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2013 survey of effluent quality and water use at European refineries

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2013 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 and the survey design has been updated over time to address various scientific and legislative developments. 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 2014 for the 2013 reporting year of European refinery effluent quality and water use.

A total of 79 refineries participated in the survey from the EU-28 countries, Norway and Switzerland. Of the 79 questionnaires returned, 79 yielded data on effluent quality and 70 provided data on site water use. A statistical assessment of site water use is presented, including aggregated data on intake and effluent volumes, water treatment processes, and costs associated with water use. In addition, annual average concentration and discharge mass for a number 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 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A total of 3.5 billion m^3 of water was withdrawn in 2013 by the 70 refineries that returned data on site water use (vs 4.5 billion m^3 in 2010 for 100 refineries). Approximately 3.0 billion m^3 or 86 % of the total abstracted water was brackish or saline and used for once-through cooling. The total freshwater withdrawal was 493 million m^3 (average 7.0 million m^3 per refinery), with 371 million m^3 (average 5.3 million m^3 per refinery) used for purposes other than once-through cooling. By way of comparison, the 2010 survey of 100 refineries indicated a total freshwater withdrawal (for purposes other than once-through cooling) of 4.2 million m^3 per refinery on average. Using the IPIECA definition for freshwater consumption (indicator E6; IPIECA, API and IOGP, 2015), refineries consumed a total of 271 million m^3 of fresh water in 2013 vs 282 million m^3 in 2010. The average relative freshwater consumption was apparently higher in 2013 at 621 m^3/kilotonne throughput vs 467 m^3/kilotonne throughput in 2010. All comparison with 2010 water use data could, however, reflect the different population of refineries reported under the 2010 and 2013 surveys, or differences in the way that the surveys were designed (the 2013 survey captured more detailed information on water uses).

An average of 0.48 m^3 of process water was discharged from the reporting refineries per tonne of annual feedstock throughput, which was lower than reported in the previous two Concawe surveys (0.82 in 2008; 0.67 in 2010).

With regard to effluent quality, the results of the 2013 survey are consistent with the long-term trend towards reduced discharge of oil (reported as Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)). While total and relative oil discharge (i.e. normalised to throughput) are lower relative to the 2010 and 2008 survey years at 354 tonnes and 0.71 g/tonne throughput, respectively, fewer refineries participated in the 2013 survey and so the discharge data are not directly comparable. For the 59 refineries that reported under both the 2010 and 2013 survey average relative TPH discharge decreased by 28% from 2010 to 2013. From 1993 to 2013 the survey data indicate a large decrease in total and relative discharge of ammonia and phenols, and a smaller decrease in total nitrogen. For Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC) survey data from 2000-2013 indicate an overall decrease in relative load.

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.

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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 and the survey design has been updated over time to address various scientific and legislative developments. 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 2014 for the 2013 reporting year of European refinery effluent quality and water use. A total of 79 refineries from the EU-28 countries, Norway and Switzerland participated in the survey from 104 potential respondents (76% response rate). The total number, capacity and throughput of refineries reporting under the Concawe water/effluent survey from 1969 to 2013 are presented in the **Table 1** below. The data returned from the surveys provides 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.

70 refineries were included in the 2013 analyses of water intake, discharge and consumption (nine refinery survey responses did not allow for adequate water mass balance computations). A total of 3.5 billion m^3 (3,485,560,351 m^3) of water was withdrawn in 2013 by these 70 sites on site water use (vs 4.5 billion m^3 in 2010 for 100 refineries). Approximately 3.0 billion m^3 or 86 % of the total abstracted water was brackish or saline and used for once-through cooling. The total freshwater withdrawal was 493 million m^3 (average 7.0 million m^3 per refinery), with 371 million m^3 (average 5.3 million m^3 per refinery) used for purposes other than once-through cooling. By way of comparison, the 2010 survey of 100 refineries indicated a total freshwater withdrawal (for purposes other than once-through cooling) of 4.2 million m^3 per refinery on average. Using the IPIECA definition for freshwater consumption (indicator E6; IPIECA, API and IOGP, 2015), refineries consumed a total of 271 million m^3 of fresh water in 2013 vs 282 million m^3 in 2010. The average relative freshwater consumption was apparently higher in 2013 at 621 m^3/kilotonne throughput vs 467 m^3/kilotonne throughput in 2010. All comparison with 2010 water use data could, however, reflect the different population of refineries reported under the 2010 and 2013 surveys, or differences in the way that the surveys were designed (the 2013 survey captured more detailed information on water uses).

Also presented in **Table 1** are summary data for aqueous effluent production by refineries reporting under the Concawe water/effluent survey from 1969 to 2013. In 2013, an average of 0.48 m^3 of process water was discharged from the reporting refineries per tonne of annual feedstock throughput, which is lower than that reported in the previous two Concawe surveys (0.67 in 2010; 0.82 in 2008).

With regard to effluent quality, the results of the 2013 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**. While total and relative oil discharge (i.e. normalised to throughput) are lower relative to the 2010 and 2008 survey years at 354 tonnes and 0.71 g/tonne throughput, respectively, fewer refineries participated in the 2013 survey and so the discharge data are not directly comparable. For the 59 refineries that reported under both the 2010 and 2013 survey average relative TPH discharge decreased by 28% from 2010 to 2013.

From 1993 to 2013 the survey data indicate a large decrease in total and relative discharge of ammonia and phenols, and a smaller decrease in total nitrogen. For Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC) survey data from 2000-2013 indicate an overall decrease in relative load.

In the 2013 survey, for the first time, a section on high level information on costs associated with refinery water use was included. Average intake and discharge costs were ca. 0.3 €/m^3 and 0.1 €/m^3, respectively, with 69 refineries reporting intake costs and 52 discharge costs.

Table 1. Number of refineries reporting for each survey year, together with their reported capacity, annual feedstock throughput and aqueous effluent discharge data.

Year of survey	Number of refineries reporting in each survey	Reported capacity (million tonne/year)	Reported throughput (million tonne/year)[1]	Total aqueous effluent (million m^3/year)[2]	Aqueous effluent (m^3/tonne capacity)[2]	Aqueous effluent (m^3/tonne throughput)[2]
1969	82	400	Not requested	3,119	8	n.d.
1974	112	730	Not requested	3,460	4.7	n.d.
1978	111	754	540	2,938	3.9	5.4
1981	105	710	440	2,395	3.4	5.4
1984	85	607	422	1,934	3.2	4.6
1987	89	587	449	1,750	3.0	3.9
1990	95	570	511	1,782	3.1	3.5
1993	95	618	557	2,670	4.3	4.8
1997	105	670	627	2,942	4.4	4.7
2000	84	566	524	2,543	4.5	4.9
2005	94/96 (capacity/throughput)	730	670	790	1.1	1.2
2008	125	840	748	612 (1,112)	0.73 (1.3)	0.82 (1.5)
2010	100	720	605	405[4] (1,583)	0.56 (2.2)[6]	0.67 (2.6)[6]
2013	79	507[3]	500	238[5] (465)	0.47 (0.92)	0.48 (0.93)

n.d. = not determined

[1] Throughput refers to total throughout, i.e. including both crude oil and other feedstocks

[2] Until 2000 the total aqueous effluent in the table refers to the sum of process effluents, cooling water and other flows such as lightly contaminated rain water. For the 2008, 2010 and 2013 surveys, there is the distinction between treated process water and other streams that are discharged at the same or separate emission points. The values between brackets are based upon the sum of all reported discharges, excluding once-through cooling water.

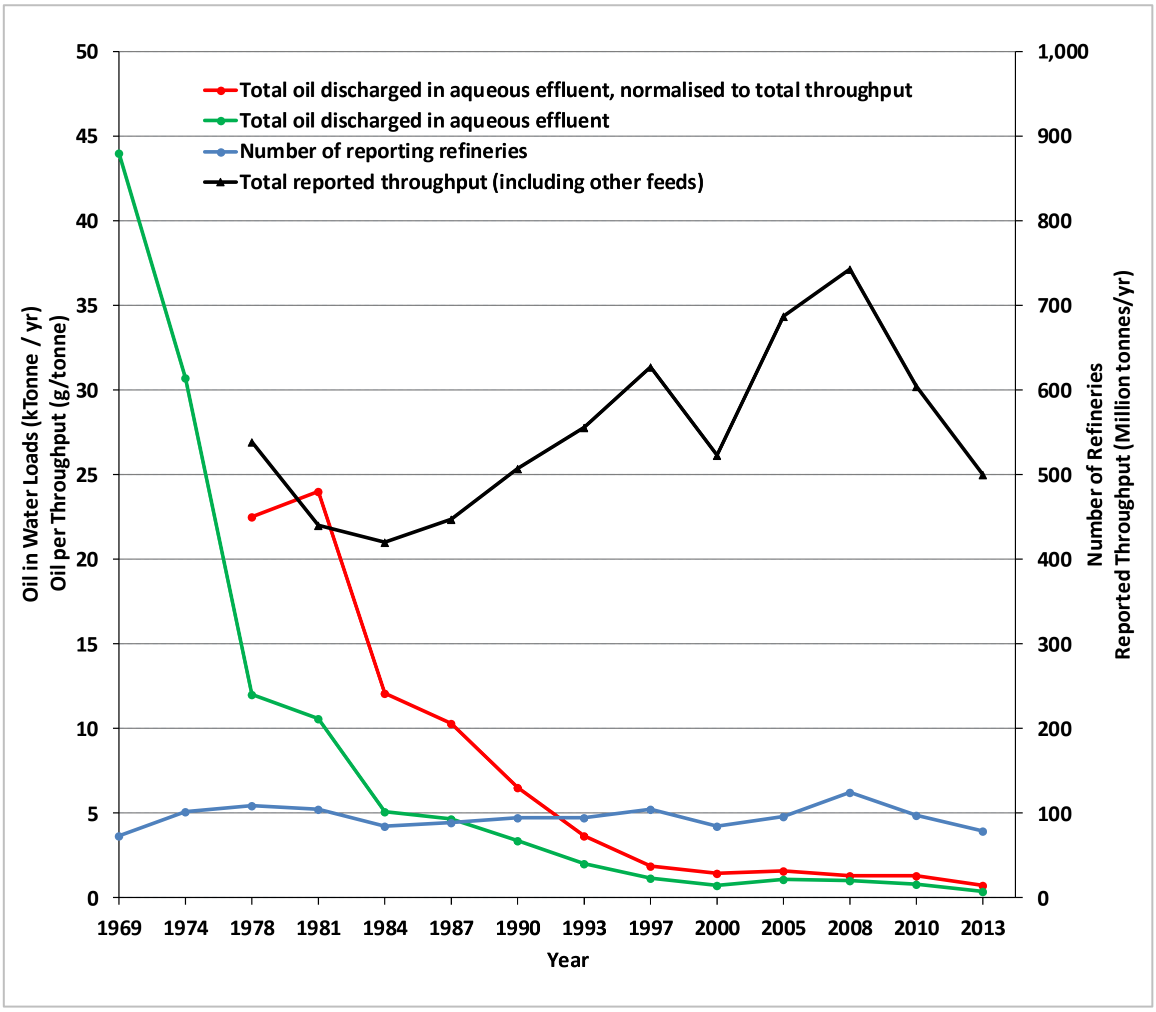
[3] Some refineries reported throughput but did not report capacity. This capacity number represents the total capacity reported and may be under-represented.

[4] In the effluent database there are reports that only consider treated process water (241 Mm^3) and reports on other water (328 Mm^3) that is treated before discharge or transfer. From the notes provided by the survey respondents it is evident that these other waters are mixes of process, cooling and storm water. For this report is has been assumed that 50 % of these effluent comprise of process water.

[5] In the effluent database there are reports that only consider treated process water (170 Mm^3) and reports on other water (136 Mm^3) that is treated before discharge or transfer. From the notes provided by the survey respondents it is evident that these other waters are mixes of process, cooling and storm water. For this report is has been assumed that 50 % of these effluent comprise of process water.

[6] In the 2010 survey report (Concawe, 2012), there was an error in the presented 2010 data of aqueous effluent per capacity and throughput (it was reported to be 0.48 m^3/tonne capacity and 0.55 m^3/tonne throughput). The corrected numbers are presented herein.

Figure 1. Trends in total petroleum hydrocarbons (TPH) loadings in effluents, reported throughput and number of refineries reporting in Concawe surveys from 1969 to 2013.



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 2014 for the 2013 reporting year. The data returned from the surveys provides 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.

1.1. PROJECT DESCRIPTION AND EXECUTION

The water/effluent survey for the 2013 reporting year was initiated in June 2014 with the distribution of a spreadsheet questionnaire to Concawe member company refineries. The 2013 survey design was based on the previous survey completed in 2010, with the following amendments:

- In 2010 the questionnaire requested volumes per water usage type. As a result, multiple water intakes were aggregated into each volume and individual water intake details were lost. In 2013, in order to preserve details about the water intake types/sources, water intake volumes were requested for each intake.
- Addition of costs for water intakes and discharges;
- Additional details on intake water streams categorizations of their types and use;
- Addition of a section on cooling water system types and characteristics; and,
- Addition of recycle water details.

A total of 79 responses of 104 potential respondents[1] (76% response rate) were collected from refineries of varying type and complexity across Europe[2]. For comparison, 100 refineries out of a potential of 112 responded to the 2010 survey (89% 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 2010 and 2013 survey response by refinery type. To facilitate comparison between the 2013 and previous survey findings key metrics have been normalised to refinery throughput. In the case of 3 refineries where no throughput data was provided in 2013, throughput was estimated by multiplying the reported 2010 throughput by the average refinery 2013 to 2010 throughput ratio.

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 Nelson complexity index, as shown in **Table 4**.

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[1] The number of potential respondents represent the number of refineries within the EU-28 countries + Norway and Switzerland that were declared to be operational in 2013.

[2] Complexity groups were derived for each site using their Nelson Complexity index from 2013 (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

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	94/96 (capacity/throughput)	730	670
2008	125	840	748
2010	100	720	605
2013	79	507[2]	500

[1] Throughput refers to total throughout, 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.

Table 2. Summary of collected responses by refinery site type in 2010 and 2013

Type of Site	Number of Responses in 2010	Number of Responses in 2013
Bitumen plant	5	3
Combined refinery and chemical plant	18	18
Lubricant plant	2	2
Refinery	68	48
Refinery and crude oil terminal	7	8
Total	**100**	**79**

Figure 2. Geographic Extent of Country Groupings

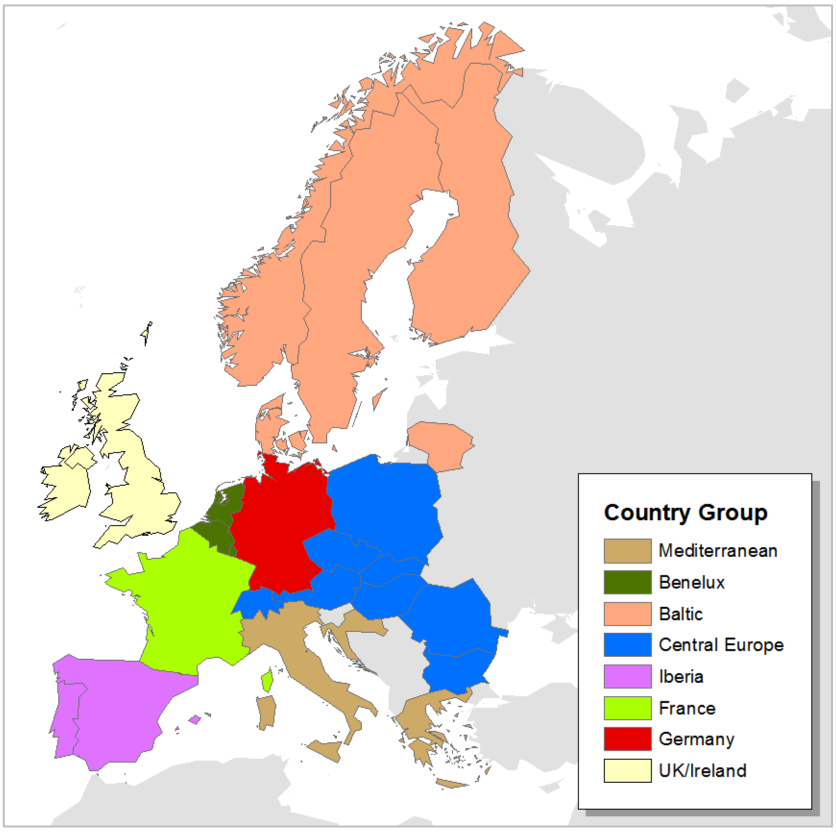


Table 3. Summary of responses collected by country group in 2010 and 2013

Country Group Name (countries included in country group)	Number of Responses in 2010	Total Throughput 2010 (kilotonne/year)	Number of Responses in 2013	Total Throughput 2013 (kilotonne/year)
Baltic (Denmark, Finland, Lithuania, Norway and Sweden)	11	63,848	9	49,612
Benelux (Belgium and Netherlands)	9	96,499	8	74,410
Central Europe (Austria, Czech Republic, Hungary, Poland, Slovakia, Switzerland and Romania)	14	64,225	13	61,291
France	11	68,359	8	50,541
Germany	17	92,536	13	81,665
Iberia (Portugal and Spain)	12	78,054	11	84,089
Mediterranean (Croatia, Greece and Italy)	17	81,856	12	55,770
UK and Ireland	9	59,154	5	42,473
TOTAL	**100**	**604,531**	**79**	**499,851**

Table 4. Summary of collected responses by site complexity groupings in 2010 and 2013. Complexity groups were derived for each site using their Nelson Complexity index from 2013

Complexity Group	Number of Responses in 2010	Total Throughput 2010 (kilotonne/year)	Number of Responses in 2013	Total Throughput 2013 (kilotonne/year)
Class 1	10	19,825	8	20,284
Class 2	18	93,144	9	40,951
Class 3	26	202,517	23	181,500
Class 4	15	103,139	18	114,693
Class 5	26	178,094	19	136,475
Not Available	5	7,813	2	5,947
TOTAL	**100**	**604,531**	**79**	**499,851**

1.2. DATA RESPONSE AND QUALITY CONTROL AND QUALITY ASSURANCE

The data collected through the completion of the questionnaires was extracted by a consultant into a Microsoft Access database. Data were stored in a normalized data structure which enabled the sorting and extraction of the acquired information in a format conducive to conducting analyses by Concawe.

Prior to major analyses, the data were subjected to Quality Assurance and Quality Control (QA/QC) checks and corrections including:

- Verifying consistent units;
- Identifying reported totals not matching individual parts;
- Investigating and validating outlier results (often unit conversion issue or required individual follow-up for verification that outlier is valid);
- Reviewing respondent notes to clarify or complete questionnaire data entries
- Removing text formatting from values;
- Missing information filled in based on other correlated data (e.g.: annual concentration provided and not the mass loadings, but the mass can be calculated using the reported effluent quantities and discharge concentration); and
- Adjusting volumes associated with once-through cooling based on cooling system types identified.

The QA/QC checks result in a limited number of follow-up for certain 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.

There were nine refineries whose survey responses did not allow for adequate water mass balance computations[3]. These were caused by incomplete data associated with intake streams, effluent volumes, and once-through cooling water volumes. As such it was unclear if the water balance discrepancy was caused by water intake volumes containing once-through cooling but effluent volumes did not, or vice versa. In addition, some sites had much larger effluent volumes than intake volumes without indication of external rain/storm water in effluent volumes. In order to minimize the inclusion of potentially faulty data, these sites were removed from intake, discharge, and freshwater consumption calculations, creating a dataset of 70 refineries for evaluation. However, data from these refineries were included in effluent concentration calculations and its related figures.

[3] These nine refineries were equally spread out within Baltic (1), Central Europe (2), France (1), Germany (1), Iberia (2), Mediterranean (1) and UK and Ireland (1) country groups. These sites were comprised of Bitumen plant (1), Combined Refinery and Chemical Plant (1), Refinery (5), and Refinery and crude oil terminal (2).

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

This section provides the 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 E6 (IPIECA, API and IOGP, 2015) is presented in this section. Due to the increased refinements made in the 2013 questionnaire for water quantities and usage as well as different number of respondents, the total volumes are not necessarily comparable to the 2010 or historical water quantities. Also, the ability to more accurately define once-through cooling water volumes in the 2013 questionnaire resulted in a more accurate measure of consumption compared to the 2010 estimates.

2.1. TOTAL WATER INTAKES

In the 2013 survey, respondents were asked to classify their water intake streams by water supply, source, and type, as summarised in **Table 5,** and **Table 6,** respectively. This classification system allowed fine granularity in parsing and grouping data according for analysis. For each classified water intake stream, respondents provided total volumes withdrawn on an annual basis according to intended water usage.

Table 5. Classifications of water sources and uses for water intake streams

Water Intake Supply	Water Intake Source	Water Intake Use
Commercial Water provider	Groundwater	Once-Through Cooling
External utility provider	Harvested storm/rain water	Recirculating cooling
On-site groundwater wells	Purchased potable water[4]	Process Water
Public water provider	Purchased raw water[5]	Domestic
Water/river authorities	Recycled from external use	Other Water
Not Specified	Surface water	Intake Not Specified
	Other[6]	

Table 6. Classifications of water types for water intake streams

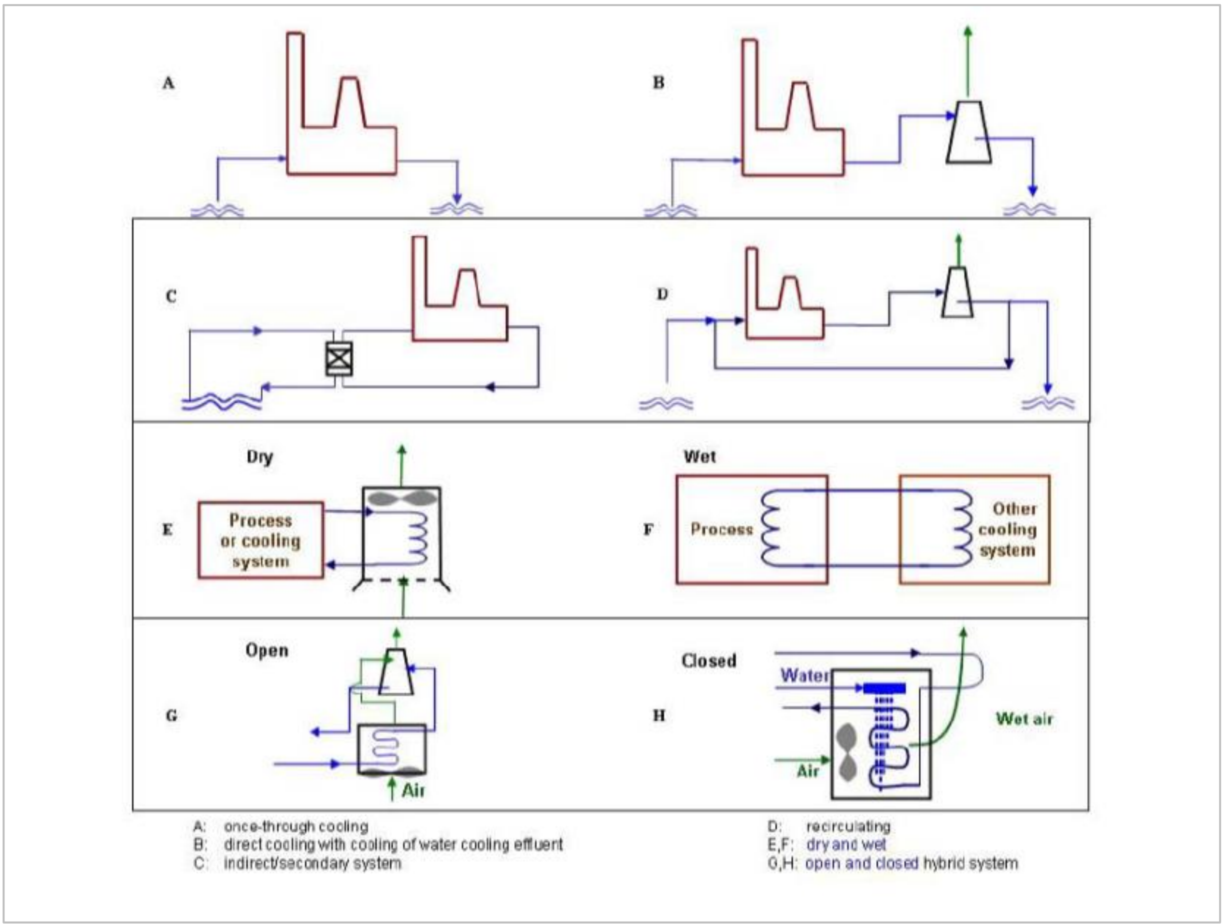
Water Type	Type Category
Fresh groundwater	Fresh
Fresh surface water	Fresh
Fresh water from network supply	Fresh
Marine/Brackish[7]	Brackish/Salt
Not Specified	Other/Not Specified
Other	Other/Not Specified
Recycled water from external source	Other/Not Specified

[4] 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).
[5] Purchased raw water was defined as water that is supplied by a vendor that is not fit for consumption.
[6] Includes purchased steam
[7] Includes brackish water, brackish groundwater, and seawater or other salt water

Water used directly in the process of refining crude (e.g. desalting water) was considered to be process water. Boiler water used to generate steam that was either used for heating, stripping or fluidizing was also defined as process water because it might have contact with crude oil and/or intermediate and final refinery products. Therefore, steam or intakes used for production was regarded as process water, which is a conservative approach that overestimates the actual process water intake streams amounts.

