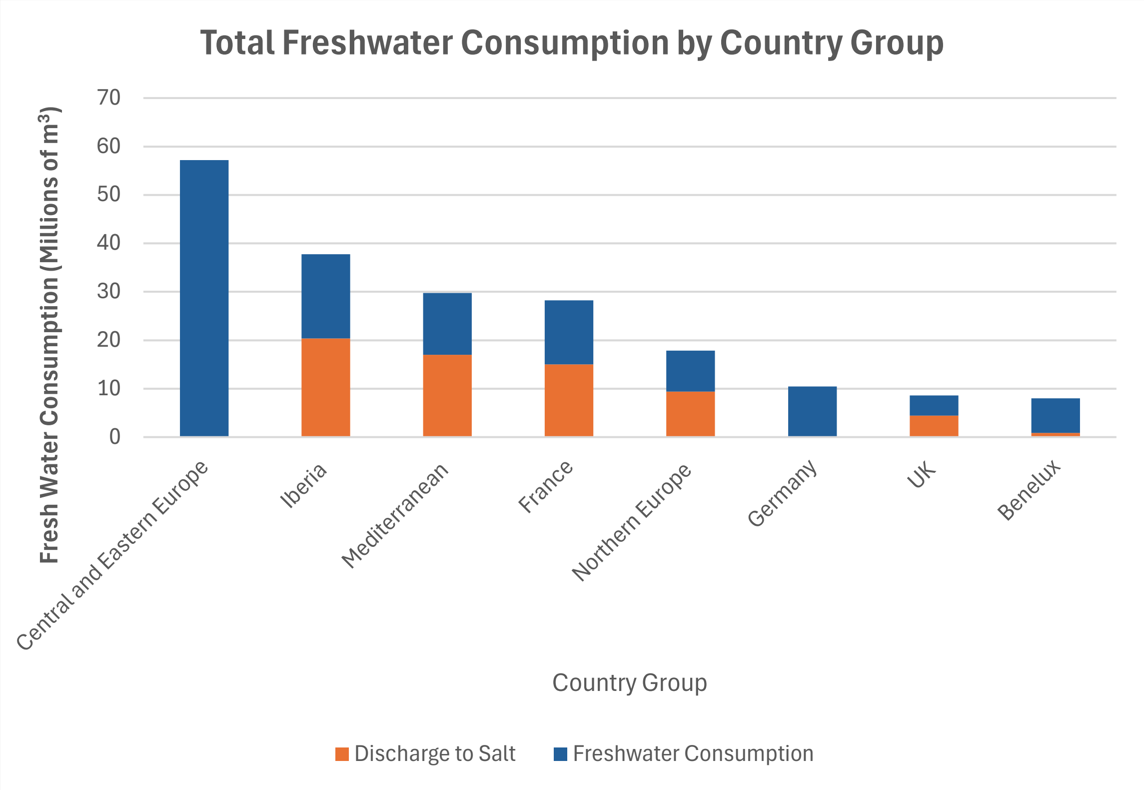


Figure 23. Relative fresh water consumption per country group

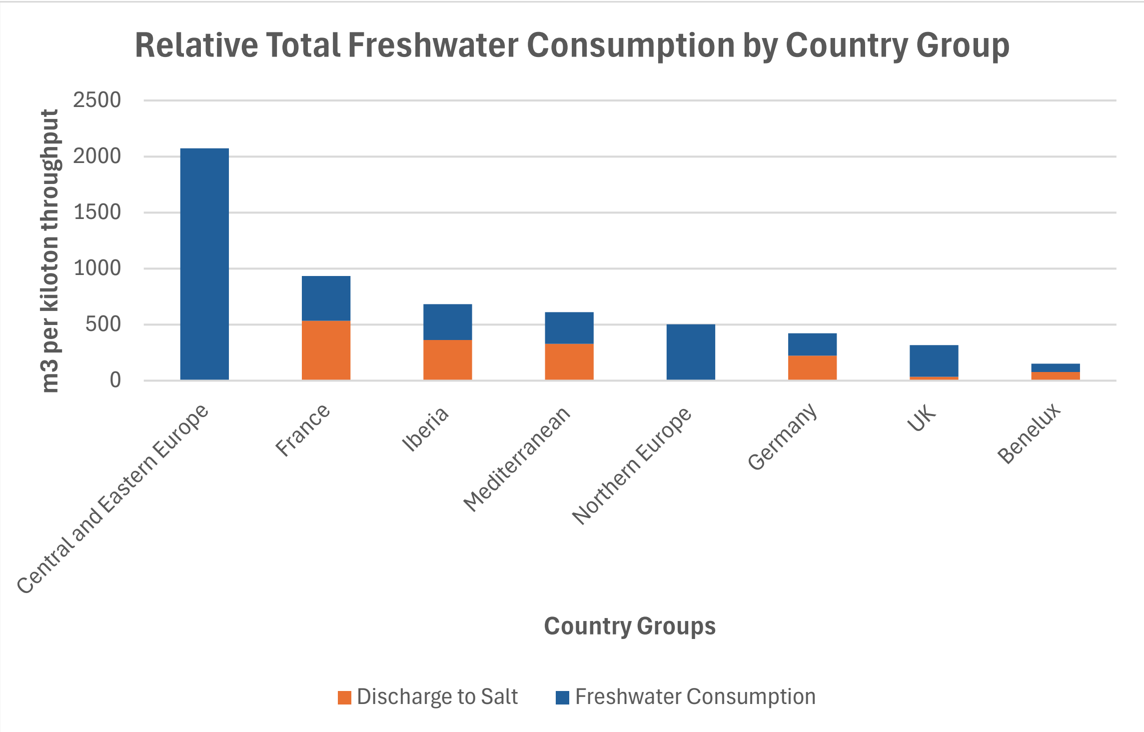
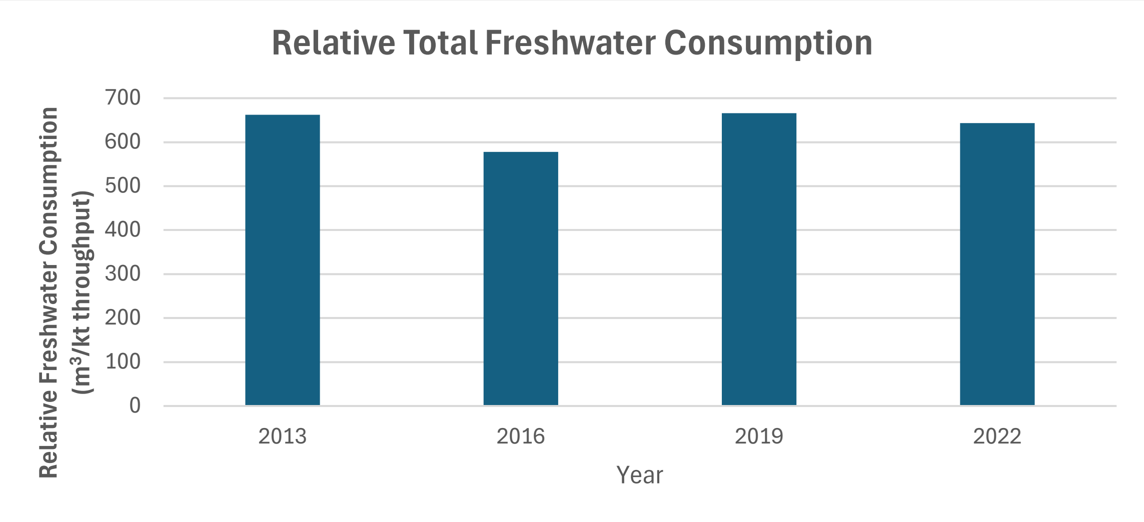


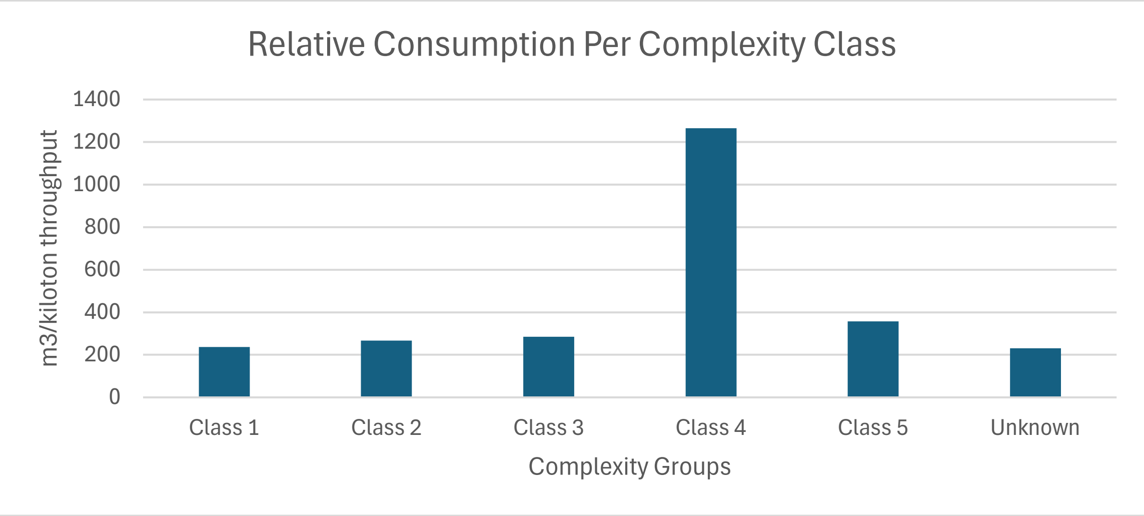
Figure 24 presents the relative freshwater consumption for the 2013, 2016, 2019 and 2022 survey data. As shown in the Figure, relative consumption is very similar across the survey years and varied from a maximum of 666 m3/kt in 2019 to a minimum of 578 m3/kt in 2016. The small differences observed are likely related to the different set of refineries that reported data in each of the four survey years from 2013 to 2022. Relative consumption is considered more representative for the sector as a whole (on the basis that use of water by refineries should not have significantly changed from 2013 to 2022).

Figure 24. Relative freshwater consumption for survey years 2013, 2016, 2019 and 2022.



Fresh water consumption was also analysed per complexity class as shown in **Figure 25**. This consumption refers only to loses within the refinery and excludes effluents discharged to brackish/salty waters. Freshwater consumption generally increases with refinery complexity (conversion capacity). The high freshwater consumption related to class 4 complexity group is due to the same refinery that caused high relative water intake in **Figure 7**.

Figure 25. Relative Freshwater consumption by complexity group



3. REFINERY EFFLUENT QUALITY

This Section presents the reported concentrations and loadings of refineries discharges. With respect to the quality of refinery effluents, Concawe has been collecting data from its membership regularly since 1969. For 2022, key parameters reported are summarised in **Table 13** which presents the number of sites that reported the parameter, the total loading (kg/year) and the average concentration (mg/L) for all refineries reporting. In the calculation of the parameters shown in **Table 13**, the following conventions were used:

- Transferred discharges are not included (this data is presented separately in **Table 14**);
- For all analytical survey data, an entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) for an analyte are treated as a reportable result;
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects;
- Concentrations for facilities with multiple effluent streams were calculated by weighting the concentration values according to the effluent volumes;
- The average relative load is the total annual effluent load divided by the total annual feedstock throughput.

The above convention can result in uncertainties as several refineries did not report applicable detection limits for some of the substances.

Table 13. Summary of parameters monitored in the refineries's effluents. Effluents transferred to external facilities are not included in these values.

Analyte	Direct Discharges		
	Number of Sites	Total Mass (kg)	Avg. Conc. mg/L
Organics			
Oil in Water (OIW) or Total Petroleum Hydrocarbons (TPH)	34	83,578	0.84
Phenols Index (by ISO Method)	31	6,642	0.04
Benzene, Toluene, Ethylbenzene, Xylene (BTEX)	13	834	0.02
Inorganics			
Total Nitrogen (TN)	34	1,343,444	7.94
Ammonia			
General Parameters			
Biological Oxygen Demand (BOD)	34	1,059,356	11.35
Chemical Oxygen Demand (COD)	38	7,149,809	46.92
Total Suspended Solids	38	1,612,606	10.84
Metals			
Cadmium	34	51	0.0003
Lead	33	256	0.0016
Mercury	33	246	0.0017
Nickel	33	1,621	0.0094
Vanadium	25	7,374	0.0452

Note: Receiving waters (fresh/brackish) are not differentiated.
The above mass calculations followed the following conventions:

- An entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) are treated as a reportable result.
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects.

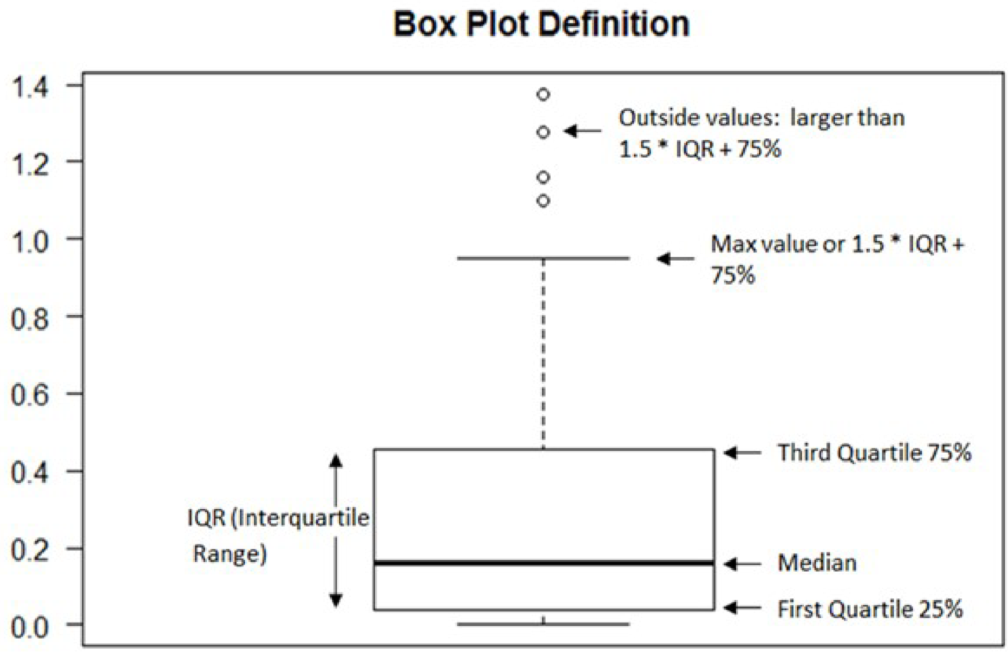
Ten refineries transferred some of their effluent water to an external facility for the purpose of treatment. Of these, two refineries monitored the effluent streams for at least one analytical parameter prior to transfer.

3.1. TRENDS IN REFINERIES WATER DISCHARGES

Results for all parameters listed in **Table 13** were analysed and this section presents 2022 data, together with historical data, and the graphics including box and whisker plots for total discharge load, relative discharge load per throughput, and average discharge concentration (**Figure 26** shows the definition of the box and whisker plot components). It should be noted that the population of reporting sites differs between survey years, and so not all metrics are strictly comparable when expressed as discharges for the sector. With regard to the plots shown, the following conventions were used:

- Data associated with transferred stream discharges are not included;
- Non-quantified concentration values are replaced with ½ the LOQ value;
- The total effluent load per refinery is the sum of all the individual effluent stream loads given for each refinery. Since total loading may be directly related to the number of refineries reporting, loadings relative to throughput are also presented. In addition, to ensure accurate trend analyses, both total and relative loadings are presented for data that is limited to the subset of sites that reported in 2016, 2019 and 2022. If less than 10 sites reported for the given parameter in each of the 3 years, then the trend plots for repeat sites are considered statistically weak and not displayed. Industry level loading values for 2022 are displayed in **Table 13** above;
- The average concentration per outfall across the industry is plotted. Refineries that have multiple outfall streams with measures for the parameter will be included more than once in the scatter plots as well as when computing industry averages. Therefore, the number "n" stated in the box and whisker charts is the number of outfalls that were used in the concentration and loading charts. The value in parenthesis is the number of refineries included.

Figure 26. Definition of box plot components



The following sections (3.1.1 to 3.1.6) describes the discharge loading and concentration data for all parameters listed in **Table 13** in more detail.

3.1.1. TRENDS IN TPH/OIL IN WATER IN REFINERY WATER DISCHARGES

As observed in **Figure 27** and **Table 14**, the number of refineries reporting for Concawe water use/effluent surveys has varied between 125 and 48 throughout the years, whereas the total oil discharged in effluents has decreased significantly from 44,000 tonnes in 1969 to 83 tonnes in 2022. Oil discharge relative to refining throughput has also continued to reduce over the whole period covered by the surveys; in recent years the relative discharge loading was 0.71 g TPH/tonne throughput in 2013 and reduced further to 0.36 g TPH/tonne throughput in 2022. The relative discharge for the reporting sites in 2022 was significantly lower than that in 2019 and 2016. The reason for this is not clear but may be due to different sites reporting in different years. To try to remove this potential bias, the relative discharge was recalculated for only the 23 sites common to the 2016, 2019 and 2022 datasets. For these 23 sites the relative TPH discharge in 2016 was 0.24 g/tonne throughput, and in 2022 was 0.17 g/tonne throughput. According to this analysis, a decrease in relative discharge between 2016 and 2022 has occurred (a 29% decrease between 2016 and 2022).

In 2022 there were two refineries who measured concentrations of oil in water in effluent streams that were subsequently transferred to an external facility for treatment. The final treatment efficiency at these external locations is unknown so exact loadings from these streams were not able to be determined, therefore it was assumed that the reduction efficiency at the external facility was 95 % (Concawe, 2012) which yielded an additional 0.6 tonnes of estimated oil that were discharged.

Table 14. Oil discharge data from 1969 to 2022

Year	Number of refineries reporting in each survey	Total oil discharged (tonne/year)	Oil discharged (g/tonne throughput)
1969	73	44,000	n.d.
1974	101	30,700	n.d.
1978	109	12,000	22.5
1981	105	10,600	24.0
1984	85	5,090	12.1
1987	89	4,640	10.3
1990	95	3,340	6.54
1993	95	2,020	3.62
1997	105	1,170	1.86
2000	84	750	1.42
2005	96	1,050	1.57
2008	125	993	1.33
2010	98[1]	798	1.30
2013	78	354	0.71
2016	72	257	0.50
2019	61	278	0.58
2022	48	83.6	0.36

n.d. = not determined
[1] Figures relate to 98 installations; they exclude the two installations that only reported data for water use.
All figures reported considering transfer streams.

Figure 27. Trends in total TPH loadings and relative TPH loadings in effluents, in Concawe surveys from 1969 to 2022.

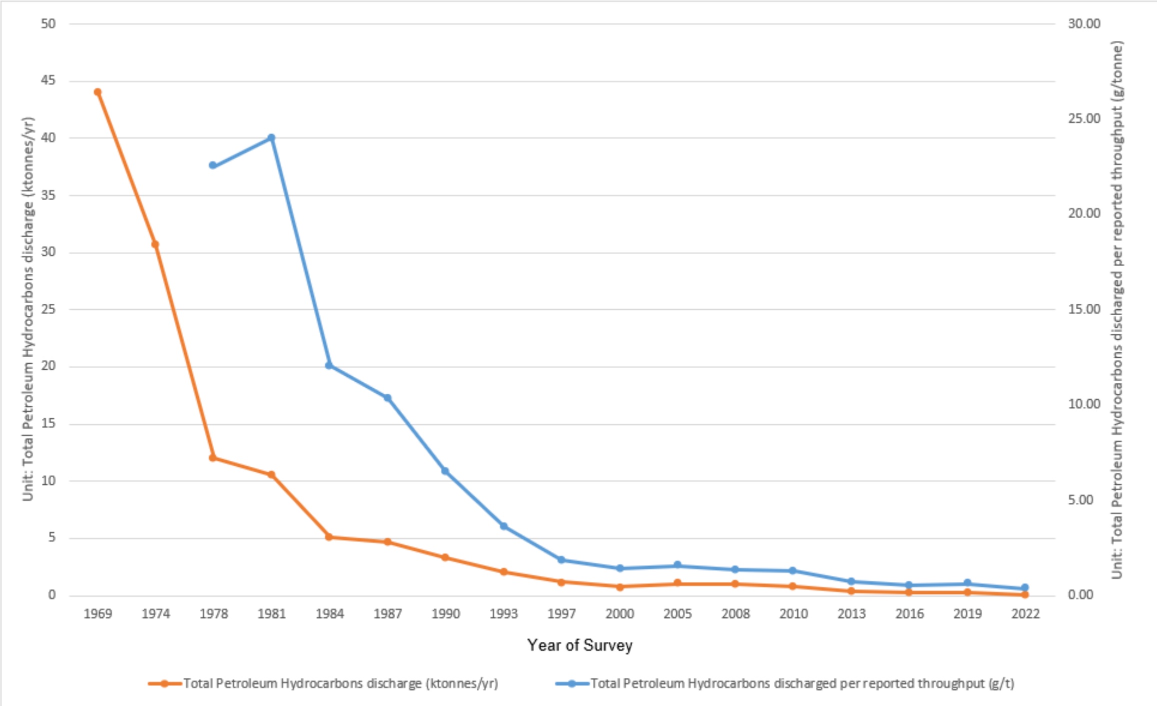


Figure 28 presents the historical trends of average annual TPH concentrations in refinery effluents from 2016 to 2022 using a box-and-whisker plot, both showing outliers, and a zoom version without outliers to allow a better view of the box plots' data distributions. The average yearly concentrations were observed to range between 0.8 mg/l (2016) and 1.9 mg/l (2019). In 2022, an average concentration of 0.83 mg/l was reported.

Figure 28. Historical Trend in TPH Refinery Effluents concentrations.

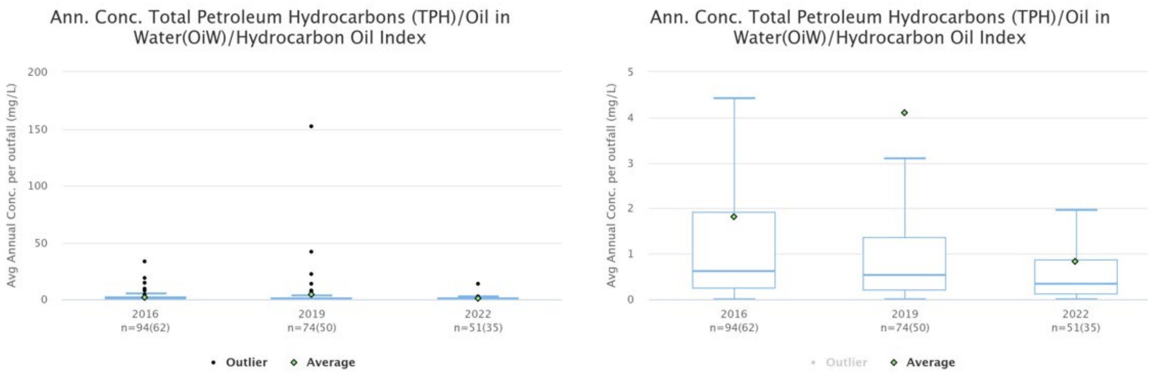


Figure 29 presents 2016, 2019 and 2022 survey results for TPH in the form of box and whisker plots for absolute and relative TPH load for all refineries that reported each year, while **Figure 30** shows the same information but for repeat sites across the three years.

Figure 29. The two upper plots show (full) box and whisker plots for Total Petroleum Hydrocarbons (TPH) showing all outliers for the 2016, 2019 and 2022 survey results for both total load and relative load per throughput for all refineries that participated in each survey. The two bottom plots show zoom views (without outliers) of the same absolute and relative loads box plots.

