Final Report

Solid Waste Analysis from Veitur Wastewater Treatment Plants

Klettagarðar, Ánanaust, and Kjalarnes, 2025

About This Report

Title:

Solid Waste Analysis from Veitur Wastewater Treatment Plants

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1. Background and Scope

1.1 Project Background and Legal Requirements

1.1.1 Introduction

ReSource International ehf (RSI) has agreed to undertake the implementation of solid waste sampling on behalf of Veitur. This sampling was conducted at three solid waste sites around Reykjavík. These three sites are Klettagarður (KL), Ánanaust (ÁN), and Kollagrund (KO) in Kjalarnes. Sampling and analysis of solid waste is required by Veitur every four years. Sampling and reporting of the results must be conducted in accordance with Regulation 798/1999 on sewers and wastewater. Additionally, optional measurements of the waste were sampled and reported.

The sewage treatment plants are all preliminary treatment plants, i.e. screened material, sand and fats are cleaned from the water. First, the coarsest material is filtered, or screened, from the sewage using sieves (<3mm); this waste is generally called screened waste (ristaúrgangur). After the coarse material is filtered, the sewage goes into sand and grease separators. The sand falls to the bottom while the grease floats to the top. These, screened, sand, and fat wastes, make up the three types of solid waste treated at these plants and must be sampled and analyzed in accordance with the operating permit requirements (1-3).

Most documentation regarding this project, including previous tests and the operating permit, refer to fat wastes, or "fituúrgangur." However, it is RSI's determination that this terminology is not fully appropriate for what it refers to. These wastes are theoretically composed almost entirely of fats, but it is clear from visual inspection that this waste contains a significant amount and variety of organic material besides lipids. Therefore, it is more appropriate to refer to fat wastes as "floating fraction" wastes instead; this terminology will occur throughout this report.

The treatment plant in Klettagarður treats wastewater from northern Reykjavík and Mosfellsbær. The treatment plant at Ánanaust treats wastewater from southern Reykjavík, Seltjarnarnes, Kópavogur, and part of Garðabær. Finally, the treatment plant at Kollagrund treats wastewater from Kjalarnes.

1.1.2 Operating Permits and Legal Requirements

According to the operating permits of the three treatment plants, Veitur is required to measure the amount of solid waste by continuous recording and weighing. Additionally, collection and analysis of samples of floating fraction, screening fraction, and sand wastes is required every four years. These wastes must be tested for various parameters. As no equipment is currently available to measure the amount of waste continuously, Veitur instead weighs each discharge of material. Table 1 provides a breakdown of the parameters to be analyzed.

Table 1 – Parameters to be analyzed in accordance with the operating permits of wastewater treatment plants.

Parameter	Method	Frequency
Solid waste quantity	Continuous measurement and weighing	Continuous, and/or as needed
Dry matter, COD, fat, TP, TN, selected inorganic trace elements (As, Ag, Cd, Cr, Cu, Hg, Ni, Pb, Zn)	Sample collection and laboratory analysis	Every four years

Further details on the methodologies for sample collection and analysis are not explicitly defined in the operating permit, except for the following:

- Control methods shall comply with the requirements of Regulation 789/1999 about sewers and wastewater.
- Recognized international research methods should be used that aim to ensure that the quality of samples does not deteriorate between the time they are collected and the time they are analyzed.
- Methods other than those mentioned in the above regulation may be used, provided that it can be demonstrated that comparable results are obtained.

The requirements set out in Regulation 789/1999 on sewers and wastewater regarding monitoring methods are as follows:

"27.1 Eftirlitsaðili gerir eða lætur gera eftirlitsmælingar:

a. Á fráveituvatni og losun frá skólphreinsistöðvum fyrir þéttbýli til að staðfesta að farið sé að þeim kröfum sem settar eru fram í B-hluta, I. Viðauka í samræmi við eftirlitstilhögun þá sem mælt er fyrir um í D-hluta, I. Viðauka

27.2 Hollustuvernd ríkisins gefur út leiðbeiningar um sýnatöku og rannsóknir miðað við vatn fráveituvatns og mismunandi aðstæður.

27.3 Að öðru leyti gilda ákvæði reglugerðar um mengunarvarnareftirlit um eftirlit og verkaskiptingu."

According to Part D of Annex I to the Regulation, it is stated that monitoring methods must at least comply with the requirements set out, but that other methods may be used if it can be demonstrated that the results will be comparable. The monitoring method is described as follows (translated from Icelandic): *"… samples are taken at regular intervals over a 24-hour period based on the flow rate or rate per 24 hours at a fixed point in the outlet, and if necessary, in the inlet of the treatment plant…."*

Optional measurements of wastes can also be performed. For example, the most likely way to dispose of the floating fraction, or fat wastes would be incineration. Therefore, it would be useful to have an understanding of the calorific value of the waste, which could be useful to a buyer seeking feed for incinerators. Ash content is another example of an optional measurement. RSI recommended conducting these optional analyses on the waste samples and Veitur agreed. Moreover, portions of all samples are to be kept frozen in long-term storage in case further analysis is needed or requested in the future.

1.2 Previous Studies

According to Veitur's operating permit, sampling and analysis of solid waste are to be carried out every four years. The last such studies were carried out in 2014 by Verkís on behalf of Veitur. Subsequent studies should have been conducted in 2018 and 2022, but they were not.

In 2010 and 2014, Verkís was responsible for the sampling and analysis of solid waste from Klettagarður and Ánanaust and submitted an annual monitoring report. In the case of the sand and screen filtered wastes, the reports do not state whether the measurements were carried out directly on the waste or on the leachate from it. In addition, Veitur's annual monitoring reports show the total amount of solid waste for each year, either divided by waste category or totals from each plant.

In 2023, Efla conducted research on floating fraction wastes from Klettagarður and Ánanaust with the aim of discovering potential uses. The parameters examined were dry matter and fat (which the operating permit specifies must be tested), but also ash, free fatty acids, peroxides, and anisidine values, which are not required by the operating permit.