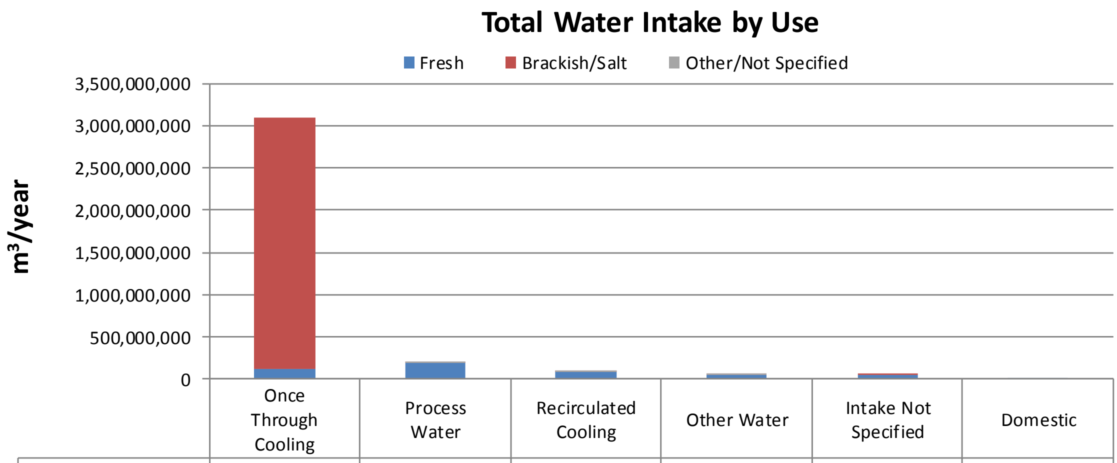
Figure 3 shows simplified diagrams of cooling systems used for the reporting of cooling system type in the 2013 questionnaire. The system types are described in detail in the 2013 Best Available Techniques (BAT) Reference document (BREF) for the Refining of Mineral Oil and Gas (REF BREF) (c.f. Figure 2.10 in chapter 2.8 on Cooling Systems). In the analysis of the survey data “once-through cooling” systems were defined as types A, B (direct, with and without a cooling tower) and C (indirect/secondary). “Recirculating cooling” systems were defined as type D (recirculating), types E, F (wet/dry indirect cooling) and types G, H (open/closed hybrid cooling systems). It should be noted that the correct identification of cooling system type is important to the calculation of freshwater consumption (Section 2.4). This is because cooling intakes associated with once-through system types A, B, C are always excluded from the freshwater consumption totals, whereas intakes associated with types D-H are not.

Figure 3. Simplified diagrams of the cooling systems as described in the REF BREF and used for Concawe 2013 Questionnaire



For the 70 refineries included in the analyses, a total of 3.5 billion m³ (3,485,560,351 m³) of water were withdrawn in 2013 for use in the European refining industry (vs 4.5 billion m³ in 2010 for 100 refineries). As shown in **Figure 4**, the vast majority (86%) of withdrawn water was brackish or saline water used for once-through cooling purposes.

Figure 4. Total water intake by water usage and type



	Once Through Cooling	Process Water	Recirculated Cooling	Other Water	Intake Not Specified	Domestic
Other/Not Specified	-	1,236,331	3,667,711	1,507,140	-	-
Brackish/Salt	2,973,473,989	6,221,311	588,167	6,471,076	1,464,564	-
Fresh	119,833,912	189,434,793	85,848,858	44,863,938	42,131,576	8,816,984

When plotted in the same graph, the high volumes of water used for once-through cooling relative to other intake volumes had the effect of dominating the scale of the graphs and therefore occluding meaningful analyses of other water use types in which contaminants are added and discharged. Therefore, in most subsequent analyses, once-through cooling waters have been removed and, where useful, have been included in stand-alone graphs. **Figure 5** shows the total water intake by usage and type with once-through cooling water removed. Total water intakes by country group without once-through cooling and with only once-through cooling are summarised in **Figure 6** and **Figure 7**, respectively.

As expected, the majority of once-through cooling comes from brackish and saline water sources. As observed on **Figure 6** and **Figure 7**, the Central Europe country grouping utilizes 65% more fresh water than any of the other country groups which was considered to be directly related to the absence of salt/brackish water sources in that region. As shown in **Figure 7**, the Baltic Country group utilizes the most salt/brackish water, with one site representing 91 percent of the total water use. Also apparent from **Figure 7**, is that refineries in the Iberia Country group reported using recirculating but not once-through cooling systems. The higher intake of brackish and saline water in the Mediterranean country group for uses other than once-through cooling was investigated and found to be due to the abstraction of saline groundwater for remediation proposes. This water was not used, but cleaned and discharged back to the sea.

Figure 5. Total water intake by usage and type (once-through cooling volumes have been excluded)

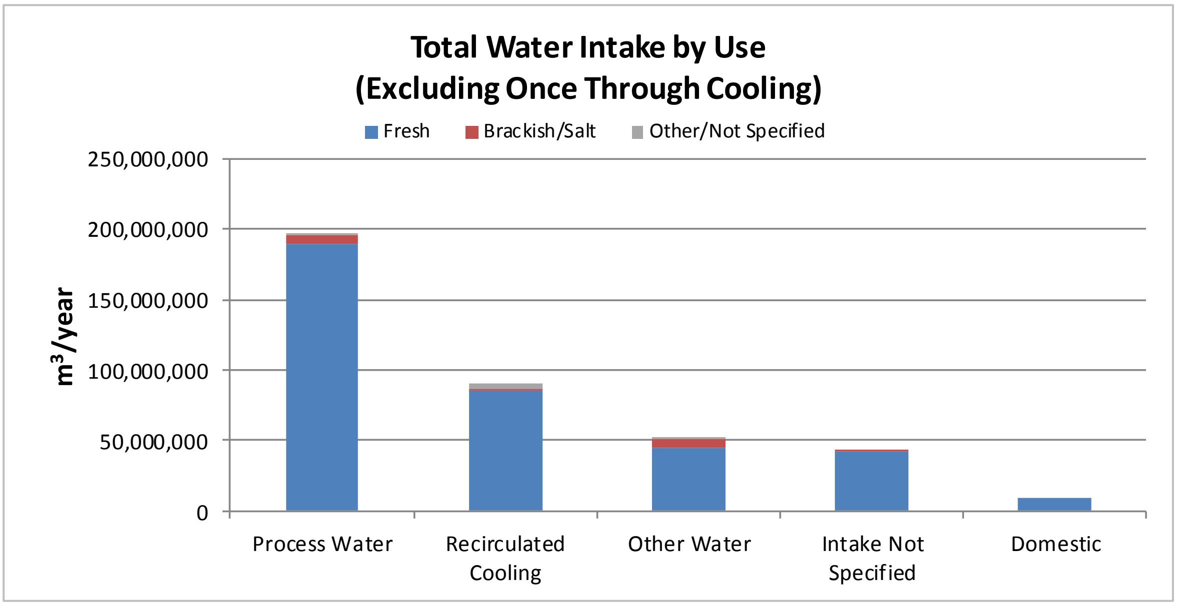
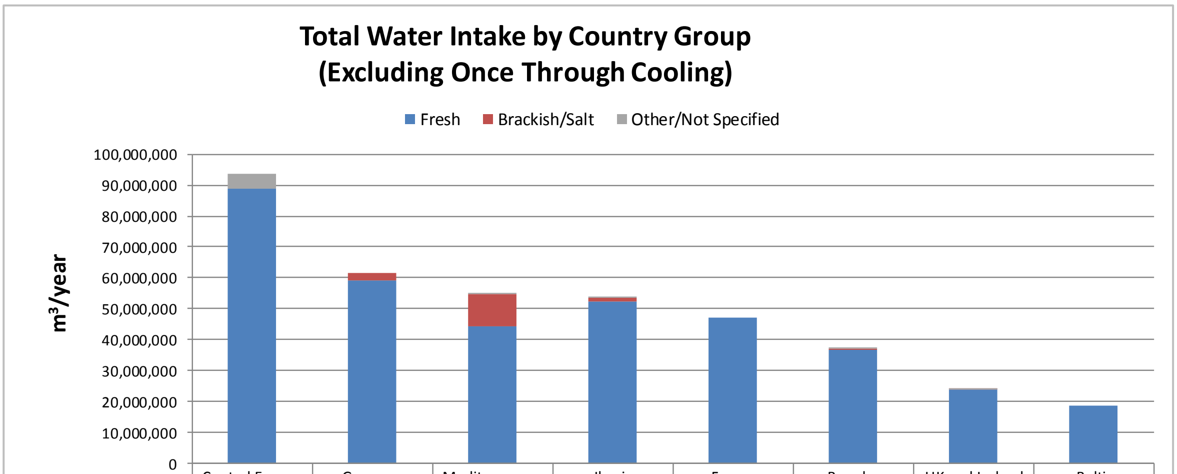
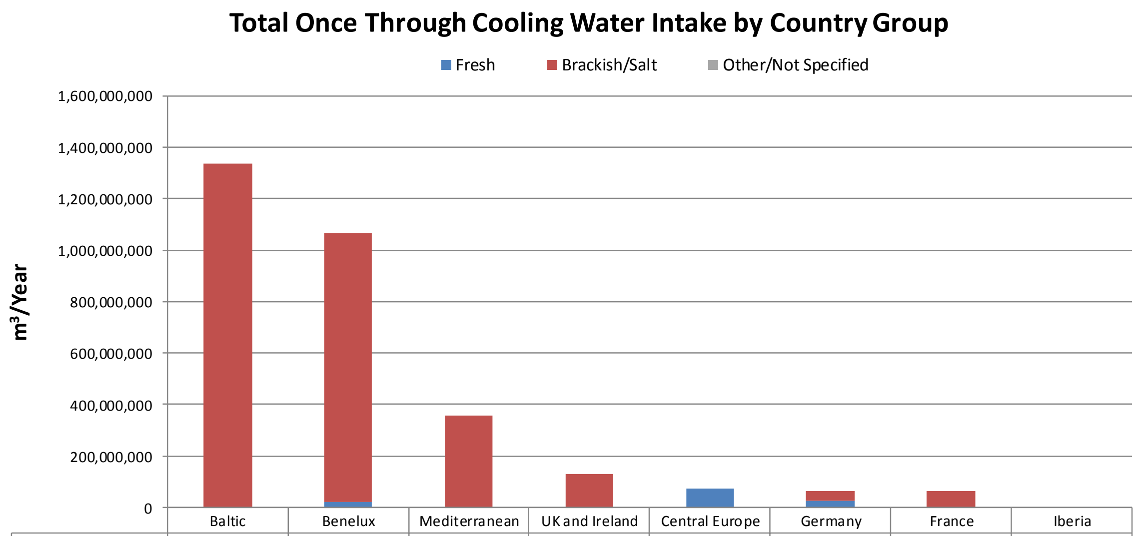


Figure 6. Total water intake by country group (once-through cooling volumes have been excluded)



	Central Europe	Germany	Mediterranean	Iberia	France	Benelux	UK and Ireland	Baltic
Other/Not Specified	4,476,785	-	431,211	417,746	-	385,440	700,000	-
Brackish/Salt	-	2,322,039	10,394,327	1,366,070	-	627,683	35,000	-
Fresh	88,984,299	59,150,554	44,501,119	52,210,887	47,283,425	36,532,632	23,690,076	18,743,158

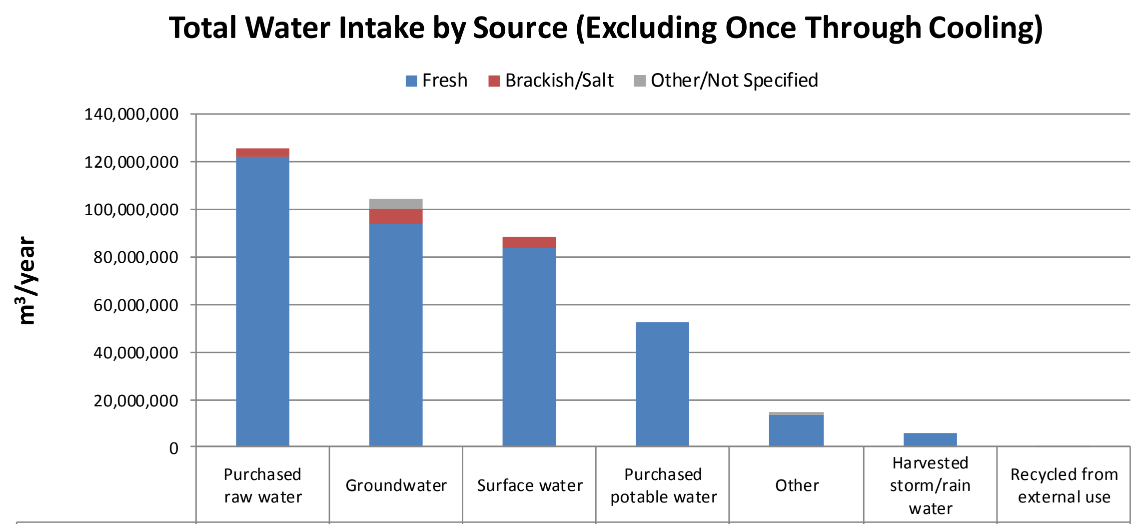
Figure 7. Total intake water used for once-through cooling split by country group



	Baltic	Benelux	Mediterranean	UK and Ireland	Central Europe	Germany	France	Iberia
Other/Not Specified	-	-	-	-	-	-	-	-
Brackish/Salt	1,338,570,321	1,043,805,801	358,485,938	132,500,000	-	38,460,000	61,651,929	-
Fresh	-	22,126,295	-	-	72,168,577	25,539,040	-	-

To fully investigate the water use by the refining industry, it is also imperative to understand the type of sources from which water is being withdrawn. As indicated in **Figure 8**, the majority of water not associated with once-through cooling was derived from purchased water or supplied from groundwater and surface water. When considering all the purchased water categories (purchased raw water, purchased potable, and external utility provider) purchased water accounted for 49% of the total intake volume across Europe. This high reliance on purchased water highlights the vulnerability of refineries on water pricing initiatives. At 27% of the total water intake, groundwater also played a prominent role in the source of intake water. In fact, 27% should be considered the minimum threshold for groundwater use as it is more than likely that water purchased from external sources also were originally derived from groundwater sources.

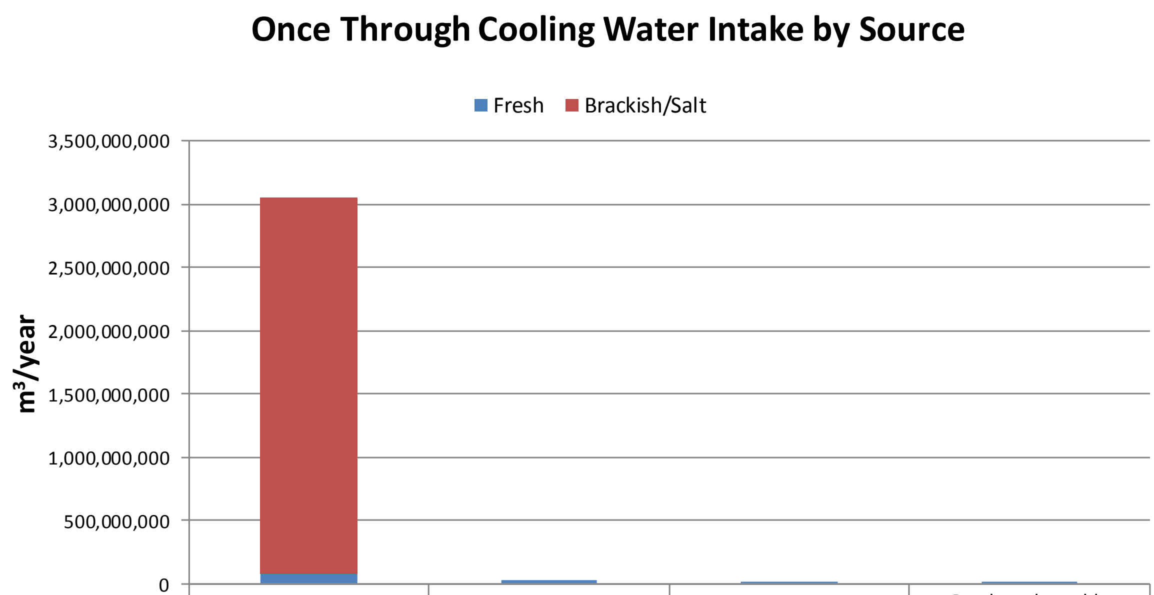
Figure 8. Total water intake by water source (once-through cooling volumes have been excluded)



	Purchased raw water	Groundwater	Surface water	Purchased potable water	Other	Harvested storm/rain water	Recycled from external use
Other/Not Specified	-	4,476,785	-	-	1,516,651	-	417,746
Brackish/Salt	3,869,784	6,221,665	4,653,669	-	-	-	-
Fresh	121,872,221	93,829,100	83,485,376	52,562,272	13,332,987	6,014,193	-

When considering the source of water used in once-through cooling, it was apparent, and expected, that the majority of the water is extracted from brackish and saline surface water sources, as shown in **Figure 9**. A very small amount of fresh groundwater was utilized for once-through cooling purposes. However, these volumes predominantly represent ground water that is pumped for hydraulic control purposes and subsequently routed through the cooling systems.

Figure 9. Once-through cooling water intake by water source



	Surface water	Groundwater	Purchased raw water	Purchased potable water
Brackish/Salt	2,973,473,989	-	-	-
Fresh	78,681,085	31,145,561	10,001,766	5,500

2.2. FRESHWATER INTAKES

The total freshwater withdrawal was 493 million m^3, with 371 million m^3 used for purposes other than once-through cooling. **Figure 10** shows a summary of freshwater intake across each country group excluding once-through cooling whereas **Figure 11** presents the once-through cooling freshwater intake by country group. By way of comparison, the 2010 survey of 100 refineries indicated a total freshwater withdrawal (for purposes other than once-through cooling) of 419 million m^3.

The total freshwater withdrawal was 493 million m^3 (average 7.0 million m^3 per refinery), with 371 million m^3 (average 5.3 million m^3 per refinery) used for purposes other than once-through cooling. By way of comparison, the 2010 survey of 100 refineries indicated a total freshwater withdrawal (for purposes other than once-through cooling) of 4.2 million m^3 per refinery on average. Comparison with 2010 water use data could, however, reflect the different population of refineries reported under the 2010 and 2013 surveys, or differences in the way that the surveys were designed (the 2013 survey captured more detailed information on water uses).

Figure 10. Total fresh water intake by country group (once-through cooling volumes have been excluded)

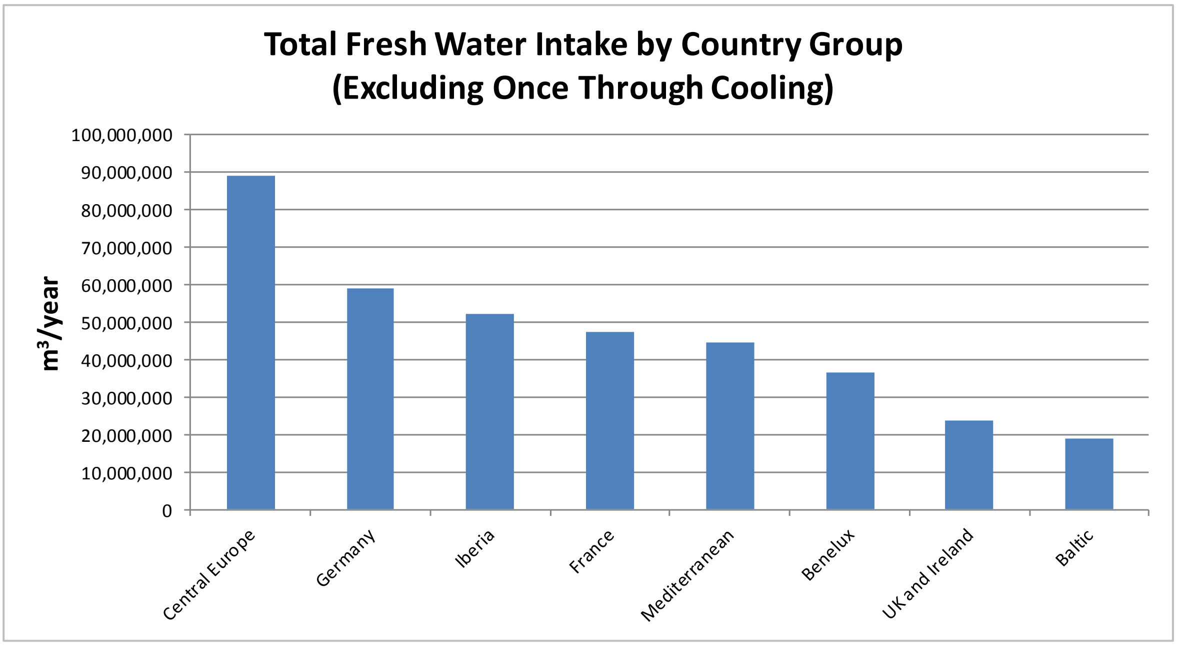
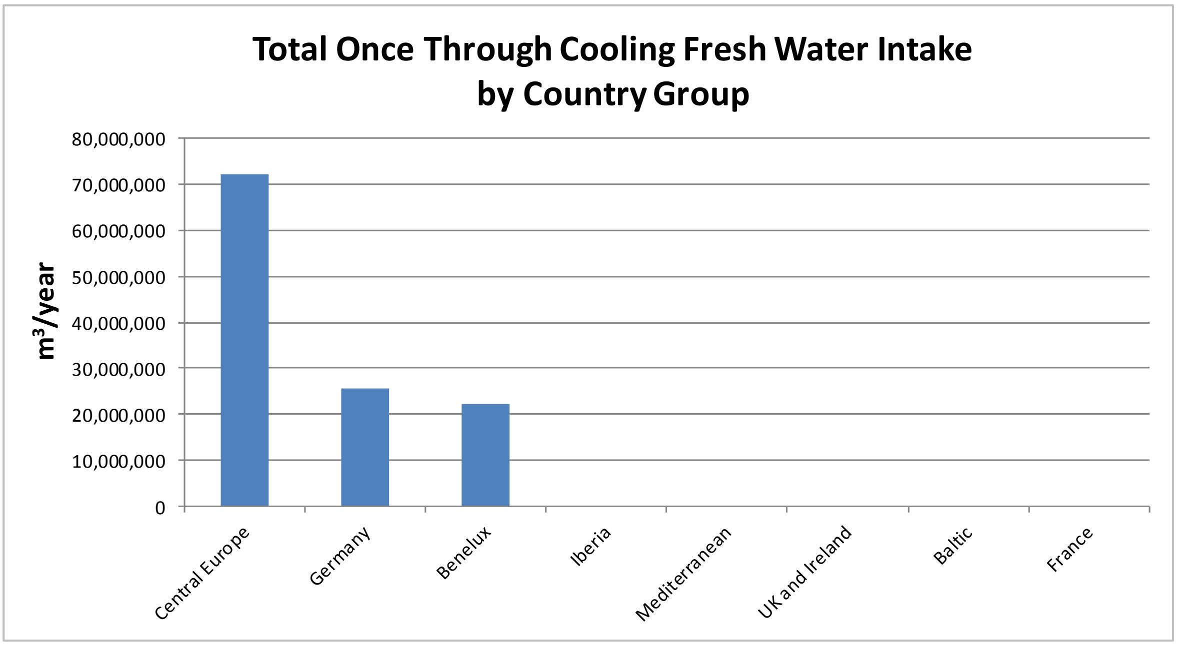


Figure 11. Fresh water intake used for once-through cooling by country group



Of the total fresh water being withdrawn, on average 23% was being utilized for cooling purposes (not including once-through cooling). As shown in **Figure 12** and summarised in **Table 7**, the majority of the fresh water used for cooling (excluding once-through cooling) was derived from purchased raw water, groundwater and surface water.