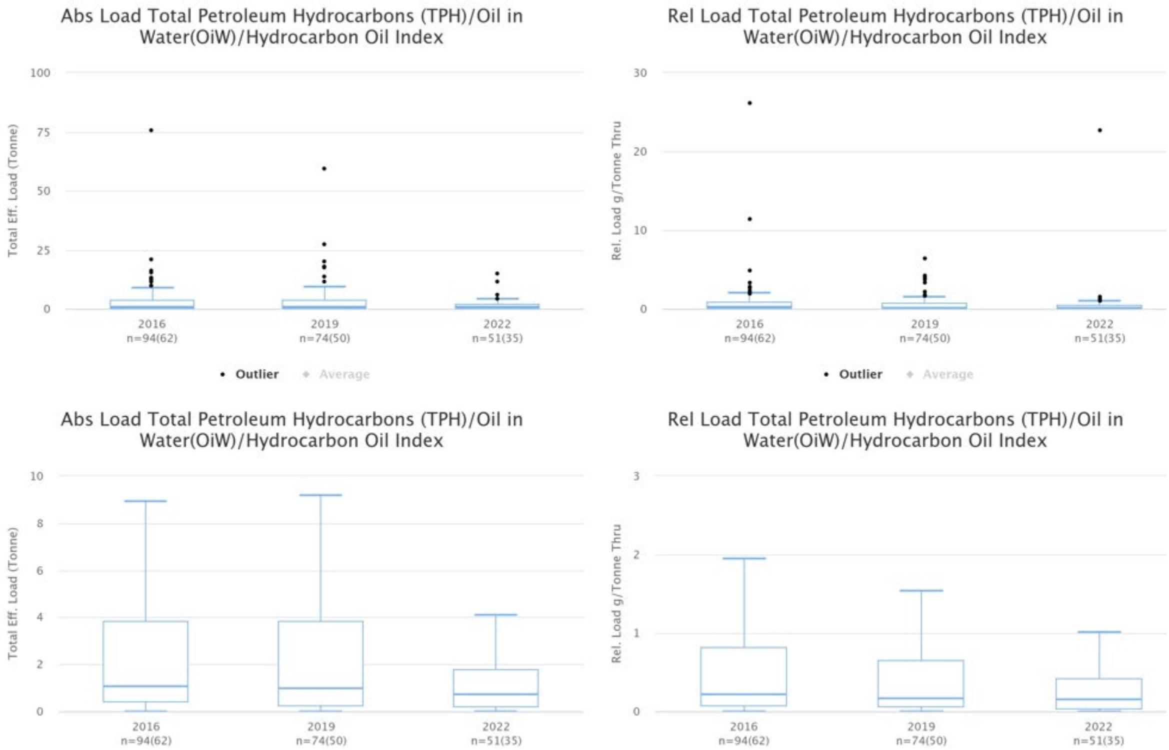


Figure 30. The two upper plots show (full view) box and whisker plots for Total Petroleum Hydrocarbons (TPH) showing all outliers for the 2016, 2019 and 2022 survey results for both total load and relative load per throughput for repeat refineries across the three surveys. The two bottom plots show a zoom view of the box plots (without outliers) for total load and relative load for the same repeat refineries.

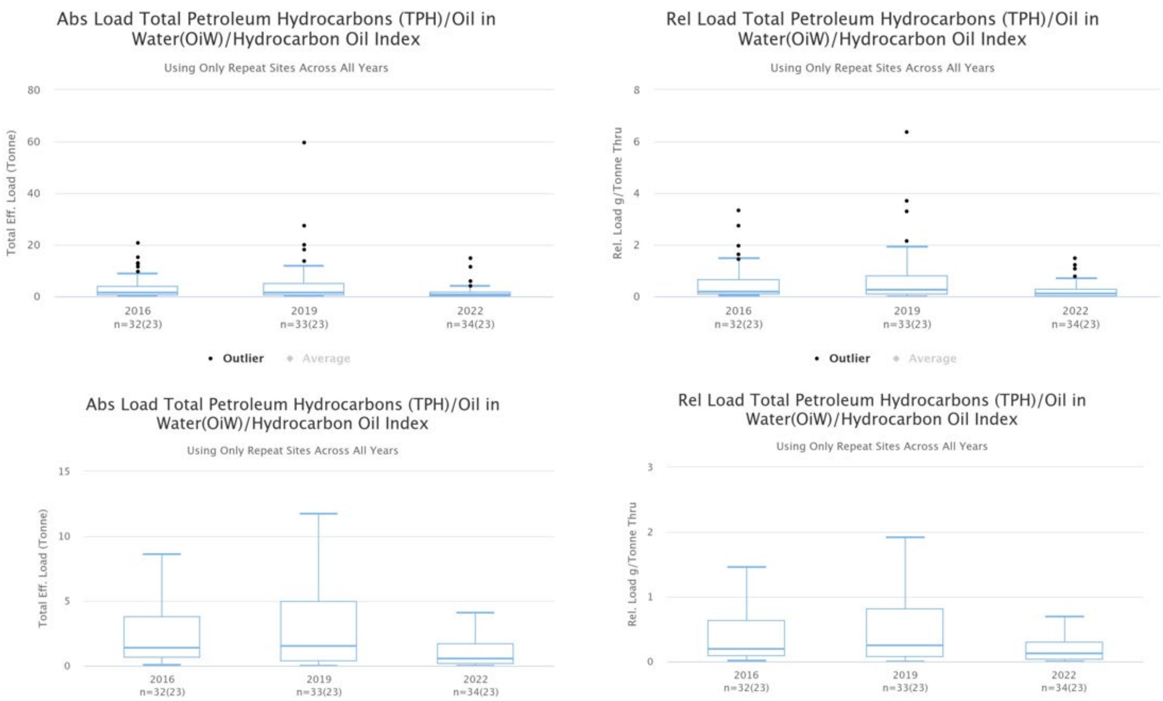
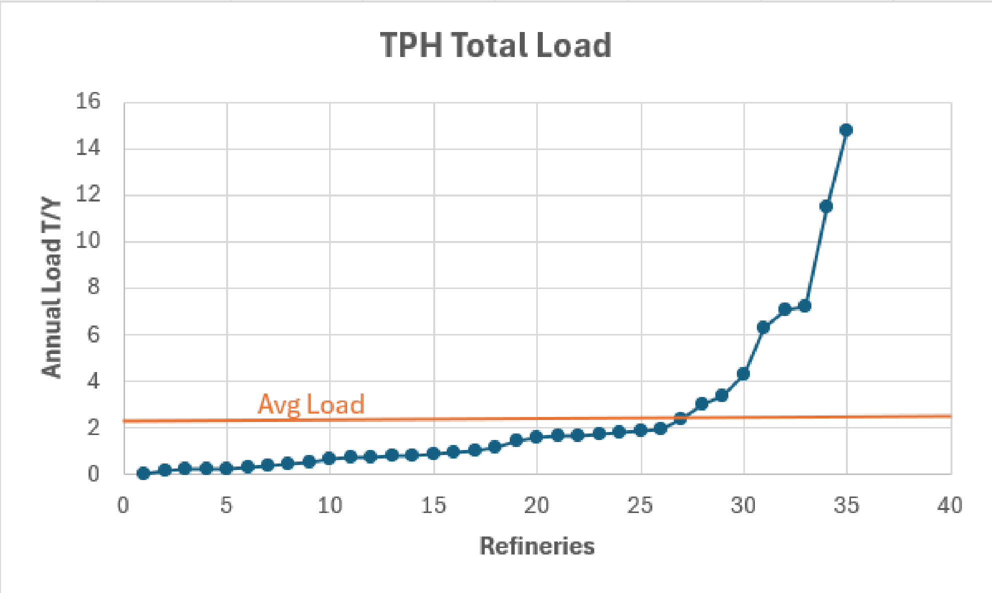
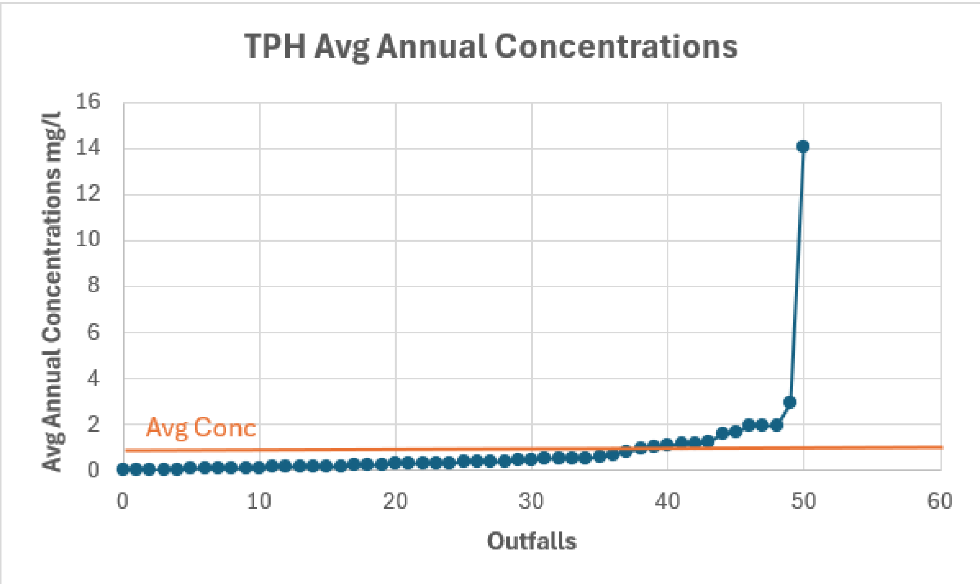


Figure 31 shows dual Y-axis plots for TPH for total load and average concentration for 2022. They show that 74% of the reported outfalls are at or below the average concentration, while approximately 78% of the refineries TPH loads are below the annual average.

Figure 31. Scatter plots of Total Petroleum Hydrocarbons (TPH) average annual concentrations and total load per outfall.





From the box and whisker plots it is clear that the 2016-2022 survey datasets contain a number of outliers, which could influence the overall discharge loads. The highest outlier in 2022 in terms of TPH concentration came from a low volume discharge site representing less than 1% of the total load for the year. The same site presented a high BOD load as well. When queried, the site responded that the concentration reported was correct. The highest load corresponds to an outfall with a large discharge volume and the second highest concentration of all those reported.

3.1.2. Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) AND Total Suspended Solids (TSS) in Refinery water discharges

Data for COD, BOD and TOC is presented in terms of absolute discharge, relative discharge (normalised to throughput) and annual average concentration. It should be noted that the population of reporting sites differs between survey years, and so these metrics are not strictly comparable when expressed as discharges for the sector.

Historic absolute and relative discharge loads from 2010-2022 for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS), are summarised in **Table 15**. For relative TSS, a large reduction is observed from 2010 to 2013 in both total load and relative load, and again between 2013 and 2016. A gentler decrease is observed for the relative load for COD and BOD from 2010 to 2022.

Table 15. 2022 and historical discharge of COD, BOD and TSS

Year	COD		BOD		TSS	
	tonne/year	g/tonne throughput	tonne/year	g/tonne throughput	tonne/year	g/tonne throughput
2010	31,765[1] 380[2]	57.7 0.63	3,450 75.9	6.3 0.13	85,093 36.6	118.6 0.65
2013	15,980 293	32 0.59	2,717 65.6	5.4 0.13	12,491 30.6	22.85 1.12
2016	16,151 995	31.6 1.95	2,397 3	4.7 0.01	4,098 19.89	8.0 0.5
2019	15,816 37.33	29.76 2.54	1,640 2.98	3.61 0.90	3,996 4.85	8.59 0.33
2022	7,149.8 9.36	21.75 32.08	1,059 0.0	3.52 0.0	1,612.6 1.62	5.00 0.16

Notes: Some refineries may have both a direct discharge as well as a transfer.
[1]The upper figure in each box is for direct discharges from installations.
[2]The lower figure in each box is for additional loading due to discharges after transfer to, and treatment by, offsite WWTP, assuming 95% reduction efficiency (Concawe, 2012).
Receiving waters (fresh/brackish) are not differentiated.
The above mass calculations followed the following conventions regarding the concentrations used:

- An entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) are treated as a reportable result.
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects;

A statistical analysis of the survey data for COD, BOD and TSS is presented below following the same format as presented for TPH.

Chemical Oxygen Demand (COD) concentration box plots for 2016 to 2022 in **Figure 32**, show a lower average concentration in 2022 (47 mg/l) than in both 2016 (91 mg/l) and 2019 (133 mg/l).

Figure 32. Box plots of annual COD concentrations in refinery effluents (on the left full view with outliers and on the right, zoom view without outliers).

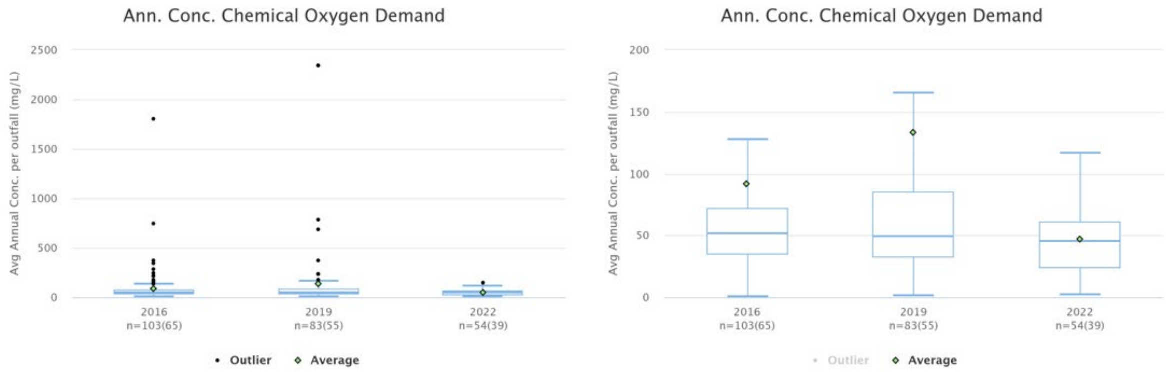


Figure 33, show the absolute and relative COD load for all reporting refineries. The median absolute load in 2022 was lower than in 2019 and slightly higher than in 2016, while the relative load in 2022 was the lowest of the three reporting years. When considering only the 27 sites that reported in each of the three years (**Figure 34),** the 2022 survey presented the lowest absolute median load of the three surveys while relative median loads varied between a maximum of 16.5 g/t of throughput in 2019 and 13.4 g/t in 2016. The median relative load in 2022 was 15.5 g/t.

Figure 33. Box and whisker plots for Chemical Oxygen Demand (COD) presenting the 2016, 2019 and 2022 survey results for both total load and relative load per throughput. The upper box plots show total and relative load with outliers (full view). The two bottom plots show same data but without outliers (zoom view).

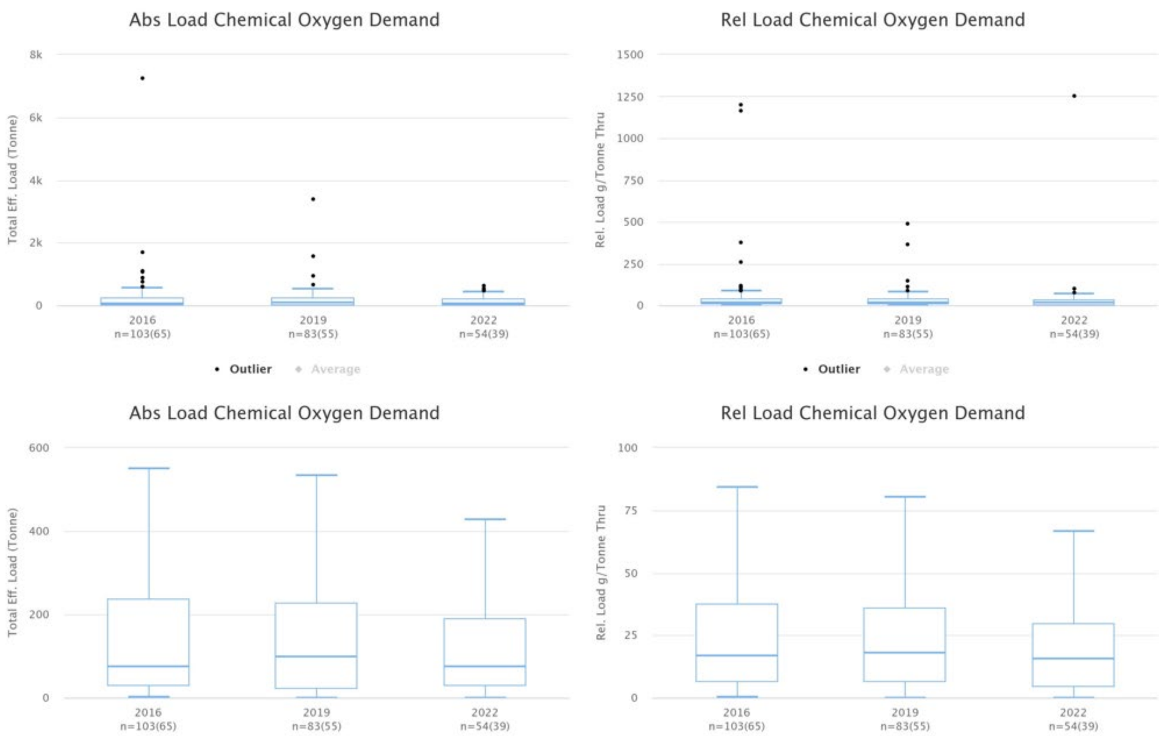
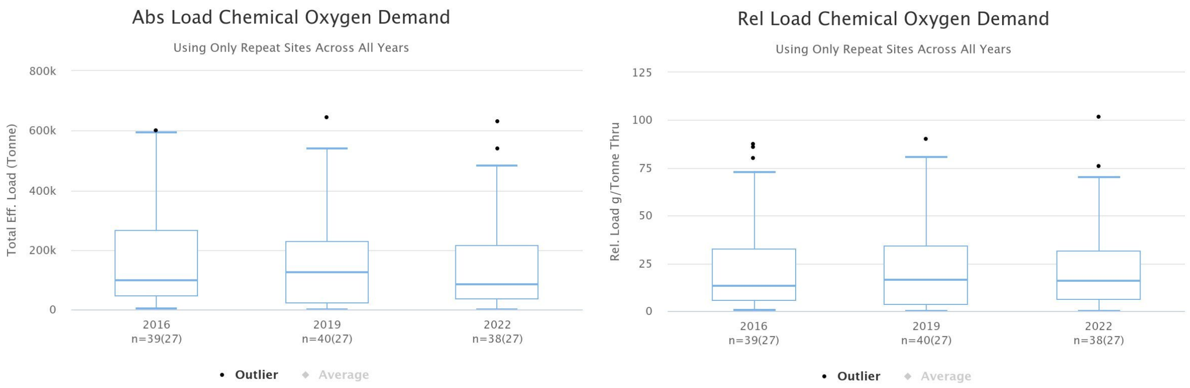
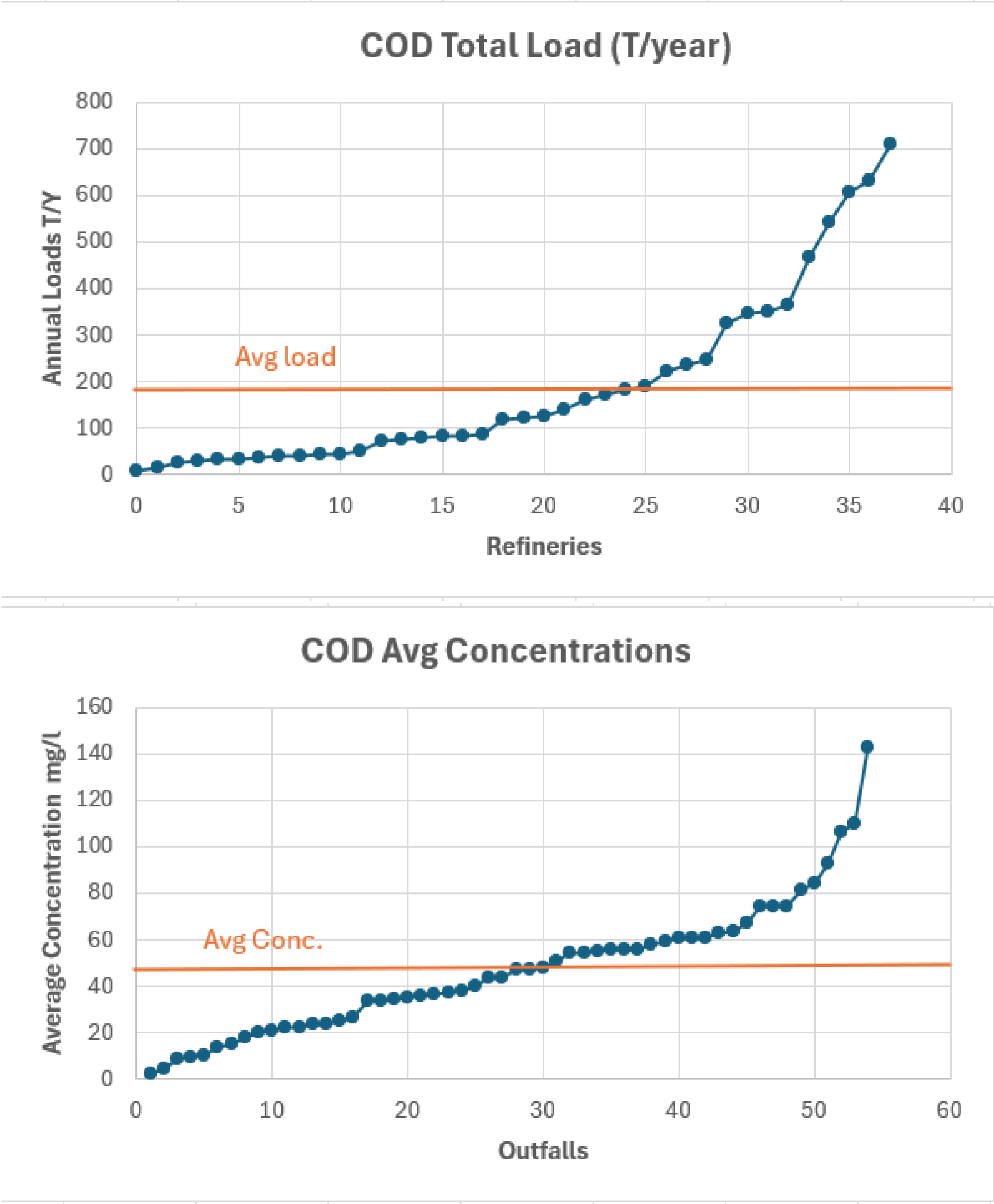


Figure 34. Box and whisker plots for Chemical Oxygen Demand (COD) presenting the 2016, 2019 and 2022 survey results for both total load and relative load per throughput for the same refineries across the three surveys.



The two scatter plots of **Figure 35** show a majority of refineries yearly loads (65%) are below the average load for 2022 while just above half (55%) are below the average concentrations.

Figure 35. Scatter plots of COD average annual concentrations and total load per outfall.



The box plots of **Biological Oxygen Demand (BOD)** concentrations for 2016 to 2022 in **Figure 36**, show a general decrease in average concentrations from 2016 (14.4 mg/l) to 2022 (10.8 mg/l). The highest outlier observed for 2022 corresponds to a low volume effluent that contributes about 3.6% to the total load of BOD for the year.

Figure 36. Box plots of annual BOD concentrations in refinery effluents (On the left with outliers; on the right zoom view without outliers).