Also in 2023, a feasibility study was conducted on the utilization of sand waste from wastewater treatment plants. The report summarized the results of experiments carried out between March 2022 and September 2023 and sought to answer the question of whether it is economical and safe to use residual sand from the treatment plants in Klettagarður and Ánanaust for projects within the company, for example, as a substrate for sewer pipes. In that report, samples of sand were taken and analyzed for the following parameters: dry matter, COD, TOC, TP, TN, Ni, Pb, Zn, Hg, Cr, Ag, and As. All measurements were made on the leachate, but not directly on the sand itself. These parameters are all specified in the operating permit, but only fat measurements were needed to meet all the permit requirements regarding sand waste. Given that this analysis was sufficiently thorough to meet the requirements of the operating permit, sand waste is not tested as a part of this project.

Given this information, some requirements of the operating permit have been met in 2023, but the rest have not been met since 2014. According to the operating license, the parameters not tested since 2014 are now overdue and should be carried out as soon as possible (Table 2).

Table 2 - Parameters to be tested in 2025

WWTP Sites	Parameters to be controlled
Klettagarður	✓ Floating fraction wastes: COD, TP, TN, Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn ✓ Screen filtered wastes: Solid material, COD, fat content, TP, TN, Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn
Ánanaust	✓ Floating fraction wastes: Solid material, COD, fat content, TP, TN, Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn ✓ Screen filtered wastes: Solid material, COD, fat content, TP, TN, Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn
Kjalarnes[1]	✓ Floating fraction wastes: Total amount (kg), solid matter, COD, fat content, TP, TN, Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn ✓ Screen filter wastes: Total amount (kg), solid matter, COD, fat content, TP, TN, Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn

2. Methodology

2.1 Equipment

A full list of equipment used during the campaign is presented here:

- Twelve 5.6 L, HCl-washed, plastic buckets
- One >15 L, HCl-washed, plastic tub
- Large shovel
- Small shovel
- Powder- and nitrile-free latex gloves
- Helmets
- Respiratory masks
- High-visibility clothing
- Field book
- Waterproof pen or marker
- Camera

[1] *The amount of waste in kg collected at Kjalarnes has been weighed with waste from other treatment plants and therefore there is no data on the amount collected only at this facility. According to the staff, waste from Kjalarnes is measured this way due to the small amount that accumulates. It is recommended to remedy this by weighing this waste on its own to fully comply with the provisions of the operating permit.*

- Scale

It is important to use caution when collecting samples and to be as safe as possible. Appropriate personal protective equipment (PPE) was worn at all times, including respiratory masks, helmets, gloves, boots, and clothing. All safety regulations were followed.

Gloves that were worn were powder free latex, as using gloves containing powder or nitrile would have risked sample contamination.

2.2 Methodology and Site Descriptions

As the regulations do not specify the period of sampling solid waste within the year, it is recommended to randomly select the week of the year in which the sampling should take place. Sampling was conducted on 10 and 11 February 2025.

As per the operating permit, a composite sample of the waste should be taken over a full 24-hour period so that the weight of the composite sample is at least 1,000-1,200 grams, and it is recommended to take at least six samples at random intervals over that period. However, in consultation with Veitur, it was determined that due to the slow rate of accumulation of wastes, a composite sample could be acquired by collecting samples from different parts of the waste and mixing them.

It is RSI's determination that the 24-hour sampling period stipulated in the operating permit is not appropriate or consistent with the physical conditions at the sites, and that the operating permit should be amended to reflect conditions as they exist. A further discussion of this is to be included in a separate memorandum.

2.2.1 Sampling Methodology for Floating Fraction Wastes

Samples were collected from the grease traps, where floating fraction wastes accumulate. At Klettagarður and Ánanaust, these grease traps are deep pits in the floor. At Kjalarnes, this is a much shallower pit. Due to small differences in the structural layout of the facilities, there were slight differences in the sampling method at each location.

Klettagarður

At Klettagarður, there is a manhole hatch in the floor with a ladder leading down to a platform where a sampler can safely stand in the pit. RSI personnel descended into the pit and gathered several large scoops of floating fraction wastes from the grease traps and piled them into a large tub. This was done at two different spots within the facility. The samples collected from each spot were collected into the same large tub with approximately 20kg of material. Once the samples were collected, they were thoroughly mixed and then distributed into two, 5.6 L acid-washed buckets. These buckets were put on a scale and weighed in order to get two samples with 1,500 ± 150 grams per bucket. One sample was designated

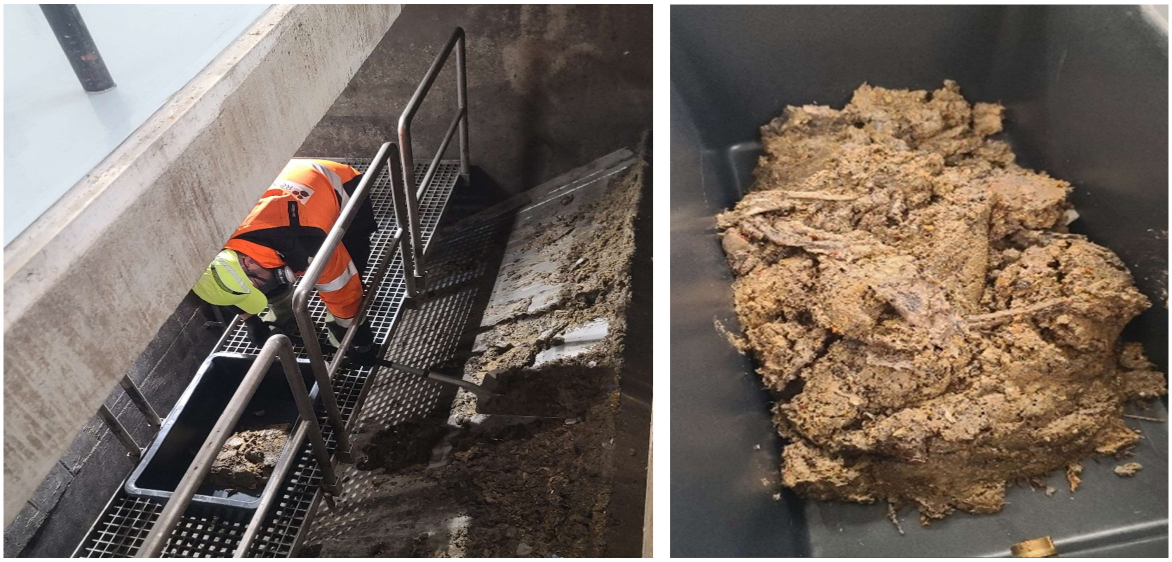

Figure 1 (left) – RSI personnel collecting floating fraction samples at Klettagarður. The upper floor can be seen in the top left portion of the photo, with the platform for collecting samples seen below.