Figure 12. Fresh water intake by source (once-through cooling volumes have been excluded)

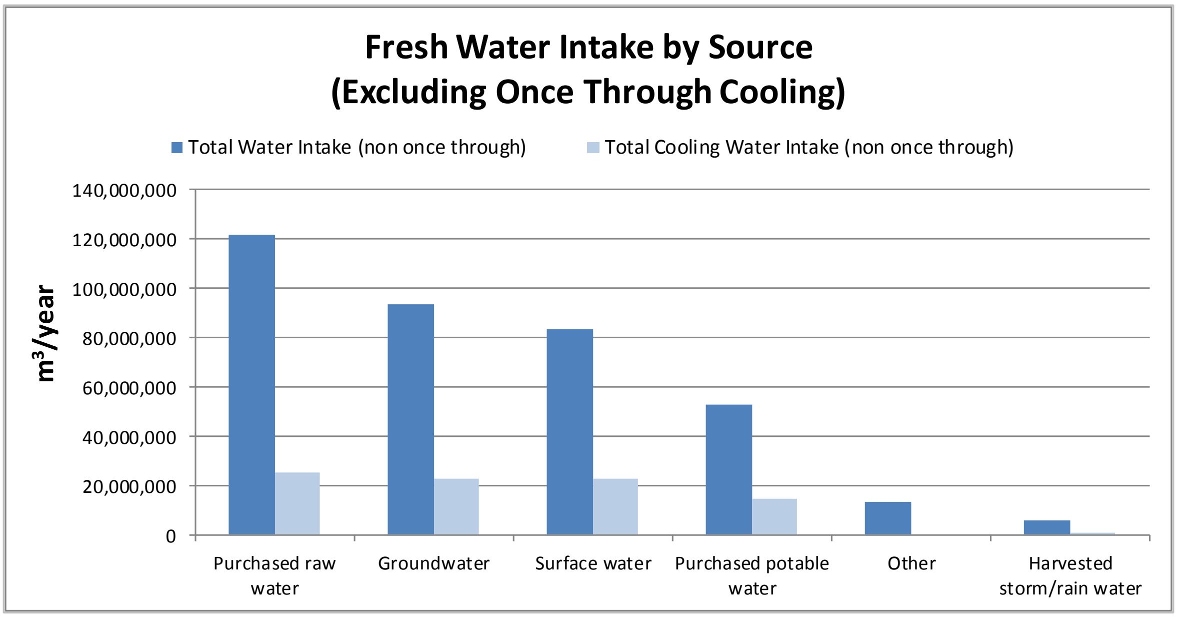


Table 7. Summary of fresh water intake and percentage utilized for cooling purposes. Once-through cooling volumes have been excluded.

Fresh Water Source	Total Fresh Water Intake excluding once-through cooling intake (m^3/year)	Total Cooling Water Intake excluding once-through cooling (m^3/year)	Overall Ratio
Purchased raw water	121,872,221	25,347,484	21%
Groundwater	93,829,100	22,894,558	24%
Surface water	83,485,376	22,539,150	27%
Purchased potable water	52,562,272	14,448,334	27%
Other	13,332,987	0	0%
Harvested storm/rain water	6,014,193	619,332	10%
Total	**371,096,150**	**85,848,858**	**23%**

The percentage of fresh water utilized for non-once-through cooling was calculated separately for each of the 35 refineries which indicated use of fresh water for cooling purposes. The percentages ranged from 15% up to 84% as shown in **Figure 13**. As shown in **Table 8,** the percentage appeared highest in country groups with limited access to brackish/salt water sources such as Germany or Central Europe. Conversely, the percentage is lowest in those regions with relatively easy access to saltwater sources, such as in Baltic or Mediterranean country groups. In addition, low ratios indicated where air-cooling is more predominant, whereas high ratios indicate where once-through cooling is prevalent. These ratios were primarily related to the type of cooling capacity onsite.

Figure 13. Fraction of fresh water utilized for cooling purposes (once-through cooling volumes have been excluded). This graph only shows sites with some fresh water used for cooling purposes. An additional 35 sites with either zero fresh water intake or zero fresh water used for cooling are not included on this graph.

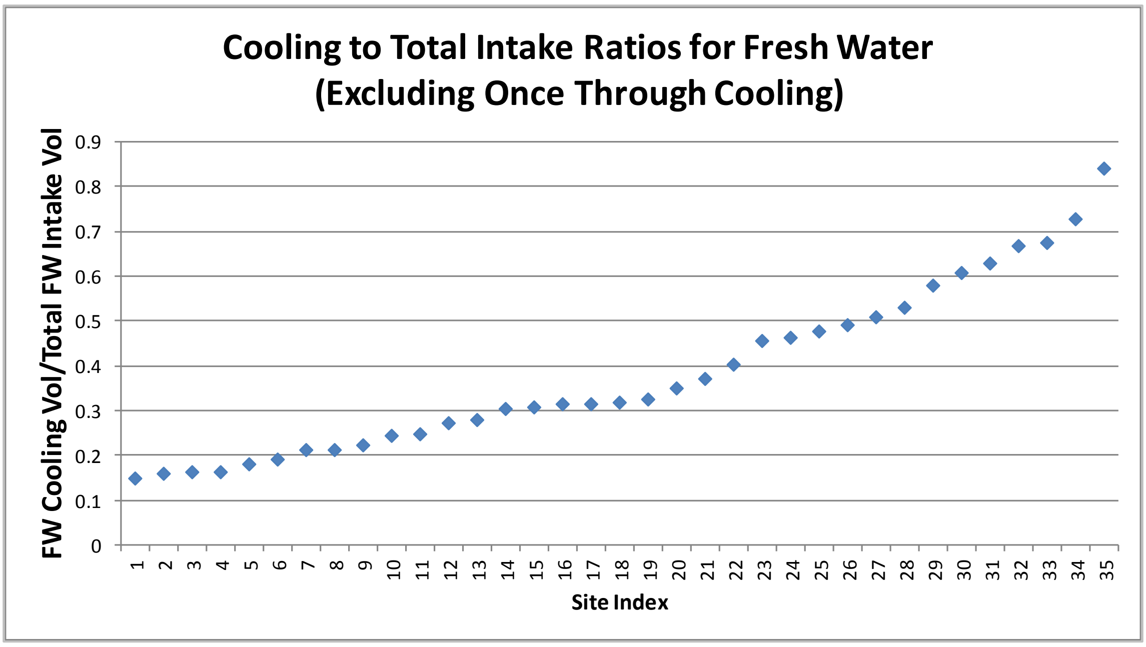


Table 8. Percent of fresh water used for cooling across country groups (once-through cooling volumes have been excluded).

Country Group	Percent fresh water used for cooling excluding once-through cooling
Baltic	0%
Benelux	19%
Central Europe	27%
France	20%
Germany	46%
Iberia	24%
Mediterranean	8%
UK and Ireland	7%

2.3. EFFLUENT DISCHARGE VOLUME

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 brief summary of water treatment types are also covered. With respect to refinery effluent volume, Concawe has been collecting data from their membership regularly since 1969, and refinery effluent discharge volume data for these survey years are summarised in **Table 9**. The results from these surveys indicate that refinery effluent discharges has been significantly reduced throughout the years. Comparing 2010 to 2013, the potentially most meaningful indicator is the m^3 of effluent per tonne of capacity or throughput. It indicated that the discharge quantities had decreased from 2010 to 2013 with regard to process water (from 0.56 to 0.47 m^3/tonne capacity and from 0.67 to 0.48 m^3/tonne throughput, respectively) and with regard to all reported discharges (from 1.9 to 0.92 m^3/tonne capacity and from 2.2 to 0.93 m^3/tonne throughput, respectively) excluding once-through cooling water.

Table 9. Effluent discharge data from 1969 to 2013

Year of survey	Number of reporting refineries	Total aqueous effluent[1] (million m^3/year)	Aqueous effluent (m^3/tonne capacity)	Aqueous effluent (m^3/tonne throughput)
1969	80	3,119	8.0	n.d.
1974	108	3,460	4.7	n.d.
1978	111	2,938	3.9	5.4
1981	104	2,395	3.4	5.4
1984	85	1,934	3.2	4.6
1987	89	1,750	3.0	3.9
1990	95	1,782	3.1	3.5
1993	95	2,670	4.3	4.8
1997	105	2,942	4.4	4.7
2000	84	2,543	4.5	4.9
2005	96	790	1.1	1.2
2008	125	612 (1,112)	0.73 (1.3)	0.82 (1.5)
2010	100	405[2] (1,583)	0.56 (2.2)	0.67 (2.6)
2013	79	238[3] (465)	0.47 (0.92)	0.48 (0.93)

[1]Until 2000 the total aqueous effluent in the table refers to the sum of process effluents, cooling water and other flows such as lightly contaminated rain water. For the 2008, 2010 and 2013 surveys, there is the distinction between treated process water and other streams that are discharged at the same or separate emission points. The values between brackets are based upon the sum of all reported discharges, excluding once-through cooling water.

[2]In the effluent database there are reports that only consider treated process water (241 Mm^3) and reports on other water (328 Mm^3) that is treated before discharge or transfer. From the notes provided by the survey respondents it is evident that these other waters are mixes of process, cooling and storm water. For this report is has been assumed that 50 % of these effluent comprise of process water.

[3]In the effluent database there are reports that only consider treated process water (170 Mm^3) and reports on other water (136 Mm^3) that is treated before discharge or transfer. From the notes provided by the survey respondents it is evident that these other waters are mixes of process, cooling and storm water. For this report is has been assumed that 50 % of these effluent comprise of process water.

[4]Error in 2010 survey report.

Figure 14 presents a summary of effluent quantities by discharge type and partitioned by receiving environment (fresh, salt/brackish, other/not specified). A limited number of refineries contributed to the high volume of untreated cooling water returned to the environment. These refineries are all plants adjacent to an ocean shore and are equipped with a once-through cooling system that discharges either in harbours or directly in the marine environment.

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

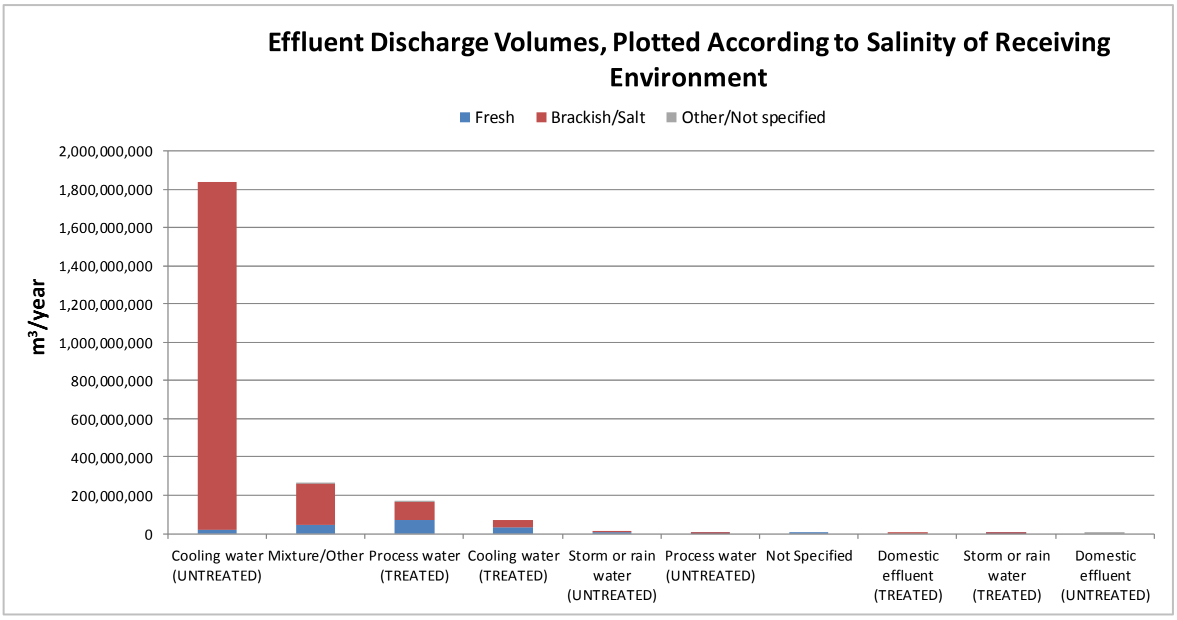


Figure 15 shows water effluent quantities by discharge type excluding discharges into brackish/salt water environments to allow the freshwater discharge environments to be scaled for readability. Untreated cooling water accounted for 78% of all water effluent types of which the majority of untreated cooling water was discharged into brackish/salt water environments. Other primary discharge types included mixed/other, treated process water, and treated cooling water. Freshwater receiving environments constituted an overall smaller percentage of total discharge within each respective type. Treated process water accounted for nearly half of the total water effluent discharges into freshwater receiving environments. Treated process water had the largest volume of both freshwater and other receiving environments at ~71,000,000 m^3/year and 5,000,000 m^3/year, respectively. This was followed in magnitude by Mixture/Other (~48,000,000 m^3/year), and treated cooling water (~33,000,000 m^3/year).

Figure 15. Annual effluent discharge volumes excluding discharge to salt/brackish receiving environments. Values include once-through cooling volumes.

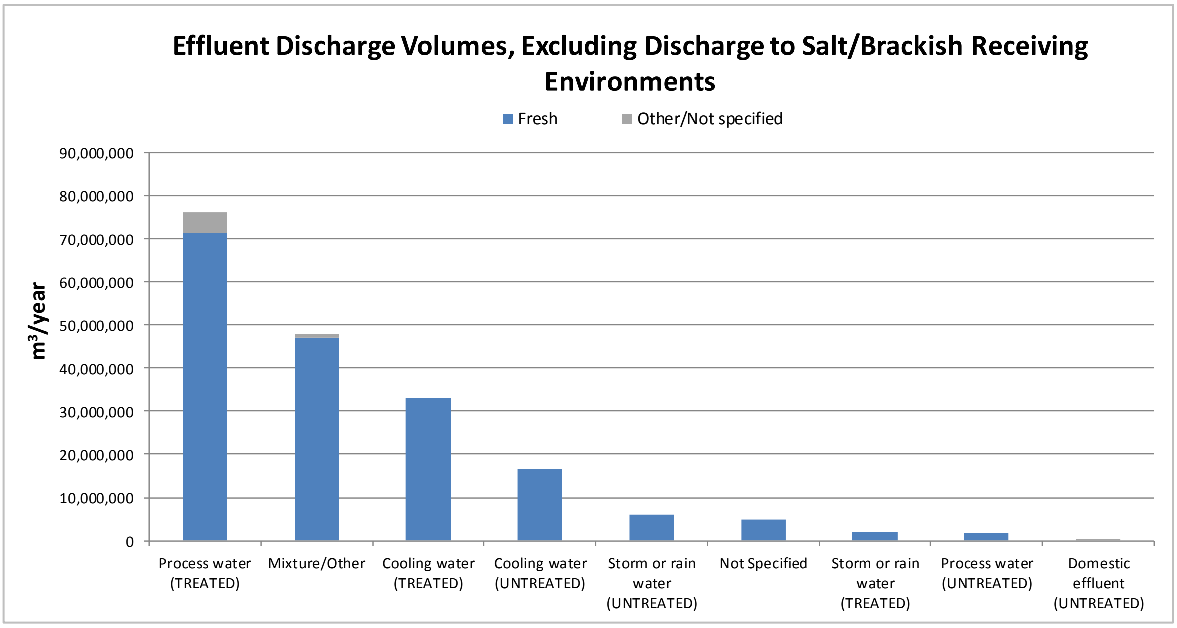


Figure 16 shows effluent quantities by discharge type and partitioned by receiving environment (fresh, salt/brackish, other/not specified), excluding once-through cooling volumes. Mixture/Other represented the largest grouping based on discharge type. The mixture/other discharge type encompasses flood control, remediation as well as other mixtures of plant cooling waters. Treated process water constituted the second largest discharge type, followed by untreated storm or rain water and untreated process water. Brackish/salt water was the majority receiving category for discharge types with the exception of not specified, treated cooling water, and untreated domestic effluent. Fresh water accounted for a larger percentage of total receiving environments (28%) with the removal of once-through volume, compared to water effluent streams that include once-through volume (8%).

Figure 17 presents the descending rank order of sites for the effluent quantities by receiving water types (fresh, brackish, other/not specified) excluding once-through cooling volumes.

Figure 16. Annual effluent discharge volumes, plotted according to salinity of receiving environment. Values exclude once-through cooling volumes

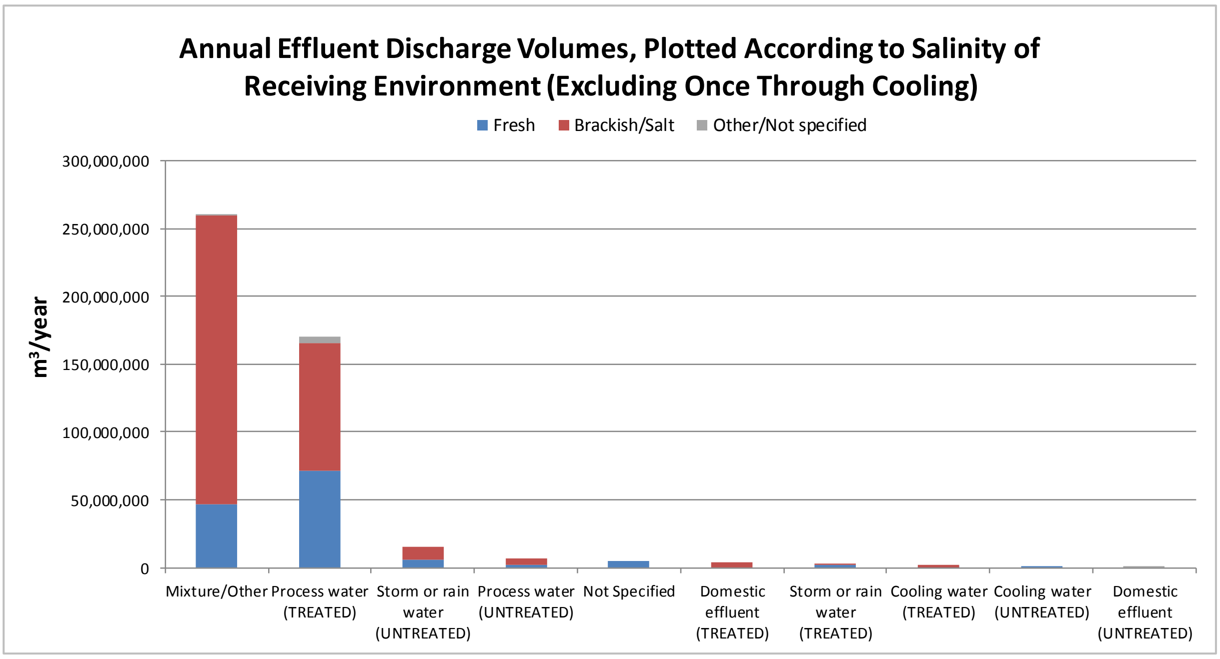


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Figure 17. Annual effluent discharge volumes according to salinity of receiving environment, plotted by site in rank order (excluding once-through cooling).

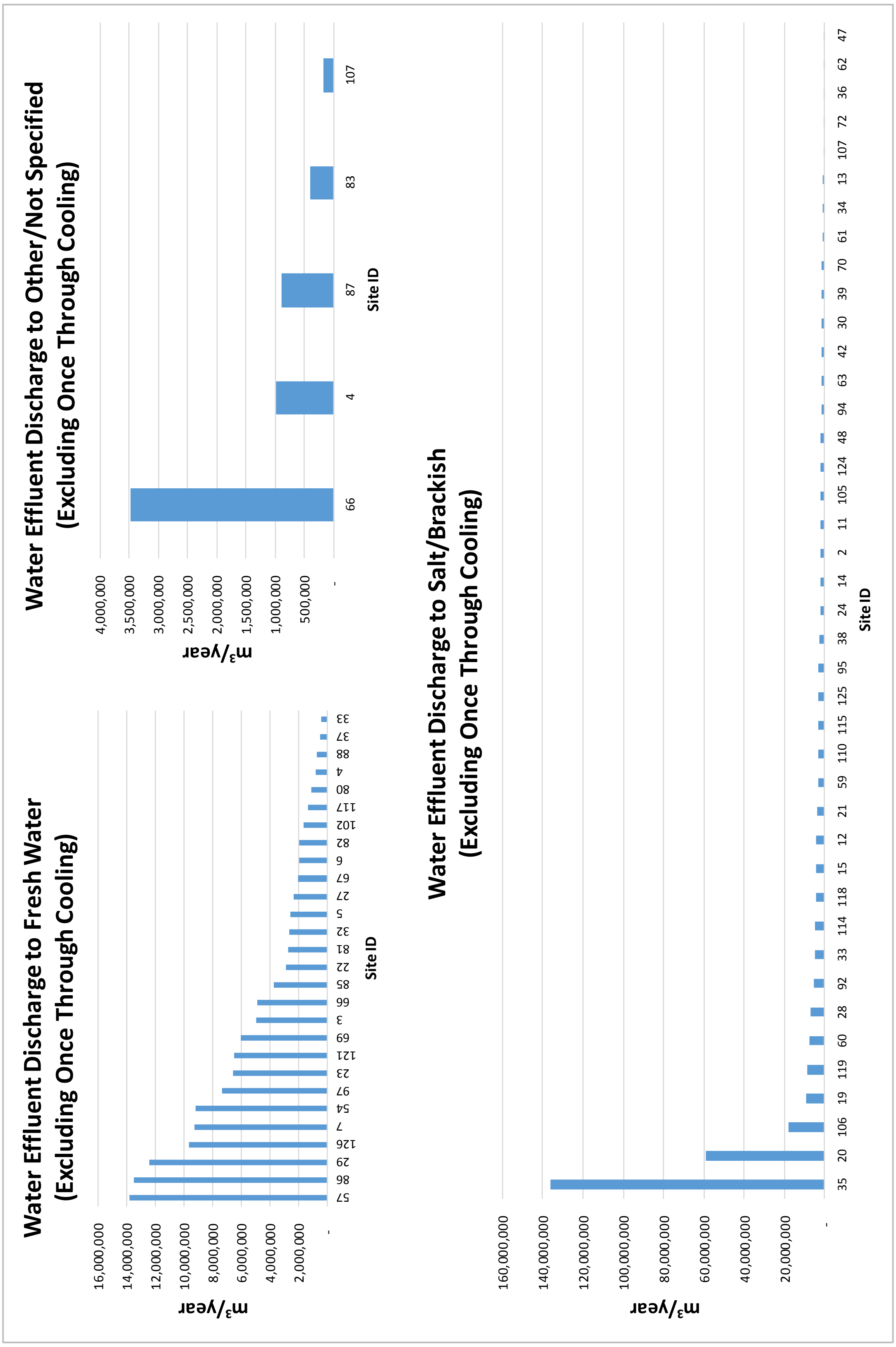
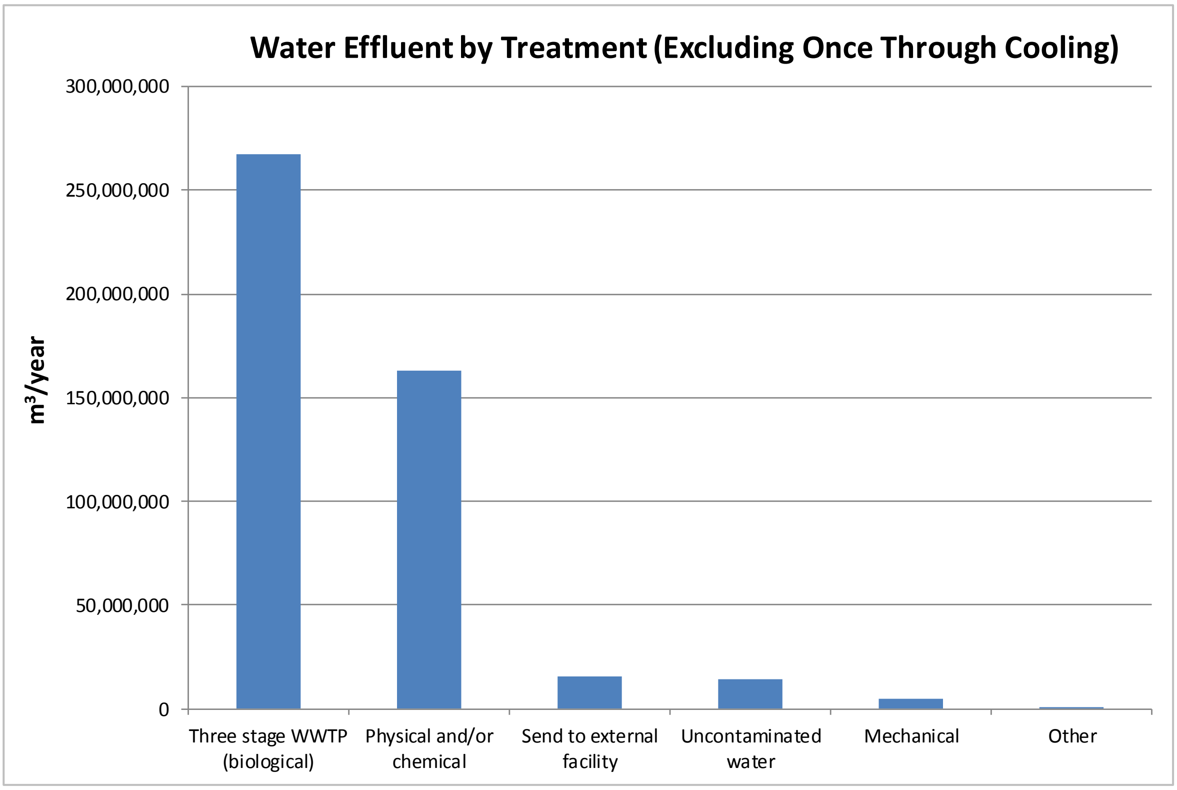


Figure 18 shows water effluent quantities with respect to treatment types, excluding once-through volumes. Three-stage biological (primary separation, biological treatment and secondary separation) waste water treatment plant (WWTP) was the most commonly used treatment type, and comprised of over 270,000,000 m^3/year and over half (58%) of water effluent volume across all treatment types. Physical (e.g. oil-water separation or settling) and/or chemical (e.g. chemical precipitation) installation was the second most common treatment type, with over 159,000,000 m^3/year and 34% of total water effluent volume. Less abundant treatment types included external facility transfer (3.4%), uncontaminated water not requiring treatment (3.1%), and mechanical (e.g. filtration or centrifugation; 1%). It should be noted that the effluent volumes plotted in **Figure 18** comprise wastewaters with variable treatment requirements, including process effluents and less contaminated waters (e.g. rainwater water runoff).