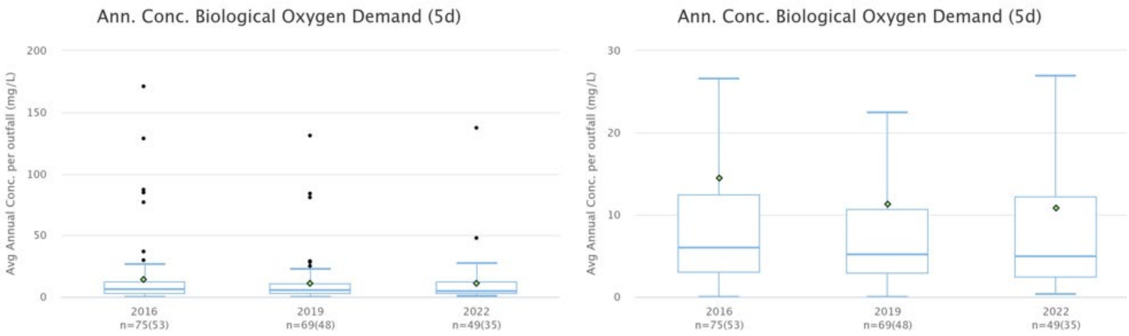


Figure 37 shows the absolute and relative loads of BOD for all refineries that participated in the three surveys, while **Figure 38** shows the data for the same refineries that reported in the three surveys. BOD median annual load in 2022 when all refineries are considered shows the lowest value of the three years considered, however, the median of the relative load in 2022 is the highest of the three surveys. This is likely a result of different refineries participating in each of the surveys since when the repeat refineries are considered both the absolute and relatives median loads are lower than (for absolute load) or similar to (for relative load) the previous years.

Figure 37. Box and whisker plots for Biological Oxygen Demand (BOD) presenting the 2016, 2019 and 2022 survey results for both total load and relative load per throughput. Upper figures show outliers, lower figures zoom views without outliers.

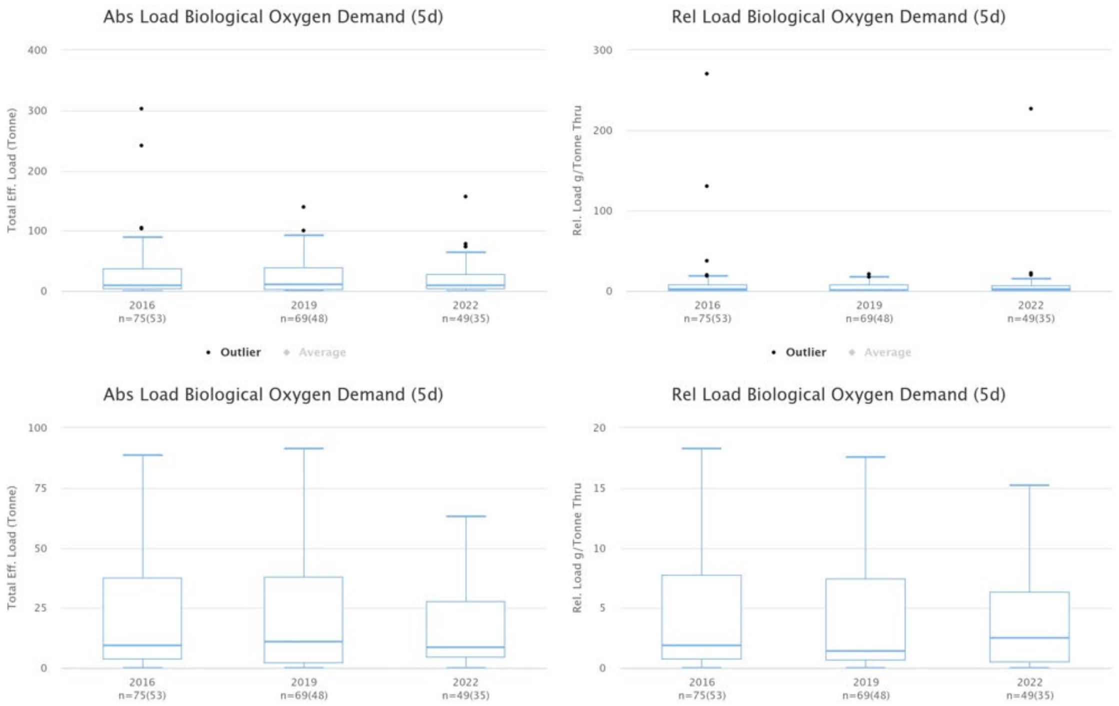
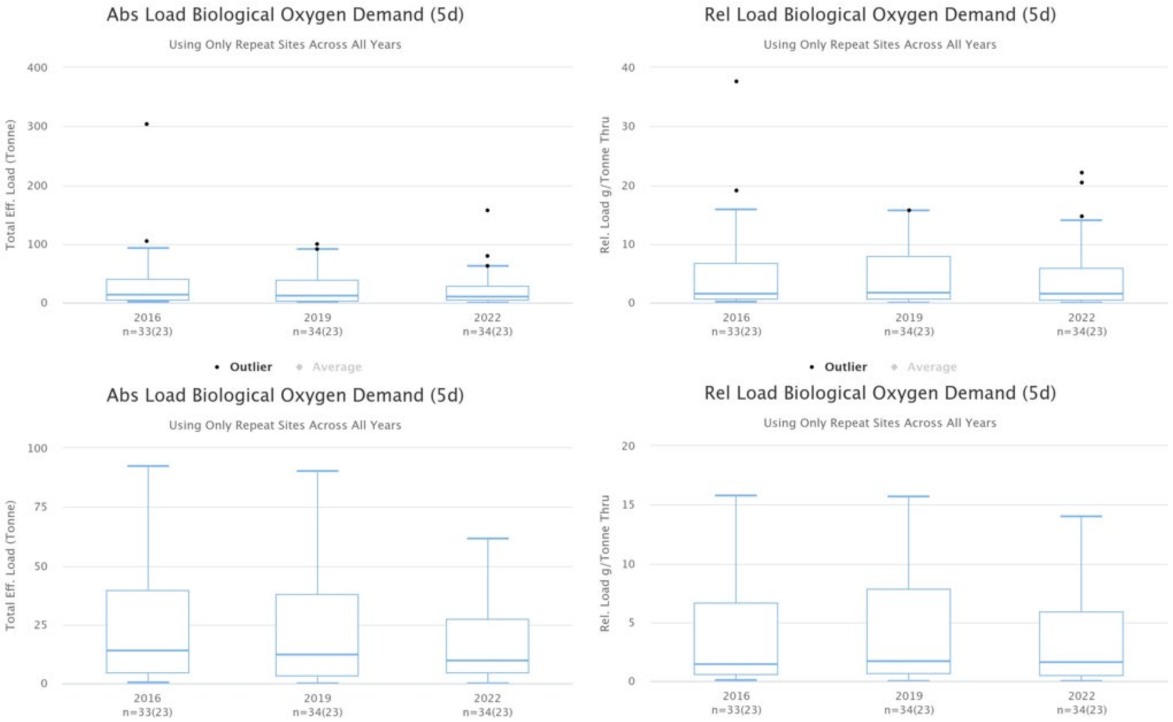
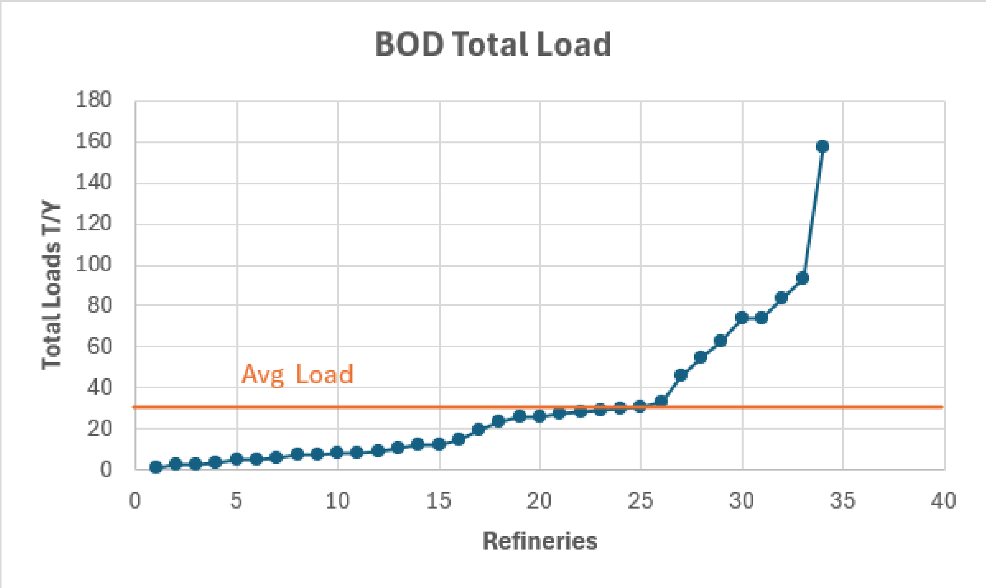


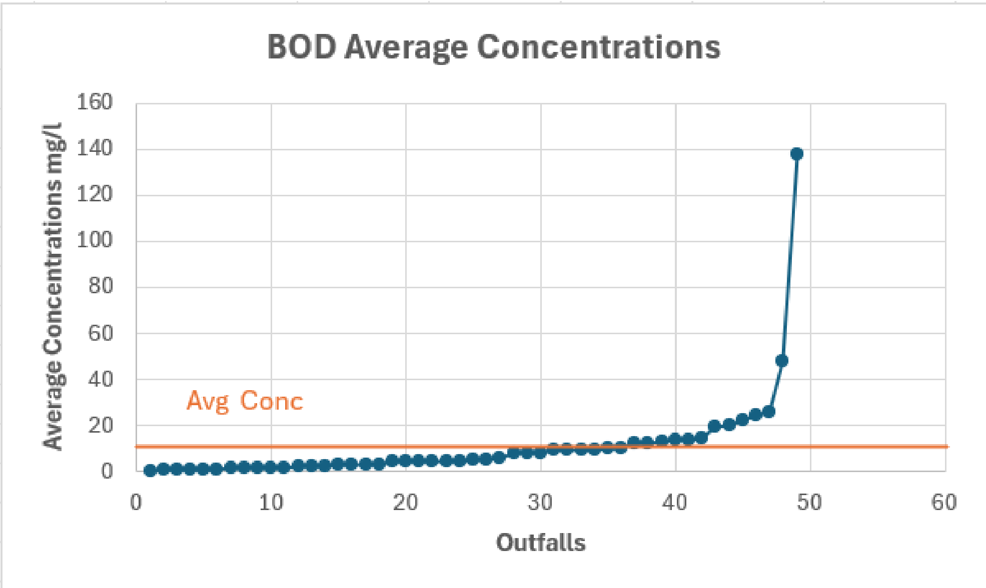
Figure 38. Box and whisker plots for Biological Oxygen Demand (BOD) presenting the 2016, 2019 and 2022 survey results for both total load and relative load per throughput for repeat sites. The upper plots show full view (with outliers) and the bottom plots a zoom view without outliers.



The scatter plots of average loading and average concentrations in **Figure 39** show the majority of outfalls (approximately 68%) are below the average concentration and average load.

Figure 39. Scatter plots of BOD average annual concentrations and total load per outfall.





The box plots of **Total Suspended Solids (TSS)** concentrations in **Figure 40** shows an average concentration for 2022 of 11 mg/l, much lower than those in 2016 (19 mg/l) and 2019 (21 mg/l). As per other substances, 2019 generally shows a higher concentration and loads than both 2016 and 2022. This could be the result of the set of refineries that participated in the 2019 survey. For TSS, a high outlier of 245 mg/l was reported in 2019.

Figure 40. Box plots of annual TSS concentrations in refinery effluents.

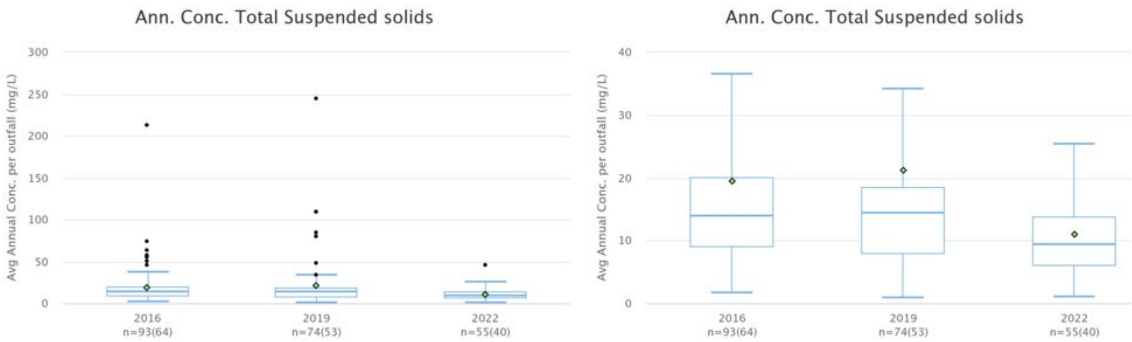


Figure 41 shows the absolute and relative loads of TSS for all the refineries that participated in the three surveys while **Figure 42** shows the same refineries in all three surveys (the so-called repeat refineries). As with the concentrations, 2022 absolute and relative loads were the lowest of the three surveys. The same decrease in absolute and relative loads is observed when only the repeat refineries are considered. The 46 mg/l outlier observed in 2022 in **Figure 40** is associated with a low volume effluent contributing only 0.7% of TSS load to the total load.

Figure 41. Total Suspended Solids (TSS) absolute and relative loads with outliers (upper plots) and without outliers (bottom plots) for all refineries in the 2016, 2019 and 2022 surveys.

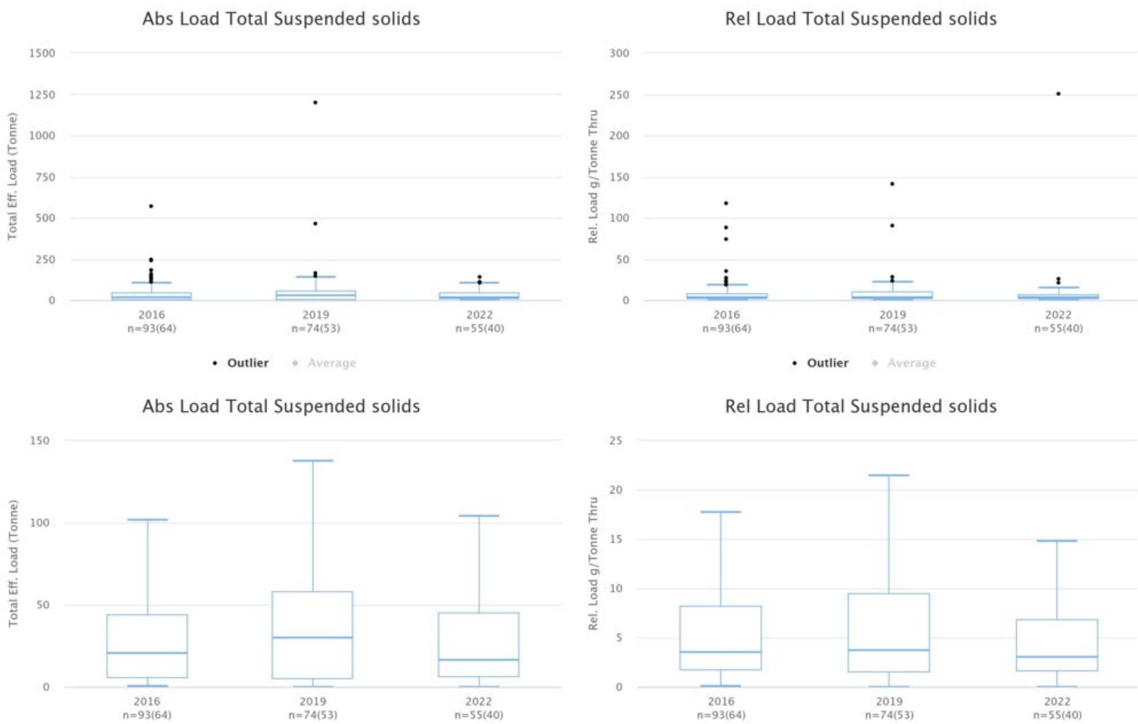
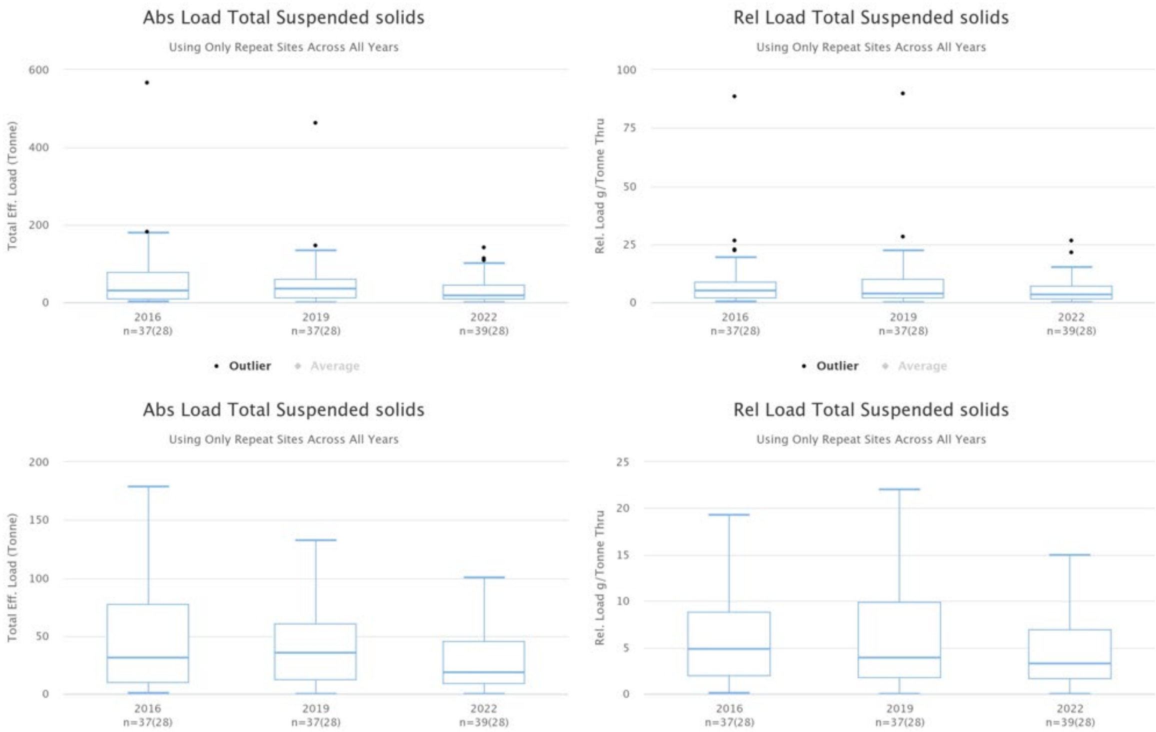
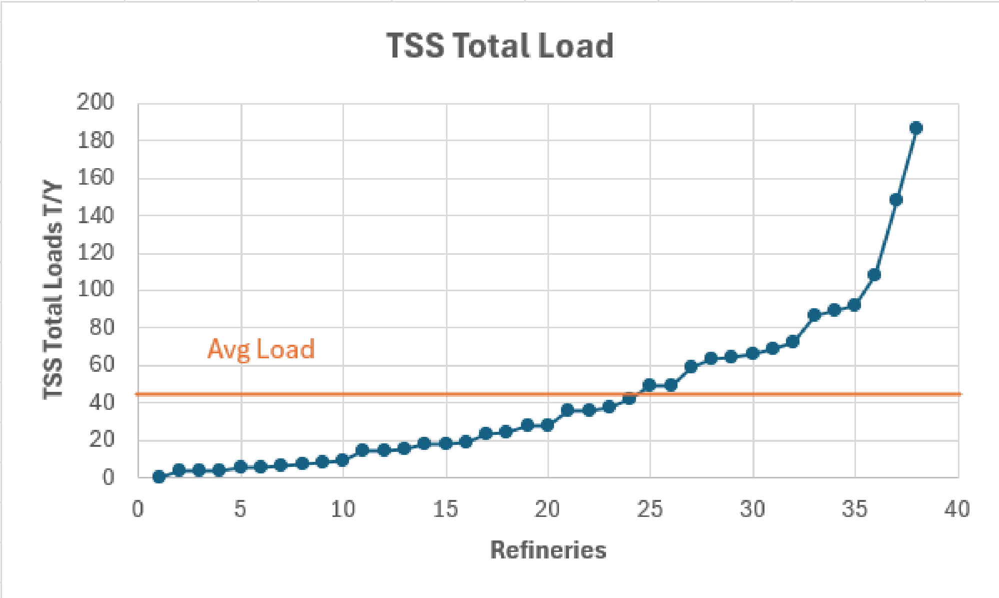


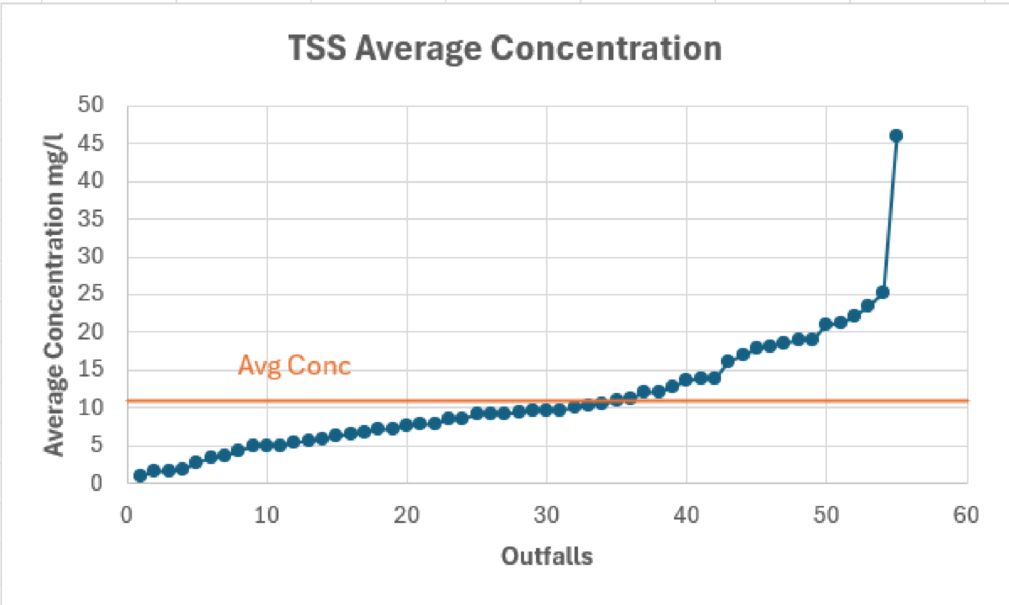
Figure 42. Total Suspended Solids (TSS) absolute and relative loads with outliers (upper plots) and without outliers (bottom plots) for repeat refineries in 2016, 2019 and 2022 surveys.



The scatter plots in **Figure 43** shows approximately 62% of reported outfalls and refineries are at or below the average annual concentration for TSS.

Figure 43. Scatter plots of TSS average annual concentrations and total load per outfall.





3.1.3. TRENDS IN AMMONIA, TOTAL NITROGEN AND PHENOLS IN REFINERY WATER DISCHARGES

Data for ammonia, total nitrogen and phenols is presented in terms of absolute discharge, relative discharge (normalised to throughput) and annual average concentration. The population of reporting sites differs between survey years and so these metrics are not strictly comparable when expressed as discharge concentrations for the sector.