Figure 1 (right) – The sample of floating fraction wastes after collection, but prior to mixing. This image illustrates why it is more appropriate to refer to this as floating fraction wastes rather than fat wastes, as close inspection of the image shows a variety of material in the sample besides fats, including bits of food and a piece of textile.

for laboratory analysis and the other was to be put into long-term storage in a freezer by Sýni. The remaining unused material was returned to the grease traps.

Ánanaust

While the Ánanaust facility is largely similar to Klettagarður, one significant difference is the lack of a platform within the grease trap on which personnel can stand. Thus, the sampling method at this location differed somewhat. The samples were only accessible through a hatch on the floor. The sampling material itself sits approximately three meters below the opening. No available tool was long enough to be able to reach the material and transfer it into a large tub for mixing. Instead, an acid-washed bucket was attached to a rope and lowered down into the pit. The bucket was carefully dragged from above through the sample, which allowed the material to accumulate in the bucket.

The bucket was then raised to the surface and the sample transferred to a clean bucket, which was then weighed in the same manner as the buckets for Klettagarður. This process was done twice to acquire two, approximately 1,500 g samples, for a total sample size of approximately 3.0 kg. Like the KL sample, one sample was to be sent out for laboratory analysis, and the other was to be put in long-term storage in a freezer.

Figure 2 – RSI personnel preparing the rope and bucket system used at Ánanaust.

Kjalarnes

The facility at Kjalarnes differs significantly from Klettagarður and Ánanaust. While the floating fraction wastes are also in a pit, it is far shallower than those at KL and ÁN and is reachable by hand. RSI personnel were able to reach the samples by hand from an access point above the hatch for the grease trap.

Samples were scooped using shovels into a clean, acid-washed bucket. The consistency of the floating fraction waste was significantly wetter than those collected at KL and ÁN, which made scooping the samples difficult. Nevertheless, a bucket was filled and weighed to be approximately 1,500 g of waste. Due to the lack of enough sample material, only one bucket was collected here, for a total of 1.5 kg. The sample was then sent for analysis.

Figure 3 – RSI personnel collecting samples at Kjalarnes with the assistance of Veitur personnel.

2.2.2 Sampling Methodology for Screen Filtered Wastes

Klettagarður

At Klettagarður, a large, clean tub was placed on the floor under the chute where the screen filtered wastes are expelled. After positioning the tub, the door of the chute was opened, allowing the screen filtered wastes to be collected.

Once the tub was sufficiently filled, mixing by hand with a small shovel was undertaken to homogenize the sample. Pieces of debris were often visible during the mixing process, including wood, textiles, and plastic, all of which are likely to have been included in the final sample submitted for analysis.

After the sample was homogenized, some of the sample was transferred into two 5.6 L, acid-washed buckets for submission to the laboratory. Each bucket held approximately 1,500 g of material for a total sample size of approximately 3.0 kg. One sample was submitted for laboratory analysis and the other was submitted for long-term storage in a freezer. The remaining, unused samples were disposed of by Veitur personnel.

Figure 5 (left) – Screen filter wastes falling from the chute into the tub.
Figure 6 (upper right) – A piece of wood debris in the screen filter wastes. Microplastics can be seen in the sample in the background.
Figure 7 (lower right) – RSI personnel transferring the sample to a smaller bucket.

Ánanaust

The sampling method at Ánanaust was very similar to that at Klettagarður, except that instead of positioning a tub beneath the chute, waste was collected in its usual repository and transferred to a large tub by shovel. This was done because the structural layout of the equipment did not allow for direct deposition to the tub from the chute.

Again, pieces of debris including wood, plastic, and textiles were observed in the screen filtered wastes, and it is likely that some of this debris was in the final samples. The screen filtered wastes were again hand mixed in the large tub to ensure homogeny among the sample and then transferred to two 5.6 L buckets. Each sample in the end weighed approximately 1,500 g for a total of 3.0 kg, one was submitted for analysis and the other was submitted for long-term storage.

Figure 8 – RSI personnel mixing the screen filter wastes in a tub at Ánanaust. Mixing the sample ensures homogeny.

Kjalarnes

Kjalarnes, like the other two facilities, also has a chute through which the screen filtered wastes are expelled. However, due to the low population that this facility serves, very little waste is actually produced. A large bag is attached to the chute at all times; this bag catches the screen filtered wastes as they are expelled. According to conversations with Veitur personnel, it can take up to a year to fill an entire bag. The sample was taken from the bag that was attached to the chute, but due to the slow accumulation of material in the bag, it is not possible to determine the age of the material in the bag.

The portion that was set aside by Veitur was transferred into two 5.6 L buckets and weighed. The samples were nearly 1,500 kg each, for a total of approximately 3.0 kg. One sample was submitted for analysis and the other was put into long-term storage.

Figure 9 (left) – The white plastic back attached to the chute where screen fraction wastes are expelled.
Figure 10 (right) – The waste collected from Kjalarnes before being transferred to buckets.

2.2.3 Laboratory Analysis

Some of the parameters that are required by the operating permit for analysis are beyond the capacity of any laboratories in Iceland, especially chemical oxygen demand for solid fraction. Therefore, in order to analyze these parameters, the samples needed to be outsourced. In conjunction with the Icelandic laboratory Sýni, these samples were shipped to Eurofins in Germany for analysis.

A summary of the collected samples for both floating fraction wastes and screen filtered wastes can be seen in Table 3.

Table 3 – Summary of samples collected from all sites.