With regard to process effluents, over 91% of the reporting refineries in 2013 applied three-stage biological waste water treatment, or transferred their process water effluent to an external facility applying three-stage biological waste water treatment. Assuming that the refineries which reported using three-stage biological waste water treatment on their process water in 2010 continued to do so in 2013, the total percentage of refineries utilizing three-stage biological waste water treatment on their process water is over 97%. This clearly illustrates that the vast majority of the reporting refineries utilize the REF BREF and its BAT for treatment of process water effluents.

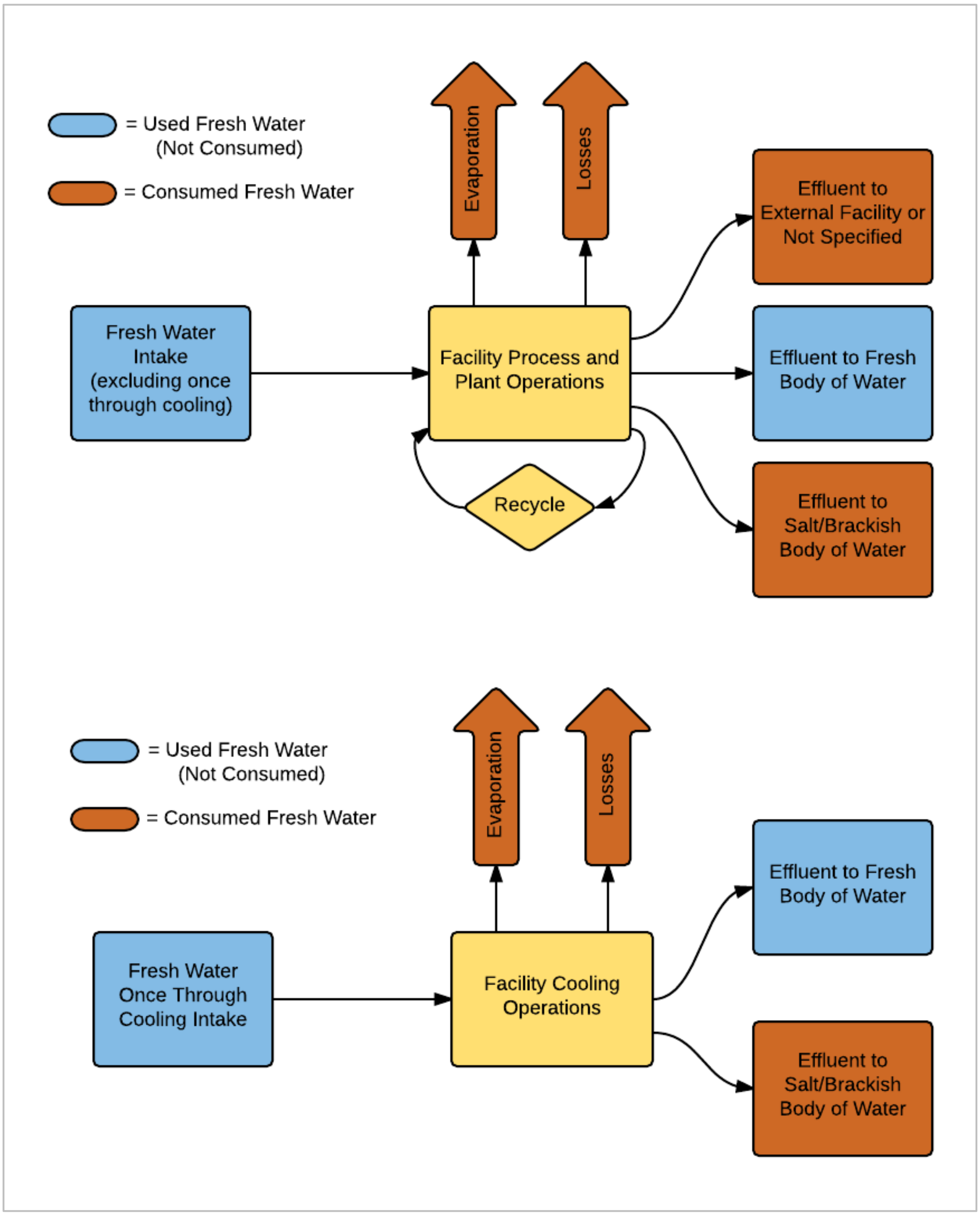
Figure 18. Water effluent by treatment (once-through cooling volumes have been excluded)



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 19.**

Figure 19. 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 E6 (IPIECA, API and IOGP, 2015). 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. In the calculations, evaporation and losses were estimated using the difference between intake and 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:

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

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 these are:

- 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);
- Harvested storm water that is not used for process or cooling purposes. In some cases, storm water was mixed in a combined effluent stream without adequate information to separate individual volumes. When storm water could not be adequately removed from the effluent volumes, the harvested rain/storm water intake was included in the freshwater calculations to offset the artificially high effluent volumes being discharged to freshwater bodies; and
- Fresh groundwater extracted solely for flood control, hydraulic control, or remediation.

In some cases, fresh intake water was discharged to an external facility for treatment (waste water treatment plant) or reuse (recycling). Based on available data, it was unknown if these latter facilities ultimately discharged the water to fresh or salt/brackish water bodies. Therefore, to provide a conservative estimate of the fresh water being consumed, water effluents that were sent to external facilities and who's receiving water type not specified were assumed to ultimately be discharged to salt/brackish water. Refinements to future questionnaires can further define transfer discharges to reduce this uncertainty in calculation of freshwater consumption.

There were nine refineries whose questionnaire responses did not allow for adequate water mass balance computations. These were typically caused by lack of data associated with once-through cooling water. As such it was unclear if the water balance discrepancy was caused by water intake volumes containing once-through cooling but effluent volumes did not, or vice versa. In addition, some sites had much larger effluent volumes than intake volumes; however, there was no indication of external rain/storm water in effluent volumes. In order to minimize the inclusion of potentially skewed data, these sites were removed from the freshwater consumption calculations. Refinement of questionnaire content in future surveys can reduce these circumstances

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. These scenarios were most often a direct result of storm/rain water being included in effluent volumes but not in intake volumes, which can be clarified in future surveys. To be able to make historical comparison with the 2010 survey data, the same conventions was also made to the 2010 data.

2.4.1. Statistical analysis of 2013 freshwater consumption

The industry-wide freshwater consumption aggregated from all considered sites was calculated to be 271 million m^3, as summarised in **Table 7**. **Figure 20** presents the freshwater consumption aggregated by country group whereas **Figure 21** presents the same on relative to throughput. Average relative values were calculated using only sites that also provided throughput metrics and are weighted by throughput mass. **Figure 22** presents the freshwater consumption aggregated by refinery complexity and **Figure 23** presents the freshwater consumption on a relative basis. **Figure 24** presents the consumption of fresh water per site in rank order. Given that it was possible to calculate freshwater consumption from 70 refineries, the average consumption of fresh water per refinery site was 3.9 million m^3 per year. **Figure 25** presents the relative freshwater consumption to throughput per each site.

Table 10. Summary of industry-wide refinery fresh water consumption

Fresh water Effluent to Brackish/Salt Water Body	**Fresh Water Evaporation and Losses**	**Fresh Water Once-through Discharged to Brackish/Salt Water Body**
(m^3/year)	**(m^3/year)**	**(m^3/year)**
105,734,421	143,065,123	22,126,295
	TOTAL	**270,925,839**

Figure 21 and **Figure 23** indicate that relative freshwater consumption varied two-fold by country group and four-fold by complexity group, respectively, and that freshwater consumption generally increases with refinery complexity (conversion capacity), which was consistent with expectation. Nevertheless, **Figure 25** shows that, outside of a handful of high values, the relative freshwater consumption was rather consistent across refineries with a weighted average relative consumption of 598 m^3 of fresh water consumed per kilotonne of throughput. Variability in freshwater consumption appears less for refineries reporting a throughput of greater than 4000 kilotonne/year, which may reflect an averaging-out of performance variation between the individual production units at larger refineries.

The sites with the highest relative freshwater consumption values (indicated on **Figure 25** with ***1**, ***2**, ***3, *4,** and ***5**, respectively) were further researched to determine if these sites were candidates for possible exclusion from the dataset or if differences are attributable to other factors which justify inclusion in the population. The site associated with the highest potential outlier (***1**) utilizes fresh surface water for once-through cooling which is subsequently discharged to a brackish environment. If this once-through cooling stream were routed to a freshwater environment, the freshwater consumption for this site would drop to a value slightly larger than the industry average. The site with the second highest freshwater consumption (***2**) sends their effluent to a third party WWTP for treatment. Since the receiving water type of the WWTP is not specified, the conservative approach is utilized where all the effluent water volumes are assumed to ultimately be discharged to salt/brackish water. Refinements to future questionnaires can further define transfer discharges to reduce this uncertainty in calculation of freshwater consumption. The site with the third highest freshwater consumption (***3**) utilizes groundwater being extracted for hydraulic control as a source of once-through cooling water. It is unclear if this volume is also reflected in the site's reported effluent volumes. If it is not, then this may be causing increased consumption calculations. However, no follow-up was received by the site and therefore there is insufficient data to determine if this outlier is erroneous or not. The next two potential outliers (***4** and ***5**) are both confirmed to be valid results. In both cases, the sites noted significant reduction on the order of greater than 50% of throughput as compared to 2010 results. The lower throughput in these cases created an increased relative consumption rate as evidenced in **Figure 25**. In addition, an industry-wide analysis was conducted on sites that reported in both the 2010 and 2013 survey to determine if throughput values had changed considerably between the two datasets and thereby potentially causing a bias on the freshwater consumption calculations. While some sites did reduce their throughput significantly (as noted above) there were also an equal number of sites that increased their throughputs during the same time period. Over all the sites compared, there was an average decrease in throughput of only 0.9%, indicating a balanced data set.