Kjeldahl Total Nitrogen (KTN) was reported instead of ammonia in 2013, due to KTN substituting for ammonia as the standard reporting parameter for reduced nitrogen species. Overall, there is a clear reduction in direct discharges of ammonia from 2013 to 2022, which is not reflected in the relative discharge data. For total nitrogen, an overall reduction is more marked, but this is not replicated in the relative discharge data. For phenols, discharge loads have been variable with 2022 data showing the lowest load of the period.

Table 16. 2022 and historical discharge of ammonia, total nitrogen and phenols

Year	Ammonia	Total Nitrogen	Phenols
	tonne/year		
2010	454[1] 22[2]	2,307 56	31 5.2
2013	560 (19 TKN[3])	2,279 9.8	17 0.15
2016	330 16	1,856 18	29.6 0.6
2019	381.7 0.96	1,547.6 3.83	15.44 11.93
2022	285.7	1,343.4 0.00	6.64 0.013
	g/tonne throughput		
2010	0.75 0.04	3.8 0.09	0.052 0.009
2013	1.12 (TKN[1])	4.6 0.02	0.034 0.003
2016	0.65 0.03	3.6 0.03	0.058 0.001
2019	1.4 0.09	3.93 0.29	0.86 0.00
2022	1.97 0.00	4.61 0.00	0.03 0.00

[1]The upper numbers in each box are for direct discharges from installations.
[2]When a second number is provided in each box, this refers to effluents transferred to offsite WWTP, assuming 95% removal for all parameters (Concawe, 2012).
[3] Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen, ammonia (NH3), and ammonium (NH4+). To calculate Total Nitrogen (TN), the concentrations of nitrate-N and nitrite-N are determined and added to the total Kjeldahl nitrogen.
Receiving waters (fresh/brackish) are not differentiated.
The above mass calculations followed the following conventions regarding the concentrations used:

- An entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) are treated as a reportable result.
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects.

A statistical analysis of the survey data for total nitrogen, ammonia and phenols are presented below. All figures are plotted according to the convention mentioned earlier in this Section.

As shown in **Figure 44**, the average concentration of ammonia in 2022 (4.35 mg/l) was slightly lower than in 2019 (4.82 mg/l) and both were higher than the average in 2016 (3.77 mg/l). This could be due to a different set of refineries in each survey. The outlier of 35 mg/l in 2022 is associated with a high-volume effluent which represents some 40% of the total load of ammonia in 2022. However, this did not affect the overall decreasing trend in absolute load when all sites are considered

(**Figure 45**), showing a lower median in 2022 than in the previous two surveys. When relative loads are considered the medians for the three surveys are very similar. When repeat sites are considered, a marked increase in both absolute and relative median concentrations are observed in 2022 as shown in **Figure 46.**

Figure 44. Box plots of annual ammonia concentrations in refinery effluents with outliers (full view) and without outliers (zoom view).

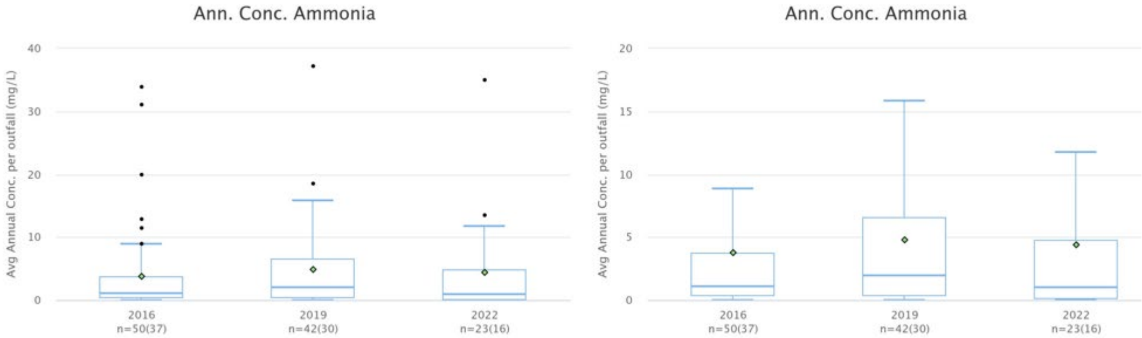


Figure 45. Box and whisker plots for ammonia presenting the 2016, 2019 and 2022 survey results for both total load and relative load per throughput (with outliers upper two figures and zoom view without outliers in the lower two figures).

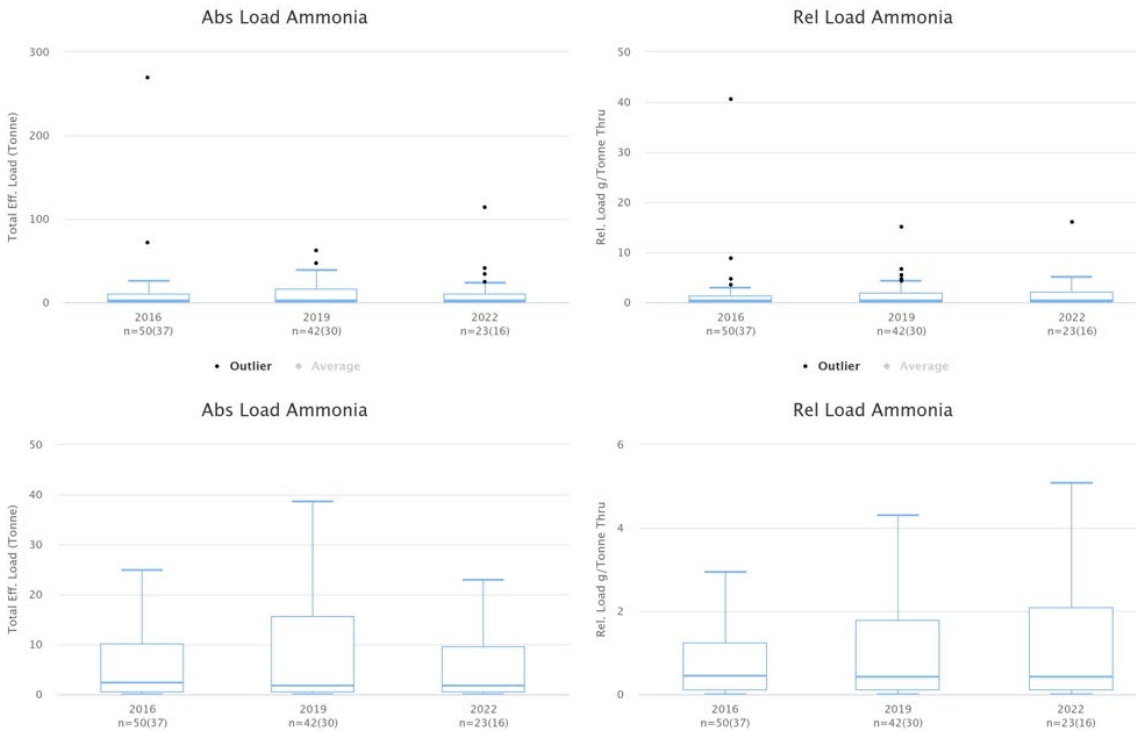
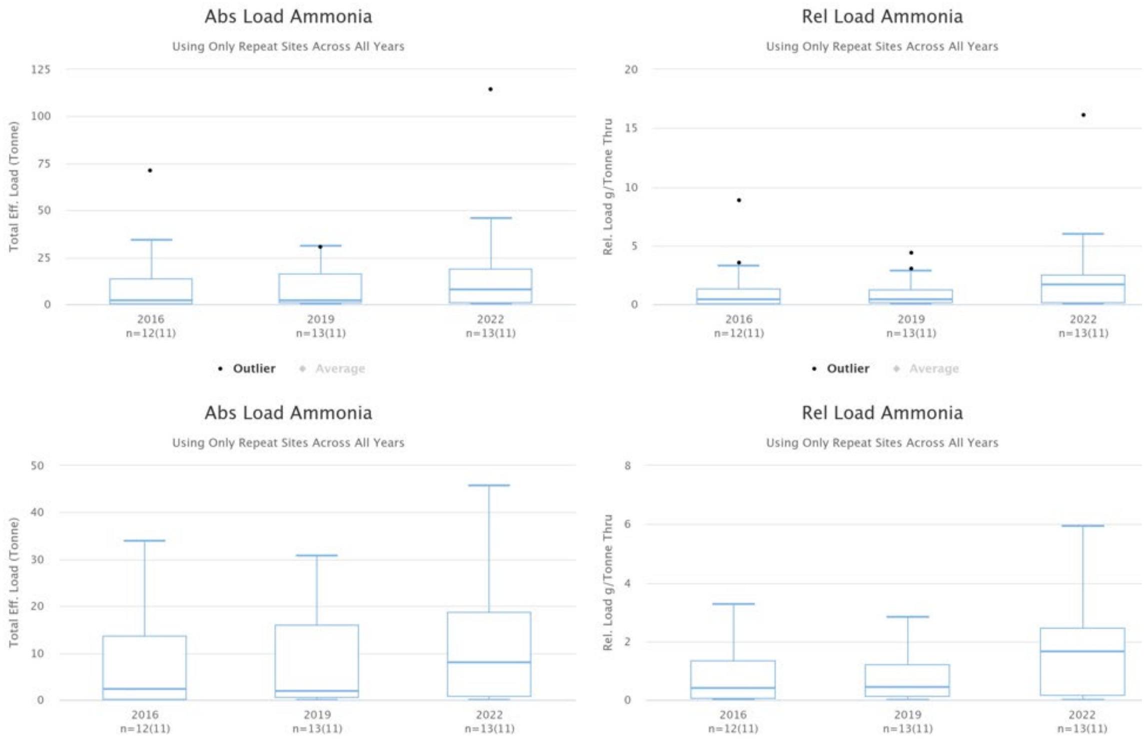
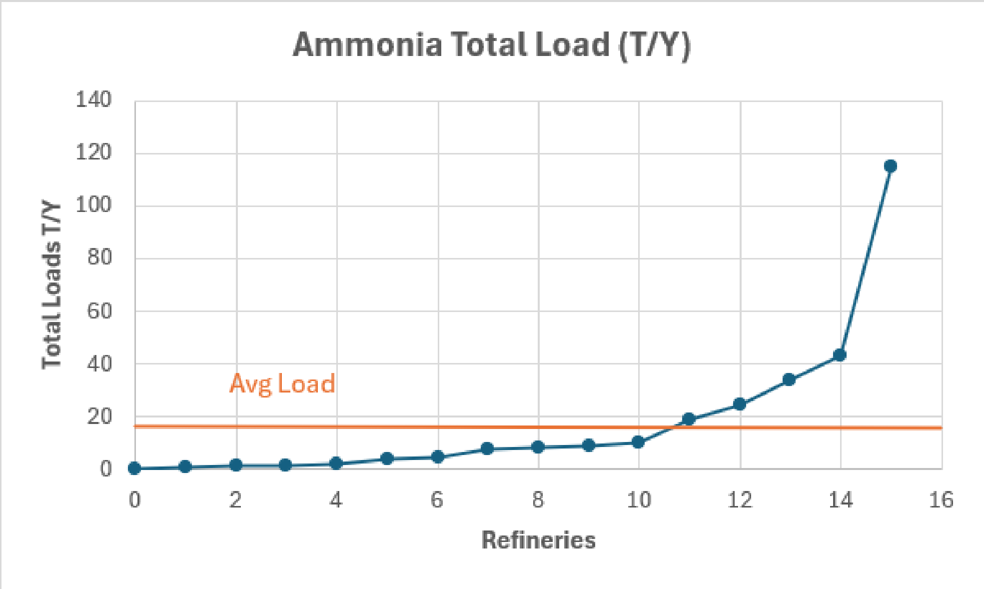


Figure 46. Box and whisker plots for ammonia presenting the 2016, 2019 and 2022 survey results for both total load and relative load per throughput when repeat sites are considered (both with outliers and zoom views).



The scatter plots of ammonia load and concentrations shows 65% of outfalls are below the average concentration and 68% of refineries are below the average load.

Figure 47. Scatter plots of total ammonia average annual concentrations and total load per outfall.



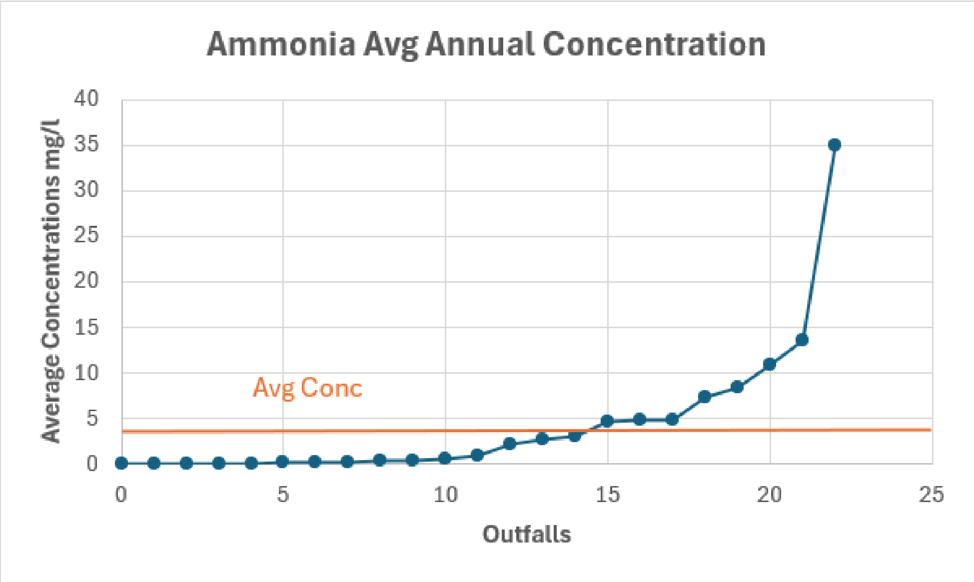
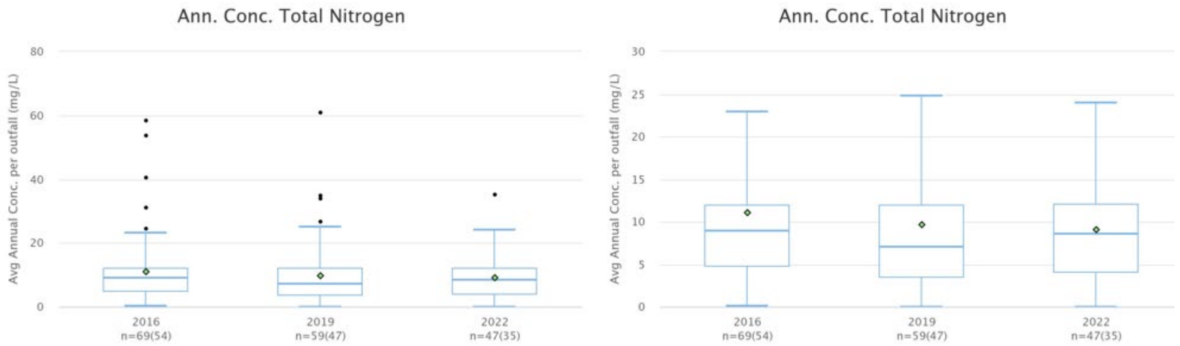


Figure 48 shows a small decrease of **total nitrogen** annual average concentrations from 11 mg/l in 2016 to approximately 9 mg/l in 2022. The outlier of 35 mg/l in 2022 amounts to 8.5 % of the total load for 2022.

Figure 48. Box plots of annual total nitrogen concentrations in refinery effluents.



Absolute loads in 2022 were the lowest of the three survey years (**Figure 49**), while the relative load has a value between 2016 and 2019. A similar distribution can be observed in **Figure 50** when repeat sites only are considered.

Figure 49. Box and whisker plots for total nitrogen presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.

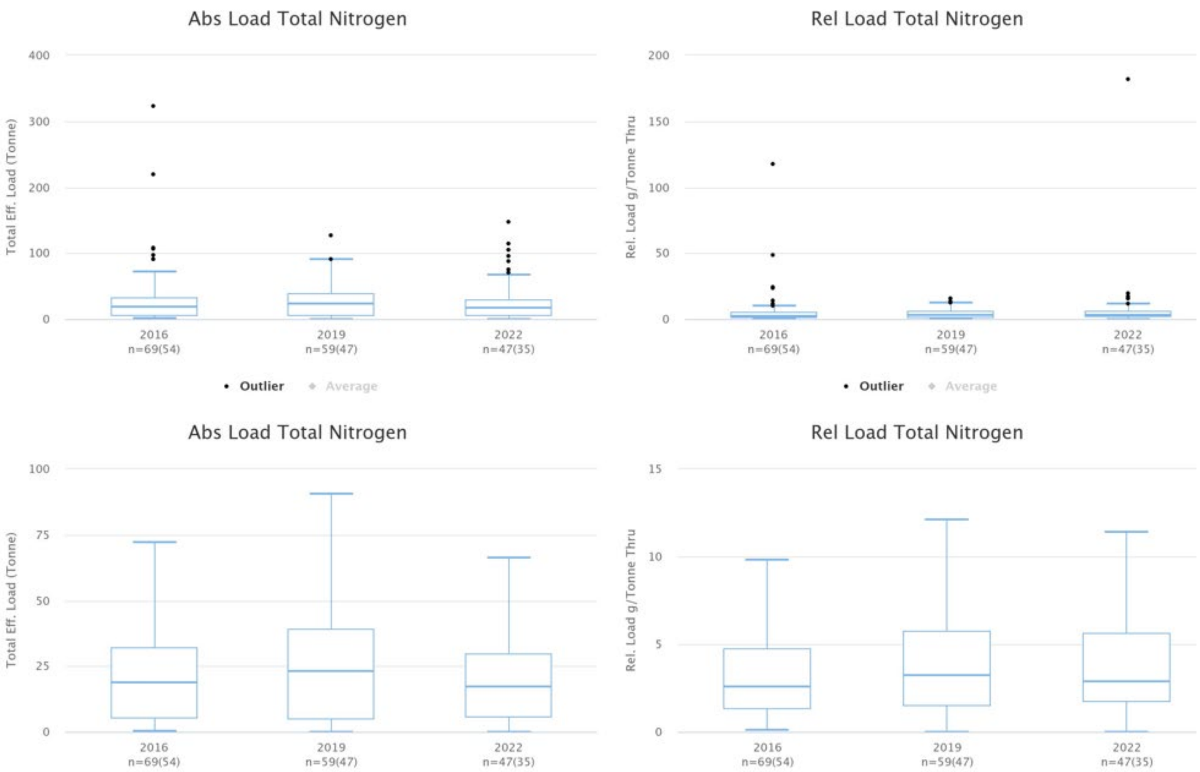


Figure 50. Box and whisker plots for total nitrogen presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.

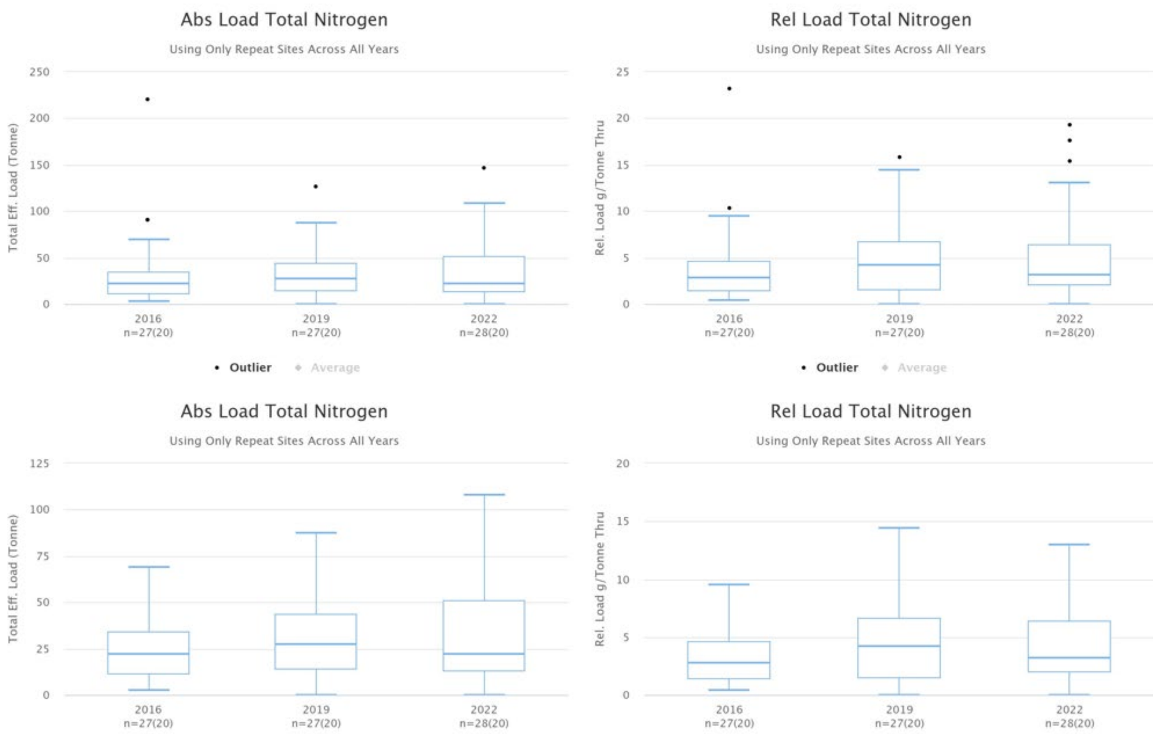
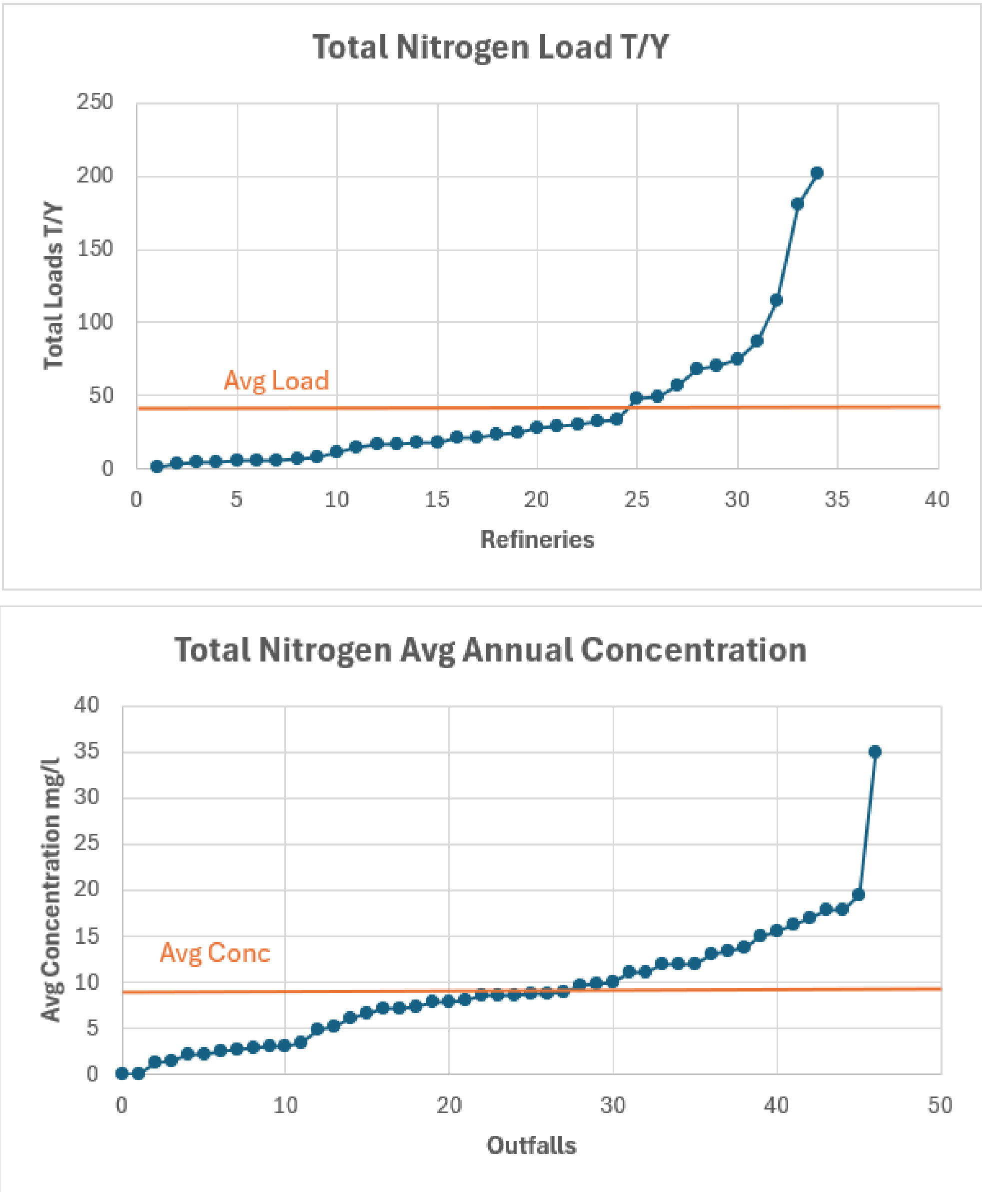


Figure 51 include the scatter plots of loading and average concentrations per refinery and outfall respectively. In general, about 70% of refineries are below the average annual load, while some 60% of outfalls are below the average concentration.