Location	Waste Type	Weight (g)	Purpose
Klettagarður	Floating Fraction	1,584	Sent for analysis
		1,546	Storage
	Screening fraction	1,569	Sent for analysis
		1,598	Storage
Ánanaust	Floating Fraction	1,692	Sent for analysis
		1,645	Storage
	Screening fraction	1,422	Sent for analysis
		1,599	Storage
Kjalarnes	Floating Fraction[2]	637	Sent for analysis
		625	Storage
	Screening fraction	1,645	Sent for analysis
		1,376	Storage

Laboratory analyses are undertaken using a variety of methods. The parameters being tested include all those required by the operating permit, plus calorific value and ash content. These two parameters, though not required by the operating permit, were assessed by RSI to be potentially useful results. Veitur agreed, and these parameters were added to the requested analysis. A thorough list of the parameters tested in the laboratory is as follows (per sample):

- Lipophilic substances [solid waste] calculated ma.-% dw (screen filtered wastes only)
- Dry substance [solid waste] (calc.) Ma.-%
- Lipophilic substances [solid waste]ma.-% (screen filtered wastes only)
- COD [leachate solid waste] calc. mg/kg dw
- Preparation of leachate 10:1 [solid waste]
- Chemical oxygen demand [leachate solid waste]mg O2/l
- Nitrogen [solid waste] ma.-% dw
- Nitrogen [solid waste] ma.-%
- Nitrogen [solid waste] [measurem.]
- Water content [solid waste] %
- Phosphorus [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Microwave-pressure digestion [13656, HNO3+HF] [solid waste]
- ICP-MS run [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Arsenic [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Cadmium [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw

[2] *Due to the low amount of material available, only one sample of 1,262 g of floating fraction wastes was collected at Kjalarnes and was then split into two smaller samples by the laboratory.*

- Chromium [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Copper [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Mercury [solid waste] [DIN EN 13656, , HNO3+HF] mg/kg dw
- Nickel [solid waste] [DIN EN 13656, , HNO3+HF] mg/kg dw
- Lead [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Zinc [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Sodium [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Potassium [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Calcium [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Magnesium [solid waste] [DIN EN 13656, HNO3+HF] mg/kg dw
- Silver [solid waste] [DIN EN 13657] mg/kg dw
- ICP-MS run [solid waste] [DIN EN 13657, KöWa] mg/kg dw
- Microwave-pressure digestion [13657, KöWa] [solid waste]
- Sulphur (organic mat.) [solid waste] [measurem.]
- IC run halogens (wo Iodine) [solid waste]
- TOC (total organic carbon) [solid waste] ma.-% dw
- TOC (total organic carbon) [solid waste] ma.-%
- GCVHO [solid waste] MJ/kg
- GCVHO [solid waste] [measurem.]
- Ash content 550°C [solid waste] [measurem.]

3. Results

3.1 Overview

3.1.1 Floating Fraction Waste

The quantities of waste recovered at the various sites were generally agreeable with each other. For both screening and floating fraction wastes, approximately 3,000 g of waste were recovered and split at all sites, except at Kjalarnes. The Kjalarnes site did not have enough floating fraction waste to recover a full 3,000 g to split.

The floating fraction waste collected at Kjalarnes differed significantly from those collected at the other two sites. Firstly, the waste here was in a significantly lower quantity. This was to be expected, as this facility only serves a few hundred people whilst the other two sites serve large, dense areas of Reykjavík, meaning significantly more waste is produced. Secondly, the composition of the waste was different. While the wastes collected at the other two sites were dense and paste-like in texture, the floating fraction waste collected at Kjalarnes was watery and unformed.

The full results of the analysis are presented in Table 4.

Table 4 - Results of floating fraction waste analysis from Eurofins Germany

Parameter	Unit	Klettagarður	Ánanaust	Kjalarnes
Dry matter	% (w/w)	41.4	49.4	12.1
Moisture	% (w/w)	58.6	50.6	87.9
Gross calorific value (qV, gr)[3]	MJ/kg Raw Product	15.7	17.4	4.16
Total nitrogen	Ma. -% Raw Product	0.38	0.33	0.17
Total nitrogen	% (w/w) dm	0.91	0.67	1.44
Sulfur (S), total	% (w/w) dm	0.069	0.102	0.152
Arsenic (As)	mg/kg dw	< 0.8	4.5	< 0.8
Lead (Pb)	mg/kg dw	< 2	< 2	4
Cadmium (Cd)	mg/kg dw	< 0.2	< 0.2	< 0.2
Calcium (Ca)	mg/kg dw	8,240	6,420	9,850
Chromium (Cr)	mg/kg dw	10	11	8
Potassium (K)	mg/kg dw	421	167	602
Copper (Cu)	mg/kg dw	10	10	18
Magnesium (Mg)	mg/kg dw	1,080	732	1,030
Sodium (Na)	mg/kg dw	1,340	437	897
Nickel (Ni)	mg/kg dw	4	5	5
Phosphorus (P)	mg/kg dw	1,230	718	2,660
Mercury (Hg)	mg/kg dw	< 0.07	< 0.07	< 0.07
Zinc (Zn)	mg/kg dw	62	89	147
Silver (Ag)	mg/kg dw	< 5	< 5	< 5
TOC (total organic carbon)	Ma. -% Raw Product	26	36	8.3
TOC (total organic carbon)	% (w/w) dm	63	73	69
COD (chemical oxygen demand)	mg/l	2,900	2,640	8,220
COD (chemical oxygen demand)	mg/kg dw	29,000	26,400	82,200

[3] *(qV, gr) net calorific value corrected for nitrogen, sulfur, halogens, according to DIN CEN/TS 16023, DIN SPEC 19524.*

3.1.2 Screened Wastes

Table 5 – Results of screen filtered waste analysis from Eurofins Germany.