Figure 20. Freshwater consumption by country group

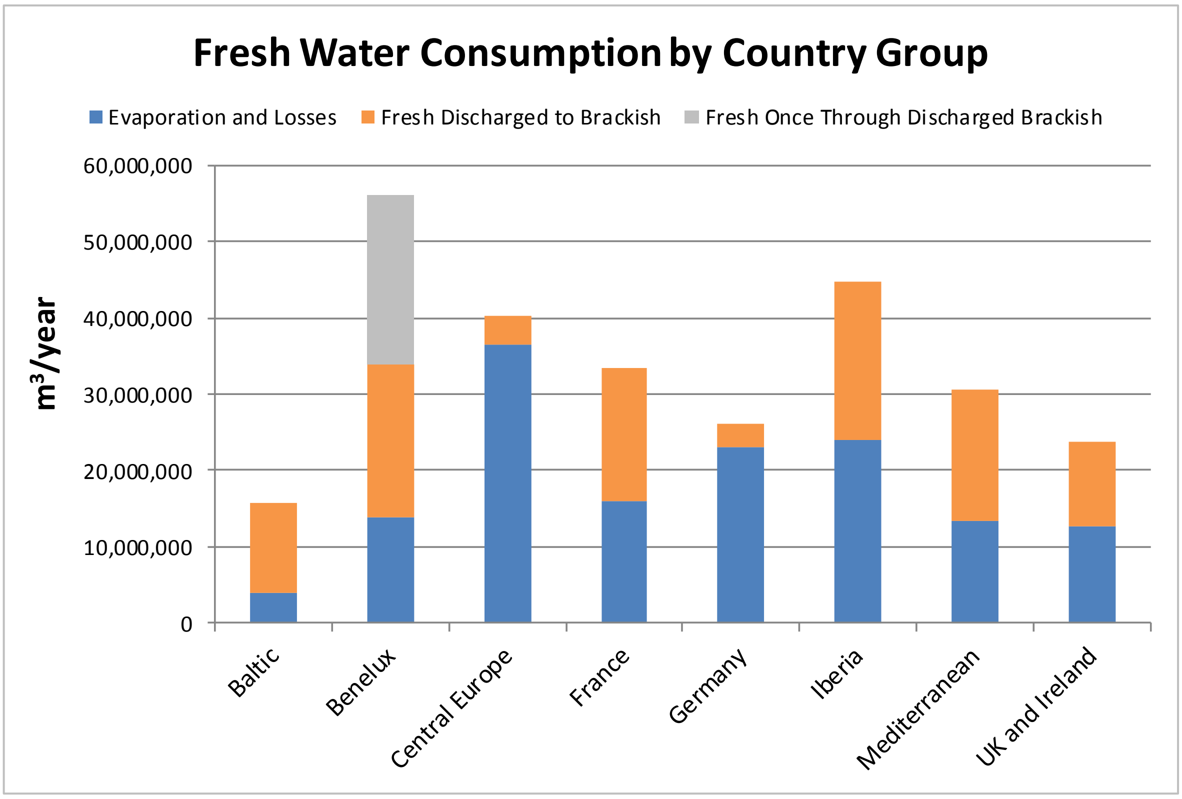


Figure 21. Average relative freshwater consumption by country group

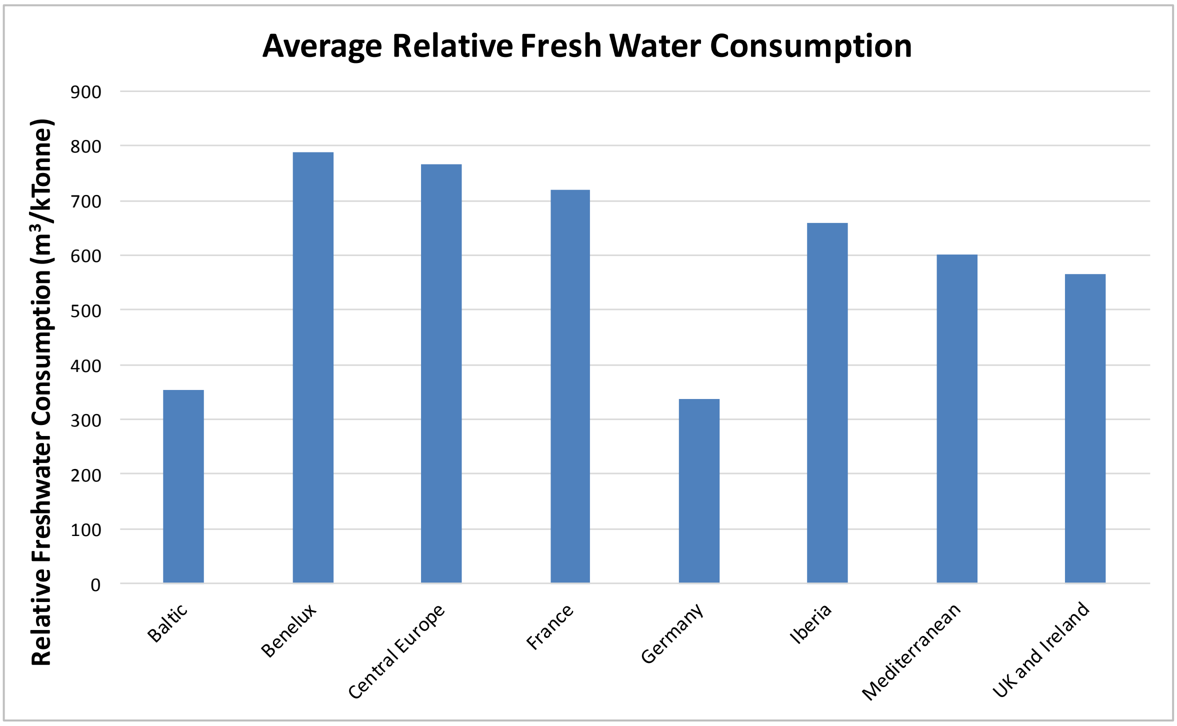


Figure 22. Freshwater consumption by complexity group

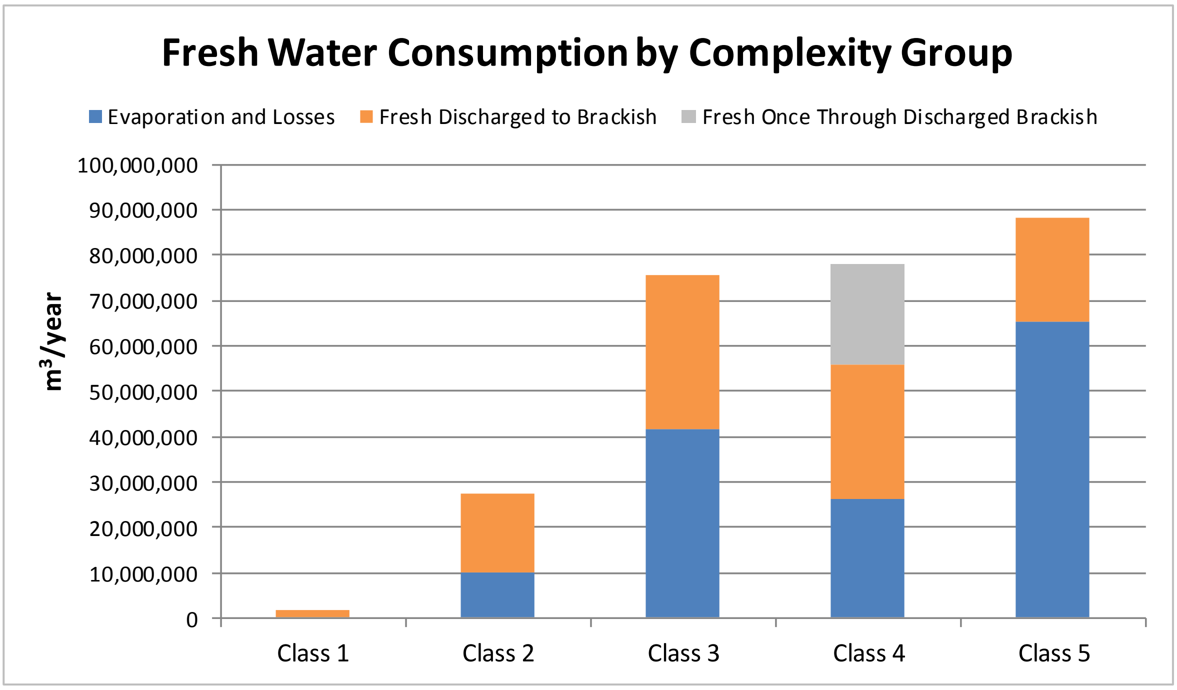


Figure 23. Average relative freshwater consumption by complexity group

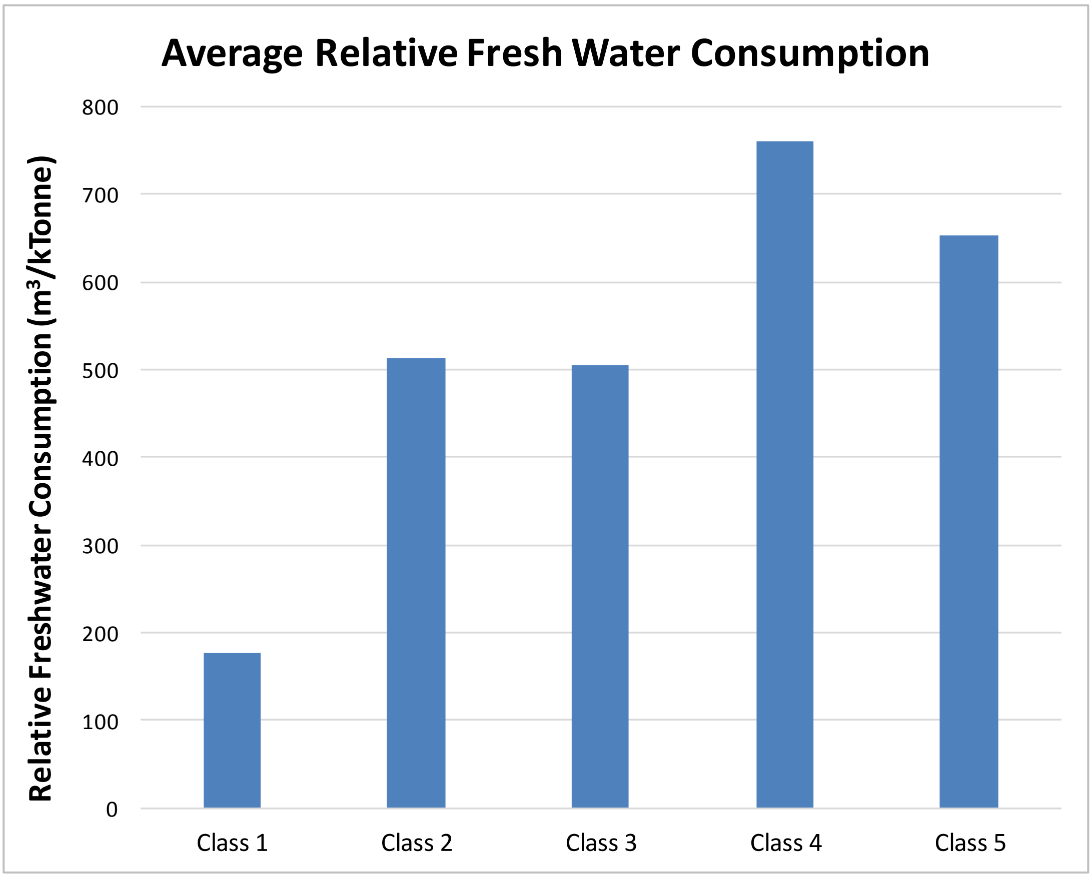


Figure 24. Freshwater consumption per site in rank order

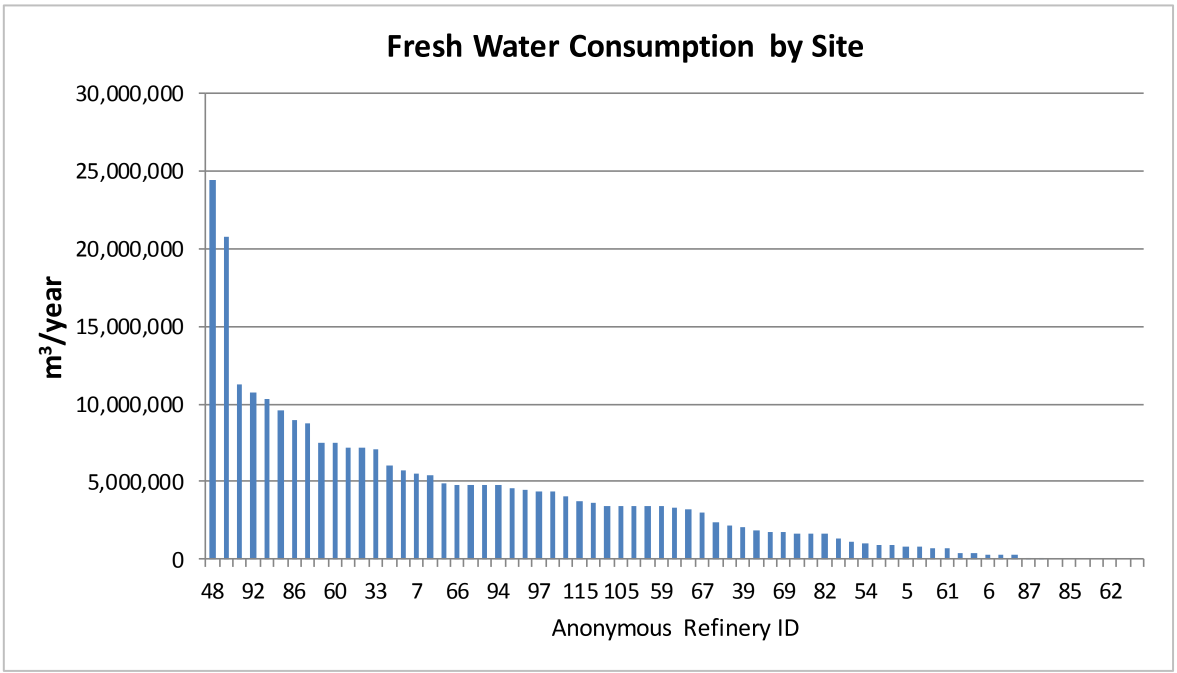
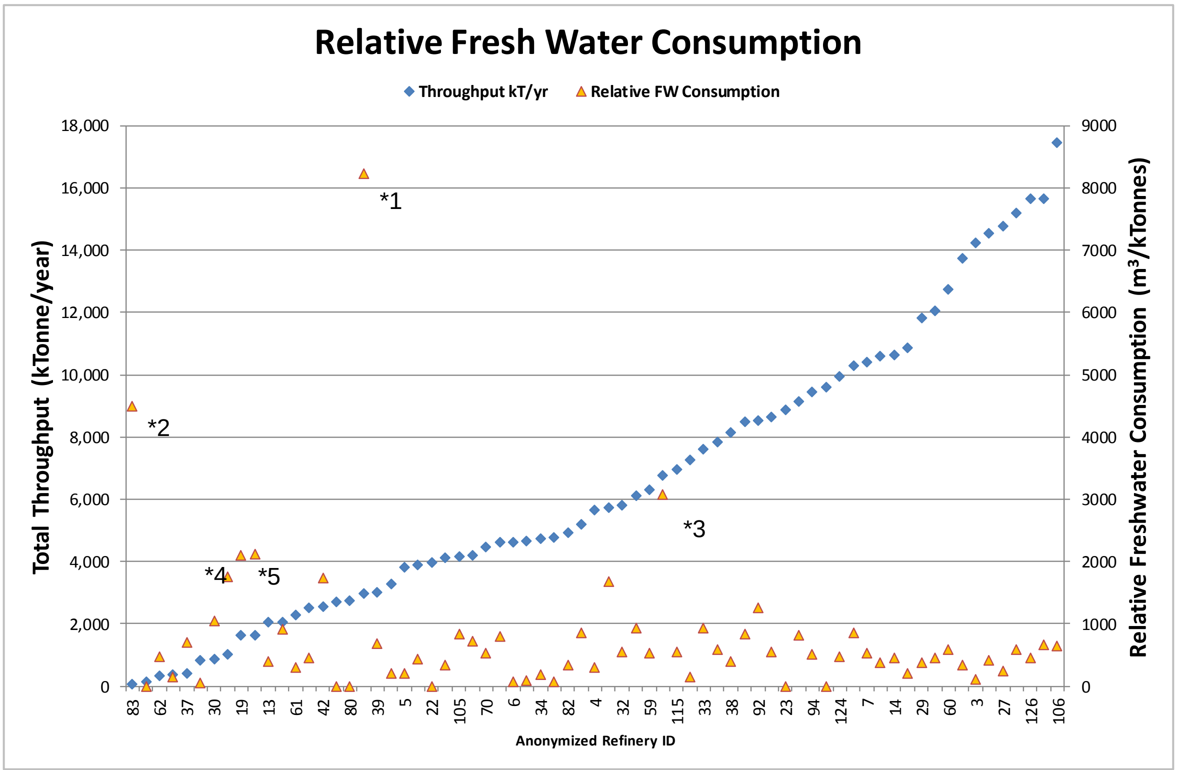


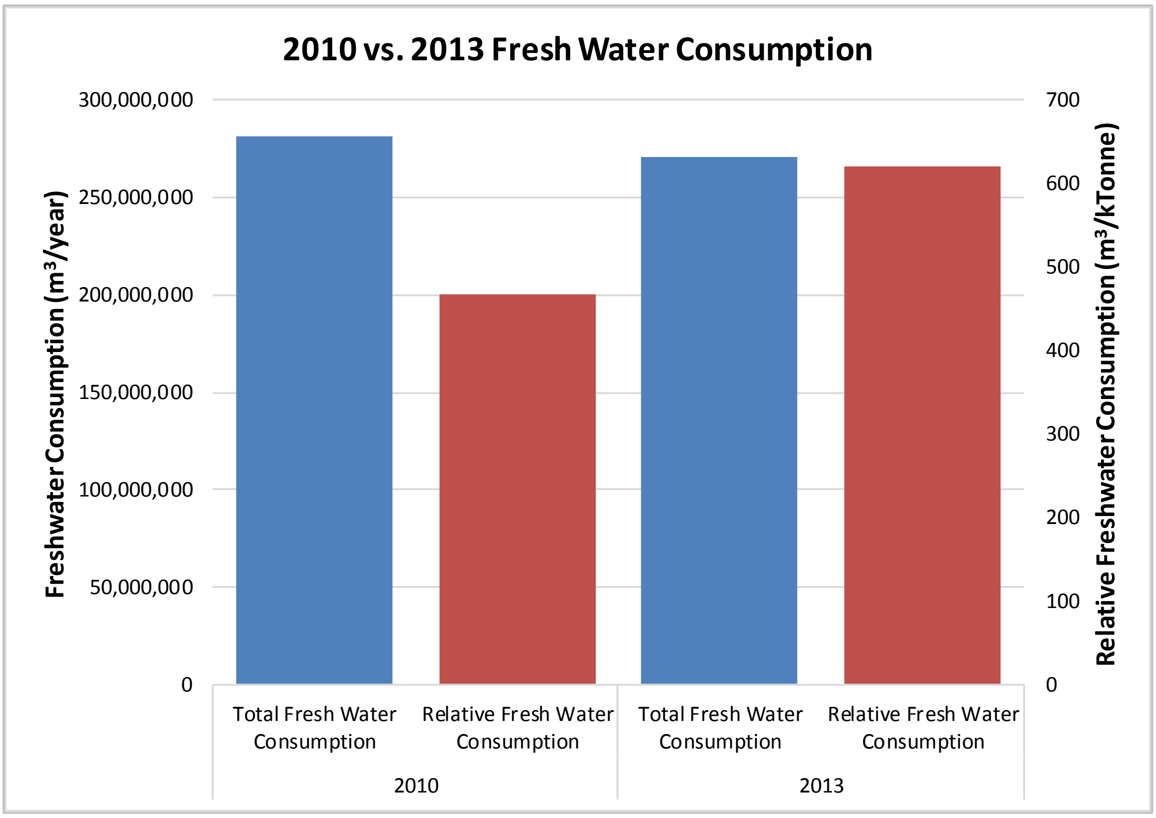
Figure 25. Freshwater consumption by refinery relative to total throughput



2.4.2. Comparison of 2010 and 2013 freshwater consumption data

When applying the same data analysis conventions to the 2010 data as applied to the 2013 survey data, the 2010 total freshwater consumption was 282 million m^3 which is slightly higher than the total freshwater consumption for 2013 (271 million m^3). The relative freshwater consumption was 467 m^3/kilotonne throughput in 2010 vs. 621 m^3/kilotonne throughput in 2013 (**Figure 26**). However, given the larger size of the 2010 dataset (100 vs 70 sites in 2013) the 2010 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 2010 to 2013).

Figure 26. Total and relative freshwater consumption for 2010 and 2013, respectively



2.5. WATER COSTS

A new addition to the 2013 survey questionnaire included a section pertaining to the costs of water. In particular, respondents were asked to provide the total annual cost related to water intake, water recycling, waste-water treatment, cooling water treatment, boiler water treatment, discharge costs and any other operational costs related to the water supply. Box plots of costs for each category are shown in **Figure 28**, whereas **Figure 27** shows the definition of box plot components.

It should be noted that because sites were not asked to specify what was included in the costs, the data from different refineries may not be comparable. For example, some sites may have also included capital expenditure (CAPEX) costs. In addition, it appears that some respondents may have combined costs associated with waste water treatment and discharge, whereas others reported these separately. Only a small number respondents specified what was included in their discharge costs; in most of those cases it was discharge tax, but in one case it was external water analyses. For the calculation of relative water treatment costs (i.e. €/m^3) it was assumed that the reported costs referred to effluent sent to: external facilities; three stage WWTP (biological); physical, and/or chemical treatment and mechanical treatment. For the calculation of relative water discharge costs all effluent streams were taken into account. An opportunity for improvement in future surveys would be to make the dataset more consistent by specifying what should be included in the reported costs.

Figure 27. Definition of box plot components

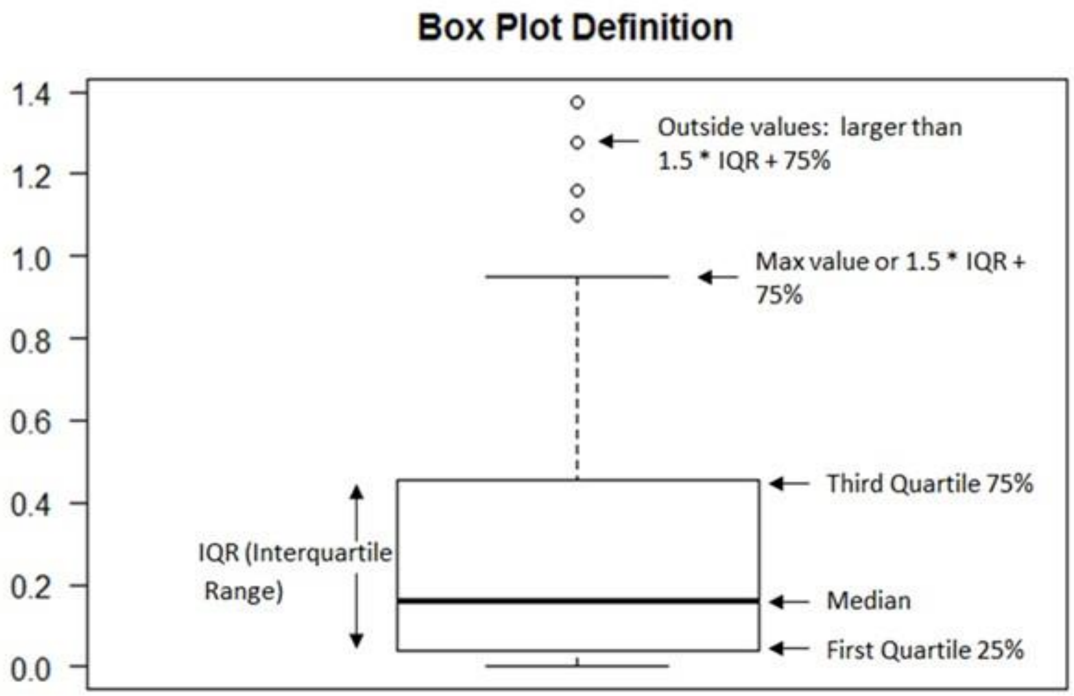
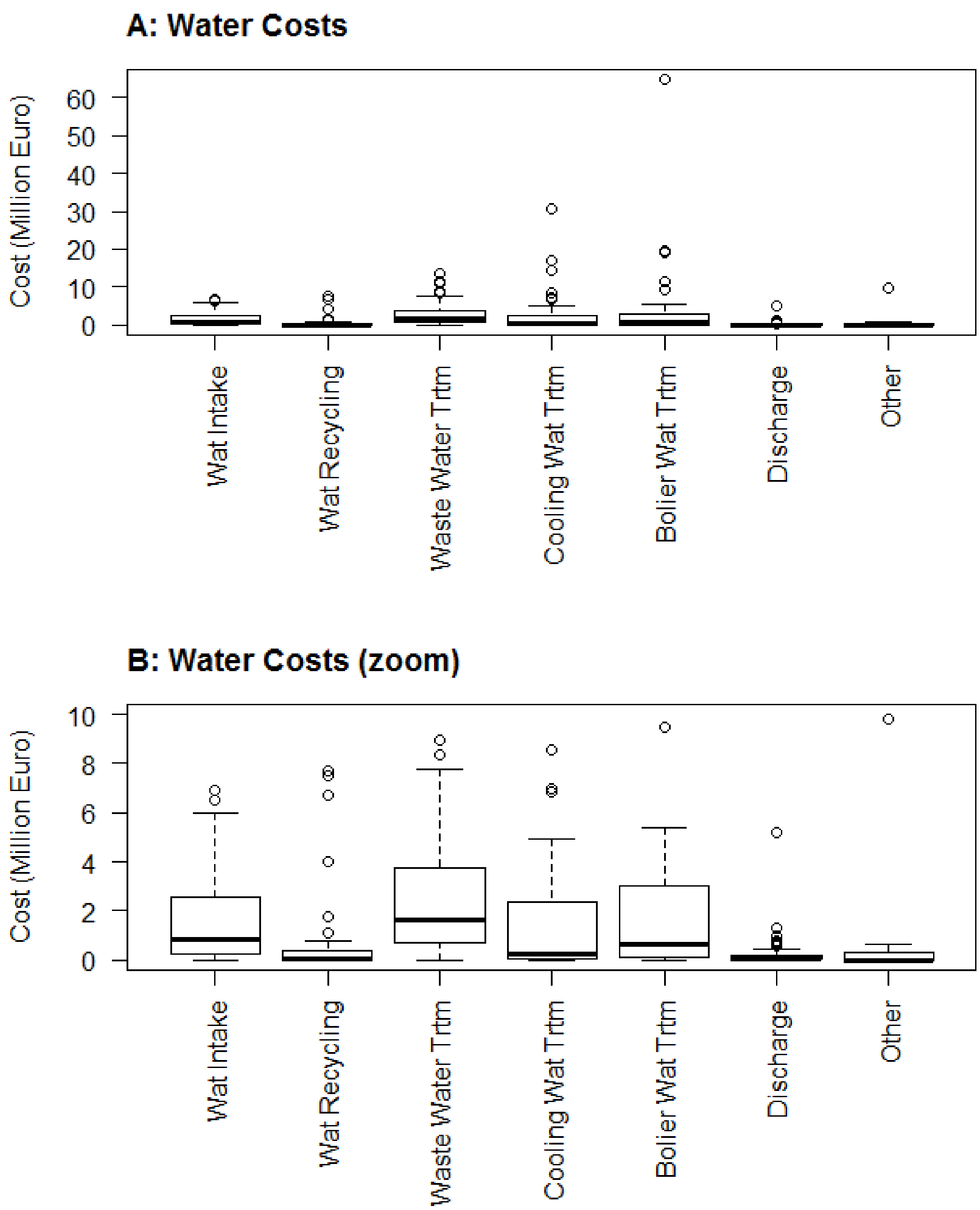


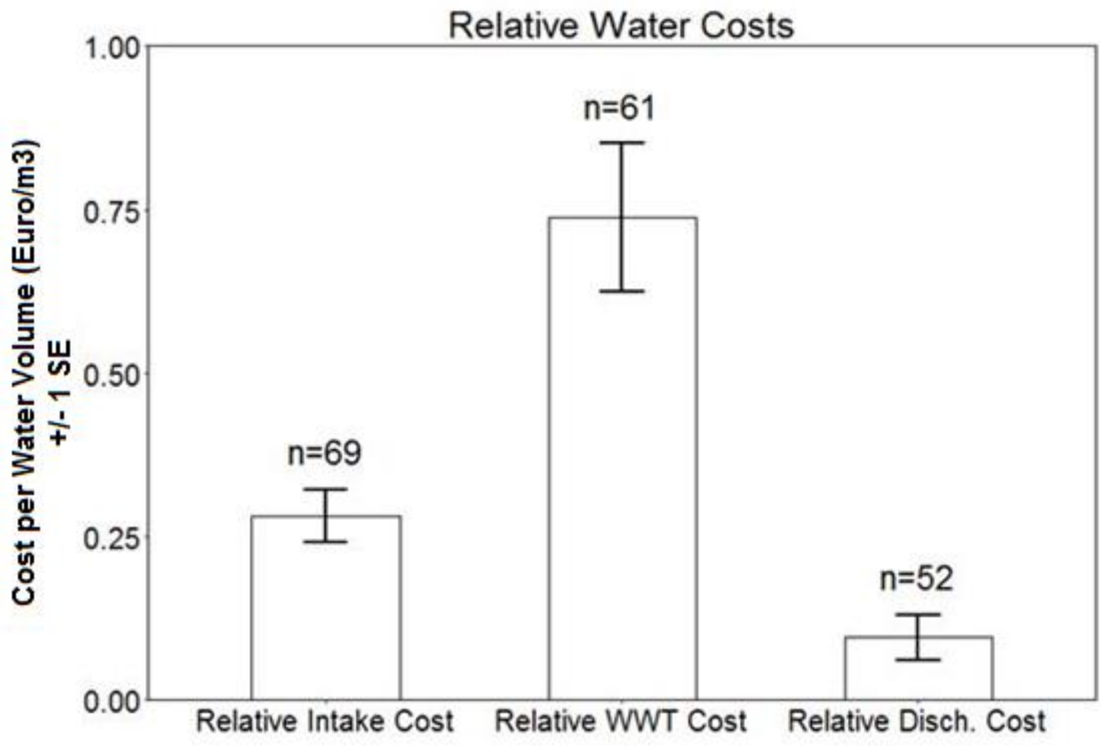
Figure 28. Boxplots of water costs by category. Plot A shows all values, including large outliers. Plot B provides a zoomed version to display more detail.



Water costs related to intake and discharge were normalized to a relative volume basis[1], as shown in **Figure 29**. It is interesting to note that on an industry level, relative intake costs exceeded relative discharge costs. However, when relative costs were segregated by country group, as shown in **Figure 30**, it was evident that not all regions exhibit this trend, with country groups such as Baltic and Central Europe having similar intake and discharge costs and UK and Ireland as well as Iberia had much higher intake costs relative to discharge costs. These regional variations likely point to differences in water supply variables which could also be related to regulation differences.

Figure 31 displays the relative intake and discharge costs by complexity class. While refineries in the lowest complexity class exhibit similar discharge and intake costs, there was no apparent trend across all the classes. This indicates that the pricing differences are more likely related to regional variations rather than refinery complexity.

Figure 29. Relative water costs. The number of refineries that reported each cost type are shown above each bar.



[1] It appears that questionnaire respondents in some cases may have included waste water treatment costs mixed with discharge costs and vice versa. Since only a single cost was provided without any additional information, there may be cases where the cost of treatment and discharge overlap. For these calculations, it is assumed that effluent discharge volumes from transfers, three-stage WWTP (biological), physical, and/or chemical, and Mechanical were relevant for the relative waste water treatment cost calculation, and all effluent volumes were relevant for the relative discharge cost calculation.

Figure 30. Relative water costs by Country Group. Error bars represents +/- 1 standard error.

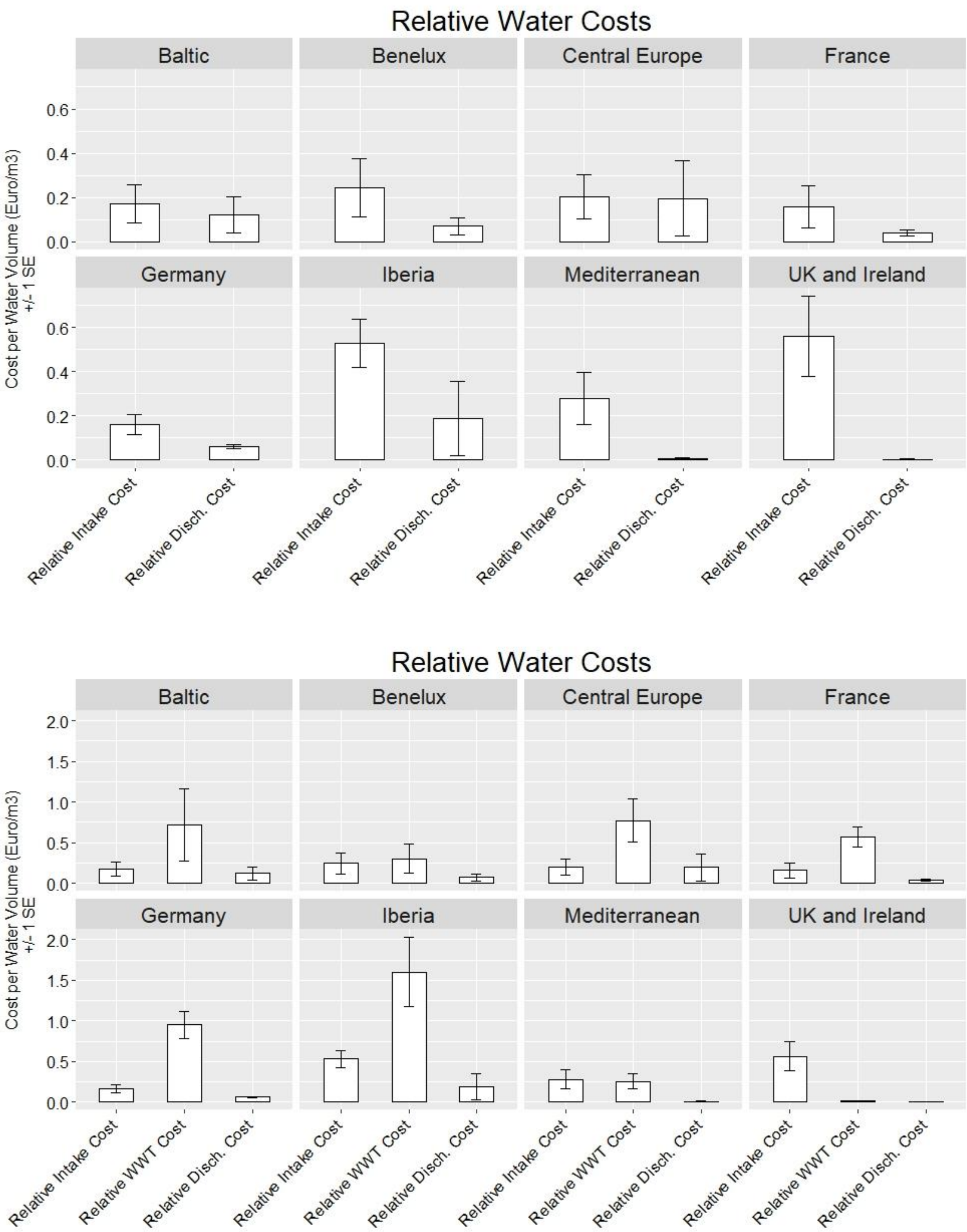
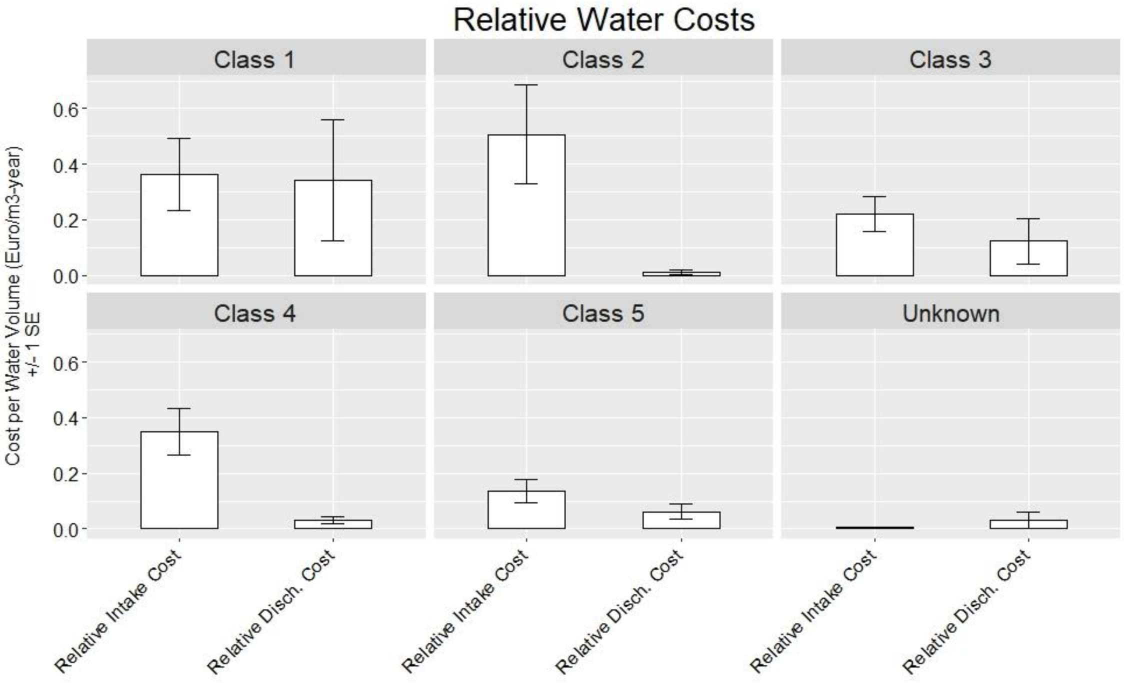
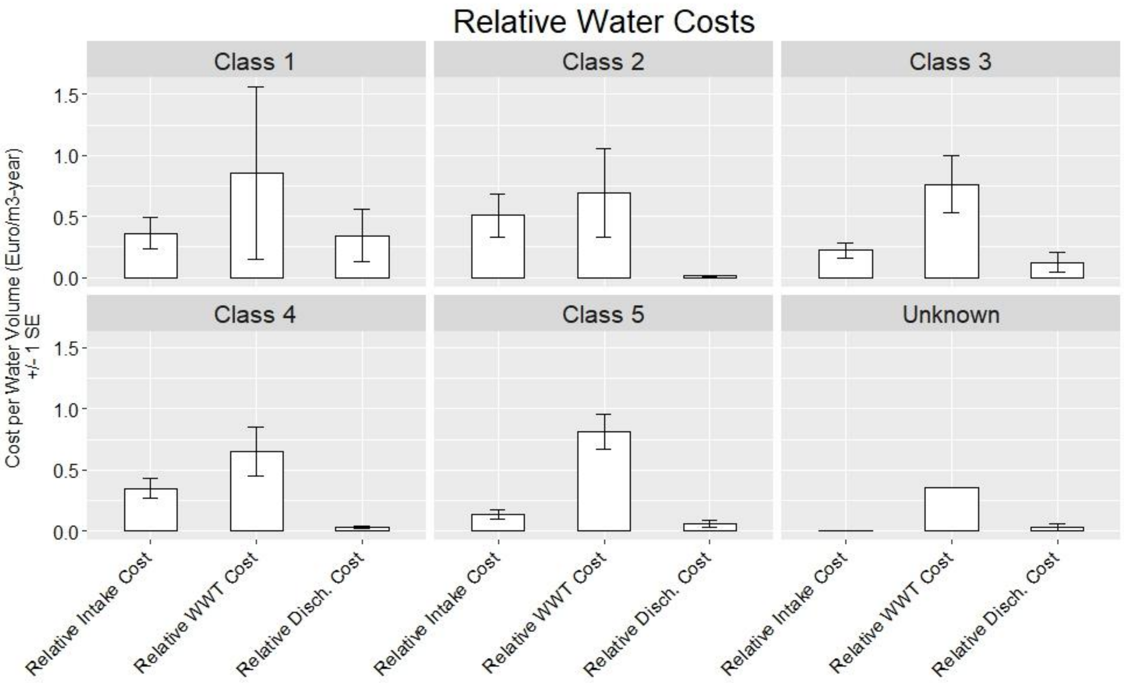