Figure 51. Scatter plots of total nitrogen average annual concentrations and total load per outfall.



The plots of **phenols** discharge concentrations (**Figure 52)**, show data for 2019 and 2022 only. The average concentration was 0.81 mg/l in 2019 and 0.047 mg/l in 2022. The 45 mg/l outlier in 2019 is likely a unit error given the same refinery had similarly high values for other substances. The box plots of annual load and relative load in Figure 53 shows only zoom plots (the outlier mentioned earlier is not shown). No box plots for repeat sites have been included as all values were reported as zero.

Figure 52. Box plots of annual phenols concentrations in refinery effluents.

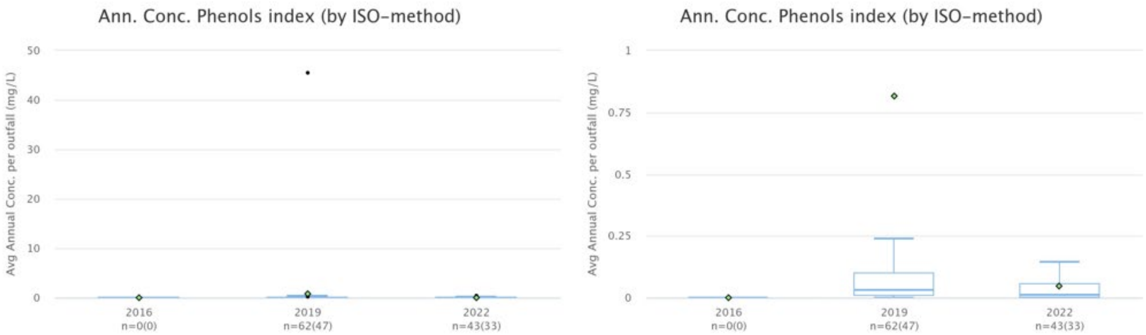


Figure 53. Box and whisker plots for phenols presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput (zoom view only).

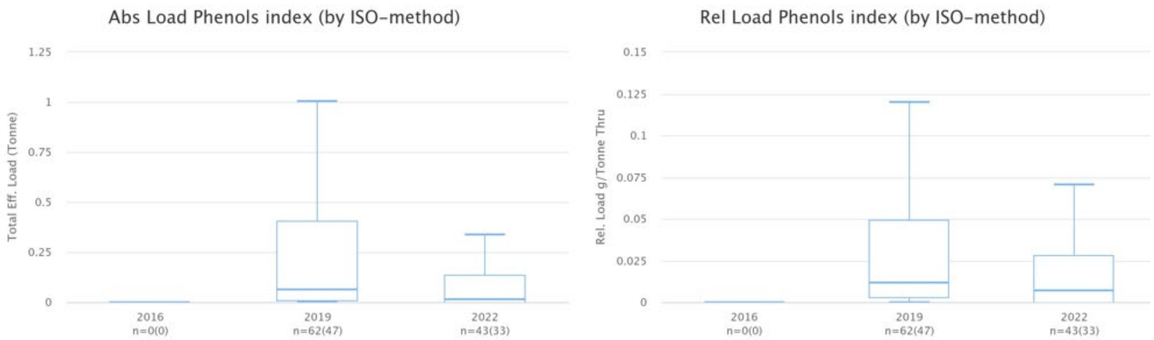
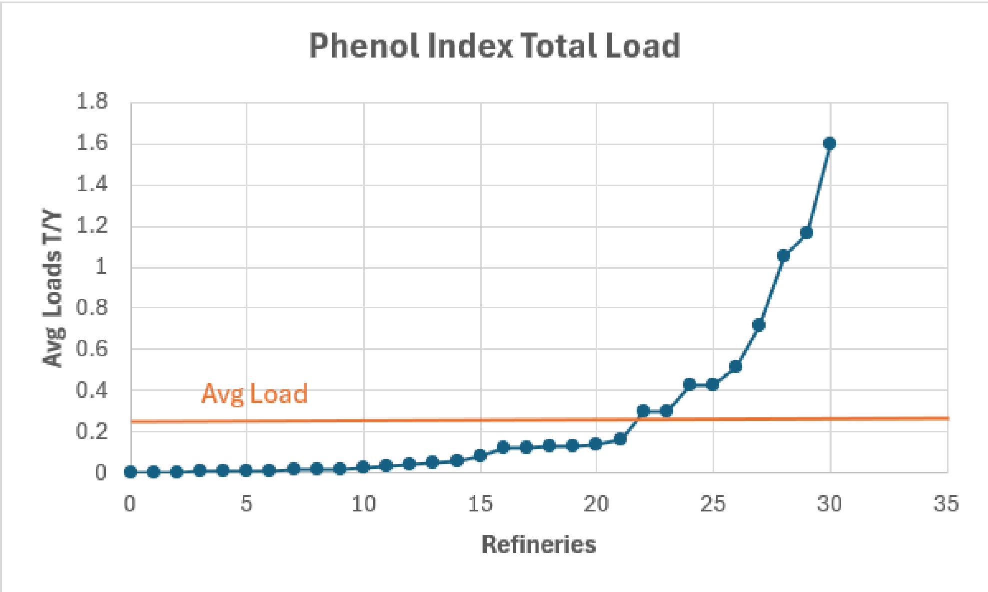
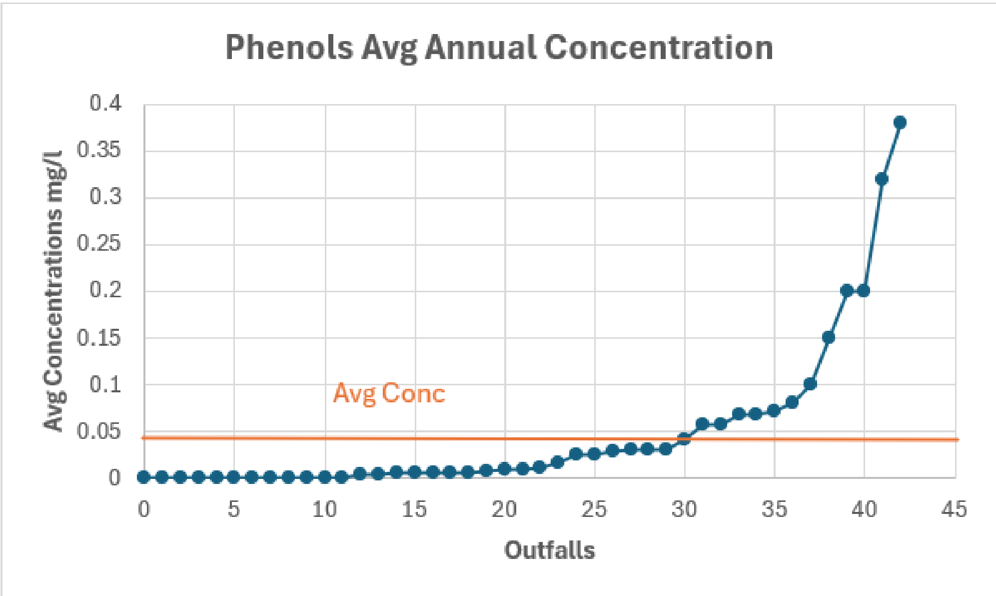


Figure 54 include scatter plots of Phenol Index total loads per refinery and average concentration per outfall. Overall, 68% of the outfalls fall below their average concentration while 65% of refineries fall below the average loading.

Figure 54. Scatter plots of total Phenol average annual concentrations and total load.





3.1.4. Trends in BTEX and total PAH in effluent discharges

Table 17. 2010 to 2022 discharge of BTEX and total PAHs

Year	BTEX	Total PAHs[1]
	tonne/year	
2010	11.3[2] 3.26[3]	0.10 0.002
2013	8.95 2.13	0.040 5.96E-05
2016	6.6 0.31	0.04 2
2019	2.22 0.015	0 -
2022	0.83 -	0 -
	g/tonne throughput	
2010	0.019 0.063	2.5E-04 0.0011
2013	0.018 0.004	8.0E-05 1.1E-07
2016	0.013 0.1	0.00008 0.00001
2019	0.01 0.02	0 -
2022	0.01 -	0 -

[1] Total polycyclic aromatic hydrocarbon (Total PAH) values in this table were calculated as the sum of individual PAHs using 0 for non-detects. PAHs included in the sum include Anthracene, Benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, Fluoranthene, and Indeno(1,2,3-cd)pyrene.
[2]The upper figure in each box is for direct discharges from installations.
[3]The lower figure in each box is for discharges after transfer to and treatment by offsite WWTP, assuming 95% removal (Concawe, 2012).
Receiving waters (fresh/brackish) are not differentiated.
The above mass calculations followed the following conventions regarding the concentrations used:

- An entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) are treated as a reportable result.
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects.

No total PAHs were reported 2019 and 2022. A statistical analysis of the survey data for **BTEX** is presented in **Figure 55** through to **Figure 58**. Average concentrations of BTEX were lower in 2022 (0.022 mg/l) than in 2016 (0.445 mg/l) and 2019 (0.87 mg/l). The highest outlier and second highest outlier in terms of absolute BTEX load in 2022 accounted for 52% and 34% respectively of the total sector load and they coincide with the highest and second highest reported concentrations. When considering all refineries in the three surveys, there has been a clear reduction in absolute and relative load from 2016 to 2022.

Figure 55. Box plots of annual BTEX concentrations in refinery effluents.

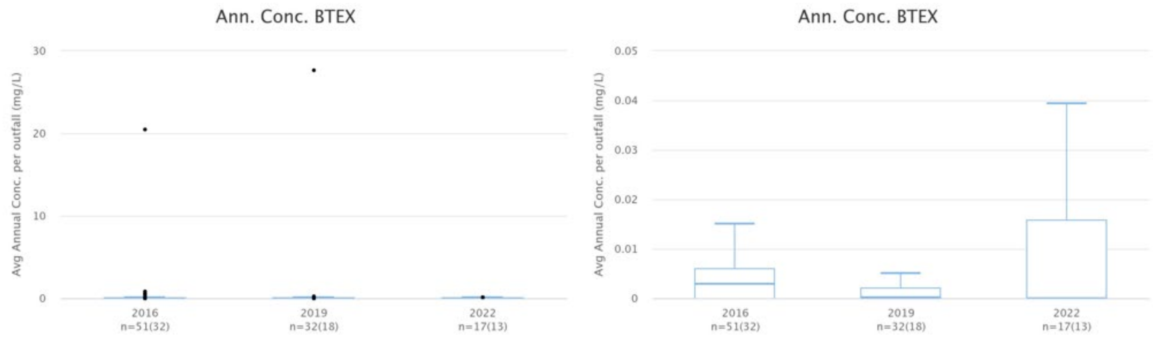


Figure 56. BTEX absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

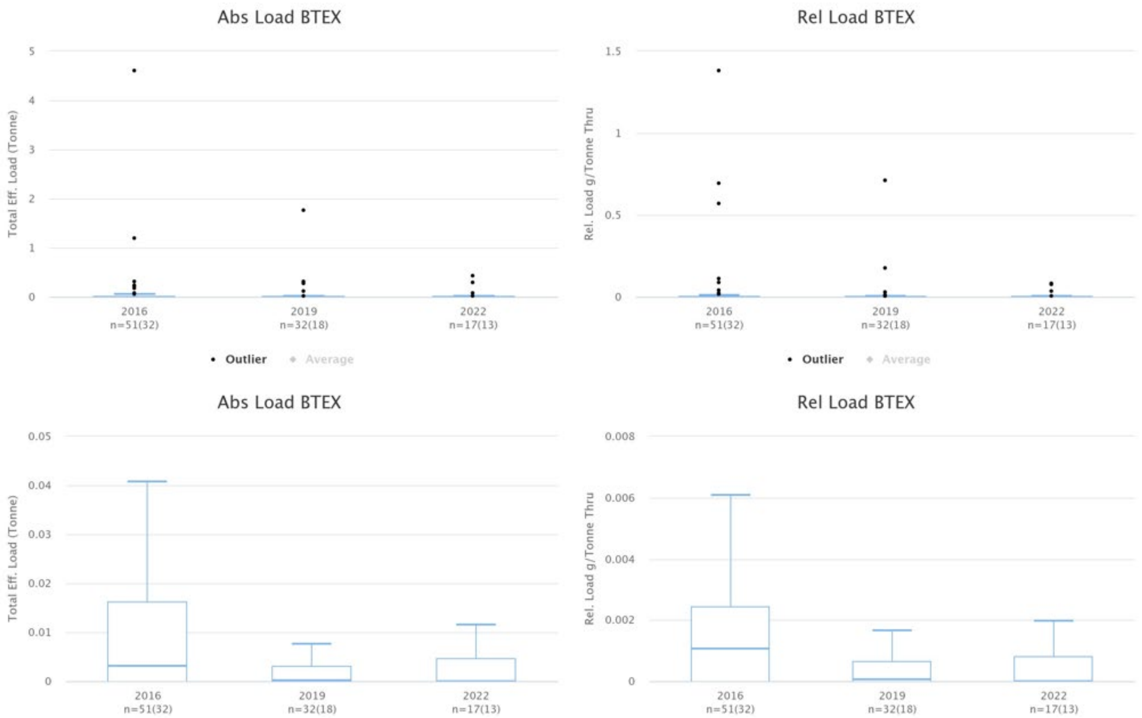
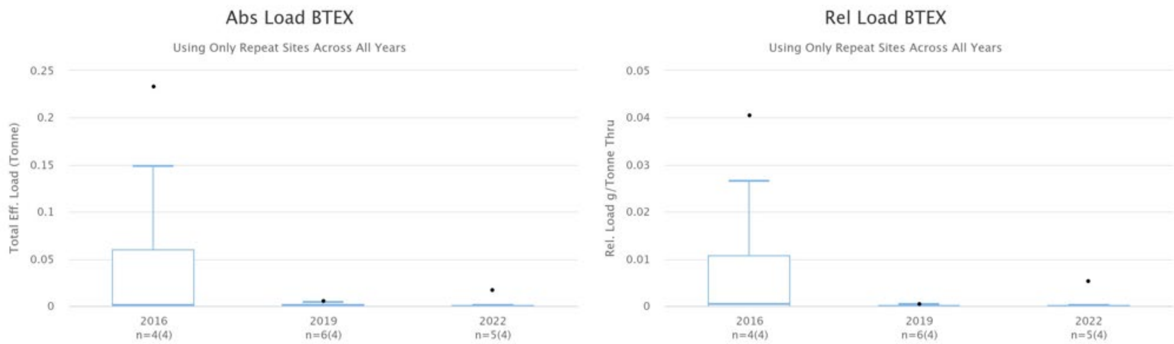
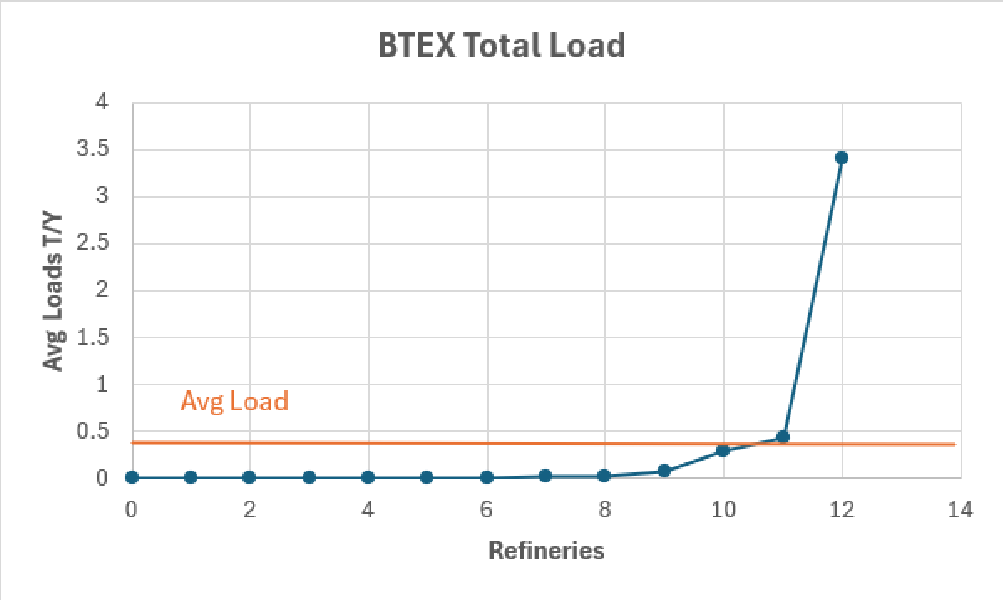


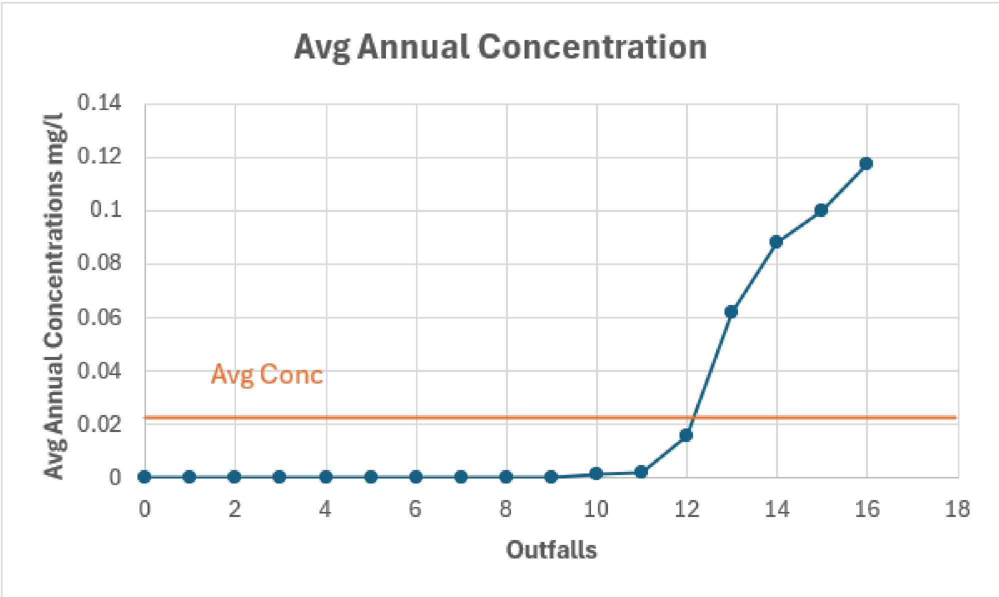
Figure 57. Absolute and relative load of BTEX for repeat refineries in the three surveys (full view only).



Total BTEX loadings per refinery and average concentrations per outfall are shown in **Figure 58**. Overall, the majority of refineries loads were below the average load (84%) and the majority of outfalls concentrations (76%) were below the average concentration.

Figure 58. Scatter plots of BTEX average annual concentrations and loads.





3.1.5. DISCHARGE DATA FOR TOTAL PHOSPHOROUS

Total and relative discharge data for total phosphorus are summarised in **Table 18.** The total load of total phosphorous has seen a consistent decrease from 238 tonnes reported in 2010 to approximately 80 tonnes in 2022. However, its relative load has remained fairly constant since 2013.

Table 18. Total Phosphorous Discharge from 2010 to 2022

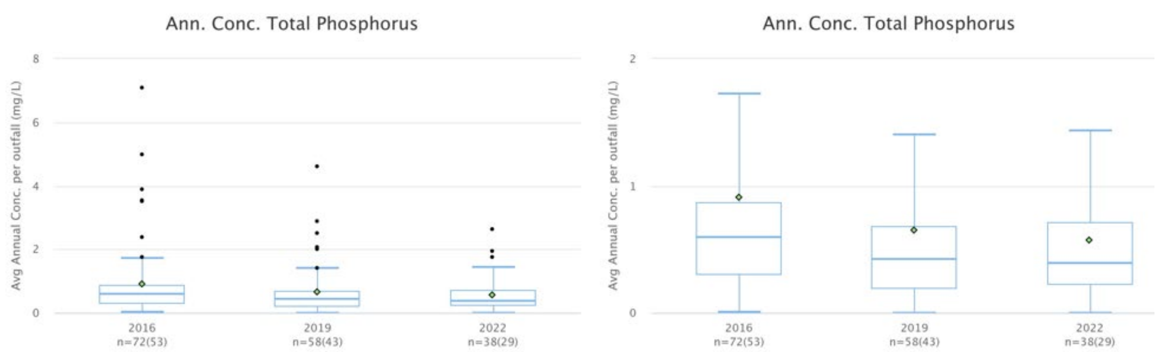
Year	Total phosphorus	
	tonne/year	g/tonne throughput
2010	238[1] 1.28[2]	0.40 0.024
2013	171 0.25	0.34 0.0005
2016	150 0.49	0.31 0.001
2019	126.3 0.056	0.34 0.00
2022	80.7 0.00	0.35 0.00

[1]The upper figure in each box is for direct discharges from installations
[2]The lower figure in each box is for discharges after transfer to and treatment by offsite WWTP, assuming 95 % removal (Concawe, 2012).
Receiving waters (fresh/brackish) are not differentiated.
The above mass calculations followed the following conventions regarding the concentrations used:

- An entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) are treated as a reportable result.
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects.

A statistical analysis of the survey data for total phosphorous is presented in **Figures 59** through **62**. These figures are plotted according to the convention mentioned in **Section 3.1.** In 2022, there have been less outliers than in previous years and lower overall concentrations.

Figure 59. Box plots of annual Total Phosphorous concentrations in refinery effluents.



When all sites are considered, total phosphorous load has decreased slightly from 2016 to 2022 while relative load remains fairly constant (**Figure 59**). When only repeat sites are included (**Figure 60**), the median and average of absolute and relative loads for 2022 where below 2016 but above 2019.