Parameter	Unit	Klettagarður	Ánanaust	Kjalarnes
Dry matter	% (w/w)	58.0	59.2	94.6
Moisture	% (w/w)	42.0	40.8	5.4
Gross calorific value (qV, gr)[4]	MJ/kg Raw Product	15.2	13.3	22.8
Total nitrogen	Ma. -% Raw Product	0.93	0.71	0.97
Total nitrogen	% (w/w) dm	1.60	1.20	1.03
Arsenic (As)	mg/kg dw	1.5	< 0.8	< 0.8
Lead (Pb)	mg/kg dw	4	< 2	7
Cadmium (Cd)	mg/kg dw	0.3	< 0.2	< 0.2
Chromium (Cr)	mg/kg dw	77	39	29
Copper (Cu)	mg/kg dw	56	22	22
Nickel (Ni)	mg/kg dw	22	23	17
Phosphorus (P)	mg/kg dw	3,600	2,910	2,470
Mercury (Hg)	mg/kg dw	0.12	0.11	0.10
Zinc (Zn)	mg/kg dw	192	102	166
Silver (Ag)	mg/kg dw	< 5	< 5	< 5
Low volatile lipophilic compounds	Ma. -% Raw Product	2.4	1.3	2.1
Low volatile lipophilic compounds	% (w/w) dm	4.2	2.2	2.3
COD (chemical oxygen demand)	mg/l	4,050	1,610	2,050
COD (chemical oxygen demand)	mg/kg dw	40,500	16,100	20,500

3.2 Comparative Analysis

3.2.1 Floating Fraction Wastes

The dry matter, moisture, gross calorific value (GCV), and COD at Klettagarður and Ánanaust were generally in agreement. The samples at these two locations ranged from approximately 41-49% dry matter and 51-59% moisture. The GCV of these samples ranges

[4] *(qV, gr) net calorific value corrected for nitrogen, sulfur, halogens, according to DIN CEN/TS 16023, DIN SPEC 19524.*

from 15.7-17.4 MJ/kg of raw product, meaning that they may be good as fuel sources for incinerators. However, the results at Kjalarnes were significantly different. Dry matter here was only 12.1% and moisture was 87.9%. The GCV was 4.16 MJ/kg of raw product, meaning it is likely a poor source of fuel for incinerators.

COD was also very similar between KL and ÁN, being 29,000 and 26,400 mg/kg dry weight, respectively, but at Kjalarnes was 82,220 mg/kg dry weight; significantly higher than the other two sites.

Concentrations of heavy metals were generally similar across all three sites, with no single heavy metal parameter being significantly out of balance. Concentrations were generally highest at Kjalarnes, where phosphorous (P), potassium (K), calcium (Ca), zinc (Zn), and copper (Cu) were higher than at the other sites. The most noteworthy may be the concentration of arsenic (As) at Ánanaust, which was 4.5 mg/kg dry weight, while at the other two sites the concentrations of this contaminant were below the detection limit. Total organic carbon (TOC) was also generally in agreement between all three sites, ranging from 63-73%.

3.2.1 Screen Filtered Wastes

Like with the floating fraction wastes, the results from KL and ÁN were very similar with regard to moisture content and GCV. Dry matter ranged from approximately 58-59% and moisture from 41-42%. The GCV ranged from 13.3-15.2 MJ/kg of raw product. However, again like with the floating fraction wastes, the moisture composition at Kjalarnes was significantly different. Dry matter here was 94.6% and moisture was 5.4% with a GCV of 22.8 MJ/kg.

The content of metals was generally higher at KL than at ÁN or KO, with concentrations of arsenic, lead, chromium, copper, phosphorous, and zinc all being significantly higher at KL than at the other two sites. Moreover, of the three sites, KL had the highest concentrations of metals for all tested parameters except for lead (Pb) which was highest at Kjalarnes.

Chemical oxygen demand was also about twice as high at KL as it was at the other two sites. The COD at KL was 40,500 mg/kg dry weight, while at the other two sites it ranged from 16,100 to 20,500 mg/kg dry weight.

3.3 Explanation of Chemical Oxygen Demand (COD) Analysis

Eurofins Germany is an accredited laboratory that conducted all chemical analysis performed on the collected samples, including chemical oxygen demand (COD). COD analysis was done using the DIN 38409-41 (H41):1980-12 method, which is a German standard for measuring COD in water, wastewater, and sludge. COD is a measure of the amount of oxygen required to break down organic matter in water. This method involves adding a chemical reagent to a water sample, which reacts with organic matter and consumes oxygen. The amount of oxygen consumed is then measured to determine the COD level. This helps assess the pollution level and the effectiveness of water treatment processes.

For screen filtered wastes, which are mostly dry, the sample preparation involves ensuring the waste is adequately homogenized and representative of the entire batch. This might require grinding or mixing to achieve a uniform sample before adding the chemical reagent.

In contrast, floating fraction wastes, which are generally wet, require careful handling to account for the water content. The wet nature of these wastes means that the sample might need to be filtered or decanted to separate the liquid phase from the solid phase. The liquid phase can then be tested directly, while the solid phase might need to be dried or homogenized before testing. This ensures that the COD measurement accurately reflects the organic matter present in both the liquid and solid components

4. Discussion

4.1 Interpretations and Implications

At Kjalarnes, the sampling method was again different, as was the consistency of the samples. The floating fraction wastes collected here had considerably higher water content than those collected at KL or ÁN. The wastes collected at KL and ÁN had a paste-like consistency, while the waste collected at KO was watery. High moisture content can dilute organic and inorganic components, leading to lower measured concentrations of the various tested parameters. Additionally, it may lead to results that are difficult to compare or inconsistent with the other sampling locations.

4.2 Treatment Potential

4.2.1 Anaerobic Digestion (Biomethane)

Biomethane production from solid waste presents a promising opportunity for sustainable energy generation. Biomethane, a near-pure source of methane, can be produced through the anaerobic digestion of organic matter in an oxygen-free environment. This process involves the breakdown of organic material by naturally occurring microorganisms, resulting in biogas, which primarily consists of methane and carbon dioxide ("An introduction to biogas and biomethane – Outlook for biogas and biomethane," n.d.). The biogas can then be upgraded to biomethane by removing contaminants and moisture, making it suitable for use as a renewable natural gas.

The solid waste generated at Veitur's wastewater treatment plants (WWTP), particularly the floating fraction and screen filtered wastes, contains significant amounts of organic material that can be utilized for biomethane production. The high dry-matter content and organic carbon levels in these wastes indicate their potential as feedstock for anaerobic digestion. However, the presence of contaminants such as plastics, textiles, and heavy metals may pose challenges to the efficiency and stability of the anaerobic digestion process circular economy. Therefore, it is essential to implement effective pre-treatment methods to remove these contaminants and optimize the process parameters, such as temperature, pH, hydraulic retention time, and organic loading rate to maximize biogas yield and methane quality (Kumar et al., 2025).