Figure 31. Relative water costs by complexity group. Error bars represent +/- 1 standard error.





3. REFINERY EFFLUENT QUALITY

Reporting of contaminant concentrations and loadings of refinery discharges are presented in this section. With respect to the quality of refinery effluents, Concawe has been collecting data from its membership regularly since 1969. For 2013, key parameters reported are summarised in **Table 11** which presents the total loading (tons/year), the relative loading (g per ton of feedstock throughput/year), the average concentration (µg/L), and the maximum concentration (µg/L) for all refineries reporting. In the calculation of the parameters shown in **Table 11** the following conventions were used:

- Transferred discharges are not included (this data is presented separately in **Table 12**);
- Concentrations below the limit of quantification (LOQ) are replaced with ½ LOQ for the calculation of average effluent concentrations, annual effluent loadings and relative loadings (in accordance with the analysis of 2010 data presented in Concawe report 6/12);
- 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.

There were a total of 11 refineries that transferred some of their effluent water to an external treatment facility. Of these, eight refineries monitored the effluent streams for analytical parameters prior to transfer. The final treatment efficiency at these external locations was not known and so it was assumed that the treatment efficiency for each substance was 95%. With this assumption, the total tonnes discharged to the environment via the transfer streams was approximated and a summary of the estimated additional tonnes discharged per substance in transfer streams is provided in **Table 12**.

Table 11. Summary of parameters monitored in the refinery effluents. Effluents transferred to external facilities are not included in these values.

Analyte	Industry Total Effluent Load (Tonne)	Average Annual Concentration (µg/L)	Max Annual Concentration (µg/L)
Organics			
Total Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	8.9	47	894
Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)	334	903	8,108
Phenol Index	17.0	47.8	660
Total Poly Aromatic Hydrocarbons (PAHs) [2]	0.04	0.09	0.55
General parameters			
Total Nitrogen	2,279	9,316	88,000
Total Phosphorus	171	536	2,811
Biochemical Oxygen Demand (BOD) – 5d	2,717	8,967	82,344
Chemical Oxygen Demand (COD) – 2h	15,980	49,174	176,000
Total Organic Carbon - TOC	2,480	13,606	37,900
Total Suspended solids	12,491	12,639	67,705

[2] Total polycyclic aromatic hydrocarbons (PAHs) value 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.

Table 12. Estimated annual discharge associated with refinery effluents transferred to external facilities for treatment. Discharge tonnage is estimated from the transferred water volume, assuming either: (i) the industry average final effluent concentration, or (ii) the pre-transfer monitored concentration (if this is already lower than the industry average final effluent quality).

Analyte	Number of Refineries[1]	Industry Total Transfer Effluent Load (Tonne)	Total Volume of Effluents Transferred to External Facility[2] (m^3/year)	Estimated Additional Tonnes due to Transfer Streams[3] (Tonnes)
Organics				
Total Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	6	42.6	15,660,296	2.13
Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)	7	415	11,714,152	20.8
Phenol Index	6	2.97	13,344,404	0.15
Total Poly Aromatic Hydrocarbons (PAHs)	4	0.00	13,283,333	0.00
General parameters				
Total Nitrogen	6	195	13,721,911	9.76
Total Phosphorus	6	5.00	15,662,661	0.25
Biochemical Oxygen Demand (BOD) – 5d	4	1,312	9,692,633	65.6
Chemical Oxygen Demand (COD) – 2h	8	5,862	20,073,084	293
Total Organic Carbon - TOC	5	655	15,255,871	32.8
Total Suspended solids	6	612	7,333,152	30.6

[1]This represents the number of refineries that transferred effluent and analysed the effluent for the given parameter prior to being transferred
[2]This represents the total effluent volume that is transferred and analysed for the given parameter prior to being transferred
[3]Discharge tonnage is estimated from the transferred effluent load by assuming a reduction efficiency of 95% at the external facility

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

As observed in **Figure 32** and **Table 13**, the number of refineries reporting for Concawe water use/effluent surveys has varied between 73 and 125 throughout the years, whereas the total oil discharged in effluents has decreased significantly from 44,000 tonnes in 1969 to 354 tonnes in 2013. Oil discharge relative to refining capacity and throughput has also continued to reduce over the whole period covered by the surveys; in 2013 the relative discharge was 0.70 g TPH/tonne capacity and 0.71 g TPH/tonne throughput.

The relative discharge for the reporting sites in 2013 was significantly lower than that in 2010 and 2008. The reason for this was 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 59 sites common to both the 2010 and 2013 datasets. For these 59 sites the relative TPH discharge in 2010 was 2.55 g/tonne throughput, and in 2013 it was 1.83 g/tonne throughput. According to this analysis, a decrease in relative discharge between 2010 and 2013 was still indicated, although the magnitude of the decrease is less (28% vs 45%). It should however be noted that 59 sites common to both 2010 and 2013 datasets was relatively small (59 out of 98 in 2010 and 59 out of 73 in 2013).

In 2013 there were seven 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 22 tonnes of estimated oil that were discharged. Since it is reasonable that the external facilities were comparable to refineries in their ability to treat oil in water, this assumption was checked by applying the average concentration of oil in water across the industry (from not transferred streams) to the volume of effluent water that was transferred. This yielded an additional 12 tonnes of estimated oil that were discharged, which is equivalent to assuming the external facilities had just under a 97% reduction efficiency. The estimated emissions assuming 95% reduction efficiency from the treated transfer are included in **Figure 34**.

Table 13. Oil discharge data from 1969 to 2013

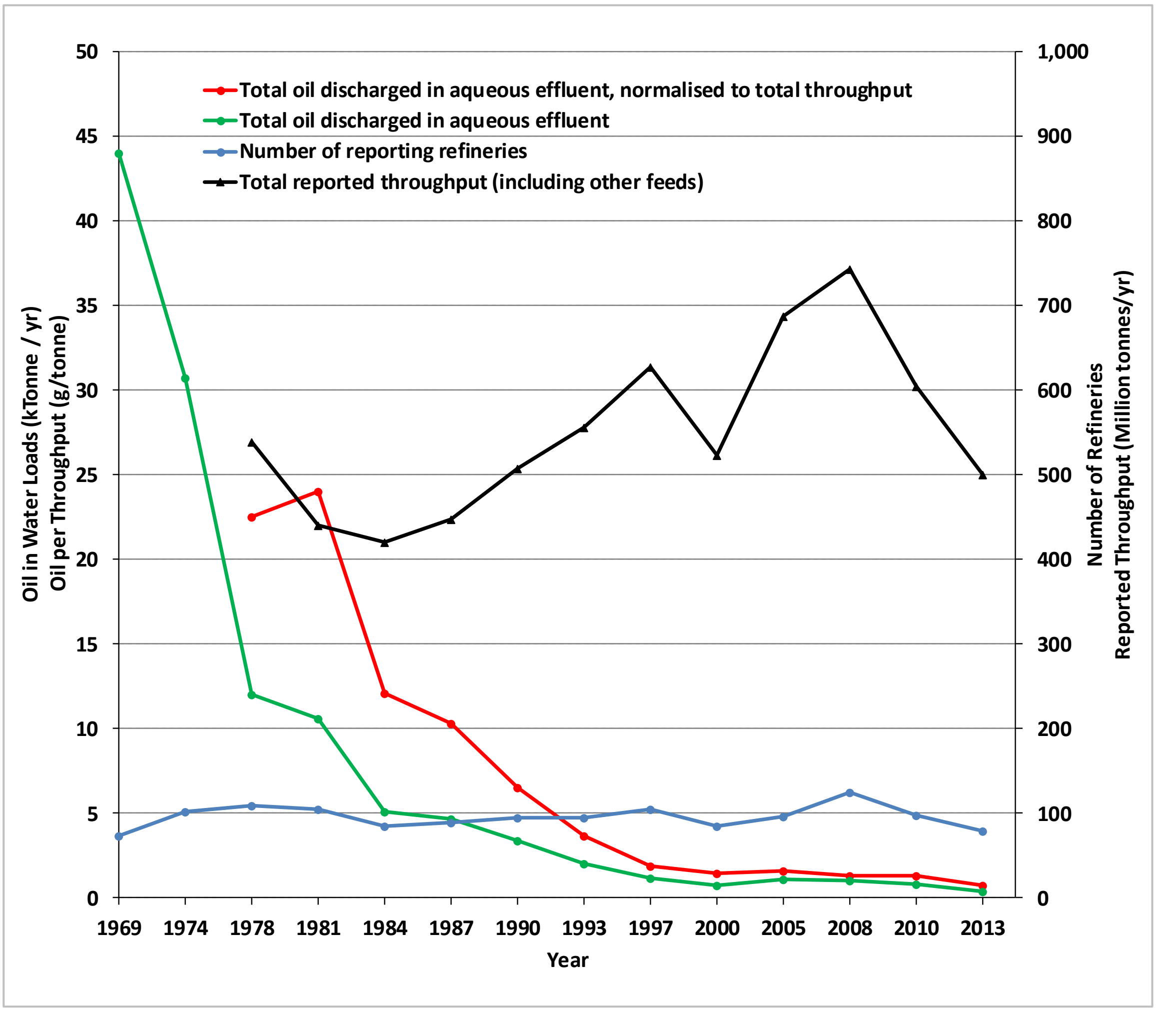
Year	Number of refineries reporting these data	Total oil discharged (tonne/year)	Oil discharged (g/tonne capacity)	Oil discharged (g/tonne throughput)
1969	73	44,000	127	n.d.
1974	101	30,700	44.8	n.d.
1978	109	12,000	15.9	22.5
1981	105	10,600	14.9	24.0
1984	85	5,090	8.39	12.1
1987	89	4,640	7.90	10.3
1990	95	3,340	5.86	6.54
1993	95	2,020	3.30	3.62
1997	105	1,170	1.74	1.86
2000	84	750	1.32	1.42
2005	96	1,050	1.44	1.57
2008	125	993	1.18	1.33
2010	98[1]	798	1.10	1.30
2013[2]	73 (66)	354 (334)	0.70 (0.66)	0.71 (0.67)

n.d. = not determined

[1] Figures relate to 98 installations; they exclude the two installations that only reported data for water use.

[2] The figures reported considering transfer streams assuming the external facilities a reduction efficiency of 95 % (this is comparable with the reduction efficiency of treatment on site). The number in brackets show the number reported when transfer streams are not considered.

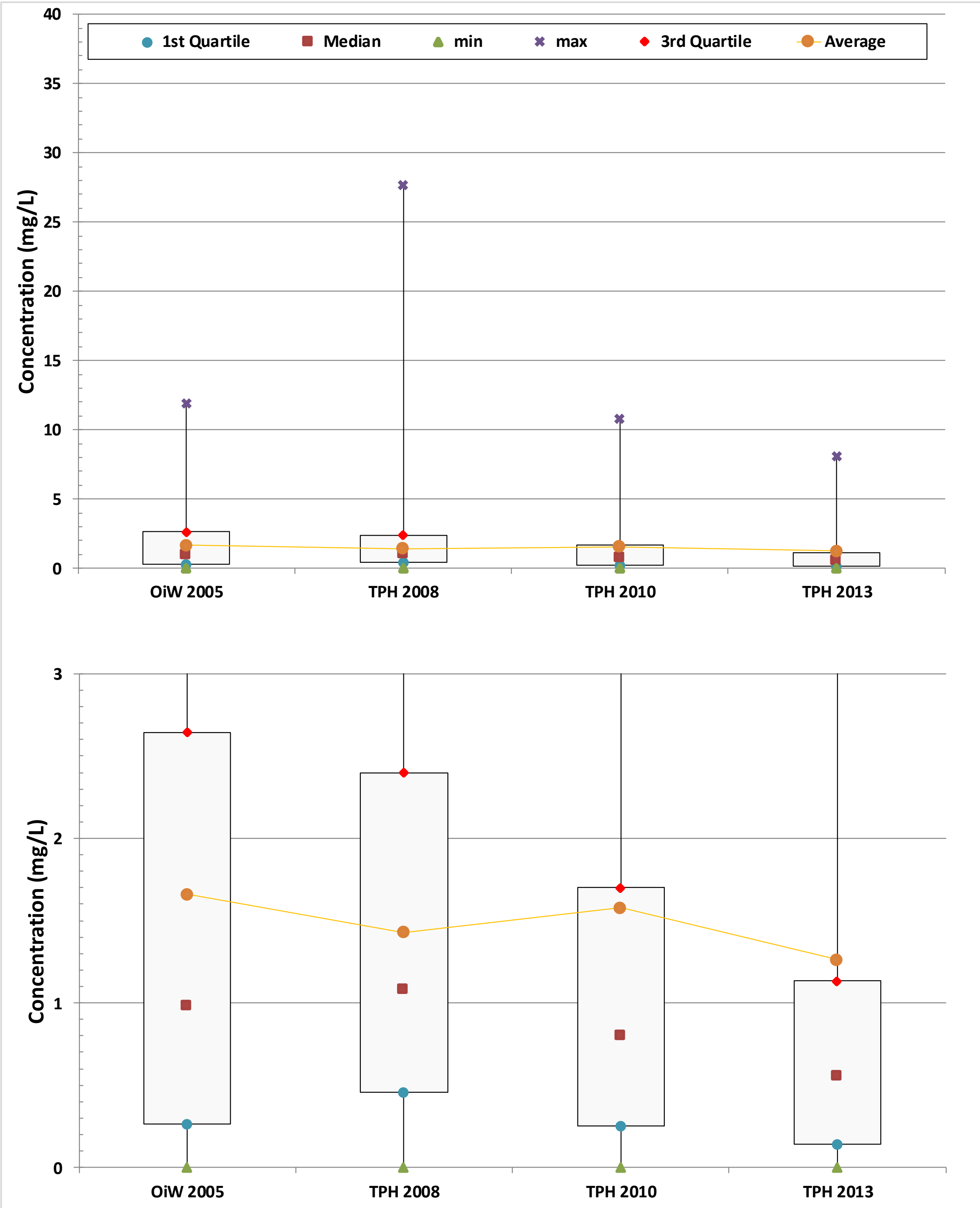
Figure 32. Trends in TPH loadings in effluents, reported throughput and number of refineries reporting in Concawe surveys from 1969 to 2013 (2013 data includes estimated emissions from treated transfer streams).



3.1.1. Statistical analysis of 2005 to 2013 trend in TPH discharge

Figure 33 presents the historical trends of average annual TPH concentrations in refinery effluents from 2005 to 2013 using a box-and-whisker plot. The median and average concentrations were observed to be fairly constant over time, being 0.44-1.1 mg/L and 1.26-1.66 mg/L, respectively. Note that the TPH maximum concentration is 10.8 mg/L in 2010 in this updated graph. The 2010 report included a maximum concentration of 33 mg/kg, which was determined to be an anomalous value. After verification from the refinery, the value was corrected for this report.

Figure 33. Historical Trend in Refinery Effluents for TPH. The bottom plot is a zoomed version of top plot.



3.1.2. Analysis of outliers in 2010 and 2013 TPH discharge data

Figure 34 presents 2010 and 2013 survey results for TPH in detail and the graphics include:

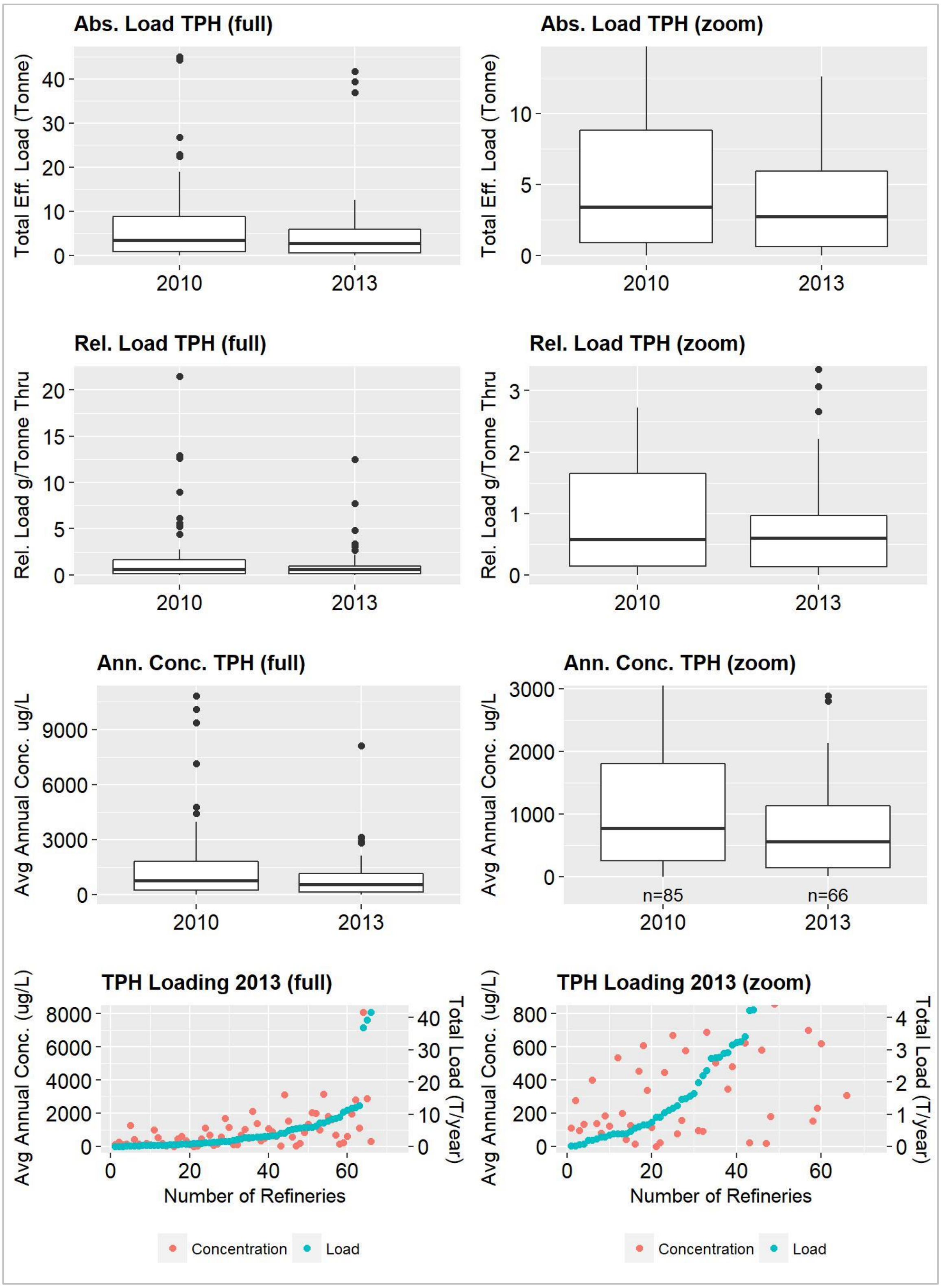
a) Box and whisker plots for all parameters presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration;
b) Dual Y-axis plots for all parameters for 2013 for total load and average concentration.

With regard to the plots shown in **Figure 34** the following conventions were used:

- Transferred streams and discharges are not included;
- Non-quantified are replaced with ½ limit of quantification;
- The total effluent load per refinery is the sum of all the individual effluent stream loads given for each refinery. Since loading is directly related to the number of refineries reporting, comparisons for total and relative loads were limited to the subset of sites that reported both in 2010 and 2013. Industry level loading values for 2013 are displayed in **Table 11** above;
- The average concentration per refinery is plotted. This means that if a refinery had multiple streams, then concentration values are averaged across the waste streams to provide one concentration per refinery. For this purpose, concentrations are weighted based on effluent volume; and
- The number "n" stated is the number of refineries for which the average effluent parameter and treated onsite are plotted.

From the box and whisker plots it is clear that the 2010 and 2013 survey datasets contain a number of high outliers, which could influence the overall discharge parameters. The highest outliers in terms of TPH load accounted for 12%, 11% and 10% of the total sector load, respectively. The highest outlier (12% of the total sector load) came from a large high throughput site with high discharge volumes, and so were not an outlier in terms of relative load. The second and third highest outliers (11% and 10% of the total sector load, respectively) were outliers also in terms of relative load and both reported similar absolute loads in 2010.

Figure 34. Six upper plots show box and whisker plots for Total Petroleum Hydrocarbons (TPH) presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for TPH for 2013 for total load and average concentration.