Figure 60. Total Phosphorous absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

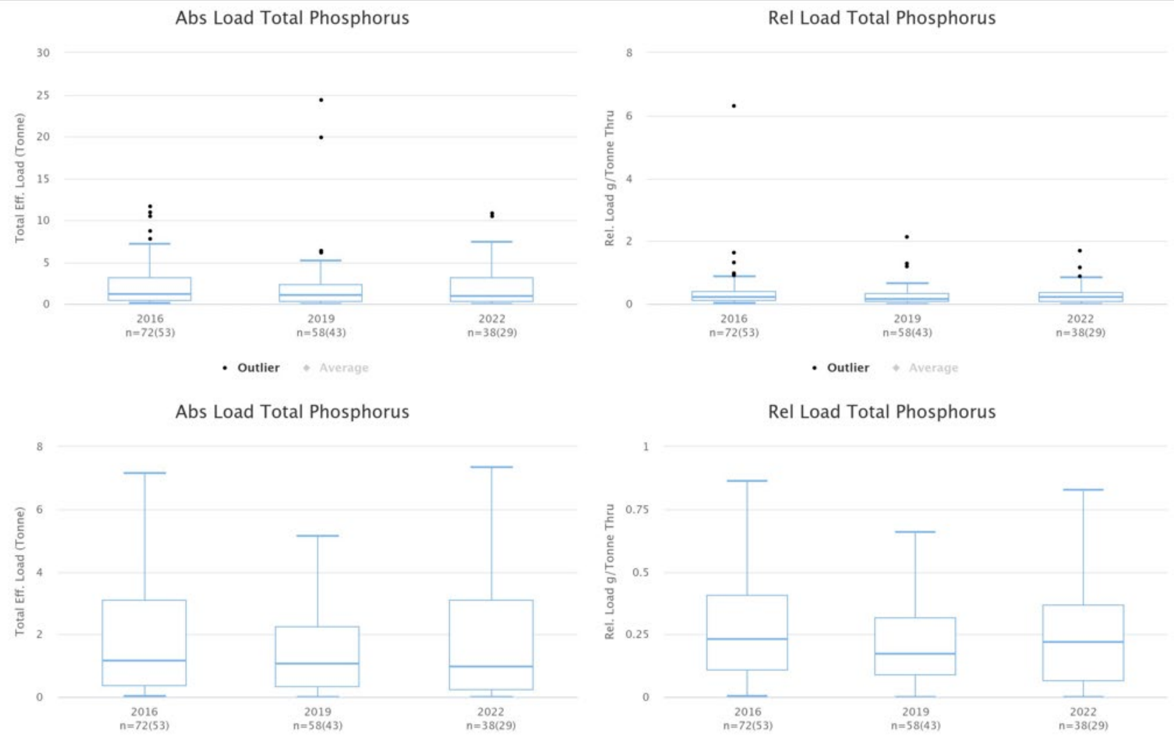
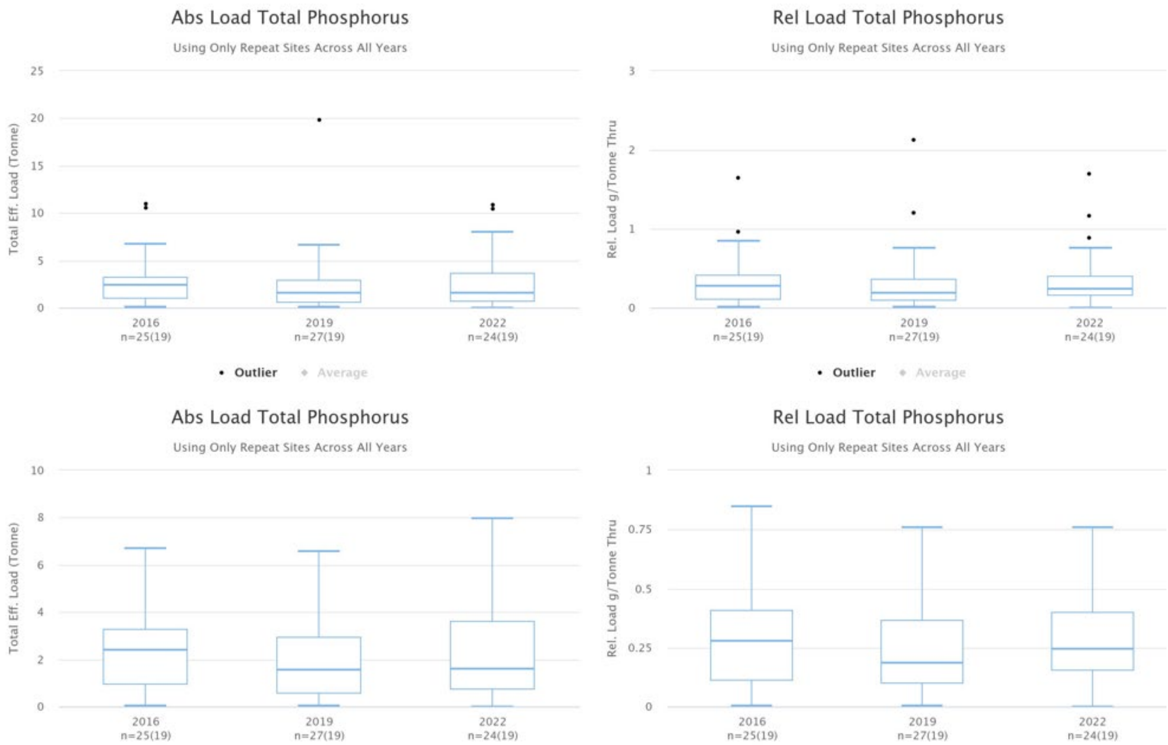
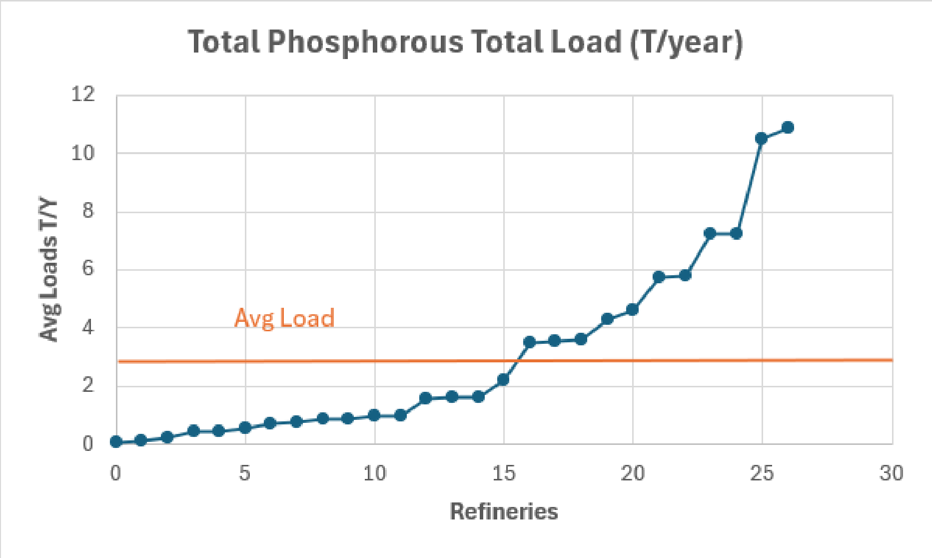


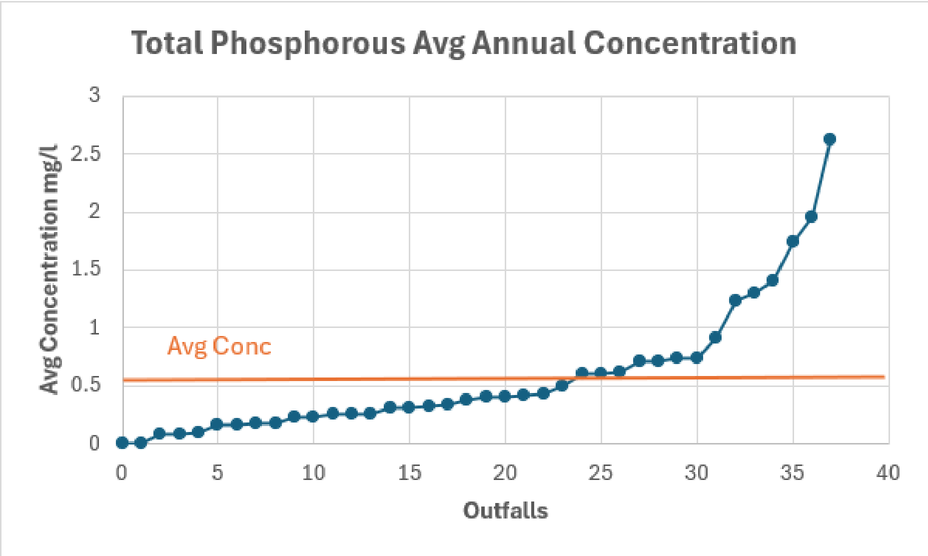
Figure 61. Box and whisker plots for total phosphorous presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.



As shown in **Figure 62**, approximately 63% of all outfalls are below their average concentration, while 59% of refineries are below the refineries average loading.

Figure 62. Scatter plots of total phosphorous average annual concentrations and total load per outfall.





3.1.6. Heavy Metals 2010 - 2022 discharge data

Total and relative discharge data for heavy metals (cadmium, lead, mercury, nickel, and vanadium - as per the REF BREF BAT Conclusions (2014/738/EU15)) for 2010 to 2016 are summarised in **Table 19**. For cadmium, 2022 showed the lowest absolute and relative load since 2010. For lead, there has been a significant reduction in absolute and relative load in relation to previous years. Mercury absolute load was highest in 2016, but 2019 and 2022 were higher than in 2010 and 2013. The highest relative load was reported in 2022. Nickel absolute load has seen steady reduction since 2010while its relative load has been constant. Finally, vanadium absolute load has been stable over the years and with the highest relative load reported in 2022.

Table 19. 2010 to 2022 discharge of heavy metals

Year	Cadmium	Lead	Mercury	Nickel	Vanadium
	kg/year				
2010	740[1] 12[2]	3,014 48	170 5	7,960 221	7,197 115
2013	542 87	2,463 278	161 1.1	5,685 481	2,020 4.5
2016	618 0.09	1,123 10	386 0.05	2,870 1.3	8.670 0.2
2019	1,109.96 0.23	1,731.94 0.7	271.85 0.1	2,839.77 2.3	6,952 0.82
2022	50.52 0.04	256.50 0.00	245.6 0.01	1,620.97	7,374 0.00
	mg/tonne throughput				
2010	1.2 0.04	5 0.05	0.28 0.002	13.2 0.36	11.9 0.72
2013	1.1 0.007	4.9 0.03	0.32 0.0001	11.4 0.05	4.04 0.0004
2016	1.2 0.0002	2.2 0.02	0.76 0.003	5.6 0.002	15.9 0.0005
2019	2.35 0.00	3.75 0.05	0.50 0.01	5.67 0.17	19.62 0.08
2022	0.16 0.00	0.86 0.00	0.81 0.00	5.37 0.00	28.47 0.00

[1]The upper figure in each box is for direct discharges.
[2]The lower figure in each box is for discharges after transfer to and treatment by offsite WWTP, assuming 95 % removal (Concawe, 2012).
Receiving waters (fresh/brackish) are not differentiated.
The above mass calculations followed the following conventions regarding the concentrations used:

- An entered value of 0 is treated as a non-detect;
- Results greater than 0 but below the specified Limit of Quantification (LOQ) are treated as a reportable result.
- For non-detects, if an LOQ is entered, ½ of the corresponding LOQ is utilised as the value for non-detects.

Metals are introduced in the processing of the crude and, as a general rule, heavier crudes contain higher concentrations of metals (in particular Cd and Pb (also Ni in some degree). Therefore, the amount of metals in the refinery effluent will depend greatly on the type of crude been processed and on the refinery configuration (for which the Nelson Index is a good indicator). Cadmium annual loads have seen a general decrease since 2010 with 2022 reported the lowest total load. The relative load has been consistent over the years with 2022 showing also the lowest relative load. As shown in **Figure 63**, annual average concentrations have decrease since 2016, with 2019 and 2022 showing much lower concentrations than in 2016. Absolute total load (**Figure 64**) is highest in 2019 due to a high outlier due to the discharge of a very large volume by one refinery, while the load distribution (box plot) consists of general lower values. When relative load is considered, the distributions are similar across the three survey years (**Figure 65**).

Figure 63. Box plots of annual Cadmium concentrations in refinery effluents (full view with outliers on the left and zoom view on the right).

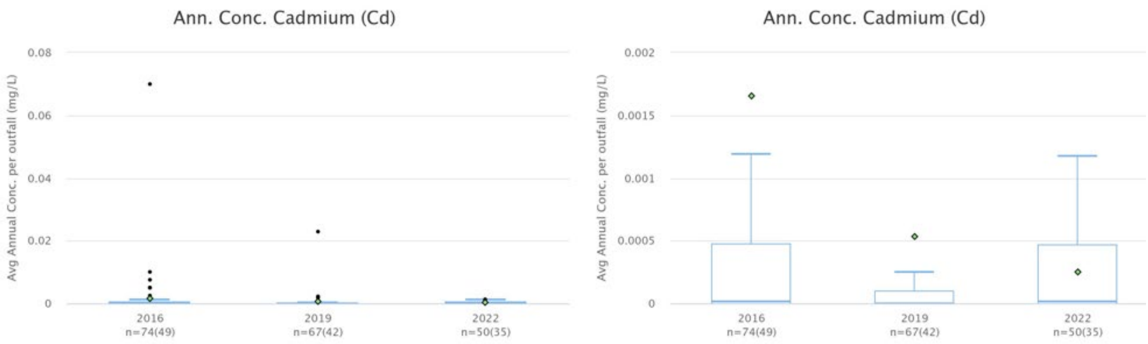


Figure 64. Cadmium absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

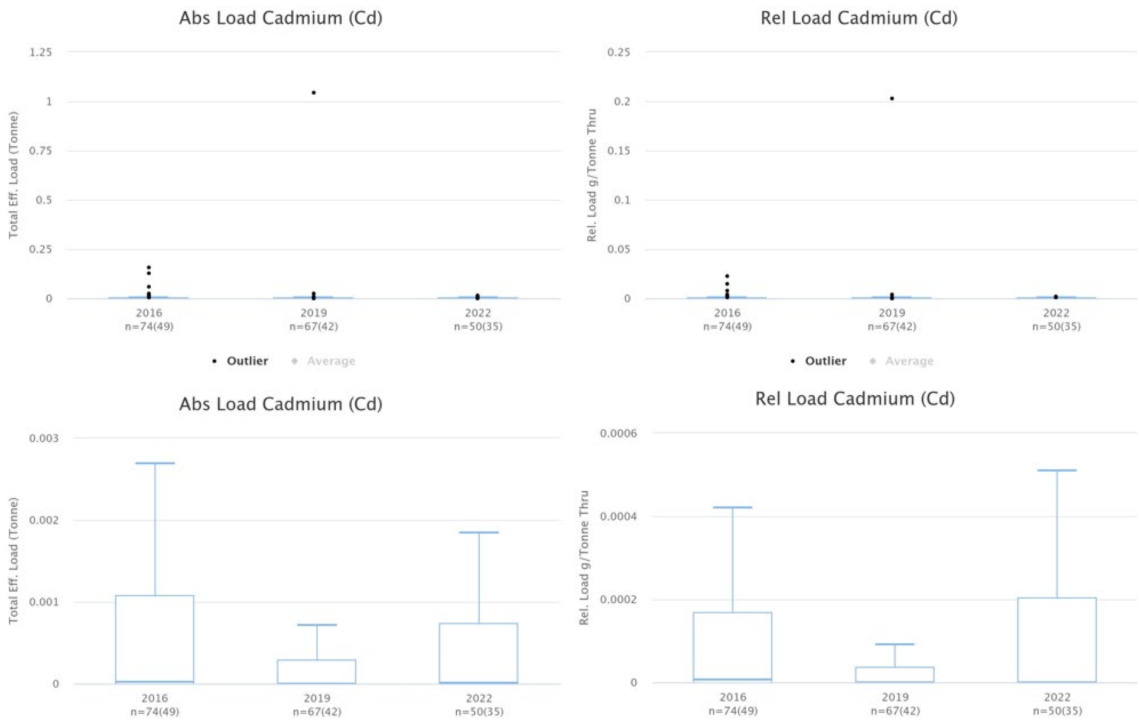
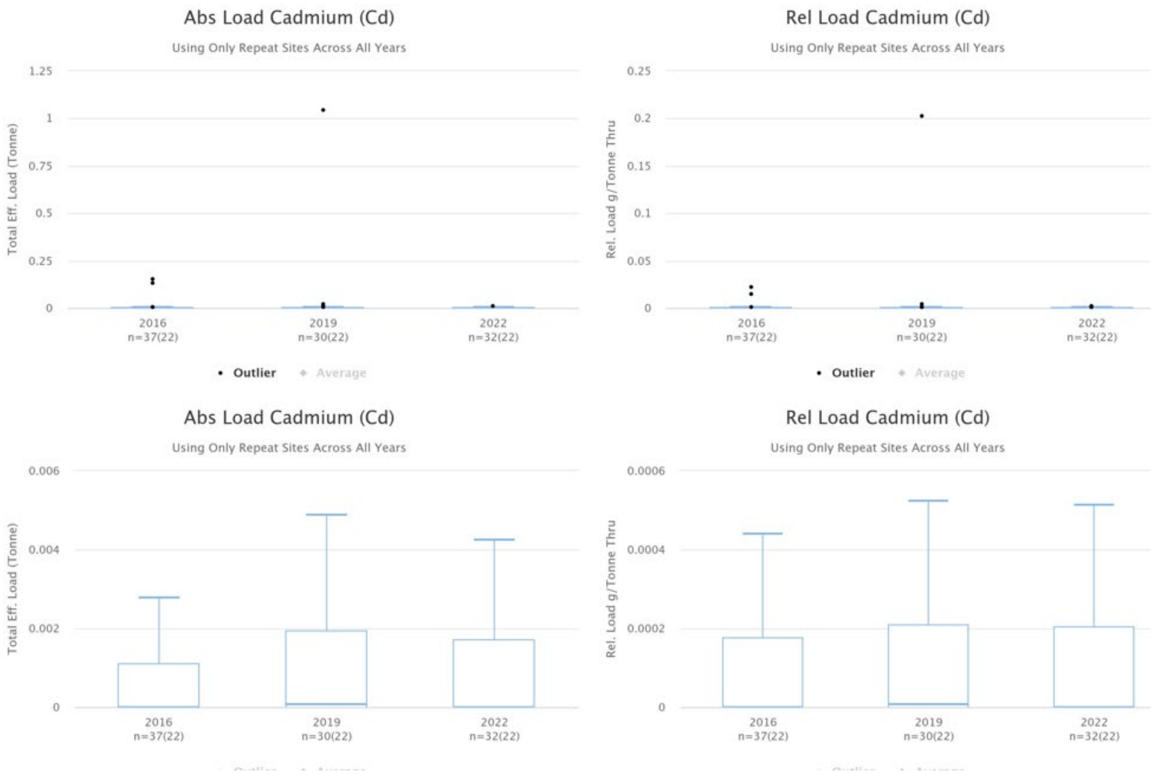
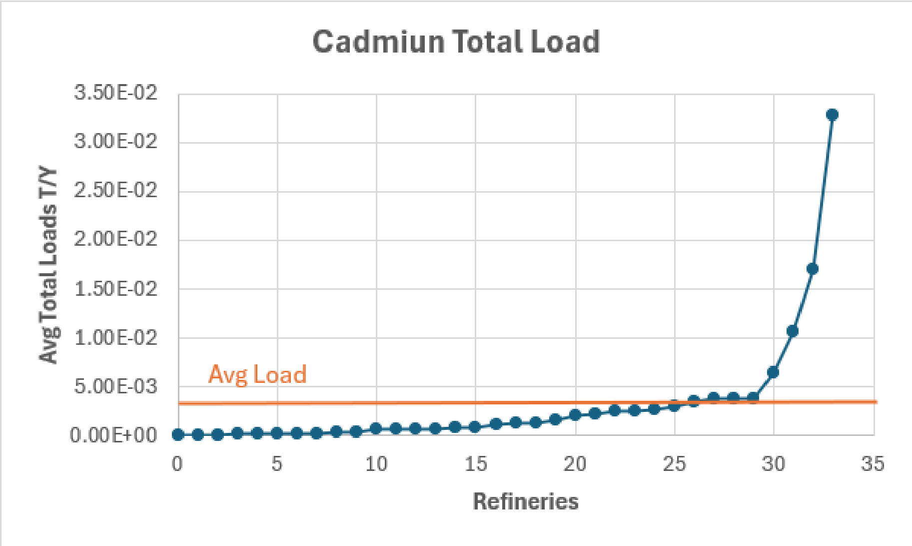


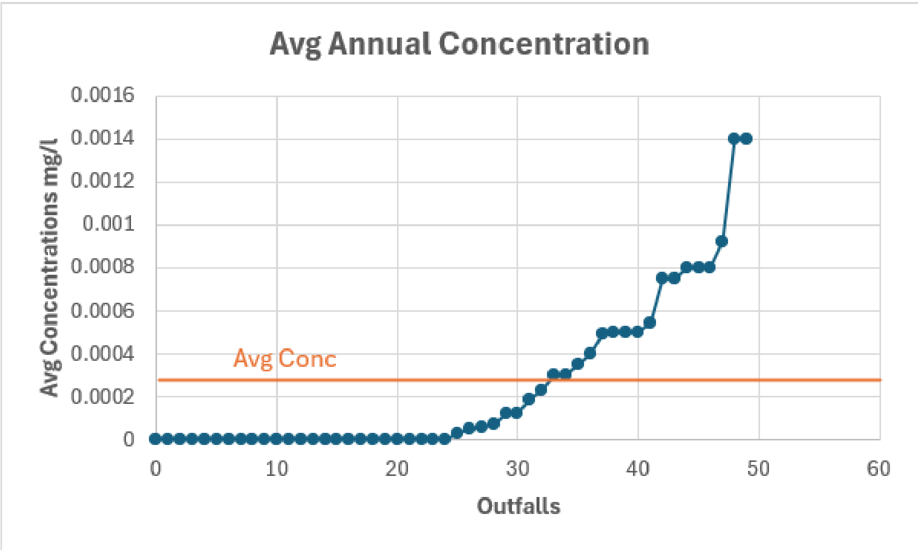
Figure 65. Box and whisker plots for cadmium presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.



The scatter plots in **Figure 66** show more than half of the outfalls below the average concentration (66%), while 76% of refineries were below the average load of cadmium in 2022. The high outlier of 1 t/y of cadmium from one refinery has been removed from the scatter plot given that when added, it obscures the distribution, with all other refineries showing essentially a flat line.

Figure 66. Scatter plots of cadmium average annual concentrations and total load per outfall and refinery.





From the plots of lead discharge concentrations (**Figure 67**), it is shown that the median concentration is similar in all the three survey datasets (2016-2022), whereas the average concentration has decreased from 2016 to 2022.

Figure 67. Box plots of annual Lead concentrations in refinery effluents.