Biomethane production from solid waste not only provides a renewable energy source but also contributes to the reduction of greenhouse gas emissions and minimizes landfill waste. By converting organic waste into biomethane, Veitur can enhance its sustainability efforts and support the transition to a circular economy.

4.2.2 Incineration

Incineration is another viable option for the treatment of solid waste generated at the WWTPs. Incineration involves the combustion of organic substances in waste materials at high temperatures in a controlled environment, resulting in the conversion of waste into heat, flue gases, and ash ("A Complete Guide to Solid Waste Incineration," 2024). This process significantly reduces the volume and mass of waste, making it an effective method for waste management especially in densely populated areas with limited landfill space.

The calorific value of the floating fraction and screen filtered wastes at Klettagarður and Ánanaust suggests their potential for incineration. The high gross calorific values (GCV) of these wastes indicate that they can serve as fuel sources for waste-to-energy schemes, where the heat generated during combustion can be used to produce electricity (Nidoni, n.d.). However, the lower GCV of the floating fraction waste at Kjalarnes may limit its suitability for incineration.

Incineration offers several benefits, including volume reduction, energy recovery, and the destruction of pathogens and harmful toxins ("A Complete Guide to Solid Waste Incineration," 2024). By diverting waste from landfills, incineration helps conserve landfill space and reduce the environmental impact of landfills. Additionally, waste incineration can partially offset the need for fossil fuels, potentially leading to lower greenhouse gas emissions.

4.3 Waste Handling Method

During wastewater treatment, the floating fraction relatively solid falls at the bottom of a slopped bit and is pumped with a vacuum truck. Based on the job description given by Veitur ("Staðlað verklag Veitna við losun fitu úr fitugryfju í Klettagörðum"), water needs to be applied to be able to clean the pit during collection but also to get the floating fraction viscous enough to be pumped with the vacuum truck.

Therefore, the value for potential reuse is decreased. A removal system that does not include water adding is recommended and should be studied further along with a costs and benefits analysis.

5. Conclusions

The solid waste analysis conducted at the wastewater treatment plants (WWTP) of Veitur in Klettagarður, Ánanaust, and Kjalarnes has provided valuable insights into the composition and potential treatment options for the various types of solid waste generated. The study highlights several key findings and recommendations. Firstly, the waste composition varied significantly across the sites. Floating fraction wastes at Klettagarður and Ánanaust had a paste-like consistency with high dry matter content, while Kjalarnes had significantly wetter waste with lower dry matter content. Screen filtered wastes at Klettagarður and Ánanaust had similar dry matter content, but Kjalarnes had a much higher dry matter content. The calorific value of the wastes also varied, with floating fraction wastes at Klettagarður and Ánanaust showing potential for incineration, while Kjalarnes was less suitable. Screen filtered wastes showed potential for incineration across all sites, with Kjalarnes having the highest calorific value. Chemical oxygen demand (COD) levels were highest at Kjalarnes for floating fraction wastes and at Klettagarður for screen filtered wastes. Heavy metal concentrations were generally higher at Kjalarnes, with notable levels of phosphorus, potassium, calcium, zinc, and copper. Arsenic levels at Ánanaust were higher than at the other sites.

Based on these findings, several recommendations were made. Improved screening processes are needed to better remove solids attached to fats, reducing the presence of debris such as textiles, plastics, and wood in the floating fraction wastes. Implementing a removal system for floating fraction wastes that does not involve adding water could maintain the potential for reuse and incineration. The calorific value and moisture content of wastes should be considered when evaluating their suitability for incineration, and drying the wastes may improve their viability and environmental friendliness. Organic content within the solid waste fractions also presents interesting potential for anaerobic digestion and the production of biomethane.

The implications of this study underscore the importance of regular monitoring and efficient waste handling practices at WWTPs. By improving screening processes and considering the calorific value and moisture content of wastes, Veitur can enhance the potential for waste reuse and energy recovery, contributing to more sustainable waste management practices.

6. References

Arnar, Birgir Tómas, Vala Jónsdóttir, and Arnór Þórir Sigfússon. "Skólphreinsistöðvar - Sýnataka og mælingar - Árleg yfirlitsskýrsla 2018 - Akranes, Borgarnes og Kjalarnes." Reykjavík, 2018. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt9fd74f0d89fab379/6387392c4ce48829fd199dc2/skolphreinsistodvar_-_synataka_og_maelingar_-_arleg_yfirlitsskyrsla_2018_-_akranes_borgarnes_og_kjalarnes.pdf.

"Skólphreinsistöðvar - Sýnataka og mælingar - Árleg yfirlitsskýrsla 2018 - Reykjavík." Reykjavík, 2018. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/bltbec051ee1dc623dd/6387392c3b057b0ff29552a9/skolphreinsistodvar_-_synataka_og_maelingar_-_arleg_yfirlitsskyrsla_2018_-_reykjavik.pdf.

"Skólphreinsistöðvar - Sýnataka og mælingar - Árleg yfirlitsskýrsla 2020 - Akranes, Borgarnes og Kjalarnes." Reykjavík, 2020. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt57f5c9b3e7509fe3/63873941557686262b9c20c1/2020-arleg_yfirlitskyrsla-abk_stodvar.pdf.

"Skólphreinsistöðvar - Sýnataka og mælingar - Árleg yfirlitsskýrsla 2020 - Reykjavík." Reykjavík, 2020. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt3a68da8a6aef7236/63873941a74a9a379fe08a9c/2020-arleg_yfirlitskyrsla-reykjavikur_stodvar.pdf.

Arnar, Birgir Tómas, Snorri Þórisson, and Arnór Þórir Sigfússon. "Skólphreinsistöðvar - Sýnataka og mælingar - Árleg yfirlitsskýrsla 2010 - Reykjavík." Reykjavík, 2010. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt3eaf1688f0f8aa5b/64cd16724e4dd506bb9eefda/Sk%C3%B3lphreinsist%C3%B6%C3%B0var_s%C3%BDnataka_og_m%C3%A6lingar_%C3%A1rleg_yfirlitssk%C3%BDrsla_2010_Reykjav%C3%ADk.pdf.