3.2. TRENDS IN BOD, COD AND TOC IN REFINERY WATER DISCHARGES

Data for BOD, COD 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. For example, as noted in section 3.1 above, in 2010 and 2013 only 59 sites were common to both TPH datasets. For parameters other than TPH the number of sites common to both datasets is similar or lower, and would decrease further if additional survey years were included. For this reason, it was not considered feasible to analyse data only from sites common to recent surveys.

3.2.1. Statistical analysis of 2000 to 2013 trend in BOD, COD and TOC discharge

Historic absolute and relative discharge loads from 2000-2013 for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC), are summarised in **Table 14**. For relative BOD discharge load, a large reduction is apparent from 2005 to 2010/2013, with the relative load in 2010 and 2013 being similar. The same as for BOD is observed for TOC, while for COD the main reduction in relative load is between 2010 and 2013.

Table 14. 2013 and historical discharges of BOD, COD and TOC

Year	BOD	COD	TOC
	tonne/year (Number refineries reporting)		
2000	3,129 (47)	19,002 (61)	3,094 (21)
2005	6,242 (84)	33,156 (90)	3,559 (45)
2010	3,450[1] (68) 75.9[2] (7)	31,765[1] (81) 1,770[2] (9)	2680[1] (41) 195[2] (6)
2013	2,717[1] (57) 65.6[2] (4)	15,980[1] (64) 293[2] (8)	2,480[1] (37) 32.8[2] (6)
	g/tonne throughput		
2000	10.4	50.9	17.9
2005	13.5	58.0	12.7
2010	6.3[1] 2.0[2]	57.7[1] 35.0[2]	4.9[1] 4.8[2]
2013	5.4[1] 0.13[2]	32[1] 0.59[2]	5.0[1] 0.07[2]

[1] Figures for direct discharges from installations.
[2] Figures for discharges after transfer to and treatment by offsite WWTP, assuming 95% reduction efficiency (Concawe, 2012)

3.2.2. Analysis of outliers in 2010 and 2013 discharge data for BOD, COD and TOC

A statistical analysis of the survey data for BOD, COD and TOC is presented in **Figure 35**, **Figure 36** and **Figure 37,** respectively. These figures are plotted according to the convention mentioned above for **Figure 34.**

The highest outliers in absolute BOD load in 2013 accounted for 14%, 12%, 9% and 9% of the total sector load, respectively. The top 3 outliers all came from large high throughput sites with high discharge volumes, and so were not outliers in terms of relative load. The site with the fourth largest absolute load (9% of the total sector load) was still an outlier in terms of relative load and reported a similar absolute load in 2010. This site also had a relatively high total suspended solids (TSS) load, which may account for the high BOD value.

For COD only one outlier was identified in the 2013 dataset, which accounted for 9% of the total sector load. This outlier was consistent with E-PRTR data and not a major outlier in terms of relative load.

The highest outliers in absolute TOC load in 2013 represented 24% and 9% of the total sector load, respectively. However, none of the outliers were not major outliers in terms of relative load.

Figure 35. Six upper plots show box and whisker plots for Biochemical Oxygen Demand (BOD) presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for BOD for 2013 for total load and average concentration.

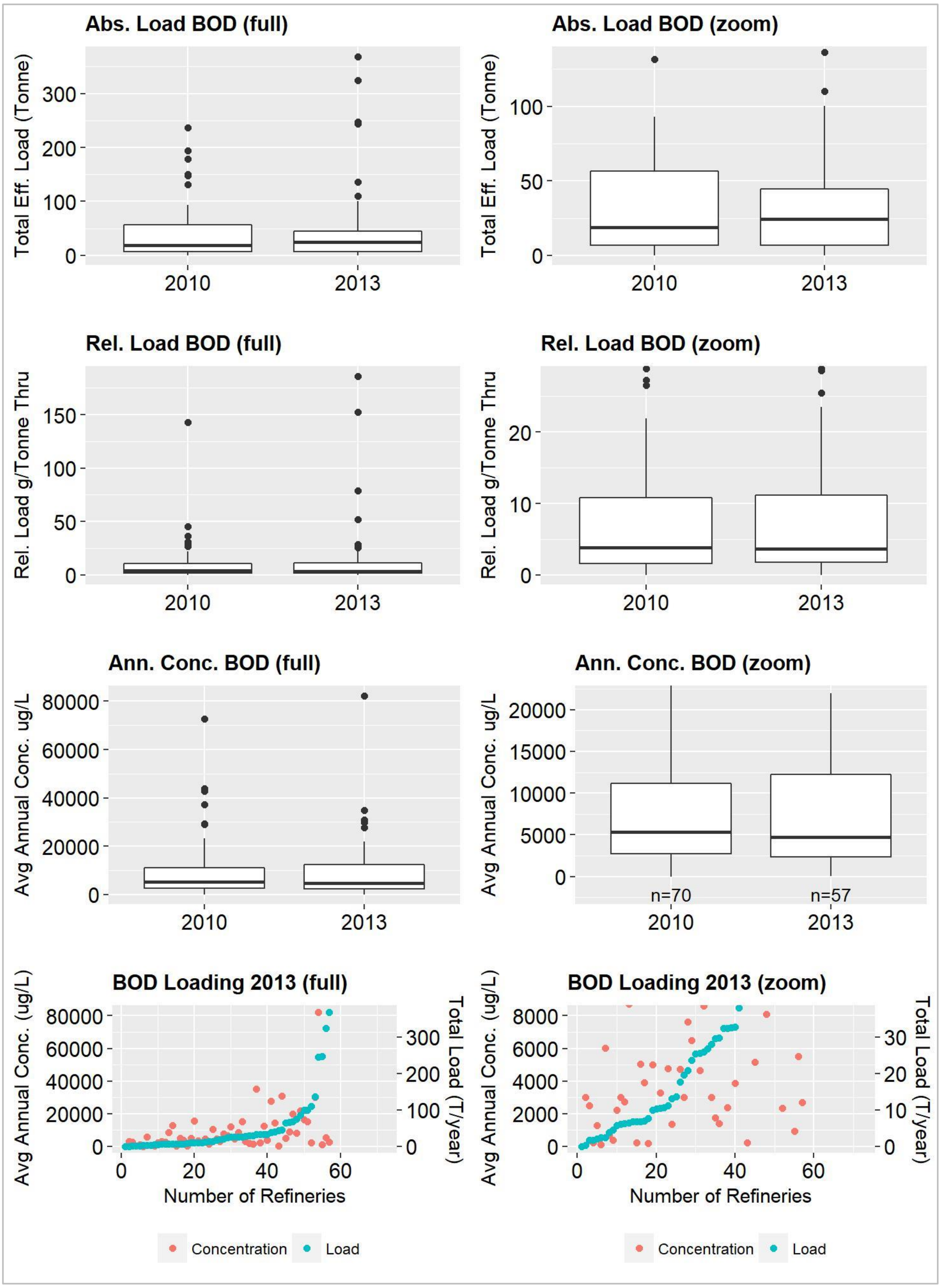


Figure 36. Six upper plots show box and whisker plots for Chemical Oxygen Demand (COD) presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for COD for 2013 for total load and average concentration.

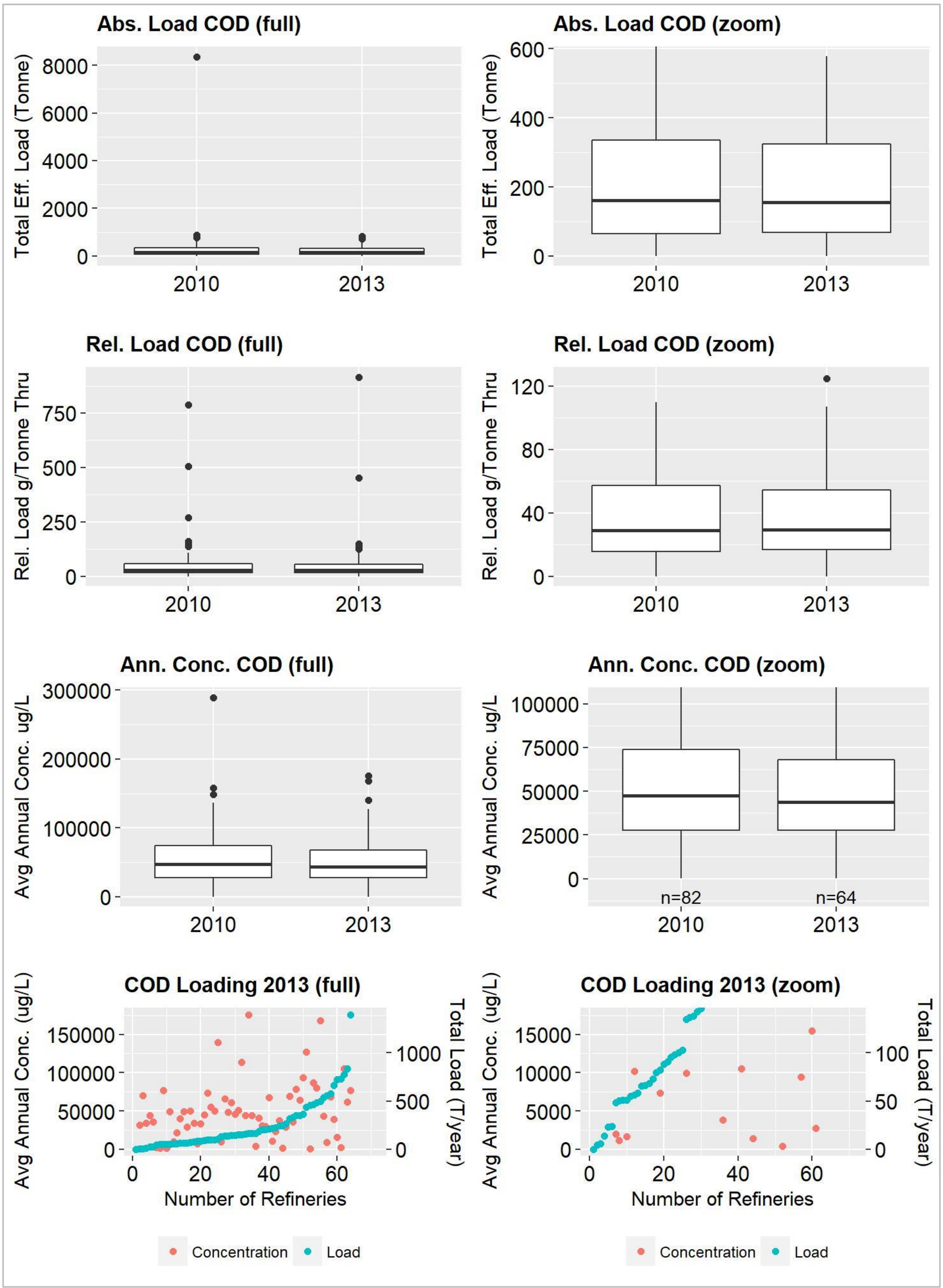
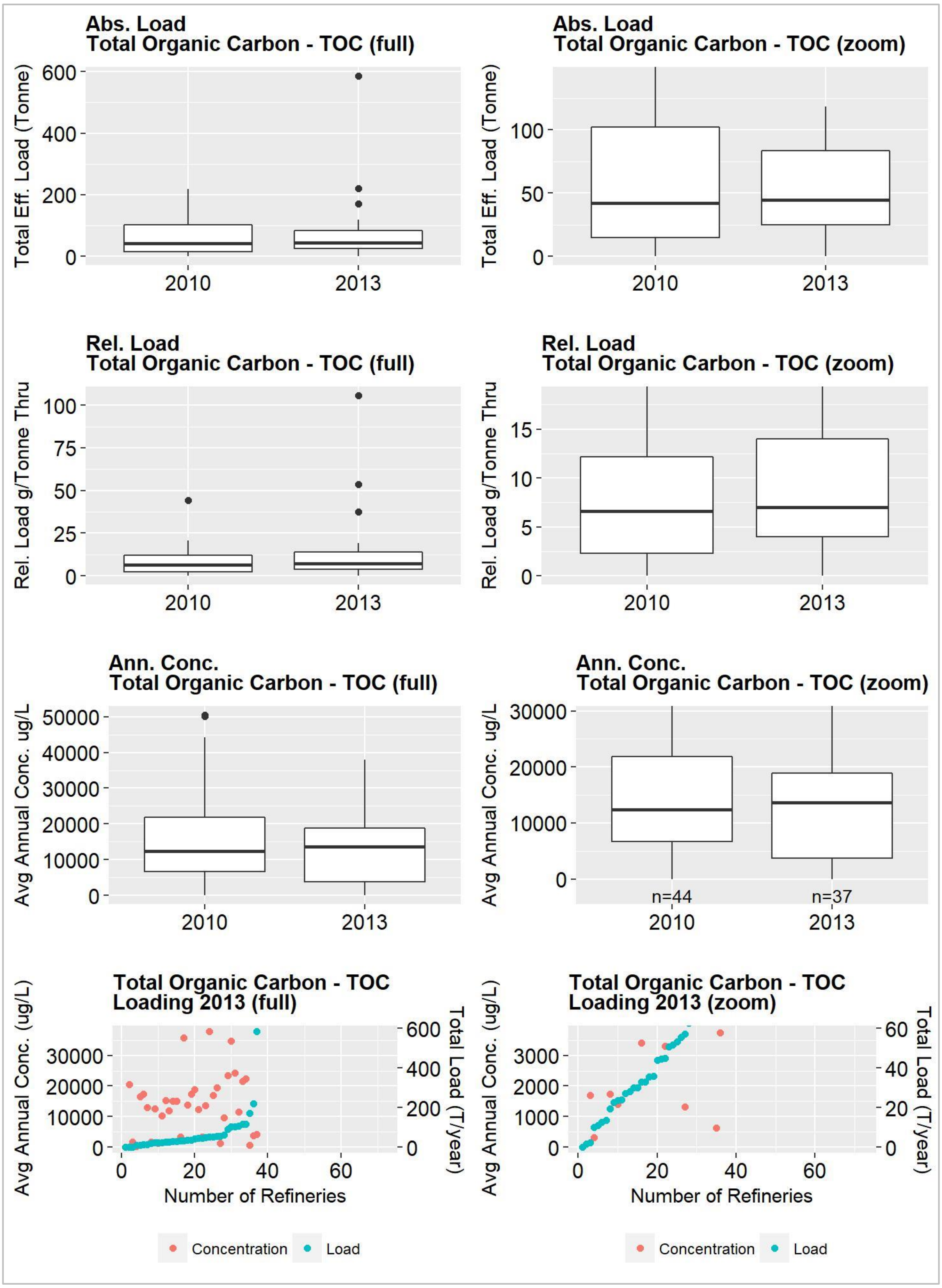


Figure 37. Six upper plots show box and whisker plots for Total Organic Carbon (TOC) presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for TOC for 2013 for total load and average concentration.



3.3. 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 discharges for the sector. For example, as noted in section 3.1 above, in 2010 and 2013 only 59 sites were common to both TPH datasets. For parameters other than TPH the number of sites common to both datasets is similar or lower, and would decrease further if additional survey years were included. For this reason, it was not considered feasible to analyse data only from sites common to multiple surveys.

3.3.1. Statistical analysis of 1993 to 2013 trend in ammonia, total nitrogen and phenols discharge

Absolute and relative discharge loads from 1993-2013 for ammonia, total nitrogen and phenols are summarised in **Table 15**. 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 decrease in direct discharges of ammonia/ KTN from 1993 to 2013, which is also reflected in the relative discharge data. For total nitrogen the decrease is less marked, however refinery intake waters will often contain significant total nitrogen in the form of nitrate. For phenols a large reduction in total and relative discharge is apparent from 1993 to 2013. With regard to effluents transferred offsite for treatment, it should be noted that the relative discharge data are highly dependent on the assumed removal rate (95%), which may be an underestimate. Furthermore, transferred effluents generally represent <10% of the total discharge load, and so the overall relative discharge will be similar to that for the direct discharges (i.e. close to 0.82 for ammonia in 2010).

Table 15. 2013 and historical discharge of ammonia, total nitrogen & phenols

Year	Ammonia/ TKN	Total Nitrogen	Phenols
	tonne/year (Number of Refineries reporting)		
1993	5,202 (82)	n.a.	179 (77)
1997	3,210 (82)	n.a.	161 (73)
2000	1,715 (46)	1,884 (46)	61 (55)
2005	1,959 (64)	4,778 (80)	180 (84)
2010	454[1] (26) 22[2] (3)	2,307[1] (66) 56[2] (8)	31[1] (76) 5.2[2] (8)
2013	560 (19 TKN[3])	2,279 (56) 9.8[2] (6)	17 (59) 0.15[2] (6)
	g/tonne throughput		
1993	10.4	n.a.	0.41
1997	8.0	n.a.	0.32
2000	5.7	7.4	0.16
2005	5.5	10.0	0.35
2010	0.82[1] 8.15[2]	4.2[1] 21[2]	0.058[1] 1.9[2]
2013	1.12 (TKN)	4.6[1] 0.02[2]	0.034[1] 0.003[2]

n.a. = not applicable
[1] Figures for direct discharges from installations.
[2] Figures for 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

3.3.2. Analysis of outliers in 2010 and 2013 discharge data for ammonia, total nitrogen and phenols

A statistical analysis of the survey data for total nitrogen and phenols is presented in **Figure 38** and **Figure 39**. These figures are plotted according to the convention mentioned above for **Figure 34**.

The highest outliers in absolute total nitrogen load in 2013 represented 10% and 9% of the total sector load, respectively. However, none of the outliers were major outliers in terms of relative load.

The highest outliers in terms of absolute phenol load represented 27% and 13% of the total sector load, respectively. The 27% outlier was associated with phenols discharged in a cooling water stream, however the site reported that phenols are also present at similar concentration in the intake water, i.e. not net input of phenols from the site. The 13% outlier was still an outlier in terms of relative load and reported a similar absolute load in 2010.

Figure 38. Six upper plots show box and whisker plots for total nitrogen presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for total nitrogen for 2013 for total load and average concentration.

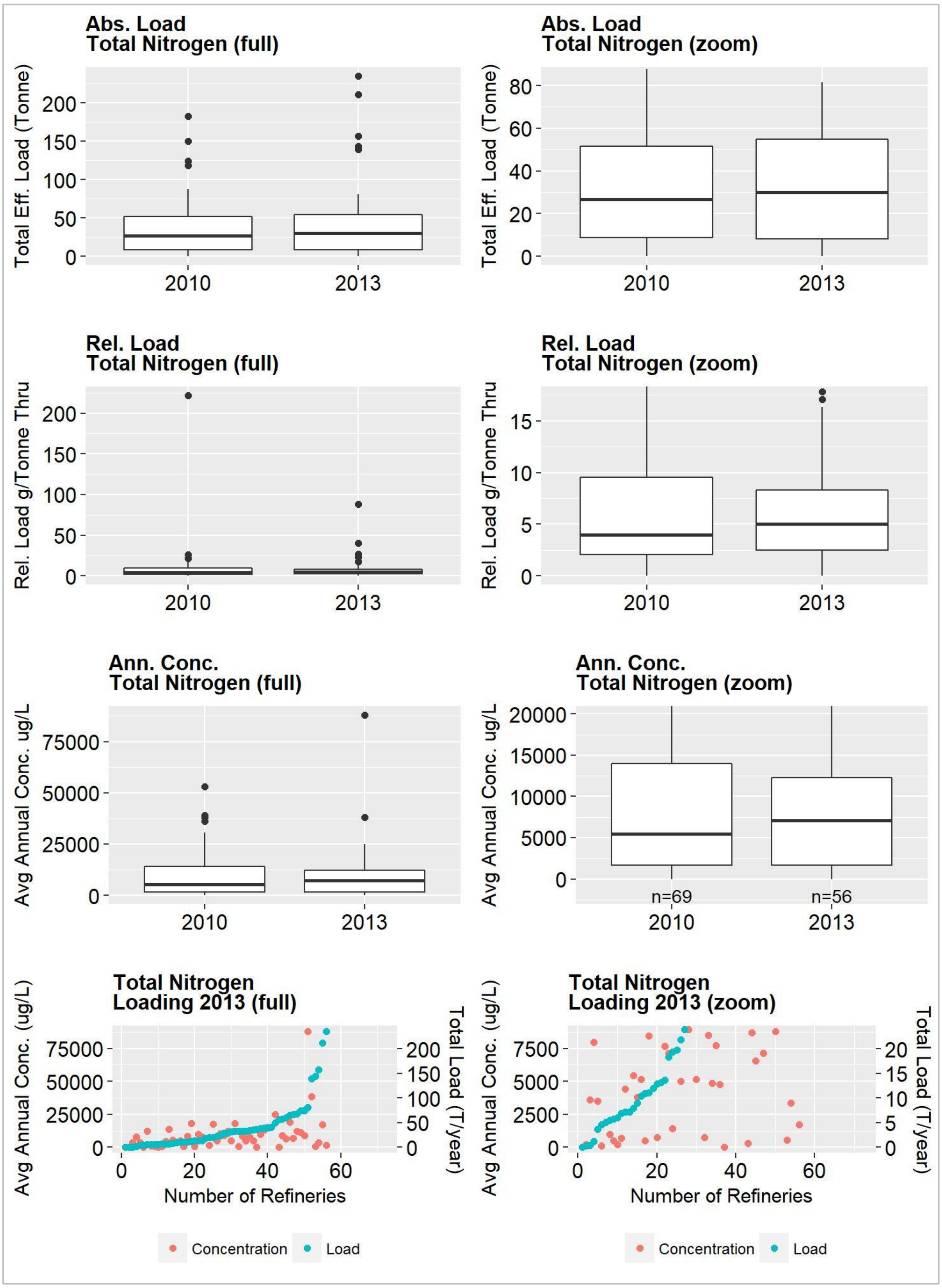
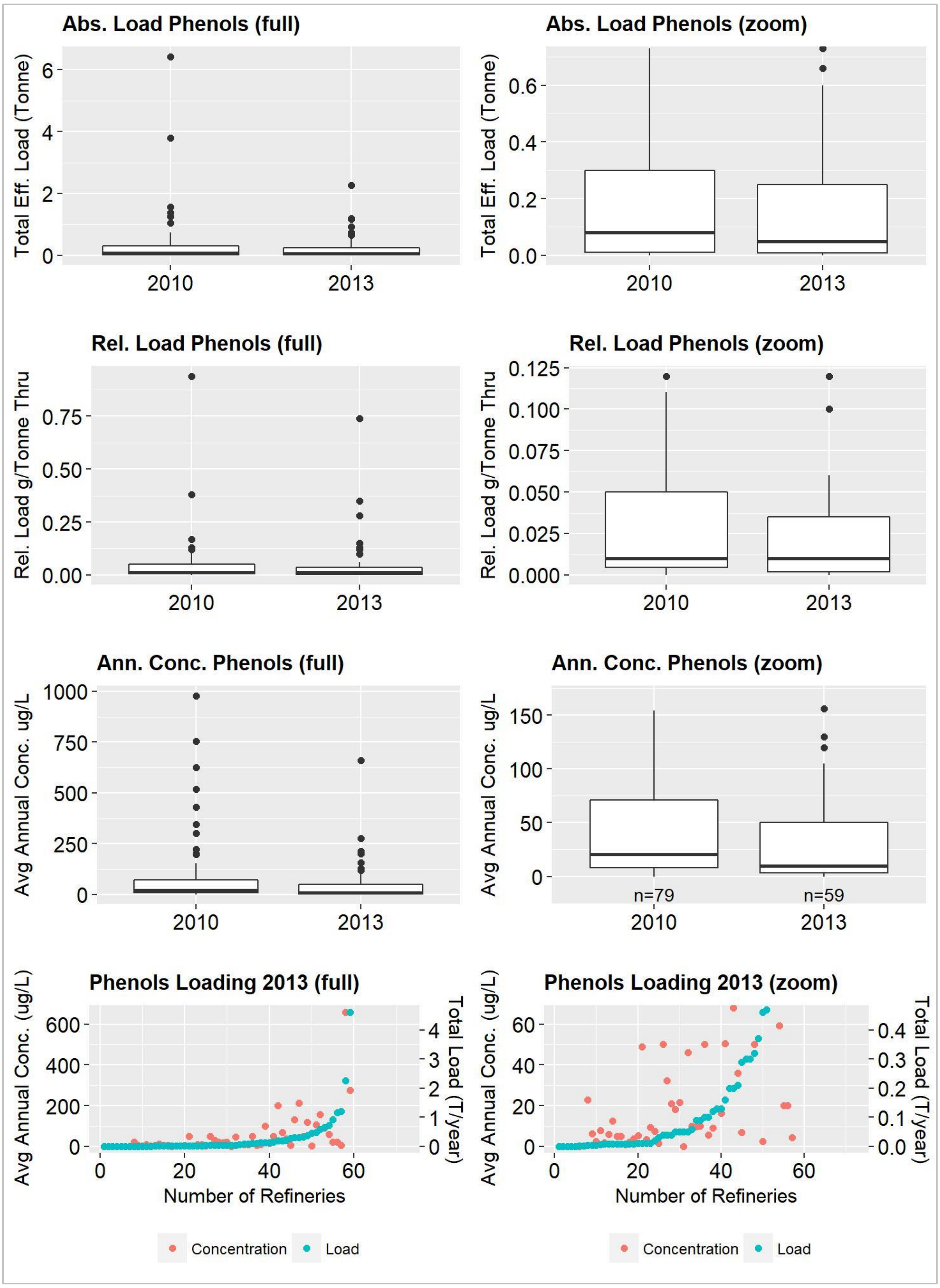


Figure 39. Six upper plots show box and whisker plots for phenols presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for phenols for 2013 for total load and average concentration.