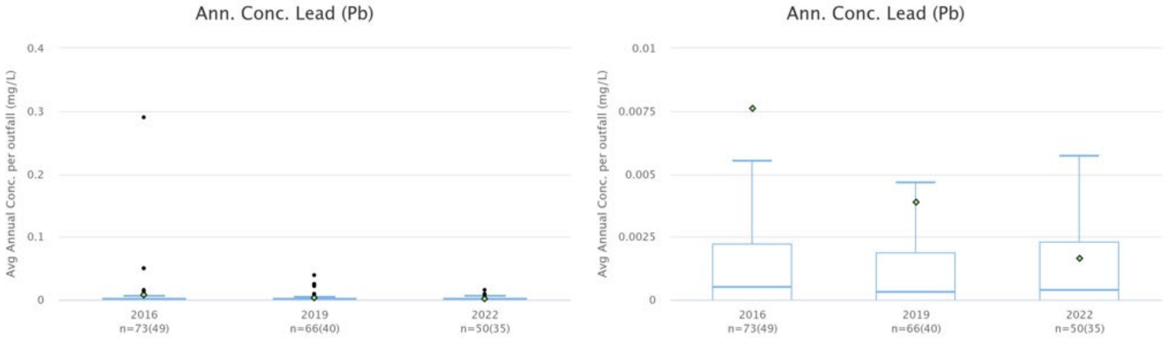


Figure 68 shows that the median load for lead is highest in 2022 and lowest in 2019, with the higher load in 2019 due to several outliers. A similar distribution can be observed when the relative loads are plotted. The absolute load and relative load show a different distribution pattern when the same sites are considered in the three surveys. In this case, the medians are higher in 2019 than in both 2016 and 2022.

Figure 68. Lead absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

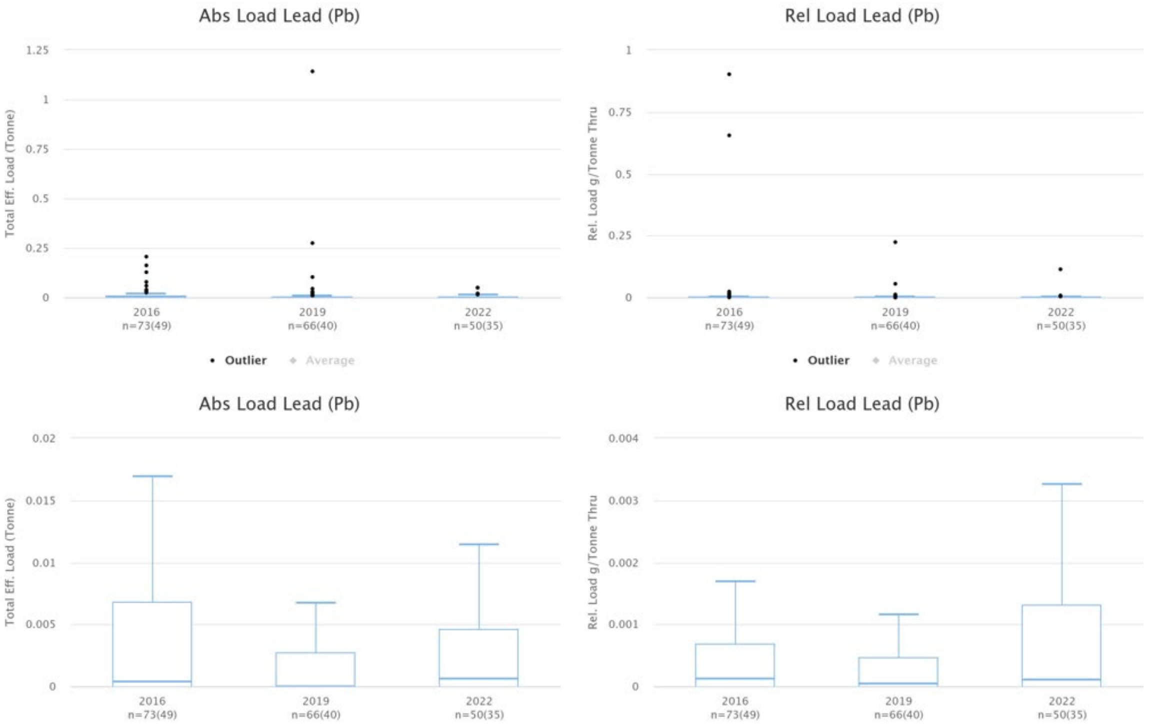
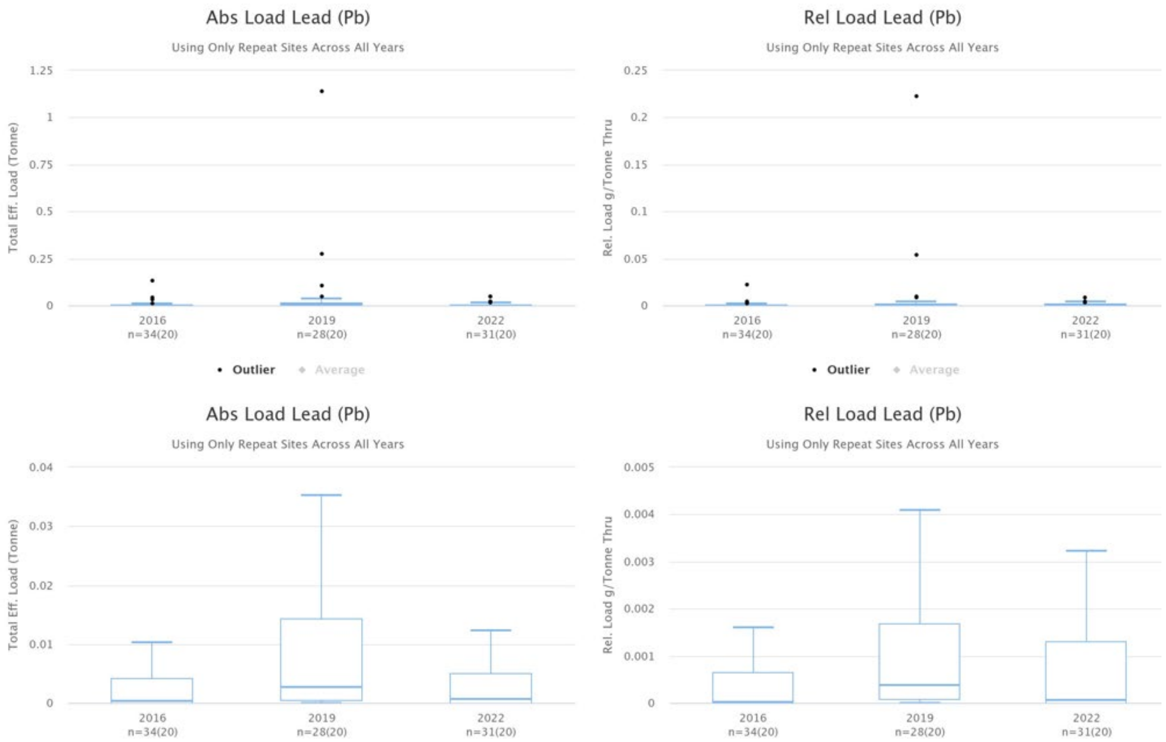
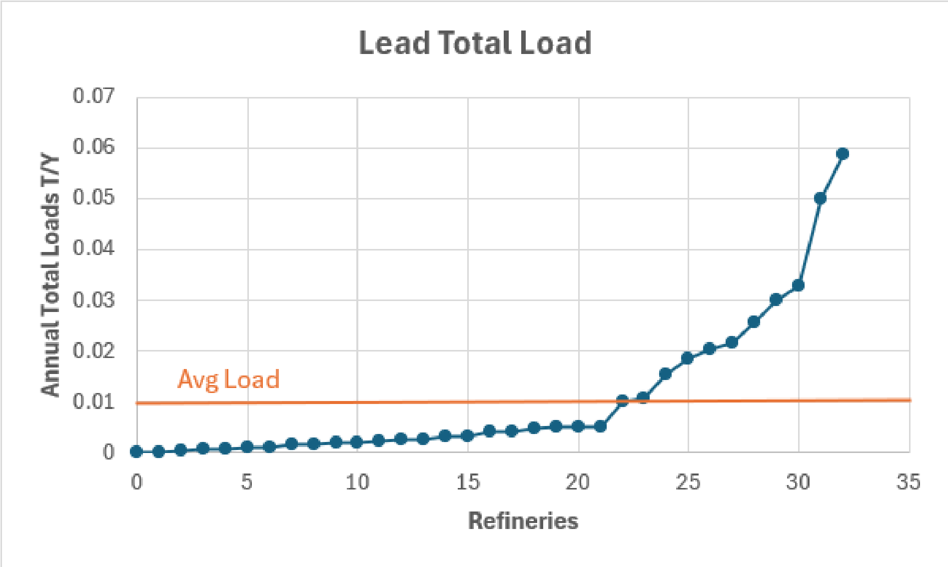


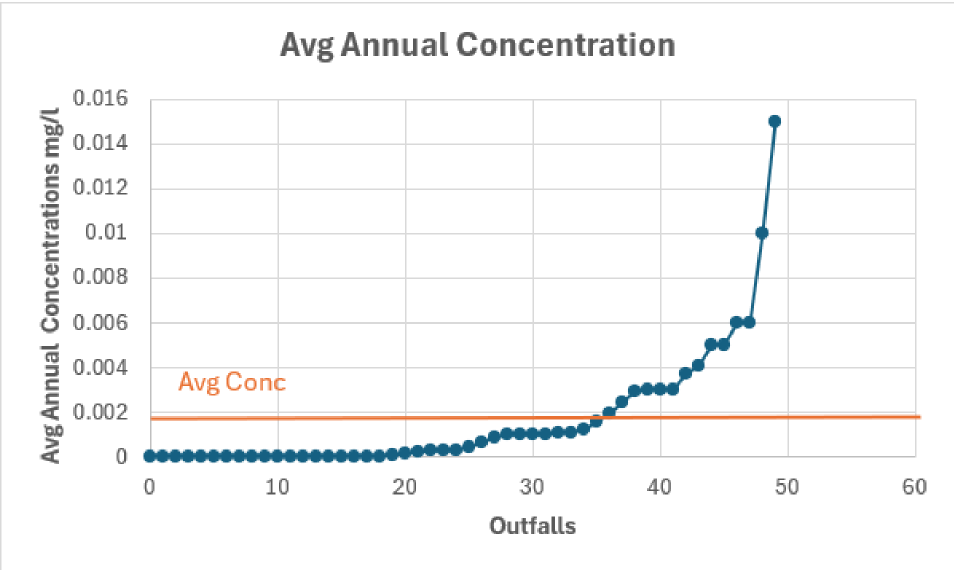
Figure 69. Box and whisker plots for lead presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.



As shown in **Figure 70**, about 72 % of outfalls were below the average concentration of lead in 2022, while 66% of refineries were below the average absolute load.

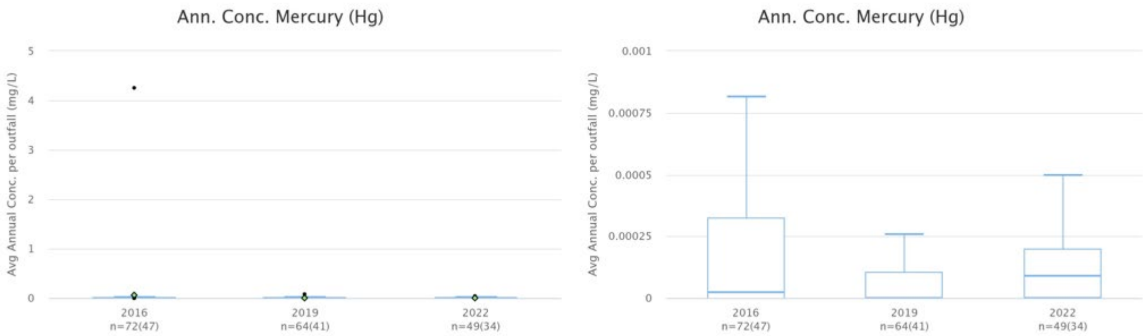
Figure 70. Scatter plots of lead average annual concentrations and total load per outfall and refinery.





From the plots of mercury discharge concentrations (**Figure 71**), it is shown that the median concentration is varying for the three survey datasets (2016-2022) with 2022 being higher than 2016, whereas the average concentration has decreased showing the lowest average concentration in 2022.

Figure 71. Box plots of annual mercury concentrations in refinery effluents.



The total load for 2022 was lower than both 2016 and 2019 (**Figure 72**). However, the relative load in 2022 was the highest of the three surveys. Both the absolute and relative loads distributions are similar. The situation is different when repeat sites only are considered (**Figure 73**). In this case a general decrease in median total and relative loads can be seen from 2016 to 2022.

Figure 72. Mercury absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

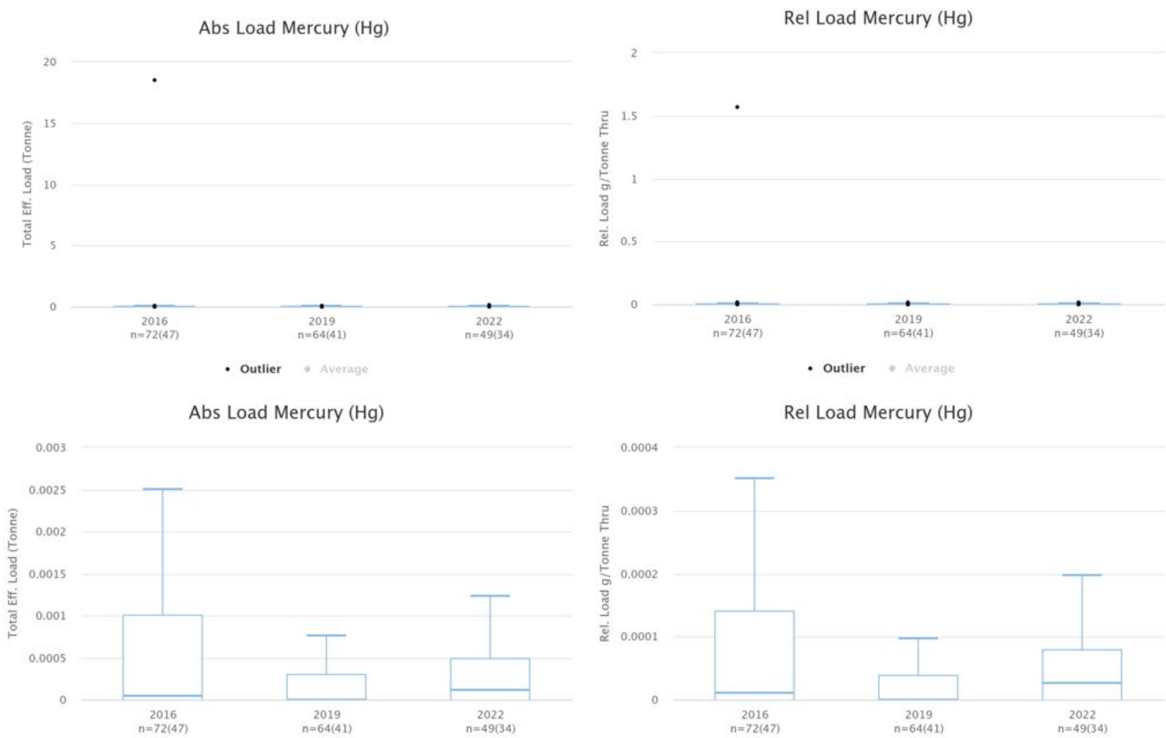
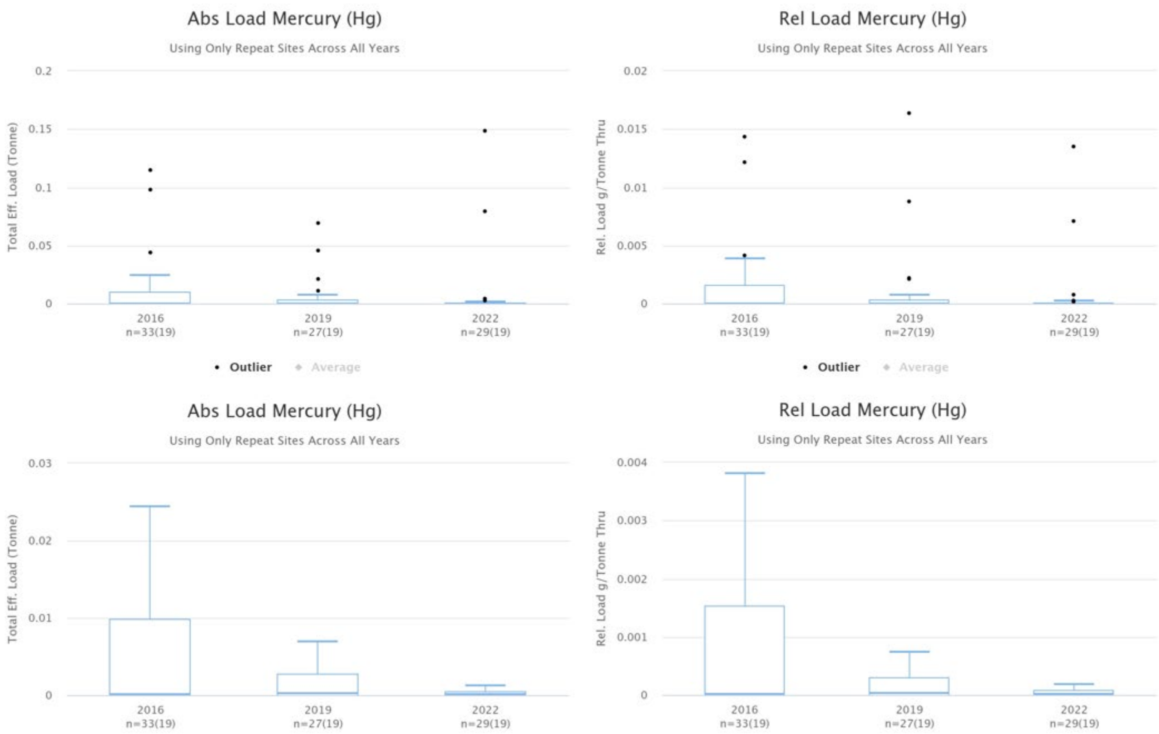
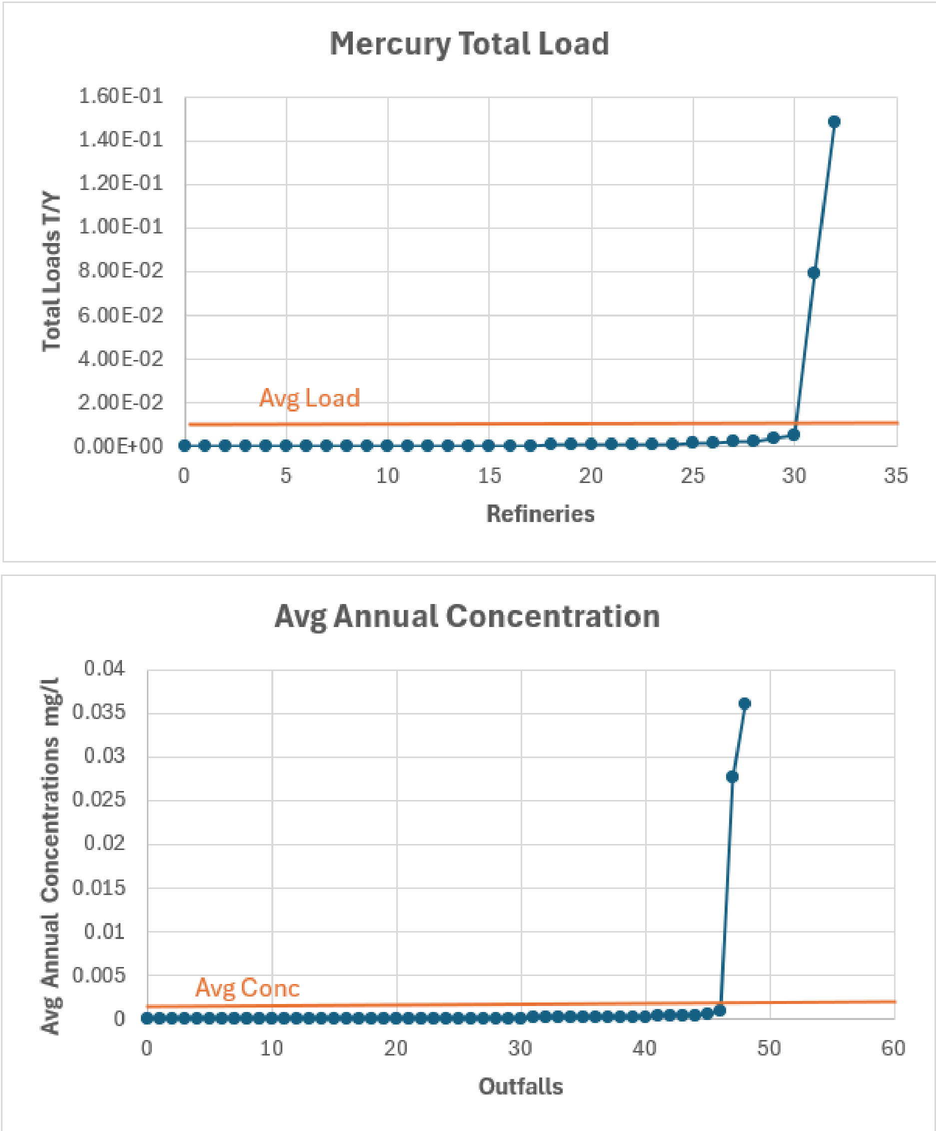


Figure 73. Box and whisker plots for mercury presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.



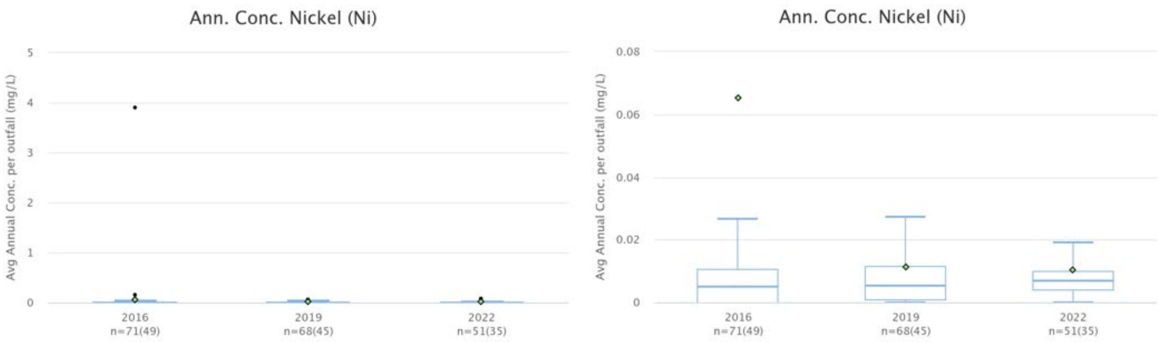
For mercury, >90% of outfalls and refineries fall below the average concentration and loading as shown in **Figure 74**. Approximately 90% of the total load is due to two refineries having the highest and the second highest concentrations. The highest load alone represents nearly 60% of the total load and corresponds to an above average discharge volume.

Figure 74. Scatter plots of mercury average annual concentrations and total load per outfall and refinery.



From the plots of nickel discharge concentrations (**Figure 75**), it is shown that the median concentration is similar in all the three survey datasets (2016-2022), whereas the average concentration has been decreasing throughout the survey years, as was the dataset distribution.

Figure 75. Box plots of annual Nickel concentrations in refinery effluents.



The box plots of absolute and relative loads for all refineries that participated in the three surveys shows very similar distributions and medians for 2016 and 2019, with a slightly elevated median in 2022. Similar distributions are observed when only the repeat sites are considered in the three survey years.