"Skólphreinsistöðvar sýnataka og mælingar - árleg yfirlitsskýrsla 2014 - Reykjavík." Reykjavík, 2014. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt8925a7767c814154/63873941726ff50de9be3931/2014_ananaust_og_klettagardar_arleg_yfirlitsskyrsla_0.pdf.

EPA. "Hazardous Waste Test Methods - SW-846 - Chapter Nine - Sampling Plan," 1986.

Heilbrigðiseftirlit Reykjavíkur. "Starfsleyfi - Skólphreinsistöð Að Ánanaustum," 2020.

"Starfsleyfi - Skólphreinsistöð Að Klettagörðum," 2020.

"Starfsleyfi - Skólphreinsistöð Kjalarnesi," 2014.

Höskuldsson, Páll. "Fita Úr Fráveitukerfi - Undirbúningur Útboðs." Minnisblað. Reykjavík, 2024.

Koottatep, Thammarat, Amédé Ferré, Saroj Chapagain, Krailuck Fakkaew, and Linda Strande. "Faecal Sludge Sample Collection and Handling." In *Methods for Faecal Sludge Analysis*. London: IWA Publishing, 2021.

Ólafsdóttir, Sædís, Hlöðver Stefán Þorgeirsson, Snorri Jökull Egilsson, and Dávid Vereb. "Feasibility Assessment on Sand Utilization from Wastewater Treatment Plants: Test Material from Klettagarðar and Ánanaust." Reykjavík, 2023. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt4d925938f0e05321/65799a978929e4040ae5eb55/Feasibility_assessment_on_sand_utilization_from_wastewater_treatment_plants.pdf.

Ólafsdóttir, Sædís, Hlöðver Stefán Þorgeirsson, Huldar Hlynsson, and Páll Höskuldsson. "Árleg Yfirlitsskýrsla - Sýnatökur og Greiningar 2022." Veitur, 2022.

Umhverfis- og auðlindaráðuneytið. "Aðgerðaáætlun í Loftslagsmálum." Stjórnarráð Íslands, 2020.

Umhverfisráðuneyti. "Reglugerð 798/1999 Um Fráveitur og Skólp." Umhverfisráðuneytið, 1999. https://www.reglugerd.is/reglugerdir/allar/nr/798-1999.

Umhverfisstofnun. "Leiðbeiningar um eftirlit og vöktun vegna Fráveitu," 2022.

Þorgeirsson, Hlöðver Stefán, Sædís Ólafsdóttir, Páll Höskuldsson, and Anna Snjólaug Valgeirsdóttir. "Sýnatökur og -Greiningar Fráveitu - Árleg Yfirlitsskýrsla Vegna Rannsókna Ársins 2021." Reykjavík: Veitur, 2021. https://eu-assets.contentstack.com/v3/assets/blt5bf0023ca96cf071/blt11ad80bcacddf678/6387394289162b1639c6ca53/arleg_yfirlitskyrsla_veitna_2021_uppfaert.pdf

Appendix 1 – Past Results

	Klettagarðar														mg/kg af ÞE								
	Dags	Aðili	Heildar-magn (kg)	Þurrefni % (w/w)	COD		TOC mg/L	Fita % af ÞE	TP (total phosphorus)		TN (total nitrogen)		Nítrat-nítrít-N mg/kg ÞE	Kjeldahl NH_3-N mg/kg ÞE	Cd	Cu	Ni	Pb	Zn	Hg	Cr	Ag	As
Fituúrgangur	*10/02/2025*	*RSI*	*44000 (árið 2024)*	*41.1*	*29000*	*mg/kg af ÞE*	*63 % (w/w) ÞE*		*1230*	*mg/kg af ÞE*	*0.91*	*% (w/w) ÞE*			*<0.2*	*10*	*4.0*	*<2.0*	*62*	*<0.07*	*10*	*<5.0*	*<0.8*
	13/10/2023	Efla		44.4				23.9															
	2022	Efla	91800																				
	2021	Efla	100220																				
	2020	Verkís	79760																				
	2019	Verkís	83740																				
	2018	Verkís	382000																				
	2014	Verkís	118000	35.3	950897	mg/kg af ÞE		78.2	413	mg/kg af ÞE	8764	mg/kg af ÞE	3096	5668	<0.3	17.1	<1.7	5.1	83.7	<0.1	8.5	<1.7	<1.4
	2010	Verkís	145000	48.3	818268	mg/kg af ÞE		85.4	2352	mg/kg af ÞE	10753	mg/kg af ÞE	5054	5699	0.5	22.3	5.4	9.3	113.3	0.1	7.6	<2	< 2
Ristarúrgangur	*10/02/2025*	*RSI*	*35800 (árið 2024)*	*58.0*	*40500*	*mg/kg af ÞE*		*4.2*	*3600*	*mg/kg af ÞE*	*1.60*	*% (w/w) ÞE*			*0.3*	*56*	*22*	*4.0*	*192*	*0.12*	*77*	*<5.0*	*1.5*
	2022	Efla	145300																				
	2021	Efla	46500																				
	2020	Verkís	267000																				
	2019	Verkís	374000																				
	2018	Verkís	382000																				
	2014	Verkís	477000	21.1	712248			3	8218	mg/kg af ÞE	33751	mg/kg af ÞE	3424	30327	<0.5	45.1	12.5	32.6	300.8	0.5	12.5	3.3	<2
	2010	Verkís	575140	13.6	911330	mg/kg af ÞE		3.6	12211	mg/kg af ÞE	47992	mg/kg af ÞE	4557	43435	<0.4	68.7	21.4	10.5	359.9	0.1	34.4	32.4	<4
Sandúrgangur	13/01/2023	Veitur		55.9	6650	mg/l	2100		62.1	mg/kg	1200	mg/kg			0.006	3.88	1.12	0.73	12.2	<0.002	0.31	<0.05	0.18
	31/03/2022	Veitur		84.8	353	mg/l	170		1.2	mg/kg	27	mg/kg			<0.003	<0.05	0.1	<0.01	0.2	<0.002	0.01	<0.05	<0.01
	2022	Efla	23700																				
	2021	Efla	71900																				
	2020	Verkís	267000																				
	2019	Verkís	374000																				