3.4. 2010 AND 2013 DISCHARGE DATA FOR TSS AND TOTAL PHOSPHOROUS

Total and relative discharge data for TSS and total phosphorus in 2010 and 2013 are summarised in **Table 16**. For relative TSS discharge a large reduction is apparent from 2010 to 2013, while for total phosphorus the relative discharge in 2010 and 2013 were similar.

Table 16. 2013 and 2010 discharge of TSS and total phosphorus

Year	TSS	Total phosphorus
	tonne/year (Number of Refineries reporting)	
2010	85,409[1] (74) 36.6[2] (6)	238[1] (72) 1.28[2] (9)
2013	12,491[1] (59) 30.6[2] (6)	171[1] (57) 0.25[2] (6)
	g/tonne throughput	
2010	138[1] 1.05[2]	0.40[1] 0.024[2]
2013	25.0[1] 0.06[2]	0.34[1] 0.0005[2]

n.a. = not applicable
[1] Figures for direct discharges from installations
[2] Figures for discharges after transfer to and treatment by offsite WWTP, assuming 95 % removal (Concawe, 2012)

3.4.1. Analysis of outliers in 2010 and 2013 discharge data for TSS and total phosphorous

A statistical analysis of the survey data for TSS and total phosphorous is presented in **Figure 40** and **Figure 41**. These figures are plotted according to the convention mentioned above for **Figure 34.**

For TSS only one outlier was identified in the 2013 dataset, which accounted for 74% of the total sector load. This very big outlier was consistent with site data reported in 2010. Moreover, the concentration itself was not being extremely high (67,705 µg/L) compared to what can be expected in a WWTP effluent.

The highest outliers in terms of absolute total phosphorus load accounted for 11% and 9% of the total sector load, respectively. The highest outlier (11% of the total sector load) was confirmed by site E-PRTR data, whereas the second largest outlier (9% of the total sector load) was not a major outlier in terms of relative load.

Figure 40. Six upper plots show box and whisker plots for Total Suspended Solids (TSS) presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for TSS for 2013 for total load and average concentration.

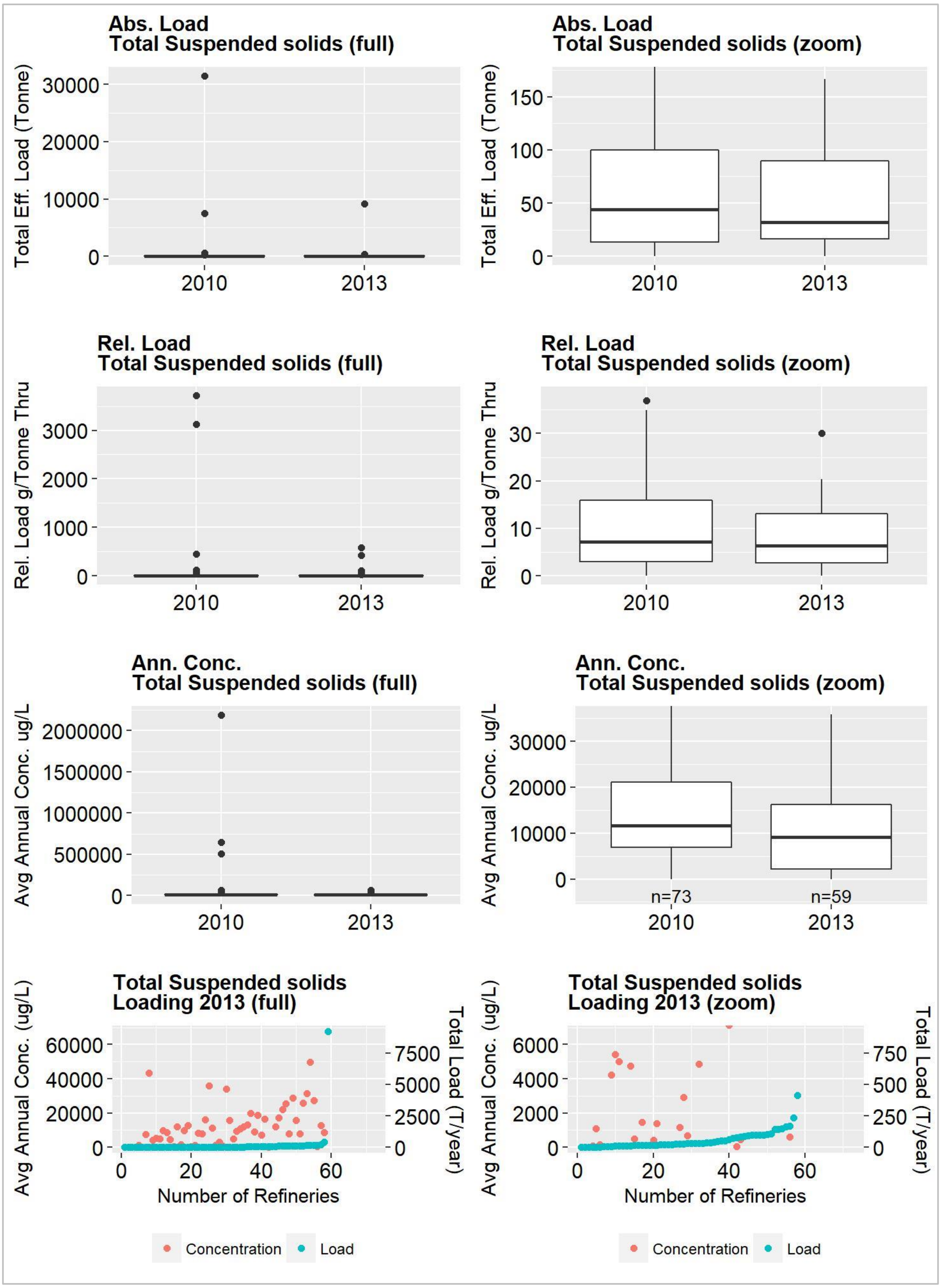
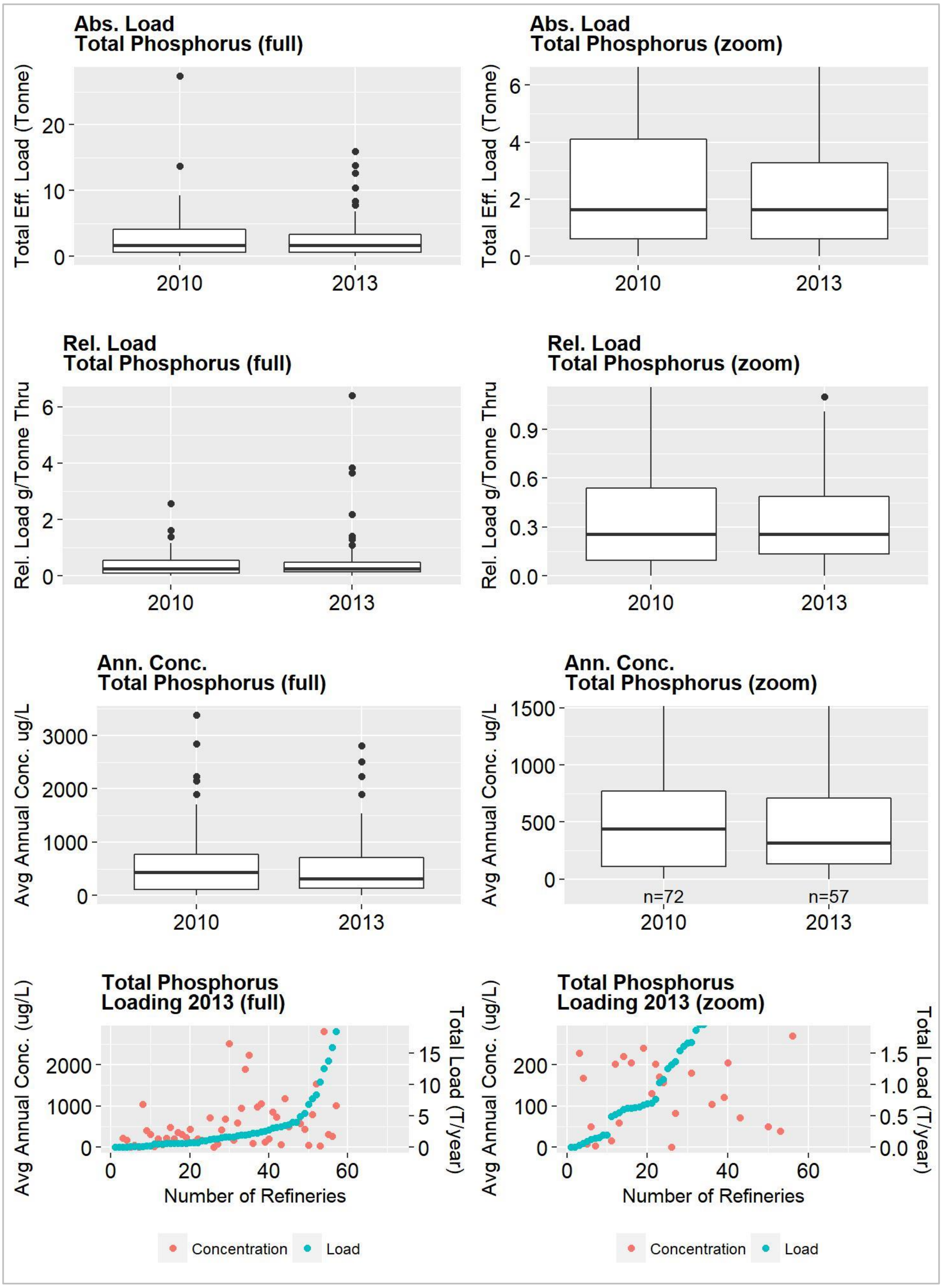


Figure 41. Six upper plots show box and whisker plots for total phosphorus presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for total phosphorus for 2013 for total load and average concentration.



3.5. 2010 AND 2013 DISCHARGE DATA FOR BTEX AND TOTAL PAH

Total and relative discharge data for BTEX and total PAHs for 2010 and 2013 are summarised in **Table 17**. For BTEX the relative discharge appear relatively stable from 2010 to 2013 while for total PAHs a reduction is apparent.

Table 17. 2013 and 2010 discharge of BTEX and total PAHs

Year	BTEX	Total PAHs[1]
	tonne/year (Number of Refineries reporting)	
2010	11.3[2] (60) 3.26[3] (8)	0.15[2] (50) 0.045[3] (6)
2013	8.95[2] (43) 2.13[3] (6)	0.040[2] (19) 5.96E-05 [3] (4)
	g/tonne throughput	
2010	0.019[2] 0.063[3]	2.5E-04[2] 0.0011[3]
2013	0.018[2] 0.004[3]	8.0E-05[2] 1.1E-07[3]

n.a. = not applicable
[1] Total polycyclic aromatic hydrocarbon (tPAH) 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] Figures for direct discharges from installations.
[3] Figures for discharges after transfer to and treatment by offsite WWTP, assuming 95% removal (Concawe, 2012)

3.5.1. Analysis of outliers in 2010 and 2013 discharge data for Total BTEX and PAH

A statistical analysis of the survey data for BTEX and PAH is presented **Figure 42** and **Figure 43**. These figures are plotted according to the convention mentioned above for **Figure 34.**

The highest outliers in terms of absolute BTEX load accounted for 33%, 22% and 18% of the total sector load, respectively. The highest and third highest outliers (33% and 18% of the total sector load, respectively) were identified to be due the loads being calculated based on high BTEX detection limits (the concentration was reported to be the LOQ-value; 100 µg/L per BTEX component). This biased the results and thus should, most likely, not be reported as outliers. The second highest outlier (22% of the total sector load) was confirmed by E-PRTR data. Moreover, the value was being highly based on data from a monitored transient overflow stream.

The highest outliers in terms of absolute total PAHs load accounted for 64% and 20% of the total sector load, respectively. The highest outlier (64% of total sector load) was an outlier also in terms of relative load and reported a similar absolute load in 2010. The second highest outlier (20% of total sector load) was an effect of the conventions used in the data analysis since all PAHs but anthracene and fluoranthene were reported to be under the LOQ, which in combination with the high throughput of the site (i.e. high discharge volumes) gave a high absolute total PAHs load.

Figure 42. Six upper plots show box and whisker plots for BTEX presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for BTEX for 2013 for total load and average concentration.

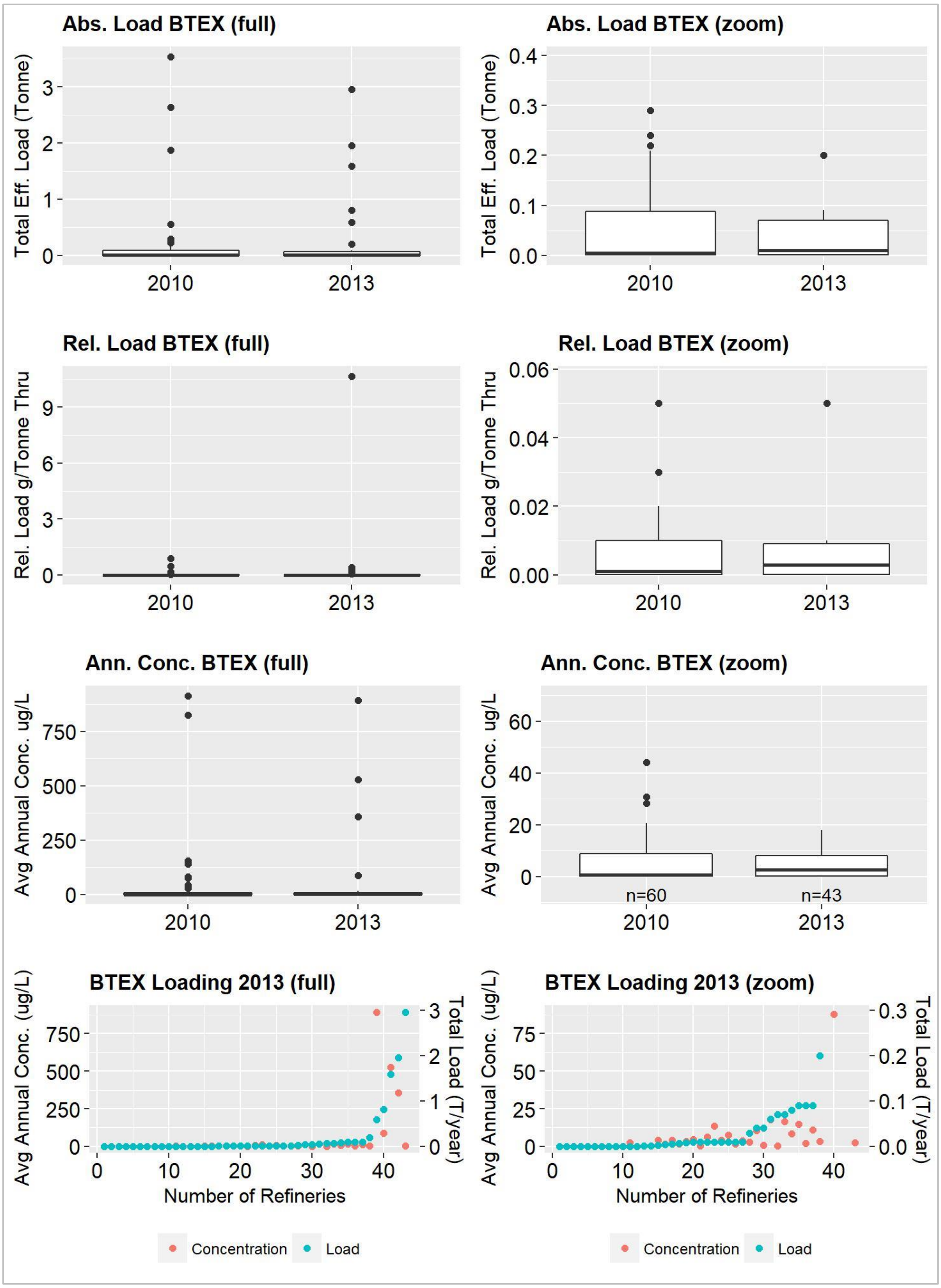
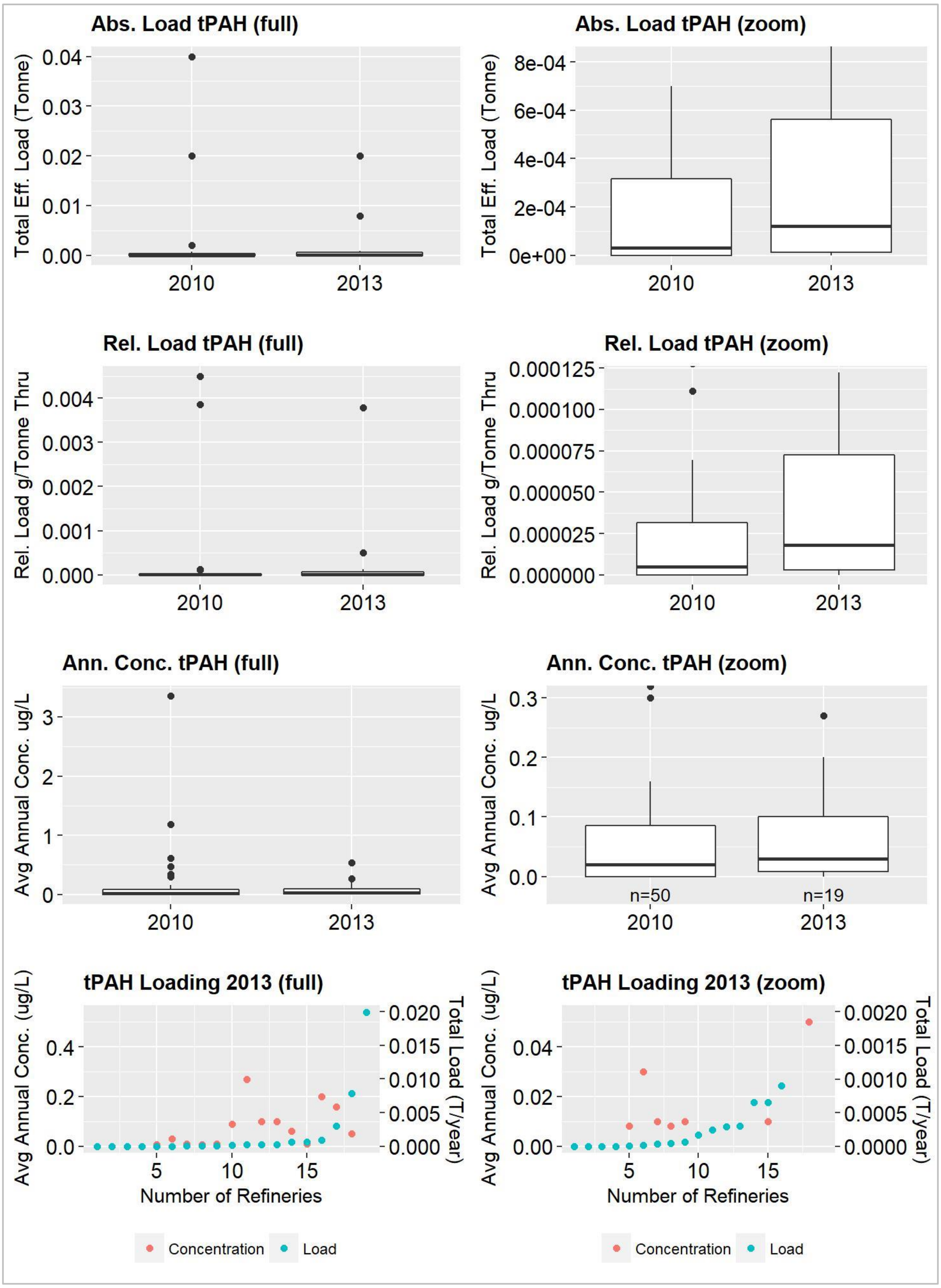


Figure 43. Six upper plots show box and whisker plots for total PAHs presenting both the 2010 and 2013 survey results for total load, relative load per throughput, and average concentration. Two bottom plots show dual Y-axis plots for total PAHs for 2013 for total load and average concentration.



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 2014 for the 2013 reporting year. A total of 79 responses of 104 potential respondents (76%) were collected from refineries that represent a wide geographic scope and range of refinery types/complexities.

70 refineries were included in the 2013 analyses of water intake, discharge and consumption (nine refinery survey responses did not allow for adequate water mass balance computations). A total of 3.5 billion m^3 (3,485,560,351 m^3) of water was withdrawn in 2013 by these 70 sites on site water use (vs 4.5 billion m^3 in 2010 for 100 refineries). Approximately 3.0 billion m^3 or 86 % of the total abstracted water was brackish or saline and used for once-through cooling. The total freshwater withdrawal was 493 million m^3 (average 7.0 million m^3 per refinery), with 371 million m^3 (average 5.3 million m^3 per refinery) used for purposes other than once-through cooling. By way of comparison, the 2010 survey of 100 refineries indicated a total freshwater withdrawal (for purposes other than once-through cooling) of 4.2 million m^3 per refinery on average. Using the IPIECA definition for freshwater consumption (indicator E6; IPIECA, API and IOGP, 2015), refineries consumed a total of 271 million m^3 of fresh water in 2013 vs 282 million m^3 in 2010. The average relative freshwater consumption was apparently higher in 2013 at 621 m^3/kilotonne throughput vs 467 m^3/kilotonne throughput in 2010. All comparison with 2010 water use data could, however, reflect the different population of refineries reported under the 2010 and 2013 surveys, or differences in the way that the surveys were designed (the 2013 survey captured more detailed information on water uses).

The 2013 discharge quantity data confirmed previous survey observations that effluent quantities have been significantly reduced throughout the years, both in terms of absolute reported quantity and for the potentially most meaningful indicators of tonne of effluent per tonne of capacity or throughput. Discharge quantities had decreased from 2010 to 2013 with regard to process water (from 0.56 to 0.47 tonne/tonne capacity and from 0.67 to 0.48 tonne/tonne throughput, respectively) and with regard to all reported discharges (from 1.9 to 0.92 tonne/tonne capacity and from 2.2 to 0.93 tonne/tonne throughput, respectively) excluding once-through cooling water.

With regard to effluent quality, the results of the 2013 survey are consistent with the long- term trend towards reduced discharge of oil (reported as Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)). While total and relative oil discharge (i.e. normalised to throughput) are lower relative to the 2010 and 2008 survey years at 354 tonnes and 0.71 g/tonne throughput, respectively, fewer refineries participated in the 2013 survey and so the discharge data are not directly comparable. For the 59 refineries that reported under both the 2010 and 2013 survey average relative TPH discharge decreased by 28% from 2010 to 2013.

From 1993 to 2013 the survey data indicate a large decrease in total and relative discharge of ammonia and phenols, and a smaller decrease in total nitrogen. For Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC) survey data from 2000-2013 indicate an overall decrease in relative load.

In the 2013 survey, for the first time, a section on high level information on costs associated with refinery water use was included. Average intake and discharge costs were ca. 0.3 €/m^3 and 0.1 €/m^3, respectively, with 69 refineries reporting intake costs and 52 discharge costs.

5. GLOSSARY

BAT	Best Available Techniques
BOD	Biochemical Oxygen Demand
BREF	BAT Reference Document
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CAPEX	Capital Expenditure
COD	Chemical Oxygen Demand
E-PRTR	The European Pollutant Release and Transfer Register
EU	European Union
EU-28	Abbreviation of European Union (EU) which consists a group of 28 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

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