Figure 76. Nickel absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

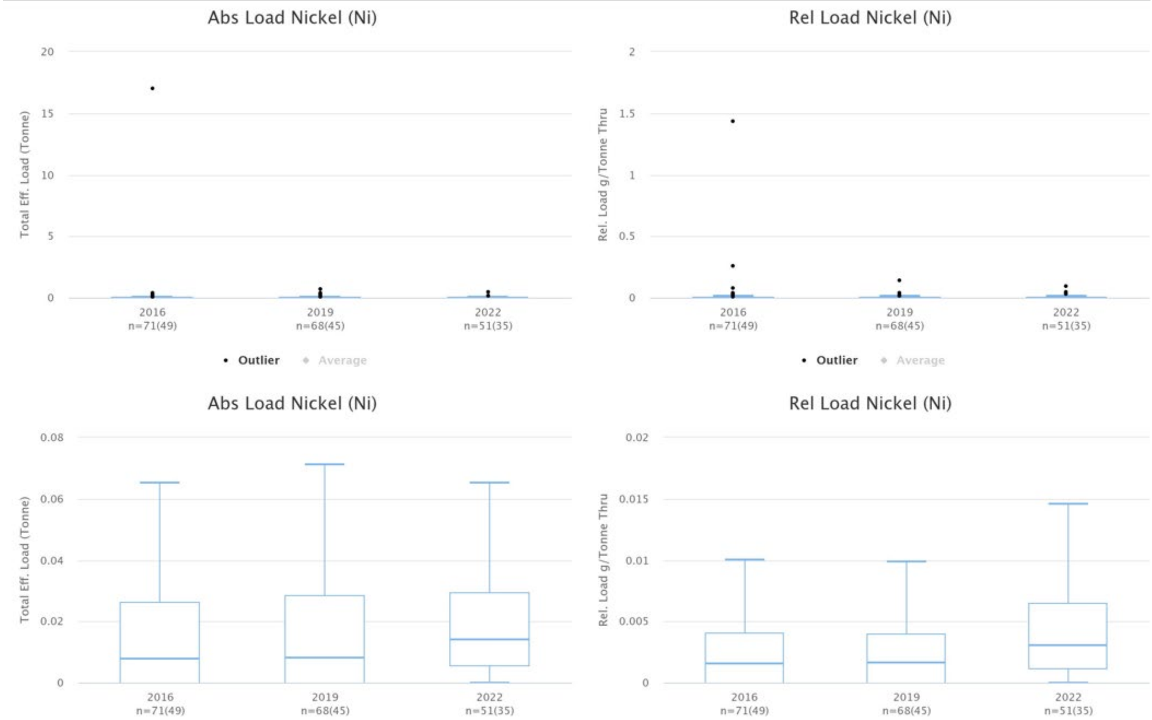
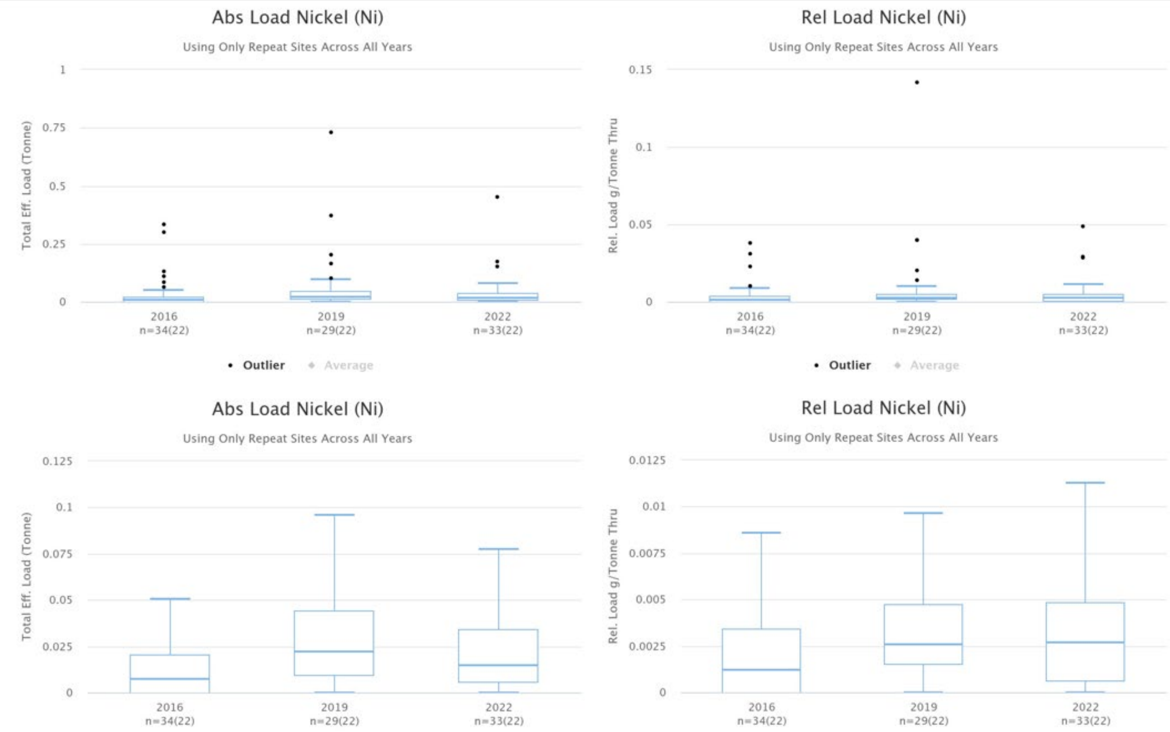
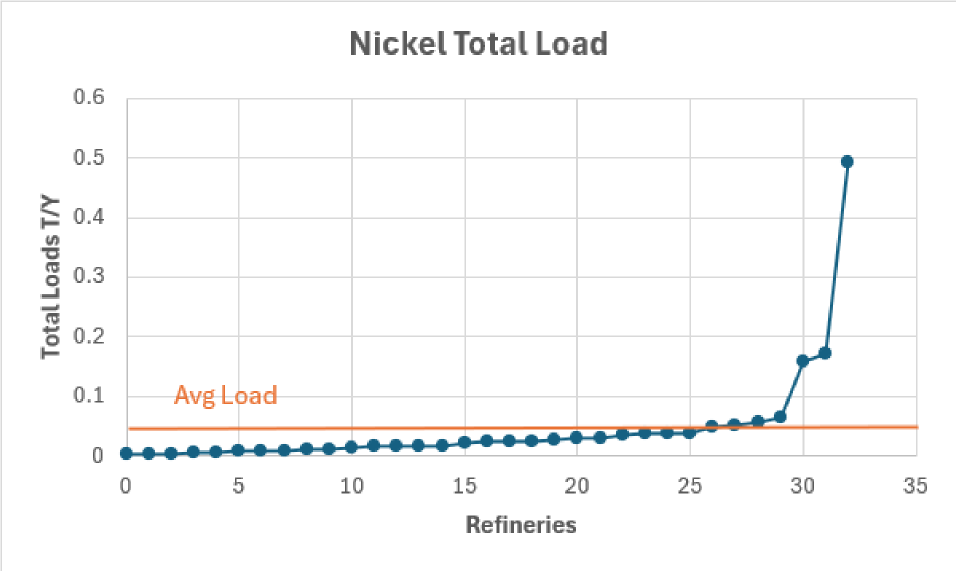


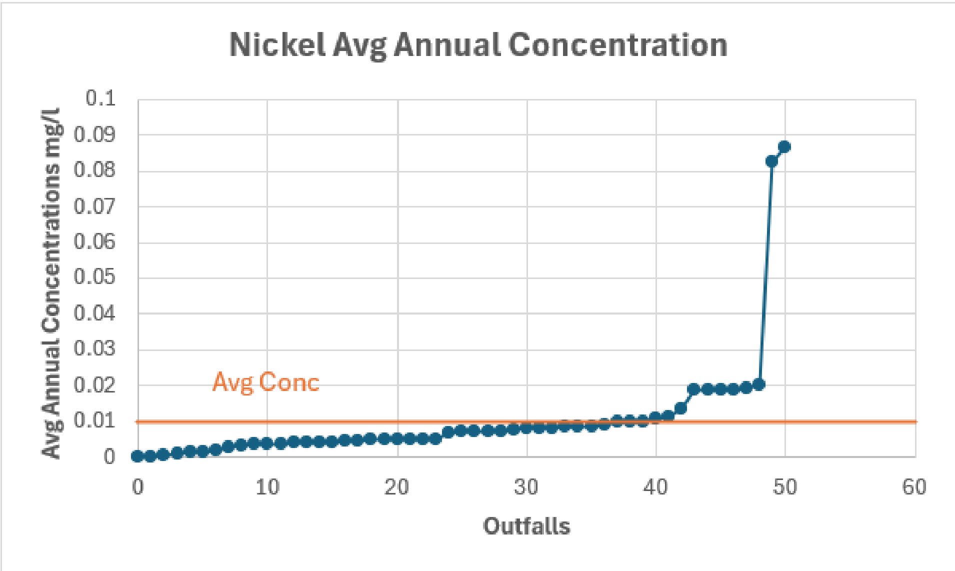
Figure 77. Box and whisker plots for nickel presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.



For nickel, approximately 78% of outfalls and refineries fall below the average concentration and average load respectively (**Figure 78**). The highest load belongs to a refinery with below average concentration but with the highest volume of discharge wastewater (20% of all waste water discharge).

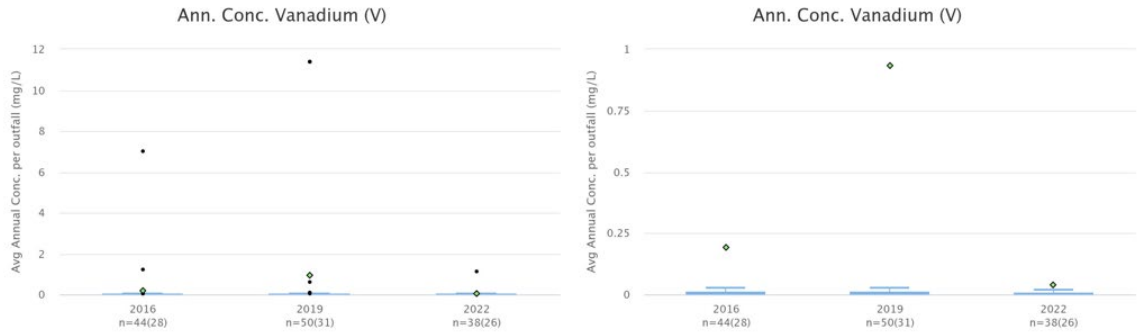
Figure 78. Scatter plots of nickel average annual concentrations and total load per outfall and refinery.





Vanadium discharge concentrations in **Figure 79** shows highest average of the three years occurred in 2019 (due to a high outlier), with lower values in 2016 and 2022. With respect to the median concentrations, these were very similar in the three survey years.

Figure 79. Box plots of annual Vanadium concentrations in refinery effluents.



The vanadium discharge loads in **Figure 80** show their median concentrations are similar in all the three survey datasets (2016-202), with a slight higher value in 2016, whereas the relative load median was highest in 2019. All three survey datasets contain high outliers which amounts did not significantly differ between the datasets. When only the repeat sites are considered (**Figure 80**) the absolute and relative loads medians are very similar.

Figure 80. Vanadium absolute and relative loads including all refineries in the survey. Upper plots show absolute load and relative loads with outliers (full view). Two bottom plots show dual absolute and relative loads without outliers (zoom view).

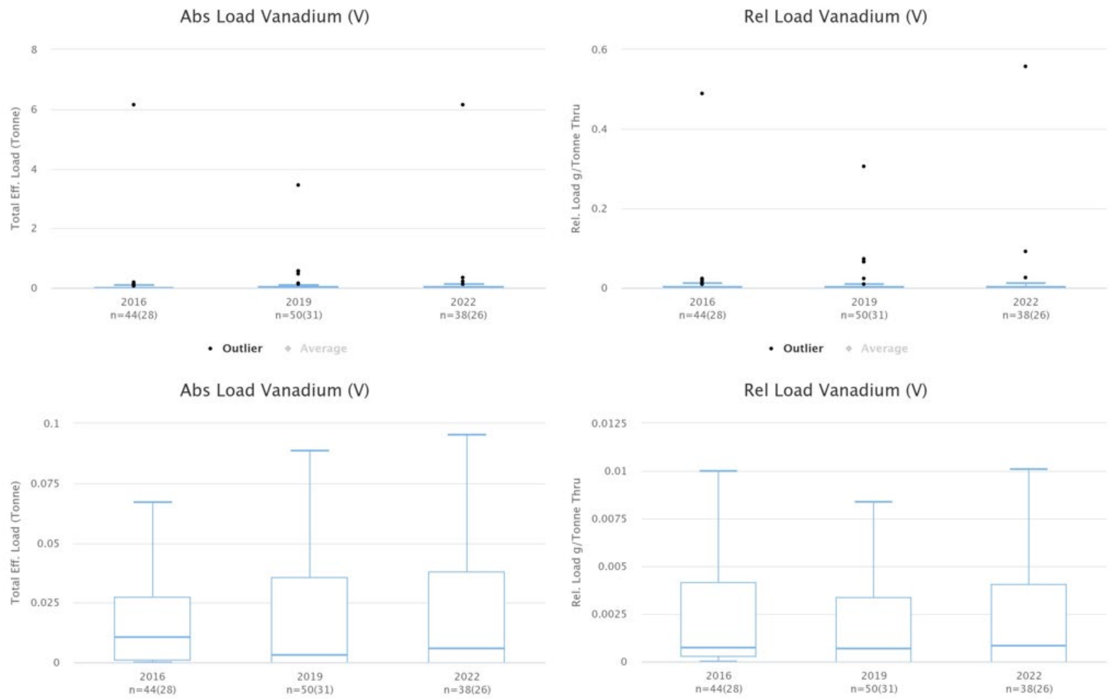
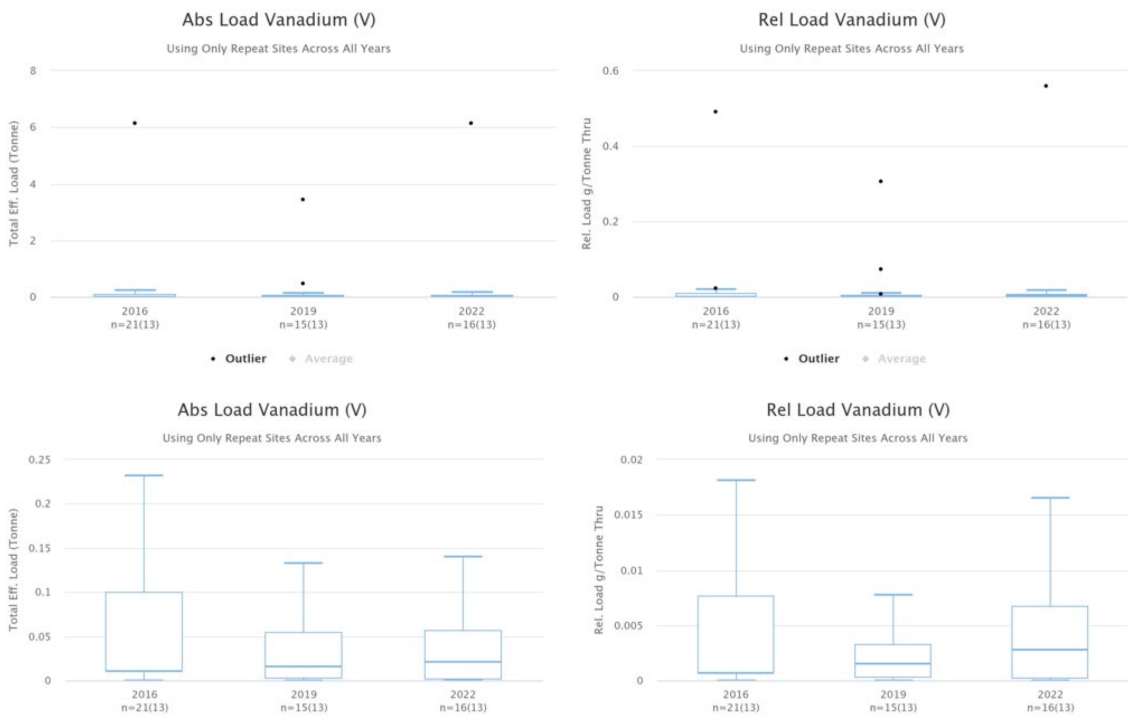
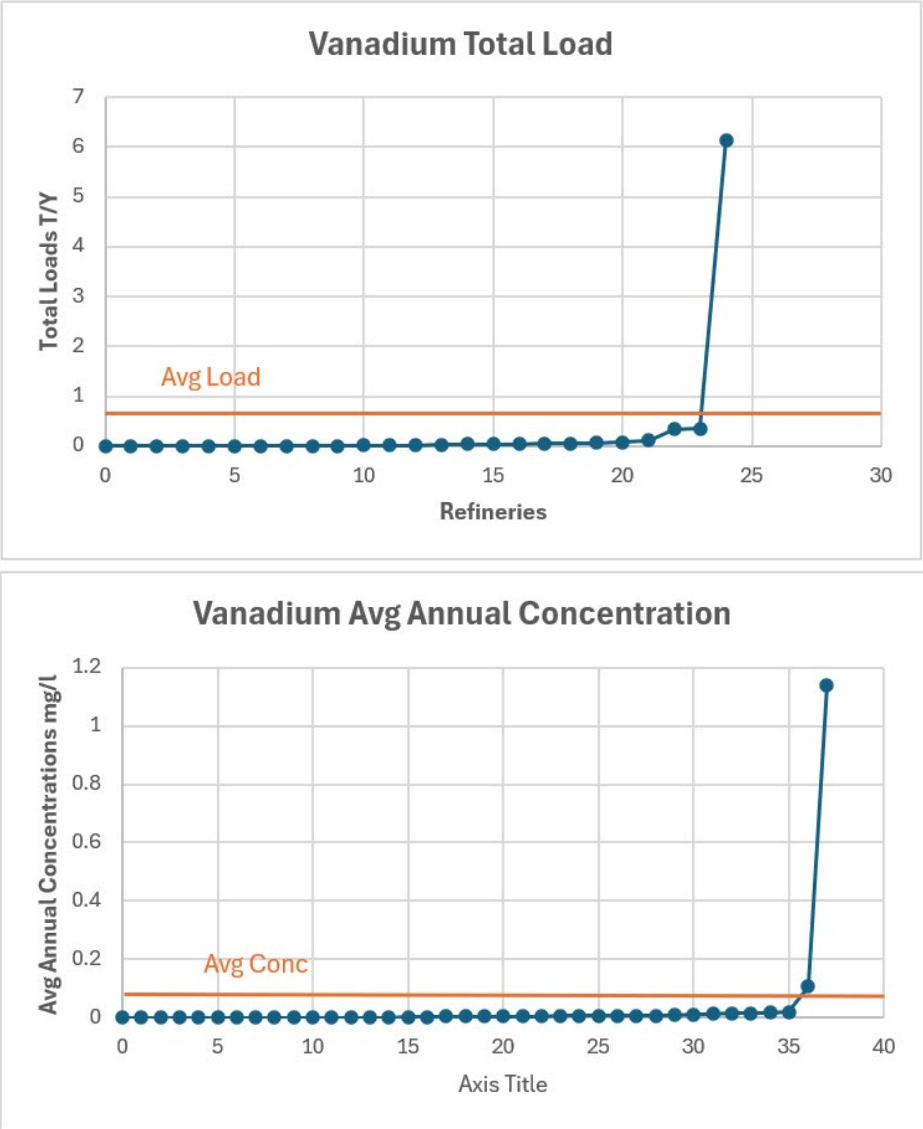


Figure 81. Box and whisker plots for vanadium presenting the 2016, 2019 and 2022 survey results for total load and relative load per throughput for repeat refineries. Upper plots show full view with outliers. Bottom plots show zoom view without outliers.



For vanadium, approximately 94% of outfalls' concentrations and 88% of the refineries' loads fall below the average concentration and average load respectively (**Figure 82**). The highest load belongs to one refinery representing 83% of the total load for 2022.

Figure 82. Scatter plots of vanadium average annual concentrations and total load per outfall and refinery.



4. CONCLUSIONS

This report provides a summary of data gathered by Concawe in a survey of refinery effluent quality and water use, which was completed in 2024 for the 2022 reporting year. A total of 48 responses out of 86 potential respondents (56% response rate) were collected from refineries that represent a wide geographic scope and range of refinery types/complexities. Comparison between years is not fully possible since there is a difference in numbers between the refineries participated in 2022 compared to the previous years, but comparison in relative terms, i.e. normalised to throughput, gives nevertheless an indication. Furthermore, the distribution of responses per complexity class between 2016 and 2022 was similar indicating that making comparisons in relative terms is relevant.

A total of 1.5 billion m^3 of water was withdrawn in 2022 by the 48 refineries that returned data on site water intakes. Approximately 1.143 billion m^3 or 75% of the total abstracted water was brackish or saline and used mostly for once-through cooling. The total freshwater withdrawal was 366 million m^3 (average 7.6 million m^3 per refinery), with 336 million m^3 (average 7 million m^3 per refinery) used for purposes other than once-through cooling. A total of 1.34 billion m^3 of effluent was discharged to the environment in 2022, including once-through cooling water. This equates to a relative discharge of 4.37 m^3/ton of throughput, down from 5.03 m^3/ton and 4.51 m^3/ton in 2016 and 2019 respectively. Some 200 million m^3 of effluent were treated in 2022, equivalent to 0.65 m^3/ton of throughput.

Using the IPIECA definition for freshwater consumption (Env-1 Freshwater (IPIECA, API and IOGP, March 2020, Revised 2023), refineries consumed a total of 197 million m^3 of fresh water in 2022. The relative freshwater consumption in 2022 was 0.64 m^3/ton, which was lower than in 2019 when it was 0.67 m^3/ton, and higher than in 2016 when it was 0.58 m^3/ton.

The quality of the effluents in 2022 is consistent with the long- term trend towards reduced discharge of oil (reported as Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)). Relative TPH load in 2022 were much lower than in 2019 and 2016 a relative load of 0.36 g/t (lower than 0.50 g/t and 0.58 g/t in 2016 and 2019 respectively). When comparing load and relative load data for the same refineries that participated in all three surveys, the average relative load in 2022 (0.58 g/t) is lower than in 2019 (0.84 g/t) but higher than in 2016 (0.27 g/t). When considering the median of the discharge distributions, the relative load in 2022 (0.12 g/t) was lower than in 2016 (0.18 g/t) and 2019 (0.25 g/t).

Comparing with the previous two surveys Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) showed slight (BOD) to strong decreases of their relative loads. Total phosphorous, ammonia and total nitrogen relative load remains fairly constant. Good discharge load decreases were also observed for BTEX, phenols, cadmium and lead in relative loads. Finally, mercury and vanadium show no decrease in relative discharge loads, with vanadium showing an actual increase in its relative discharge load.

5. GLOSSARY

BAT	Best Available Techniques
BOD	Biochemical Oxygen Demand
BREF	BAT Reference Document
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
COD	Chemical Oxygen Demand
E-PRTR	The European Pollutant Release and Transfer Register
EU	European Union
EU-27	Abbreviation of European Union (EU) which consists a group of 27 countries
LOQ	Limit of Quantification
OiW	Oil in Water
PAH	Polycyclic Aromatic Hydrocarbon
REF BREF	BREF for the Refining of Mineral Oil and Gas
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
QA/QC	Quality Assurance and Quality Control
WSWMG	(Concawe) Water, Soil & Waste Management Group
WWTP	Waste Water Treatment Plant

6. ACKNOWLEDGEMENTS

The project team would like to acknowledge the support received from refineries in assembling the effluent quality and water use data, and in particular the focal points for each site.

We would also like to acknowledge the contribution of the member company experts for their detailed review and critique of the report.

7. REFERENCES

1. Concawe (2020), 2016 Survey of Effluent Quality and Water Use at European Refineries, Report 10/20, Brussels.
2. IPIECA, IOGP, API, 2020, Sustainability Reporting Guidance for the Oil and Gas Industry, 4th Edition.

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