Klettagarðar															mg/kg af ÞE								
	2018	Verkís	382000																				
	2014	Verkís	477000+ 155000	73.5	82063	mg/kg af ÞE		27.7	664	mg/kg af ÞE	5935	mg/kg af ÞE	3213	2722	0.3	136.6	125.2	68.3	341.5	13.5	105.3	12.8	1.4
	2010	Verkís	575140+ 46120	36.3	176150	mg/kg af ÞE		12.4	8655	mg/kg af ÞE	30266	mg/kg af ÞE	1762	28504	<0.2	154.2	64.2	34.3	428.2	0.5	62.1	4.3	<2

Ánanaust															mg/kg af ÞE								
	Dags	**Aðili**	**Heildar-magn (kg)**	**Þurrefni % (w/w)**	**COD**		**TOC mg/L**	**Fita % af ÞE**	**TP (total phosphorus)**		**TN (total nitrogen)**		**Nítrat-nítrít-N mg/kg ÞE**	**Kjeldahl NH_3-N mg/kg ÞE**	**Cd**	**Cu**	**Ni**	**Pb**	**Zn**	**Hg**	**Cr**	**Ag**	**As**
Fituúrgangur	*11/02/2025*	*RSI*	*21800 (árið 2024)*	*49.4*	*26400*	*mg/kg af ÞE*	*63 % (w/w) ÞE*		*718*	*mg/kg af ÞE*	*0.67*	*% (w/w) ÞE*			*<0.2*	*10*	*5.0*	*<2.0*	*89*	*<0.07*	*11*	*<5.0*	*4.5*
	2022	Efla	96900																				
	2021	Efla	87780																				
	2020	Verkís	106960																				
	2019	Verkís	76360																				
	2018	Verkís	256000																				
	2014	Verkís	151000	53.5	2085466	mg/kg af ÞE		2.2	323	mg/kg af ÞE	5012	mg/kg af ÞE	3890	1121	< 0.3	< 1.6	< 1.6	< 1.6	83.3	< 0.1	< 1.6	< 1.6	2.3
	2010	Verkís	100780	28.1	232629	mg/kg af ÞE		100	4970	mg/kg af ÞE	29367	mg/kg af ÞE	2326	27041	< 0.25	29.6	11.3	2.7	184.7	0	14.3	< 2.5	5.2
Ristarúrgangur	*11/02/2025*	*RSI*	*20000 (árið 2024)*	*59.2*	*16100*	*mg/kg af ÞE*		*2.2*	*2910*	*mg/kg af ÞE*	*1.20*	*% (w/w) ÞE*			*<0.2*	*22*	*23*	*<2.0*	*102*	*0.11*	*39*	*<5.0*	*<0.8*
	2022	Efla	92400																				
	2021	Efla	43300																				
	2020	Verkís	215000																				
	2019	Verkís	222000																				
	2018	Verkís	256000																				
	2014	Verkís	219000	15.6	882709			2.8	8893	mg/kg af ÞE	48177	mg/kg af ÞE	7020	41156	< 0.6	51.4	12.8	19.3	263.3	0.6	16.1	8	< 2.6
	2010	Verkís	272180	13.8	25273	mg/kg af ÞE		53.5	12043	mg/kg af ÞE	53636	mg/kg af ÞE	3538	50098	< 0.4	36.8	12.4	< 4	259.7	0.1	18.8	59.9	< 4
Sandúrgangur	13/01/2023	Veitur		85	147	mg/l	260		0.6	mg/kg	130	mg/kg			<0.003	0.09	0.22	0.01	0.4	<0.002	<0.01	<0.05	0.03
	31/03/2022	Veitur		87.8	162	mg/l	66		0.2	mg/kg	49	mg/kg			<0.003	<0.05	0.21	<0.01	0.4	<0.002	<0.01	<0.05	0.01
	2022	Efla	42200																				
	2021	Efla	36500																				

Ánanaust															mg/kg af ÞE								
	2020	Verkís	215000																				
	2019	Verkís	222000																				
	2018	Verkís	256000																				
		Verkís	219000+5 300219000 +5300	50.4	244162	mg/kg af ÞE		11.4	22402	mg/kg af ÞE	41005	mg/kg af ÞE	2715	38289	< 0.3	107.9	86.3	16.6	365.2	0.4	94.6	< 1.7	1.5
	2010	Verkís	272180+9 780	40	14748	mg/kg af ÞE		10.5	20938	mg/kg af ÞE	45193	mg/kg af ÞE	1721	43472	< 0.2	118.1	81.4	59	325.7	101.8	93.7	63.1	< 2

Kjalarnes															mg/kg af ÞE								
	Dags	Aðili	Heildar-magn (kg)	Þurrefni % (w/w)	COD		TOC mg/L	Fita % af ÞE	TP (total phosphorus)		TN (total nitrogen)		Nítrat-nítrít-N mg/kg ÞE	Kjeldahl NH_3-N mg/kg ÞE	Cd	Cu	Ni	Pb	Zn	Hg	Cr	Ag	As
Fituúrgangur	*11/02/2025*	*RSI*	*1000 (árið 2024)*	*12.1*	*82200*	*mg/kg af ÞE*	*69 % (w/w) ÞE*		*2660*	*mg/kg af ÞE*	*1.44*	*% (w/w) ÞE*			*<0.2*	*18*	*5.0*	*4.0*	*147*	*<0.07*	*8.0*	*<5.0*	*<0.8*
	2022																						
	2021																						
	2020	Verkís	Magn ekki skráð																				
	2019	Verkís	Magn ekki skráð																				
	2018	Verkís	Magn ekki skráð																				
Ristarúrgangur	*11/02/2025*	*RSI*	*180 (árið 2024)*	*94.6*	*20500*	*mg/kg af ÞE*		*2.3*	*2470*	*mg/kg af ÞE*	*1.03*	*% (w/w) ÞE*			*<0.2*	*22*	*17*	*7.0*	*166*	*0.10*	*29*	*<5.0*	*<0.8*
	2022																						
	2021																						
	2020	Verkís	Magn ekki skráð																				
	2019	Verkís	180																				
	2018	Verkís	Magn ekki skráð																				
Sandúrgangur	2022																						
	2021																						
	2020	Verkís	Magn ekki skráð																				
	2019	Verkís	Magn ekki skráð																				
	2018	Verkís	Magn ekki skráð																				